Evaluation of Valve Port Size in Intermittent Gas Lift

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(Portions of this paper were originally presented in the 1961 Fall Meeting of the Society of Petroleum Engineers and was published in the March, 1962 issue of Journal of Petroleum Technology.)

Introduction

In the past few years most of the advancement in gas lift operations has been made in continuous flow operations. Yet, it is estimated that at least 70 per cent of the wells on gas lift in the United States are of the intermittent type. Since the term "slug flow" is sometimes used in both intermittent and continuous flow operations, it would be well to distinguish between the two types of flow. "Continuous flow gas lift" is defined as a method by which the fluids are produced at a continuous rate at the surface. This rate generally requires a continuous injection of gas through a surface choke; however, various additional control devices are sometimes installed to eliminate freezing, shut-off gas during natural flow periods, etc. The actual flow of fluids in the tubing may be of the slug type (one of many flow patterns known to exist in continuous flow).

"Intermittent flow" is defined as a gas lift method in which the liquid is produced in separate piston type slugs. Perhaps this type of flow could best be thought of as a ballistic type flow in which the liquid leaves bottom as a piston, propelled by a slug of expanding gas. Gas is generally injected through some type of control at the surface at predetermined intervals. However, the valve may have characteristics which cause gas to be injected through a small choke and still result in a ballistic type flow.

The purpose of the experimental work was to evaluate the most efficient port size to be used on the operating valve for the ballistic type of lift. This work is part of a comprehensive study of both intermittent and continuous flow gas lift and represents a joint project conducted by the Ohio Oil Co., the Sun Oil Co., Otis Engineering Corp., and The University of Texas.

The problem of evaluating port sizes has been given little previous attention. Undoubtedly, there has been done some work which has not been published to date. For example, some tests were conducted when the wireline, mechanically opened valve (Nixon) first came on the market. This valve was capable of utilizing full tubing as its port size; and although it is known that this was a very efficient valve, to the authors' knowledge the results of tests have never been published.

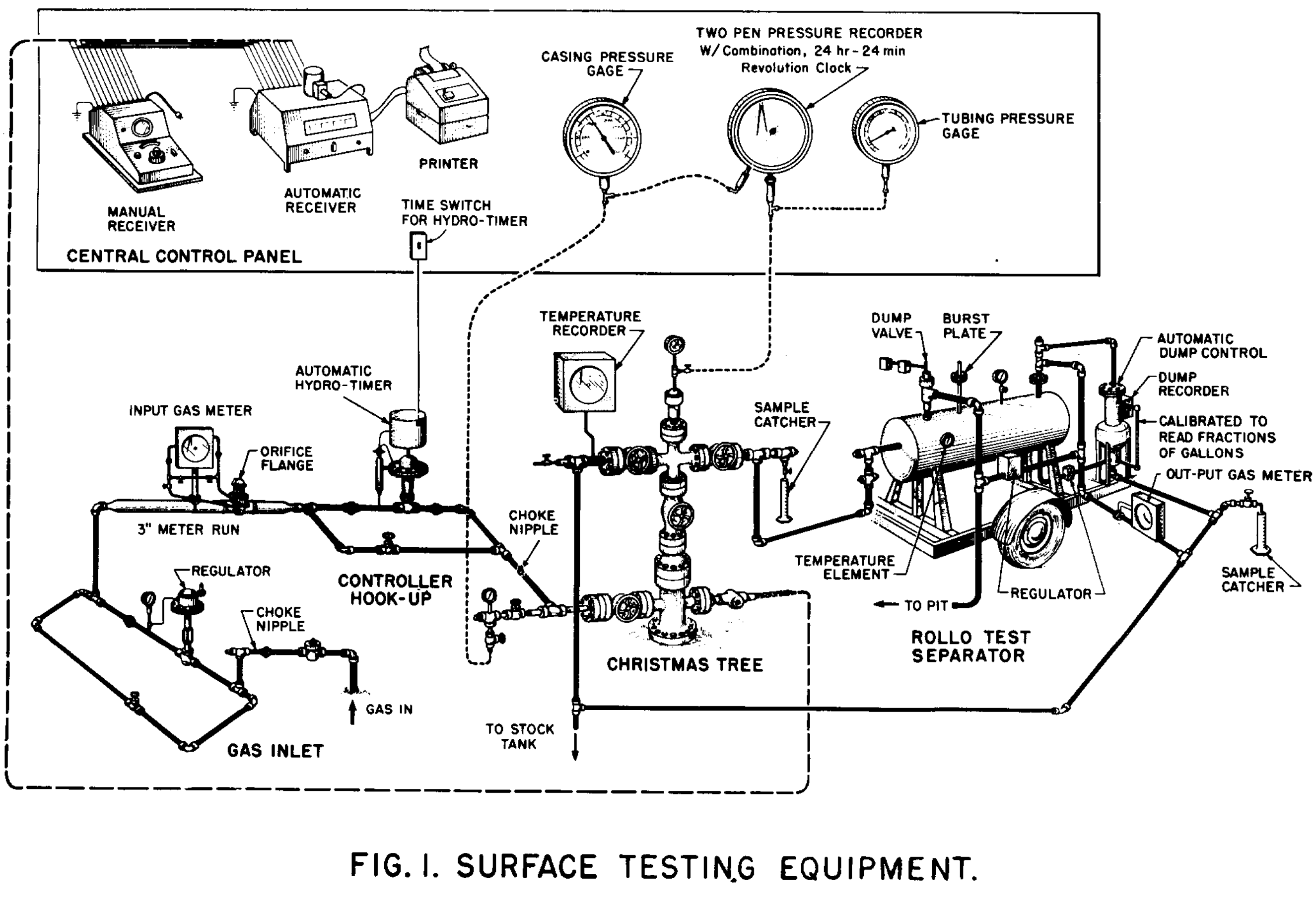


FIG. I. SURFACE TESTING EQUIPMENT.

Experimental Equipment

These tests were conducted on an actual field well, the Ohio-Sun Unit, Well No. 2-E, in the North Markham-North Bay City Field, Matagorda County, Texas. The well incorporated 2-3/8 in. O D tubing and produced 95 per cent water.

Since the running of equipment was to be quite elaborate and expensive, a well was selected in which both intermittent and continuous flow tests could be conducted. This particular well was capable of producing in excess of 1,000 B D of liquid (95 per cent salt water), yet with a 3/64-in. diameter bottom-hole choke production was controlled to 82 B D. Most of the intermittent tests were conducted at this low rate. Reference should be made to Figures 1 and 2 which show all the surface and down-hole equipment.

As can be seen, every attempt was made to insure that ample equipment was available for reliable testing procedures. Figure 1 shows the surface testing equipment. The input gas was controlled first by a regulator, then through a 3-in. meter run, on through the hydrotimer, and into the well. The production, upon leaving the test operator, went through a liquid test meter and finally into a tank. This test system allowed three checks on liquid produced; and, to eliminate any possible error in liquid production, the well was periodically checked in this manner. The test separator was carefully calibrated and periodically checked.

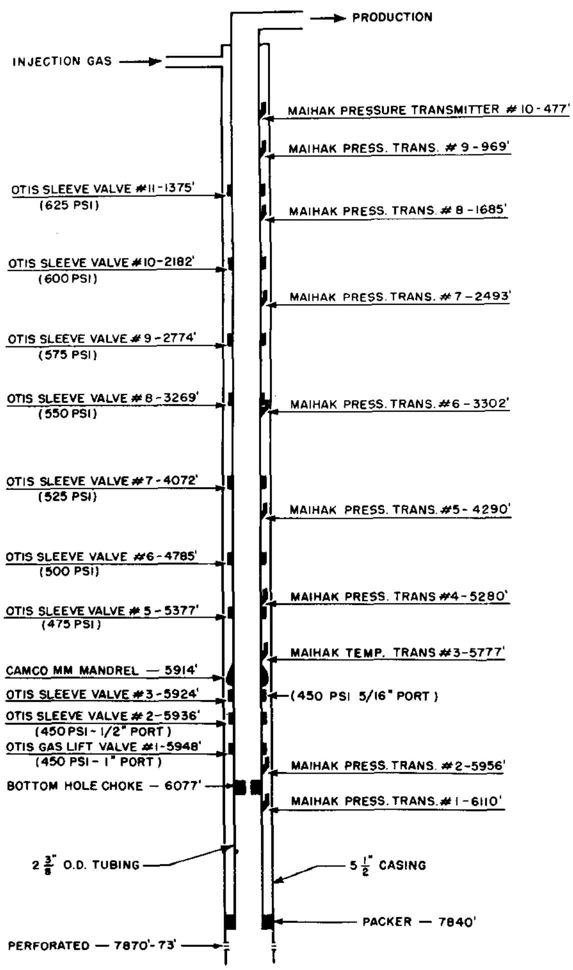


FIG. 2. DOWN-HOLE EQUIPMENT.

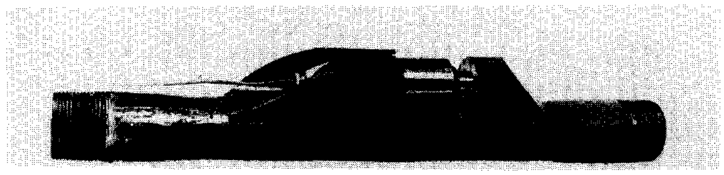


FIG. 3. MAIHAK PRESSURE TRANSMITTER.

The down-hole equipment (Fig. 2) was quite elaborate with the installation of a bottom-hole choke, a side-pocket mandrel, and 10 sliding side door gas lift valves. In addition, for the purpose of recording downhole pressures at selected points in the tubing string, 10 Maihak pressure transmitters were installed in the well. The Maihak pressure transmitter provides a means by which, from a pressure transmission in the well, pressure can be recorded at the surface. However, an electrical connection must be made from the instrument to the surface.

Since these instruments have been fully described in an earlier paper (1), suffice it to say that the Maihak pressure device operates on the principle of measuring the frequency of a stressed wire, the frequency being correlated to pressure. (Fig. 3, 4, and 5). The transmitter is connected to the surface by a single conductor

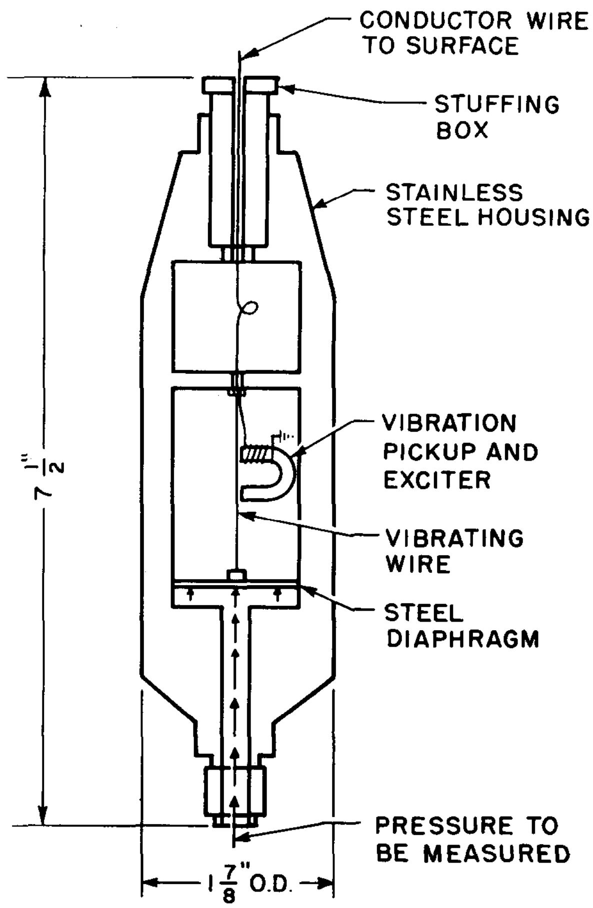


FIG. 4. MAIHAK TRANSMITTER.

cable. The tubing acts as the ground to complete the circuit. These particular instruments were calibrated both before and after the tests and showed a maximum of 0.62 per cent error. Instruments No. 4 and 6 were

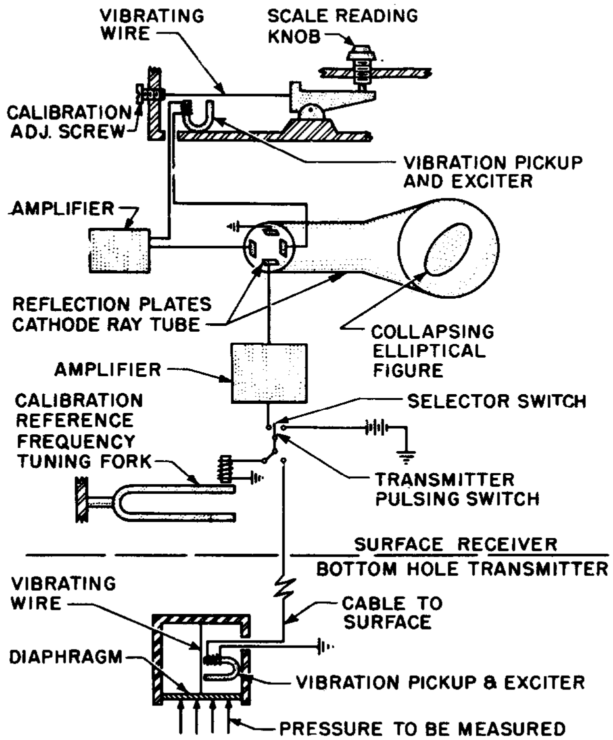


FIG. 5. SCHEMATIC DIAGRAM OF MAIHAK INSTRUMENTS.

shorted on going in the hole, and instrument No. 5 faulted the last few days of the test. Otherwise, all instruments worked very satisfactorily.

Ten electrical lines had to be run to the top of the string, and tape was used to strap these lines in place on the tubing string after being run over a centralizer. The lines were brought through the casing wing valve, through a sealing device, and into a central control panel

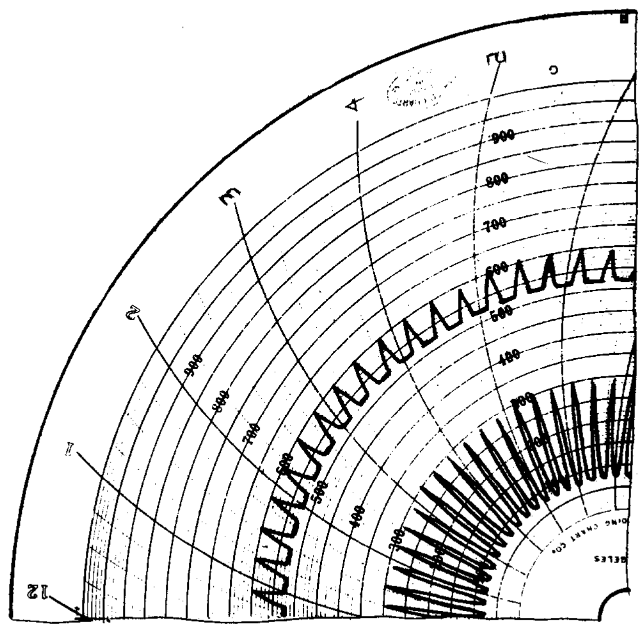


FIG. 7. 24 HR REVOLUTION RECORDING CHART $\frac{3}{8}$" SURFACE CHOKE VALVE PRESSURE = 550 PSIG DEPTH = 5940' 350 PSI LOAD

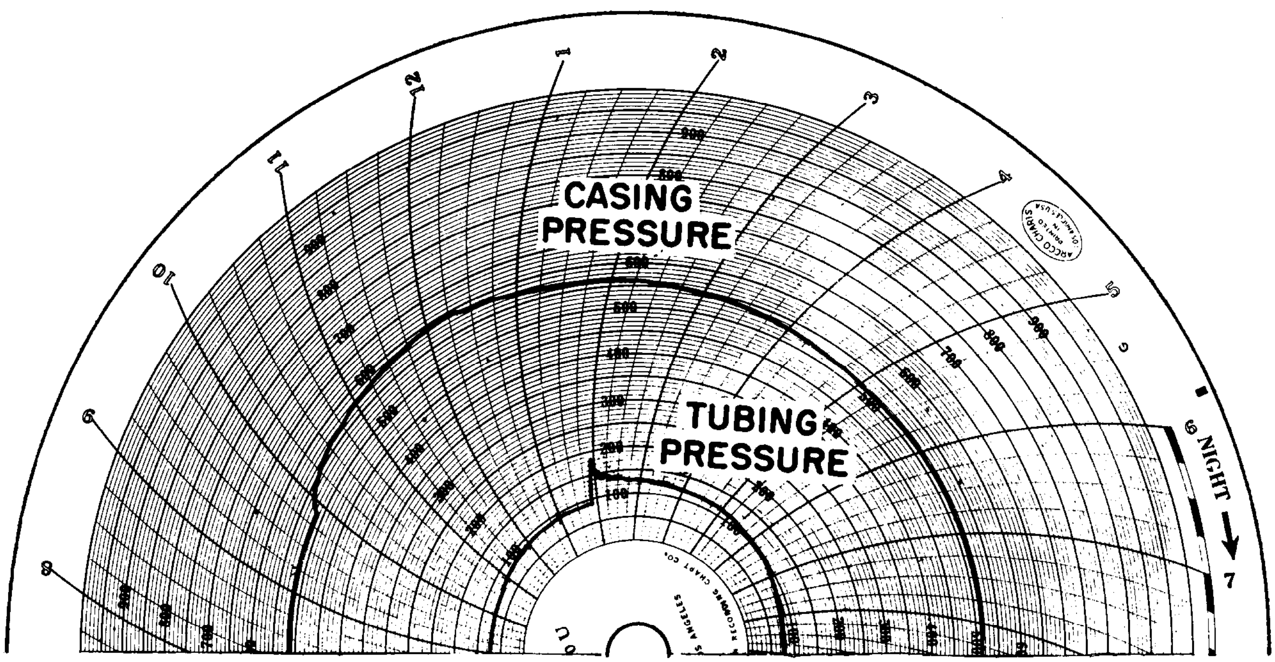


FIG. 6. 24 MIN. REVOLUTION RECORDING CHART

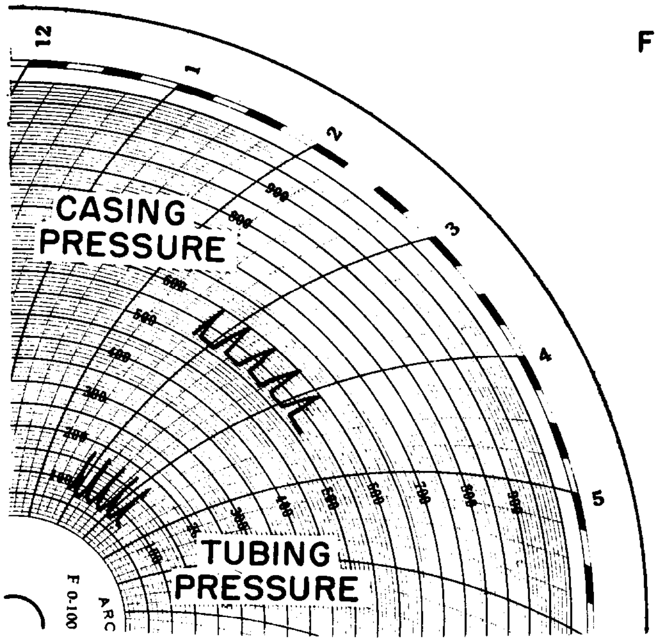


FIG. 8. 24 HR REVOLUTION RECORDING CHART $1\frac{1}{2}$" SURFACE CHOKE

FIG. 10. SLIDING SLEEVE GAS LIFT VALVE.

located in a small trailer unit. A two-pen chart for recording both tubing and casing pressure was also housed in the trailer unit. This recorder was equipped with a 24-hr-24 min revolution combination clock so that detailed pressure observations could be made. In addition, a large master gauge for both tubing and casing pres-

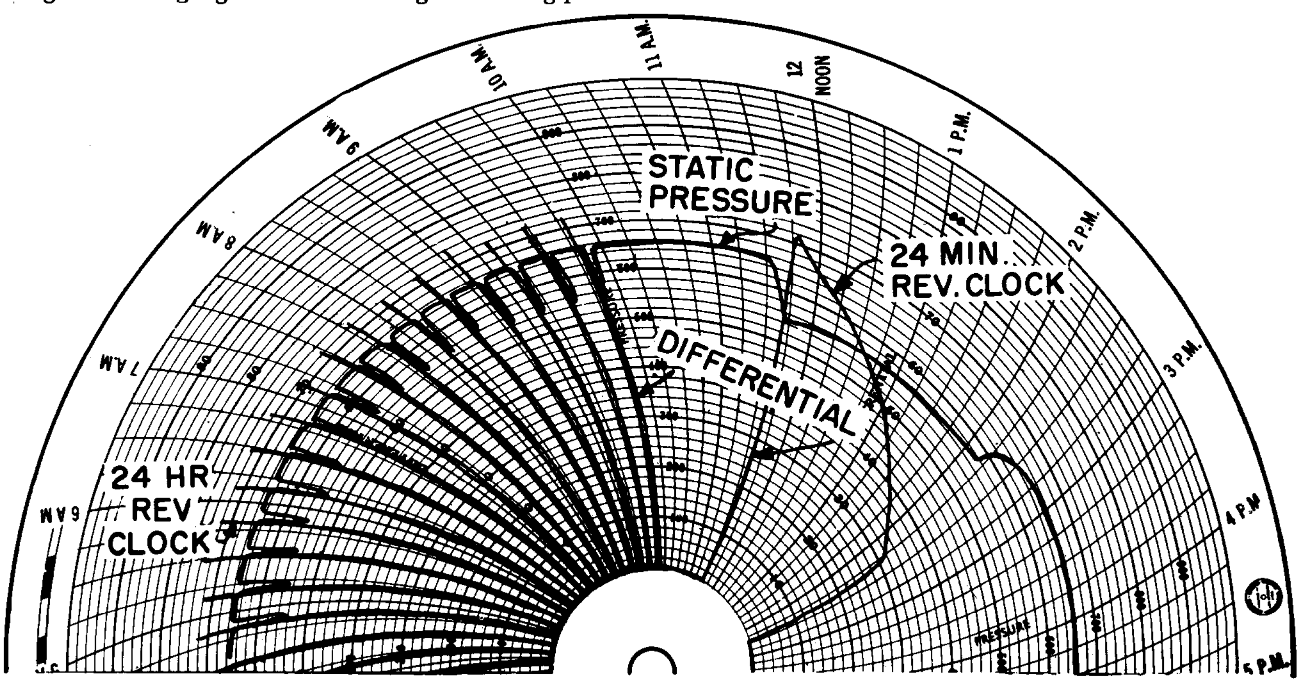


FIG. 9 COMPARISON OF GAS MEASUREMENT 24 HOUR REVOLUTION CLOCK AND 24 MINUTE REVOLUTION CLOCK

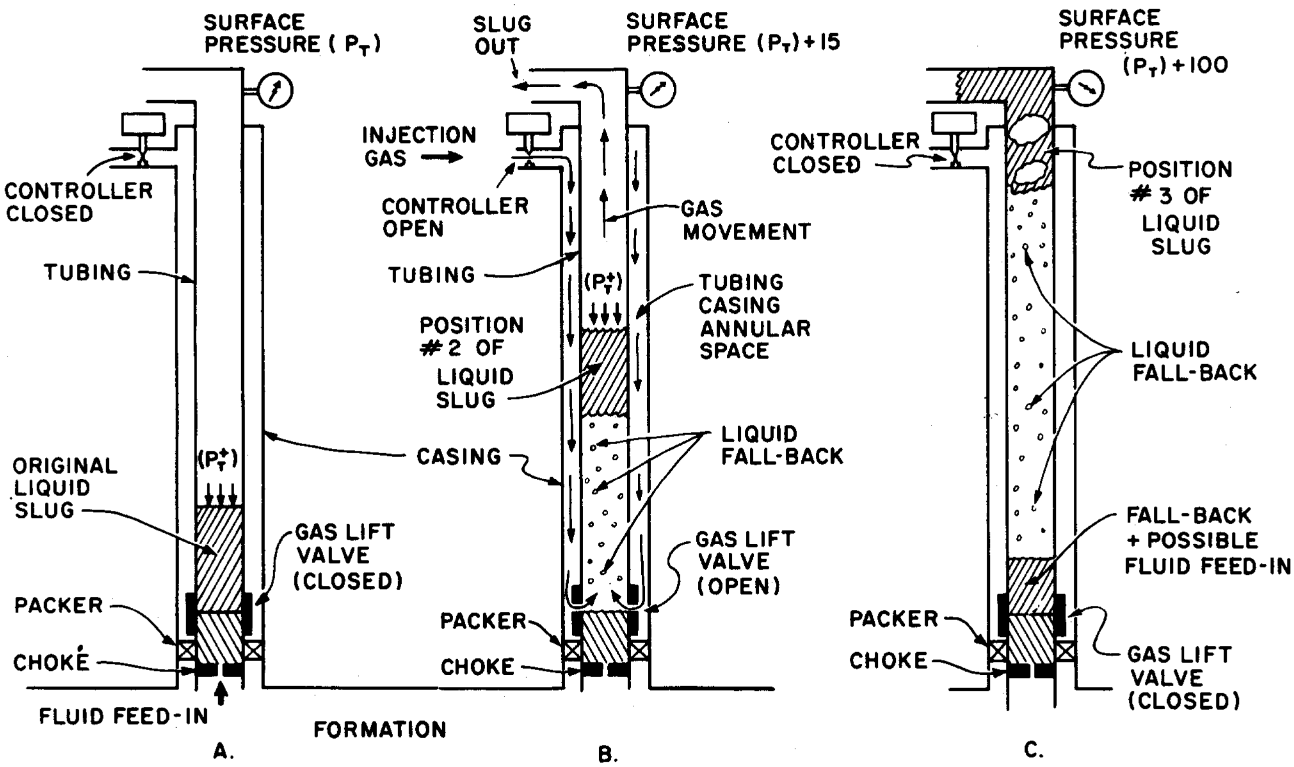


FIG.11. LIQUID SLUG POSITION.

sure was housed in the unit. All these instruments were periodically checked with a dead-weight tester. A typical 24-min intermittent tubing pressure slug may be observed in Figure 6 while typical slugs on a 24-hr revolution clock may be noted in Figures 7 and 8.

In put gas was measured through a 3-in. meter run and this gas measuring meter was also equipped with a 24-hr -24 min revolution clock. Utilizing the 24-minute revolution clock gas measurements were taken and were spot-checked by an integrating device. Typical gas meter kicks are noted in Figure 9.

At a depth of approximately 5930 ft three sliding side door valves were equipped with 5/16-, 1/2-, and 1-in. ports respectively. These sliding side doors could be opened or closed independently of each other and thereby allow each one to be tested separately (Fig. 10). A side pocket mandrel immediately above these valves allowed the testing of any valve and/or port size that could be run in that mandrel. In turn, any valve up the hold could be selectively opened or closed.

Testing Procedure

The following procedure was typical for testing one cycle of intermittent lift (Fig. 11). For example, assume a 350 psi total load to be lifted from the 1-in. ported valve. This represents 607 ft of liquid (2.345 bbl.) or 261 psi of pressure exerted by the liquid load, and 89 psi of gas pressure at that point with 65 psi surface tubing pressure.

(1) The well was first blown practically dry using excess gas.

(2) Maihak instrument No. 2 was observed on the automatic printer counter for a build-up in pressure.

(3) The gas meter chart and two-pen recording chart were equipped with new charts and both placed on 24-min revolution clocks.

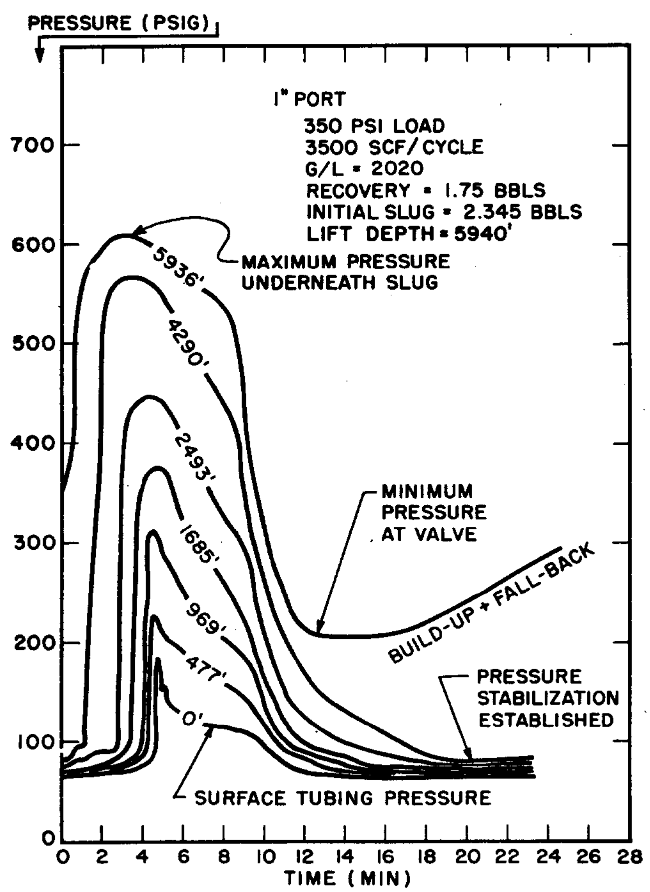


FIG. 12 TYPICAL PRESSURE RECORDINGS FOR 1" PORT.

(4) The test separator was read to the fraction of a gallon.

(5) All Maihak instruments above No. 2 were observed, and it was made certain that a condition of pressure equilibrium was attained.

(6) Once Maihak instrument No. 2 showed a pressure of 350 psi, the automatic switch for the hydro-timer was turned on and the gas was started into the casing of the well.

(7) An automatic recording of all Maihak instruments was then started. Since each instrument had to be manually switched, a simultaneous recording at each instrument was not possible. However, after much practice only seconds were involved in switching from one instrument to the next. Since it was desired to follow the slug of liquid to the surface, the instruments were read immediately ahead of the slug; therefore, the pressures at these points were easily determined. As can be noted in Figures 12 and 13 ample readings were obtained at each instrument to allow a good plot of the pressures at each depth.

(8) To give the desired gas volume the automatic switch for the hydro-timer was closed after a predetermined time.

(9) The pressure readings were made at each pressure transmitter until pressure equilibrium conditions were again established.

(10) The gas meter chart and the two-pen recorder chart were removed, and a final test separator reading was taken. This reading concluded one test for a particular liquid load and gas volume.

Each port size was tested for 250, 300, 350, 400 and 450 psi loads, and each loading was carried through several gas volumes per cycle, which ranges generally from 1500 scf/cycle to 5500 scf/cycle in 500 scf/cycle increments and which allowed the selection of an optium gas liquid ratio for each port size and each loading.

Discussion of Results

Introduction. As mentioned previously, total loads of 250, 300, 350, 400 and 450 psi were tested, and the tests, in turn, were done with 5/16-, 3/8-, 1/2-, 11/16- and 1-in. port sizes. Table 1 gives the port areas and their comparative size. Several sizes were tested more than once, since valves from different companies were tested; but no attempt has been made in this paper to distinguish, except by port size, one valve from another. However, it should be pointed out that all port sizes behaved similarly, regardless of the valve make. Therefore, in this discussion all valves will be referred to by port size only.

TABLE I

Number of Holes of Various Standard Port Sizes to be Equivalent to a 1" Diameter Port

Nominal Port Diameter (in.)	Equivalent Area (in.^{2})	No. Ports Required To = 1" Diameter Port	% of 1" Port
.3125 5/16"	.0767	10.24	9.77
.375 3/8"	.1104	7.12	14.05
.500 1/2"	.1963	4	25.00
.6875 11/16"	.3710	2.11	47.40
1.000 1"	.7854	1	100.00

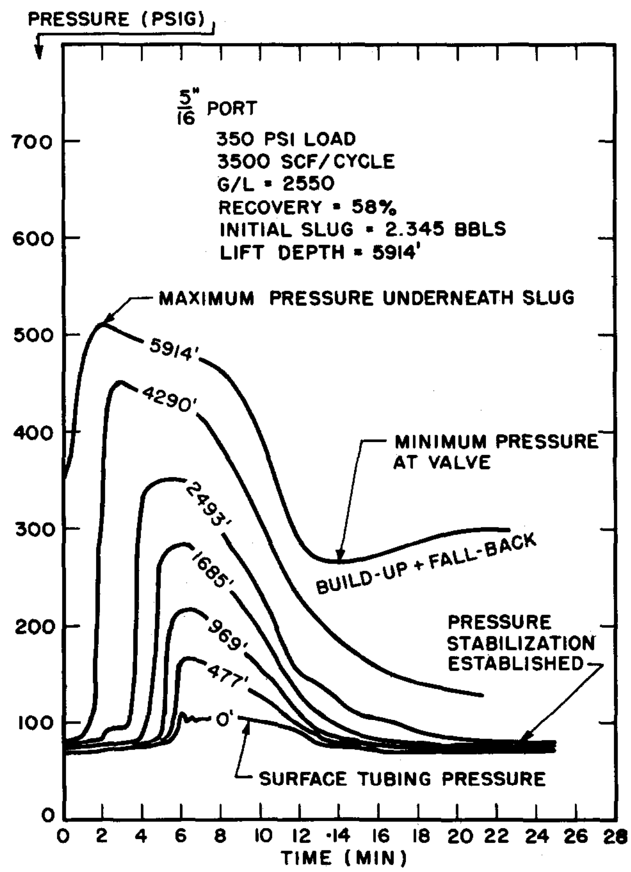


FIG. 13 TYPICAL PRESSURE RECORDINGS FOR 5/16" PORT.

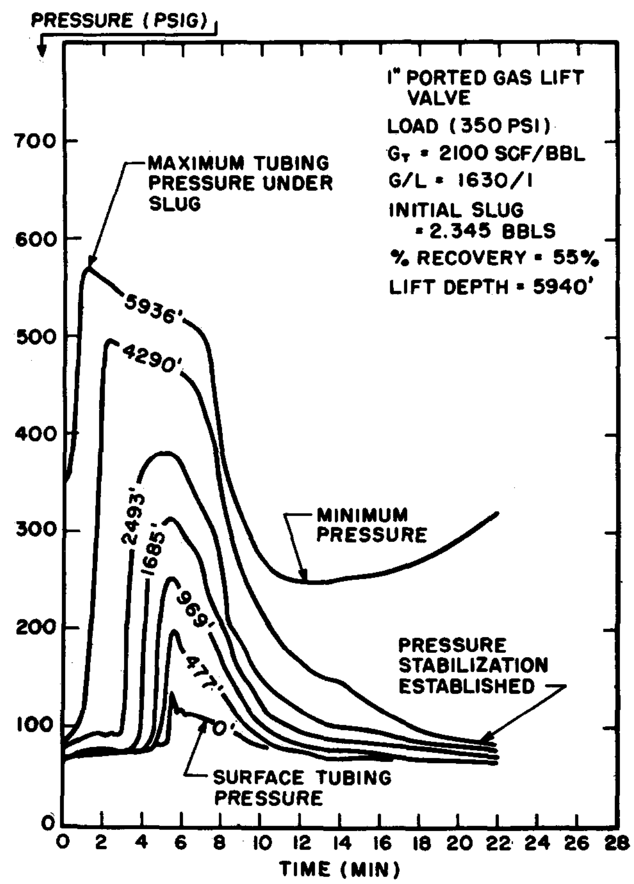


FIG. 14. TYPICAL PRESSURE RECORDINGS FOR A 1" PORT (MINIMUM GAS LIQUID RATIO).

The operating pressure opposite the gas lift valve was held as closely as possible to 550 psi for all valve types. Thus, in the balanced valves tested, the valve opened and closed at 550 psi in the well and had a surface operating pressure of approximately 500 psi. The bellows valves with spread were pressure-set so that the closing pressure approached 550 psi opposite the valve, and thereby, depending upon the tubing load, gave them an opening pressure above 550 psi. However, the bellows valves generally closed 10 to 20 psi lower and opened some 10 to 20 psi higher than did the flexible side door valves. The spread of a valve is defined as the difference between the opening and closing pressure of the valve and varies depending upon operating conditions.

In all cases it was found that the larger the port size the greater was the efficiency. Also, it was noted that, in general, the heavier the liquid load to be lifted, the greater was the efficiency for all ports. However, a 450-psi tubing load was difficult to lift with the large ports and could not be handled at all with less than a 1/2-in. port. The smaller ports showed greater efficiency at 400 psi loads than at lesser roads, and the 400 psi and 350 psi loads checked very closely with each other in horsepower requirements. On the other hand, the larger,ports showed better results at 350 psi than at 400 psi. As the total tubing load decreased, the margin of better efficiency increased for the 1-in. port over all other port sizes; and the lighter loads were accelerated more quickly with the larger ported valves.

Most of the comparisons noted in this paper will be for the 350-psi load which was selected because the 350- and 400-psi loads gave very similar results, and also because the smaller port sizes were unable to lift

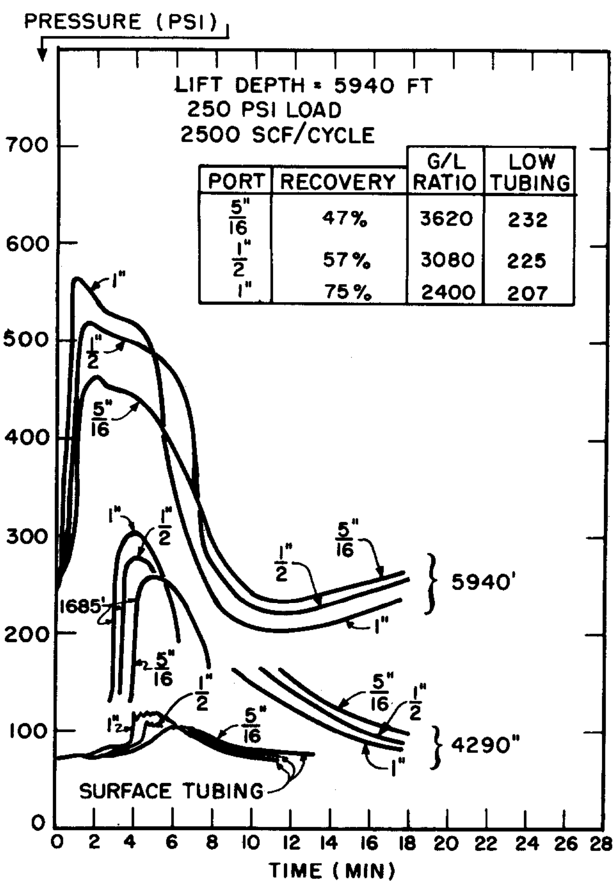


FIG. 15. COMPARATIVE PRESSURE RECORDINGS OF 5/16", 1/2" AND 1" PORTS (250 PSI LOAD).

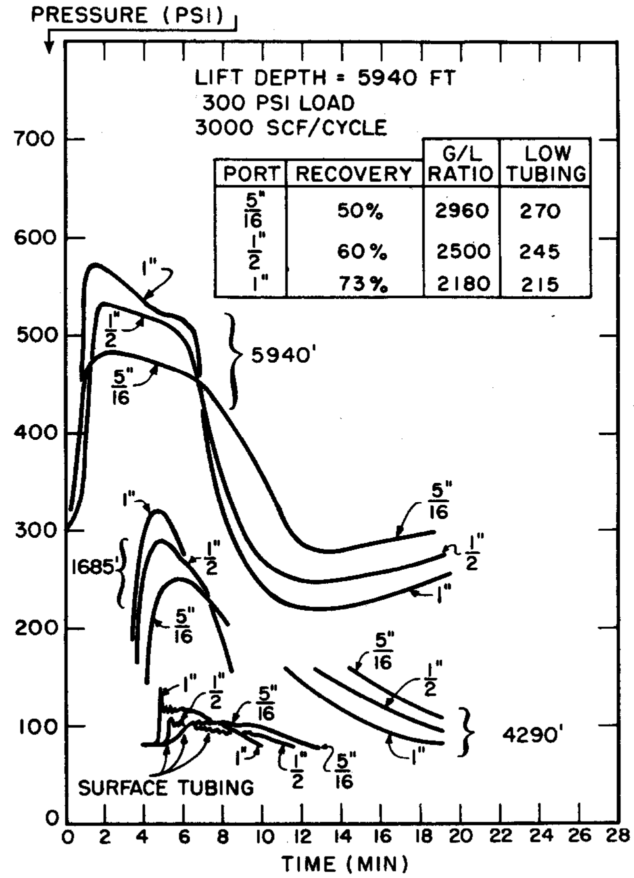


FIG. 16. COMPARATIVE PRESSURE RECORDINGS OF 5/16", 1/2" AND 1" PORTS (300 PSI LOAD).

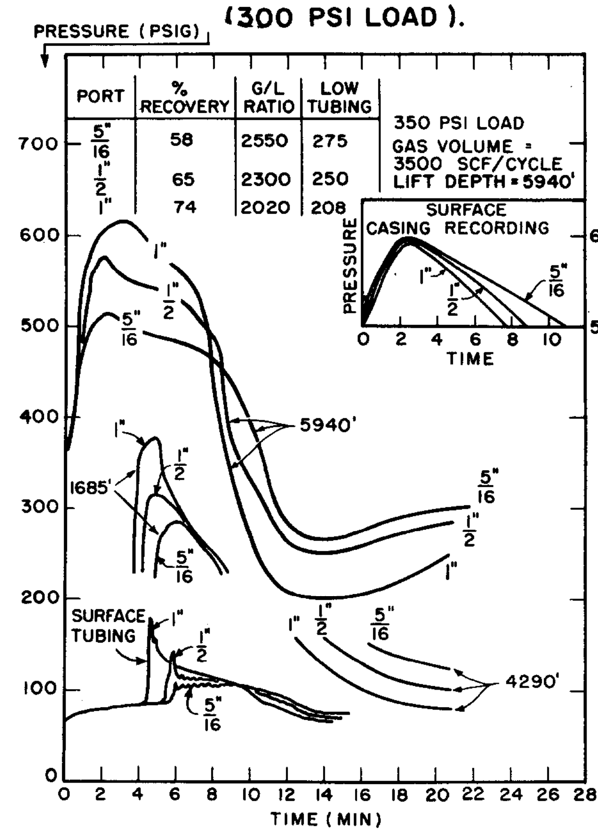
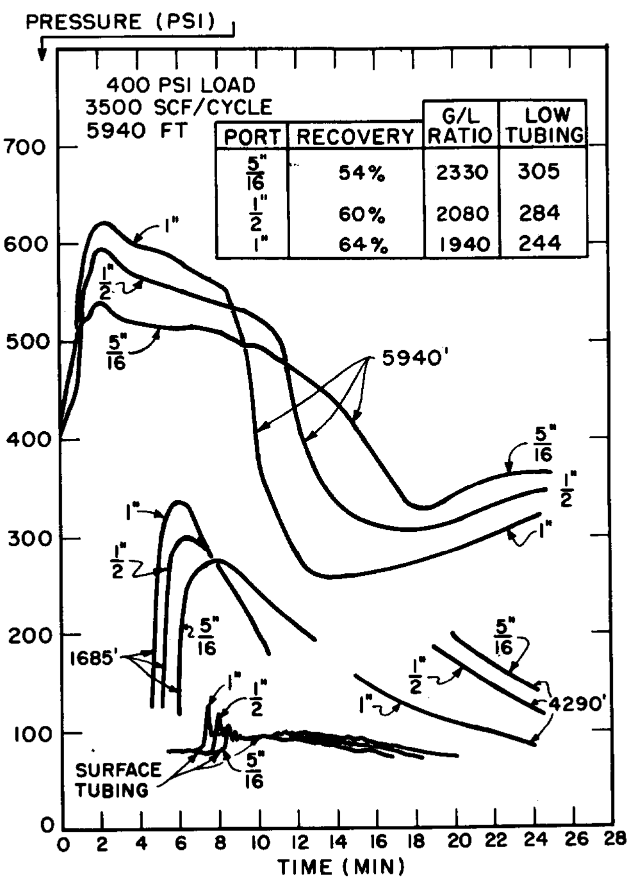


FIG. 17. COMPARATIVE PRESSURE RECORDINGS OF 1", $\frac{1}{2}$" AND $\frac{5}{16}$" PORTS.

the 400-psi load for gas volumes less than 3,000 scf/cycle.

Figures 12 and 13 show a typical plot for the information obtained on a 1-in. ported valve and a 5/16-in. ported valve for the same conditions of lift. Figure 14 shows a plot for the information obtained on a 1-in. ported valve for a low gas liquid ratio. Pressures were recorded at 0, 477, 969, 1,685, 2,493, 4,290, and 5,914 ft (valve location). The maximum pressure underneath the slug at each depth, minimum tubing pressure at the valve, and pressure stabilization time at each depth were recorded. Figures 15, 16, 17, and 18 show a comparison of a 1-, 1/2- and 5/16-in. port sizes for 250, 300, 350, and 400 psi loads. The superiority of the 1-in. port is shown by greater pressure underneath the slug, lower minimum tubing pressure, higher surface tubing pressure, faster travel of slug, and quicker pressure stabilization time at 4,290 ft.

Per Cent Recovery. In many instances the operator is interested only in oil in the tank and fails to consider efficiency as an important factor. There are some instances in which gas from a nearby plant is being utilized and the use of additional gas is not so critical as it might be for other gas lift systems; but a little closer look at the economic picture discloses additional horsepower requirements for the return of excess lift gas. The per cent recovery shows that when an excessive amount of gas is utilized, the port size of the operating gas lift valve is not too critical. However, if an efficient lift ratio is to be maintained, then the larger port offers a greater per cent recovery for the same injection gas volume per cycle. This fact is noted in Figure 19 where a total gas volume of 2,500 scf/cycle is being injected.



PORT	RECOVERY	G/L RATIO	LOW TUBING
5"/16	54%	2330	305
1"/2	60%	2080	284
1"	64%	1940	244

FIG. 18. COMPARATIVE PRESSURE RECORDINGS OF 5/16", 1/2" AND 1" PORTS (400 PSI LOAD).

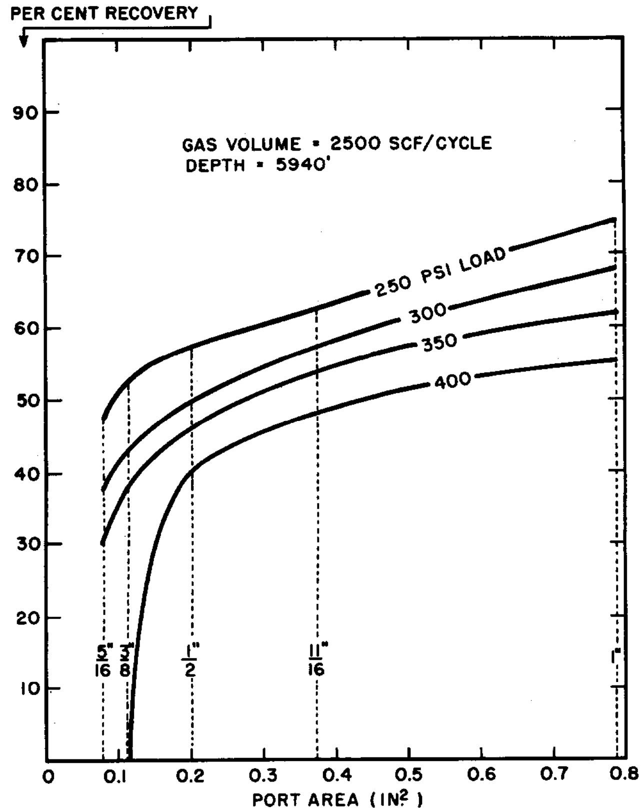


Fig. 19 PER CENT RECOVERY VS. PORT AREA FOR CONSTANT GAS VOLUME = 2500 SCF/CYCLE.

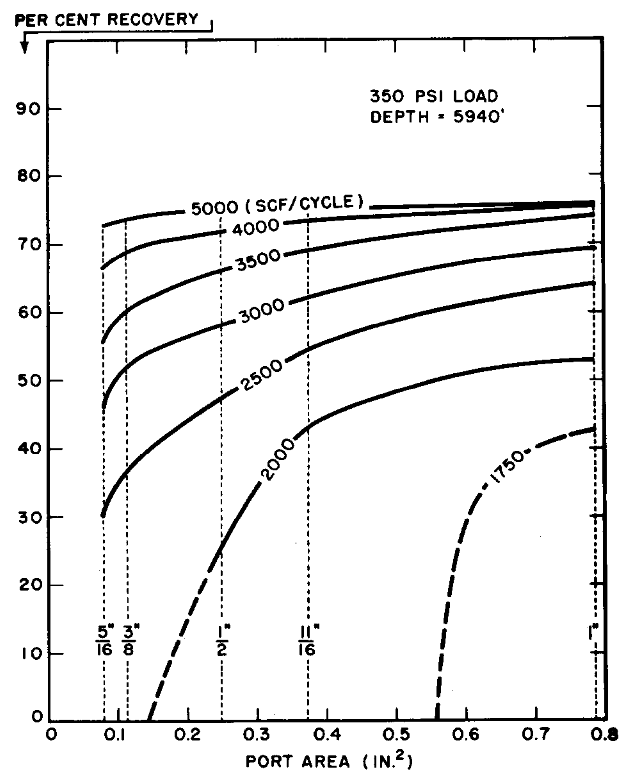


FIG. 20 PER CENT RECOVERY FOR ALL PORTS (350 PSI LOAD)

For a total load of 400 psi (2.80 bbl) the 5/16- and 3/8-in. port fail to recovery any production; whereas the 1-in. port recovers some 55 per cent of the initial starting load. For the lighter load of 250 psi (1.451 bbl) the difference is still quite pronounced with the 5/16-in. port showing a recovery of 47 per cent compared with 75 per cent for the 1-in. port.

In general, from a recovery standpoint, greater recovery was obtained at the lower loads. For example, almost 90 per cent recovery could be obtained by lifting the 250-psi load. However, the horsepower requirements were high per bbl of liquid recovered.

Figure 20 is a plot for the 350-psi pressure loading and the per cent recovery vs port area for varying gas volumes per cycle. This plot shows that if excess gas is used (3,000 scf/cycle and above), the port size is not so critical. If enough gas is continued through the smaller port it will eventually blow the tubing almost as dry as when a large port is used. It is interesting to note that below 2000 scf/cycle the 5/16-and 3/8-in ports failed to recover any liquid; whereas the 1-in. port had a recovery of 53 per cent and the 1-in. port sill had a recovery of 42.5 per cent at 1,750 scf/cycle. In the neighborhood of 2,500 to 3,000 scf/cycle -- one of the more efficient lift ranges -- practically a straight line increase occurs from the 3/8- to the 11/16- in. port, and some increase in recovery is obtained with the 1-in. port.

From the 3/8 - to the 11/16-in. port (at 3,000 scf/cycle) and (.261 sq in. area difference) there is a 10 per cent increase in recovery; whereas from 11/16 to 1-in. port (.414-sq in. area difference), there is only a 6 5 per cent increase in recovery.

Gas-Liquid Ratio. The operator is always interested in maintaining efficient gas lift operation, and he attempts to keep gas usage at a minimum and yet maintain optimum operations. For these particular tests each loading was carried through a series of gas volumes per cycle from the range of excess gas to insufficient gas

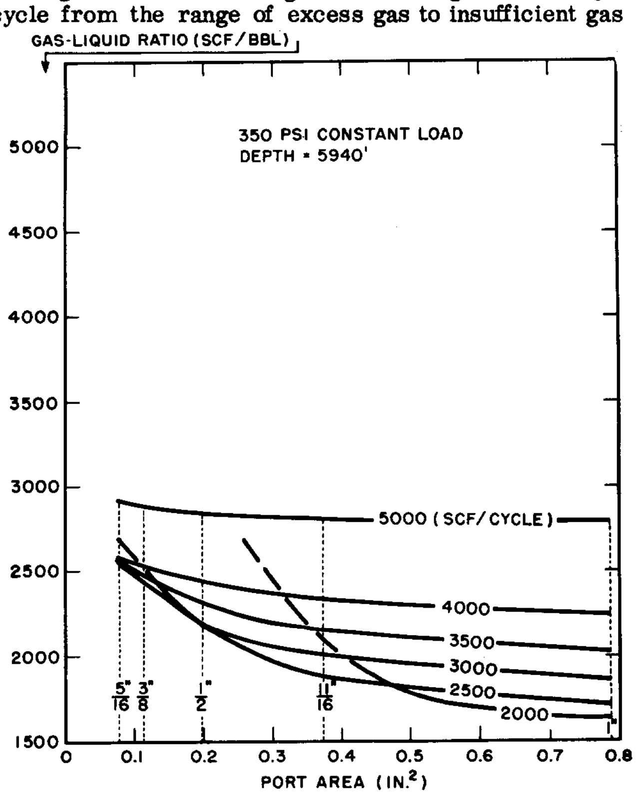


FIG. 21 GAS-LIQUID RATIO FOR ALL PORTS (350 PSI LOAD)

Figure 21 shows a plot of gas-liquid ratios vs port area for varying gas volumes per cycle for a loading of 350 psi. It is noted that, at 5,000 scf/cycle, there is little difference in the gas liquid ratios for each port size; but as the gas volume per cycle is reduced, the larger ports show lower gas liquid ratios than do the smaller ports. For a gas volume of 3,000 scf/cycle the 1-in. port shows a gas liquid ratio of 1960:1; whereas the 5/16-in. port shows a gas liquid ratio of 2560:1. For 82 BD this amounts to a difference of 49,200 scf/D, or a difference in horsepower requirements of 4.92.

The point of minimum gas liquid ratio does not correspond to the point of maximum recovery. Figure

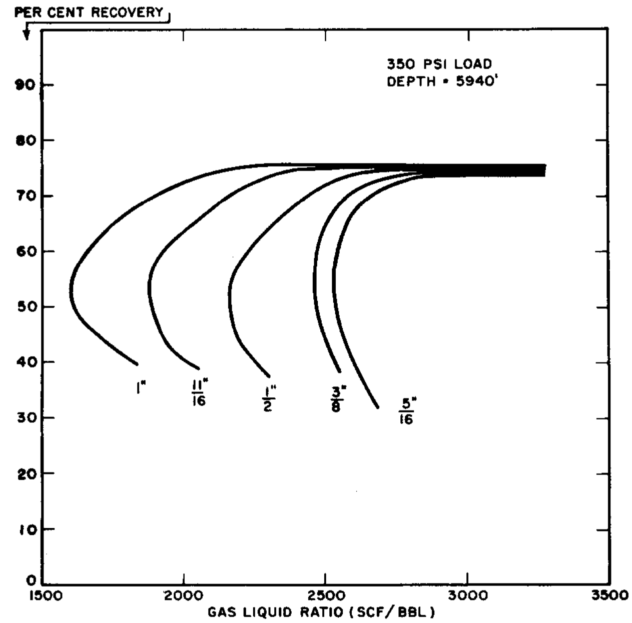


FIG. 22. PER CENT RECOVERY VS. GAS-LIQUID RATIO (350 PSI LOAD).

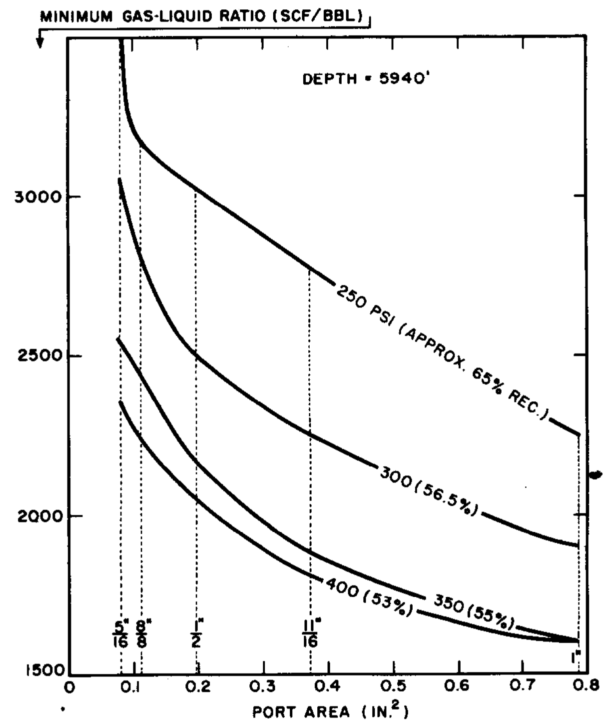


FIG. 23. MINIMUM GAS-LIQUID RATIO (ALL LOADS).

22 is a plot of per cent recovery vs gas-liquid ratio for a 350-psi load, and the point of minimum gas liquid ratio seems to occur at approximately the same recovery (55 per cent) for each port size. However, the smaller ports offer a wider range of recoveries for approximately the same gas liquid ratio. In other words, the point at which the minimum gas liquid ratio occurs seems to be more critical for the 1-in. port than for the 5/16-in. port. Figure 23 shows a plot of minimum gas liquid ratio vs port area for varying pressure loads: the approximate recoveries for each minimum is indicated, but there is little difference between the 350 and 400-psi load. Figure 24 also shows the ratios to be practically the same for the 350 and 400-psi loads.

Minimum Pressure Created at the Operating Valve. One of the most important factors in evaluating port sizes of valves for intermittent gas lift operations is the minimum pressure that it is possible to create at the operating valve. This situation, of course, reflects directly on the flowing bottom-hole pressure of the well itself. The flowing bottom-hole pressure in turn influences the in-flow performance characteristics of the fluids from the formation into the wellbore. Many such wells may have a productivity index of such magnitude that a slight increase in drawdown materially affects the daily production rate. For example, a well with a productivity index of 0.2 would produce an additional 10 BD for an additiona drawdown of 50 psi. In looking at Figures 25 and 26, it is noted that it is not uncommon to obtain 50 psi more drawdown (minimum tubing pressure at the operating valve) with a 1-in. port valve. Again, the minimum pressure created at the operating valve seems to decrease as the port size increases and also to decrease as the gas volume per cycle is increased.

Pressure Stablization Time. Another of the more important factors to consider from the standpoint of evaluating port sizes is the time required for complete liquid fall-back in the tubing string. This time was in-

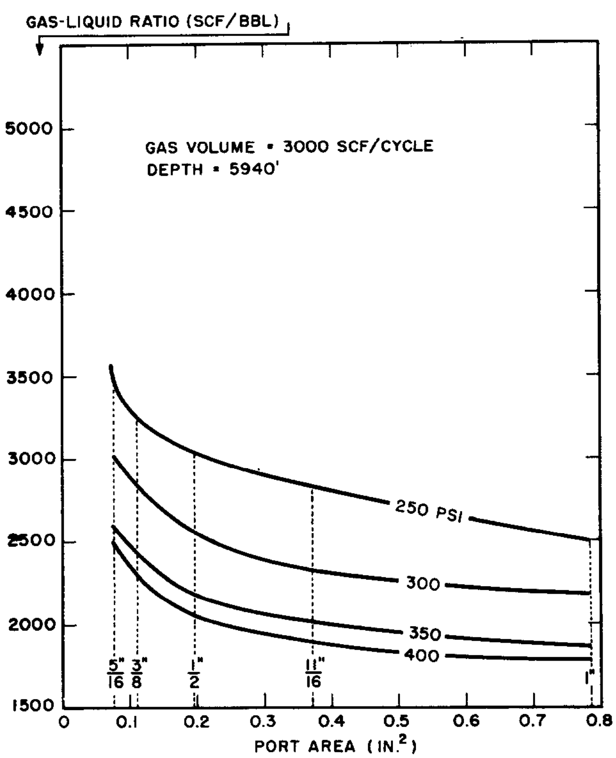


FIG. 24. GAS-LIQUID RATIO VS. PORT AREA FOR ALL LOADS (CONSTANT GAS VOLUME = 3000 SCF/CYCLE).

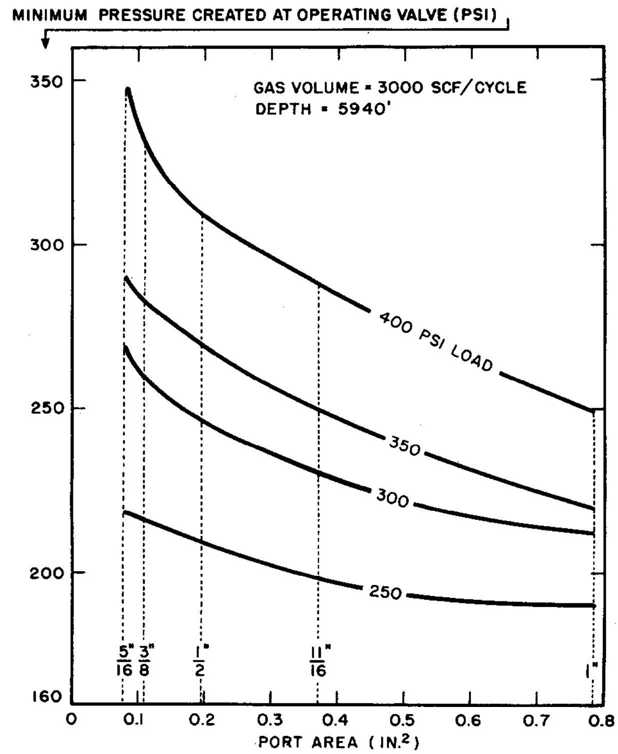


FIG. 25 MINIMUM PRESSURE CREATED AT THE OPERATING VALVE (GAS VOLUME CONSTANT= 3000 SCF/CYCLE).

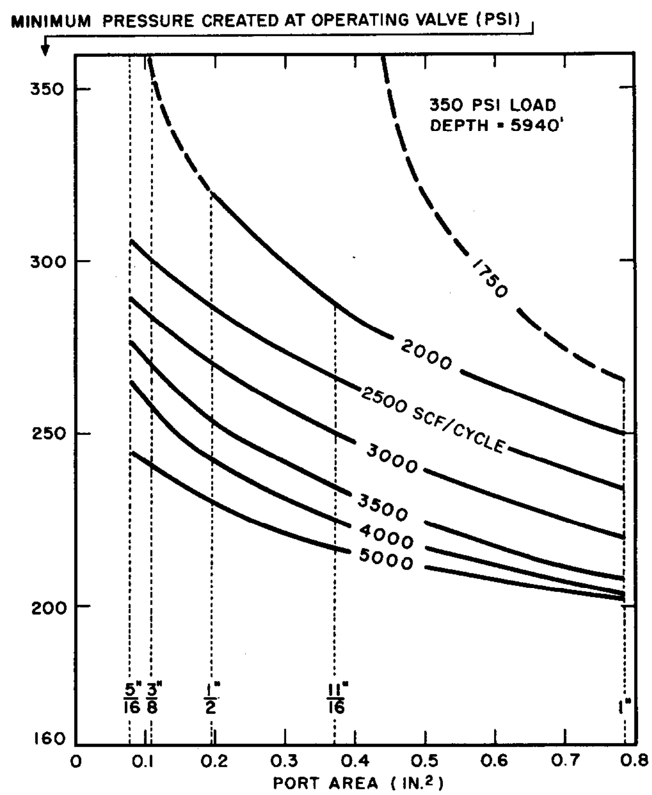


FIG. 26 MINIMUM PRESSURE CREATED AT THE OPERATING VALVE FOR 350 PSI LOAD AND VARYING GAS VOLUMES PER CYCLE.

dicated in these particular tests by a pressure stabilization at different depths. The pressure at different depths was recorded vs time as noted in Figures 12 and 13. Complete pressure stablization was required before starting another intermittent cycle. Fig. 27 is a recording of the pressure stablization time vs depth for a 350-psi load and a gas volume of 3,000 scf/cycle. The lowest depth recorded above the operating valve itself was 4,290 ft; and it is noted that at 4,290 ft the 1-in. ported valve achieved pressure stablization in 19-1/2 minutes compared with 30 min for the 5/16-in ported valves.

It should be kept in mind that this represents complete pressure stablization, i.e., the same as that achieved prior to starting any one cycle; however this achievement does not mean that a cycle could not be started sooner, but does mean that a cycle started sooner would lift a partial spray of liquid that had not yet reached equilibrium in the tubing string and, of course, would result in decreased efficiency.

The main point to notice is that cycle frequencies can be set much closer with the large ported valve than with the small valve. This point can be of extreme importance in a well requiring frequent injection cycles and yet requiring maximum drawdown.

Time for the Slug to Reach the Surface. Figure 28 shows the time necessary for the liquid slug to reach the surface for total loads of 250, 300, 350 and 400 psi for the various port sizes and a constant gas volume of 3,000 scf/cycle. It is noted that the slug travel time increased as the port area decreased, and the effect becomes more pronounced as the slug size increases. For a total gas volume of 3,000 scf and a 400-psi total load (2.80 bbl of liquid) the liquid failed to reach the surface with the 5/16-and 3/8-in. ports. and the 1-in. port required over 6 min of travel time.

Figure 29 shows the 350 -psi load for varying gas volumes per cycle. The travel time for the top of the slug decreased with port size and, of course, decreases with the gas volume injected per cycle. For a gas volume of 3,000 scf/cycle there is a difference of 1.67 min in travel time for the slug if started with 5/16-in port of a 1-in. port. Again, the greater velocities are a direct indication of greater recovery and better gas liguid ratios.

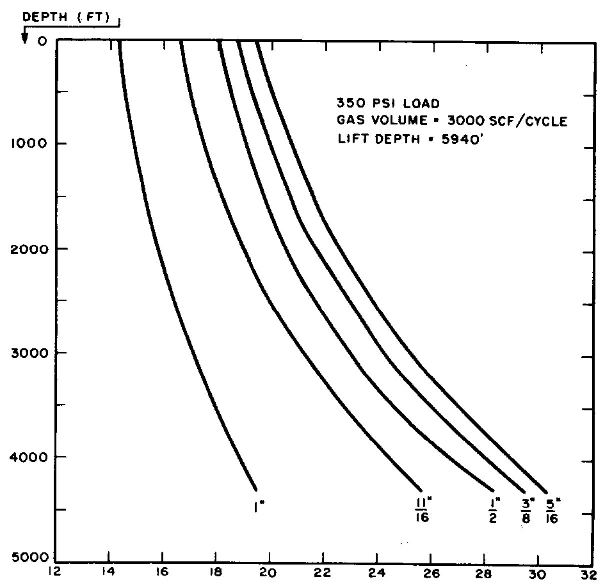


FIG. 27. PRESSURE STABILIZATION TIME FOR 350 PSI LOAD (CONSTANT GAS VOLUME = 3000 SCF/CYCLE).

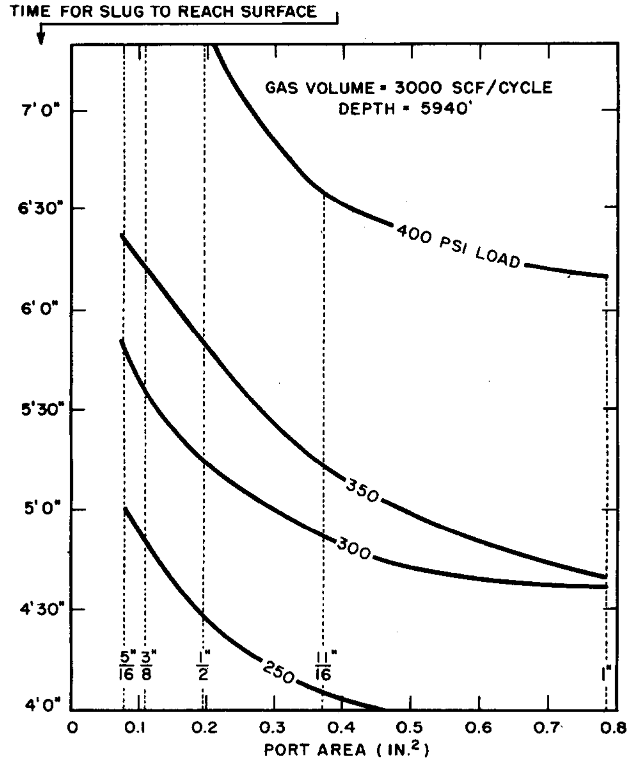


FIG. 28 TIME FOR SLUG TO REACH SURFACE FOR ALL LOADS (CONSTANT GAS VOLUME = 3000 SCF/CYCLE).

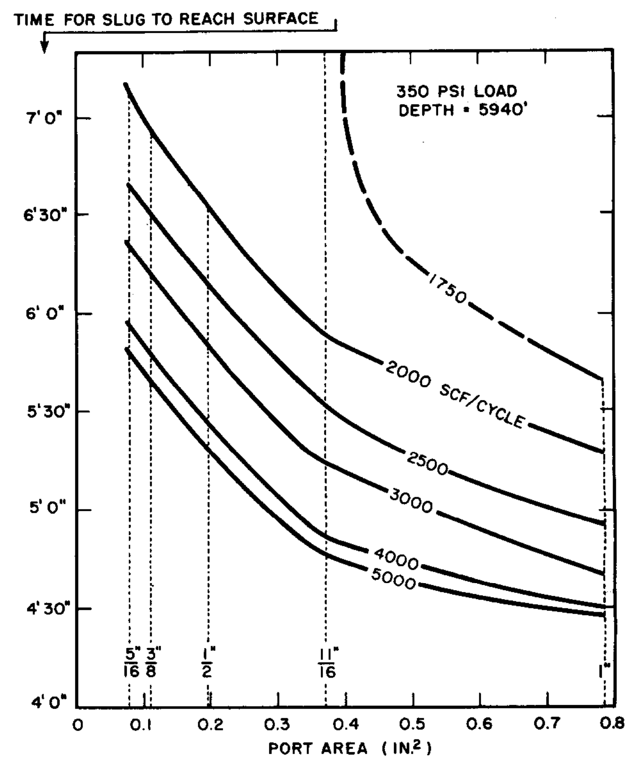


FIG. 29. TIME FOR SLUG TO REACH SURFACE FOR ALL PORTS AND VARYING GAS VOLUMES PER CYCLE (350 PSI CONSTANT LOAD).

Maximum Pressure Underneath the Slug. The maximum pressure beneath the slug is a direct indication of eventual slug velocity and has indicated additional recovery in all cases. Figure 30 shows the relationship between the maximum pressure induced under the slug vs port area for a constant gas volume of 3,000 sfc/cycle. It is noted that the maximum pressure difference occurs at the lighter liquid loads, or at that condition in which maximum pressure difference occurs between the gas pressure underneath the slug and the slug load. This occurrence is as expected, since the lighter slug can be accelerated faster, and thereby can allow the larger ported valve to inject more gas at a faster rate and at a higher pressure than can the smaller ported valve.

Figure 30 also shows that as the pressure differential across the port decreases (liquid load increases) the advantage of the large port is decreased. However, the 5/16-and 3/8-in. ports still appear quite inadequate in placing maximum available pressure beneath the slug; velocity and efficiency are eventually sacrificed. These curves represent points of maximum pressure under the slug and are taken directly from the pressure curves beneath the slug.

Figure 31 shows a 250 psi load for varying gas volumes per cycle. The pressure under the slug offers a decided increase up to the 11/16 in. port, then levels off considerably. However, these data may be somewhat misleading since recovery is more a function of the ability to maintain a high pressure beneath the slug rather than to place a high initial pressure under the slug.

Figure 31 also quite clearly illustrates the smaller port sizes limited capacity to establish sufficiently high gas pressure under the liquid slug. This limitation explains why many of the other curves -- per cent recovery, gas liquid ratio, etc. -- show inefficient operations when utilizing small ports. Available gas pressure is not utilized.

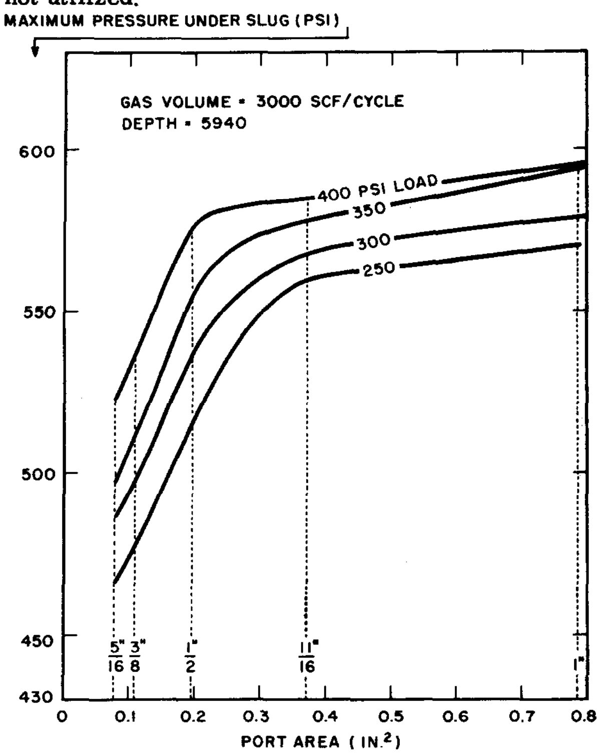


FIG. 30 MAXIMUM PRESSURE UNDER SLUG VS. PORT AREA FOR CONSTANT GAS VOLUME OF 3000 SCF/CYCLE.

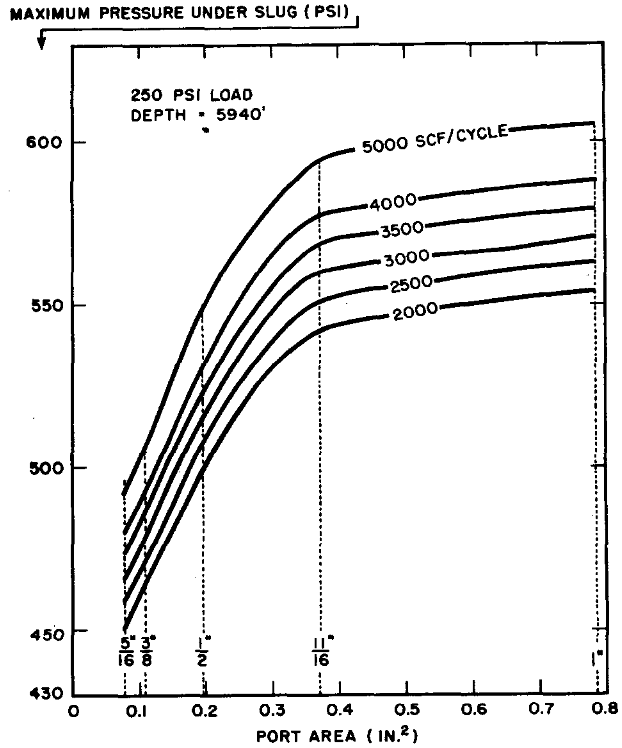


FIG. 31. MAXIMUM PRESSURE UNDER SLUG VS. PORT AREA FOR 350 PSI LOAD AND VARYING GAS VOLUMES PER CYCLE.

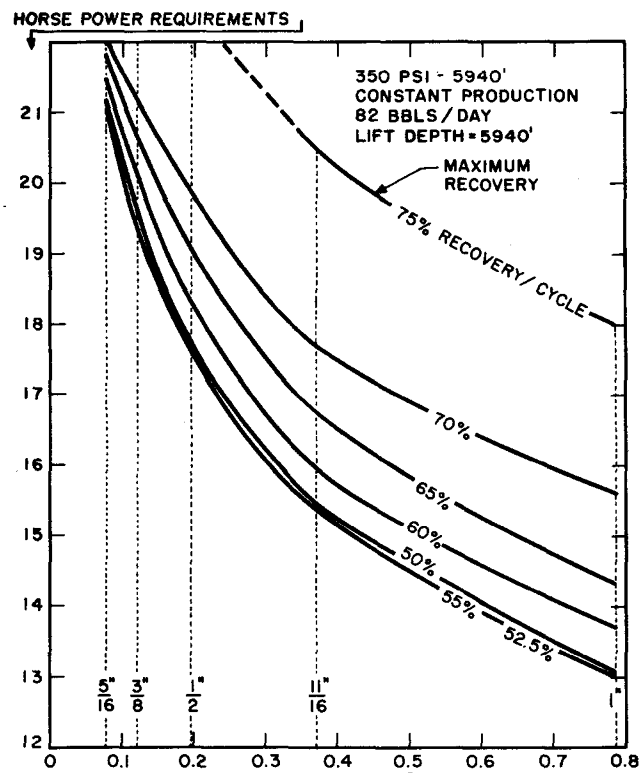


FIG. 32. HORSEPOWER REQUIREMENTS FOR 350 PSI CONSTANT LOAD AT VARYING RECOVERIES PER CYCLE.

Horsepower Requirements. To make a comparison of efficiency and costs, an indicated horsepower for 82 BPD from the experimental well was considered.

Figure 32 shows horsepower requirements for the 350-psi load vs port area for varying recoveries per cycle. The minimum requirements occur at approximately 55 per cent recovery with the 1-in. port showing 13.0 hp compared with 21.2 hp for the 5/16-in. port. Conditions were such that 100 hp/MMscf of gas were required. For 10 wells in a system this situation represented a difference of 82 horsepower.

The assumption is made that the 82 bbl can be successfully recovered with each port size and that the time for pressure stabilization after each cycle is ample for all ports. Actually this well would have to be cycled every 22-1/2 min to recover 82 BPD, if it is assumed that 55 per cent of each 2.345-bbl slug (350 psi) is recovered by each cycle. Figure 27 shows that stabilization time occurs in 19-1/2 min at 4,290 ft for the 1-in. port, but is 30 min for the 5/16-in. port. This difference would mean that the 5/16-in. port installation would have to be cycled inefficiently; thereby its horsepower requirements would have to be increased still further. Since drawdown creates well production, it might not be possible to wait for a heavier load per cycle.

Summary and Conclusions

Port Size Evaluation. If a well is to be placed on intermittent gas lift, consideration should be given in selecting a gas lift valve with as large a port as practical.

The following factors are noted as being accomplished with a larger ported valve:

(1) Greater recovery is obtained at a lower gas-liquid ratio.

(2) A lower minimum tubing pressure is created at the operating valve and allows greater bottom-hole pressure drawdown.

(3) The time for liquid fall-back or pressure stabilization time in the tubing string is minimized; thereby faster cycle frequency is permitted.

(4) The time for the slug to reach the surface is lessened; greater velocity is given and efficiency is directly increased.

(5) The maximum pressure under the slug is increased; a faster gas entry is indicated, and over-all efficiency is increased.

(6) Horsepower requirements are shown to be considerably less for the same recovery.

(7) Large ported valves have a smaller range in which better over-all efficiency is obtained. In other words, the small ported valve has a wider range of gas volumes per cycle; therefore, it gives essentially the same results, but fails to reach the efficiency of the larger port in any range.

Acknowledgements

The authors would like to express their sincere appreciation to the Ohio Oil Company and the Sun Oil Company for furnishing the experimental well, surface equipment and tubing jobs. In particular, thanks are extended to Jack Herring, Division Superintendent of Ohio Oil Company; and the men of the North Bay City Field, including Bill Howard, Doyle Jones, Gilbert Naert, Chris Murray; and all the men of the gang and gas plant. Special thanks are extended to Jim Evans, petroleum engineer for the Ohio Oil Company of that area, who stayed with the project most of the time.

Sincere appreciation is also expressed to the Otis Engineering Corporation that furnished all the down-hole equipment, all the surface recording instruments, and all the wire line work in changing gas lift valves, shifting sleeves, and changing choke sizes. In particular, thanks are due Carlos Canalizo, Don Taylor, and Wally Robertson, of the Dallas office, and Bill Bertman, Harold Menke and Walter Groth of the Bay City area, and to those many wire line specialists and assistants who worked on the well at various times.

Thanks is also extended to the Society of Petroleum Engineers of AIME for permission to publish this paper.

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