Gas Lift Design and Analysis

By N. J. ISTO
Shell Oil Co.

INTRODUCTION

The gas lift method of artificial lift involves the use of energy in the form of high pressure gas to lift fluid from the wellbore. Either continuous or intermittent injection of the high pressure gas can be employed depending upon the productive capacity of the well to be produced by gas lift. Continuous flow gas lift involves the continuous injection of gas into the flowstring which reduces the flowing gradient and bottomhole pressure and induces flow from the formation. This technique is generally applied to wells which have high productivities and reservoir pressures. Intermittent flow gas lift involves the periodic injection of gas into the flowstring to lift the fluid in slugs. Wells with low productivities and reservoir pressures are usually candidates for intermittent flow gas lift.

Although continuous and intermittent flow gas lift differ in their application, one basic design method combining mathematical and graphical design techniques can be used to design and analyse the 2 methods of gas lift. By expressing well and gas lift valve performance in mathematical terms which can be translated into graphical terms in the form of a pressure-depth diagram, one standard procedure can be employed to design either continuous or intermittent flow gas lift installations using any basic type of gas lift valve. This approach to gas lift design provides a complete graphical picture of the changing pressure conditions that occur during the kick-off and producing phases of gas lift.

To apply a standard procedure for designing and analysing gas lift installations using the pressure-depth diagram, the problem should be divided into the 3 following phases:

(1) A summary of well and equipment information required for the design.
(2) The establishment of well and equipment performance that will provide the boundary conditions for the design.
(3) The calculation of gas lift valve specifications and spacing for the established boundary conditions.

The factors involved in these phases and the method in which these factors are incorporated into the final gas lift design will be presented.

INFORMATION REQUIREMENTS

The design of a successful gas lift installation is dependent upon complete and accurate well and equipment information. Data must be available that will describe the physical properties of the well and gas lift equipment and that will permit the prediction of well and gas lift valve performance. To fulfill these requirements, the following information should be available before commencing a design:

(1) Inflow performance relationship for well, IPR
(2) Static bottomhole pressure and fluid gradient of well
(3) Flowline pressure under static and producing conditions
(4) Specific gravities of lift gas, produced gas, oil, and water
(5) Water cut and gas-fluid ratio of produced fluid
(6) Injection gas pressure
(7) Casing and tubing sizes
(8) Depth of producing intervals
(9) Gas lift valve specifications
 (a) Type of valve
 (b) Bellows and port area
(10) Static and flowing temperature gradients

The inflow performance relationship of a well is required for selecting the type of gas lift to be used and for analysing operating gas lift installations. The design of successful continuous flow installations is virtually impossible without the IPR for the well. The location of the top gas lift valve and the spacing between successive valves in a gas lift string is governed by the static bottomhole pressure and static fluid gradient. These 2 factors facilitate the calculation of the static fluid level from which the location of the top gas lift valve can be determined.

The flowline pressure influences the flowing and fallback gradients; consequently, the formation pressure drawdown and production rate are affected. To obtain the maximum production rate with optimum lift efficiency, the flowline pressure should be maintained at a minimum level. If the installation being designed is part of an existing system, the available injection pressure will govern the depth of gas injection and control the formation pressure drawdown and production rate. In the design of an initial installation, the injection gas pressure must be selected on the basis of well performance and economics.

Gas lift valve performance is governed by the type of valve being used. There are 3 basic types of gas lift valves available including those controlled primarily by injection pressure (pressure-operated valves), by fluid pressure in the flowstring (fluid-operated valves), and by differential pressure across the valve (differential valves). Several variations of these basic types of valves are tabulated below:

(1) Pressure-operated valves
 (a) Continuous-flow valves
 (b) Intermittent-flow valves (conventional & pilot-operated)
 (c) Balanced valves
(2) Fluid-operated valves
 (a) Conventional fluid-operated valve
 (b) Intermittent valve
 (c) Balanced valve
(3) Differential valve
 (a) Spring-type valve

Schematic drawings of these gas lift valves are presented in Fig. 1. If gas lift valves with gas-pressured domes are used, static and flowing temperature gradients must be available to enable the prediction of valve performance in the wellbore. Casing and tubing sizes are

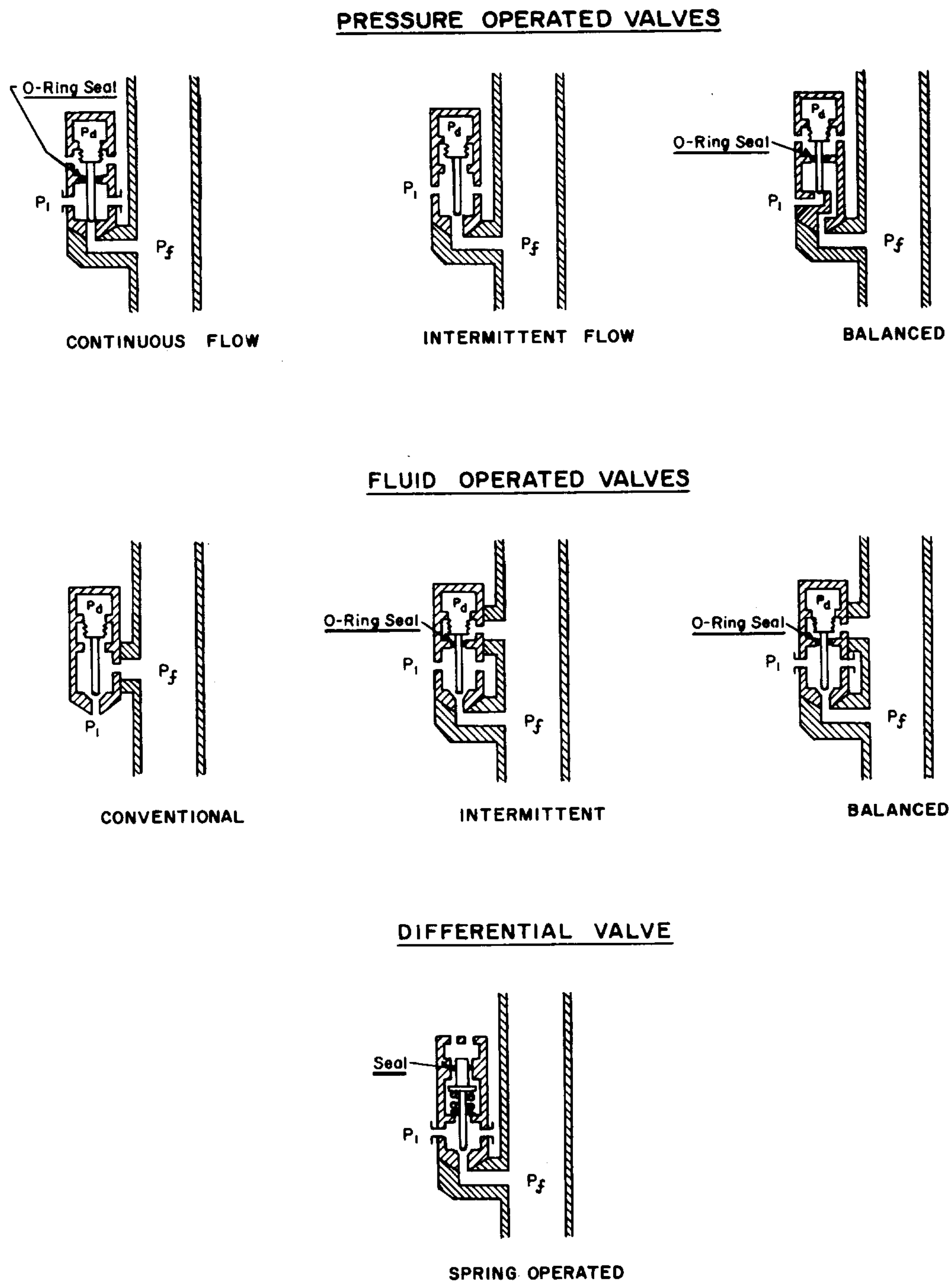


FIG. Nº 1 BASIC TYPES OF GAS LIFT VALVES

required for calculating valve spread requirements and for determining fallback and flowing gradients in the flowstring.

With this basic well and equipment data, it is possible to determine well and equipment performance that will serve as the boundary conditions for the gas lift design. These boundary conditions are discussed in the following paragraphs.

BOUNDARY CONDITIONS
OF WELL & EQUIPMENT PERFORMANCE

To design a gas lift installation, it is necessary to determine the pressure conditions that will occur in the wellbore throughout the kick-off and producing phases of lift. The operating characteristics of the gas lift valves must be established so that valve performance can be balanced with these pressure conditions into a successful design. This can be achieved by describing the pressure conditions in the wellbore and the operating characteristics of the gas lift valves in mathematical terms which can be translated into graphical terms in the form of a pressure-depth diagram.

The pressure conditions which are encountered in the wellbore throughout the kick-off and producing phase are described in the following paragraphs.

Injection Pressure Curve

The injection pressure curve is a function of the surface injection pressure, gas density, and friction in the downward flowing gas column. The injection pressure is denoted by Line A in Fig. 2 and can be calculated using Equation 1. Symbol definitions are presented in Table 1.

$$P_i = P_{is} + G_g L - F \qquad \text{Equation 1}$$

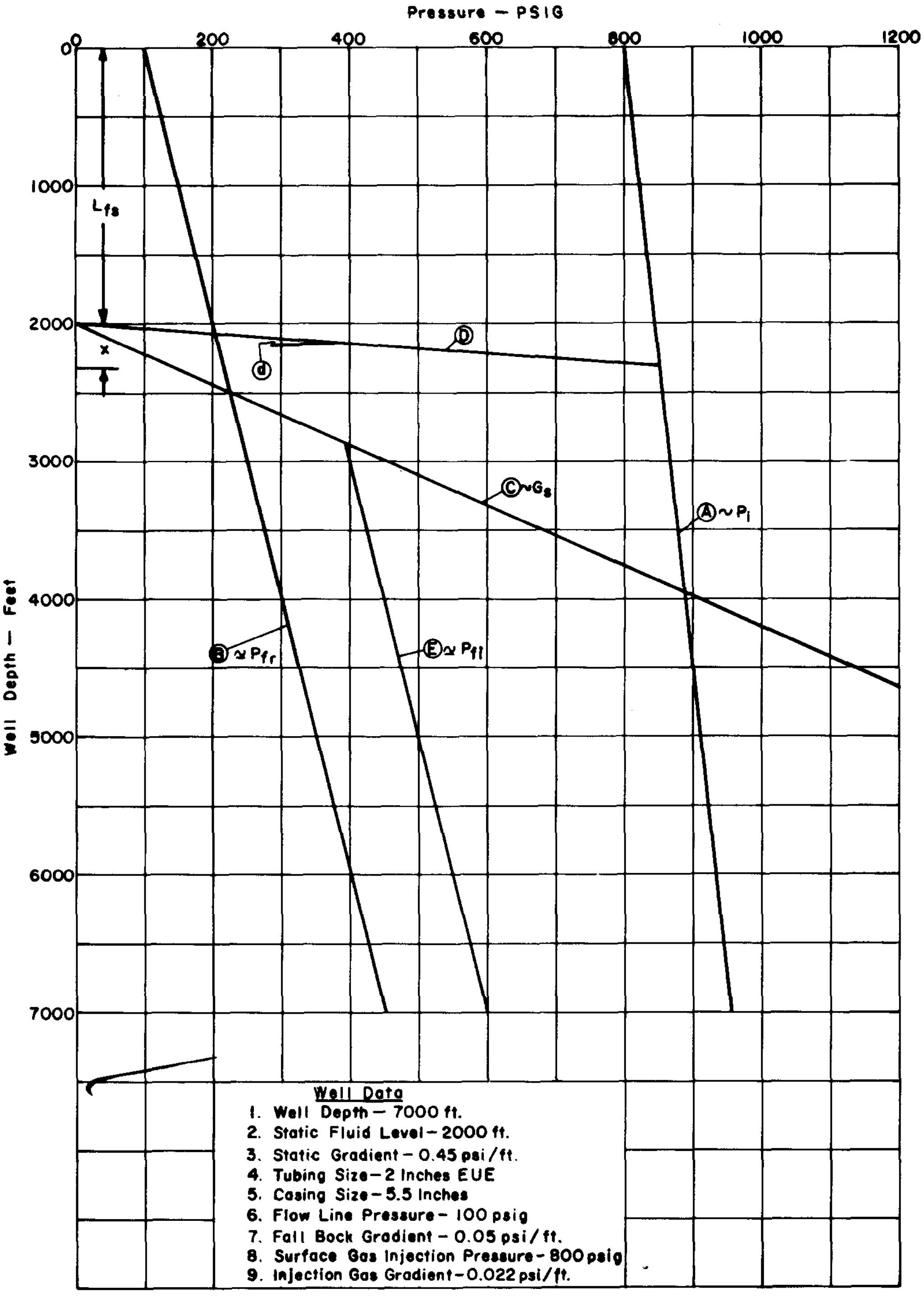


FIG. Nº 2 BOUNDARY CONDITIONS — GAS LIFT DESIGN

Symbol	Description	Symbol	Description
A_b	Bellows area - sq. in.	P_{fc}	Flowstring pressure to close valve - psi
A_p	Port area - sq in.	P_{fo}	Flowstring pressure to open valve - psi
A_f	Flowstring area - sq in.	P_{fr}	Fallback pressure - psi
A_g	Gas passage area - sq in.	P_{frs}	Surface flowline pressure - psi
C_t	Temperature effect	P_n	Nominal pressure setting of valve - psi
F	Friction in flowing gas column - psi	P_{dn}	Dome pressure of valve SC - psi
G_f	Fallback gradient - psi/ft	P_{nc}	Closing pressure of valve in test block - psi
G_g	Lift gas gradient - psi/ft	P_d	Dome pressure of valve operating conditions - psi
G	Produced fluid gradient - psi/ft	P_o	Opening pressure of valve in test block - psi
G_s	Static fluid gradient - psi/ft	P_{fi}	Feed-in pressure - psi
IPR	Inflow performance relationship	R_b	Bellows factor
L	Depth - ft	R_p	Port factor
L_{fs}	Static fluid depth - ft	P_x	Pressure exerted on bellows or port area - psi
P_i	Injection pressure - psi	P_y	Pressure exerted on bellows or port area - psi
P_{io}	Injection pressure when valve opens - psi	s	Spring tension - psi
P_{ic}	Injection pressure when valve closes - psi	S	Spring force - lbs
P_{is}	Surface injection pressure - psi	T_{sc}	Temperature SC - °F
P_{ior}	Injection pressure when valve opens, reduced - psi	T_{oc}	Temperature operating conditions - °F
		x	Fluid level depression - ft
P_f	Flowstring pressure - psi	Z	Surface slug size - ft

TABLE NO. 1 - LIST OF SYMBOLS

Fallback Pressure Curve

The slippage of fluid as the liquid slug rises in the flowstring imposes a back pressure on the formation. This slippage or "fallback" is a linear function with depth related to slug and bubble velocity as set forth in an article entitled "An Analytical Concept of the Static and Dynamic Parameters of Intermittent Gas Lift" in the March, 1963, issue of the Journal of Petroleum Technology. Therefore, the fallback pressure curve which is shown as Line B in Fig. 2 can be calculated using the following equation:

$$P_{fr} = P_{frs} + G_f L \qquad \text{Equation 2}$$

The fallback gradient will range from 0.01 to 0.20 psi per ft and should be determined for local conditions using bottomhole-pressure surveys.

Static Fluid Level and Fluid Gradient

These 2 factors control the location of the top gas lift valve and the spacing between successive valves. The location of the top valve in relation to the static fluid level is controlled by the amount of fluid that can be transferred from the gas passage area to the flowstring area and the height of fluid column that the injection gas pressure can support. This is shown graphically in Fig. 2 where the depth of the top valve

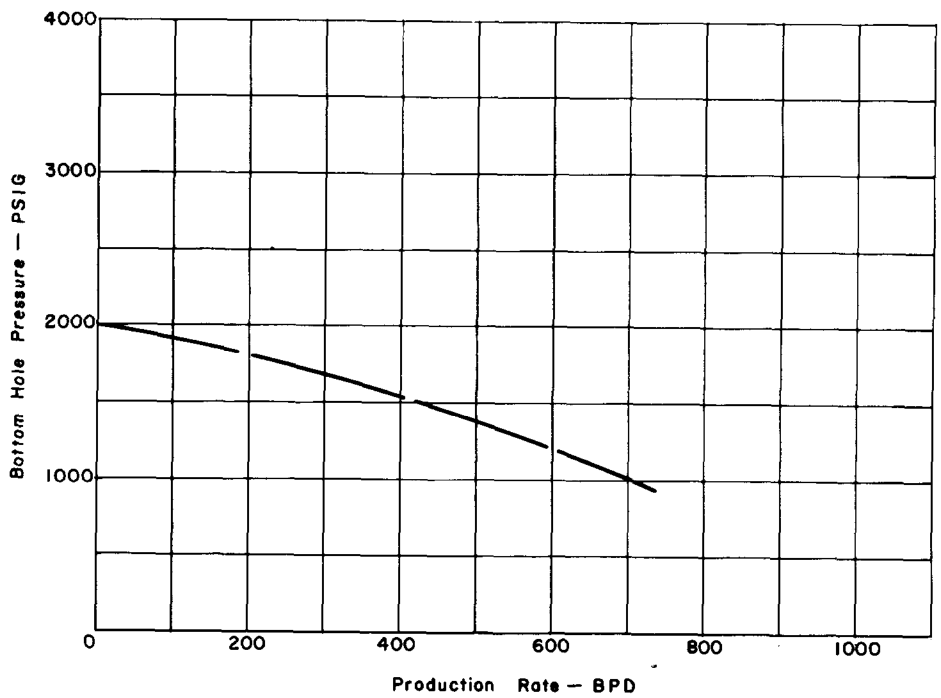


FIG. № 3 INFLOW PERFORMANCE RELATIONSHIP is determined by the intersection of Line D of slope (d) with the injection pressure gradient, Line A. The slope of Line D can be calculated using Equation 3.

$$\tan\alpha = d = \frac{A_f \, L_{fs} \, (\text{Graph Scale Factor})}{A_g \, (1 + A_f/A_g) \, L_{fs} \, G_S + P_{frs}} \qquad \text{Equation 3}$$

Where Graph Scale Factor

$$\frac{\text{Graph Divisions per ft}}{\text{Graph Divisions per psi}}$$

The spacing of valves below the top gas lift valve is controlled by the height of the fluid column that can be

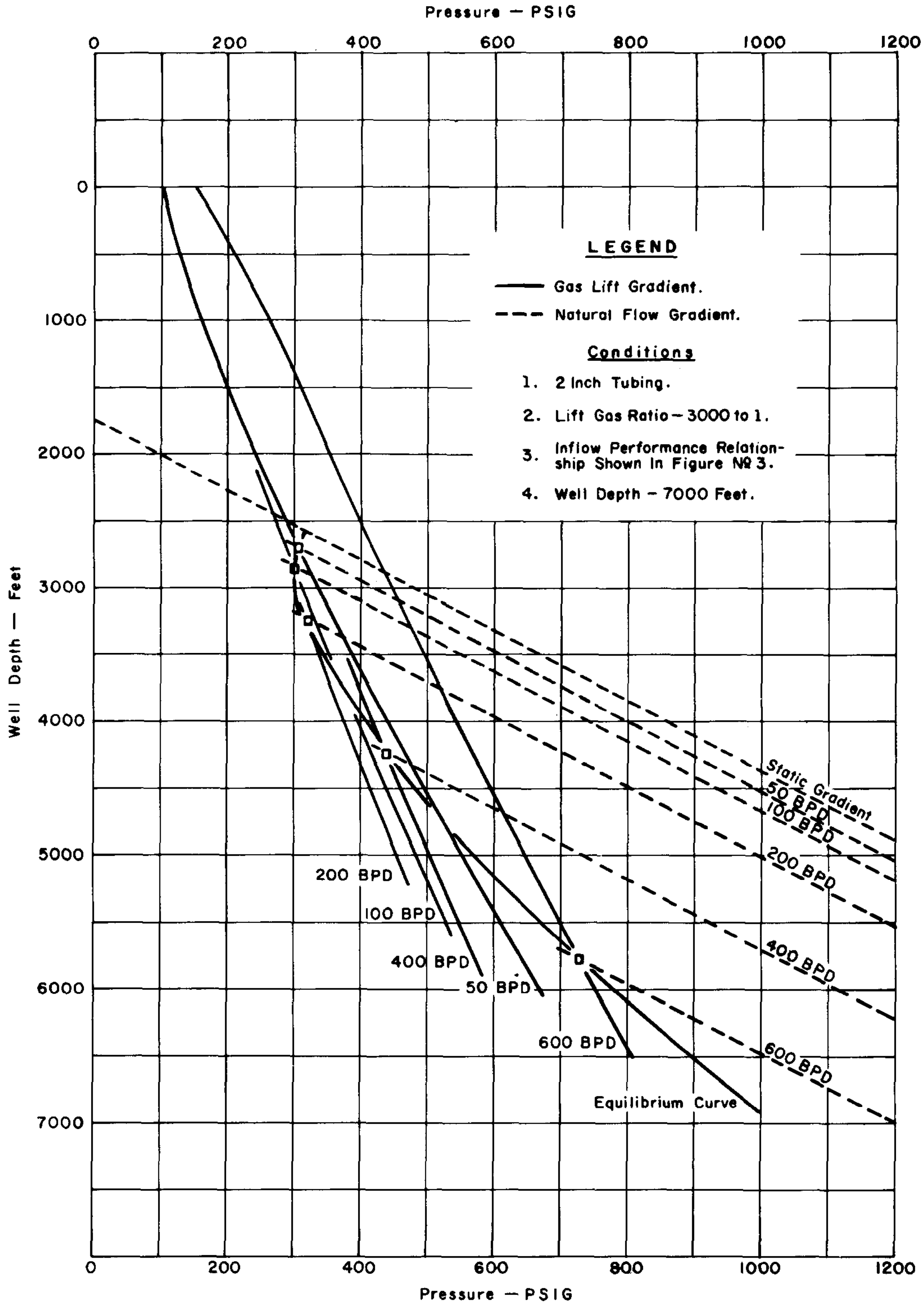


FIG. Nº 4 EQUILIBRIUM CURVE

supported by the injection pressure. Thus, the spacing between successive valves can be determined using the static gradient shown as Line C in Fig. 2.

Feed-in Pressure Curve

When a well is produced by intermittent flow gas lift, the influx of formation fluid into the wellbore must be considered as a boundary condition. This fluid influx, known as the feed-in pressure curve, is an empirical relationship based on desired surface slug size and denoted by Line E in Fig. 2. This curve is assumed to have a slope equal to the fallback gradient but displaced to the right of the fallback curve by an amount equal to the surface slug size. Equation 4 can be used to calculate the feed-in pressure.

$$P_{fi} = P_{frs} + G_f L + G_i Z \qquad \text{Equation 4}$$

The feed-in curve is bounded by the static fluid gradient, since no formation fluid is produced when the pressure in the wellbore exceeds the static pressure.

Equilibrium Curve

In the design of a continuous flow installation, a flowing gradient must be established that describes the pressure conditions in the flowstring from commencement of continuous flow until a stabilized maximum flow rate is achieved. This gradient, which is required to determine the maximum depth of gas injection and the maximum production rate, is obtained by balancing the natural flow and gas lift gradients in the flowstring for several production rates. The resulting gradient, known as the equilibrium curve, is established by connecting the intersection points of the 2 flowing gradients as shown in Fig. 4.

The natural flow gradients are governed by the IPR of the well; whereas, the gas lift gradients are controlled by the amount of gas available for injection into the flowstring. The maximum depth of gas injection is determined by the intersection of the equilibrium curve and the injection pressure curve.

Flowing Gradient

In order to establish the flowing gradient, the maximum production rate, gas liquid ratio and flowline pressure must be known. The maximum production rate can be determined by constructing a natural flow gradient from the intersection point of the equilibrium and injection pressure curves to a horizontal line denoting the depth of producing perforations. Once this pressure is established, the maximum production rate can be determined from the IPR of the well. Once the production rate, flowline pressure, and quantity of injection gas have been established, the flowing gradient can be obtained from one of several published sets of gradient curves.

To predict the performance of the basic types of gas lift valves for all operating conditions, general equations describing valve characteristics must be established. The characteristics that can be used to describe and predict valve performances include:

(1) Valve area factors
(2) Tension of valve spring
(3) Nominal pressure or test block pressure setting of valve
(4) Valve spread
(5) Temperature effect on valve
(6) Opening and closing equations of valves

Valve Area Factors

Valve performance is influenced by pressure acting over the bellows and port areas of the valve. To simplify equations which describe valve performance, relationships between the bellows and port areas are established and expressed in the following terms:

$$\text{Bellows factor} = R_b = \frac{A_b}{A_b - A_p} \qquad \text{Equation 5}$$

$$\text{Port factor} = R_p = \frac{A_p}{A_b - A_p} \qquad \text{Equation 6}$$

$$R_b = 1 + R_p \qquad \text{Equation 7}$$

Tension of Valve Spring

Valves can be equipped with springs to supplement the bellows pressure as a closing force and alter the operating characteristics of the valve. The tension of such springs is expressed in psi acting over the area, $A_b - A_p$. However, some valves are manufactured with the spring providing the only closing force. In this case, the spring force is expressed in force acting over the bellows area.

Nominal Pressure or Test Block Pressure Setting of Valve

These 2 factors are the constant reference points that describe the operating characteristics of gas lift valves. The nominal pressure setting of a valve (P_n) is used to describe the operating characteristics of a valve equipped with a gas pressured dome and is defined as the pressure at standard temperature conditions required to open the valve when zero pressure is exerted on the port area (A_p). Thus, the nominal pressure setting of a valve can be described by summing forces when the valve opens.

$$P_o (A_b - A_p) + P_f A_p = P_{dn} A_b + s(A_b - A_p)$$

By definition $P_o = P_n$ when $P_f = O$; thus,

$$P_n = P_{dn} R_b + s \qquad \text{Equation 8}$$

The test block closing pressure (P_{nc}) is used to describe the operating characteristics of a valve utilizing only spring force to open and close the valve and is defined as the pressure exerted over the bellows area of the valve at the moment the valve closes. By summing the forces existing when the valve closes, the test block closing pressure of the valve is expressed as follows:

$$P_o (A_b - A_p) + P_f A_p = P_{dn} A_b + S$$

By definition, $P_o = P_f = P_{nc}$, $P_{dn} = O$, thus

$$P_{nc} A_b = S \qquad \text{Equation 9}$$

Valve Spread

The difference between the opening and closing injection pressures of a valve is defined as valve spread, thus,

$$\text{Valve spread} = P_{io} - P_{ic} \qquad \text{Equation 10}$$

Temperature Effect on Valve

The operating characteristics of valves equipped with gas charged bellows are influenced by the expansion and contraction of gas in the bellows when the valve is exposed to wellbore temperatures. The static and flowing temperature gradients of a well must be available so that the bellows pressure of gas lift valves can be corrected for temperature effect using Boyle's Law. The effect of temperature changes on valve performance can be calculated with the following equations:

$$P_d = \frac{(460 + T_{oc})\, P_{dn}}{520}$$

$$C_t = \frac{460 + T_{oc}}{520} \qquad \text{Equation 11}$$

$$P_d = C_t\, P_{dn} \qquad \text{Equation 12}$$

Valve Opening and Closing Equations

The opening and closing equations for a valve summarize the forces that must exist for a valve to function, thus facilitating the prediction of valve performance. The general equation which can be used to derive opening and closing equations for all basic types of valves is presented below:

$$P_x\,(A_b - A_p) + P_y\,A_p = P_d\,A_b + s(A_b - A_p)$$

Dividing the equation by $A_b - A_p$, then

$$P_x + P_y\,R_p = P_d\,R_b + s$$

Substituting Equations 8 & 12, then

$$P_x + P_y\,R_p \rightleftharpoons C_t\,P_n - s(C_t - 1) \qquad \text{Equation 13}$$

Equation 13 can be used to express the opening and closing equations for any gas lift valve where P_x and P_y denote either injection or flowstring pressure. The opening and closing equations for the basic types of valves are presented in Table 2.

Type of Valve	Opening Equation	Closing Equation
1. Pressure Operated Valves		
a. Continuous Flow w/Chokes	$P_{io} + P_{fo}R_p \geq C_tP_n - s(C_t - 1)$	$P_{ic} + P_{fc}R_p \leq C_tP_n - s(C_t - 1)$
b. Intermittent Flow	$P_{io} + P_{fo}R_p \geq C_tP_n - s(C_t - 1)$	$P_{ic}R_b \leq C_tP_n - s(C_t - 1)$
c. Balanced	$P_{io} \geq C_tP_n$	$P_{ic} \leq C_tP_n$
2. Fluid Operated Valves		
a. Conventional	$P_{fo} + P_{io}R_p \geq C_tP_n - s(C_t - 1)$	$P_{fc}R_b \leq C_tP_n - s(C_t - 1)$
b. Intermittent Flow	$P_{fo}R_b \geq C_tP_n - s(C_t - 1)$	$P_{fc} + P_{ic}R_p \leq C_tP_n - s(C_t - 1)$
c. Balance	$P_{fo} \geq C_tP_n$	$P_{fc} \leq C_tP_n$
3. Differential Valves		
a. Spring actuated	$P_{io} - P_{fo} \leq s$	$P_{ic} - P_{fc} \geq s$

TABLE NO. 2 - GAS LIFT VALVE OPENING & CLOSING EQUATIONS

With the boundary conditions that describe well and gas lift valve performance established and set forth in graphical form, it is possible to proceed with the calculation of valve spacing and setting pressures for an operating installation.

GAS LIFT VALVE
SPACING AND SETTING PRESSURES

To assure a successful gas lift design, it is advisable to review the objectives of the gas lift string below commencing with the calculation of valve spacing and setting pressures. The objectives of a gas lift string are: (1) the automatic operation of the valves throughout the kick-off and producing phases of lift, and; (2) the deepest injection of gas and, consequently, the greatest production rate with the available gas pressure. To fulfill the objectives of the gas lift string, several factors must be fulfilled to insure successful valve operation. These factors include:

(1) When a gas lift valve becomes exposed to injection gas, it must open.

(2) Although the deepest valve must open when exposed to lift gas, all other exposed valves must remain closed.
(3) The deepest uncovered valve must stay open or be capable of reopening if it closes.
(4) The maximum injection gas pressure must be utilized unless the gas lift valves will not operate under these pressure conditions.
(5) The gas lift valves must be capable of passing sufficient gas to maintain efficient lift.

With these conditions in mind, the design of a gas lift installation can be carried to completion. Although the procedure for determining valve spacing and setting pressures for continuous and intermittent flow installations is similar, each design will be discussed separately, since some of the boundary conditions that govern the designs are different.

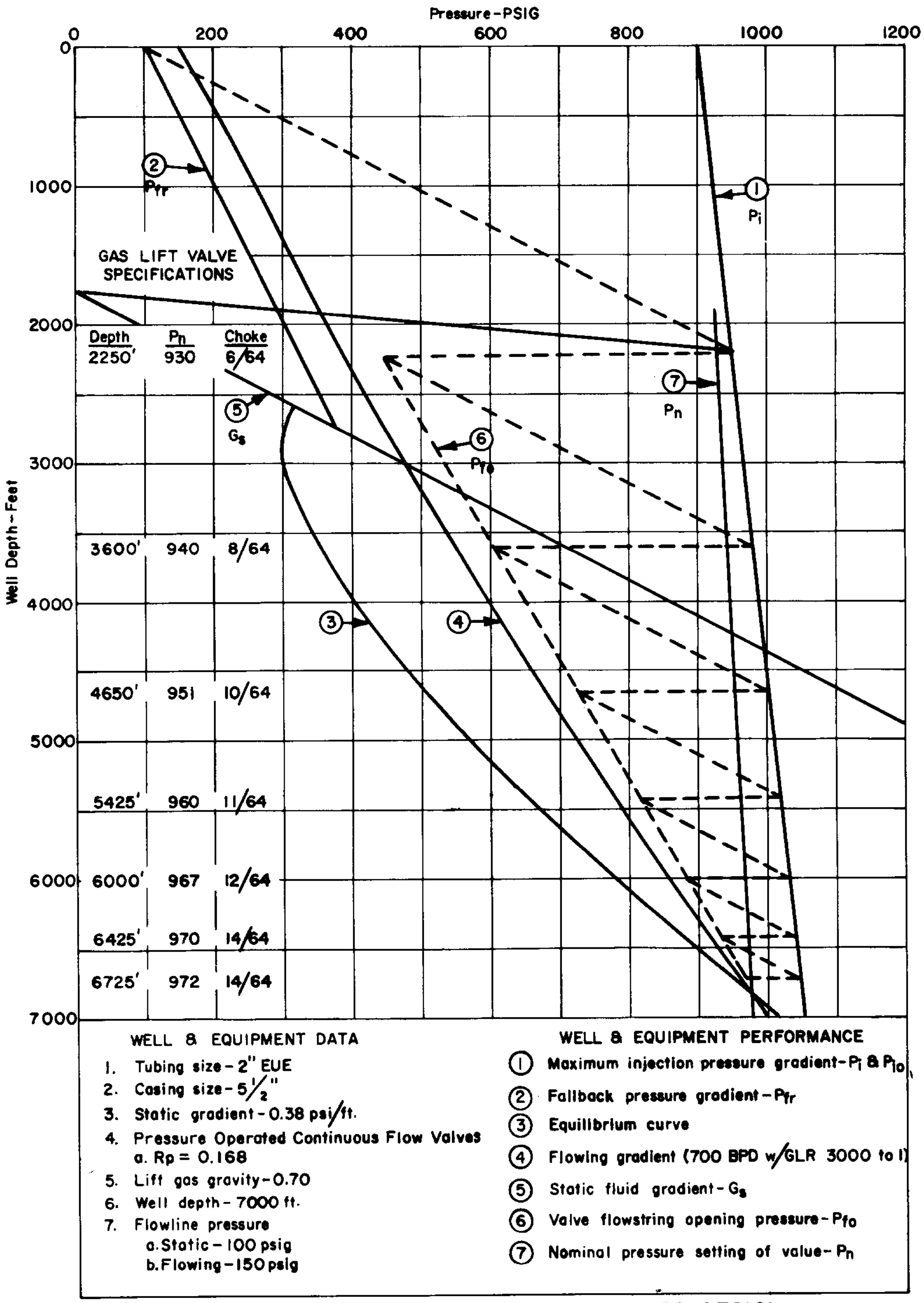


FIG. No 5 CONTINUOUS FLOW GAS LIFT DESIGN USING PRESSURE OPERATED CONTINUOUS FLOW VALVES

Continuous Flow Gas Lift Design

The first step in the design of a continuous flow installation is to establish an equilibrium curve so that the maximum injection depth and production rate can be determined. With these 2 factors available, the boundary conditions which describe well performance can be set forth in graphical form, as shown in Fig. 5. These boundary conditions include:

(1) Gas injection pressure curve - P_i versus L
(2) Static fluid level and static fluid gradient - G_s
(3) Fallback pressure curve - P_{fr} versus L
(4) Equilibrium curve and flowing gradient

Once the well performance conditions have been established, the type of gas lift valve must be selected so that valve performance can be determined. Any of the basic types of valves can be used in continuous flow; therefore, valve selection is dependent on valve availability, cost, and preference of the designer. For the purpose of this discussion, it is assumed that pressure-operated continuous-flow valves are used and that maximum valve spacing is desired.

First, it is necessary to determine the pressure conditions to which the valves will be subjected. Since maximum valve spacing is desired, a maximum opening injection pressure (P_{io}) and minimum opening flowstring pressure (P_{fo}) must be selected. This can be achieved by setting the opening injection pressure of the valve (P_{io}) equal to the injection pressure (P_i), and flowing gradient equal to the flowstring opening pressure of the valve (P_{fo}). Because flowing gradients are difficult to predict, a pseudo-flowstring opening pressure, as shown in Fig. 5, must be selected to insure that the valves will open and close at the proper times. With the opening injection and flowstring pressure gradients established, it is possible to calculate the nominal pressure setting gradient for the valves (P_n) using the valve opening equation for pressure operated continuous flow valves.

With the boundary conditions for both well and equipment performance set forth in the pressure-depth diagram, the valve spacing and nominal setting pressures can be determined graphically. The depth of the top valve can be determined from the static fluid level, as previously discussed, with the depth of the lower valves determined by constructing static or natural flow gradients from the flowstring opening pressure curve to the injection pressure curve, as shown in Fig. 5. The intersection of the static or natural flow gradient with the injection pressure curve denotes the depth of the next lower valve, and the intersection of this depth coordinate with the P_n curve supplies the nominal pressure setting for this valve. This procedure is followed in spacing successive gas lift valves until there is insufficient pressure differential between the flowstring and injection pressure gradients (P_{fo} & P_{io}) to allow the valves to pass sufficient gas to sustain lift.

If choke equipped valves are used, the gas passing requirements and required choke size for each valve can be calculated by determining the production rate which the well could sustain if it were being lifted from the valve in question. This production rate can be determined by using the equilibrium curve and IPR of the well. With the required gas liquid ratio and pressure differential across the valve available, the required choke size can be obtained from choke performance charts available from most gas lift valve manufacturers.

Although this design example was based on the use of continuous flow valves equipped with chokes, any gas lift valve can be successfully applied to continuous flow gas lift. However, it is necessary to accurately describe the operating performance of a gas lift valve for the pressure conditions existing within the wellbore so that the valves can be spaced to operate within these boundary conditions.

Intermittent Flow Gas Lift

The design procedure used in intermittent flow designs is essentially the same as used for continuous flow designs; however, the pressure boundary conditions existing within the wellbore are different. Instead of using the equilibrium curve to establish the maximum gas injection depth and well productivity, the feed-in pressure curve is used to denote well productivity. The slope and displacement of the feed-in pressure curve are empirical in nature and are influenced by the desired surface slug size, lift efficiency, and required pressure differential existing across the valve when the valve opens.

Although any type of valve can be used in an intermittent flow installation, a large port valve is generally preferred because of its ability to pass large instantaneous rates of gas with a small pressure drop. This factor helps achieve a high liquid slug velocity; consequently, reducing fallback and improving lift efficiency.

Assuming that an installation is being designed for maximum spacing using pressure operated intermittent valves, the following design procedure should be used. First, well performance must be established by determining the following boundary condition:

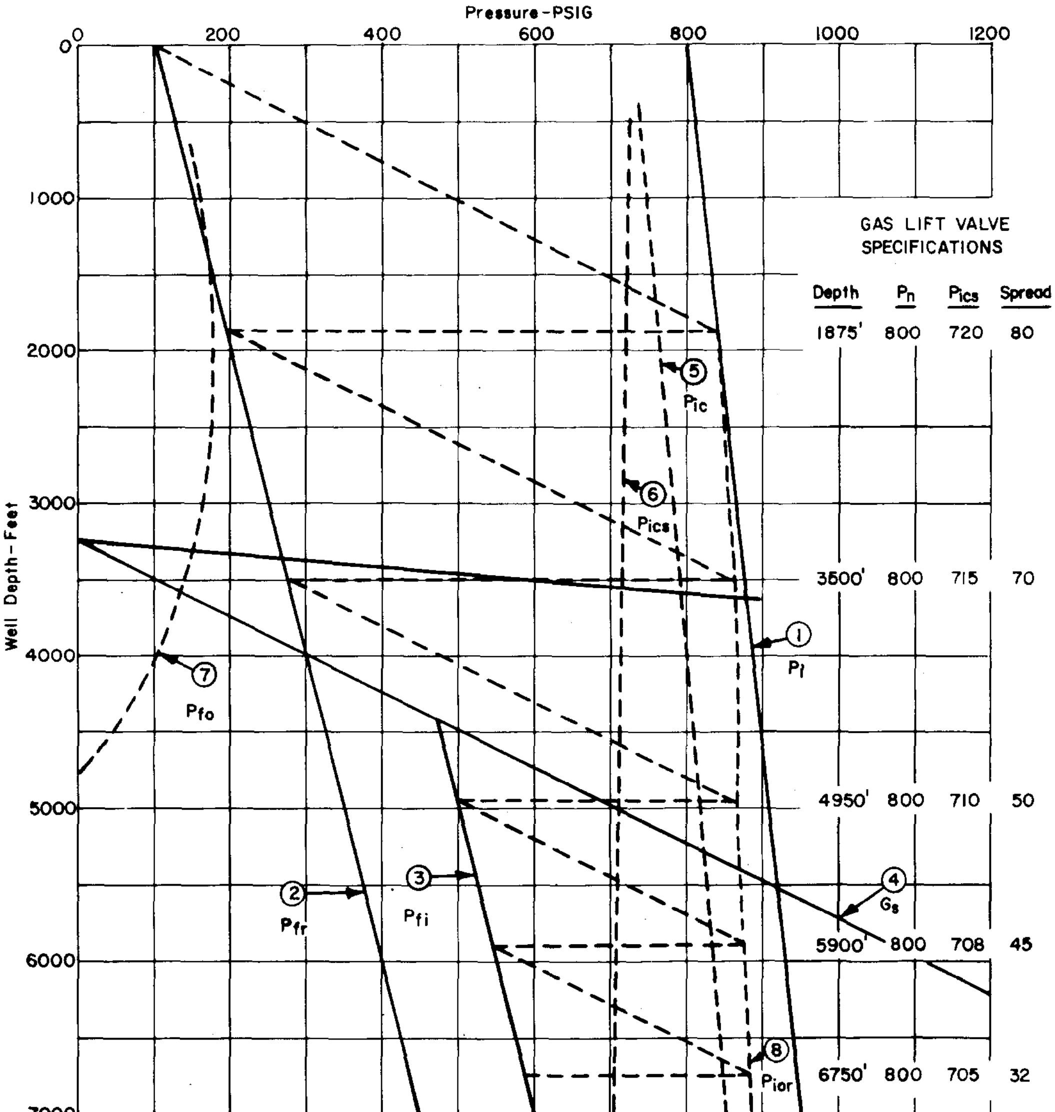
(1) Injection pressure curve - P_i versus L
(2) Fallback pressure curve - P_{fr} versus L
(3) Feed-in pressure curve - P_{fi} versus L
(4) Static fluid gradient - G_s

Next, valve performance must be established. When intermittent flow valves are used, the surface closing injection pressure of the valves (P_{ics}) must decrease with depth to insure the closure of upper valves in the string. To fulfill this requirement, the slope of the closing injection pressure versus depth curve (P_{ic} versus L) must not exceed the slope of the injection gas gradient (G_g). A design example is presented in Fig. 6 that is based on the use of valves which have a constant nominal setting pressure.

Once the nominal setting pressure of the valves has been established, the opening flowstring pressure (P_{fo}), closing injection pressure (P_{ic}) and surface closing injection pressure (P_{ics}) for the valves must be calculated for the maximum opening injection pressure (P_{io}). Valve spacing is governed by the opening flowstring and injection pressure; however, as is evident in Fig. 6, the opening flowstring pressure is exceeded by the fallback and feed-in pressure. If the spacing were based on the opening flowing pressure curve (P_{fo} versus L), the upper valves would not close; therefore, valve spacing is governed by the maximum flowstring pressure which, in this case, is the fallback and feed-in pressure curves. When the actual flowstring pressure is greater than the calculated opening flowstring pressure, a reduced opening injection pressure (P_{ior}) must be calculated to insure proper valve operation and spacing. The spacing between valves is determined by constructing a static or natural flow gradient between the controlling pressure curves. The surface closing injection pressure of each valve can be determined by the intersection of the depth coordinate of the valve with the surface closing injection pressure curve (P_{ics}).

ANALYSIS OF GAS LIFT INSTALLATIONS

The analysis of existing installations can be achieved using essentially the same techniques as employed in the design of initial installations. First, it is necessary to assemble all the well and equipment



WELL & EQUIPMENT DATA

1. Tbg. size-2" EUE
2. Csg. size-5½"
3. Static gradient-0.40 psi/ft.
4. Pressure intermittent valves
   a. Pn = 800
   b. Rp = 0.126
5. Lift gas gravity-0.70
6. Surface slug size-1.5 bbls.
7. Well depth-7000 ft.
8. Flowline pressure-100 psig

WELL & EQUIPMENT PERFORMANCE

1. Maximum injection pressure gradient-P_i
2. Fallback pressure gradient-P_{fr}
3. Feed-in pressure-gradient-P_{fi}
4. Static fluid gradient-G_s
5. Valve closing pressure-P_{ic}
6. Valve surface closing pressure-P_{ics}
7. Valve opening pressure-P_{fo} for $P_{io} = P_i$
8. Reduced valve opening pressure-P_{ior}

FIG. Nº 6 INTERMITTENT FLOW GAS LIFT DESIGN USING PRESSURE OPERATED INTERMITTENT FLOW VALVES information, and the boundary conditions that govern the operation of the installation must be established and set forth in a pressure-depth diagram. The pressure conditions in the flowstring are the most difficult to predict; therefore, they should be measured with a pressure "bomb" before an analysis is attempted.

By incorporating the measured pressures in the flowstring with the boundary conditions describing injection pressure and gas lift valve performance into a pressure-depth diagram, the reason for malfunction of the installation should be evident. Unless the gas lift valves have failed physically, operational problems are usually traced to erroneous prediction of boundary conditions. The analysis of the design using the pressure-depth diagram will show if the valve spacing is correct and if the gas lift valves are opening and closing at the proper time.

CONCLUSION

This basic approach to gas lift design incorporating well and equipment performance into a pressure-depth diagram provides a design method that can be used in the design and analysis of any gas lift installation. The designer is provided with a complete graphical picture of the pressure conditions existing in the wellbore throughout the "kick-off" and producing phases of lift, resulting in a better understanding of gas lift operation and design.

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