Urban Utilities Planning: Water Supply, Sanitation and Drainage
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Module - 04
Pumping and Storage
Lecture - 17
Pumps

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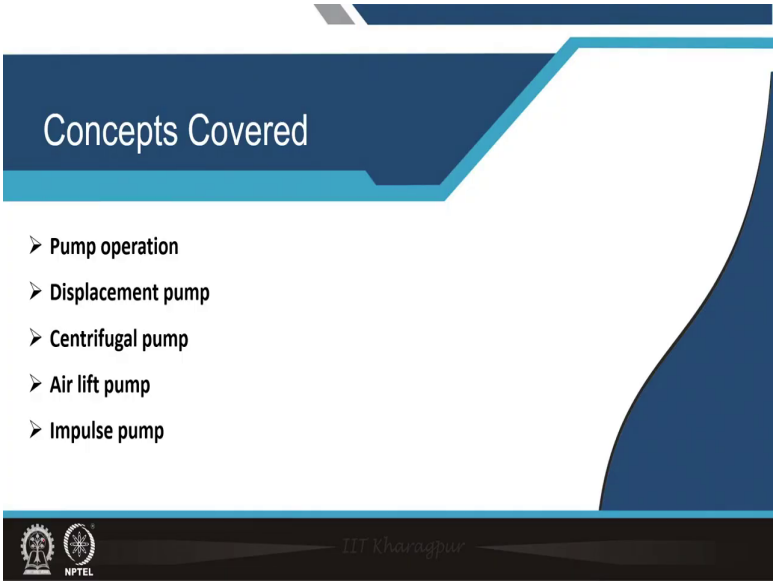

In lecture 17, pump operations, displacement pumps, centrifugal pumps, air lift pumps and impulse pumps will be discussed.

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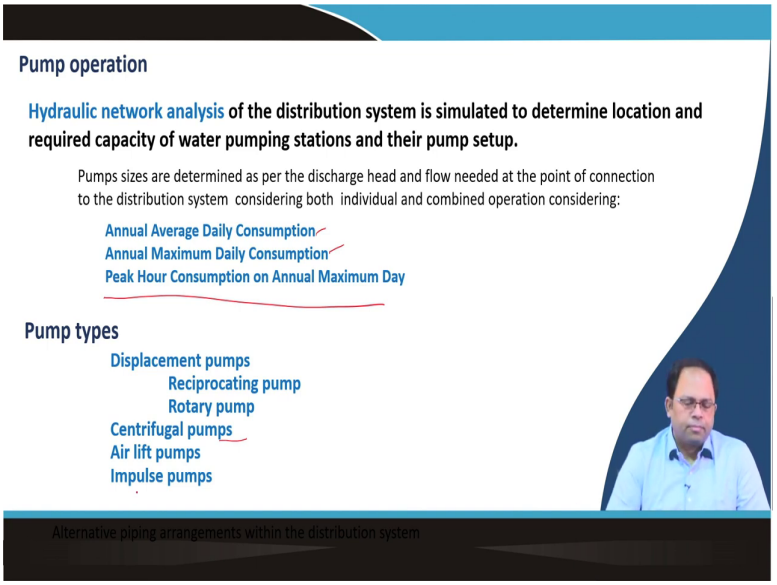

To determine pump operation, there is a need to conduct hydraulic network analysis of the distribution system. This helps in determining the size of pipe lines, the pressure at different points and the height of overhead reservoir. Similarly, there is a need to understand of the type of discharge that should be required from a pumping station as well as the discharge head that is required at that point where the particular pumping station is connected to the distribution network. So, pumps sizes are determined as per the discharge head and flow needed at the point of connection to the distribution system considering both individual and combined operation considering average annual average daily consumption, annual maximum daily consumption or peak hour consumption on annual maximum day. It could be either a individual pump operation or a combined operation. For example, if two pumps are used to develop the pressure or discharge head, it is a combined operation. If only one pump is used, it is a single/individual operation. Thus, there is a need to understand the discharge head and required flow for a particular pump or at a particular pumping station so that one can serve the entire downstream distribution system in a more effective or an efficient way.

For hydraulic network analysis (which is usually done by software), the data on annual average daily consumption, annual maximum daily consumption and peak hour consumption on annual maximum day is required. Annual maximum daily consumption can be determined from average daily consumption based on certain standards as well as surveys Peak hour

consumption on annual maximum day is the case where the system would be stressed to the max and the most amount of water is required. The entire network should be designed to take care of the peak hour consumption at given pressure on the annual maximum day.

In case of pumping station, different pumps can be used. Some pumps could be based on average demand flow, while some could be based on a higher demand or a peak demand. In case when there is peak hour consumption of a particular peak day, multiple pumps can be run together as well. This is how entire system should be designed.

There are different kinds of pumps that are available. All kinds of pumps cannot be used everywhere. Certain kinds of pumps are used in certain situations. However, the broad categories of pumps are; displacement pumps which include reciprocating pump and rotary pump, then, centrifugal pumps, air lift pumps and impulse pumps. Usually in water supply and sewerage networks, centrifugal pumps are used wherever a pumping station is connected to a distribution network. Reciprocating pumps or rotary pumps are also found in some situations. Reciprocating pumps are used to lift water from a well or from a hand operated deep tube well. Air lift pumps are used whenever there are lot of impurities in the water that has to be lifted. Impulse pumps are used in remote areas where there is no power.

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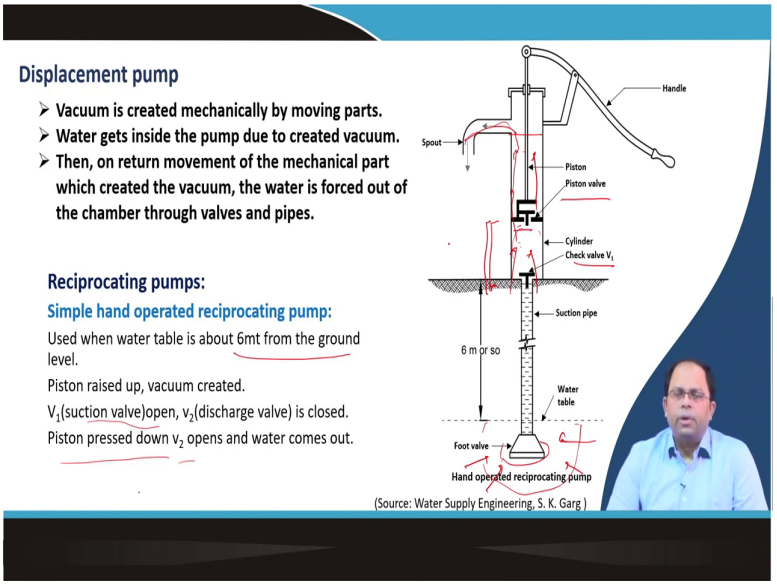

In displacement pumps, a vacuum is created by moving mechanical parts in a given direction. When the vacuum is created inside the pump, water is pushed out of the chamber. Different valves and pipes are used to control the flow of water. The mechanical pump in one stroke creates the vacuum in another stroke sends the water out of the chamber through the valves and pipes. Displacement pumps include single hand operated reciprocating pumps, power operated deep well reciprocating pump, and rotary pumps.

A simple hand operated reciprocating pump is installed when water table is at very high level (about 6 meter from the ground level) or very near to the ground. These can be installed in different localities, in the neighborhoods, and at certain locations where people can actually get water by just pumping using their hands. There are different components of this pump which includes a body, a spout from where the water comes out, a handle which is connected to a piston. When the handle is pushed up, the piston goes down.

In the cylinder made of gun metal, vacuum is created. It is where the water comes in. In addition, there are two check valves in this system which include suction valve (V_1) and discharge valve (V_2). The pipeline is put into the water table. A strainer is put at the bottom so that the water that comes in is free from sand and other kind of particles. Usually these kinds of pumps are operated first and then after certain time of operation, the sand and other particles will not come because there would be a hole created similar to wells. The water can be drawn by simple action of moving the handle or the piston.

The working of simple hand operated reciprocating pump is explained as follows. When the piston is raised up, vacuum is created and V_1 (suction valve) is open and V_2 (discharge valve) is closed. The cylinder is empty and water rushes in and get filled in the cylinder. When piston is pressed down; V_2 opens, the water goes up and comes out from the spout. Thus, the water is extracted by the upward and downward motion of the piston.

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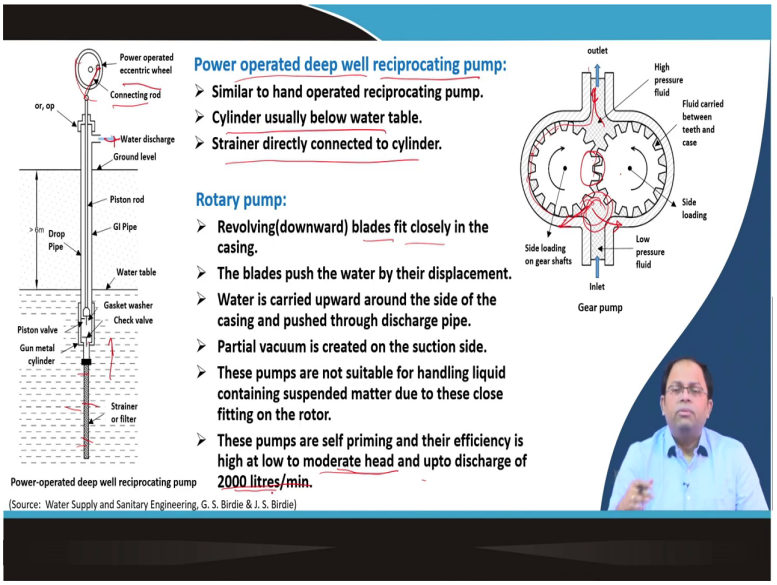

A power operated deep well reciprocating pump can be operated following the similar principles as that of a hand operated reciprocating pump.. However, in this case, the well is relatively deeper. Instead of hand operated handle, there is a piston and an eccentric wheel.This wheel is connected to a motor and the arm of the piston is connected with the edge of the wheel. Thus, when the wheel rotates, the piston will move up and down that helps in creating the vacuum in a similar way and water is drawn out of the water discharge point. This water is used mainly for irrigation and other purposes. The cylinder in this case is below the water table as compared to the hand operated pump and the strainer is directly connected to the cylinder. The entire pipe line is connected with the strainer and water gets inside through the different slots in the pipe line.

Rotary pump is another displacement pump which has moving mechanical parts that creates the suction to draw the water. In this case, there are two revolving blades that fit closely in the casing and there is seal. When both blades rotate downwards, the water is pushed by the displacement. Water is carried upward around the side of the casing and pushed through the discharge pipe. Thus, because of the rotation of this mechanical part, the water is pushed, rotated, goes up and goes out through the outlet. When it goes out through the outlet, a partial vacuum is created that ensures more water to be drawn inside.

These pumps are not suitable for handling liquid containing suspended matter. The mechanical parts are very closely fitted and if there are lot of impurities such as sand and

gravel in the water, these parts can get clogged and might break. In addition, these pumps are self priming. There is no requirement to prime because the water is being drawn from outside and their efficiency is high at low or moderate heads and up to discharge of around 2000 liters per minute. Beyond this, for a given amount of power, the work performed by the pump will be less and it becomes inefficient.

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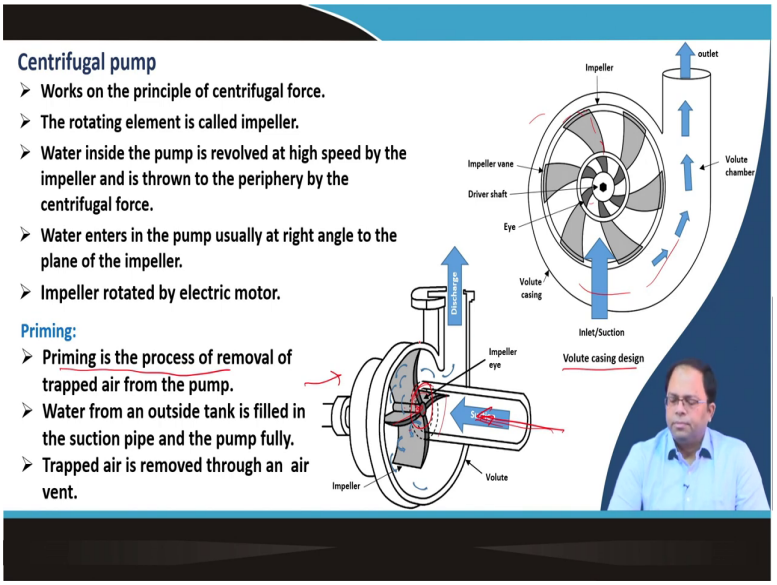

Centrifugal pumps are the most suitable and most common in water supply and sewage operations. These pumps work on the principle of centrifugal force. Water is thrown to the periphery and then pushed upwards. In the pump, there is a rotating element called impeller, impeller vanes, and a driving shaft. The driving shaft rotates the impeller at a very high speed and because of that the water that is present inside the pump is thrown to the periphery because of centrifugal force. Then it is pushed through the outlet. The water enters at right angle to the plane of the impeller through the impeller eye. Due to rotation of the motor of the impeller, water comes out to the periphery and then discharged. This pump requires priming which is a process of removal of trapped air from the pumps. Initially there is air inside the pump which needs to be removed otherwise the pump will keep on operating without suction and it will not draw water. Thus, there is a need to prime the pump by filling it with water first so that when it starts operating, it will throw the water, vacuum would be created and water would be sucked in. This is the reason why water from an outside tank is filled in the

suction pipe and the pump fully to remove the trapped air through an air vent. This requires a set up where there is a water chamber and a air realize valve through which air goes out . Every time the pump has to be started, priming is needed.

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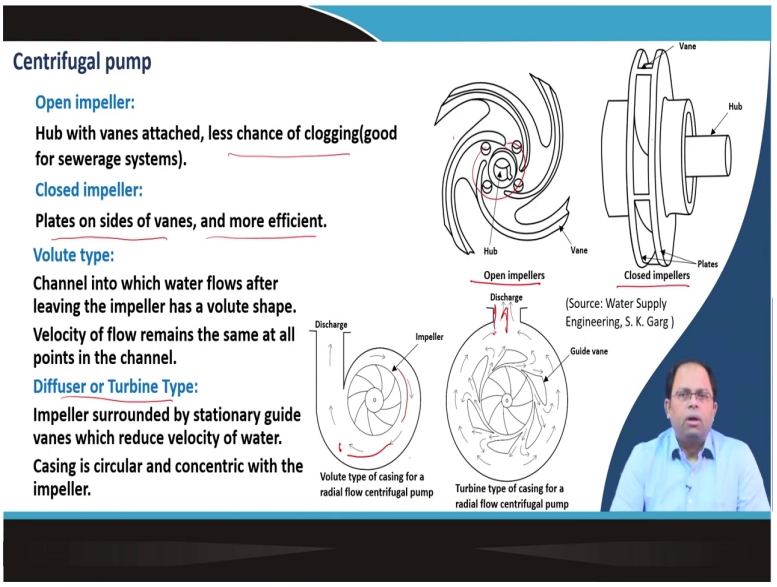

In case of centrifugal pumps, the impeller design and the casing design is important. Based on the type of impeller, centrifugal pumps are of open impeller type and closed impeller type. Open impeller type pump includes a hub with vanes attached. In addition, there is less chance of clogging, thus, good for sewerage network. During pumping of sewage, bigger particles in the sewage can get stuck in the pump and then the pump will stop operating. The closed impeller type pump has plates on the sides of the vanes and is good for water supply networks. Because of the vanes, there is some amount of protection. These pumps are more efficient because of these plates.

Based on the casing design, centrifugal pumps are of volute type and diffuser or turbine type. For volute type pump, the channel into which the water flows after leaving the impeller has a volute shape. The velocity of flow remains same at all points in the channel. The volute shape ensures that the velocity is kept constant at all parts of the channel. Diffuser or turbine type pump has the impeller surrounded by stationery guide vanes which reduce velocity of water. In this case, the casing is circular and concentric with the impeller. The vanes guide the water towards the periphery from there it is sent towards the discharge point. Each of these designs

has their pros and cons and accordingly, these are selected for water supply or sewerage networks.

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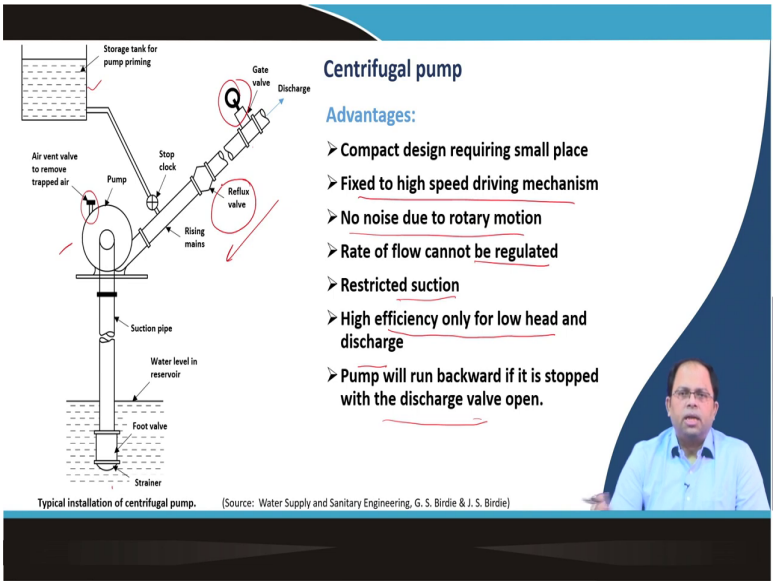

This image shows the priming set-up of the centrifugal pump which includes storage tank for pump priming and air vent valve to remove trapped air. When priming happens, this valve is open, the air goes out entirely and the water is filled from the storage tank when the stop clock is opened. The water enters back into the pump and then the pump can be operated. In addition, there are reflux valves to discourage back flow. Gate valve is also present. Without these valves, water will fall back into the pump. As the pump is at a lower level and when it is not operated, water will go back into the sump well from where it has been drawn.

There are various advantages and disadvantages of centrifugal pumps. These are of compact design and requires relatively smaller place compared to other pumps. These are fixed to a high speed driving mechanism. Thus, the motor is separate and it is fixed. In addition, there is no noise due to the rotary motion of the impeller. However, the rate of flow cannot be regulated which is a disadvantage of these pumps. Thus, there is a need to have a multiple pumps. In addition, the suction is restricted. It has got high efficiency only for low head and discharge. The pump will run backwards if it is stop with the discharge valve open. If the valve is open, it will starts running in the opposite direction. These are the different

characteristic of a centrifugal pump which one must be aware of so that one can understand its benefit as well as the challenges while operating.

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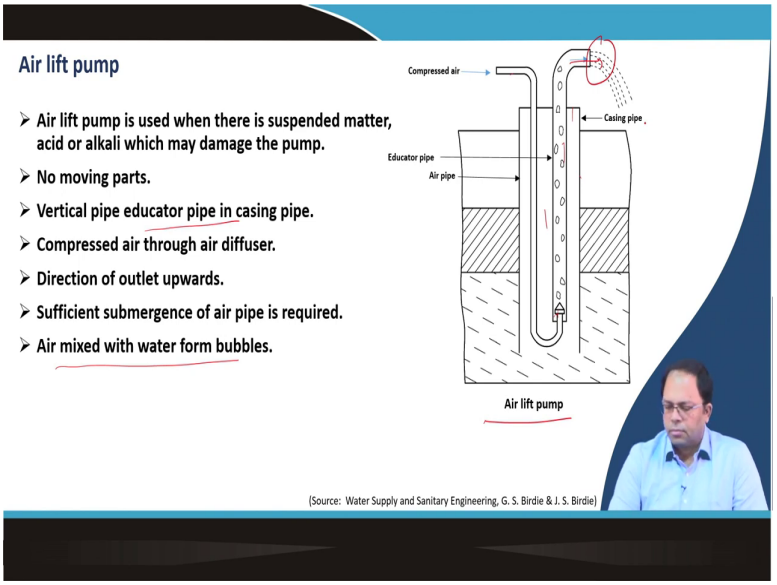

Air lift pumps are specialized pumps used in certain cases when there is suspended matter or acid or alkali which may damage the pump. The pump cannot come in contact with the water for certain mechanical parts. In this pump, there are no moving mechanical parts and there is a vertical pipe or educator pipe in casing. The compressed air is send through air diffuser into this educator pipe which is inside a casing pipe. The direction of the outlet is upwards. Pushing in compressed air pushes the water out of the discharge end. Thus, the amount of water drawn depends on the pressure of the compressed air. For this pump, sufficient submergence of air pipe is required. If the air pipe is not submerged, it will not be able to send the water out. Air mixed with water form bubbles and that is why the discharge has the air mixed with the water. Thus, the flow rate is lower than based on the size of the outlet. This has to be considered during design.

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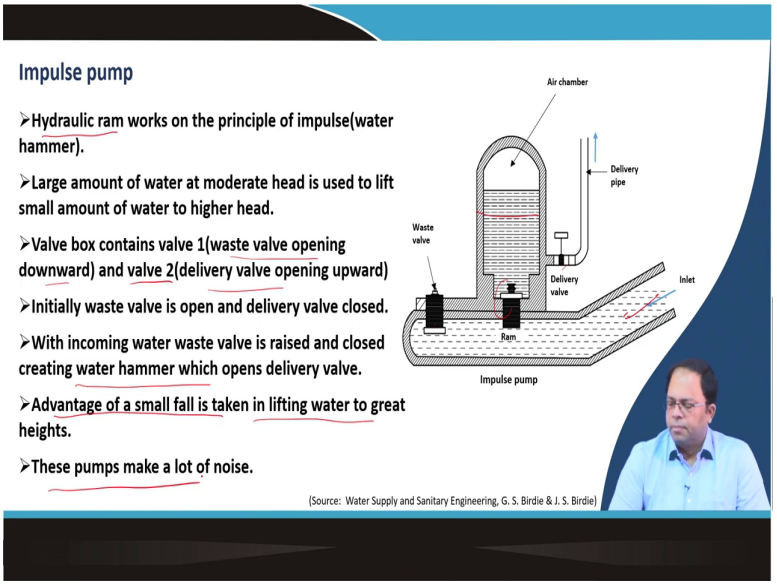

The impulse pump is a type of pump which does not requires power and it operates by pressure that is developed inside its own system. These kind of pumps are suitable for cases when large amount of water at moderate head is used to lift small volume of water to higher head. Thus, if there is some amount of water at a small head at a given pressure, it can be used to lift small amount of water to a higher head. It works on the principles of this impulse pump or a hydraulic ram. The hydraulic ram works on the principle of water hammer. Whenever there is change in the pressure or there is stopping of operation of the pump, water hammer builds inside the pump that creates large amount of pressure.

There is a valve box containing valve 1 which is the waste valve opening downwards and valve 2 which is the delivery valve which opens upward. Initially, waste valve is open and the delivery valve is closed, the pressure gradually builds up. Followed by this, the waste valve is shut and it is raises up, it creates the pressure. With incoming water waste valve is raised and closed creating water hammer which opens the delivery valve. Because of the air chamber, the air is being pressed that results in opening of the final delivery valves through which the water is sent out. When the water is sent out, automatically the pressure is released and this valve again falls back. The entire cycle repeats and happens very fast. This ensures a steady flow of water coming out of these kinds of pumps. In these pumps, advantage of a small fall is taken in lifting the water to a greater height. This is the basic working of an impulse pump.

One disadvantage related to these pumps is that these make a lot of noise. One has to be aware that if impulse pump is used, it will not require power but it will make a lot of noise.

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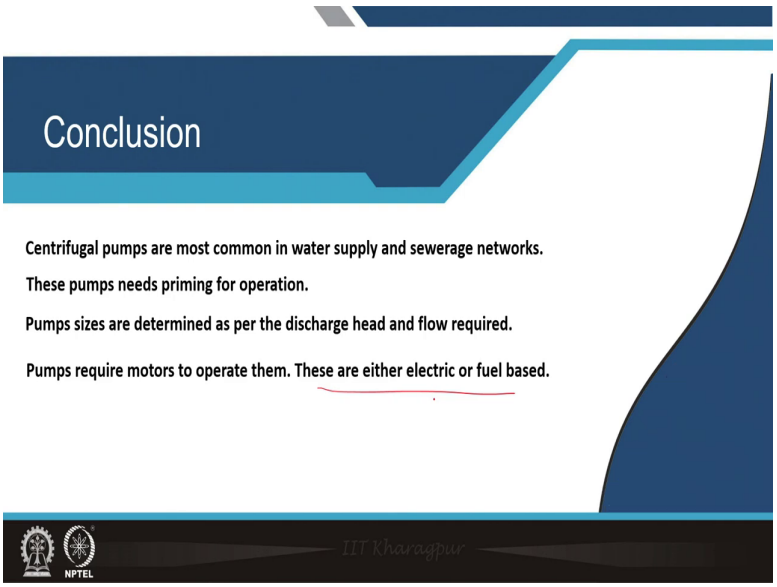

To conclude, centrifugal pumps are most common in water supply and sewerage networks. These pumps need priming for operation. Pump sizes are determined as per the discharge head and flow required in a given network. These requires motors to operate them and these are either electric or fuel (gasoline or diesel) base. The maximum amount of operation and maintenance cost in a water supply network is 50 to 60 percent which is because of operation of the motors for running of these pumps.

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These are the references that can be utilized for further readings.