Design and Operation of the Gas Lift System

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INTRODUCTION

Many articles have been written about the mechanics of gas lift valves, their applications, and the techniques of designing a string of gas lift valves for a well, and rightly so, for the gas lift installation is the heart of this artificial lift system; but it is not the total substance of the system. The complete artificial lift system consists of various surface and sub-surface components. It is very important that the engineer designing a system and the personnel operating a system understand all of these components and how the design or operation of one of the components affects the others. For it is with this understanding that the designer will get the most economical design and it is with this understanding that the operating personnel will get the most efficient operation.

Before developing the complete description of the various components of the gas lift system, it will be good to review briefly the two types of gas lift that are presently in service and the operating characteristics of these two types. The methods for selecting which of these two basic types to use will not be discussed here; the purpose here is to understand the operating characteristics of these two types so that a better design of the system's components can be developed.

Continuous flow gas lift is a process of mixing gas into a column of fluid so that column of fluid is aerated to a desired gradient. This aeration, of course, results in a reduction of pressure at the point of mixing. When a continuous flow installation has stabilized at its optimum point of injection, steady-state flow conditions exist in the fluids from the wellbore into the tubing, in the gas through the gas lift valve into the tubing, in the aerated mixture from the well to the flow line and hence, to the separation facilities, and from the high pressure gas source to the casing annular space. A lift system like this is ideal because there are no sudden changes in production rate or in gas requirement, no demanding surges of pressure at the separator, and no high rate demands for gas from the high pressure gas source. Unfortunately, all of our gas lift applications do not fit in this classification. In fact, continuous flow applications are in the minority.

The "other side of the coin" is intermitting lift. Its name implies a cyclic action. Its operation consists of periods of inactivity followed by periods of high velocity and surging pressures. There is a repetitious cycle in intermitting gas lift consisting of three distinct periods. The feed-in period begins the cycle as reservoir fluids are pushed into the tubing until a certain volume of fluid accumulates above the gas lift valve. The lift period begins when the gas lift valve opens to admit high pressure gas under the accumulated volume of fluid. This high pressure gas literally expels the slug of fluid from the tubing and into the flow line (in much the same way as a bullet is expelled from a gun). The third period follows the closing of the gas lift valve and the delivery of the slug of fluid to the storage facilities. It is the period in which the high pressure gas behind the slug of fluid is allowed to expand through the separation facilities and is called the pressure reduction period. The completion of this period ends the cycle and the three periods are then repeated. From this description of the intermitting cycle, it is apparent that nothing is stable or steady-state about intermitting gas lift. It is also apparent that during the feed-in period, high pressure gas is not needed and no fluid is being produced through the flow line or into the separator. However, during the lift period, a relatively large volume of high pressure gas must be supplied through the gas lift valve in a very short time interval (a large ported valve is best suited here) because the accumulated slug of fluid must be expelled up the tubing rapidly for efficient recovery. And likewise, the flow line and separator are suddenly confronted with handling a relatively small volume of fluid and gas, but they must be handled at a high rate: When the gas lift valve closes and the pressure reduction period begins, no high pressure gas is needed, but the flow line and separator should allow the rapid expansion of the lift gas from the tubing.

FOUR COMPONENTS OF A GAS LIFT SYSTEM

As described above, these two basic forms of gas lift are completely different. However, both forms of gas lift are part of the complete artificial lift system consisting of four basic components. These components are:

(1) A source of high pressure gas
(2) Surface gas controls
(3) Sub-surface gas controls
(4) Separation and storage facilities

Each of these four components will be fully described, then their importance in the system and their effect on the other components of the system can be better understood.

HIGH PRESSURE GAS SOURCE

The high pressure gas source, of course, is paramount. This source may be available in the form of a high pressure gas well, a gas transmission line, a local gasoline plant, or a compressor station that is designed to compress and circulate enough gas for gas lift purposes. (See Fig. 1.) This high pressure gas source must fill two requirements. First, the pressure must be high enough for gas lift operations; and second, the gas volume must be sufficient for the task at hand. Because of these requirements, the distribution lines from the gas source to the well locations are considered part of the high pressure gas source. The distribution lines must be properly sized to fill the above named requirements.

SURFACE GAS CONTROLS

The surface gas controls consist of motor valves or chokes on the gas line to the well head, two-pen pressure recorders, and meter runs. (See Fig. 2.) The motor valve or choke is used to adjust the lift gas to the well to regulate production from the well. The two-pen pressure recorder records the changes in casing and tubing pressures and is a valuable aid in expediting optimum adjustment of a well and in trouble-shooting. The meter run is necessary to measure the volume of high pressure gas which is used to produce the well.

FIG. 2

SURFACE GAS CONTROLS

A. METER RUN
B. TIME CYCLE CONTROLLER
C. CHOKE
D. INDICATING PRESSURE GAUGES

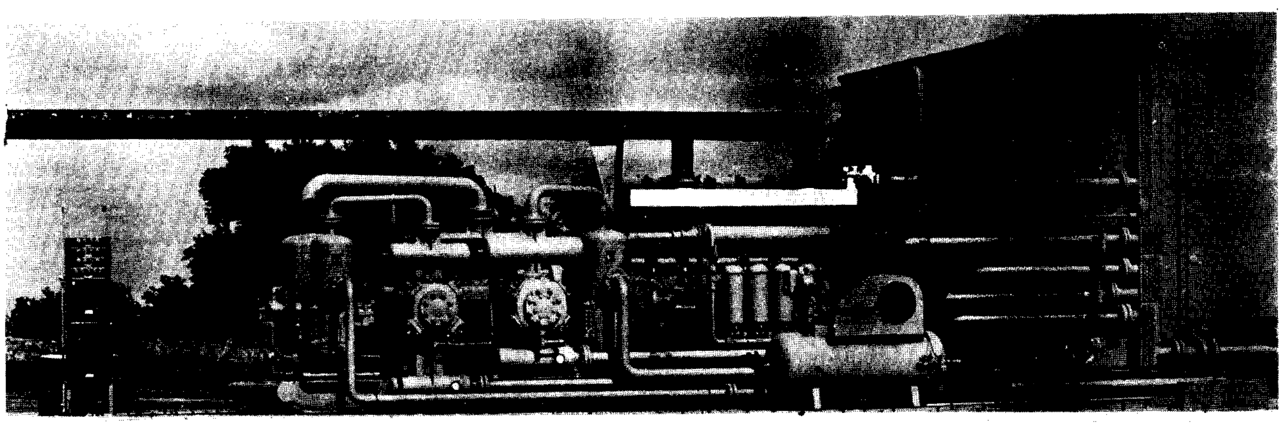


FIG. I : HIGH PRESSURE GAS SOURCE (CLOSED ROTATIVE SYSTEM)

SUB-SURFACE GAS CONTROLS

The sub-surface gas controls consist of the casing, gas lift valves, packers, standing valves and any other miscellaneous equipment that may be used for special installations. There are basically three types of installations which are used in the sub-surface gas controls as illustrated in Fig. 3. The "Open Installation" consists of casing, tubing, and gas lift valves only. It is apparent that the formation is not isolated from the casing and tubing pressures. Without a packer the well fluids will rise in the annular space any time that the casing pressure becomes lower than normal. Return of the casing pressure then, would mean that the well fluids must be repeatedly transferred through the gas lift valves, occasionally resulting in damage to the valves. However, this type of installation is sometimes recommended for continuous flow applications.

An improved installation for continuous flow utilizes a packer so that the casing pressure is isolated from the formation. The packer then, would also exclude the well's fluid from the annular space once the well had been un-

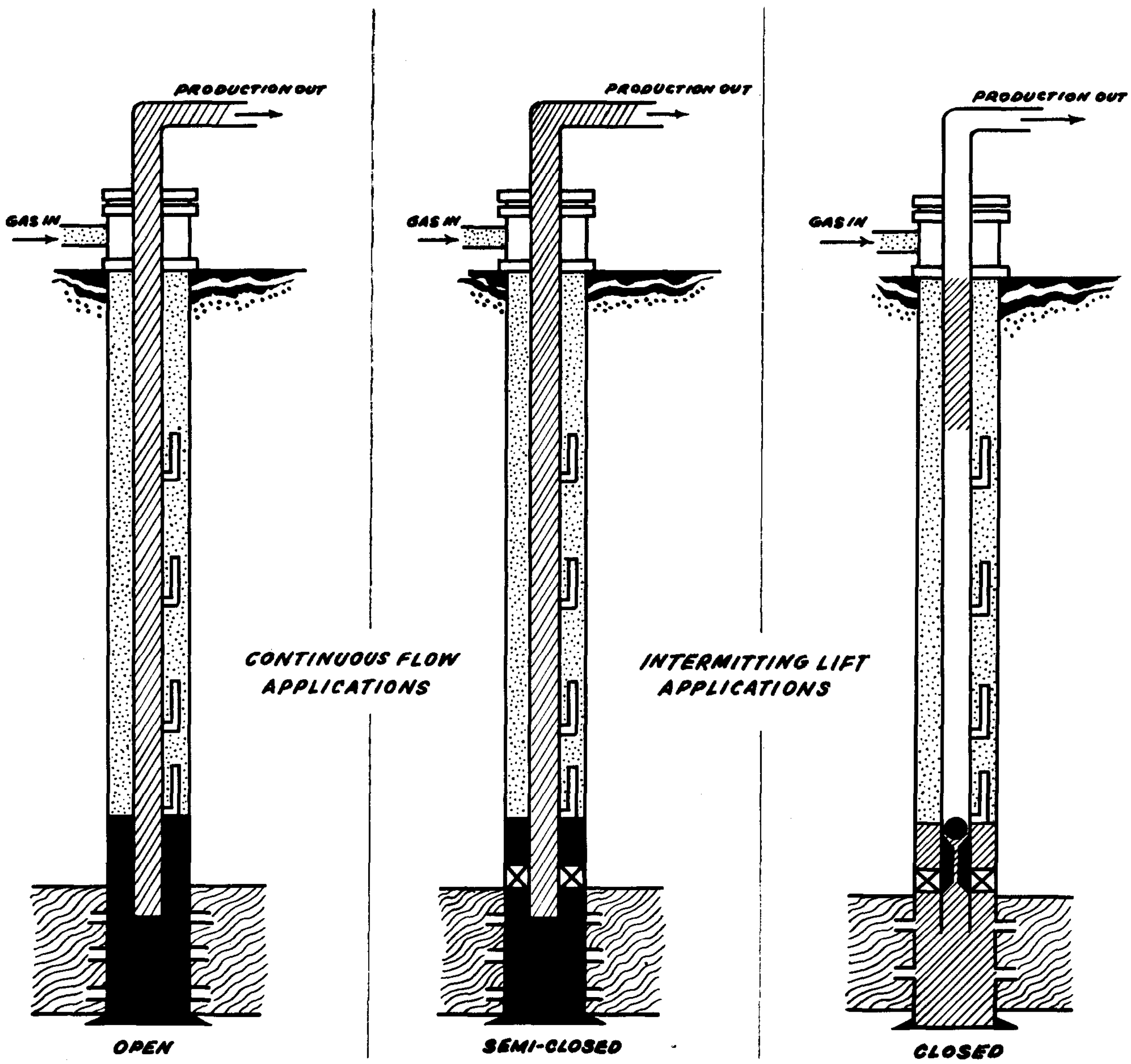


FIG. 3 SUBSURFACE GAS CONTROLS

loaded to the bottom valve. This "Semi-closed Installation" is the preferred installation for continuous flow, and is sometimes recommended for intermitting lift (when the flowing bottom hole pressure is greater than the operating gas pressure).

The flowing bottom hole pressure of many intermitting applications is much lower than the operating gas pressure. For this reason, the

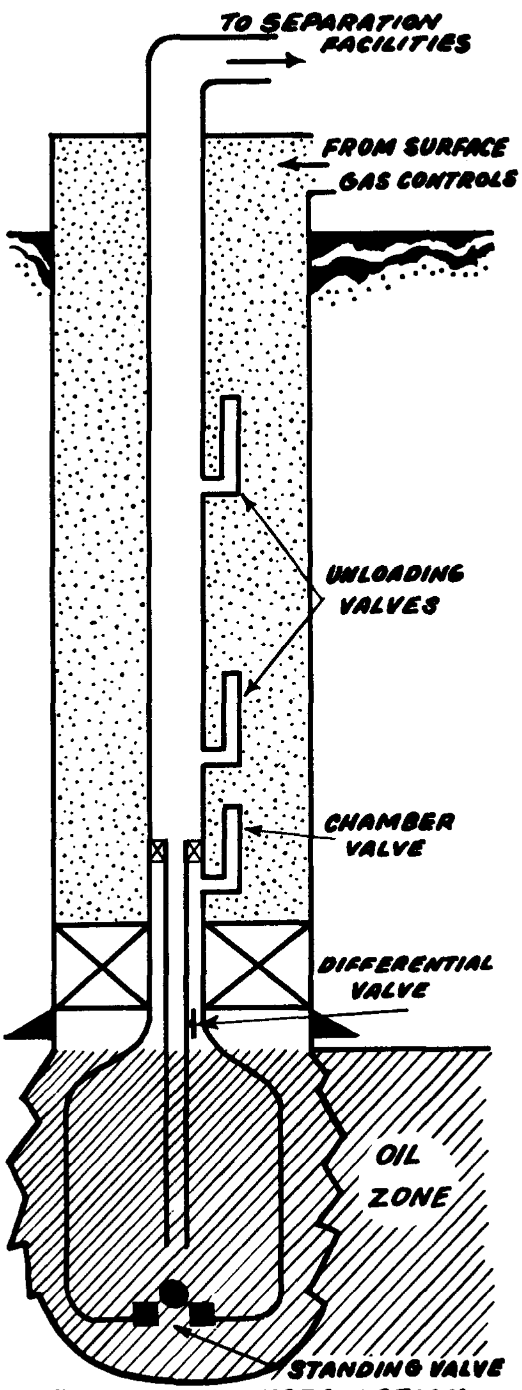


FIG.4 CHAMBER INSTALLATION

"Closed Installation" is preferred. It utilizes a packer and standing valve, and isolates the formation from the casing pressure, and the cyclic high tubing pressures that occur during the lift period. A special form of the closed installation is a chamber. (See Fig. 4.) The chamber installation permits the accumulation of a relatively large volume of fluid in a shorter length so that flowing bottom hole pressures less than 100 psi can often be effected.

In each of the installations discussed above, the selection of both intermitting and continuous flow gas lift valves falls into two categories, conventional or retrievable. The retrievable valves permit pulling, running and servicing of the valves with a wire line. This choice is based on economic considerations of the well location and the downhole conditions. If wireline servicing of the gas lift valves offer an economic advantage, as in offshore application, extremely rough terrain, or swampy areas, it should be used.

SEPARATION AND STORAGE FACILITIES

The fourth component of the gas lift system is the separation and storage facilities. This component consists of the flow line, the separator and/or the heater, the stock tanks, the meter run to the sales outlet and the low pressure gas storage volume (if required) in a closed rotative system. The flow line should be as large as possible and streamlined so that the well fluids can get to the separator as quickly as possible with a minimum pressure drop. The separator should be selected to handle the fluid volumes in question, but more important than that is the separator's capacity to handle gas. The separator and the lines between the separator and sales outlet should be sized to easily handle the additional volume of gas which is the energy source used to produce the well fluids. Heaters may be necessary in this component. Tank vapor recovery systems or crude stabilizers can play an important part in this component. (See Fig. 5.)

Remember that the purpose of this component is to efficiently separate the produced gas and liquid and divert these two phases to sales or storage facilities. The high pressure gas that is used to lift the wells is not consumed; it is merely circulated. With proper design of the separation facilities, the loss of this circulated gas through vent lines to the asmosphere can be eliminated or substantially

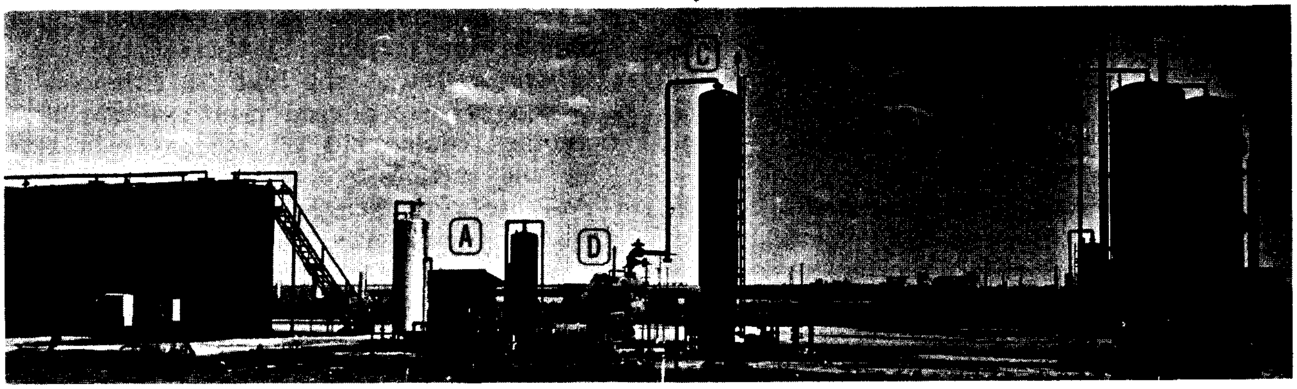


FIG. 5 SEPARATION AND STORAGE FACILITIES

A. SEPARATORS
B. HEATER TREATERS
C. CRUDE STABILIZER
D. SALES LINE COMPRESSOR
E. SALES METER RUN

reduced so that the efficiency of the total lift system is enhanced. When a closed rotative gas lift system is being designed, an investigation should be made of the requirements for a low pressure storage volume to provide a relatively constant suction pressure to the compressors. This is particularly important in intermittent lift applications.

DESIGN CONSIDERATIONS

These four components are present in any gas lift system whether it is a continuous flow or an intermittent lift application. Their relative importance, dependence, and effect on each other are quite different for the two basic applications. For simplicity, these components will be considered for a continuous flow application and then for an intermitting lift system, of course, will necessarily be a design compromise to get the most production for the least dollar invested.

CONTINUOUS FLOW DESIGN CONSIDERATIONS

When the high pressure gas source is an existing source such as a gas well, gas transmission line, or nearby product plant, the designer merely sizes the distribution lines properly to get the gas to the wells at the desired pressure and volume. For continuous flow applications, the most desirable operating pressure is the highest pressure compatible with the reservoir draw-down requirements; for, the higher the pressure, the deeper the point of injection and the less gas that is required per barrel of liquid produced. For this reason, sometimes a single stage booster compressor may be a very attractive addition to the high pressure gas source. When a closed rotative system is designed for continuous flow applications, a close study should be made of the separator pressure (part of the separation and storage facilities) to be sure that the calculations are based on a minimum compression ratio compatible with the discharge pressure requirements. Since continuous flow is a stabilized steady-state flowing condition, there is no need to design storage volume into the distribution lines, but only to size them properly to transport the required volume and pressure to the surface gas controls at the well.

The control valve in the surface gas controls may be a choke only, a choke and pressure reducing regulator, or a constant rate controller to maintain a desired differential across the orifice plate of the meter run. Each of these controllers have relative advantages and disadvantages as related to freezing problems, operating personnel and local conditions.

The design of the sub-surface gas controls requires more effort. A gas lift valve should be selected which has a throttling characteristic compatible with the mixing and aeration requirements of continuous flow gas lift. This paper will not deal with the pressure setting and spacing of the valves as that is adequately covered in existing design manuals. Let it suffice to say that the gas lift valve design should be such that the maximum possible pressure is directed to the greatest depth consistent with the draw-down requirements. The tubing string must be sized to meet the design requirements. If the tubing is too small for this, a special form of the "Open Installation" may be utilized by directing the gas down the tubing and producing the aerated fluid up the casing annular space. This type installation is called casing flow. (The surface gas controls for a casing flow installation are illustrated in Fig. 6). When the gas is directed down the casing annular space, a packer is preferred to keep the well fluids from reentering the annular space once the well has been unloaded. In any case, an account should be made of the pressure drop that exists in the gas flow stream from the surface to the bottom gas lift valve. This is particularly true in small diameter well completions where the cross-sectional area available for the injection of gas is rather small. The design of the sub-surface gas controls is going to have more effect on the draw-down potential of the installation than any other component (that is, after the surface operating pressure has been determined). However, the produced fluids and lift gas must be properly handled on the surface to prevent unnecessarily high wellhead back pressures on the tubing.

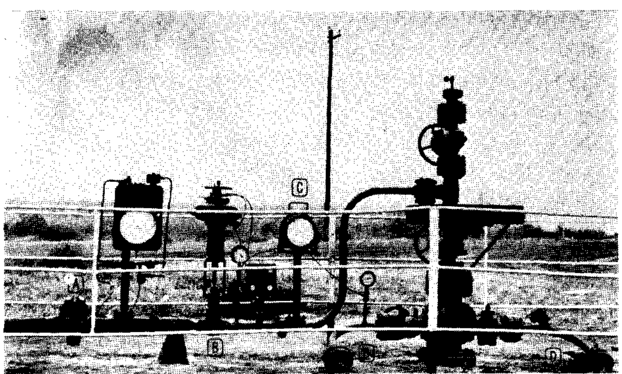


FIG. 6

SURFACE GAS CONTROLS FOR CASING FLOW INSTALLATION

A. METER RUN AND METER
B. PRESSURE CONTROLLED MOTOR VALVE
C. TWO PEN PRESSURE RECORDER FOR CASING AND TUBING
D. FLOW LINE CONNECTIONS

Therefore, the design of the separation and storage facilities includes proper sizing of the flow line, separators, and/or heaters. The flow line should be as streamlined as possible and free of restrictions and unnecessary swings. The separator and/or heater should be large enough to efficiently separate the total volumes of gas and liquids from the wells. Oversizing of the separation equipment is not necessary for continuous flow applications because there are no surging pressures and high instantaneous flow rates as are experienced in intermittent lift. The volume requirement of low pressure storage for the suction feed to the compressor in a closed rotative system is almost nil when all of the wells are continuous flow installations.

In summary, it is evident how each of the four components of the system has a direct bearing on the adjacent components and, of course, each is affected by the adjacent components. The efficient dovetailing of these components into a properly engineered gas lift system is relatively easy for continuous flow applications. The reasons are simply that continuous flow is a very smooth operation of steady-state conditions requiring a relatively constant instantaneous rate from the high pressure gas source, through the surface gas controls, through the sub-surface gas controls, and through the separation and storage facilities. For these reasons the system is easy to operate when it is properly designed and the operator is familiar with the various components and their functions.

INTERMITTING LIFT DESIGN CONSIDERATIONS

Intermitting gas lift systems require more design thought because of the surging pressures and sudden high rate requirements which are a result of the three periods of the intermitting cycle. When designing the gas lift system for intermitting applications, the designer must consider the same four components of the system but in the new light of the cyclic requirements of the intermitting cycle. These cyclic requirements are reviewed as follows: during the feed-in period, a minimum pressure is desired at the tubing well head while well fluids accumulate in the tubing and above the gas lift valve. No gas is required during this period, but it must be stored someplace so that it can be furnished very quickly for the lift period. During the lift period, a large volume of gas must be furnished in a very short time. To accomplish this the gas should be stored as close as possible to the point to where it is needed—at the operating gas lift valve. The gas lift valve should have a large port so that it can efficiently pass the large volume of gas required to expel the slug of fluid to the surface. After the lift period is accomplished, the gas lift valve must close (preferably on a signal from the casing pressure) and the flow line and separator should be large enough to accomplish the pressure reduction period very rapidly. Rapid reduction of this back pressure on the well can increase the production from the well by 25 to 100 per cent. It should be evident that designing the system components to meet the demands of this cyclic operation will be more difficult than that for continuous flow.

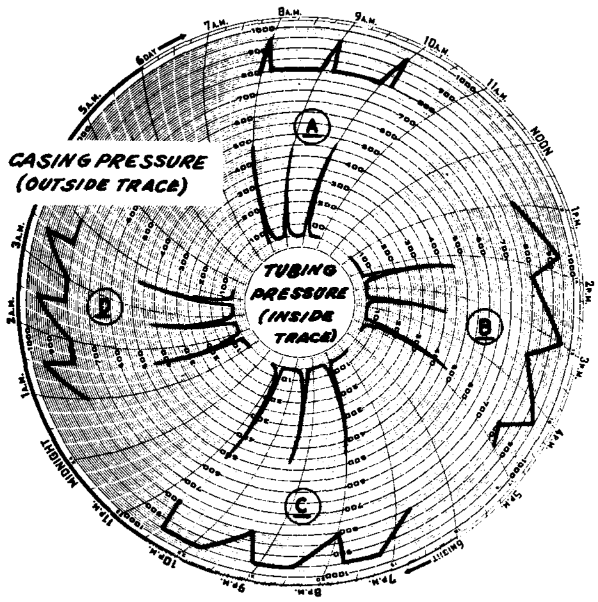
In the high pressure gas source, again the gas must be available in sufficient pressure and quantity. The gas distribution lines must be sized properly to furnish these requirements at the well location. These distribution lines may be sized to store the gas required during the lift period of the intermitting cycle; or by design, the casing annular space in each well may be used for that purpose. Use of the casing annular space is much better for two reasons:

(1) it is adjacent to the gas lift valve
(2) it is free

But the design of the surface gas controls and selection of the gas lift valves play an important part in this choice.

The surface gas control may be a variation of four basic methods of controlling the gas to intermitting applications. These are illustrated by the record of casing and tubing pressures shown in Fig. 7. The first, in quadrant A, is the use of a time cycle controller only. This is probably the most popular. But notice how the time is open for a very short period of time. In this short period of time, the required volume of gas must be drawn from the high pressure gas system. This creates a very critical high rate demand on the high pressure gas source and is a disadvantage. It requires that the high pressure system be large enough to store this large volume that is demanded by the timer. This storage requirement adds cost to the distribution lines.

This disadvantage can be overcome by using another type of control as shown in quadrant B of Fig. 7. Here, a choke only is used to control gas to the casing for intermitting gas lift. The casing pressure slowly increases (storing gas in the annular space) until the gas lift valve opens, then the casing pressure decreases sharply to the closing pressure of the gas lift valve. While the casing pressure is decreasing, the high pressure gas is moving from the annular space into the tubing to expel the accumulated slug of fluid from the tubing. This type of control eliminates the high rate demand from



SURFACE GAS-CONTROL SYSTEMS

A: TIME CYCLE CONTROLLER

B: CHOKE CONTROL

C: CHOKE AND PRESSURE REGULATOR

D: CHOKE AND TIME CYCLE CONTROLLER

FIG. 7

the gas source, and, in fact, a steady rate of gas is required from the gas source over a 24-hour period. This requirement is very similar to that of the continuous flow gas lift. It is the most ideal control when the high pressure gas source is relatively low in pressure and limited in volume, and it permits the economy of small gas distribution lines. However, the use of this control is dependent upon the spread characteristics of the gas lift valve. If the gas lift valve has no operating spread, then this form of surface control cannot be used. Freezing across the choke and a somewhat limited range of cycle frequency control are disadvantages of the choke control. However, variations to overcome these problems are illustrated in quadrants C and D of Fig. 7.

Quadrant C illustrates the combination of a pressure regulator and choke. This system is utilized to extend the application of choke control to decrease or increase the cycle frequency in that more time or less time can be permitted between the intermitting cycles. It also helps to reduce freezing problems across the choke. It offers the primary advantage of the choke control and eliminates some of the disadvantages. It is an excellent automatic controller for an intermitting installation since it allows the casing pressure to build up to a desired point where it remains until enough fluid accumulates in the well tubing to trip the gas lift valve.

Another variation is illustrated in quadrant D — the combination of a time cycle controller and choke. This illustrates a very simple and economical way to overcome the disadvantages of the timer by merely installing a choke in the line. (Refer to Fig. 2.)

It must be remembered, however, that the gas lift valves must have operating spread before any form of choke control may be utilized.

Reference to Fig. 7 emphasizes the fact that in cases B, C and D the gas lift valve did not open as soon as the casing pressure started increasing. Why? Because the gas lift valves are partially dependent on the tubing pressure for their opening operation (this is not necessarily true in case A when the time cycle control is used). So then, the design of the gas lift valves (part of the sub-surface gas controls) can dictate the selection of the surface controller. The gas lift valve must have operating spread to permit the use of a form of choke control as illustrated in quadrants B, C and D of Fig. 7. So, the selection of the surface gas controller depends on the facilities of the high pressure gas source and the design of the sub-surface gas controls.

The semi-closed and closed installations are generally recommended as the sub-surface gas controls for intermitting applications. The size of the casing and tubing and the operating characteristics of the gas lift valves are very important design considerations. If a no-spread gas lift valve is selected, then a time cycle controller must be used on the surface and the gas volume required for each cycle must be stored in the distribution lines. But, it is much better practice to design the gas lift valves so that a form of choke control may be used—and when choke control is used, the gas required to expel a slug of fluid from the tubing is stored in the casing annulus, not in the distribution lines. To store the correct volume of gas, the operating spread of the gas lift valve must be determined by the relative sizes of the casing and tubing, the size of the slug to be expelled, and the depth of the operating valve. When the spread is selected, the operator must use any of the four basic surface controllers illustrated in Fig. 7 and preferably one of the variations of choke control. On the other hand, if a no-spread gas lift valve is used, the operator must use a time cycle controller.

The gas lift valve pressures can be set so that every valve in the string operates at the same surface pressure. This is compatible with safe design principles in most cases. With this kind of design the individual wells can be unloaded, operated and periodically kicked off at virtually the same pressure. Use of this design technique will save many dollars when a closed rotative system is being designed. Of course, in those few cases where very high pressures are available, the use of the high pressures on the upper unloading valves will result in the use of fewer valves per string. But keep in mind the fact that as more wells are added to a high pressure gas source, the operating pressure frequently drops and then the installations designed on the higher pressures are no longer operable. Perhaps the most important consideration concerning the selection of the gas lift valve pressures is that the operating valves of all wells be set at a common system pressure. Invariably, when some wells operate at a low pressure and others at a higher pressure, the system pressure reduces until the higher pressure wells cease to operate. Proper design of the valve pressure as related to the high pressure gas source will prevent this problem.

The requirements of the separation and storage facilities for intermitting lift are more detailed than those for continuous flow because of the cyclic operation of this application. Since slugs of fluid are being expelled from the tubing at very high rates, the flow line should be adequate to handle this high rate and to transport the large volume of tail gas behind the slug. Because of these high rates the separator for a 40 or 50 BPD well should be capable of handling 500 to 1000 BPD because it must handle the desired slug at the higher rates. It also follows that the separator should have large dump valves and large gas lines going to the sales line or to the low pressure storage volume. Heaters may be required on intermitting applications but it is never advisable to produce an intermitting well directly to a heater. A separator should always be installed upstream of the heater.

In a closed rotative system, the design of the low pressure gas storage (Fig. 8) is very important and must be properly sized to prevent unnecessary flaring of gas and to provide a relatively constant suction pressure for the compressors. Proper design of the low pressure storage will eliminate the need for make-up gas.

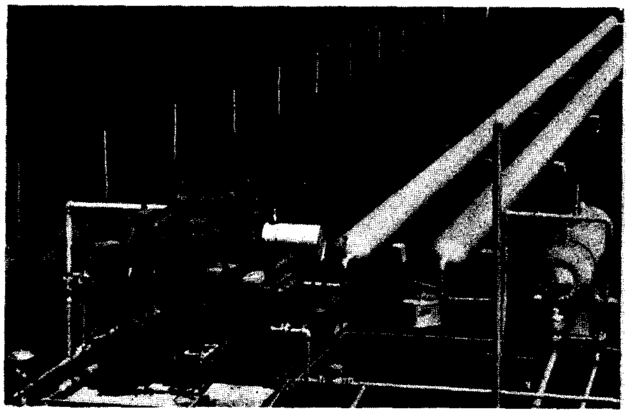


FIG. 8
LOW PRESSURE GAS STORAGE FOR CLOSED ROTATIVE SYSTEM

CONCLUSION

Emphasis has been placed on the mutually compatible design of the various components of the gas lift system because design is the first step in any artificial lift system. However, what value is realized in a properly designed artificial lift system, if the operating personnel are not familiar with the system components? So then, the operators should be schooled on the components of the system and how changes in one component may affect the others. Better understanding of a job always results in better performance of the job.

How many times has this expression been heard, "This system wasn't designed, it just happened," or "This system wasn't designed, it just grew until we had so many wells on lift that we didn't have enough gas to supply them." But who will argue with this—it takes less time, effort, and money to get the facts and properly design a system than to grope and stumble and work with a lift system that "just happened."

REFERENCES

1. Brown, Doerr, Brill, "Practical Use of Recent Developments in Two-Phase Horizontal and Vertical Continuous Flow," Southwestern Petroleum Short Course Proceedings, 1965.

2. Drake, R. W., "Tailor the Lift to the Job," The Oil and Gas Journal, January 4, 1960.

3. Kirkpatrick, C. V., "Fundamental Design of Gas Lift Systems," The Petroleum Engineer, July, 1957.

4. Orris, Bicking, DeMoss, Ayres, Merla's Practical Gas Lift Manual #165.

5. Wall, P. T., "Effect of Back Pressure on Intermittent Gas Lift," Southwestern Petroleum Short Course, Proceedings, 1965.

6. Winkler, H. W., "Design Calculations for a Closed Rotative Gas Lift System," West Texas Oil Lifting Short Course, Proceedings, 1960.