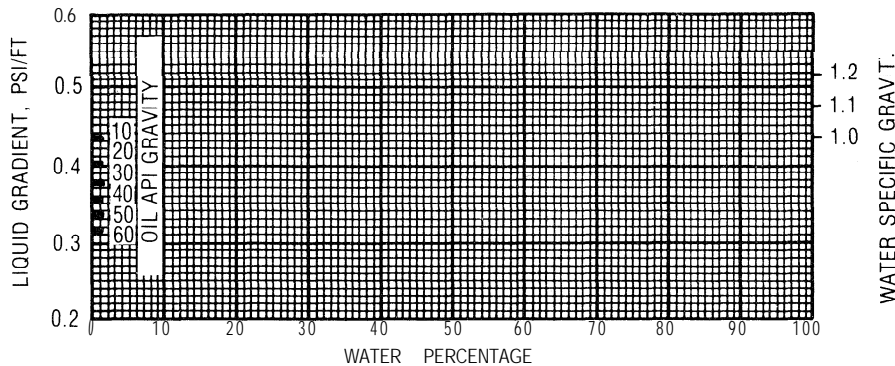


Acoustic Determination Of Bottomhole Pressures In Gas Lift Wells

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- DIRECTIONS:**
1. CONNECT OIL API GRAVITY AND WATER SPECIFIC GRAVITY WITH A STRAIGHT LINE.
 2. READ LIQUID GRADIENT AS A FUNCTION OF WATER PERCENTAGE.

Fig. 1. Liquid gradient.

“TABLE 1. Liquid Gradient.

API Gravity Degrees	Fluid Gradient Lb/Sq In/Ft	Specific Gravity
80	0.290	
75	0.297	
70	0.304	
65	0.312	
60	0.320	
55	0.329	
50	0.338	
48	0.342	
46	0.345	
44	0.349	
42	0.353	
40	0.358	
38	0.362	
36	0.366	
34	0.370	
32	0.375	
30	0.380	
28	0.384	
26	0.389	
24	0.394	
22	0.399	
20	0.405	
18	0.410	
15	0.419	
12	0.427	
fresh water	0.433	1 .000
salt water	0.477	1.100
range	0.500	1.154
	0.520	1.200

1 psi is approximately 2 ft of water
1 psi is approximately 3 ft of oil

Information about producing and static bottomhole pressures in gas lift wells is useful in designing and operating gas lift installations and measuring over all efficiency.

The static bottomhole pressure can be accurately measured in the normal gas lift well using an acoustic liquid level instrument. The normal gas lift well is assumed to be a continuous flow well in which a packer is placed immediately above the formation at the bottom of the tubing. The inside of the tubing is open from the bottom to the top of the well. Gas lift valves placed in or on the tubing are either casing pressure operated or tubing fluid pressure operated.

The static bottomhole pressure is easy to measure accurately in a gas lift well of this type. Simply close in the tubing and gas injection line at the surface and allow the well to stabilize. Then determine the liquid level in the tubing using the acoustic liquid level instrument. The surface tubing pressure reading should be made at time of test. The static bottomhole pressure is the summation of the surface tubing pressure plus the gas column pressure plus the pressure exerted by the column of liquid above the formation. The liquid above the formation consists of water and oil in the same ratio that is produced by the well. In a well which has tubing extending to the formation, the average gradient in the column can be determined by using Fig. 1. The hydrostatic pressure of the liquid column is determined by multiplying the height of the liquid column by the average gradient of the liquid column.

Fig. 2 gives the pressure exerted by the gas column. If the packer is set a considerable distance above the formation, the total volume of liquid above the formation must be calculated. The percentages of oil and **water produced** by the well times the volume of liquid above the formation indicates the volume of water and the volume of oil. Height of the water column is determined by dividing the water volume by the casing volume per ft. Then the heights of water column and oil **column are** known. The liquid column gradients are given in Table 1.

Bottomhole Pressure

Gas lift valves in a casing pressure actuated system operate as follows: The gas lift valve opens when it is exposed to a casing annulus pressure in excess of a pre-set value. The valves are arranged in the tubing string so that the highest pressure operating valve is at the top, and the operating pressure of each valve decreases with depth. Gas injection in the casing annulus lightens the load in the tubing above the operating valve. All valves below this point are open and permit liquid or gas to pass into the tubing if the tubing pressure is less than the casing annulus pressure. The liquid level in the casing annulus will be depressed until the pressure in the casing annulus at the bottom valve is equal to the pressure in the tubing at the bottom valve, or until the bottom gas lift valve is exposed to gas. Check valves prohibit back flow from the tubing into the annulus. As the liquid bleeds from

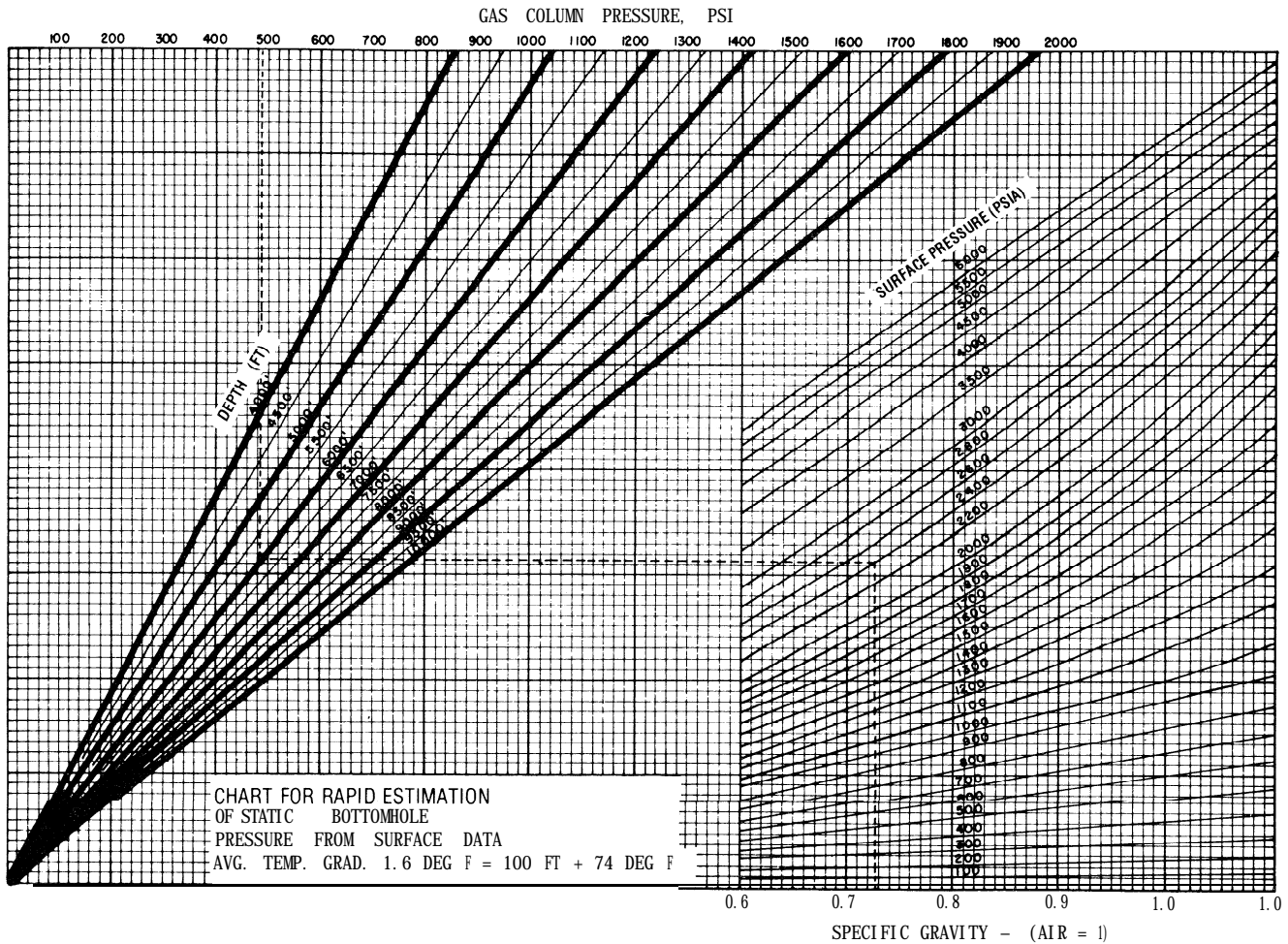


Fig. 2. Gas column pressure.

EXAMPLE:
THE GAS COLUMN PRESSURE OF 0.727

the annulus into the tubing and exposes a gas lift valve to gas, the gas will pass into the tubing if the tubing pressure is less than the casing annulus pressure. A gas lift valve above this point will close if the pressure in the casing annulus is reduced below its pre-set operating value by the loss of gas to the lower valve. The bottom valve is always open unless it is the injection valve and sufficient gas is not available to maintain a pressure in excess of its operating pressure, then it will throttle or intermit. If the bottom valve is exposed, gas injection through it has occurred, and the bottom valve may still be the gas injection valve.

A tubing operated gas lift valve system operates as follows: The gas lift valve will open if the pressure in the tubing exceeds a pre-set value. The lowest operating pressure valve is set near the top of the tubing, and the operating pressure settings increase with depth. When gas injection into the casing annulus starts, gas is injected into the valve nearest the top which has sufficient fluid pressure in the tubing to open the valve. The bottom valves will be open and permit liquid to pass from the casing annulus into the tubing.

Gas valves will become exposed as the liquid level drops, and gas injection will begin if the casing annulus pressure exceeds the tubing pressure and sufficient tubing pressure exists to open the gas lift valve. Upper gas lift valves usually will close since injection at the lower depth decreases the tubing pressures and closes the upper valve. In a normal installation, if liquid exists above the bottom valve, the bottom valve will be open and the pressure in the tubing will be equal to the pressure in the casing annulus. If the liquid is below the bottom gas lift valve, gas injection has and may still exist at the bottom valve. If the valve is throttling, the pressure drop across the valve is not known. When a valve is throttling, the pressure in the tubing always is less than in the casing annulus.

Note the following facts about gas lift systems which have liquid above the lowest valve.

- 1 When the system is first put in operation and the well is permitted to stabilize, the pressure in the casing annulus opposite the bottom valve is the same as the pressure in the tubing because the bottom valve is open.

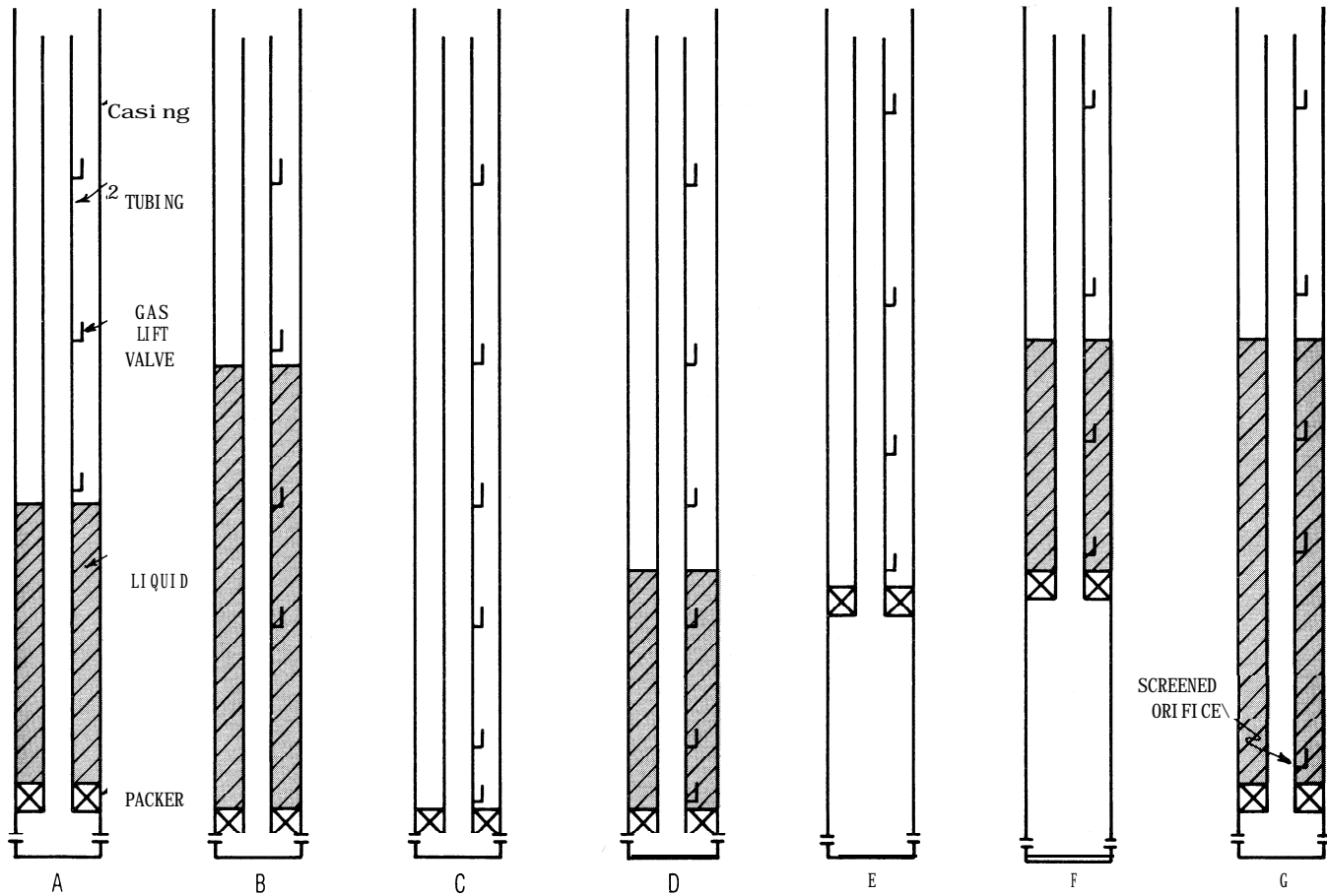


Fig. 3. Types of gas injection systems.

- 1 The casing annulus pressure opposite the lowest valve in a well which has been in operation for a long period of time indicates the lowest pressure which has existed in the tubing since last equalization of tubing and casing annulus pressures.
- 1 If the tubing pressure opposite the lowest gas lift valve is suspected to have been lower at some time since the last tubing and casing annulus equalization, liquid could be added to the casing annulus until the liquid level ceases to rise. Then the current pressure in the tubing opposite the bottom gas lift valve would be the same as the casing annulus pressure.
- 1 The liquid level in the casing annulus could be and probably is several gas lift valves lower than the point of gas injection because of the difference in the gradient of the gas free liquid in the casing annulus above the bottom valve and the gradient of the gaseous fluid column which exists in the tubing between the gas injection valve and the bottom valve. If the pressures in the tubing and the casing annulus at the bottom valve are equal, then the pressure drop in the tubing from the bottom valve to the gas injection valve plus the pressure drop across the gas injection valve must be equal to the liquid column pressure in the casing annulus above the bottom valve plus the gas column pressure

between the casing annulus liquid level and the gas injection valve. Since the casing annulus liquid is gas bubble free, the height of the casing annulus liquid will be small compared to the distance to the gas injection valve in a gaseous well. The following equation offers approximate numbers.

$$D \times G_F + P_{GLV} = H_{LL} \times G_{LL} + \Delta P_{GC}$$

D = distance between bottom gas lift valve and gas injection valve, ft

G_F = gradient of the fluid in the tubing between the bottom valve and the gas injection valve, psi/ft

P_{GLV} = pressure drop across gas injection valve, psi

H_{LL} = height of the liquid level above the bottom gas lift valve.

G_{LL} = gradient of the liquid in the casing annulus above the bottom valve, psi ft.

ΔP_{GC} = the difference in the gas column pressure at the liquid level and the gas injection valve, psi (can be found from Fig. 2).

Further, note the following facts about gas lift systems in which the bottom valve is exposed to gas:

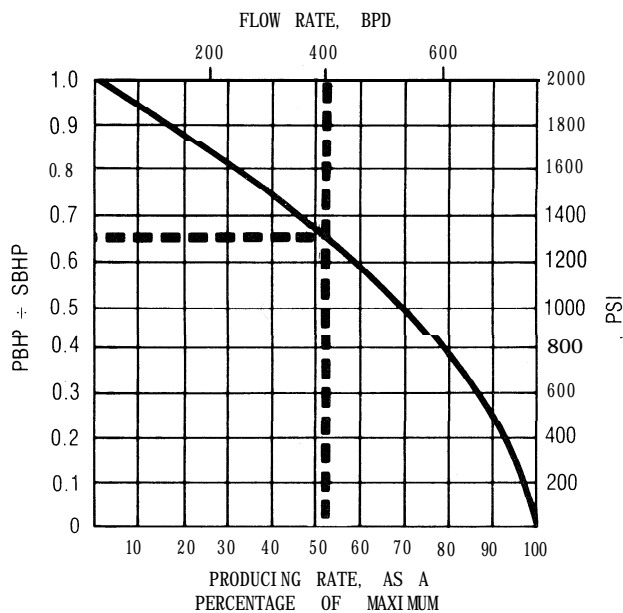


Fig. 4. Flow rate and producing rate efficiency as a function of SBHP and PBHP.

- The bottom valve has been and may still be the gas injection valve. To verify that the bottom valve is still the gas injection valve, add liquid to the casing annulus. If the bottom valve again becomes exposed, the casing annulus pressure exceeds the tubing pressure and gas injection will occur.
- The pressure in the tubing at the bottom valve is the pressure in the casing annulus at the bottom valve less the pressure drop across the valve.

Fig. 3 shows 7 different types of gas lift systems. Reference to the above notes will help determine if the producing bottomhole pressure calculated is the current producing bottomhole pressure or, possibly, the minimum producing bottomhole pressure since last tubing and casing annulus equalization.

In case A (Fig. 3), the bottomhole pressure is the sum of the casing pressure plus the gas column pressure, less the pressure drop across the valve plus the pressure due to the flowing fluid column in the tubing between the bottom valve and the formation. In case B, the bottomhole pressure is the sum of the casing pressure, plus the gas column pressure, plus the liquid column pressure above the bottom valve plus the pressure due to the flowing fluid column in the tubing between the bottom valve and the formation.

In case C, the bottomhole pressure is the pressure in the casing annulus at the bottom valve less the pressure drop across the valve. The pressure drop across the valve can be estimated by the gas lift valve manufacturer. The pressure in the casing annulus at the bottom valve is the surface casing pressure plus the gas column pressure. In case D, the producing bottomhole pressure is the casing pressure plus the gas column pressure plus the liquid column pressure above the bottom valve.

In case E, the producing bottomhole pressure is the casing pressure plus the gas column pressure minus the pressure drop across the bottom valve plus the fluid column pressure between the bottom valve and the formation. In case F, the producing bottomhole pressure is the casing pressure plus the gas column pressure plus the liquid column pressure above the bottom valve plus the fluid column pressure between the bottom valve and the formation.

The pressure thus obtained is the minimum producing bottomhole pressure that has occurred since the last time liquid was permitted to enter the casing annulus. If the producing bottomhole pressure is greater than it was at some time in the past, an additional test should be made. Liquid should be injected to fill the casing annulus until the height of liquid has stabilized. Then, the pressure calculated will represent the current producing bottomhole pressure.

Completion Recommendation

Accurate producing bottomhole pressures can be obtained by completing a gas injection well as shown in Fig. 3 by types D or G. The producing bottomhole pressure is the casing pressure plus the gas column pressure plus the liquid column pressure above the bottom valve or screened orifice.

Application of Pressures

The static and producing bottomhole pressures offer valuable information for selecting a gas lift valve installation. The static bottomhole pressure is beneficial for selecting top valve setting. The flow characteristics given by the static and producing bottomhole pressures are useful in selecting the depths for additional valves, determining gas injection rates, and optimizing the gas injection system.

The gas lift efficiency can be determined readily by utilizing the following technique in gas injection systems shown by types C, D, and G in Fig. 3. Add liquid to the casing annulus until the liquid height stabilizes (which indicates the static bottomhole pressure). Start gas injection at a relatively low rate and measure the gas injection rate, oil production rate, water production rate, and the producing bottomhole pressure. Increase the gas injection rate and continue measurements until additional gas injection no longer produces a reduction in the flowing bottomhole pressure and, consequently, no additional liquid.

The flow rate at any producing bottomhole pressure can be determined by using Fig. 4. The data needed to construct the curve are the static bottomhole pressure, the producing bottomhole pressure, and the flow rate at that producing bottomhole pressure. The resulting chart shows maximum well flow rate and the flow rates at different producing bottomhole pressures. The chart assumes the reservoir pressure is below bubble point.