Down - Well Gas Separation

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The oil occuring in oil reservoirs is associated with varying quantities of water and gas. Both the water and the gas entering the well bore must be produced in order to produce the oil. In the early life of a field, when the reservoir pressure is high, the gas is used as a means of lifting the fluid. This is generally accomplished by shutting in the casing, and permitting sufficient pressure to build up in the annulus between the casing and the tubing to cause the well to "flow" up the tubing. When this occurs, oil, gas and water rise up the tubing in a frothy mixture and pass through the flow bean into the lead line. In this case, an actual bottom hole mixing rather than a bottom hole separation occurs.

Down well separation of gas and oil becomes desirable when the well must be pumped. If there is no separation the gas must go through the pump. When it does, it takes up displacement that would otherwise be utilized for oil. If an ideal separation of gas and fluid could be accomplished, all of the gas would flow up the annulus between the casing and tubing and would enter the gas gathering system or lead line at the casing head. The de-gassed fluid would enter the suction of the pump and be produced up the tubing. It would then enter the production lead line at the well head.

The actual separation of the gas from the oil is accomplished by gravity. Bubbles will rise through oil at a rate dependent principally on the viscosity of the oil. Tests have shown that the rate of rise of bubbles in water is more than 6" per second. To separate gas from the oil, it is necessary to cause the oil to flow downward at a rate less than the rate of rise of the bubbles. If the downward velocity of the oil is greater than the rate of rise of the bubbles, no separation will occur. Assuming a constant production rate, the only way to decrease the downward velocity is to increase the down-pass area. Thus it is apparent that the most perfect gas separator possible would be the one with the largest down pass area possible within the space limitations of the casing.

The closest approach to an ideal gas separator occurs in wells where it is possible to set the pump at a point below the lowest entry of gas into the well bore. When this occurs, the entire annular space between the tubing and casing (or liner) becomes the downpass area of the separator. Unfortunately, this ideal situation seldom occurs. In many wells, it is undesirable to run the tubing all the way to the bottom. Also, in most wells, there is some entrance of gas through the entire perforated section, and pumping near the bottom would still permit gas to enter the pump. It is therefore desirable in most cases to accomplish the separation directly beneath the pump so that the point of gas entry (whether above or below the pump) is of little significance. This is done by means of a gas anchor.

A form of gas anchor frequently fabricated in the field is known as a "Poor Man's" Anchor. There are numerous designs of "Poor Man's" anchor, but it usually consists of a joint of tubing run directly under the pump shoe. This joint is perforated at the top and bull plugged at the bottom. Inside of this joint, and serving as a suction to the pump, is a section of line pipe, frequently called a "skeeter bill." This pipe extends for some distance below the bottom of the perforated section of the anchor.

The gas anchor works as follows: The gas-oil mixture flows into the well bore from the producing formation through the perforations in the casing. The larger bubbles tend to rise directly to the surface of fluid and separate out as free gas in the casing. A portion of the medium and smaller bubbles are drawn into the perforations of the anchor by the suction of the pump. As this oil-gas mixture is drawn downward through the body of the anchor, the bubbles tend to rise to the top of the anchor and accumulate and break free as larger bubbles. As more bubbles rise, the descending fluid becomes less agitated and the smaller, slower rising bubbles have opportunity to become separated from the oil. Thus as the oil descends in the anchor it becomes increasingly gas free and, if the anchor has sufficient capacity, the suction to the pump through the skeeter bill will be oil entirely free of entrained gas.

Actually, the amount of vertical drop required is comparatively small. Except where the problem is one of foam separation, a very few feet is adequate. The important factor is to provide as large an area as possible in the downpass to minimize the fluid velocity and reduce the entrained gas carryover. The maximum outside diameter of the anchor must be somewhat smaller than the inside of the casing or liner in which it is hung. Since some separation occurs at the anchor perforations, sufficient clearance must be provided between the anchor and the casing to prevent an excessive turbulance outside the perforations.

The anchor just described is run with either a bottom anchored pump or a tubing pump. Where a pump is top anchored, the gas anchor is run immediately below the shoe, and the pump itself extends into the anchor and takes the place of the "skeeter bill" in the "Poor Man's" anchor. This type of anchor enjoys the advantage of having the standing valve submerged in the fluid, but it does have a smaller downpass area and consequently less separating capacity than a properly designed conventional type anchor.

Before selecting the down-well gas separating equipment for a well, the operator should analyze the particular problem that makes gas separation difficult in his well. Although a good gas anchor should assist in any gas separation problems, the choice of the optimum gas anchor and pump may vary with the individual well conditions. To generalize, we will group the separation problems into three classifications. Most wells will fall to a greater or lesser degree into more than one of the classifications, but a careful analysis of conditions should indicate which one is limiting the separation.

1. High Gas-Oil Ratio Wells—These are wells where the character of the fluid is such that the gas separates readily from the oil, but the volume involved is sufficient that separation capacity is the problem.

2. Wells Where The Oil Tends to Form Foam—In these wells, the gas separates very slowly and makes a good pump suction very difficult. In this same bracket are heavy oils where the entrained gas leaves the oil very slowly.

3. Wells With Gas Saturated Oil—These are wells where gas dissolved in the oil is near the saturation point, and differential pressure across the standing valve liberates free gas as the oil enters the pump.

General

In all installations where gas separasome gas will be pumped with the fluid. Therefore, it is desirable to design and operate the pump in all cases to produce both gas and oil with a minimum loss of efficiency. The most important contribution to pump efficiency lies in properly spacing the well. When the well is properly spaced, the traveling valve will come very close to the standing valve at the bottom of the stroke. This will reduce to the minimum the amount of stroke wasted on each cycle expending and compressing gas. It also reduces the possibility of a complete gas lock. In a gas locked pump, the gas pressure inside the barrel is sufficient to keep the standing valve closed at the top of the stroke, but is not sufficient to open the traveling valve at the bottom of the stroke.

The need for close spacing brings up additional problems in the case of a tubing pump. The standing valve normally run on a tubing pump makes close spacing impossible. Where gas separation conditions are severe enough to justify the additional disadvantage of pulling the well wet, a rigid type oversize standing valve can be run. The traveling valve can then be spaced to stroke very close to this.

A stationary barrel pump is preferable in gassy wells. The fluid, in order to enter the pumping chamber of a traveling barrel pump must pass up through the pull tube and plunger. In a stationary barrel pump, the fluid is in the pumping chamber as soon as it passes the standing valve at the bottom of the pump. As an additional advantage, the standing valve is larger on a stationary barrel pump (where it is in the barrel blind cage) than it is on a traveling barrel pump (where it is in the plunger top cage.)

It is important that the stationary barrel pump be equipped with a blind cage at the bottom of the plunger so that close spacing of the valves is possible. This is general practice in most pumps, but in many of the soft packed plungers and in tubing pumps equipped with garbutt rods, the valve is at the top. If it is desired to double valve a plunger, the second valve can be run either in a plunger top cage or in a double valve blind cage at the bottom of the plunger.

High Gas-Oil Ratio Wells

The solution to this problem is to provide adequate separating capacity. This is generally accomplished by running a gas anchor underneath a tubing pump or bottom anchored insert pump. If the volumes are small, the "Poor Man's" Anchor may be adequate. If larger volumes are involved, some design of anchor should be adopted that utilizes more effectively the relatively small area available within the well bore. If the well has large casing, it is possible to run an "oversize" gas anchor, or one which has a larger outside diameter than the O. D. of the collars in the tubing string. Frequently, very good separation can be established in this manner since the oversize anchor provides a large downpass area and consequent low vertical velocity. An oversize an-

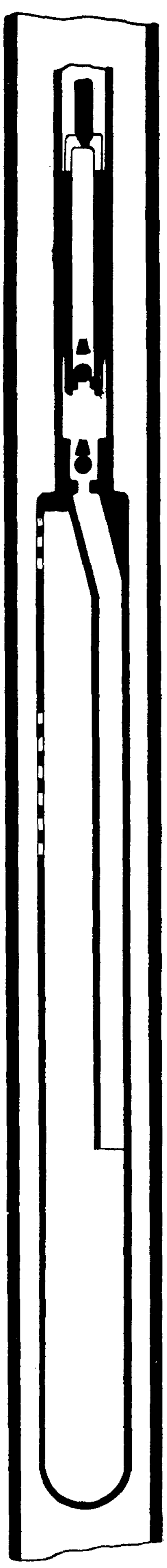

Fig. 1

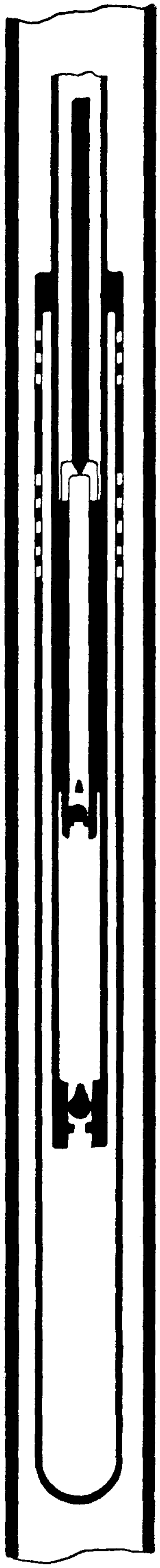

Fig. 2

chor is considered bad production practice in a sandy well, since it presents an enlarged section at the bottom of the tubing. If the well sands up covering this enlarged portion, it greatly reduces the possibility of pulling the tubing free from the sand. It is only in exceptional cases where an operator will risk the possibility of a washover fishing job in order to enhance gas separation, so this alternative should be approached with caution.

Fortunately, gas separation problems can be effectively handled in most cases by use of normal sized gas anchors, the O. D. of which is no larger than the tubing collars. By holding to this diameter and fabricating the anchor out of thin-walled tubing, its is possible to approximately double the downpass area of a similar anchor constructed of upset tubing. The Marsh Anchor (Fig. 1) offers a further refinement on this by substituting a baffle at the side of the anchor for the "skeeter bill" normally run down the center. This effectively increases the hydraulic radius of the separating chamber with a resulting increase in the slip velocity of the bubbles and a consequent increase in the capacity of the anchor.

The efficiency of the downwell pump is the yardstick by which the efficiency of the gas anchor is measured. If possible, pump efficiency should be calculated as accurately as possible before and after any changes are made. If after installation of the anchor, the efficiency is still low, different setting depths on the tubing are frequently tried. If the anchor is in the perforated section, lowering the pump will sometimes put the suction below the point of principal gas entry and permit a better suction. In other wells where the gas entry is large all the way to the bottom, a better separation can sometimes be affected by raising the anchor above the top of the perforated section. This reduces the turbulence between the casing and perforations of the anchor and permits a better separation to occur at the inlet ports. Where a well is completed with an insert liner, it is usually advantageous to set the pump above the top of the liner except in cases where low reservoir pressures make it desirable to draw down the fluid level in order to keep the back pressure off the face of the formation. The velocity of fluid passing the anchor hung in the casing would be much lower than it would be in the restricted annular space of the smaller liner, and the separation should be more effective.

In special cases of wells completed with small liners, the "packer anchor" finds an application. A packer equipped with a tail pipe which will run to the bottom of the well is set in the casing immediately above the top of liner. A conductor pipe above the packer carries the gas and oil to a point above the suction of the pump. In operation, the well flows by its own pressure through the tail pipe and conductor pipe, and discharges into the casing. The oil then drops down to the pump suction and the gas rises up the casing. The cross section area of the casing less the area of the tubing and conductor pipe become the effective downpass area, and a very efficient separation can be accomplished.

To summarize, in high gas-oil ratio wells, a stationary barrel insert pump or a tubing pump and a well-designed gas anchor are the best general application. The best setting point for the anchor must frequently be determined by trial. Pump efficiency should be used as a measure of how successfully the anchor is separating the gas.

Wells Where the Oil Tends To Form Foam

In wells that tends to form foam, frequently the time required to separate gas from the foam so that solid fluid could be pumped is too great to permit a reasonable rate of production, and much of the gas must necessarily be produced through the pump. It is well to remember when designing these installations that foamy oil is a relatively homogeneous mixture of non-compressible liquid and highly compressible gas. The downwell pump may very well operate at close to 100 percent efficiency based on this mixture, but when compared to oil as gauged in a tank after ample separating time has been allowed, the pump efficiency may be as low as ten or twenty percent.

The most practical solution is, therefore, to provide adequate production capacity in the downwell pump to displace both the oil and the gas at the existing well conditions. It is probable that the foam is formed in the producing formation just adjacent to the well bore. The dissolved gas breaks out of solution and expands as the oil is driven by the higher pressure of the reservoir into the lower pressure of the bore hole. In its final expansion into the well bore, a relatively stable foam is created.

Some entrained gas will be separated in a good gas anchor even in a relatively stable type of foam, and a top anchored pump in an immersion type anchor (Fig. 2) has proved to be the best under these conditions. In this type of installation, the pump itself takes the place of the up pass area in a conventional gas anchor, and the standing valve is submerged inside the anchor in the fluid being pumped, permitting the head of separated fluid surrounding the pump to aid in filling the pump on each upstroke.

In foamy oil, it is important to pump from as deep a point as is practical in the well. If conditions permit pumping right from the bottom, a higher efficiency (based on tank oil) will be obtained. If the well is a gun perforated completion and there is a section of blank pipe below the perforated interval, no gas anchor need be run if the shoe is set down in this natural sump formed in the bottom of the well. Such a completion forms the finest possible downwell gas separator.

The above description indicates that it is not possible to separate with any degree of efficiency the gas entrained with the oil in a stable type of foam. Therefore, it is important to run a pump which will tolerate this quantity of gas with the greatest efficiency and the minimum undesirable other effects. Until recently, the best recommendation was simply to space the pump as closely as possible, thereby raising the compression ratio to a point where the valves would operate on every stroke and the pump would not go into complete gas lock. In addition to low efficiency, a bad gas pound is characteristic of a conventional pump operating in foamy oil.

About two years ago the Ratio-Compound pump was introduced to improve efficiency in foamy or gassy oil, and to eliminate fluid or gas pound. It is essentially a stationary barrel (either top or bottom anchored) pump, but a long hollow polished rod replaces the pull rod and the top of the pump barrel terminates in a short packoff barrel closely fitted to the hollow rod. It contains the normal standing and traveling valves but a third valve controls the fluid flow through the hollow rod, and the annular chamber between the polished rod and the pump barrel serves as a second pumping chamber. Thus we have a compound pump that will act as a two stage compressor on gassy fluids. The ratio between the area of the pump barrel and the annular chamber is about 2:1, and in fluids containing over 50 percent gas, all of the fluid will be displaced and the gas compressed during the down-stroke into this smaller annular chamber. Since the plunger is sealed off from high pressure during the downstroke, no fluid pound can occur, and the traveling valve in the plunger is actually subjected to a suction force from the top instead of the high pressure of fluid in the tubing when the downstroke begins.

The Ratio-Compound has proved to be an excellent pump to run in foamy oil since it improves pump efficiency due to eliminating gas lock and improving pump valve action. Perhaps of greater importance is the fact that it eliminates gas or fluid pound, and greatly reduces the load range on the rods and gear box and therefore the horsepower requirements of the prime conventional gas anchor or top anchored in an immersion type anchor.

If a tubing pump is run, a comparatively short anchor should be used. In a longer anchor, more gas would be separated in the long downpass, but more foam would be generated in the long up-pass before it reached the standing valve. Except in rare cases, the overall result would be a loss in efficiency.

To summarize, in pumping foamy oil, be prepared to accept a lower pump efficiency, run the tubing as close to the bottom of the well as conditions permit, and if it is not possible to get the pump below the point of gas entry, run a gas anchor and pound Pump.

Well With Gas Saturated Oil

top anchor the pump. To improve pump efficiency, run a Ratio - Com-

The treatment for this type of well is much the same as a foamy oil. The most important factor is to permit easy access of the oil into the pump bore. When running an insert pump, a traveling barrel type should be avoided. A top anchored pump would be preferable, since the standing valve is submerged in the fluid in an immersion anchor and filling the pump could be accomplished with very little pressure drop.

Pumping the well as close as possible to the bottom is advantageous, since holding some fluid head over the pump would permit it to fill with a minimum of gas coming out of solution. If the unit has the capacity, it is best to run the largest practical bore pump in order that the number of strokes per minute can be reduced. A certain amount of gas is flashed out of the oil at the start of each upstroke, and by reducing the strokes per minute, the losses from this factor are reduced. A "Poor Man's" Anchor with a long "skeeter bill" should be avoided in this type of production.

The above information is submitted only as a guide, and may not prove out best in all cases. Oil wells rarely seem to follow the rules, and it is difficult to predict all that happens many thousands of feet below us in the well bore. It is a fact, however, that the best gas anchor cannot lower, and in almost all cases will improve downwell pump efficiency. Since higher pump efficiencies can permit use of smaller units, less horsepower, smaller rod strings, and increased equipment life, the problem has an important economic aspect. The best gas anchor on an original installation costs less than the price of pulling the tubing and installing a "Poor Man's" Anchor later on.