Artificial Lift

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Lecture-05 Pumps, Compressors, and Flow through Pipes

So, regarding surface units, when I mentioned compression and production, production also involves some pumping systems. These pumps are typically installed during the completion and drilling stages. Additionally, they may be required during surface production operations. Let me explain this further. First, let's discuss why pumps are necessary. During drilling, it's essential to pump drilling mud into the wellbore. This requires the use of a pump. These pumps can be of various types, such as centrifugal, reciprocating, or others.

Another instance where pumps are needed is for artificial lifting systems. Surface pumps may be required for this purpose. Additionally, during the separation stage, specific pumps might be needed. For example, a pump can greatly assist if the pressure is too low and you need to increase it before sending the fluid to a pipeline or another location. Now, let's talk about compressors. Compression comes into play when injecting gas into the wellbore for gas lifting operations. In such cases, you need compressors. Also, if you have natural gas and you intend to convert it into LNG, compression is necessary, and you'll require compressors for this process.

The different compressor options typically fall into two categories: turbo machines or positive displacement pumps. These categories have two main types: positive displacement pumps and kinetic (rotary) pumps. Many of you may be familiar with the positive displacement pump, commonly used in the oil industry. It's the type of pump that can work reliably for decades. In fact, a pump with remarkable durability has been around for 70, 80, 90, or even 100 years — the human heart. It, too, operates on positive displacement principles, taking in a certain amount of fluid and pumping out the same amount without any leakage.

If there is leakage, you must consult a heart center like the one in Chennai. If your heart is working well, you're alive; if not, it's a different story. Our mechanical pumps may not last 100 years, but can work for several years. For instance, refrigerators and other similar pumps typically operate for around 10 to 15 years in my experience. Positive displacement pumps are used to generate very high pressure. Such pumps include progressive cavity pumps, sucker rod pumps, and screw pumps. Positive displacement pumps can achieve very high pressure but have a lower flow rate, producing high pressure while maintaining a lower flow rate.

On the other hand, if you look at kinetic or centrifugal pumps, these are prevalent types used in various applications, including household, lawn care, and many industrial settings, among others. They offer high flow rates but lower pressure compared to positive displacement pumps. Another example of a positive displacement pump is found in medical applications, such as injection syringes. These pumps are used to deliver a precise amount of fluid. Everyone is familiar with this concept, especially with the COVID-19 vaccine, where a small amount of fluid is drawn and then precisely injected. Similarly, the human heart is a positive displacement pump in our bodies. Additionally, you can find positive displacement pumps in everyday household applications, like filling a tank or pumping water for various purposes.

So, there are several applications where the same pump is used in the oil and gas industry, including artificial lifting applications, which I will explain later. Another type of pump, as I mentioned earlier, is the rotary pump. Rotary pumps, including centrifugal types, deliver high-volume fluid at relatively lower pressures, although it's possible to create higher pressures using multiple stages. I will cover this topic in more detail when discussing centrifugal pumps and ESP (Electric Submersible Pump) systems.

Now, let's talk about compressors. The term 'pump' is typically associated with liquid handling, but when it comes to compression, we use the term 'compressor.' Compression usually applies to gases. Various compressors are available, including positive displacement pumps and rotary pumps. Where do we use compressors? Well, in gas lift applications and LNG production. Let's say you have low-pressure gas and want to convert it into high-pressure LNG. For example, Indane is a liquified petroleum gas (LPG).

So, the gas is compressed somewhere. What are the different types of compressors? There are positive displacement and rotary displacement compressors. When compressing gas, there are some issues to consider. When you compress gas, the temperature will increase because of the ideal gas law,

$$pV=nRT$$

For the same number of moles, if you increase the pressure (p), the temperature (T) must also increase, as we are not changing the number of moles (n) or the gas constant (R). In this case, the compression system must include a cooling arrangement to prevent system failure. However, compressibility is very low in the case of liquids, so you may not need a cooling arrangement when compressing them.

For example, you may have seen cycle pumps in shops with a big cylinder and an electric motor-like device. These pumps have many fins on them for cooling purposes. They use positive displacement pumps to pump air into the cylinder, which is transferred to your cycle tube or vehicle tires. However, if you are using a manual cycle pump, commonly found in roadside cycle shops in India, it is also a positive displacement pump. It operates as a reciprocating pump, continuously pumping air. Once you pump, if you touch the bottom part of the pump, it will be very hot. This is because, due to the pressure increase (P) in the ideal gas law, the temperature (T) increases significantly. So, it becomes quite hot to the touch, and you might get burned if you touch it immediately. So, when discussing the oil and gas industry upstream, you will have a wellbore, and then you will have tubing.

So, I've already mentioned the wellbore, which includes a casing—a metal pipe made of materials such as iron. However, when using iron-based materials, it's essential to check whether the wellbore fluid contains sand, corrosive substances, carbon dioxide, or H_2S. If any of these are present, you may need to use non-metallic materials and ensure proper cementing. Once the cementing is done, you can install tubing, which is used for production. Fluid flows through this tubing from the well to the production choke and surface facilities. All of these components are pipes.

Now, how do you design a pipe? Choosing between a 1-inch pipe and a 10-inch pipe depends on specific criteria. For instance, if you select a very narrow pipe, like a thin straw used for drinking juice, can it be used in the oil industry for production? The answer is technically yes, but there's a significant issue: it would create high friction. This friction can be calculated using the formula,

$$\Delta p = \frac{flv^2}{2gd}$$

Here, 'ΔP' represents pressure drop through the pipe, 'f' is the friction factor, 'l' is the length of the pipe, 'v' is the velocity of the fluid, 'g' is the acceleration due to gravity (9.81 m/s^2 in SI units), and 'd' is the diameter of the pipe.

Several issues arise if you use a tiny straw like a juice drinking straw instead of a 3-inch pipe. The friction factor remains constant, and the length 'L' becomes very long, resulting in a significant pressure drop. This means you would need to exert substantial force to draw fluid through the long, narrow straw. Conversely, with a larger-diameter pipe and higher fluid velocity, you'd require less force to maintain flow. However, if you're trying to suck up a large volume of fluid, you'll need more energy, which can strain your cheeks due to the increased pressure drop.

So, the pressure drop will be high when the pipe length is very long. When trying to move more fluid quickly through the pipe, you're expending more energy. This high pipe velocity results in more energy being lost as pressure drop. Conversely, you'll also need to exert more energy when the pipe diameter is very narrow. Choosing a larger or smaller pipe diameter affects your energy requirements. Similarly, in the oil industry, if you have a very narrow tube aiming for the same fluid velocity, the narrowing of the tube will demand more energy. This means that if the reservoir pressure is, for instance, 1000 bar, it might not be sufficient to push the fluid to the surface if you're dealing with high friction.

Additionally, if your fluid velocity is very high, you'll encounter the same issue: a significant increase in frictional pressure drop. Moreover, when piping is exceptionally long, say 10,000 or 5,000 feet, the extended length results in significantly higher friction and, consequently, a substantial pressure drop. Regarding 'f,' which represents the friction factor, it's important to note that all surfaces have some roughness. While a surface may appear smooth when viewed from a distance, it features countless small bridges and valleys when examined under a microscope. These micro-irregularities disrupt the smooth movement of fluid particles. To illustrate, consider a rough road. If the road isn't properly constructed, your bike will slow down as it encounters more resistance. Similarly, you'll need to use more fuel, such as gasoline for a bike, to maintain speed. The greater resistance means higher energy consumption, preventing you from moving forward faster.

When the internal flow of a pipe encounters a rough surface with high roughness levels, it consumes more energy. The friction is significantly increased in such cases because the pipe impedes the fluid's movement. The symbol 'f' represents roughness; when the pipe's roughness is high, it provides substantial resistance. This leads to a high frictional pressure drop, demanding more energy. Consequently, for the same reservoir pressure, the fluid may not be lifted to the surface, or the wellhead pressure requirement, let's say 100 bar, may not be met if there is a loss of 100 bar in pressure between the pipe and the reservoir in the wellhead. In such a scenario, you may need to change the tubing diameter or adjust the wellhead or surface conditions.

The separator system may not function correctly if surface conditions are not modified. Every separator system has pressure, flow rate, and temperature limits. Altering any of these parameters may cause the separator to malfunction. You must maintain proper pressure, temperature, and flow rate to ensure the entire system operates smoothly. It's essential to understand the frictional pressure drop associated with installing tubing in the wellbore, whether for regular wellbores or those with artificial lift systems. Another consideration is that while very narrow tubes are generally inefficient, as an engineer, you might think, 'Samad sir (course teacher) mentioned that narrow tubes are inefficient, so let's make them wider.' Instead of using a half-inch or two-inch tubing, you might opt for a five-inch tubing. However, this approach can also present challenges.