Use of Vent Strings in Artificially Lifted Wells

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INTRODUCTION

During recent years, multiple completions have become more commonplace. This is to be expected due to the obvious economic advantages derived from producing two or more allowables while having to drill but one hole. Problems encountered in producing multiple completions, as in single completions, are usually minimum until artificial lift is required. With the installation of lift equipment, production from zones beneath a packer can be adversely affected if the pump intake pressure is below the bubble point of the produced fluid and the gas production is not adequately vented. The use of vent strings in these cases can result in maintaining producing rates at or near normal, and thereby increase income and shorten producing life over what would be anticipated if the well were produced unvented.

SUBSURFACE EQUIPMENT

There are many types and combinations of subsurface equipment that may be used to artificially lift-multiple completed wells. The following discussion will be confined to the types used in the wells on which vented and unvented tests were conducted. Tests conducted on Mobil leases in West Texas will be discussed later.

Figure 1 shows a well dually completed in 5-1/2 in. OD casing. Both zones are being pumped with conventional insert type subsurface hydraulic equipment. This installation consists primarily of one string of 2-in. tubing, one string of 3/4-in. tubing which is run inside the 2-in., two strings of 1-in. tubing, the pumps and a special bottom-hole assembly. The lower zone power oil is pumped down the 3/4-in. tubing, and lower zone production and exhaust power oil are returned through the 3/4-in., 2-in. tubing annulus. Upper zone power oil is pumped down one string of 1-in. and upper zone exhaust power oil and production are returned through the other string of 1-in. tubing. Upper zone gas production is vented through the casing-tubing annulus. Lower zone gas production cannot be vented in this installation. The two pumps are run in tandem on the 3/4-in. tubing, and although they must be pulled together, each operates independently of the other.

Figure 2 is a sketch of a two-zone rod pump installation. This type assembly permits venting gas from the lower zone in a 5-1/2 in. dual installation. The equipment consists primarily of two rod insert pumps run on a single string of rods, one string of 2-in. tubing, two strings of 1-in. tubing and a crossover assembly. The upper zone is produced as a conventional sucker rod installation. Production is pumped up the 2-in. tubing above the crossover assembly and gas is vented in the casing-tubing annulus. Lower zone production is pumped up the 2-in. tubing to the crossover assembly. Here it is transferred through the crossover assembly to the short string of 1-in. tubing and up the 1-in. to the surface. Gas is vented from the lower zone through the long string of 1-in. tubing. The only method of varying production in this type installation is the use of different pump plunger sizes. The upper zone can be circulated through the casing-tubing annulus.

Figure 3 shows a dual installation in 7-in. OD casing with the lower zone vented. The equipment consists of two strings of 2-in. tubing, two strings of 3/4-in. tubing, one string of 1-in. tubing and two subsurface hydraulic pumps. Each pump is run on a 3/4-in. string inside a 2-in. string. The 1-in. string is used to vent the gas from the lower zone. The upper zone is vented through the casing-tubing annulus. Each pump is operated and can be pulled independently of the other. Power oil is pumped down the 3/4-in. string and returned with the production through the 3/4-in., 2-in. tubing annulus. This installation can be converted to a dual sucker rod installation by using rods in lieu of the 3/4-in. power oil tubing; and rod insert pumps in lieu of the hydraulic pumps.

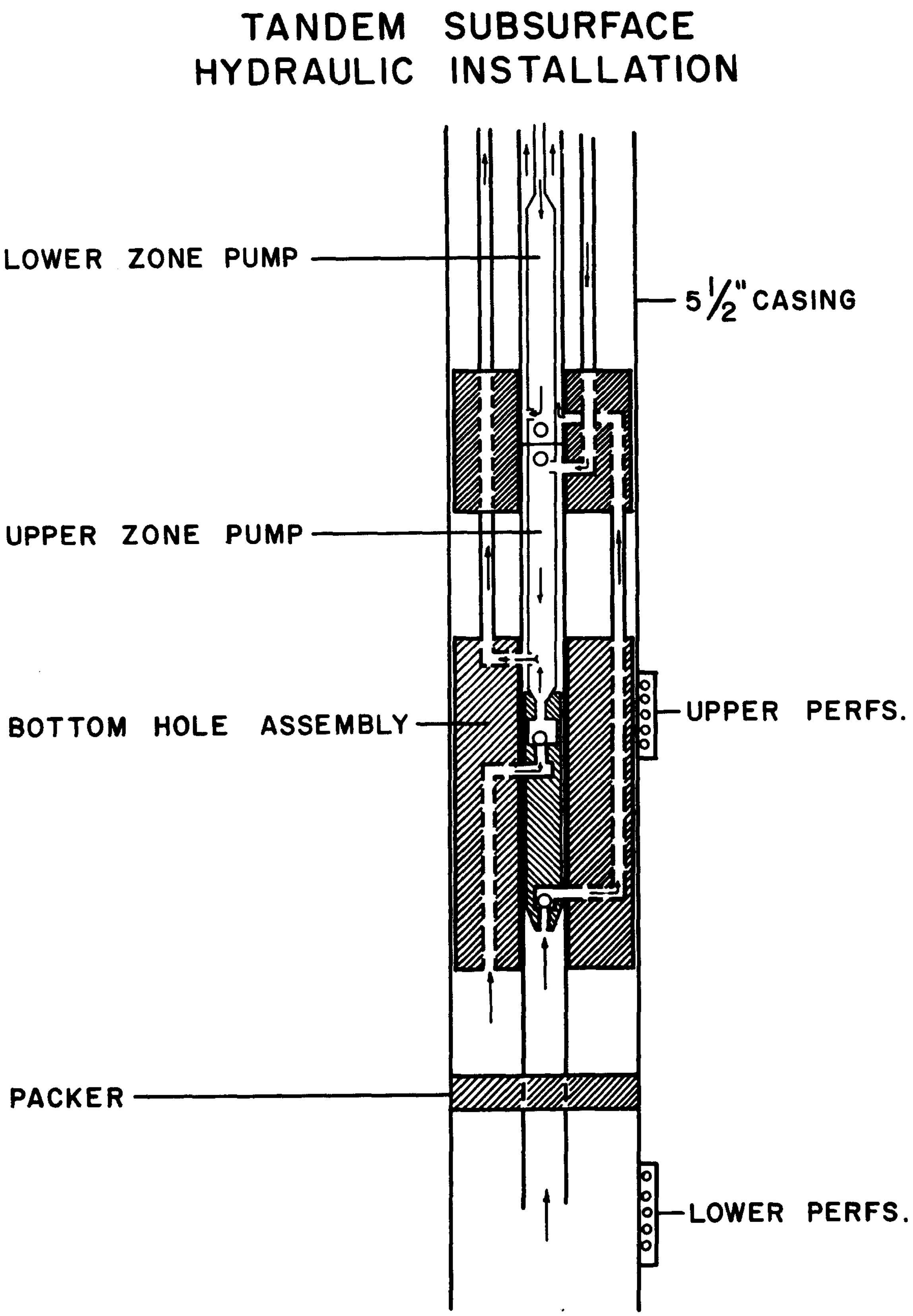

TANDEM SUBSURFACE
HYDRAULIC INSTALLATION
LOWER ZONE PUMP
5 1/2" CASING
UPPER ZONE PUMP
BOTTOM HOLE ASSEMBLY
UPPER PERFS.
PACKER
LOWER PERFS.

FIGURE 1

TWO ZONE ROD PUMP INSTALLATION

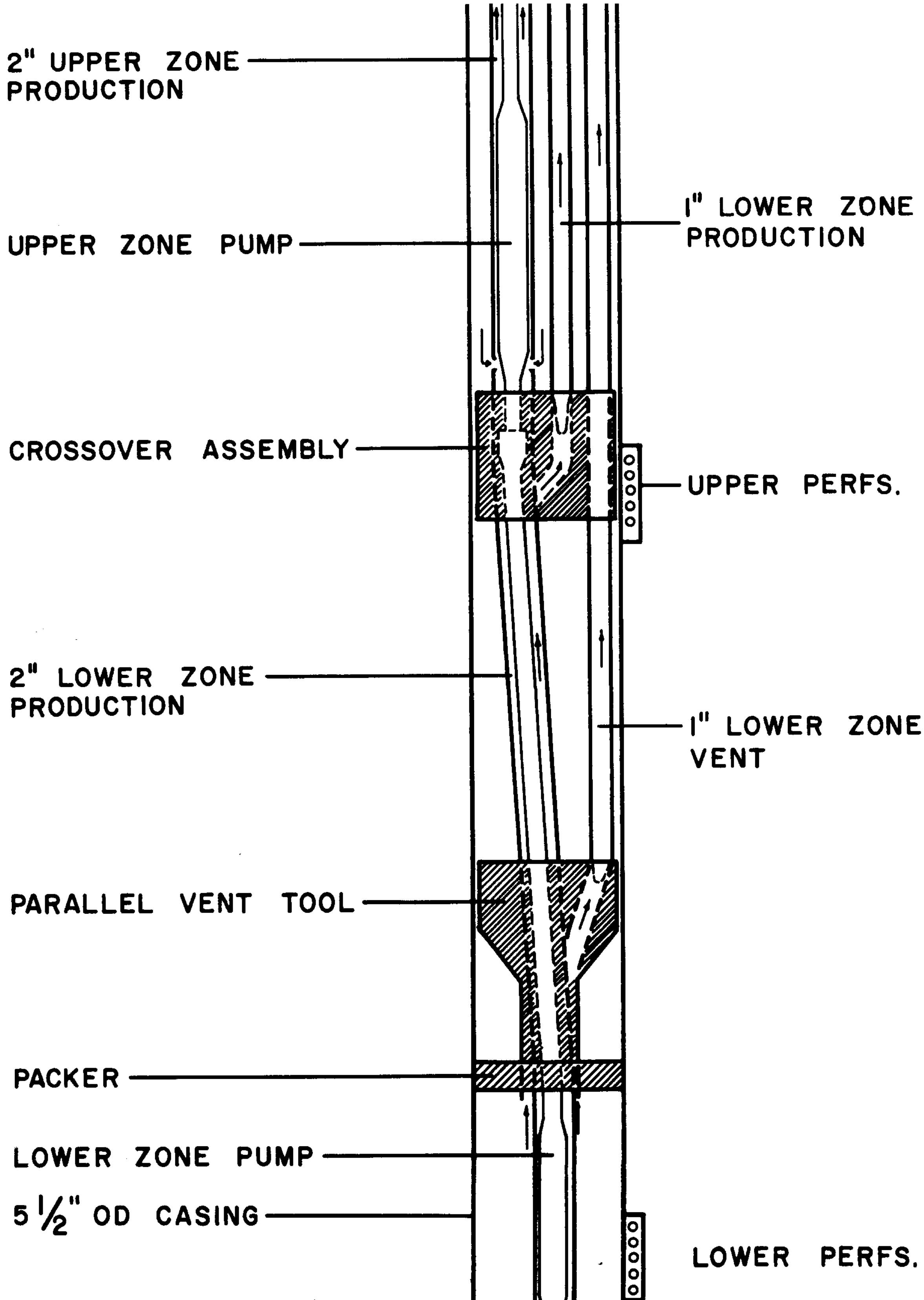


FIGURE 2

DUAL HYDRAULIC OR SUCKER ROD INSTALLATION

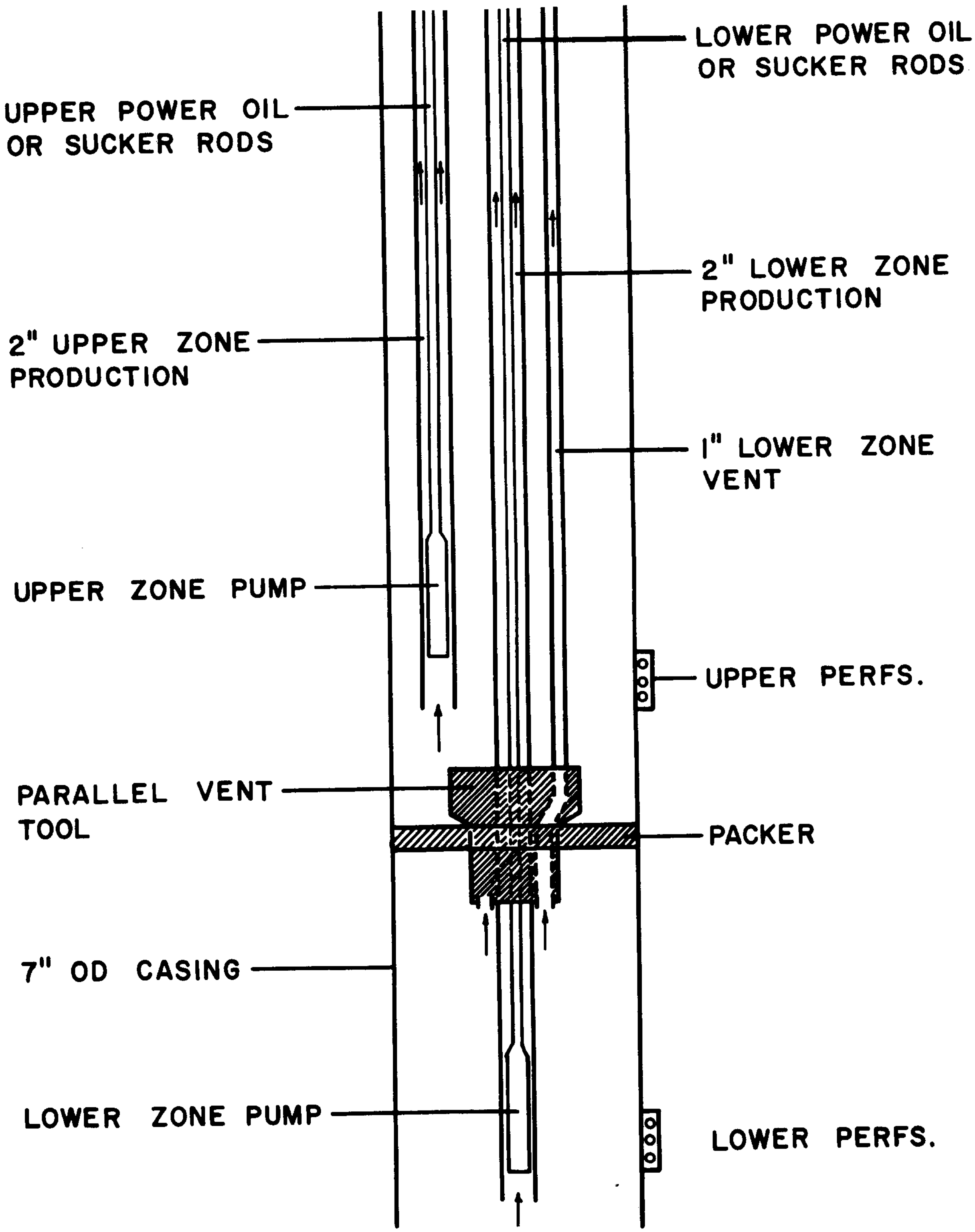


FIGURE 3

TABLE I
VENTED AND UNVENTED PRODUCTION - SAME EQUIPMENT

	Vent String Closed				
	Production		Length of	Daily Average Production	
	Oil (Bbls)	Water (Bbls)	Test Period (Days)	Oil (BPD)	Water (BPD)
Well A	233	60	10	23.3	6.0
B	88	48	3	29.3	16.0
C	64	271	3	21.3	90.3
D	49	288	3	16.3	96.0
E	27	22	4	6.8	5.5
F	69	37	3	23.0	12.3
G	1	-	1	1.0	-
H	-	-	1	-	-
J	8	2	2	4.0	1.0
K	-	-	1	-	-
L	-	-	1	-	-
Total				125.0	227.1
	Vent String Closed				
Well A	172	24	4	43.0	6.0
B	268	62	4	67.0	15.5
C	82	347	4	20.5	86.8
D	46	289	3	15.3	96.3
E	23	24	4	5.8	6.0
F	77	37	3	25.7	12.3
G	10	3	1	10.0	3.0
H	6	-	1	6.0	-
J	61	5	2	30.5	2.5
K	15	-	1	15.0	-
L	26	-	1	26.0	-
Total				264.8	228.4

VENTED VERSUS UNVENTED PRODUCTION — SAME EQUIPMENT

A few years ago, tests were conducted on several Mobil leases to determine the effect of the use of vent strings on the production of the lower zone in dual completions. The procedure was simply to test the lower zones with the vent strings open and closed. The tests varied in length from two days to 14 days. Eleven wells in five fields, ranging in depth from 2400 ft to 7500 ft were involved. Production equipment included two-zone rod pump installations in three wells, seven dual subsurface hydraulic installations and one dual rod pump installation. Table I shows the results of the tests. With the vent strings open, the average fluid production from the eleven wells was 141 BPD higher than with the vent strings closed. The increase from 352 BPD to 493 BPD is a 40 per cent gain overall. Oil production accounted for 140 BPD of the total increase. Based on the oil production increase, a 111 per cent gain was realized. Of the 11 wells tested, seven wells had significant increases in oil production. In no instance was there a decrease in oil production exceeding one BPD. The two high water cut wells showed little effect of opening and closing the vent string. Since the fluid production from these two wells was 75 to 80 per cent of the calculated pump displacement, the lack of effect can be attributed to the pump intake pressure being above the bubble point. Three of the eleven wells produced no fluid when the vent string was closed indicating an immediate "gas lock" condition. These tests show that producing rates can be adversely affected when wells are produced in an unvented condition.

VENTED VERSUS UNVENTED PRODUCTION — EQUIPMENT CHANGED

About the same time the previous tests were being conducted, four dual wells with 5-1/2 in. OD casing were being pumped with tandem subsurface hydraulic equipment which did not permit venting gas production from the lower zone. Production in the lower zone of these duals had declined rapidly and it was felt the rates were being curtailed because the gas was not being vented. The existing equipment was replaced with two-zone rod pump equipment which permitted venting gas from the lower zone. No remedial work was performed; only the changing of equipment was involved. Table II compares tests run immediately prior to the change, immediately after the change and approximately one and two years later. Immediate results were excellent. An average production increase of 77 BPD per well was realized. After one year the increase was 20 BPD per well and after two years the increase was still 10 BPD per well. The increase is based on the assumption that production prior to the change did not decline. Again in the case of these four wells, the use of vent strings proved avantageous.

There are other specific examples where production benefited from venting or was curtailed because venting was not accomplished. A 3000-ft well in Scurry County was hydraulically fractured and potentialed for over 100 BOPD which was equipment capacity. Shortly afterward, the well was re-entered and dualled with an upper zone. The equipment installed was such that the lower gas production could not be vented. Immediately following the installation of the dual equipment, the well tested only 35 BPD from the lower zone. Production rate recorders showed that all the fluid was being produced in a two-hour period each day and dynamometer cards showed the pump to be "gas locked". Because the reduced rate was in excess of the required calendar day rate for a top allowable well, the well continued to produce in an unvented condition until permission to commingle the two zones downhole was granted.

Another example of the benefit to be derived from venting is the case of two 1700-ft. wells which were drilled as tubingless completions. Within a few months, the conventional rods had to be replaced with hollow rods because, due to the unvented condition, production was being

TABLE II

VENTED AND UNVENTED PRODUCTION - EQUIPMENT CHANGED[1]

	Test Prior to Change Gas Not Vented		Test After Change Gas Vented		Test 1 Year After Change Gas Vented		Test 2 Years After Change Gas Vented	
	Oil (BPD)	Water (BPD)	Oil (BPD)	Water (BPD)	Oil (BPD)	Water (BPD)	Oil (BPD)	Water (BPD)
Well A	12	3	46	-	13	2	15	2
B	Temp. Abnd.		124	5	29	13	18	3
C	7	-	66	2	13	10	19	2
D	29	-	122	-	47	4	27	4

Note: [1]Wells completed with 5-1/2" OD production string. Equipment changed from subsurface hydraulic tandem installation to two zone rod pump installation.

sharply curtailed. Five years later these two wells are producing at a higher daily rate than when unvented. In five multiple tubingless completions producing from depths of 1700 ft, 2400 ft, 3000 ft and 3500 ft, conventional sucker rod equipment had be to replaced with 1½ in. tubing and 5/8-in. slim-hole rods because the pumps had become "gas locked" in their unvented condition.

These tests and experiences indicate that there are a great many wells in which venting of the gas is essential in maintaining production rates near normal. However, some wells may never require venting, such as wells with pump intake pressures at or above the bubble point throughout their producing life. An example would be wells completed in the Russell, North (Devonian) Field, Gaines County, Texas. Some wells in this field are producing over 1000 BPD from 11,000 ft without benefit of the gas being vented. Bubble point of the reservoir fluid is approximately 1000 psi. Current reservoir pressure is near 4000 psi. Despite the large withdrawal rates, the pump intake pressure is above the bubble point and pump efficiencies of 80 per cent or greater are common. Unless withdrawal rates are significantly increased, these wells will probably never require venting of the gas production.

VENTING THROUGH 1-IN. TUBING VERSUS ANNULAR VENTING

Within the past two years, the productive capacity of several dual completions had declined to the point at which the combined daily oil production from both zones was less than the top marginal allowable of the upper zone. For this reason, along with others, an exception to Statewide Rule 10 was granted for these wells by the Texas Railroad Commission and downhole commingling was permitted. Lower zone production was being vented in all these wells through 1-in. tubing. After the commingling work was completed, gas production from both zones was being vented in the casing-tubing annulus. Table III compares production prior to and after the commingling work. The test results show a total fluid production increase of 80 BPD, from 340 BPD to 420 BPD, a 24 per cent gain. The increase in oil production was 63 BPD, from 168 BPD to 231 BPD, a 38 per cent gain. Based on total fluid production, venting string efficiency was 81 per cent. Based on oil production alone, vent string efficiency was 73 per cent. These figures are based only on lower zone production. In order to determine production from the lower zone after commingling downhole, it was assumed that any additional fluid, above the combined production from both zones prior to commingling, would be produced from the lower zone. Considering that all pumps used in conducting the post-commingling tests had been pulled and repaired during the commingling work and had been back in service only a few days whereas those used in conducting the pre-commingling tests had been in service for several months, it is reasonable to assume that the vent string efficiencies shown are a minimum. Water production reported during the last series of tests varied considerably. In some instances water production decreased markedly; in others it increased. This can probably be attributed to inadequate or faulty water-measuring equipment.

TABLE III

VENTING THRU I IN COMPARED WITH ANNULAR VENTING

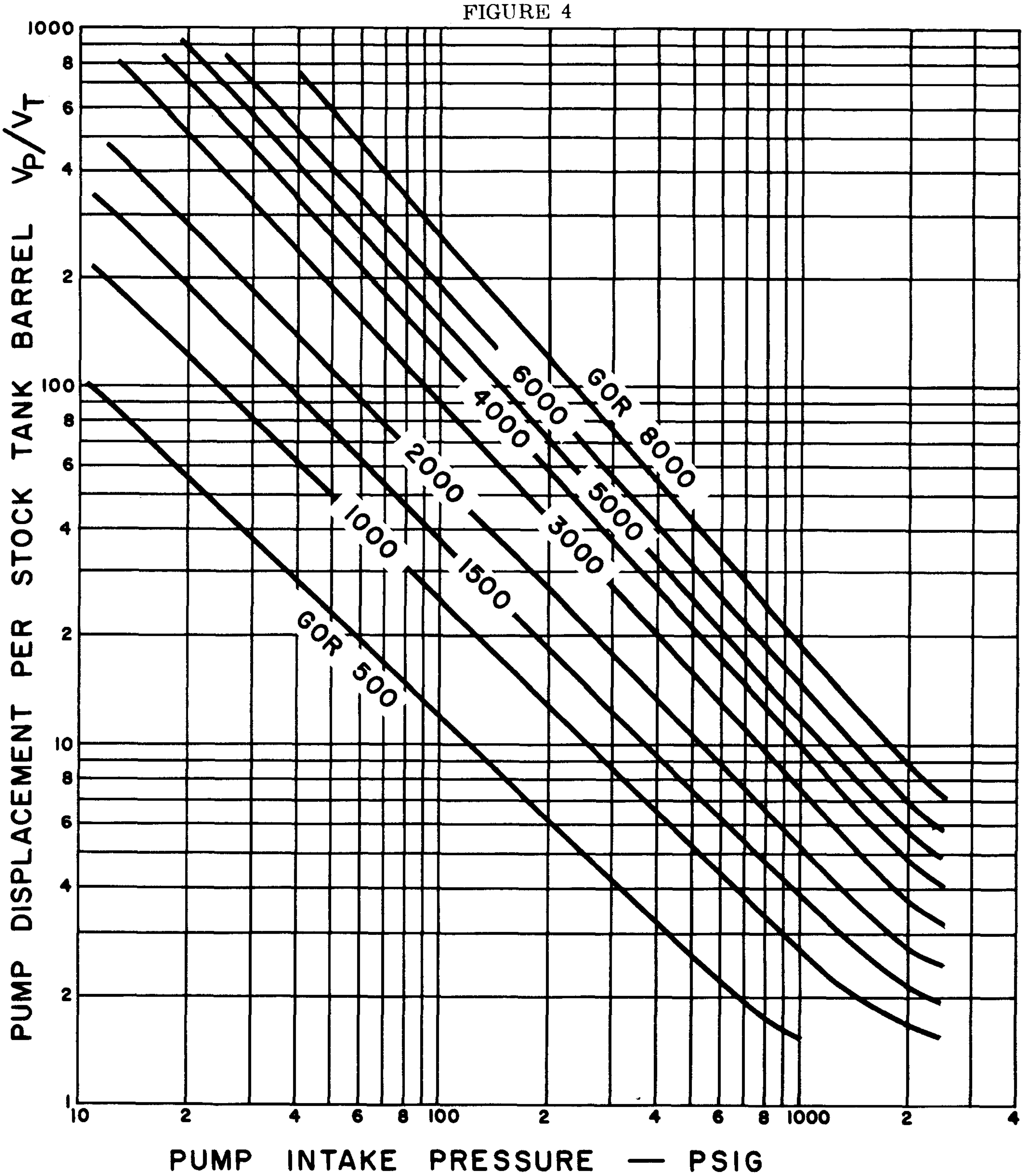
	Venting Thur I In. Tubing Oil (BPD)	Water (BPD)	Annular Venting Oil (BPD)	Water (BPD)
Well A	9	8	12	1
B	12	5	16	4
C	13	5	18	4
D	13	23	14	1
E	9	11	11	13
F	7	13	14	36
G	9	29	17	1
H	6	14	12	-
J	10	13	17	47
K	13	4	18	9
L	6	-	9	9
M	20	2	22	-
N	10	-	14	7
O	8	1	17	11
P	9	41	9	41
Q	8	2	11	5
Totals	168	172	231	189

ESTIMATING UNVENTED PRODUCTION

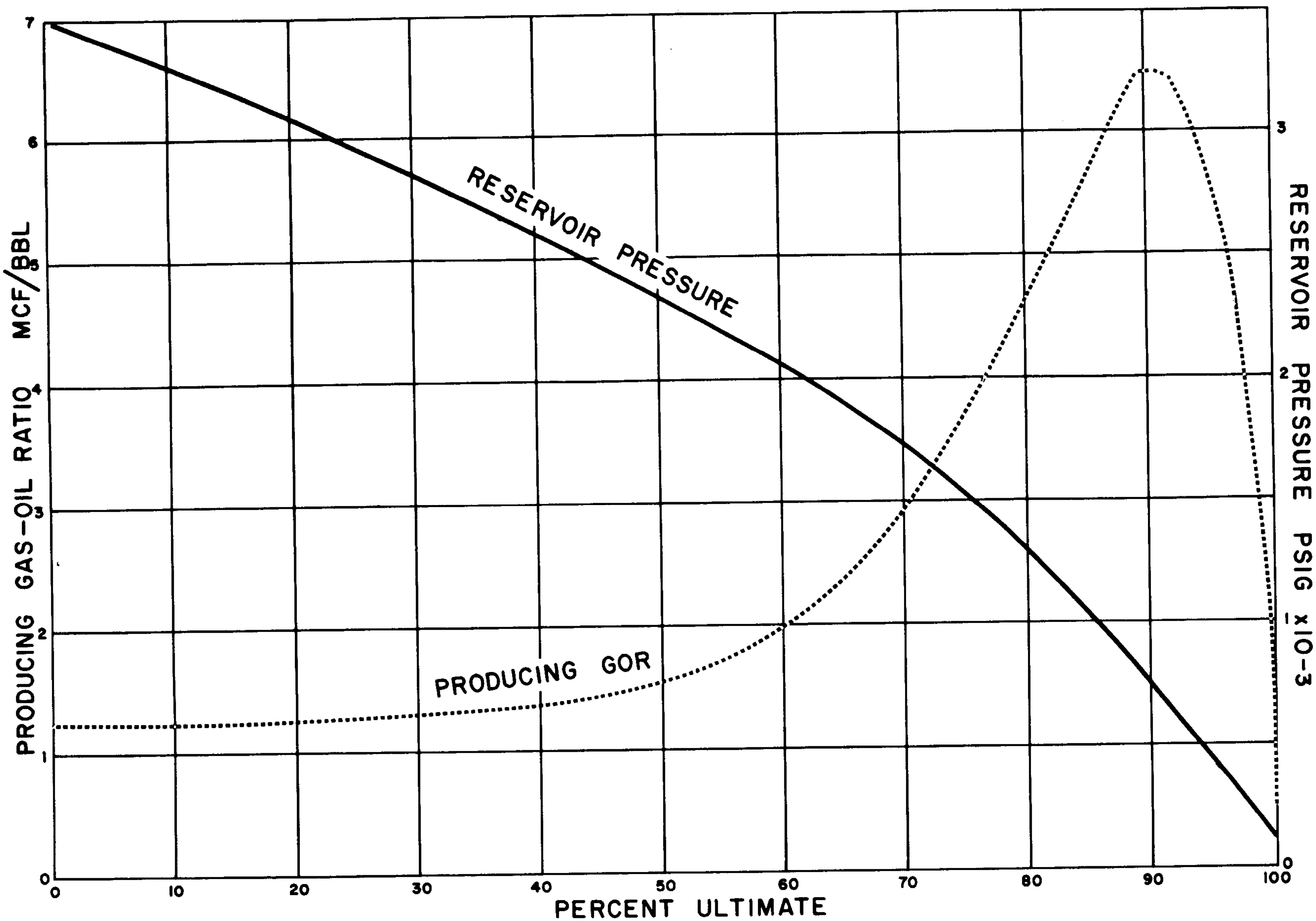
Thus far, vented production has been compared with unvented production, and annular venting has been compared with venting through one-in. tubing strings. In some instances venting proved to have little or no effect on production; in other instances venting was critical. If unvented production rates could be predicted when drilling a well is being considered, then the economics of vented production could be compared with the economics of unvented production. Factors such as hole-size, casing size, type and number of completions, and methods and size of artificial lift equipment could be affected. For example, if a

PUMP DISPLACEMENT PER STOCK TANK BARREL VERSUS PUMP INTAKE PRESSURE AT VARIOUS GORS

FIGURE 4



RESERVOIR PRESSURE AND PRODUCING GOR VS PERCENT ULTIMATE



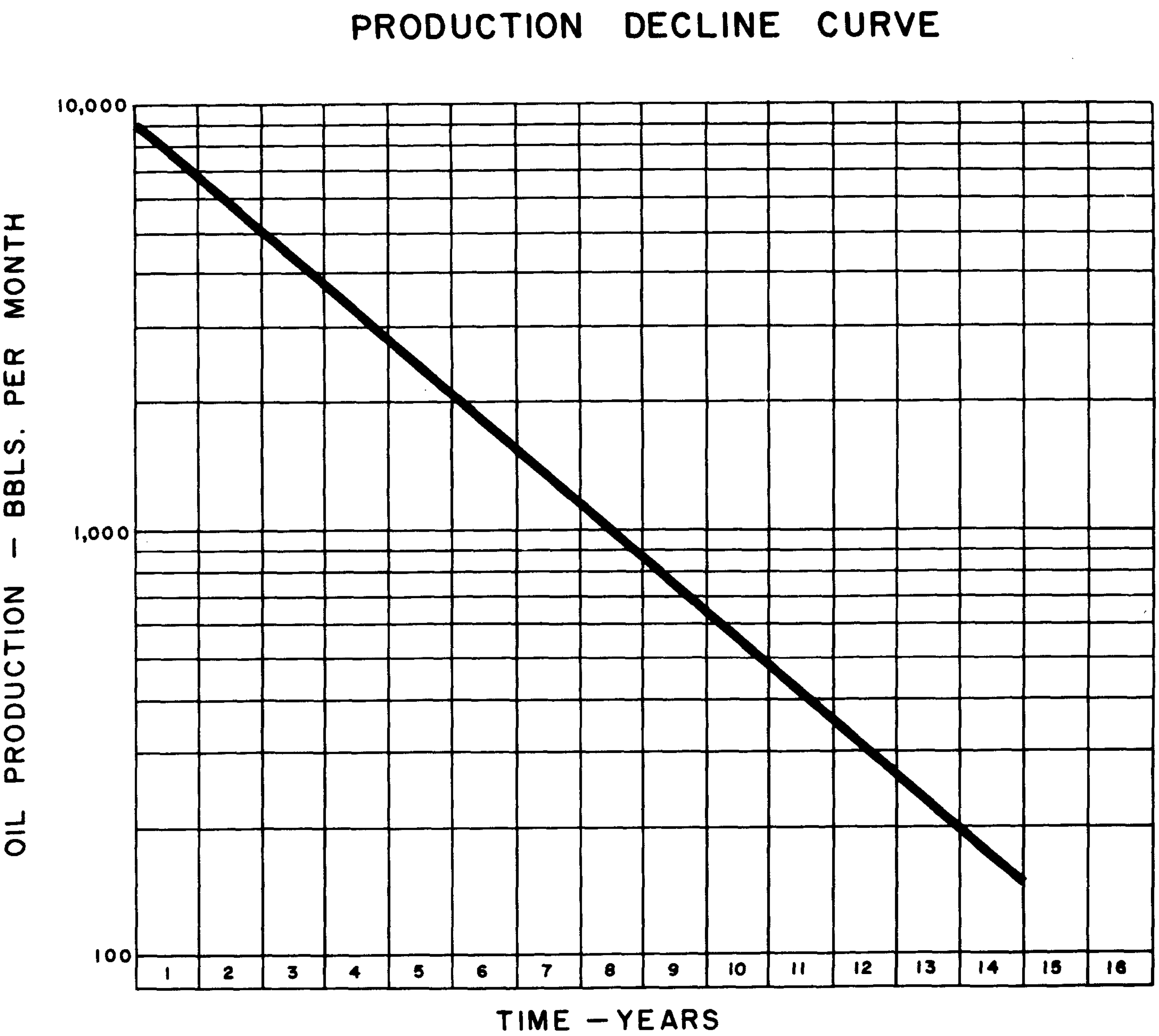

PRODUCTION DECLINE CURVE
OIL PRODUCTION - BBLS. PER MONTH
10,000
1,000
100
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
TIME — YEARS

FIGURE 6

tubingless completion is being considered and due to depth and volume requirements venting is not feasible, a comparison of economics may indicate a conventional completion permitting venting would afford a more profitable project. Or a triple completion with the two lower zones producing unvented may prove less profitable than a dual completion with both zones vented originally with the third zone being produced following the depletion of one of the other zones. The comparison of vented and unvented production may dictate that one method of lift should be recommended because its use does not require venting or because its use permits venting when other methods do not.

A method for predicting unvented production will now be offered. This method necessitates a trial-and-error solution and excludes any possible "agitate and flow" or "gas lock" condition. Clegg[1] presented a chart of displacement required per stock tank barrel versus pump intake pressure with various gas-oil ratios. Figure 4 is such a chart prepared for a field in Southeast New Mexico. Other data required are plots of producing GOR and reservoir pressure versus per cent ultimate recovery as shown in Fig. 5, production decline curve, Fig. 6, the productivity index of the well and the capacity of the artificial lift equipment to be installed.

The application of this method can perhaps be best demonstrated through the use of an example. A well is to be drilled in the field in Southeast New Mexico. What would be the effect of producing the well unvented? Artificial lift will be required after three years. Beam equipment with a capacity of 225 BPD is to be used when artificial lift is required. From Fig. 6 the average production rate during the fourth year is estimated to be 105 BPD. Cumulative production at the mid-point of the fourth year is estimated to be 65 per cent of the ultimate production. From Fig. 5 the reservoir pressure and producing GOR are estimated to be 1900 psi and 2400 SCF/BBL, respectively. Since the capacity of the well is 105 BPD and the capacity of the artificial lift equipment is 225 BPD, the well, if vented, would pump off. The PI of the well can be estimated by dividing the capacity of the well by the reservoir pressure or PI = 105 BPD ÷ 1900 psi = 0.0553 BPD/psi. Although the unvented production of the well will be curtailed the PI should remain the same. Assuming an unvented rate of 35 BPD, the pressure drawdown would be determined as follows: 35 BPD ÷ 0.0553 BPD/psi = 633 psi. Pump intake pressure is 1900 psi – 633 psi or 1267 psi. With a pump intake pressure of 1267 psi and a producing GOR of 2400 SCF/BBL the displacement required per stock tank barrel V /V is estimated from Fig. 4, to be 5. If the assumed curtailed rate times V /V and divided by the pump capacity equals unity, the assumed curtailed rate is correct. If the solution is less than unity, the assumed rate is too low; if the solution is greater than unity, the assumed rate is too high. In the example, 35 BPD X 5 ÷ 225 = 0.778. Therefore the assumed rate is too low. A curtailed rate, higher than 35 BPD is assumed and the procedure is repeated until the solution approaches unity. In the example, the correct curtailed rate is 42 BPD at a pump intake pressure of 1141 psi. The ratio of vented to unvented production is 2.5 indicating that under the existing conditions the well would have to be produced 2.5 years unvented to get one year's production vented. This procedure could be repeated for each year and the well life and producing rates unvented could be estimated. In the example, the well with production vented has a life of approximately 14 years and with production unvented the well life is approximately 25 years. The added operating expense due to the longer life and the reduced annual income due to the curtailed producing rate would have an adverse effect on the profitability of this venture, making additional investment and/or higher annual operating expense for equipment that would permit or did not require venting appear more attractive.

SUMMARY

Field tests have indicated that the use of vent strings in artificially lifted wells can result in increased rates in comparison to producing unvented. There are wells on which venting of the gas production has little or no effect on the producing rate. If sufficient reservoir and production data are available or can be estimated, unvented producing rates can be approximated using the method presented. As a result the economics of producing unvented can be compared with those of producing vented. This comparison could affect such factors as hole size, casing size, type and number of completions, and method and size of artificial lift equipment.

REFERENCE

1. Clegg, J. D., "Get Rid of Gas Problems in Those Pumping Wells", Oil and Gas Journal, p. 106, April 29, 1963.

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