Artificial Lift

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Lecture-57 Surface Pump Units for Jet Pump - Part 1

I have previously explained the various types of pumps used in the oil industry and other general applications. For instance, your household has pumps for getting water from a surface tank. These pumps are also used in industrial and agricultural applications. However, for specific applications like surface pumping in hydraulic pumping, you require very high pressure as the primary need. Flow rate is essential as well, but high pressure is the top priority. These types of pumps are also used in drilling applications, such as mud pumping, and during completion operations. Another example is hydraulic fracturing, where you need a high-pressure fluid pump on the surface.

There are various applications in the wellbore and on the surface production side. For instance, you might get gas or fluids with lower pressure at the surface, which need to be compressed before being sent to customers. Alternatively, you may receive fluids like water or oil at the surface, which you need to transport through pipelines. There will be pressure drops when flowing through pipelines, so you must add energy using pump or compressor systems. Pumps and compressors are integral to the oil industry, as it would come to a standstill without them.

Now, let's explore the different types of pumps. Pumps come in various types. The primary difference between pumps and compressors is that pumps handle liquids, whereas compressors typically deal with compressing air or gases. Compressors work with gases in their gaseous form, adding pressure while reducing the total volume. In pumps, you develop pressure, but you typically ignore the low compressibility of oil or gas because the main goal is to transfer the liquid. Some compressibility exists in pumping applications, but we usually disregard it. Pumps for moving liquids come in two main categories: positive displacement and dynamic or centrifugal.

Another type, actually, we should mention jet pumps. Jet pumps are sometimes included in positive displacement pump books, but I should clarify that they are a separate category.

When discussing positive displacement pumps, we have single-acting and double-acting pumps. I will explain later what single-acting and double-acting mean. Single-acting pumps can be further classified as simplex, duplex, triplex, and so on. This "plex" classification goes on, including single-cylinder, double-cylinder, triple-cylinder, four-cylinder, five-cylinder, seven-cylinder, eight-cylinder, nine-cylinder, and ten-cylinder pumps. The number of cylinders in a multiple-cylinder pump, such as simplex, duplex, or triplex, determines its classification.

Double-acting pumps can also have various numbers of cylinders, but typically, simplex, duplex, or triplex single-acting pumps are commonly used.

Now, when you consider dynamic pumps, positive displacement includes reciprocating pumps. Apologies for the earlier mistake; I should write "reciprocating" here. Another category is rotary pumps, where a rotor rotates in gear pumps, screw pumps, vane pumps, and scroll pumps. There are many types of rotary pumps available. You can even create hybrid types by combining different principles. One such type is the diaphragm pump. These are all considered positive displacement pumps.

Now, dynamic pumps, specifically centrifugal pumps, come in three types: centrifugal, mixed, and axial.

Now, which type can develop very high pressure? You can recall the pump curves where flow rate (Q) and head (H) are plotted. I've drawn vertical curves for positive displacement pumps and a curve like this for centrifugal pumps. Centrifugal pumps have limitations in terms of pressure development, while positive displacement pumps like reciprocating pumps, diaphragm pumps, gear pumps, screw pumps, vane pumps, and peristaltic pumps have unlimited pressure development capabilities. However, in terms of flow rate, positive displacement pumps typically have lower flow rates, while centrifugal pumps have higher flow rates.

When selecting a pump for a specific application, you should consider your required flow rate and pressure development. Based on these factors, you can choose between reciprocating pumps or dynamic pumps like centrifugal pumps.

In the case of centrifugal pumps, we've already discussed in the ESP (Electric Submersible Pump) system that they consist of an impeller and diffuser. Multiple stages are created, with each stage providing a certain amount of pressure, and the stages are stacked to achieve very high pressures.

In many instances, positive displacement pumps can be replaced with centrifugal pumps if you design multiple stages of centrifugal pumps.

Mixed flow pumps follow a similar mechanism, but axial flow pumps should not be classified under centrifugal. Instead of "centrifugal," I will write "radial" to clarify the categories: radial impeller, mixed flow impeller, and axial impeller.

An axial impeller doesn't generate centrifugal force; it produces axial force. It's a separate division of centrifugal pumps. Axial pumps typically have very low flow rates. In contrast, radial pumps have low flow rates and high heads, while centrifugal pumps generally have low heads and high flow rates. In this lecture, I have consistently used "Q" to represent flow rate and "h" for head or pressure.

When selecting a pump for hydraulic pumping applications, such as hydraulic engine pumps or jet pumps inside wellbores, you should choose carefully. You can opt for reciprocating pumps if you have a single wellbore or only a few with lower flow requirements. However, a centrifugal system may be more suitable if you're dealing with a centralized system and multiple wellbores because you need to handle larger fluid volumes.

Another consideration is specific speed, which I discussed earlier. Low specific speed (Ns) corresponds to higher head and lower flow rates, while high specific speed means lower head and higher flow rates. You typically require pumps with lower specific speed values for hydraulic pumping applications to deliver the necessary pressure. Pumps with higher specific speeds may not provide the required pressure for jet or hydraulic engine-pumping applications.

$$N_s = \frac{N\sqrt{Q}}{H^{\frac{3}{4}}}$$

$$Volumetric\ flow\ rate, Q_{th} = \frac{\pi}{4}\ D^2LN$$

$$Actual\ flow\ rate, Q_a = Q_{th}\eta_v$$

In surface hydraulic pumping applications, various types of pumps are commonly used. As mentioned earlier, centrifugal pumps can be employed, often with multiple stages to achieve the necessary pressure. The addition of multiple stages allows you to achieve higher heads without significantly altering the flow rate.

Reciprocating pumps are also frequently used. In many cases, gear or screw pumps find applications. Diaphragm pumps are useful, especially for chemically sensitive situations, but diaphragm pumps can also be utilized in hydraulic pumping applications. It appears there is a typographical error with the letter "G" in one place in the text.

The correct spelling is that diaphragm pumps are suitable for metering applications.

Metering pumps are primarily used for metering or compression applications. You may need to pump a specific, fixed amount of fluid, making metering pumps appropriate for such cases. Centrifugal pumps are unsuitable for metering because changes in pressure or flow rates affect the head. However, reciprocating pumps like PCP can control both flow rate and head through rotational speed. These pumps ensure a fixed volume of fluid is moved with every rotation or stroke, making them ideal for metering applications. Diaphragm pumps can also be used in metering applications because they are positive displacement pumps that can accurately meter specific fluid volumes.

The picture illustrates a triplex pump, showing how it operates. Triplex pumps have three pistons that move one by one, connected to a single rotating shaft. This results in varying flow rates. The rotation of the shaft causes the pistons to reciprocate, pumping fluid.

Triplex pumps are one type of positive displacement pump with multiple cylinders, offering increased flow rates and smooth outflows.

The text mentions duplex, quadruplex, and other variations, with more cylinders leading to increased flow rates and smoother outflows. This applies to positive displacement pumps like sucker rod pumps, where increasing the number of strokes or the RPM of the motor increases the flow rate. In the case of the triplex pump, different models are available with varying plunger diameters and displacement rates, depending on the RPM.

Different types of pumps have various parameters, including plunger diameter, which is related to volume flow rate. A larger plunger diameter corresponds to a larger volume flow rate. For instance, when the plunger diameter increases from 1.7 to 2, the flow rate also increases at 100 RPM: 42 to 54, 62 to 82, 83 to 109, and so on.

The text mentions a "quadplex" or "quintuplex" pump, which features five cylinders. The arrangement includes five pistons and piston rods driven by a motor. The pistons move one by one, powered by the motor's rotation. The gear mechanism is utilized to reduce the motor's speed. Gear ratios are shown as 6.17 to 1, 7.30 to 1, and 9.57 to 1, helping to achieve the desired pump speeds. The splash-based lubrication system ensures proper lubrication to reduce friction and heat.

The material used for construction is A104 carbon steel, with various connection types specified. The sheet demonstrates how a system with five pistons and an 8-inch stroke length functions.

In case a problem needs to be solved using this sheet, parameters like stroke length, plunger diameter, and gear ratio can be applied to calculate the volume flow rate. Volumetric efficiency, often less than 100%, is then considered to find the actual flow rate.

Additional parameters such as motor speed and gear ratio can be used if you need to calculate the theoretical or actual flow rate. You can determine the resulting RPM (N) for flow rate calculations by reducing the motor's speed using the gear ratio.

Here is the revised text:

Various types of pumps possess different parameters, including plunger diameter, closely related to volume flow rate. An increased plunger diameter corresponds to a larger volume flow rate. For instance, when the plunger diameter increases from 1.7 to 2, the flow rate also increases at 100 RPM: 42 to 54, 62 to 82, 83 to 109, and so on.

The text mentions a "quintuplex" pump, indicating the presence of five cylinders. This setup features five pistons, each with an associated piston rod. These pistons operate sequentially, driven by a motor. A gear mechanism is employed to reduce the motor's speed. Gear ratios are provided as 6.17 to 1, 7.30 to 1, and 9.57 to 1, contributing to the achievement of the desired pump speeds. The lubrication system relies on a splash method, ensuring proper lubrication to reduce friction and heat.

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You may use additional parameters such as motor speed and gear ratio to calculate the theoretical or actual flow rate. You can determine the resulting RPM (N) for flow rate calculations by reducing the motor's speed using the gear ratio.