Design Calculations For A Closed Rotative Gas Lift System

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ABSTRACT

The purpose of this paper is to outline and illustrate the calculations required to design a closed rotative gas lift system. Design considerations that are required for continual operation of a closed rotative system without make-up gas after initial charging are discussed. Detailed calculations for a single intermittent well system are offered. These calculations are presented in a step-by-step manner. The effect oı expanding the system to include other wells is illustrated.

INTRODUCTION

A closed rotative gas lift system for a single well is illustrated by a simplified flow diagram in Fig. 1. The installation illustrated is called a closed system because the total gas-out from the well (formation and lift) is returned to the suction of the compressor for compressing and gas lifting the well.

After a closed rotative system is initially charged, the only make-up gas of any significance is the fuel requirement for the compressor prime mover, provided no gas is vented, sold, or used for lease operation. Generally, the produced gas from the wells is more than adequate for supplying the fuel requirement. A closed rotative gas lift system has the advantages of a central power plant and these advantages increase with an increase in the number of wells in the system.

If all wells to be gas lifted are in the continuous flow category, the design of the closed rotative gas lift system presents no problem. The gas required to lift the wells represents a constant demand from the compressor station and the total gas returning from the wells is nearly constant also. However, actual closed rotative systems are generally not this simple because a few, if not all wells, may be in the intermittent gas lift category.

If time cycle surface controllers are employed on the injection gas lines to the intermittent wells, a large volume of injection gas is required for short periods of time and no injection gas is needed between the periods of gas injection. Consequently, the output of the compressor must be capable of supplying this high per-minute requirement while the surface controller on the injection gas line is open, or the additional injection gas in excess of the compressor output must be obtained from the high pressure injection gas sytem.

Generally, the cost of an adequately designed high pressure injection gas system is less than the cost of additional compressor horsepower required to deliver the per-minute intermittent gas requirement. Many intermittent installations are designed to lift with a continuous injection of gas into the casing, thus eliminating the high per-minute requirement for short periods of time followed by long intervals when no gas is required.

Regardless of how the injection gas is introduced into the well, the lift plus formation gas returns to the low pressure gas gathering system at a relatively high rate following surfacing of the liquid slugs. The low pressure system should be designed to hold the fluctuating gas volumes produced from the wells. If too much gas leaves the low pressure system after the liquid slugs surface, make-up gas must be supplied from an outside source. If make-up gas is costly, the design of the low pressure system is important.

The purpose of this paper is to illustrate the calculations required for designing a closed rotative gas lift system which requires capacity in the high pressure injection gas and low pressure gas gathering systems. These calculations are divided into the following five parts:

1. Estimation of Daily Injection Gas Requirement for Assumed Injection Gas Pressure
2. Calculation of Approximate Compressor Brake Horsepower
3. Design of the High Pressure Injection Gas System
4. Calculation of Excess or Make-up Gas Volume
5. Design of the Low Pressure Gas Gathering System

DISCUSSION OF DESIGN CALCULATIONS

Estimation of Daily Injection Gas Requirement for Assumed Injection Gas Pressure

The injection gas requirement is a function of the injection gas pressure available to lift the well and the wellhead tubing pressure. The injection gas pressure selected should be adequate to efficiently gas lift the well to depletion. The wellhead tubing pressure used to calculate the injection gas requirement must exceed the suction pressure of the compressor.

The relationship between compressor suction pressure, operating gas lift pressure, and the injection gas requirement are beyond the scope of this paper. However, the effect of injection gas pressure and suction pressure on injection gas requirements and compressor costs are illustrated in Table 10, page 80, of The Power of Gas by C. V. Kirkpatrick.

An estimation of the daily injection gas requirement can be calculated as follows:

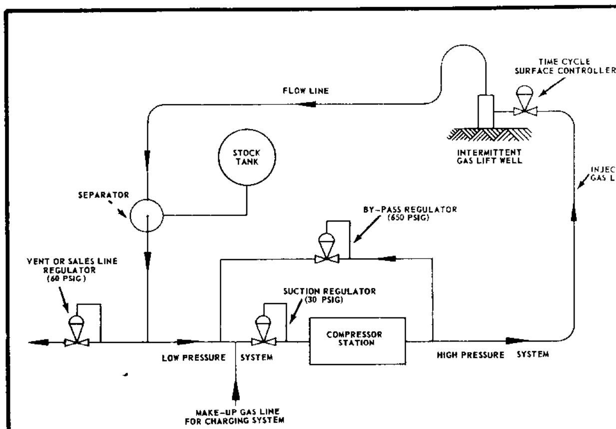


FIGURE 1: SIMPLIFIED FLOW DIAGRAM OF A CLOSED ROTATIVE GAS LIFT SYSTEM FOR SINGLE INTERMITTENT WELL

1. Tabulate the producing data (present and abandonment) for all wells to be included in the closed rotative system. This data should include total producing rate, gas-oil ratio, water cut, depth of producing zone, static bottom hole pressure, productivity index, wellhead tubing pressure, oil gravity, water gravity, tubing size, casing size, etc.
2. Group wells into as few representative wells as possible. The wells should be divided into categories based on type of gas lift installation, depth of operating valve, producing rate, etc. This reduces the number of required calculations.
3. Calculate the gas requirement for each representative well for the present and final producing rates. The gas requirement for an intermittent installation should be calculated based on the injection gas required to fill the tubing under the slug.[1] Flowing gradient curves or volumetric balance calculations should be used to determine the gas requirement for a continuous flow installation.[2,3]
4. Multiply the gas requirement for each representative well by the number of wells in each category to obtain the total gas requirement per category. Then total the gas requirements for all categories to obtain the total daily gas requirement needed for compressor calculations.

Calculation of Approximate Compressor Brake Horsepower

1. Select a suction and discharge pressure for the compressor. The compressor discharge pressure should be 100 to 200 psi higher than the operating injection pressure required to lift the intermittent wells. A line pressure higher than the operating pressure assures gas storage in the high pressure system, due to a pressure difference, and permits the use of higher opening pressure gas lift valves for unloading the well. The suction pressure must be less than the wellhead tubing pressure assumed for calculating the injection gas requirements.
2. Calculate the approximate compressor brake horsepower for present and maximum injection gas requirements using curves supplied by a compressor manufacturer or the compressor brake horsepower calculation curves in the Natural Gasoline Supply Men's Association Engineering Data Handbook. The daily injection gas volume must be corrected to a pressure base of 14.4 psia and intake temperature before the brake horsepower can be calculated for most compressor design curves.
3. Select a nominal brake horsepower rated compressor which exceeds the brake horsepower requirement calculated above. Many times the compressor installation is designed initially for the present gas requirement and compressors added as needed. The brake horsepower rating of the initial compressor should be based on the brake horsepower of the final compressor station so that the compressor station required to deplete the wells will not consist of an excessive number of small brake horsepower compressors.
4. Contact the compressor manufacturer for specific sizing of the compressor. Prior to contacting this representative, tabulate the data needed to accurately size a compressor. This data should include: ratio of specific heat ("N" value) of the gas, suction pressure, discharge pressure, intake gas temperature, volume of gas at given pressure and temperature base, atmospheric pressure, ambient air temperature, etc.

Two-stage horizontal type belt-driven compressor units are available in nominal brake horsepower ratings of approximately 70, 120, 200, and 310 BHP. Horizontal balanced opposed direct drive units are offered in 100 to 450 BHP ratings. Integral skid-mounted compressor units rated at 175 to over 1,000 BHP are available, with the 440 to 660 BHP units being the most popular sizes of integral compressor units used for gas lift service. The BHP rating will vary slightly between manufacturers; but generally, the compressor units offered by various manufacturers are competitive in size and price for each type.

An excessive number of small brake horsepower compressors increases the detailed attention and maintenance and will increase the final cost of a compressor station. The difference in cost between very small compressors based on dollars per BHP can be significant and can be illustrated by a recent quotation for two skid-mounted two-stage horizontal type belt-driven compressor units complete with prime mover, scrubbers, coolers, safety switches, etc.

A two-stage 80 BHP 8 inch x 4 inch x 9 inch compressor capable of delivering 425,000 cubic feet per day at 14.4 psia and inlet temperature with a suction pressure of 20 psig and a discharge pressure of 600 psig costs approximately $20,250 f.o.b. Houston, Texas. A two-stage 5-1/2 inch x 4 inch x 9 inch compressor capable of delivering only 185,000 cubic feet per day with same suction and discharge pressures costs approximately $19,000 f.o.b. Houston, Texas.

Design of High Pressure Injection Gas System

If the injection gas enters the casing of all wells at a constant rate through a small restriction in the injection gas line, the design of the high pressure system is of no concern. When surface controllers with a time cycle pilot are used to control the injection gas for lifting the wells, the injection gas requirement is high during the time that the surface controller is open, and no injection gas is needed for the long periods of time that the controller is closed.

The high pressure system should be designed to supply the difference between the deliverability of the compressor station and the injection gas requirement to lift the wells during the time the surface controllers are open. Abandoned wells can be used for increasing the capacity of the high pressure system.

One of the most important concepts in the design of both the high and low pressure systems is that there is no gas volume stored in a conduit above a given pressure unless there is both capacity and pressure difference (pressure of gas must be higher than given pressure). Capacity is a fixed value based on the physical size of the conduit. Gas volume varies with the capacity of the conduit and the pressure and temperature of the gas.

Higher pressure differentials and, consequently, greater gas volumes for the same capacity are possible in the high pressure system than in the low pressure system. The following equation, which disregards gas deviation and temperature correction, can be used for approximate calculations of gas volume-in and capacities-of the high and low pressure systems:

$$\text{Approximate Gas Volume at Atmospheric Pressure} = \left[\frac{\text{Pressure Difference}}{\text{Atmospheric Pressure}}\right] \text{Capacity}$$

A standard pressure base may be substituted for the atmospheric pressure term if the volume of gas at a given pressure base is desired. Generally, the gas deviation tends to partially offset the temperature correction in calculations relating to the high pressure system.

1. Calculate the deliverability of the compressor during the time that a surface controller is open.
2. Calculate the difference between the compressor deliverability and the injection gas requirement during the time that injection gas is entering the wells. This volume of injection gas must be stored in the high pressure system.
3. Calculate the approximate capacity of the high pressure system using Equation 1. This calculation is based on the minimum volume of gas calculated in step 2, which must be stored in the high pressure system, the injection gas line pressure immediately before the surface controllers open, and the maximum casing pressure buildup during the time that the surface controllers are open.
4. Calculate the pressure loss in the longest and/or smallest I.D. injection gas line in the system. The per-minute gas requirement must be converted to an hourly or daily basis in order to use most gas flow equations.

An alignment chart for the solution of Weymouth's formula of gas flow in small high pressure lines can be used to find pressure loss with relation to daily gas volume and upstream pressure.[5] If pressure loss is excessive, larger lines should be employed.

Calculation of Excess or Make-up Gas Volume

Operators report an unaccountable gas loss in most closed rotative systems. The bulk of these losses is believed to be due to error in gas measurement; however, it is advisable to base excess or make-up gas volume calculations on an unaccountable loss in the system of approximately four per cent of the deliverability of the compressor station. If the wells have a high gas-oil ratio and a high pressure gas sales line is nearby, the operator should consider sizing the compressor for the additional capacity required to deliver the excess gas into the high pressure sales line.

1. Calculate the total daily produced formation gas from the wells. Multiply the gas-oil ratio times the daily oil producing rate from each well and total these volumes of gas.
2. Calculate the daily fuel requirement for operating the compressor station. Fuel consumption of a compressor driven by a gas engine can be estimated by assuming a gas requirement of approximately ten cu. ft./BHP-Hour.
3. Compare the total daily produced formation gas with the summation of the daily fuel requirement for the compressor and the unaccountable volume of gas loss in the system. If the produced gas exceeds the fuel requirement by more than four per cent of the daily deliverability of the compressor station, no make-up gas should be required, provided the closed rotative system is properly designed and operated.

Design of Low Pressure Gas Gathering System

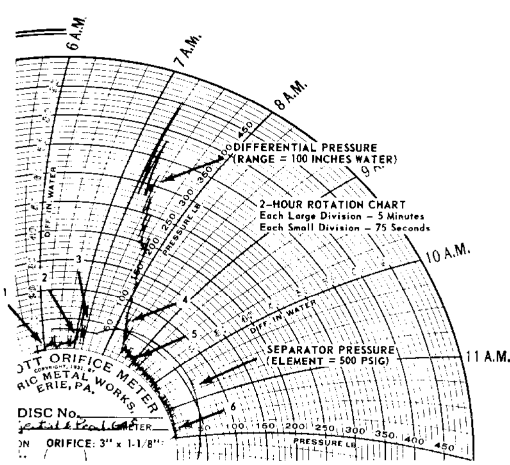
When the injection gas plus the formation gas is entering the low pressure system at a constant or near constant rate, as from a continuous flow gas lift well, the capacity of the low pressure system is of no importance. Although an intermittent gas lift installation may be designed for controlling the high pressure injection gas into the casing with a choke (continuous injection with no high rates for short periods of time), the total volume of gas-out returns to the system at a relatively high rate immediately after the slug surfaces.

If the produced gas (injection and formation) cannot be stored within the low pressure gathering system, the gas will be vented or enter a sales line. High gas-oil ratio wells which produce gas between injection gas cycles minimize the problems associated with the gas gathering system. Generally, the difference between the compressor suction and the maximum separator pressure is much less than the difference between the casing pressure and the injection gas line pressure.

Consequently, an adequately sized low pressure system is important for small closed rotative systems with intermittent wells if no central timer is employed to operate the surface controllers. The gas gathering system for a closed rotative gas lift installation should include as many wells as possible, regardless of whether or not these wells are on gas lift.

In the following design procedure, the gas gathering system is designed to retain the produced formation gas necessary to supply the fuel requirement for the prime mover of the compressor and the make-up gas volume based on an assumed per cent unaccountable loss in the system.

1. Estimate the maximum volume of gas which will enter the low pressure gas gathering system during any given period of time that the deliverability of the compressor is exceeded. This calculation should be based on the maximum number of intermittent wells which could have a liquid slug entering the surface facilities simultaneously. An actual total gas-out chart from an intermittent well, shown in Fig. 2, will be used to illustrate these calculations. This estimation is the most difficult one to make in the design of a closed rotative system. An assumption which may be helpful is that approximately one-half of the total gas volume produced per cycle, which includes injection and formation gas, enters the gas gathering system in a five minute interval, provided the well is not choked and the flow line is not extremely long or smaller than the tubing.



SEQUENCE OF EVENTS: No. [illegible]2 – Liquid Slug Entered Flow Line and Traveled to Separator; No. 2 to No. 3 – [illegible]uid Slug Entered Separator; No. 3 – Injection Gas Immediately Behind Liquid Slu[illegible]an to Enter Separator; No. 3 to No. 6 – Total Injection and Formation Gas Beh[illegible]iquid Slug Entered Separator.

GAS VOLUMES: No. 3 to No. 4 – Injecti[illegible]nd Formation Gas Volume = 1300 cu. ft.
No. 3 to No. 5 – Injection[illegible]d Formation Gas Volume = 1840 cu. ft.
No. 1 to No. 6 – Total Injection and Formation Gas Volume Per Cycle = 2600 cu. ft.

FIGURE 2: QUARTER SECTION OF LOW PRESSURE SALES LINE TWO-HOUR ROTATION ORIFICE METER CHART OF TOTAL VOLUME OF GAS-OUT (INJECTION AND FORMATION) PER CYCLE FROM INTERMITTENT GAS LIFT WELL.

2. Calculate the volume of gas required to supply the gas input volume for the compressor, the fuel requirement for the compressor, and the unaccountable gas losses in the system during the time that the compressor capacity is exceeded. One method for calculating this total gas volume is to multiply the summation of these daily gas volumes by the number of minutes that the capacity of the compressor is exceeded and divide the result by 1440. These daily gas volumes were computed in the previous calculations for determining the excess or make-up gas volume.
3. Calculate the volume of excess gas which can be sold or vented per cycle from the low pressure system if the produced gas from the wells exceeds the summation of the fuel requirement for the compressor and the estimated unaccountable volume of gas loss from the system. This gas volume is obtained by dividing the estimated excess daily gas volume which can be sold or vented by the number of injection gas cycles per day. For the design of the low pressure system, all gas is assumed to be vented or sold from the system during the time that the compressor capacity is exceeded.
4. Calculate the volume of gas which should remain in the low pressure system during the period of high rate of gas entry into the system. For this period of time that the compressor capacity is exceeded, add the volume of gas required for deliverability, fuel, and losses calculated in step 2 to the volume of excess gas which can be sold or vented calculated in step 3 and subtract this total gas volume from the maximum volume of gas entering the low pressure system during the same period calculated in step 1.
5. Calculate the approximate capacity of the low pressure system using Equation 1. These calculations are based on the volume of gas calculated in step 4, maximum separator pressure (due to sales line or vent line regulator opening pressure), and suction pressure of the compressor. In other words, the pressure of the gas gathering system is assumed to increase to to the sales line or vent line regulator opening pressure during the time that the capacity of the compressor station is exceeded. When the rate of gas produced from the well is less than the deliverability of the compressor, the pressure of the gas gathering system begins to decrease. When the compressor suction pressure is reached, the gas from the wells enters the gas gathering system at a rate which exceeds the capacity of the compressor and the cycle repeats.
6. Select adequately sized flow lines and eliminate as many restrictions, bends, fittings, etc., as possible between the wellhead and separator. The flow line should never be smaller than the tubing in the well; preferably, it should be larger. If the well will eventually have a high water cut and must be produced at a high producing rate, the flow lines should be sized initially for maximum fluid production for depletion.

If it is difficult to retain gas in the low pressure gathering system, choking the intermittent wells at the battery may solve the problem. An intermittent gas lift well should not be choked at the wellhead. An inexpensive source of additional low pressure capacity can be obtained by using large obsolete separators with all internal parts removed.

EXAMPLE CALCULATIONS FOR SINGLE WELL INSTALLATION

A closed rotative gas lift system for a single intermittent well represents the worst possible operating conditions, particularly if a time cycle surface controller is used on the injection gas line. The design of this one well system, which will operate without make-up gas after the system is initially charged, will clearly illustrate all calculations and design considerations required for intermittent wells with time cycle surface controllers. The following data will be used for designing a closed rotative system for a single intermitent well:

Depth of operating valve	= 5,000 ft.
Daily producing rate	= 48 bbls. oil/day
Formation producing gas-oil ratio	= 600 cu. ft./bbl.
Injecting gas for 2 min. every 30 min.	= (48 cycles/day)
Production per cycle	= 1 bbl. oil/cycle
Injection gas requirement per cycle	= 2,000 cu. ft./cycle
Compressor suction pressure	= 30 psig
Compressor discharge pressure	= 650 psig
Compressor gas inlet temperature	= 100° F.
Injection gas gravity	= 0.6
Injection gas pressure and temperature base	= 14.65 psia & 60° F
Average temperature of gas in high pressure system	= 100° F
Sales line regulator opening pressure	= 60 psig
Size and length of injection gas line	= 2 in., 1,000 ft.

Obtain volumes of gas-out from orifice meter chart, Fig. 2

Several steps have been simplified in the following example calculations by giving certain information which normally would be calculated. These calculations are offered to illustrate how to design a closed rotative system rather than how to figure individual well and compressor problems. For this reason, such items as injection gas requirement and compressor suction and discharge pressures were given, rather than calculated.

A. Estimation of Daily Injection Gas Requirement
Daily Inj. Gas Reqmt. at Std. Cond.

= 2,000 cu.ft./cycle (48 cycles/day)

= 96,000 cu.ft./day at 14.65 psia and 60 ° F.

B. Calculation of Approximate Compressor Brake Horse power

From a manufacturer's compressor BHP curves for 30 psig suction pressure and 650 psig discharge pressure:[4]

Approx. BHP/MMCFD at 14.4 psia and Intake Temp. of 100° F. = 182 BHP Daily Inj. Gas Reqmt. at 14.4 psia and 100° F.

$$= 96{,}000 \left(\frac{14.65}{14.4}\right) \left(\frac{560}{520}\right)$$

= 105,000 cu.ft./day at 14.4 psia and 100° F.

$$\text{Approx. Compressor BHP} = 182 \quad \frac{105{,}000}{1{,}000{,}000}$$

= 19.1 BHP

C. Design of High Pressure Injection Gas System

1. Per-Minute Compressor Deliverability

$$= \frac{96{,}000 \text{ cu.ft./day}}{1440 \text{ minutes/day}}$$

= 67 cu.ft./min.

2. Inj. Gas Vol. Required from H. P. System

$= 2000$ cu.ft./cycle $-$ 2 min. (67 cu.ft./min.)
$= 1866$ cu.ft.

3. Approx. Capacity of H. P. System Using Equation 1:

$$1866 = \left[\frac{650 - 500}{14.65}\right] \text{Capacity}$$

Capacity = 182 cu. ft.

4. Approx. Press. Loss in H. P. Inj. Gas Line Using Weymouth's Alignment Chart:[5]

Daily Inj. Gas Vol. Based on Per-Minute Reqmt.

$$= \frac{2000 \text{ cu.ft./cycle}}{2 \text{ minutes/cycle}} \text{ (1440 minutes/day)}$$

$= 1{,}440{,}000$ cu.ft.day at 14.65 psia and 60° F.

$$= 1{,}440{,}000 \left(\frac{14.65}{14.4}\right)\left(\frac{560}{520}\right)$$

$= 1{,}578{,}000$ cu.ft./day at 14.4 psia and 100° F.

From Alignment Chart $(P_1^{\,2} - P_2^{\,2}) = 12{,}500$

$(P_2)^2 = (664.65)^2 - 12{,}500$

$= 441{,}800 - 12{,}500 = 429{,}300$

$P_2 \cong 655$ psia $\cong 640$ psig (Pressure Loss Negligible)

D. Calculation of Excess or Make-up Gas Volume

1. Daily Prod. Form. Gas

$= 48$ bbls. oil/day (600 cu. ft./bbl.)

$= 28{,}800$ cu. ft./day

2. Daily Compressor Fuel Reqmt.

$= 10$ cu. ft./BHP-Hr. (24 hr./day) 19.1 BHP

$= 4590$ cu. ft./day

3. Est. Unaccountable Losses in System

$= 0.04\ (96{,}000) = 3840$ cu. ft./day

Est. Excess Daily Gas Vol. Which Can Be Sold or Vented

$= 28{,}800 - (4590 + 3840)$

$= 20{,}370$ cu. ft./day

E. Design of Low Pressure Gas Gathering System

1. Vol. of Gas Entering L. P. System During Period of Time that Compressor Capacity Is Exceeded from Fig. 2:

Approx. Orifice Meter Reading = 60 psig and 2 in. when Gas Volume = 96 MCFD = Compressor Capacity

Compressor Capacity Exceeded from Points 2 to 5

Approx. Gas Vol. Between Points 2 and 5

$= 1840$ cu. ft. in 10 minutes

2. Vol. of Gas Required for Deliverability, Fuel and Losses During Same Period

$$= \frac{104{,}430 \text{ cu.ft./day (10 min./cycle)}}{1440 \text{ min./day}}$$

$= 725$ cu.ft./cycle

Where:	Deliverability	= 96,000	cu.ft./day
	Fuel Reqmt.	= 4,590	cu.ft./day
	Est. Losses	= 3,840	cu.ft./day
	Total	= 104,430	cu.ft./day

3. Vol. of Excess Gas Which Can Be Sold or Vented per Cycle

$$= \frac{20{,}370 \text{ cu.ft./day}}{48 \text{ cycles/day}} = 425 \text{ cu.ft./cycle}$$

4. Vol. of Gas to Be Stored in L. P. System

$= 1840 - (725 + 425) = 690$ cu.ft. at 14.65 psia and 60° F.

$= 690 \left(\frac{560}{520}\right) = 743$ cu.ft. at 14.65 psia and 100° F.

5. Approx. Capacity of L. P. System Using Equation 1:

$$743 = \left[\frac{60 - 30}{14.65}\right] \text{Capacity}$$

Capacity = 363 cu. ft.

EFFECT OF ADDITIONAL WELLS IN SYSTEM

The effect of additional wells in a closed rotative gas lift system is shown in Tables 1 and 2. The tabulations in these tables are based on the following assumptions:

1. The well data for all wells is assumed the same as that used for the previous single well calculations.
2. The two-minute periods of gas injection for each well are perfectly staggered in relation to the injection gas periods for the other wells. In other words, a central time-operated programmer is controlling the injection gas cycle frequency and duration of gas injection for all wells.

TABLE 1

HIGH PRESSURE INJECTION GAS SYSTEM

Number of Wells in System	Daily Inj. Gas Reqmt. (MCFD)	Deliverability of Compressor During 2-Min. Inj. Period (cu. ft.)	Inj. Gas Volume from H.P. System (cu. ft.)	Approx. Required Capacity of H.P. System (cu. ft.)
1	96	134	1866	182
2	192	268	1732	169
4	384	536	1464	143
8	768	1072	928	91

TABLE 2

LOW PRESSURE GAS GATHERING SYSTEM

Number of Wells in System	Gas Volumes During Time Compressor Capacity Exceeded				Approx. Required Capacity of L.P. System (cu. ft.)
	Est. Vol. Entering L.P. System (cu. ft.)	Vol. for Deliverability, Fuel & Losses (cu. ft.)	Excess Vol. to Be Sold or Vented (cu. ft.)	Inj. Vol. to Be Stored in L.P. System (cu. ft.)	
1	1840	725	425	690	363
2	1300*	725	425	150	79

*Assume volume of total gas-out for each cycle has entered low pressure system before next cycle begins. This is not exactly correct as can be seen from Fig. 2.

Several conclusions are readily apparent from the tabulations. As the number of wells in the system increases, the importance of the capacity of the high and low pressure systems decreases. Actually, the high pressure injection gas and low pressure gas gathering systems increase in capacity as more wells are included in the system, which is one factor that reduces the operating problems in large systems.

The calculations for the high pressure system with several intermittent wells are straightforward, as can be seen in Table 1, but the calculations for the gas gathering system are not. Since the volume of total gas-out does not enter the low pressure system instantaneously following surfacing of the liquid slug, the capacity of the gathering system for several intermittent wells will be adequate generally, due to the flow lines, separator or separators, suction lines, etc., provided the liquid slugs enter the system alternately and there are not over 10 to 15 minutes between slugs.

The difference between a liquid slug entering the system every 30 minutes and every 15 minutes can be illustrated using the orifice meter chart in Fig. 2. The calculations for the low pressure system in which an injection gas cycle occurs every 30 minutes were given in the design of the one well system. When this system is increased from one well to two wells, the injection gas cycle frequency increases from 48 to 96 cycles per day or an injection gas cycle every 15 minutes.

The total injection gas requirement for the two wells is approximately 192 MCFD. Therefore, the compressor capacity is exceeded between points 3 and 4 in Fig. 2. The capacity of the compressor is exceeded for five minutes, at which time approximately 1300 cu. ft. of gas would enter the low pressure system. Actually, slightly more gas than the 1300 cu. ft. would enter the low pressure system during this interval because some gas would still be entering the system from the other well, as can be seen from Fig. 2.

Neglecting this small volume of gas from the other well and the difference in the change in separator pressure for the two well system as compared to the one well system, the approximate required capacity of the low pressure system would decrease from 363 cubic feet to 79 cubic feet, as given in Table 2. If a third well were added to the system and the periods of gas injection were synchronized, a liquid slug would be entering the separator every ten minutes. Therefore, the capacity of the low pressure system would be of little or no concern for a 30 psi difference between maximum and minimum pressure in the gas gathering system.

The one factor which affects the validity of all calculations related to the high and low pressure systems for intermittent wells in a closed rotative system is synchronization of the time cycle surface controllers on the injection gas lines. It is difficult, if not impossible, to keep the periods of gas injection synchronized with individual clocks in the time cycle pilot on the surface controllers. A programmer is the only positive way of synchronizing the injection periods. Generally, solenoid valves which are operated by a central programmer are recommended as pilots for the surface controllers.

CONCLUSIONS

Small closed rotative gas lift systems with intermittent wells require proportionately larger low pressure gas gathering and high pressure injection gas systems than large systems when time cycle surface controllers are used. These small systems should be carefully designed if make-up gas is costly and a central programmer is not used. Central programmers should be considered for small closed rotative systems with intermittent gas lift wells for synchronizing the injection gas cycles.

Synchronization of the injection gas cycles assures that each well receives adequate injection gas volume at the designed operating injection gas pressure and no gas is vented or sold from the low pressure system due to several wells being lifted simultaneously. Synchronization of the injection gas cycles is not imperative in large systems due to the greater number of wells and the large capacity of the high and low pressure systems.

As a closed rotative system increases in size, the operating problems diminish, provided the system is properly designed. An operator who is designing a closed rotative gas lift system should consult other papers on this subject for additional specific design considerations.[4,6]

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