Understanding And Combating Gas Interference In Pumping Wells*

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ABSTRACT

Gas interference continues to be one of the major operating problems in pumping wells. In order to combat this problem effectively, we need a better understanding of what the pump volumetric efficiency should be under various well subsurface conditions Once we know how the pump should perform, it will be possible to select the best setting depth and determine whether a gas anchor is needed.

Care must be used in the selection and in the installation of gas anchors, otherwise the results will be disappointing. If free gas is present, not only must an effective gas anchor be used but also must the pump develop a high compression ratio Thus, the type and design pump used is critical.

Pumping wells from under a packer and small diameter casing completions are two practices that have increased the gas interference problem. Pump efficiencies and production can often be improved in such type wells.

UNDERSTANDING PUMP VOLUMETRIC EFFICIENCY

In order to better understand gas interference, we need to analyze the pumping conditions as they occur in an oil well. In Figure 1 the pump volumetric efficiency is plotted vs the pump intake pressure. Pump intake pressure is defined as the pressure in the casing opposite the pump under producing conditions. Figure 1 is for a typical reservoir and for conditions where there are (1) no slippage of fluid past the plunger and (2) near zero clearance between the standing and traveling valves at the bottom of the stroke. Such a graph can be drawn for any field or reservoir using the appropriate PVT conditions.

Under bottom-hole conditions, a barrel of stock tank oil will occupy a greater volume because of the gas in solution; thus a larger volume must be pumped to obtain one barrel of stock tank oil. If all the gas can be vented, the pump efficiency will increase as the pressure is reduced This is shown by line BC in Figure 1. At pressures greater than the bubble point (line AB) the pump efficiency remains almost constant. The lower curve (line BF) shows that the efficiency rapidly decreases for pressures less than the bubble point if all the free gas is pumped. If part of the gas can be vented, then the pump efficiencies will be higher

Usually very little gas is vented from the casing at pressures approaching the bubble point. This probably results since at the high pressures the gas bubbles are small; thus gravity has very little influence in separation. The small size gas bubbles are easily entrained and are carried in the same direction as is the oil. As the pressure is decreased, the gas bubbles grow in size and more separation occurs. As reported by Peebles and Garber, relatively large gas bubbles will rise at about 0.5-0.6 ft/sec. [1] In general, the rising velocity depends on the bubble size and shape and the physical characteristics of the liquid. When the pressure is decreased, bubble size increases and gas separation begins to improve. As can be noted in Figure 1, line BD, in the lower pressure range relatively good pump efficiencies can often be obtained with an effective type gas anchor. The efficiency will decrease, however, with higher production rates.

Without a gas anchor (line BE) some separation will occur, but the pump efficiencies are often found to be erratic and in many cases sustained pumping is impossible. This is especially true at relatively low pressures.

The pump should be set at a depth where the intake pressure is high (near or higher than the bubble point), or where the intake pressure is low (less than 300 psia). In the latter case, a gas anchor should be used; whereas, if the pressure is high enough, gas anchors are not needed. In many wells even with the pump set at total depth, the pump intake pressure will be low due to the bottom-hole pressure or productivity index; thus gas anchors must be used to obtain relatively high pump efficiencies.

The optimum pumping depth is difficult to calculate and under most conditions must be determined by trial and error. If the pump is set too low, the pump intake pressure will be high; gas separation will be poor; and efficiencies may be low. If the pump is set too high, the gas separation may be good; however, the well will pump-off and the over-all efficiency will again be low. To determine the optimum pumping depth without a trial and error approach requires good information on the well's inflow performance relationship (IPR) [2] and a knowledge of the flowing gradients and anticipated gas anchor performance.

Pump efficiencies as shown in the Figure 1 are decreased by slippage. The slippage effect will move all curves downward. If 10% of the displaced fluid slips by the plunger, then about 10% efficiency will be lost at both low and high intake pressures for a fixed production rate. The reduction in efficiency due to slippage [3] is usually small unless the plunger-barrel fit is relatively loose, i.e , greater than three thousandths.

The pump efficiencies are also reduced because of the clearance in the pump between the pump standing and traveling valves at the bottom of the stroke. Clearance does not affect efficiencies where all the gas is in solution or where all the gas is vented. However, if free gas becomes present, the clearance allows some of the produced fluid to remain in the pump, which in turn may not permit a complete new charge of fluid to enter the pump on the upstroke

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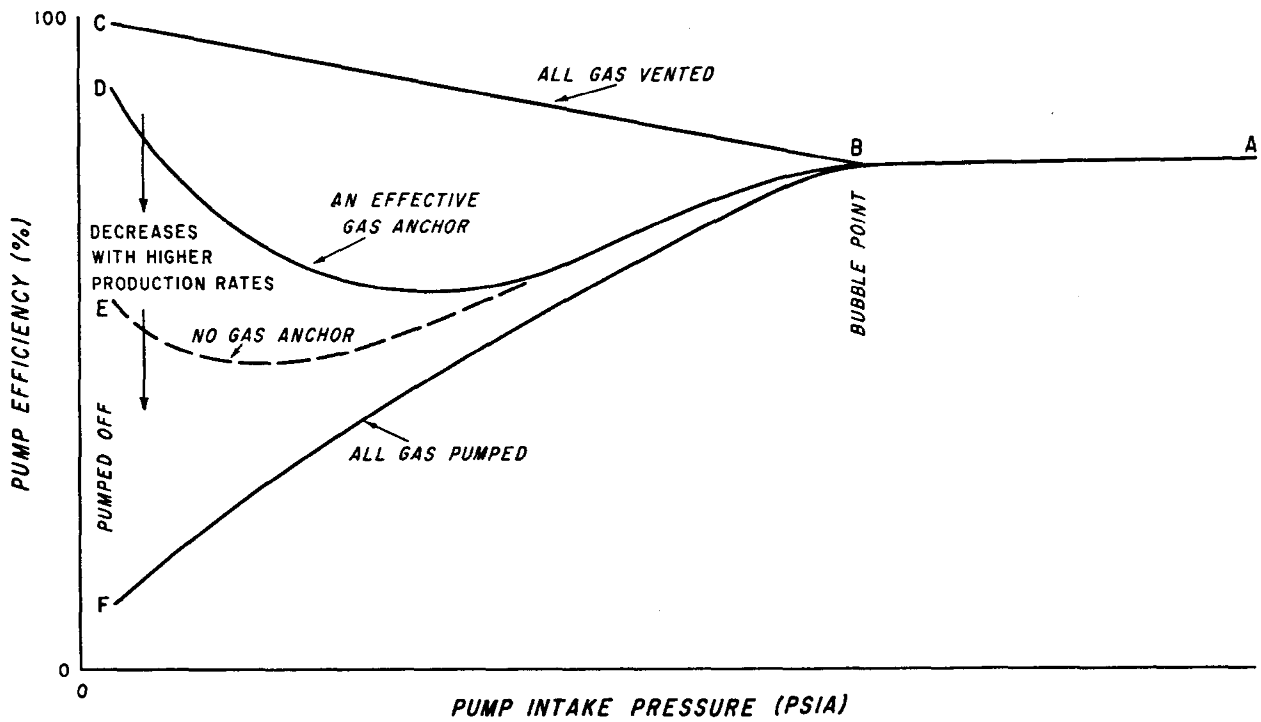
FIGURE I

PUMP EFFICIENCY

(NO SLIPPAGE)

AND

(ZERO CLEARANCE BETWEEN PUMP TRAVELING AND STANDING VALVES)



because of gas expansion. This remaining fluid reduces pump efficiencies [4] and can be considerable if the clearance is excessive. [5]

The worst condition which may result from clearance is "gas locking" where the trapped fluid is compressed and then expands without letting any additional fluid into the pump barrel. "Gas locking" also increases the temperature which decreases pump efficiency because of (1) increased slippage [6] and (2) possible gas break-out. Clearance between the standing and traveling valves will reduce efficiencies drastically in the lower pressure range. This often occurs even where an effective type gas anchor is installed, since 100% gas separation cannot normally be obtained.

GAS ANCHORS

Wells with high fluid levels are often excellent candidates for gas anchors since an improvement in pump efficiency will increase oil production. An increase in production is usually sufficient justification to pull the tubing to install a gas anchor. Often overlooked is the fact that gas anchors are beneficial in reducing costs since less displacement is required to obtain the same production.

There are a number of different types of gas anchors. Some of the better known are the "natural", packer and "poor boy". Nearly all gas anchors use the principle that gas is lighter than oil and that the free gas will move upward, whereas oil will move downward. There is usually a down passage for oil flow and a vent for the gas. The better anchors are designed so that free gas cannot easily flow into the down passage of the gas anchor.

One of the better gas anchors consists of merely setting the pump below the casing perforations. Since this requires no special equipment, it is often referred to as a "natural" type gas anchor (shown in Figure 2A). The "natural" gas anchor is very simple but it is in principle and practice very good. The down passage is at a maximum size since it utilizes the casing. This allows the oil to move downward relatively slow and permits the gas to flow upward. A large storage volume for the oil makes possible the maintaining of a high draw-down on the reservoir even during periods of down time. However, high working fluid level wells, wells producing considerable sand or sediment, and wells with open hole or no sump are not suitable for the "natural" type gas anchors.

Another type gas anchor (Figure 2B) that has given good results [7] is the packer gas anchor. This anchor utilizes a packer and a spill-over tube. Production flows up the casing annulus where the packer directs it up through a spill-over tube. The oil then flows down the tubing-casing annulus to the pump intake, while the gas continues on to the surface through the annulus. A desirable characteristic of the packer-type anchor is the gravity filling which tends to reduce the ill effects of heading.

In order to achieve a relatively low pressure at the point of spill-over and thus achieve good gas separation, it may become necessary to raise the packer gas anchor up the hole or extend the length of the spill-over pipe. In troublesome fields with high BHP and low IPR's, the use of a special back pressure valve in conjunction with the packer may prove worthwhile.

The most frequently used gas anchor (Figure 2C) is the "poor boy" or "Mother Hubbard". In many fields this anchor has resulted in some increase in production. The anchor is inexpensive; however, without some modifications or refinements it is usually not very effective. There are a number of refinements (Figure 2D) that can be made to the "poor boy" gas anchor which will improve its efficiency considerably. One of the more important modifications is to increase the down passage size. In addition, the down passage area shape or hydraulic radius (cross section area/wetted perimeter can be improved. Also, the entrance into the gas anchor may be modified to give better oil and gas separation.

There are other types of gas anchors, some of which may have application in certain fields or for unusual pumping conditions. But there is no intent in

Fig. 2A
NATURAL GAS ANCHOR

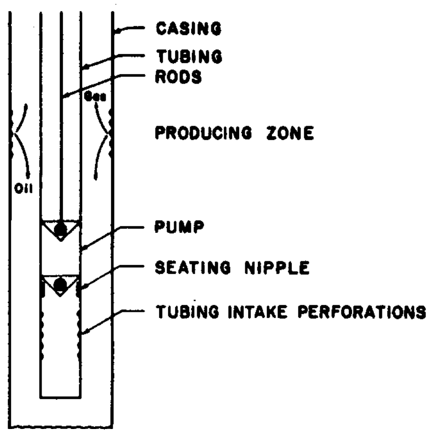


Fig. 2B
PACKER TYPE GAS ANCHOR

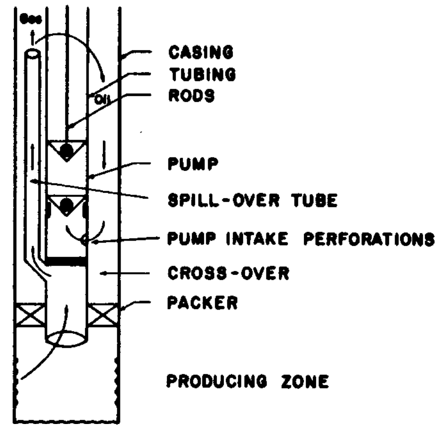


Fig. 2C
POOR BOY GAS ANCHOR

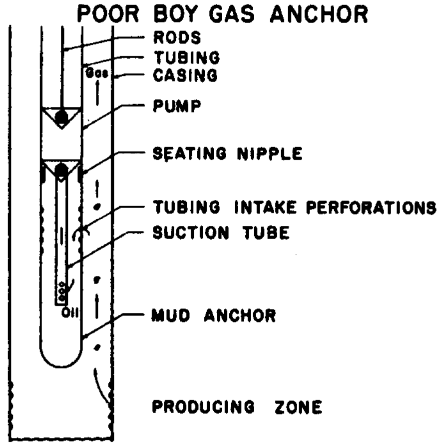


Fig. 2D
MODIFIED POOR BOY GAS ANCHOR

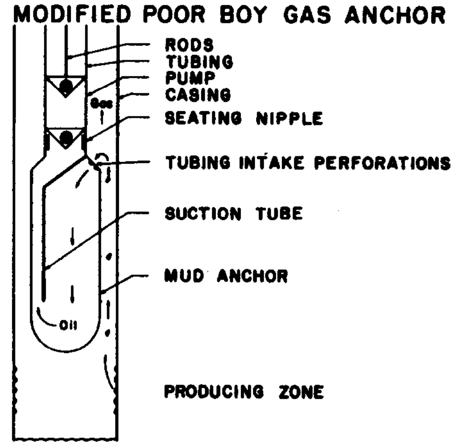


Fig. 2E
MODIFIED NATURAL GAS ANCHOR
(For Small Diameter Casing)

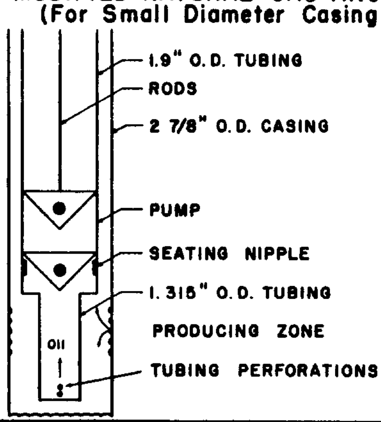
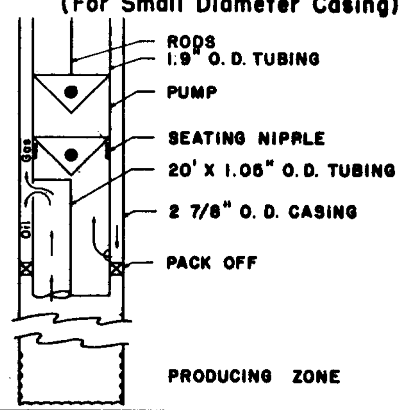


Fig. 2F
MODIFIED PACKER GAS ANCHOR
(For Small Diameter Casing)



this paper to cover all the types of gas anchors and their advantages and disadvantages.

INSTALLATION OF GAS ANCHORS

The installation of gas anchors must be carefully planned with special consideration given to the setting depth and the gas anchor design. In general, the down passage in all gas anchors should be as large as practical. Table A lists the superficial downward velocities for various production rates in some of the common size anchor arrangements. It must be remembered that, in general, a slower downward velocity increases gas separation; however, if the downward velocity is sufficiently high, little or no separation will occur in the anchor.

The suction tube or entrance passage into the pump should be sized for a small pressure drop. The length of the suction tube normally should not exceed 20 ft. For rates less than 100 BPD, 3/4 in. line pipe is usually adequate. For rates up to 250 BPD, the use of 1 in. line pipe may be employed with little pressure drop. This will, of course, vary with the crude viscosity and PVT characteristics. In general, higher viscosity crudes require larger suction tubes.

The gas anchor should be as close as is practical to the pump. If there is considerable distance between the gas anchor and the pump, gas will break-out because of the reduction in the hydrostatic head, and pump efficiency will be reduced. The length of the suction tube should be only sufficiently long to give a storage volume in the gas anchor equal to the intake volume of the pump. This minimum volume is needed to keep the downward velocity to a minimum and thus prevent sucking gas into the pump on the upstroke.

A number of bad practices have, in the past, resulted in gas anchors not increasing pump efficiencies. Frequently a tapped bull plug is installed at the bottom of the mud anchor underneath the gas anchor. This opening allows gaseous fluid to enter the pump. An additional set of perforations is often installed in the gas anchor near the bottom of the suction tube. This installation reduces the gas anchor storage volume. Fluid will take the path of least resistance and will enter the lower set of perforations and may carry gas into the pump if the storage volume is inadequate.

As previously mentioned, it is bad practice to place the tubing perforations at a considerable depth below the pump. If the intake is not relatively near the pump, considerable gas will break-out of solution while flowing into the pump. Avoid, if possible, placing the tubing perforations opposite the casing perforations since this is a region of high turbulence. Gas bubbles will be small in size and flow of gas directly into the pump may occur.

Tubing anchors or other relatively large tools should not be placed directly above the gas anchor. If tools are located at this point, they will restrict the gas from flowing up the annulus, and more gas will be directed into the pump. Thus a tubing anchor should be located either below the gas anchor or at least 200 ft above.

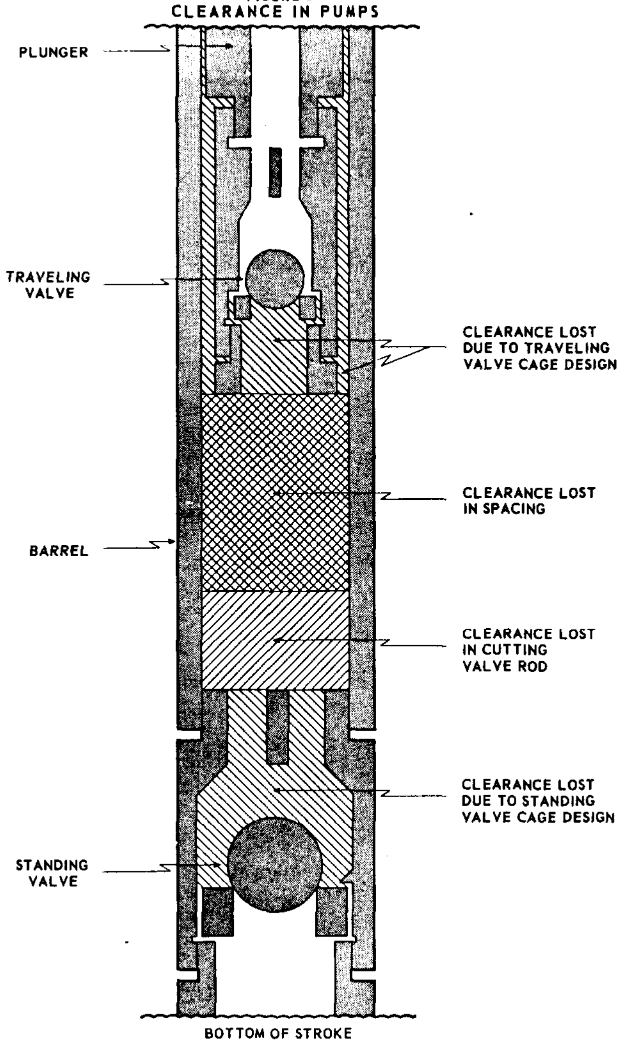
Use of small screens (perforated nipples with small holes) is another frequently observed bad practice. These screens will result in a pressure drop and gas will be liberated. If the suction tube (stinger) is attached to the pump, the end should be bull plugged to prevent it from becoming filled with paraffin when running in the hole. Large perforations should be used on the suction tube over the bottom 1 to 2 ft in order to prevent limiting fluid entry.

PUMPS

The type of pump must be carefully selected where gas interference is anticipated. By far the most important consideration is the compression ratio. Without the high compression ratios, "gas locking" and low sweep efficiency may occur. Conversely, with sufficiently high compression ratio, gas locking cannot occur. This is true whether it is a rod or hydraulically operated pump.

An enlarged section of a typical rod actuated pump is shown in Figure 3. For pumps of this type there are generally four places in which clearance volume is lost. (In addition, an extension on the bottom of the pump barrel will slightly increase the clearance volume.) The first two of these are the traveling valve cage design and the standing valve cage design. The volume lost in these areas is usually small; however, it cannot be ignored. Cutting the valve rod results in more loss of clearance. Generally speaking, the pump shops may cut the valve rod so that approximately 1/2 in. clearance results in the "clutched" position. This clearance is increased to 1 in. when the pump

FIGURE 3
CLEARANCE IN PUMPS



is "unclutched", which is the normal pumping position. Thus, unless especially requested, considerable clearance will be built into the pump. This clearance can be eliminated simply by removing one of the clutch surfaces and cutting the valve rod to give a clearance of approximately 1/8 in. or less between the standing and traveling valves.

Unless the clearances resulting from the traveling valve cage design, standing valve cage design, barrel extensions, and the valve rod spacing are kept to a minimum, "gas locking" will be possible even when the pump is closely spaced out. For sucker rod pumps, the greatest loss of clearance usually results from improper spacing. Anyone experienced in producing gaseous wells knows the importance of spacing once the well has stabilized; however, many wells with a gas interference are not spaced out closely. Low sweep efficiency can be eliminaged if care is used in selecting a pump with little clearance and if the pump is then spaced out closely in the well.

Since the compression ratio is frequently low in conventional type pumps, two or three-stage compression rod pumps are sometimes used. The justification for using these pumps, since they cost considerably more, is that a higher compression ratio will be possible. If care is not taken in the design of these two or three-stage compression pumps, (particularly in selecting the pump lengths), higher compression ratios will not result. These pumps must also be spaced out closely in the well. Most of the two-stage compression pumps must be spaced out near the top of the stroke to obtain maximum compression. However, spacing out near the top is usually more difficult than at the bottom since a change in the fluid load alters the "top dead center" position of the plunger stroke. For this reason, in some wells it may be worthwhile to use a back pressure valve on the tubing to stabilize the fluid load on the plunger and thus permit closer spacing.

The question of using single or double valves for producing gaseous wells has been debated extensively. There is normally little pressure drop across a standard API valve [8]; however, additional clearance in the pump results when double valves are used. Few people maintain that double valves help in producing gaseous wells; however, double valving may increase pump life. Then the problem is whether the detriment to gas interference by double valving is outweighed by the longer pump life. If the lower traveling valve is inoperative, a substantial reduction in pump efficiency will occur.

Where double traveling valves are used, they should normally be located together on the bottom of the plunger. The improvement in valve materials has reduced the need for double valvings and the new API pumps have only single traveling and standing valves.

In producing gaseous wells, the stroke length should be as long as possible since longer stroke lengths give higher compression ratios. In low capacity wells which pump off and pound fluid, use small plungers and reduce the strokes per minute rather than shorten the stroke.

Hydraulic pumps do not need to be spaced and for this reason clearance is usually small. Thus, most hydraulic pumps develop high compression ratios. Of course, even with hydraulic actuated pumps, efficiency will be reduced if free gas enters the pump. When installing hydraulic pumps, do not forget to install an effective type gas anchor.

PUMPING FROM UNDER A PACKER

Many operators are now producing formations from beneath the packer and from wells equipped with small diameter casing. These installations frequently have low pump efficiencies.

When producing a well from beneath a packer all free gas must be handled by the pump (unless a vent string is run). In such wells, high compression ratios must be maintained. However, even with infinite pump compression ratios, the pump efficiencies will be low and often very low due to handling the free gas. Only on wells which tend to agitate and flow, those which have pump intake pressures near or in excess of the bubble point, or those having extremely low GOR's, can relatively high pump volumetric efficiencies be obtained.

To determine the displacement needed to produce these wells, refer to Figure 4 which is a plot of pump intake pressures vs displacement required per stock tank barrel when encountering various gas-oil ratios. The curves in Figure 4 are based on Standing's correlations [9]. However, such a chart can be prepared for any field in which PVT data are available and can be used in estimating pump intake pressure when a production test is available. Once the pump intake pressure has been established, it may then be possible to predict the production at other bottom-hole pressures. The BHP will be higher than that indicated by Figure 4 unless clearance is near zero.

Many of the dual wells producing from underneath a packer might profitably be equipped with 1 in. vent string. Maximum storage volume between the packer and the tubing intake perforations should be provided when equipping a well with a vent string. If this volume can be made relatively large, the free gas will collect and possibly will head up and blow out the vent string. Where possible in these installations, the tubing should be run below the casing perforations and the pump seating nipple located near bottom creating a natural type gas anchor. The additional production by using a vent string can be predicted by using Figure 4 if IPR data are available.

SMALL DIAMETER COMPLETIONS

When producing wells inside 2-7/8 in. or other small casing, gas interference is frequently a problem. Hollow sucker rods can be used for venting of some gas; however, their use does not appear to be as effective in venting gas as using 1-1/2 in. or other small tubing in conjunction with 5/8 in. or 1/2 in. solid sucker rods. When using 1-1/2 in. tubing inside 2-7/8 in. casing, a natural gas anchor can be effectively used for production less than 100 BOPD. Experience in these wells is limited; however, the use of a 1 in. stinger on the bottom of the 1-1/2 in. tubing run through the perforated interval (if this interval is short) may be worthwhile in wells with relatively low pump intake pressures (Figure 2E). This is true since the downward velocity is reduced and better gas separation occurs.

Where higher fluid levels are encountered in small diameter casing completions, the use of a modified packer type anchor may prove worthwhile. In these installations the fluid is directed up through 3/4 in. tubing; then it falls back down the annulus to the tubing intake as shown in Figure 2F. These unique type gas anchors strive for a minimum downward velocity and are proposed since the conventional types

FIGURE 4

PUMP DISPLACEMENT REQUIRED PER BARREL OF OIL IN STOCK TANK

WHEN ALL WELL FLUID MUST BE PUMPED (NO GAS VENTED OUT ANNULUS), CURVES CAN BE USED TO DETERMINE VOLUME WHICH MUST BE HANDLED BY THE PUMP. ALSO THE CURVES CAN BE USED WHEN THE GAS RATE OUT THE TUBING HAS BEEN MEASURED. CURVES ARE BASED ON STANDING'S CORRELATIONS WITH GAS GRAVITY = 1, GRAVITY 35°, TEMPERATURE 125° F.

$$V_p/V_t = \frac{\text{CALCULATED PUMP DISPLACEMENT X SLIPPAGE FACTOR} - \text{WATER PRODUCTION}}{\text{OIL PRODUCTION}}$$

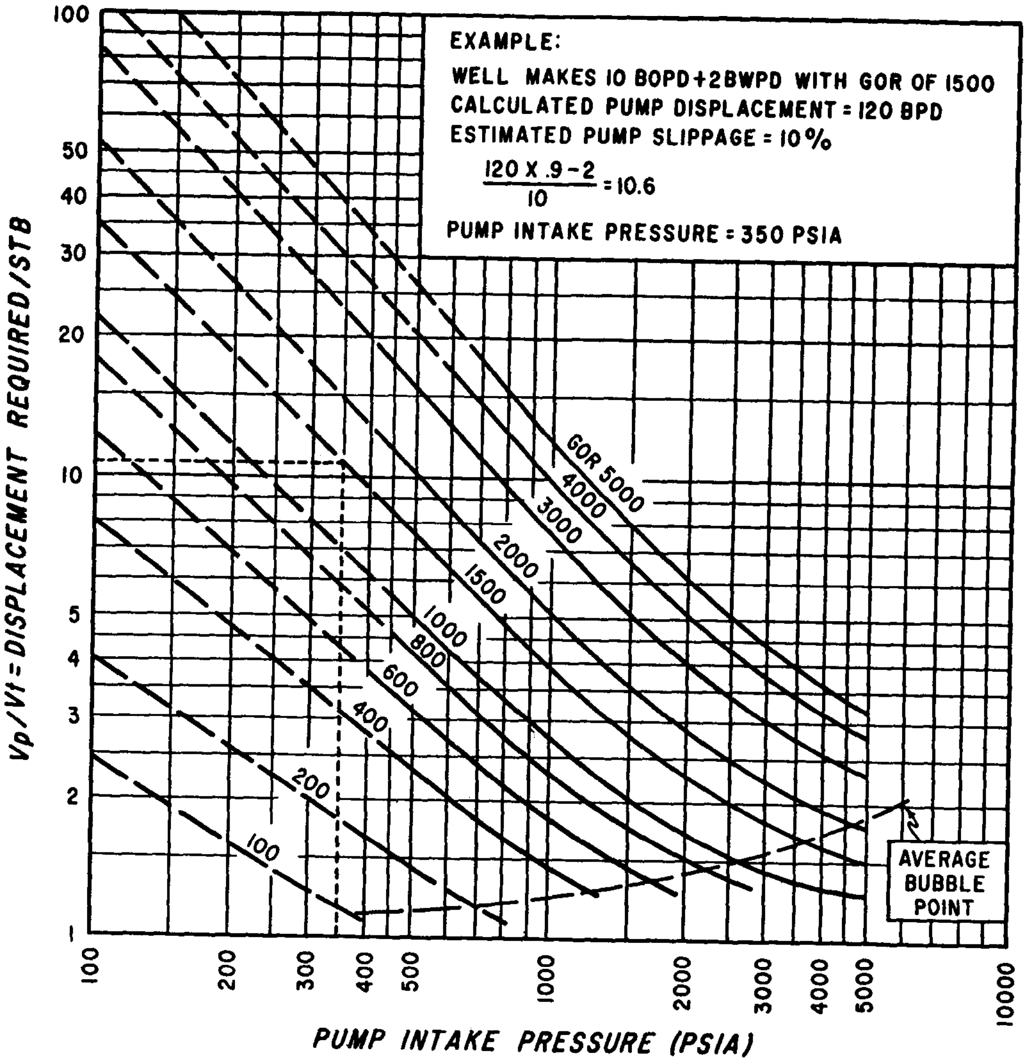


TABLE A
SUPERFICIAL OIL VELOCITIES IN FT/SEC.

Gas Anchor Size (Nominal)-Inches	Area of Down Passage Sq. In.	Production (Barrels per Day) 10	20	30	40	50	60	70	80	90	100	125	150	175	200	250	500
2 x 1	1.76	.053	.106	.159	.212	.265	.318	.372	.424	.477	.532	.665	.798	.931	1.065	1.200	2.65
2 x 3/4	2.26	.041	.083	.123	.165	.207	.248	.289	.331	.373	.414	.517	.621	.726	.829	1.039	2.07
2-1/2 x 1-1/2	1.85	.051	.101	.152	.203	.254	.304	.355	.405	.456	.506	.634	.760	.886	1.012	1.140	2.54
2-1/2 x 1-1/4	2.51	.037	.074	.112	.149	.186	.224	.261	.298	.236	.373	.466	.559	.652	.745	.931	1.87
2-1/2 x 1	3.32	.028	.056	.085	.113	.141	.169	.197	.225	.253	.282	.352	.422	.494	.564	.705	1.41
2-1/2 x 3/4	3.82	.025	.049	.074	.098	.122	.147	.171	.196	.220	.245	.306	.367	.428	.490	.612	1.22
3 x 1-1/2	4.19	.022	.045	.067	.089	.112	.134	.156	.179	.201	.223	.279	.335	.391	.446	.558	1.12
3 x 1-1/4	4.85	.019	.039	.058	.077	.096	.116	.135	.154	.173	.193	.241	.289	.337	.385	.482	.97
3 x 1	5.66	.016	.033	.050	.066	.083	.099	.115	.132	.149	.165	.206	.248	.289	.330	.412	.83
3 x 3/4	6.16	.015	.030	.046	.061	.076	.091	.106	.121	.136	.152	.190	.228	.265	.304	.380	.76
3-1/2 x 2	5.48	.017	.034	.051	.068	.085	.102	.119	.137	.153	.171	.213	.256	.299	.342	.427	.85
3-1/2 x 1-1/2	7.07	.013	.026	.040	.053	.066	.079	.093	.106	.119	.132	.165	.198	.231	.264	.331	.66
3-1/2 x 1-1/4	7.73	.012	.024	.036	.048	.060	.073	.085	.097	.109	.121	.151	.182	.212	.242	.302	.60
3-1/2 x 1	8.54	.011	.022	.033	.044	.055	.066	.077	.088	.099	.110	.137	.164	.192	.219	.274	.55
4-1/2 x 2-1/2	6.09	.015	.031	.046	.061	.077	.092	.108	.123	.138	.154	.192	.230	.269	.307	.384	.77
4-1/2 x 2	8.16	.011	.023	.034	.046	.057	.069	.080	.092	.103	.114	.143	.172	.200	.229	.286	.57
4-1/2 x 1-1/2	9.75	.010	.019	.029	.038	.048	.058	.067	.077	.086	.096	.120	.144	.168	.192	.240	.48
4-1/2 x 1	11.22	.008	.016	.025	.033	.042	.050	.058	.067	.075	.083	.104	.125	.146	.167	.208	.42
5-1/2 x 2-1/2	12.74	.007	.015	.022	.029	.037	.044	.051	.059	.066	.074	.092	.110	.128	.147	.183	.37
5-1/2 x 2	14.81	.006	.013	.019	.025	.032	.038	.044	.051	.057	.063	.079	.095	.110	.126	.158	.32
5-1/2 x 2 x 1	13.45	.007	.014	.021	.028	.035	.042	.049	.056	.063	.070	.087	.104	.122	.139	.174	.35

Velocity in ft/sec. = 0.00935 x Rate (B/D)/Area of Down Passage (sq. in.)

Size (Inches)	3/4	1	1-1/4	1-1/2	2	2-1/2	3	3-1/2	4-1/2	5-1/2
OD "	1.05	1.315	1.660	1.900	2.375	2.875	3.500	4.00	4.500	5.000
ID "	.824	1.049	1.380	1.610	1.995	2.441	2.992	3.548	4.00	4.950
ID Area (Sq.In.)	--	--	1.49	2.04	3.12	4.68	7.02	9.90	12.58	19.23
OD Area (Sq. In.)	.865	1.36	2.17	2.83	4.42	6.49	9.60	12.58	--	--

are not usable due to limited space.

Figure 4 and Table A can be used in the selection of equipment for small diameter completions. Certainly where the GLR is relatively high and the well must be pumped, some venting of the gas will be necessary. Also, consideration should be given to the casing size when planning wells where the downward oil velocities are near the rising velocity of the gas. Where high downward velocities result, little gas separation will occur and pump efficiencies will normally be low. In such cases, use of larger casing may be justified.

CONCLUSIONS

To efficiently produce wells with gas problems, it is necessary to have the correct pump setting depth. Also, an effective gas anchor must be used where the pump intake pressure is relatively low. In addition, a high compression ratio must be developed by the pump.

ACKNOWLEDGMENT

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REFERENCES

1. Fred N. Peebles and Harold J. Garber - "Studies on the Motion of Gas Bubbles in Liquids", Chemical Engineering Progress, (February 1953).
2. W. E. Gilbert - "Flowing and Gas-Lift Well Performance", API Drilling and Production Practices, (1954), 126
3. Glenn M. Stearns - "An Evaluation of the Rate of Slippage of Oil Past Oil-Well Pump Plungers", API Drilling and Production Practices, (1944).
4. C. A. Connally, C. R. Sandberg and N. Stein - "Volumetric Efficiency of Sucker Rod Pumps When Pumping Gas-Oil Mixtures", AIMME Transaction, 198, (1953), 265.
5. H. G. Haddenhorst and Kurt Horn - "Attacking Deep 2-Phase Pumping Problems", Petroleum Engineer, (July 1962), 31.
6. Glenn M. Stearns - "An Experimental Investigation of the Volumetric Efficiency of Sucker Rod Pumps", API Drilling and Production Practices, (1943).
7. W. P. Schmoe - "Bottom-Hole Gas Separation Increases Production", API Drilling and Production Practices, (1958).
8. E. P. Tallant - "Report on API Pump Performance Experiment", API Drilling and Production Practices, (1938).
9. M. B. Standing - "A Pressure-Volume-Temperature Correlation for Mixtures of California Oils and Gases", API Drilling and Production Practices, (1947).