Principles and Practices of Process Equipment and Plant Design

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Module - 05
Lecture - 61
Process Utilities

Hello, good day to you all. So, we are going to talk about the Process Utilities today. And we will have an idea that how much important the process utility is like the supply of power, steam, compressed air and similar things are important for any process design.

And the process design must have an idea about these; because he is going to utilize all these in his main process. And at times generation of these utilities also belong to the responsibility of the process engineer wherever possible and wherever feasible. To start with let us have a list of the utilities.

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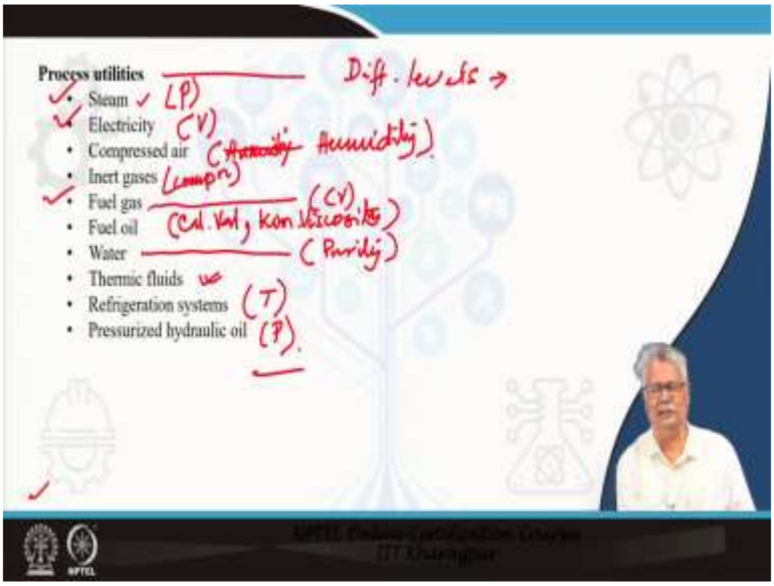

The first and foremost thing is the steam. The steam normally is either generated in a boiler or is used in various processes generated from different waste heat streams, which maybe available within the process itself. You will notice one thing in case of any process utility, there are different levels.

In case of steam, naturally the differentiation is done by the pressure. In case of electricity, it is as per voltage; in case of compressed air, it is primarily humidity, I will tell you later on why humidity is important. And then naturally you have inert gas; in case of inert gas what is important is basically the composition.

In case of fuel gas, it is again the calorific value which naturally is of importance. The same thing is in case of fuel oil also; that means a calorific value is important. But at the same time, the kinematic viscosity is also important; we will know why it is important in case of fuel oil.

In case of water naturally, there are different types of water which is used in the process; it could be raw water, it could be demineralized water. So, naturally I will put it here as the purity and there are different tests for purity we will talk about as we go on. In case of thermic fluid, there are different thermic fluids which are used for heating or cooling a system, like dowtherm or it could be some other thermic fluid also which is available commercially.

You have refrigeration systems, in case of refrigeration system normally what you talk about is the temperature of the refrigerant; you have pressurized hydraulic oil system, which definitely the major parameter is P. So, all these utilities are used usually within a plant; if it is a large plant, there will be different levels of these process utilities.

Some of these are generated from the waste energy which is available, for example steam. If you have cogeneration, it could be electricity also. Compressed air normally require compressors, inert gas usually you have inert gas generators. Fuel gas often part of it is generated within the process itself. Fuel oil it depends; if it is a refinery, the fuel oil will be entirely supplied by the refinery itself, because fuel oil is the refinery product as well. So, but I am not counting the fuel oil here.

Water naturally has to come from a source, thermic fluids are usually bought out items, refrigeration systems are run by powered in most of the cases, and the pressurized hydraulic oil is also a similar thing.

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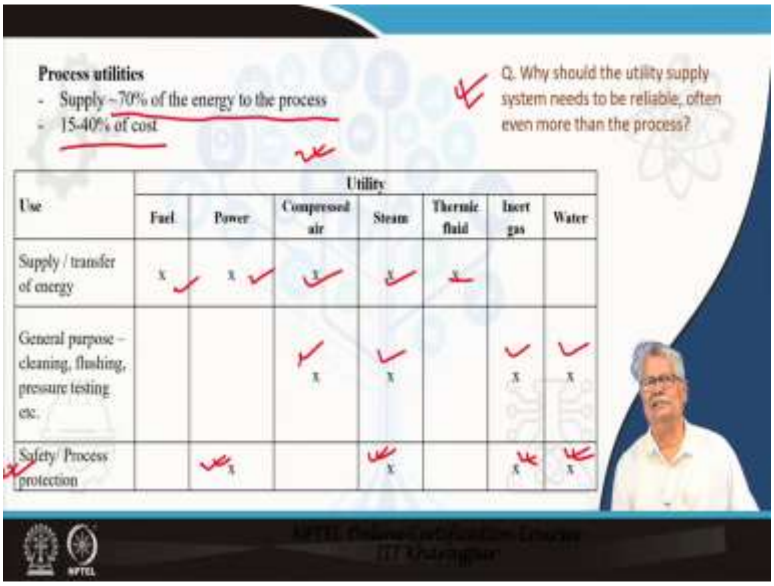

Let us look at the different utilities and their utilization. And before that, let us see and realize that in a process roughly 70 percent of the energy passes through the utility system to the process. That means it could be fuel, it could be steam, it could be power, whatever is the energy supply to the process, approximately around 70 percent of the energy passes through the process utilities.

And these utility systems they are quite expensive, in fact we do not realize and think that it is an auxiliary support system for the main process; but roughly about 15 to 40 percent of the cost is involved in this.

Now, I have got a question for you, why should the utility supply system need to be reliable often even more than the process. that means you must have a very reliable utility system, utility supply system. The reason is very simple. If you look at the use of utility which is given in the table below; let us have a look at it, you will be getting your answer yourself.

Except water and inert gas, all the utilities are used for supply or transfer of energy. So, quite naturally this accounts for roughly about 70 percent of the energy transfer. The general purpose cleaning, flushing, pressure testing etcetera is done with compressed air, sometimes with steam, sometimes with inert gas. And quite often for pressure testing or pressure vessel, it is water which is used.

You will also note power plays a very important part in adding safety. Like plenty of the engineered safety is through systems, which involve power and which require a supply of power. The same thing is true in case of steam. For example, in case of fire, you require the fire to extinguish and particularly if it is a oil fire, in that case extinguishing it with steam is what is done. So, it must be available to you from the standpoint of safety as well.

The inert gas is often used to drive out combustible gases in any enclosure. And quite naturally, so there is a contribution to the safety from the inert gas also and water that is for firefighting everyone knows it. So, by this time you must have got the answer to your question that, in order to have safe operation of a plant it is essential that specifically these four components, rather these four utility component should have a reliable supply. Often more reliable than the process itself.

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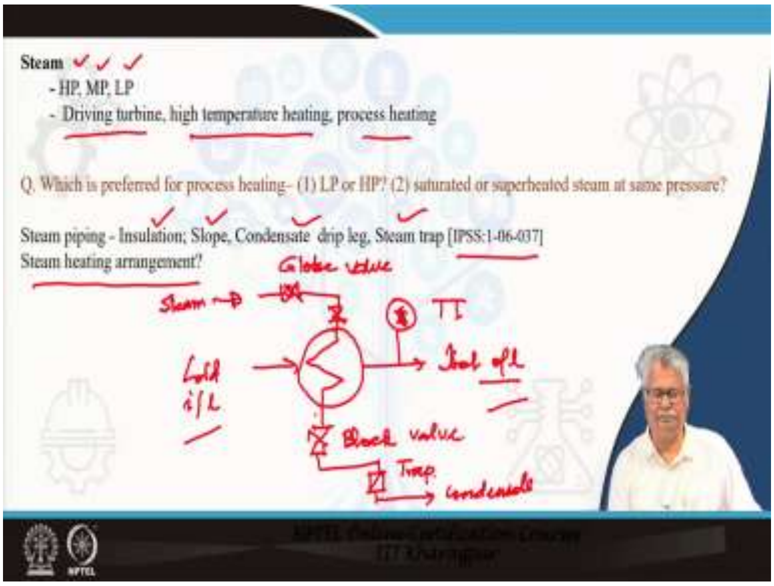

Now, we look into the details of individual components of these utilities. I mentioned that you will be having steams of different pressure ratings; typically high pressure, medium pressure and low pressure. Driving turbine normally will be done by super heated high pressure steam.

High temperature heating often will be done by medium pressure steam; when you really require a high temperature and you cannot do with low pressure steam in that case, and normal process heating is definitely done by low pressure steam.

So, you know now what are the major uses of these, these are only indicative. It is also to be kept in mind that, normally all these steams will be transported in a super heated state. Why super heated? Because in your pipes which carry these steam there will be heat loss.

If you supply it with a saturated steam right at the beginning, there will be condensation inside which you do not want. So, what is done typically is, it around say 30 to 50 or sometimes 70 degree superheat is present in the upstream of these steam headers.

Obviously your steam piping must have insulation. It must have a slope, because whatever condensate forms should be carried forward typically 1 in 100 or; sorry it is 100 centimeters and 10 meters. You must require it provide condensate drip legs, there has to be steam traps. We talked about stream traps earlier and typically here is the standard which is used in our steel industry for the steam trap.

You require for a steam heating arrangement naturally, an arrangement something which will be looking like this; you will be having your steam heated exchanger. This will be the tube, it will come here, you will have a an isolation valve, then it will be coming to a, this will be your condensate, this will be the condensate trap, this will be a block valve which is nothing, but a gate valve for the isolation, the same thing will be there upstream.

But possibly in order to regulate the temperature of whatever is getting heated from here, you will require a temperature indicator here and how much of heat will be going will be regulated by the inflow of steam through a globe valve.

So, this is typically what you find here; in case this is basically a temperature indicator. So, and this is the cold inlet and this is the hot outlet after heating basically of the same fluid. So, this is what you expect to find whenever you are having a steam heating arrangement for any steam which is cooled and it is getting heated to a final hotter temperature.

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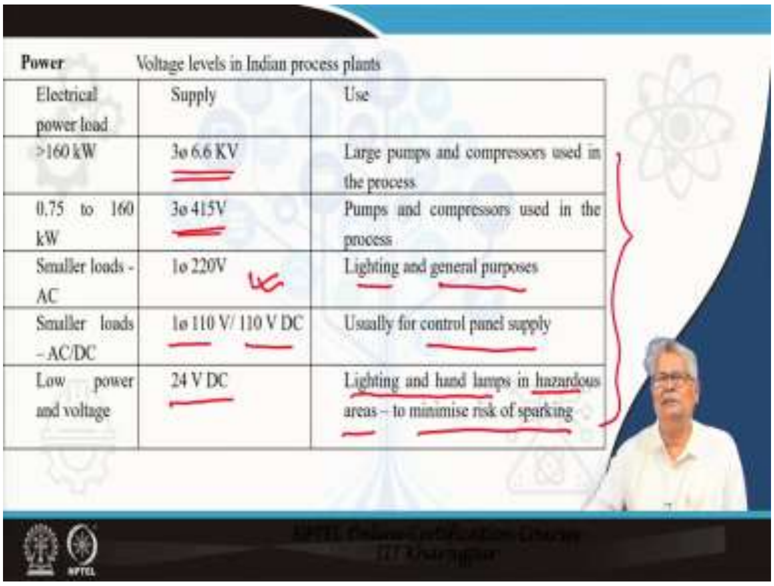

The next item that we had listed is power, electrical power; typical voltages of supply vary a lot. The most common one which we use domestically is single phase 220 volt. It is used for lighting and the general purpose, may be a fan as well. Most of the industrial pumps, they are 3 phase motor run. So, it will be 3 phase 415 volts. The pumps and compressor draw much higher power, so naturally you require a 3 phase supply.

The large pumps and compressors draw even more power. So, they are supplied with 3 phase 6.6 KV motors. So, those are the loads; you can see the corresponding load keeps on increasing as you go up. You will normally have in a large industry, some amount of single phase 110 volt; because quite a few particularly American instruments they require this particular one single phase 110 volt supply for their control panel.

Similarly, you may require 110 volt DC for the control panel some of the instruments. It depends basically what control pan, what type of control panel instrumentation you have and normally the control panel supply will be 110 volt single phase or 110 volt DC. Or it could be a combination; some will be using one, the others will be using the other two option.

You normally in an in any hazardous plant, particularly which handles inflammable material, you have a 24 volt DC supply. This is primarily for lighting and hand lamps in the hazardous areas, this minimizes the risk of spark. So, we realize one thing that, you will have to select your different levels of power depending on what exactly are the requirements in your field.

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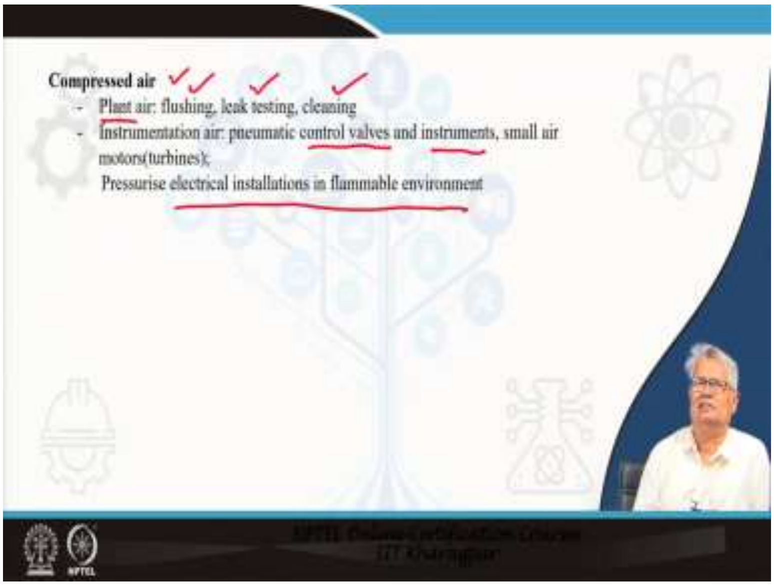

The next utility is compressed air. You usually have a supply of compressed air which you call plant air, which is used for flushing of vessels and pipelines. It is also used for leak testing; the most common way to test a leak in a pipeline, in a within the plant itself is to pressurize.

Use soap solution at the junctions and see whether there is any soap, any soap bubble which is forming due to the compressed air leaking out from there. This identifies the location of the leaks you tighten or you weld whatever you want to way you want to repair your leaks, you do it. Plant air is often also used for cleaning, it is another term for flushing you can see.

Now, you require instrumentation air for your instruments. Traditionally the control valves have been used, have been powered by pneumatic power. The main reason for this is safety. If you have, you definitely do have electrical control valves, but the process industry traditionally has been using pneumatic control valves, because they do not produce or do not have any scope of producing a spark. And they are thought to be very safe, in fact they are.

Quite a few of the pneumatic instruments, in fact all of the pneumatic instruments will be require the newer instrumentation air supply. Small air motors like turbines are also used for certain handheld instruments at times or sometimes even for installed equipment; like in furnaces you have suit blowers driven by air motors or air turbines whatever you may call it.

You have an arrangement of making electrical installations in flammable environment safer by enclosing them and pressurising with a small supply of instrumentation air. Through all the leakages present, it leaks out; but the inside pressure naturally is more than the ambient and the ambient inflammable environment cannot intrude inside.

So, that makes such enclosures safer against any electrical spark and its contact and generating disastrous situations in a flammable environment. Typically the plant air if you and the instrument air, there is not much of difference, let us see.

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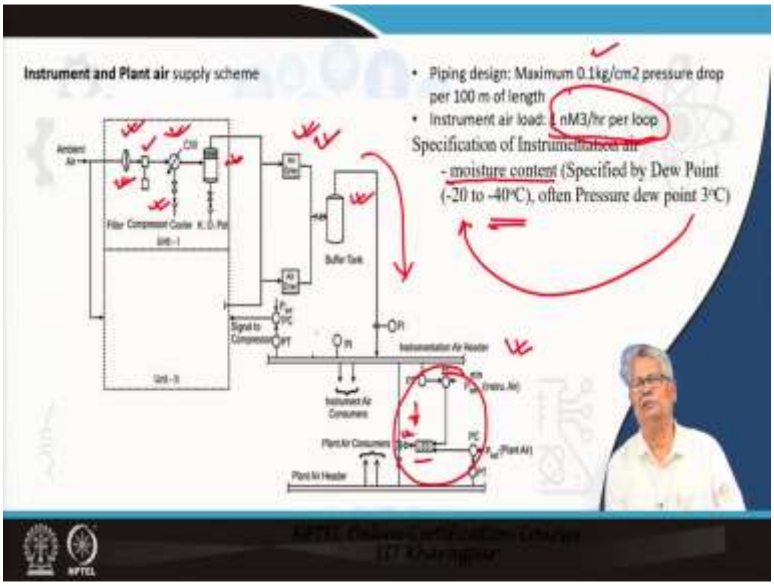

Here is a typical plant air supply scheme. If you are talking about any fairly large chemical complex, it will have its own instrument and plant air supply. And if you look at the quality of these, the difference of these lies mostly in the moisture content.

Now, the moisture content that can be tolerated by the pneumatic instruments is rather low, it is specified by the dew point. Typical dew point is specified as pressure dew point. That means if 6 kg per cm square is your supply pressure, in that case the your client may say that I want my instrument here to have at this operating pressure a dew point or 3 degree centigrade. Which typically turns down to around minus 20 to minus 22 degree centigrade at 1 atmospheric pressure.

Similarly, in cold climate and there are plenty of manufacturers abroad, who insist on the atmospheric dew point to be minus 40 degree centigrade. In fact this is very very common in the refining industry, all over the world almost. Whenever you are talking of instrument or plant air, you definitely as a designer, you are also required to estimate what will be the consumption of the instrument and instrument air particularly, the. For estimation normally it is taken as 1 normal meter cube per loop.

So, if you have 50 numbers of loops in your panel, so you will be you have to provide for 50 normal meter cube per hour supply of instrument air and normally at least 50 percent or at times you have you are supposed to give 100 percent excess; because to keep to provide for the future expansion and losses.

These compressed air lines are designed with maximum of 0.1 kg loss in pressure per 100 meter of length. Obviously you do not go for the exact size of your pipe diameter, you go for the next commercially available size.

The system if you see, the ambient air passes through a micron filter, it is basically a felt filter; then it goes to the compressor, then after compressing it is cooled with cooling water. Naturally you have a drain for whatever moisture that condenses in this particular vessel. Then it goes to a knockout drum or a knockout pot whatever we may call.

Then it goes to an air drier, which could be filled with either silica gel or alumina adsorbent for moisture. Then it goes to a buffer tank; the buffer tank, if your supply pressure is something around 7 kg or 8 kg, your buffer tank pressure will be a kg more and naturally from there the supply comes to the instrument here.

The plant air often is taken as a part from the instrument air, because the requirement of plant air may not be continuous. But one thing is there, you have a special control arrangement to ensure that, instrument air since it have to be prioritized over plant air.

In case the pressure in your instrument air header falls, the supply of plant air as a as from the instrument air header gets stopped by closing of this valve. So, you have a low selector switch here. So, that is a part of the instrumentation that you normally have.

So, what I would like to say here is typical air pressures will be around 6 to 8 kg per cm square. The basic difference between instrument air and plant air is, the plant here requirements are usually intermittent; instrument air is free of any dirt particle, which is definitely due to this micron filter, which is the felt filter. And it is the drier which reduces the moisture content and brings it to the specified dew point, either pressure dew point specification or the atmospheric dew point specification.

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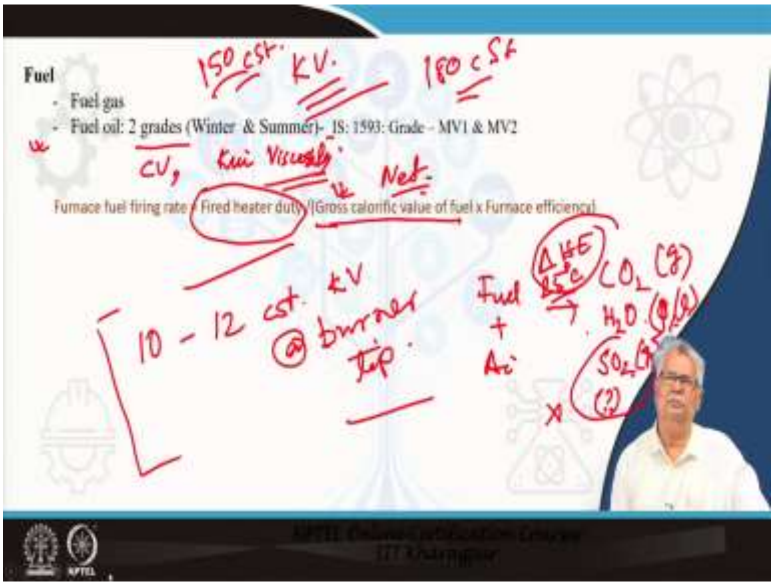

Beyond this we had supposed to look for the fuel. In India, let us look at the fuel gas first. In India there are typically 2 grades of fuel oil. And I mentioned earlier that there are two things naturally we are interested in the calorific value, but we are also interested in the kinematic viscosity as well.

It is very important, because the fuel oil in order to burn at the tip of the burner needs to be atomized. And most of the burners require typically 10 to 12 centistokes kinematic viscosity at burner tip, which could be achieved by preheating the fuel oil or it could be achieved even by using steam as the atomizing medium.

So, depending on what you have, you definitely be using the fuel oil or the proper grade and the winter and the summer grade primarily differs in two things. It differs in two properties, one is kinematic viscosity, quite naturally kinematic viscosity limit at 50 degree centigrade, during summer is 180 centistokes, during winter it is 150 centistokes.

And there is a difference in port point also, that is because primarily the fear of congealing. The grades of the values for the specification of port point, they are different in winter and summer.

Now, how to estimate the furnace fuel firing rate? When you do your process design, you have found out what is the heat duty required in your furnace. This is divided by the gross calorific value of the fuel. See whenever you are talking about a fuel, upon its complete combustion, if it will contain some amount of hydrogen.

So, what I say is, from the fuel and air after combustion what you get is basically ideally carbon dioxide, moisture and possibly some amount of sulphur dioxide if there be some quantity of sulphur in it, I am assuming here a hydrocarbon is the fuel.

Now, this is going to be a gas, this could be a gas or a liquid phase; this definitely will also be a gas, well let us forget about this for the moment. So, depending on whether the product moisture is gas or liquid the delta heat of reaction which is report, heat of reaction which is reported at 25 degree centigrade will be different.

So, if you consider this product moisture, a product water to be liquid, you will be extracting more amount of air. So, the there are two definitions of the gross of the calorific value; one is the gross, the other is the net calorific value. And you are supposed to use the gross calorific value here in this case, which considers C O 2 (Refer Time: 23:27), which continues H 2 O produced from this combustion as gas. So, that you extract less amount of heat from it during your estimation.

Now, regarding fuel gas, most of the cases in Indian situation it is going to be either LPG vaporized or it is going to be natural gas in this case. There are some cases where you may have a coal gas supply or methane supply which is cold made methane, which could also be used. And what is important in that particular case is certainly the calorific value. And the moisture content is also definitely important, but as long as everything nothing condenses, you are happy.

In fact fuel gas is a very clean fuel and wherever you are required to heat something, where you cannot have; I mean where there is a chance of having contact with your combustion system and the process, an example of this is a glass furnaces. You use fuel gas and this fuel gas could be from the source could be from coal, coal gas or producer gas or it could also be the natural gas, it could also be LPG which is vaporized and used as fuel.

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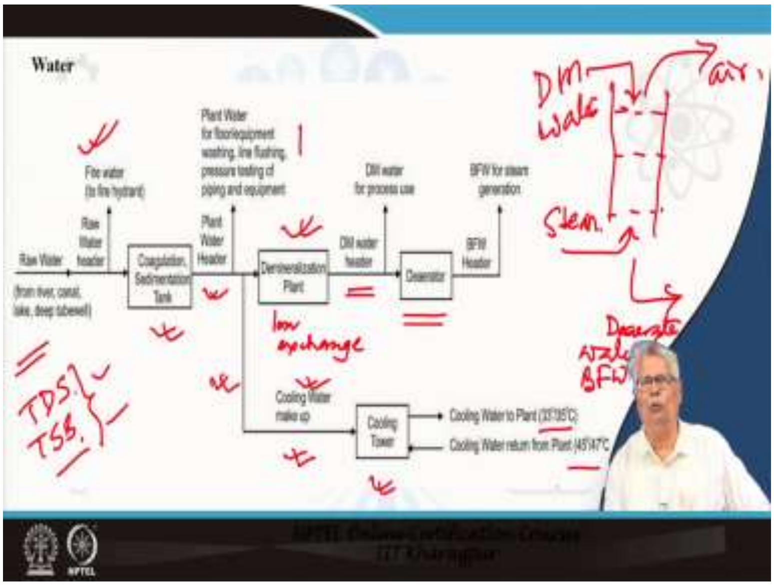

Now, comes a very important thing, all industries will be using water. The water will be coming from in the form of raw water from the river, canal, lake, tube well what could be whatever could be the different sources. Now, there is one thing which is very difficult in case of water; that is they will contain some amount of solids, there will be total dissolved solids and total suspended solids.

So, the quality of raw water is primarily defined by the quantity of TDS and the TSS which is present. Water is used for firefighting which can use this water directly. So, naturally you have a fire water header network to which it will be pumped. You will definitely have to reduce the TDS and TSS in a coagulation and sediment and the sedimentation tank.

After sedimentation is over and the TDS and TSS reduces; in fact TDS does not reduce much, TSS gets reduced a lot. You may have a small sand filter, from which you will be getting the supply. And from here your plant water will be sent to the different plants, mainly for floor and equipment washing, line flushing and sometimes for pressure testing also.

Now, if you use this directly for steam generation; the steam generation heatings are the boiler heating surface will get coated with the deposits, which is due to the TDS and TSS present there. The TSS is very nominal, but in that case the TSS there that is dissolved solids will get deposited and it will found your heat transfer surfaces. So, they are to be removed.

So, they are sent to a demineralization plant and what you produce is a DM water or demineralized water. How is this done? This is mainly done by ion exchange. Typically you will have an anion exchanger, a cation exchanger, and a mixed exchanger bed. So, it will be passing through these in sequence and the DM water will be taking out and normally whatever process requires water, you supply dm water only.

Then what you do is, you have to use it in your boiler, your; DM water still contains dissolved air. If you use dm water directly which contains the dissolved air, the air will be liberated along with your steam generation. So, you will have a non-condensable present along with your stream, which you do not want.

So, you provide a deaerator, the deaerator is nothing, but a stripper. They deaerator is basically a stripper column, often with about 4 to 6 trays, these are perforated trays. You will have the DM water coming in from the top and you put here stream and the water is taken out, this is your deaerated water or boiler feed water.

So, your stream takes out any dissolved air which may be present here. So, this is basically the water scenario in any large plant. The upstream of DM water you also have a tapping, which is for the cooling tower makeup. Your cooling tower will be cooling, the hot cooling water by vaporizing a part of it and it will also have a part. So, you will definitely have to make it up and this is the stream, which makes it up.

Typical cooling water supply is at a pressure of around 5 kg per cm square, the return pressure normally is lower by about 2 kg; that means the delta p between these two is around 2 kg usually. And in Indian condition, the cooling water we have said many times is usually available at 33 or 35 and is to be returned at a temperature not exceeding 45 to 47 degree centigrade. Why it is? We have talked earlier, definitely in your earlier classes.

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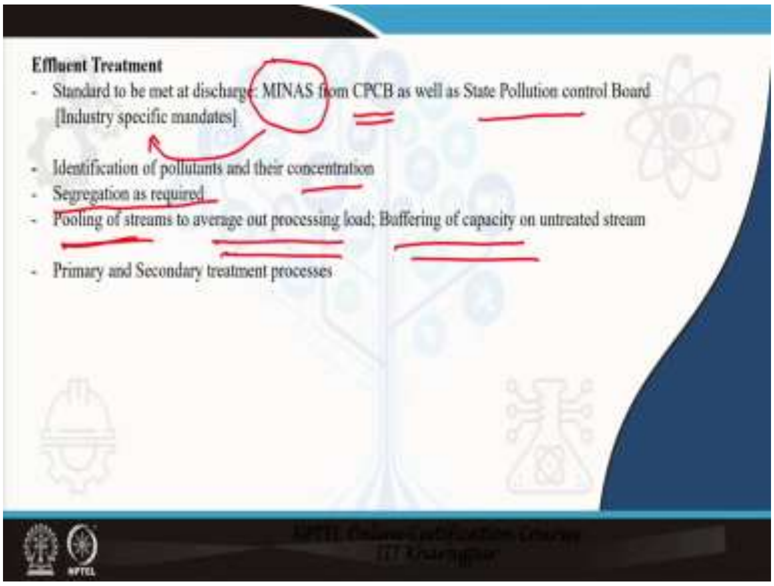

At the end before I conclude and talk about the, in fact I have spoken about the utilities in very brief; but your plant design is never complete until and unless you have handled all your effluents, any process will generate effluent. Right now I am talking about the liquid effluent which is mostly aqueous.

It is essential for you to know that before you discharge any liquid effluent or even a gas effluent, you must meet the norms and these norms are set by Central Pollution Control Board as well as the state pollution control board. I have written here an acronym, MINAS which is with stands for Minimum National Standards; it is for minimum national standards.

You can go to the CPCB side, have a look at the MINAS, in fact I strongly ask you to do so. Where you should look into industry specific mandate; that means the maximum limits of concentration or that amount of discharge they are all specified in a MINAS and the many of these are industry specific.

Now, we talk about the treatment in just two lines. In order to decide on the effluent treatment, you have to identify the pollutants in your process and their concentration. You may have to segregate the streams if required. An example of this is, in a refinery you have streams which are contaminated with oil and there are streams where there is no oil in it, no hydrocarbon in it.

So, they can be treated segregation and only the stream which is, only several streams which are contaminated with hydrocarbon, maybe pulled together and treated for hydrocarbon removal. You will always have, and you will always require poolling in order to average out the processing load. That means one stream contains a very high concentration of a particular pollutant, whereas the same thing could be low in another stream.

So, if you mix them your in, your concentration which is reaching your effluent treatment plant will average out and it will get lowered. Similarly, buffering of capacity on untreated system is also there. At times I mean you will find that normally in your effluent system, the generation rate could be diurnal, it could be different in different weather conditions also; if it rains, your effluent is much more.

So, quite naturally you if you have a buffered capacity of storing your untreated stream, where you can accumulate and reprocess that particular stream, when your capacity utilization is effluent treatment plant is lower.

Similarly, after you have decided on the segregation of the pollutants and the streams; you have to decide on the primary and secondary treatment processes, which are usually specific to the pollutant type present in your plant.

I think, with this I have been able to give you an overall idea of the utilities and I have added a little bit more; just mentioned you can say about the effluent treatment requirement of process plants. With this I stop here today.

Thank you.