Artificial Lift

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Lecture-49 Gas Lift Basics- Part 2

Unloading sequence: If I have a reservoir here with perforations and fluid flowing through tubing and a packer, and if the fluid's density (ρ) remains constant, whether it's water, oil, or a combination, the change in density is negligible due to the hydrostatic effect. If gas is present, density will vary, but the density change is not significant for liquid.

The equation hρg = p represents the pressure at this point (P_{wf}). It's completely filled with liquid, and the gradient (g) is changing due to the varying depth (h). So, if we draw a line from P_{wf} to the surface and take pressure at points 1, 2, 3, and 4, the pressure decreases as we move upwards due to the reduction in hydrostatic pressure (h). We assume that density remains constant (not changing), and we cannot change g (gravity).

Now, several valves are fixed at the beginning—valves 1, 2, 3, and 4 are already open. You start injecting gas from the surface. First, you open the first valve, and gas is injected, creating numerous bubbles in the first valve. As a result, the hydrostatic pressure is reduced at the top but remains unchanged at the bottom. So, your pressure curve changes in the upper section.

Next, you inject more gas, activating the second valve while closing the top valve. This changes the hydrostatic pressure for the entire column, except the bottom section. Gradually, you activate the third valve, changing the pressure in the entire column, with the bottom section remaining unaffected. You continue this process until you reach the operating valve. The operating valve may or may not be the bottommost one; it depends on the engineer's assessment of the optimal production rate and valve location.

Gradually, as shown in the figure sequence A, B, C, D, E, the well is initially fully filled with liquid. Then, you inject gas from the surface into the annular area, gradually moving gas from one section to the next. Eventually, the entire annular area is filled with gas, and inside the tubing, numerous bubbles are present, creating a bubble flow rather than mist flow or other types of flow.

This discussion involves a gas lift valve. So, what does a gas lift valve look like? A gas lift valve typically consists of a spring-loaded section and a diaphragm. The diaphragm area is typically filled with nitrogen gas.

We do not fill the system with oxygen or any other active gases; we use inert gases like nitrogen to avoid safety issues in case of leaks. The gas lift valve consists of a spring-loaded section with a stem, body valve, diaphragm, and an orifice or port. The valve can be classified as a casing pressure-operated valve (pressure valve) or a tubing pressure-operated valve (fluid valve).

If the upstream pressure is very high, it operates as follows: there is a nitrogen dome with a piston inside. The piston is sealed by a flexible diaphragm that acts like a membrane and is filled with nitrogen or a spring. This high pressure pushes the diaphragm up, creating a flow path at the bottom. The stem connected to the diaphragm moves up, opening a port. When this port opens, fluid from the casing enters the tubing. This mechanism allows gas to be injected into the tubing, and the orifice in the tubing has an effect on the valve's opening.

The reason for this complexity is to control the valve from the surface because once it's inserted into the wellbore, you can't access it to open or close it. The valve is controlled from the surface by manipulating the pressure. Reducing the pressure closes the orifice path, while increasing the pressure opens it.

In a previous explanation, I mentioned balanced and unbalanced valves. Tubing pressure can affect unbalanced valves, while balanced valves are not influenced by tubing pressure. The valve operates with casing pressure (P_c) and tubing pressure (P_t), and the system ensures that the surface pressure controls the valve's opening and closing.

This is how it works. You have a stem below, and it controls the valve by opening and closing it. It's like this: a casing hole is here, and the gas flows into your tubing. The stem is responsible for the valve's operation. It works like this: the casing hole is here, the gas flows to the tubing, and the casing gas comes like this. A diaphragm, denoted as 'P_d,' stands for diaphragm pressure. The notation I'm using is 'a' for below, 'b' for below pressure, and 'P_c' for casing pressure. Here, 'P_t' represents tubing pressure.

This area with the stem is denoted as 'A_p,' which is the port area. So, to open or close the valve, you need to apply pressure. Let's say 'A_b' is 10 square inches, and you're giving it a casing pressure of 100 or 200 bar, and 'A_p' is also being subjected to the same pressure. 'A_b' requires a force that's 100 times greater to open. This is because 'A_b' has a larger area, while 'A_p' has a smaller area, resulting in a difference in pressure. To open using 'A_p' or tubing pressure, you'd need to apply 100 times more pressure than 'A_p' requires. However, if you use 'P_c' (casing pressure), the pressure required is much lower, and you can easily control it from the surface. Tubing pressure does have some effect, but it's minimal compared to the influence of casing pressure, which is 100 times greater than tubing pressure.

Now, this is only for casing pressure-operated valves. Unbalanced below valves with a pressure-charged dome as a loading element are controlled by casing pressure, with tubing pressure being largely negligible. The notation 'A_b' or 'A_p' remains the same, as well as the nitrogen-filled dome. The use of inactive gas is a key consideration.

Let's examine the opening pressure of the valve under operating conditions. 'F_o' is the summation of all opening forces, and 'Fc' is the summation of all closing forces. 'F_c' is calculated as 'P_d' times 'A_b.'

$F_c=P_dA_b$

'F_o' can be calculated as 'P_c' times 'A_b' minus 'A_p,' plus 'P_t' times 'A_p.'

$F_0=P_c(A_b-A_p)+P_tA_p$

The formula for 'force' is 'pressure times area,' which is why we have 'P_t' times 'A_p' and 'P_c' times 'A_b'.

$(A_p/A_b)=R$

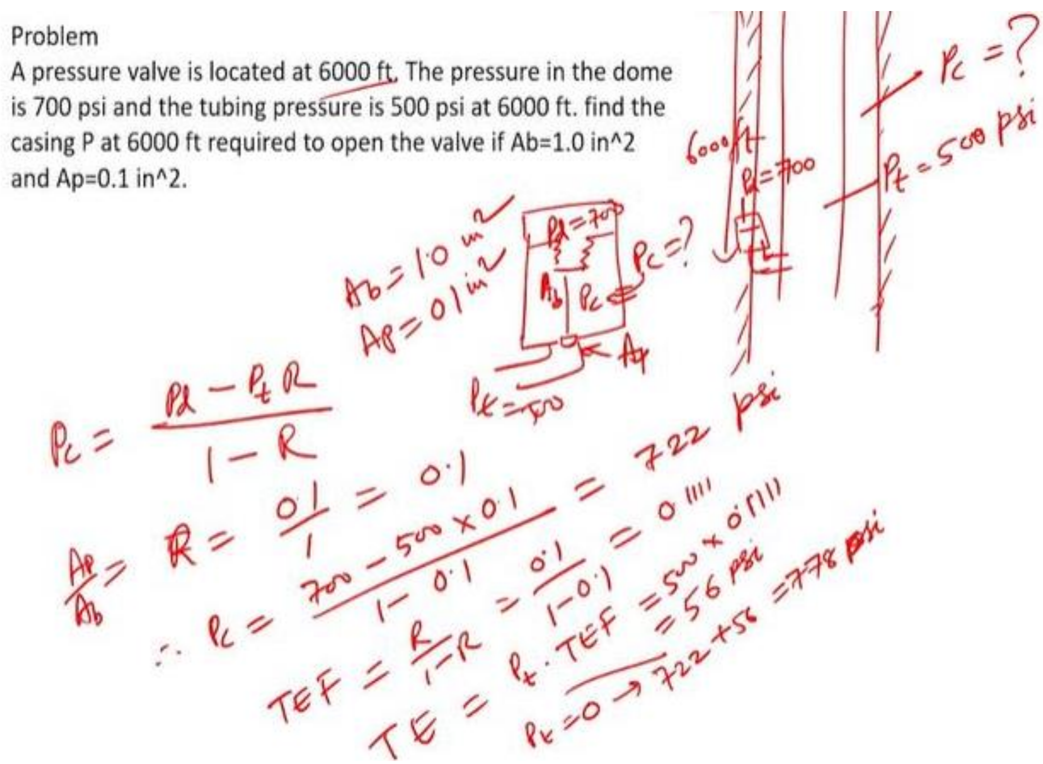
$$P_c = \left(\frac{P_d - P_t\, R}{1 - R}\right)$$

Now, P_c becomes P_d minus P_t times R times 1 minus R. So, the tubing effect factor, TEF, equals R times 1 minus R, and tubing effect equals Pt times R times 1 minus R. You should remember this formula, as we'll use it to solve problems later.

$$TEF = \left(\frac{R}{1 - R}\right)$$

$$Tubing\ Effect = P_t\ \left(\frac{R}{1 - R}\right)$$

Using this previous formula, you need to solve a problem. A pressure valve is located at 6000 feet. The valve is at a depth of 6000 feet. The dome pressure, P_d, is 700 psi, and tubing pressure, P_t, is 500 psi. You need to find the casing pressure, P_c. P_c is the casing pressure that needs to be determined. A_b is given; if you look at the valve, I'm using a common notation. I've given names accordingly. The stem is here, and this is P_c, P_t, P_d, and the dome pressure is given as 700 psi, while P_t is given as 500. P_c is not given, but A_b is provided, and A_b is equal to 10 square inches. A_p is also given as 0.1 square.



Using the previous formula, P_c equals P_d minus P_t times R times 1 minus R. So, this formula will yield R, which is equal to 0.1 divided by 1 minus 0.1. R equals Ap divided by Ab. Therefore, P_c equals P_d, which is given as 700, minus P_t, which is 500, times R, which is 0.1, divided by 1 minus 0.1. This results in a casing pressure of 722 psi.

In the previous formula, we've seen TE, which is R divided by 1 minus R. R divided by 1 minus R equals 0.111. Now, TE, the tubing effect, equals P_t times TE, which is 500 times 0.1111, yielding 56.

If P_t is 0, P_t 0 means there's no tubing pressure, so casing pressure must be 778 psi. This is referred to as the maximum casing pressure, and it needs to be applied if tubing pressure is 0.

Thank you very much for today's lecture. Tomorrow, we will start with more calculations and cover more topics on the gas lift system. Thank you very much.