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A COMPARATIVE ANALYSIS OF CONTINUOUS GAS LIFT VALVE POSITIONING METHODS AND ITS APPLICATION WITH MS EXCEL & VBA

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ABSTRACT

Studies in the past have made it clear that reservoir pressure and formation gas provide the natural energy in the flowing well. When the reservoir energy is too low for the well to flow, it becomes necessary to put the well on some form of artificial lift. The wide variety of parameters that are considered for lifting each barrel fluid by artificial lift mode is a challenging and interesting task for petroleum engineers. Gas lift is the most widely preferred artificial lift method in practice. It is a method where external source of high pressurized gas is used for supplementing formation energy to lift the well fluid to the surface. Two types of gas lift are used to meet the specific requirements. Continuous gas flow lift is used in wells with a high productivity index and a reasonably high BHP relative to well depth. The heart of any gas lift installation is the gas lift valve. Proper designing of gas lift system to locate the gas lift valve position for its better optimization and smooth operation has a great influence on the efficiency of gas lift system. Our primary objective is to analyze the gas lift method with emphasis on its operations, installations and the parameters affecting its design, performance and optimization. We have put our inputs on the basic designing of gas lift by developing an application using MS Excel and Visual basic, which will help in the positioning of side pocket mandrels (gas valves) in the tubing effectively. We have used a set of procedures for our work, which includes the graphical and analytical methods. We have formulated our program with a user-friendly interface. Conclusions have been drawn on the basis of efficiency and accuracy levels.

Keywords: Analytical method, Continuous flow, Excel-Visual Basic Application, Gas lift valve, Graphical method.

I. INTRODUCTION

Gas lift is a widely used artificial lift in the production operations. Thus, it's apt installation designing has a key effect on optimization of production performance. Many factors must be considered in the design of a gas lift installation. One of the first is to determine whether to place it on continuous flow. Some wells must be done without prior selection. Such borderline wells usually present a very difficult design problem. Further, selection

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of gas lift valves is an important criterion. Some valves are suitable for continuous, while some are for intermittent only. Some can be used for both types of lift as well.

The purpose of gas lift valves is to unload the fluids from the well so gas may be injected at the optimum point in the tubing string, to control the flow of injection gas both under operating and unloading conditions.

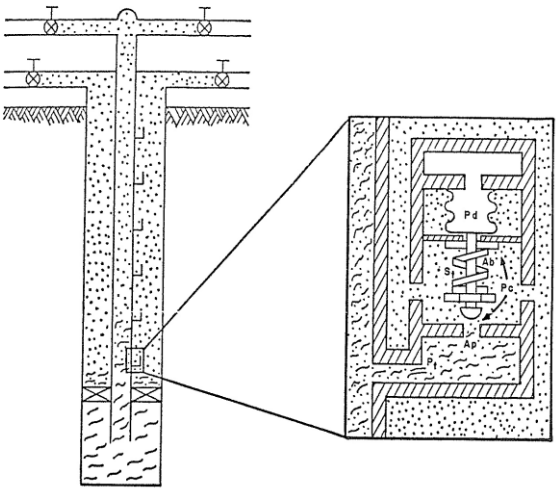

Fig.1: Operating valve in the mandrel and magnified operating valve[2]

1.1 Installation Operation for Continuous Gas Lift Valves

Prior to gas injection, a well is generally loaded with kill fluid. The injected gas displaces the kill fluid through the tubing which is termed as Unloading Operation. During unloading of the first gas lift valve, there occurs a surge in the wellhead tubing pressure and a decrease in the injection-gas casing pressure (surface operating pressure) as depth of injection gas increases. In continuous flow, all gas lift valves above an operating valve are closed.

As the injection gas is injected in the annular space, the injection gas pressure-at-depth increases as the kill-fluid level in the annulus is lowered. The injected gas enters the tubing through the open valves displacing some of the kill fluid to the surface. The lifting process starts as the injection gas enters through the first valve.

At initial stages, the pressure in casing and tubing are equal as U-tubing through the first valve occurs. Immediately after injection gas begins to enter the tubing through the next gas lift valve, the injection pressure in the casing (surface operating pressure) begins to decrease because the lower valve is set to open at lower pressure (surface operating pressure) than the valve above. Injection gas then enters through the valve below at a greater rate to the point where the injection gas pressure in the casing decreases for the upper valve to close.

There occurs a decrease in the flowing-production pressure as injection gas enters the tubing through a new valve. The injection gas pressure-at-depth starts increasing due to decrease in opening force developed from decreasing flowing production pressure in tubing. But with further increase in the injection pressure, the flowing-production pressure-at-depth increases. But the pressure is to be set such that it does not result in opening of the upper valve. For the injection gas to enter a valve, the flowing production pressure in tubing should be less than injection gas pressure in the annular space.

1.2 Continuous flow gas lifts designs:

Continuous flow in a well is similar to natural flow but the well can be divided to two distinct pressure regions. The region below the point of gas injection consists only of formation gas and the region above the point of gas

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injection consists of both formation and injection gases. The entry of the injected gas into the tubing depicts the position where the valve is to be placed. This position can also be said to be the point of gas injection.

Determining this point of gas injection is generally based on various multiphasic correlations and gradient curves. If possible, field data validation is required to verify the accuracy of these results. At greater depths where sufficient field data is unavailable to determine the point of injection, bracketing operations are done.

There are several gas lift installation methods but this paper mainly focuses on the design based on constant decrease in operating pressure for each succeeding lower valve. With a help of a set of formulae the depth at which a valve is to be placed can be determined. Along with depth, the operating injection gas pressure, flowing production pressure and temperature during unloading can also be calculated.

Determining the depth of each valve can be done with the help of two processes:

- Analytical method
- Graphical method

Analytical Method is based on a set of mathematical formulae which provides us the depth at which the gas lift valve is to be placed. It comprises of various steps which includes determination of flowing production pressure-at-depth, injection gas pressure and also unloading temperature. Analytical Method is generally tabulated on excel sheets which provides us faster and accurate results.

In graphical method, a depth v/s pressure plot is used to determine the depth considering various parameters like gas column weight in the well, kill fluid gradient, surface operating pressure etc. This method can also develop an approximate temperature v/s depth plot which enables the determination of the temperature of each valve at various depths installed in the well. Although it is a time consuming process, the depth derived is more accurate as compared to the analytical process.

II. METHODS

2.1 Determination of valve depths by Analytical method [1]**:**

As the final injection-gas pressure is unknown until the installation is designed, a pressure difference of about 100-200 psi is assumed between injection pressure at depth in annulus and flowing-production pressure in tubing for the deepest $valve_1$. The following steps are to be carried out:

Step 1: Determination of maximum unloading GLR based on injection-gas rate available for unloading and maximum daily flow rate.

Step 2: Calculation of unloading flowing pressure, P_{pfd} based on calculated GLR and flow-rate with the help of multiphasic correlations.

Step 3: Unloading flowing-pressure-at-depth gradient, G_{pfa} above the point of gas injection is calculated, where P_{pfd} is unloading flowing pressure at depth, P_{whu} is well-head pressure, D_d is reference depth.

$$G_{pfa} = \frac{(P_{pfd} - P_{whu})}{D_D} \quad \text{(i)}$$

Step 4: Injection-gas pressure-at-depth gradient, G_{gio} is calculated from surface injection gas pressure, P_{io} and injection-gas pressure at depth, P_{iod}.

$$G_{gio} = \frac{(P_{iod} - P_{io})}{D_D} \quad \text{(ii)}$$

IJARSE
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Step 5: Calculating unloading temperature-at-depth gradient, G_{tvu} from surface well-head temperature, T_{whu} and bottom-hole temperature, $T_{wsd.}$

$$G_{tvu} = \frac{(T_{wsd} - T_{whu})}{D_D} \quad \text{(iii)}$$

Step 6: Calculation of top gas lift valve depth, $D_{v1.}$

$$D_{v1} = \frac{(P_{ko} - P_{whu} - \Delta P_{sd})}{(g_{ls} - g_{gio})} \quad \text{(iv)}$$

Step 7: Minimum flowing production pressure, $[P_{pfD(n)}]_{min}$, Injection gas pressure, $P_{iod(n)}$ and unloading gas lift valve temperature, $T_{vuD(n)}$ is calculated from the following relations.

a. $[P_{pfd(n)}]_{min} = P_{whu} + G_{pfa}[D_{v(n)}]$ (v)

b. $P_{ioD(n)} = P_{io} + G_{gio}[D_{v(n)}]$ (vi)

c. $T_{vuD(n)} = T_{whu} + G_{tvu}\ [D_{v(n)}]$ (vii)

Step 8: Calculation depth of next valves:

$$D_{v\,(n)} = D_{v\,(n-1)} + \frac{P_{ioD\,(n-1)} - [(n-1)\ \Delta\ P_{io}] - [P_{pfd\,(n-1)}]_{min} - \Delta P_{sD}}{(g_{ls} - g_{gio})} \quad \text{(viii)}$$

Distance between valves, D_{bv}:

$$D_{bv} = \frac{P_{ioD\,(n-1)} - [(n-1)\ \Delta\ P_{io}] - [P_{pfd\,(n-1)}]_{min} - \Delta P_{sD}}{(g_{ls} - g_{gio})} \quad \text{(ix)}$$

When this distance D_{bv} is less than the assigned minimum distance, then to calculate the position of the next valve $D_{bv\,(min)}$ is added to the depth of the preceding valve.

2.2 Determination of valve depths by Graphical method [2]:

- We plot a graph, with pressure (psi) in X-axis & depth (feet) in Y-axis.
- We plot the kick off pressure (P_{ko}), surface operating pressure (P_{so}) & P_{so}-$P_{wh.}$
- We draw the injection gas pressure line, surface operating pressure line & P_{so}-P_{wh} line including the gas column weight in the wellbore (as per well data).
- We find P_{wf} by using the relation "PI=Q/(P_r-P_{wf})" & locate the point. This calculates the flowing bottom hole pressure
- Now, with the help of vertical flowing pressure gradients corresponding to the available well data, we find the point of gas injection [point of intersection between the extended P_{wf} line & the (P_{so} - P_{wh}) line].
- We draw the design tubing pressure line from the surface to the point of gas injection. This line starts from a surface pressure of P_{wh}+0.2(P_{so}) or P_{wh}+200 whichever is greater.
- We locate the first valve by drawing a line having the kill fluid gradient (as per well data). This line begins at the wellhead pressure and is extended downward until intersecting the kick-off gas pressure line.
- The rest of the valves are now spaced to the injection point as follows:

1. From the location of valve#1, extending a line horizontally to the left until intersecting the design tubing pressure line.
2. From the previous extended point, extending a line downward parallel to the line including the kill fluid gradient until intersecting the operating pressure line at the surface. This locates the valve#2.
3. We repeat the procedure of (2) until reaching the point of gas injection or below.

IJARSE
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- Taking a different X-axis as temperature (^oF) with a common Y-axis as depth (feet), we draw an inclined line considering the geothermal temperature gradient, surface temp^r and bottom temp^r.
- Bracketting is the procedure which allows valves to be installed below the point of gas injection. In practical cases several valves can be placed below the point of gas injection to optimize the oil recovery. The placing of valves depends on various well characteristics such as decreasing static BHP and variation in productivity.
- Bracketting procedure [2]:
  - Plot the gas gradient line for the operating casing pressure.
  - Subtract the desired operating differential from the surface operating pressure (say x). Draw a line parallel to the surface operating pressure starting at 'x' at the surface.
  - Construct the flowing tubing pressure gradient for the desired production rate and GLR. Draw this gradient down from the flowing wellhead pressure until it meets the casing pressure differential line. Calculate pressures which are 20% or 10% (percentage error) greater or less than the flowing wellhead pressure. Locate and mark P_1 and P_2 on the pressure vs. depth graph ($P_1 = P_{wh} + 0.2\ P_{wh}$;$P_2 = P_{wh} - 0.2\ P_{wh}$).
  - Find the pressure where the flowing tubing pressure gradient intersects the casing pressure differential line. Plot this point as P_1' and similarly plot a point P_2'.
  - Now, locate and mark the point where the line P_1 P_1' intersects the casing pressure differential line. This depth is where the bracketing envelope should start.
  - Similarly, the intersecting point for the line P_2 P_2' and the casing pressure differential line will give the approximate depth where the bracketting envelope should stop.
- Now, the temperature of each valve in the bracketing envelope can be determined by the previously discussed procedure.

III. DATA ENTRY VISUAL BASIC USERFORM

The figure below depicts the desired parameters that has been calculated using the MS excel & VBA programming. The blue columns represent the input data of a well and the pink columns represent the output data. In output data gives us the result in the form of depth of the valve to be installed, its flowing production pressure, injection gas pressure and unloading temperature.

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IJARSE
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WELL DATA	VALUES	UNIT	VALVE NO.	Depth of the valve Dv (in feet)	Flowing production pressure Ppfd (in psi)	Injection gas pressure PioD (in psi)	Unloading temperature TvuD (in °F)
Tubing length	8000	ft					
Daily flow rate	800	STB/day	1	1928.530913	292.8530913	1037.12422	116.8746455
Bottom Hole Temperature	170	°F	2	3458.357638	445.8357638	1066.573385	130.2606293
Unloading Temperature	100	°F	3	4662.526942	566.2526942	1089.753644	140.7971107
Kill Fluid Gradient	0.46	psi/ft	4	5600.702664	660.0702664	1107.813526	149.0061483
U-tubing Well Head Pressure	100	psi	5	6321.617604	732.1617604	1121.691139	155.314154
Flowing Well Head Pressure	100	psi	6	6865.076205	786.5076205	1132.152717	160.0694168
Kick-off Pressure	1000	psi	7	7263.590321	826.3590321	1139.824114	163.5564153
Injection Gas Pressure	1000	psi	8	7543.715293	854.3715293	1145.216519	166.0075088
Daily Gas Injection Rate	800000	SCF/day	9	7727.141249	872.7141249	1148.747469	167.6124859
Wellhead Injection Temperature	100	°F	10	7831.584458	883.1584458	1150.758001	168.526364
Valve Spacing Pressure Differential	50	psi					
Minimum Decrease in Surface Operating Pressure Between Valves	20	psi					
Flowing Production Pressure	900	psi					
Static Injection Gas Pressure	1154	psi					
Unloading Flowing Pressure At Depth Gradient	0.1	psi/ft					
Static Injection Gas Pressure At Depth Gradient	0.01925	psi/ft					
Unloading Gas Lift Valve Temperature At Depth Gradient	0.00875	°F/ft					

CALCULATE   CLEAR

Fig. 2: Excel-visual basic interface of analytical gas lift valve positioning layout.

The figure below represents the graphical solution achieved using the input data of a well. The output results shows the valve locations downhole, unloading temperature and also represents the bracketing envelope below point of gas injection.

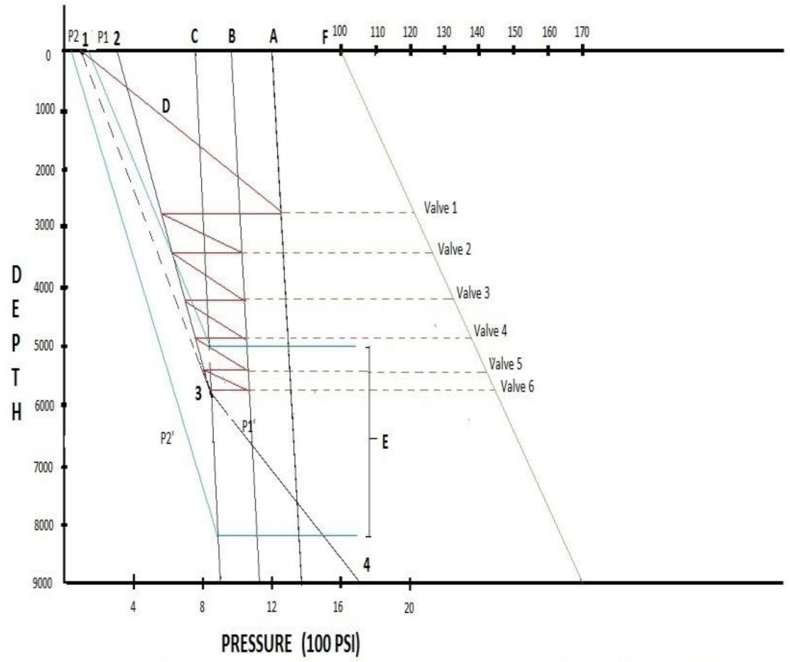

Fig.3: Graphical representation of a continous-flow gas lift installation design: 1. Wellhead pressure, P_{wh}; 2. $P_{wh}+0.2(P_{so})$ or $P_{wh}+200$; 3. Point of gas injection; 4. P_{wf} ; A. Kick off pressure line, P_{ko} ; B. Surface operating pressure, P_{so}; C. $(P_{so} - P_{wh})$; D. Kill-fluid gradient line ; E. Bracketting region ; F. Temperature gradient line.

IV. RESULT

Despite of its demerits the analytical method has found its way into the industrial use for determining the depth of valves in continuous gas lift operations because of its faster computation and high reliability. Moreover, this

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method can be used for determining the parameters simultaneously for a number of wells provided the well data is available, thus enabling large scale execution.

On the other hand, graphical method involves repeating the entire process for different wells again and again (time consuming process).

V. APPLICATION

The analytical method when used in accordance with excel and visual basics interface creates a medium for non-technical users to calculate the desired parameters. With better knowledge of coding and designing in visual basics, the interface can be used as a software which could be promising in terms of creating a user friendly console. The software would enable users to calculate the desired parameters with a single click of a button irrespective of the user's knowledge. Moreover, in the times to come we have provisions of calculating others parameters like the port size of the valve, injection gas volume and volume of production gas.

VI. CONCLUSION

- This paper gives an idea of the various procedures that could be used to find the depths of valves to be installed in the continuous gas lift operation. The positioning of the gas lift is vital in aerating the fluid in the well thereby enhancing the overall recovery of hydrocarbons.
- The observations of this paper is tabulated below:

ANALYTICAL METHOD		**GRAPHICAL METHOD**	
ADVANTAGES	LIMITATION	ADVANTAGES	LIMITATIONS
• Based on computer application of mathematical procedures and formulae • faster and accurate results without human errors • proper validation of field data	• It lacks on field human experience and is solely based on mathematical formulae and assumptions. • Not applicable in unconventional situations or reservoir.	• High accuracy in depth determination in comparison to analytical method. • Input of human knowledge and experience.	• Time consuming • Possibility of human errors • Not applicable in unconventional cases.

Table 1: Advantages and limitations of the procedures used in determining depths of continuous gas lift operations.

IJARSE
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