Plant Design and Economics
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Lecture No-06
Selection of Process Equipment

Welcome to module 2 of a plant design and economics. This is lecture 6, in this week; we will talk about selection of process equipment, utilities, plant location and layout. Today is the first lecture of module 2 and in this lecture we will talk about how to select process equipment.

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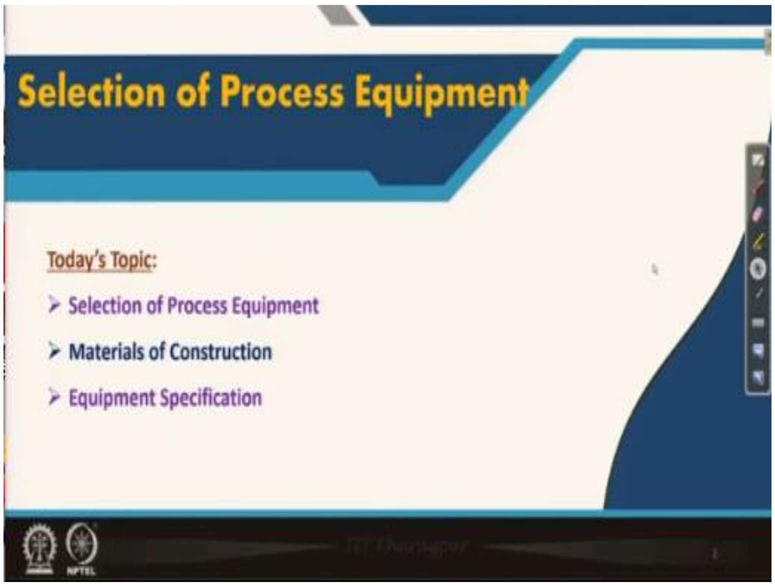

So this is today's topic; selection of process equipment, materials of construction and equipment specification.

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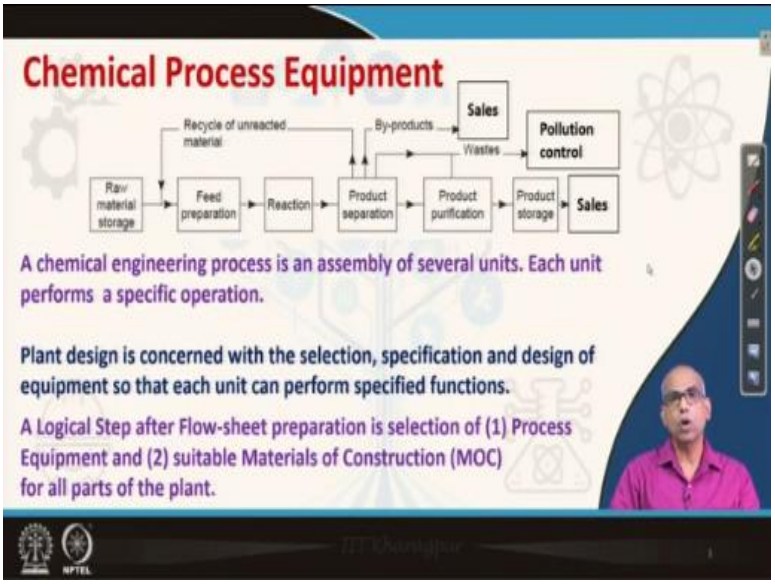

What you see is a schematic of a typical chemical process represented in terms of functional blocks. So, first block represents raw material storage, then feed preparation, feed goes to reactor for reaction. Then the inference from the reactor goes to product separation. Part of separated products is recycled back; the un-reacted material is recycled back. The by-products are taken out and the saleable by-products are send for sales.

The product is purified, those goes to pollution control and the purified product is stored for sales. So what you see is a chemical engineering process is an assembly of several units. Each unit performs a specific operation. Plant design is concerned with the selection specification and design of equipment, so that each unit can perform specified functions. Once you have prepared the flow sheet diagram the logical state after that will be the selection of process equipment and suitable materials of construction for all parts of the plant.

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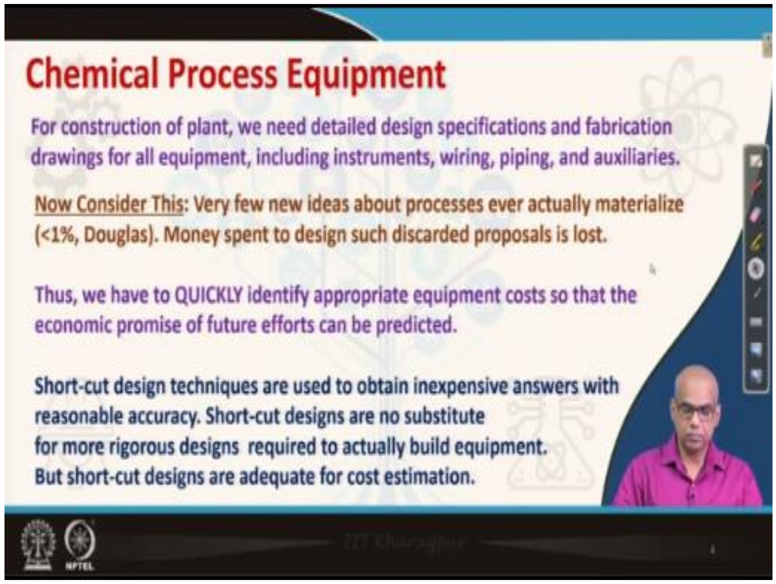

For construction of plant, we need detailed design specifications and fabrication drawings for all equipment, including instruments wiring, piping and auxiliaries. So we need to have very detailed design specifications for all equipment and auxiliaries. Now experience tells us very few new ideas about processes ever actually materialize. According to James Douglas this number is less than 1%.

So you can well imagine that money spent to design such discarded proposals is lost forever. Thus we have to quickly identify appropriate equipment cost, so that the economic promise of future efforts can be predicted. So, that will tell us whether to go ahead with the new proposal or not. Shortcut design techniques are used to obtain inexpensive answers with reasonable accuracy. Remember that, shortcut designs are no substitute for more rigorous designs required to actually build equipment, shortcut designs are adequate for the purpose of cost estimation.

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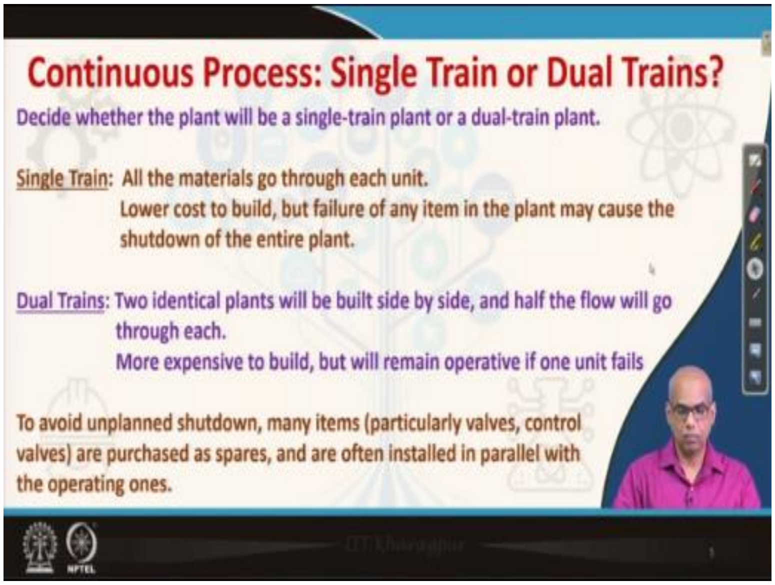

In the very beginning of your selection of equipment you need to decide whether the plant will be built as a single train or dual train, when you are going to design a continuous process. A single train plant means that there is no duplication of units. There is a single sequence of units and all the materials go through each unit. It is low cost to build but you can imagine that failure of any item in the plant will cause the shutdown of the entire plant.

For dual trains there will be two identical plants built side by side, and half the flow will go through each. It will be something like two trains in parallel. So, obviously, it will be more expensive to build but one we need will remain operative if the other one unit fails. So, that is an advantage, so these advantages come with higher cost to avoid unplanned shutdown many items particularly valves control valves are purchased as spares and often installed in parallel with the operating ones.

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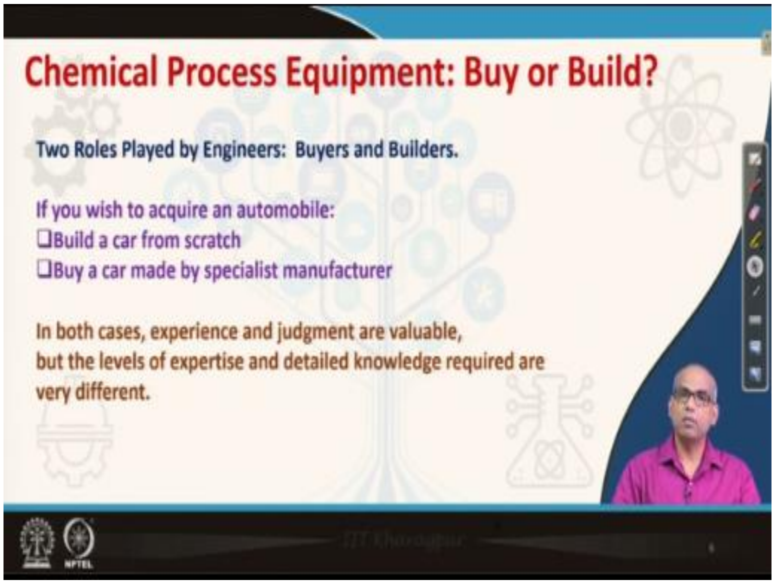

Now when you are going to select process equipment, a question will arise whether to buy the equipment or build the equipment both the roles are played by engineers. Engineers are buyers of equipment; engineers are builders of equipment as well. Imagine a case, you wish to acquire an automobile you have two options; you can build a car from scratch or you can buy a car made by a specialist manufacturer.

What will we do? Will depend on which company work with. For example, if you are working with an automobile company and you are in the charge of designing a car, you will build the car from scratch. Otherwise, you can buy a car made by a specialist manufacturer. In both the cases experience and judgment are valuable but the levels of expertise and detailed knowledge required are very, very different.

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Now, let us be familiar with certain terminology; Cookers, Coolers, Economizers, Kettles, Preheaters, Reboilers, Superheaters, Thermosyphons, all are heat exchangers and they are often identical in designs. Fume collections, Stripping, Scrubbing, Humidification, and Fractionation, all are carried out in packed towers or tray towers. And these towers, you know as distillation columns or absorption columns as you have studied in mass transfer courses.

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A large number of chemical process equipment found in chemical engineering Catalogs can be combined into a smaller set of generic groups. These groups for example may be evaporators, vaporizer, conveyors, crushers, millers, grinders, furnaces, gas movers, compressors, gas solid contacting equipment, heat exchangers, mixers, etcetera. So there may be several equipment which are using in industry like coolers, heaters, furnaces etcetera all may come under heat exchangers.

Furnaces will be put separately but you have coolers, you have heaters, you have economizers etcetera as you have seen in our previous slides. Now it is important to be familiar with these generic groups as well as the equipment that come under these generic groups. Then it will be easier for us when you select a particular piece of equipment for our purpose. The other set of groups; process vessels, pumps, reactors, separators, size enlargement equipment, storage vessels.

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Now, broadly there are two types of equipment that are used in chemical process industries. We call them proprietary equipment and non-proprietary equipment. Proprietary equipment are designed and manufactured by specialist manufacturers and sold as standard catalogue items. For example, pumps, compresses, filters, centrifuges, dryers etcetera. What is non-proprietary equipment are designed specifically for particular process.

These are custom built for a company by specialist fabricators. Examples are reactors, distillation columns, heat exchangers etcetera. So proprietary items are like standard equipment, whereas non-proprietary equipment are special equipment. So if you are not working with Automobile Company who is in charge of designing a car, you will buy proprietary equipment. If you are not working with specialist equipment manufacturers a chemical engineer is not normally involved in the detailed design of proprietary equipment.

So again with the analogy of that building a car or buying a car if you are not working with automobile company we will design a car. You will buy from the standard manufacturer of the curve. So chemical engineer who is not working with equipment manufacturers will not normally be involved in the detailed design or proprietary equipment because the proprietary equipment are standard equipment and you can buy it as off the shelf items. It is like you go to market and buy a piece of equipment.

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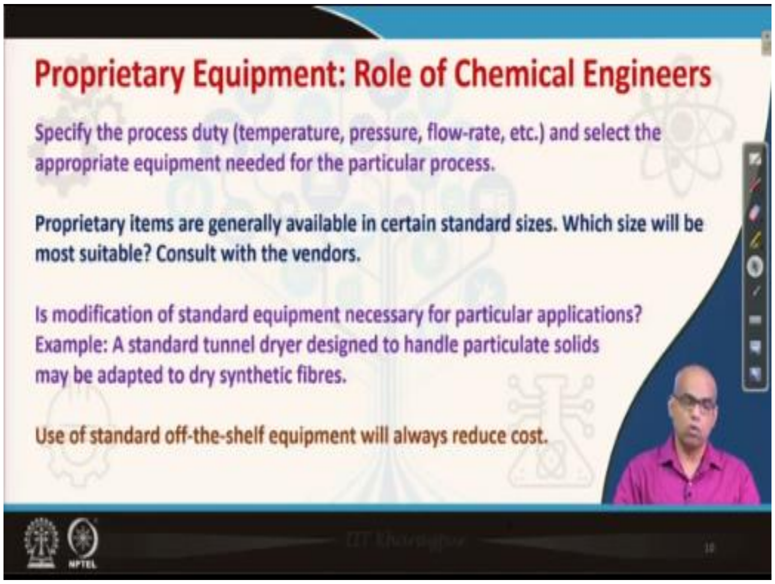

So, if you are not working with the company who manufactures equipment then what will be your role as chemical engineer for selecting proprietary equipment? You have to specify the process duty, such as temperature, pressure, flow rate, etcetera and select the appropriate equipment needed for the particular process. Proprietary items are generally available in certain standard sizes. So you have to decide on which side will be most suitable for your process.

Perhaps you need to consult with the supplier of that property equipment for this purpose. You may also have to think whether any modification of standard equipment is necessary for the particular application, you have in hand. For example a standard tunnel dryer which has been designed to handle particular solids may be adapted to dry synthetic fibers. So you have to talk to the vendor or the supplier of the equipment, whether there is any scope for such adaptation or modification of standard equipment.

So that it will be useful for your particular application in hand. Remember use of standard off the shelf equipment will always reduce the cost.

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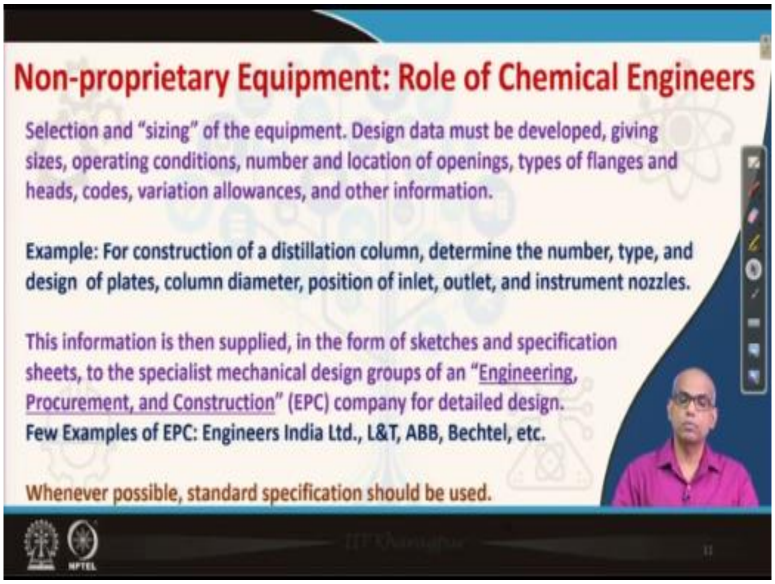

For non-proprietary equipment, the role of chemical engineers will be selection and sizing of the equipment. You have to develop detailed design data giving sizes, operating conditions number and location of openings, types of flanges and heads, variation allowances and other information. For example for construction of a distillation column, you have to determine the number of plates, the types of plates, the design of plates, the diameter of the column, the position of inlet nozzle, outlet nozzle and instrument nozzles.

You have to specify the basic control loops; this information is then supplied in the form of sketches and specification sheet to the specialist mechanical design groups of an engineering procurement and construction company for detailed design. Engineering Procurement and Construction Company which are known as EPC Company will take the specification from you and will perform detailed design.

There are several such companies some of the popular companies you may be familiar with are

Engineers India limited, L and T, ABB, Bechtel, etcetera. Remember again whenever possible standard specifications should be used.

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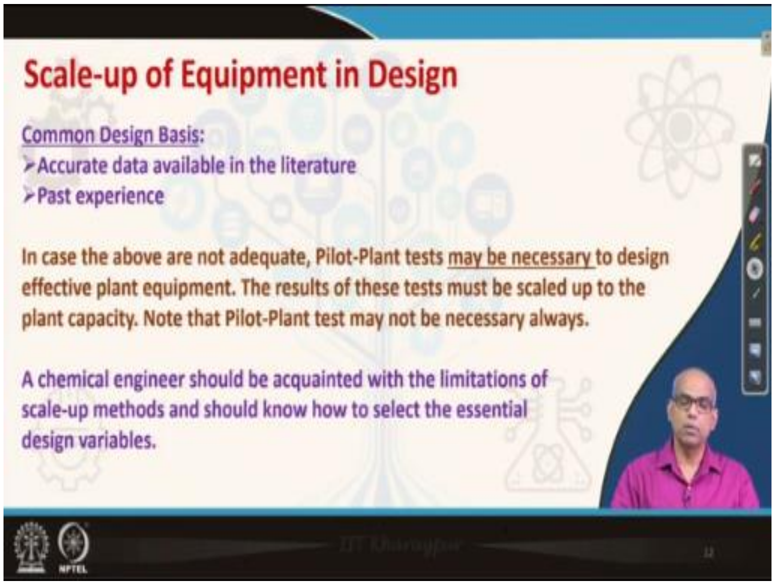

The common basis for design is past experience and accurate data that are available in the literature. Now for the particular design you have in hand, if the above two things like past experience as well as data available in the literature are not adequate then it may be necessary to perform pilot plant tests. So pilot plant tests may be necessary to design effective plant equipment when you do not have past experience or you do not have adequate past experience or you do not have accurate data available in literature.

So, the results of the pilot plant test must be scaled up to the plant capacity. But remember the pilot plant test will not be necessary for design of every piece of equipment will shortly see. The cases where pilot plant testing are always necessary and the cases where they are not necessary always. A chemical engineer should be acquainted with the limitations of scale up methods and should know how to select the essential design variables.

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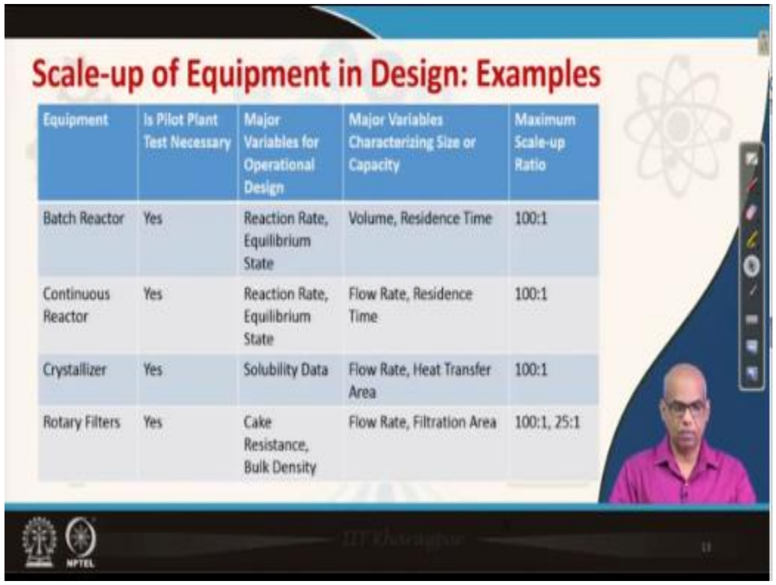

So, this table shows some of the equipment when it is always necessary to perform pilot tests for the purpose of design of those equipment. For example, batch reactor, continuous reactor, crystallizer, rotary filters, plate and frame filters etcetera. The table also shows the major variables for operational design, major variables characterizing size or capacity and also maximum scale up ratio.

For example the major variables for operational design for continuous reactors will be reaction rate at equilibrium state. The major variables characterizing size or capacity for continuous reactors will be flow rate and residence time. The maximum scale up ratio is 100:1.

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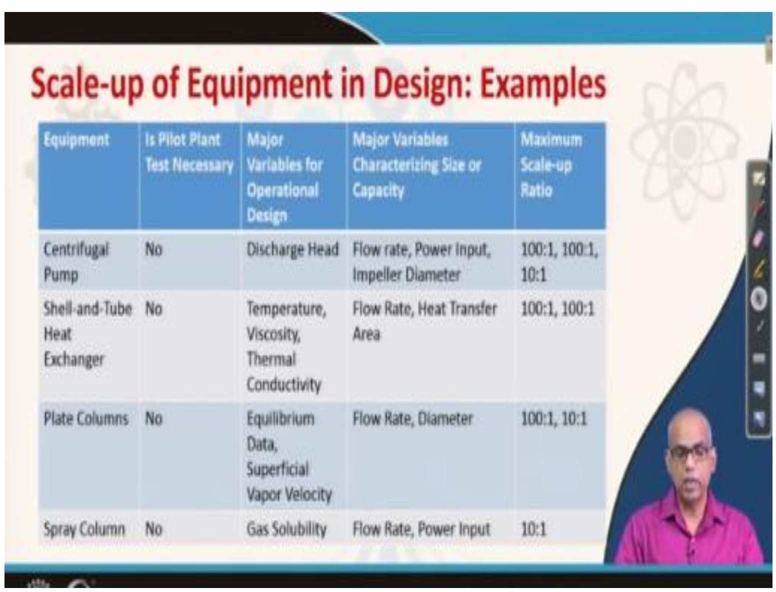

This table tells you that for this equipment the pilot plant test is always not necessary. So, centrifugal pump exchanger, plate columns, sprays columns for this equipment you do not need to perform pilot plant tests. The table also gives you major variables for operational design, major variables characterizing size or capacity as well as maximum scale up ratio.

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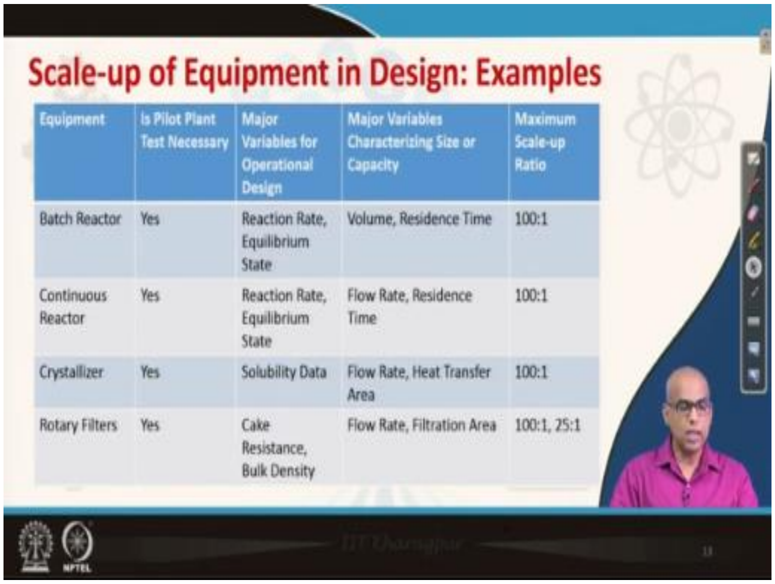

Equipment	Is Pilot Plant Test Necessary	Major Variables for Operational Design	Major Variables Characterizing Size or Capacity	Maximum Scale-up Ratio
Batch Reactor	Yes	Reaction Rate, Equilibrium State	Volume, Residence Time	100:1
Continuous Reactor	Yes	Reaction Rate, Equilibrium State	Flow Rate, Residence Time	100:1
Crystallizer	Yes	Solubility Data	Flow Rate, Heat Transfer Area	100:1
Rotary Filters	Yes	Cake Resistance, Bulk Density	Flow Rate, Filtration Area	100:1, 25:1

So you see that batch reactor, continuous reactor, crystallizer all types of filters for the pilot plant test is necessary. Whereas equipment like centrifugal pump, shell and tube heat exchanger, plate column, spray columns pilot plant is not necessary. This list is of course was not exhaustive so you need to consult text books for an exhaustive list.

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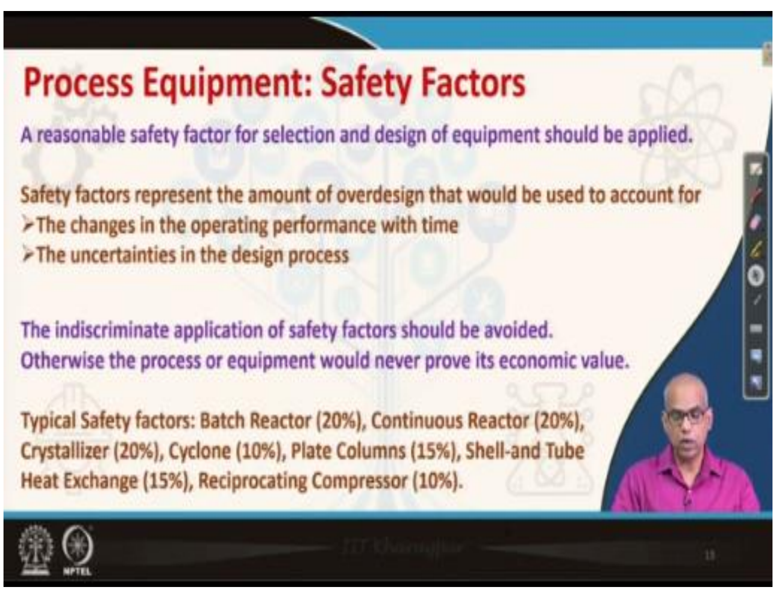

Now while selecting equipment or reasonable safety factor for selection and designer equipment should be applied. Safety factors represent the amount of over design that would be used to account for the changes in the operating performance with time and the uncertainties in the design process. That will always be there due to uncertainty in data lead to uncertainty in the calculation process.

Remember the indiscriminate application of safety factors should be avoided. So too much of overdesign must be avoided. Otherwise the process or equipment would never prove it is economic value. Some typical safety factors are given here batch reactor 20%, continuous reactor 20%, crystallized at 20%, cyclone 10%, plate columns 15%, shell and tube heat exchanger 15%, reciprocating compressor 10%, so on and so forth. So typically the safety factors lie between 10 to 20%.

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Generally the magnitudes of safety factors are determined by economic or market considerations, accuracy of the design data and calculations, potential changes in the operating conditions, background information available on the overall process, amount of safety factors used in other components of the design.

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Now, let us talk little more about standard vs. special process equipment. We have talked about proprietary equipment and non-proprietary equipment. Proprietary equipment are standard equipment and non proprietary equipment is special equipment. As you have told again and again standard equipment should be selected whenever possible. Standard equipment has stored the rigorous taste of service.

A new design thus a special equipment is a new experiment equipment for both user and designer. So there may be uncertainty involved in the performance. So if possible we should always use standard equipment that can be purchased of the shell from specialist manufacturers. These are standard equipment reduces the cost; if you use standard equipment the duplication will be easy.

The manufacturers may have the desired size in stock, better guarantee of satisfactory performance may be obtained for standard equipment because the supplier has confidence in the design which has been mature over a longer period of time, also standard equipment are easy to repair.

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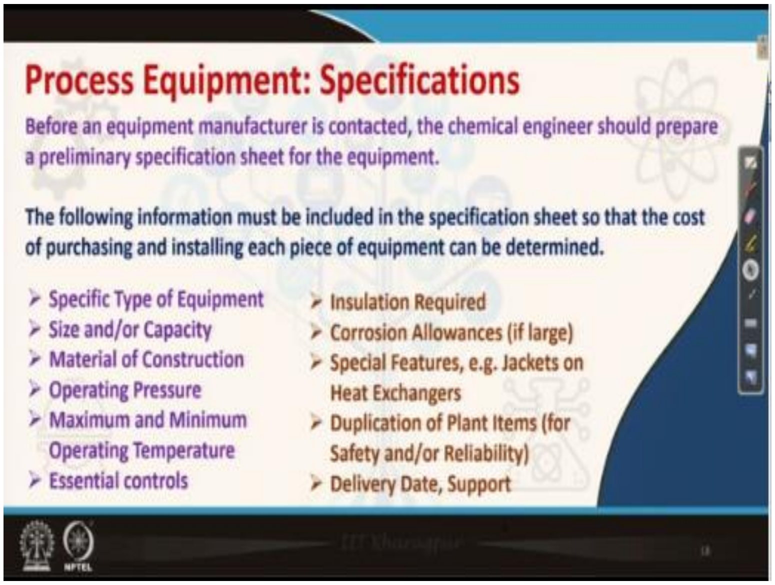

Now, about process equipment specifications; before an equipment manufacturer is contacted, the chemical engineer should prepare a preliminary specification sheet for the equipment. The following information must be included in the specification sheet, so that the cost of purchasing and installing each piece of equipment can be determined. Specific type of equipment, size and or capacity, material of constructions, operating pressure, maximum operating temperature; when the operating temperature is above ambient.

Minimum operating temperature; when the operating temperature is below ambient or maybe under refrigerated conditions, essential controls, insulation required, corrosion allowances if it is large. Special features such as jackets on heat exchangers, duplication of plant items for safety and or reliability, delivery date, support etcetera. So, all this information must be included in the specification sheet.

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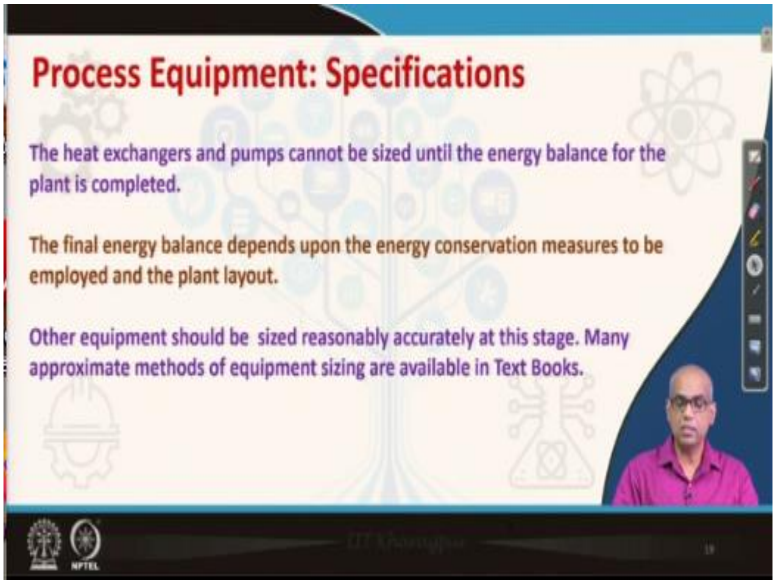

Now, the heat exchangers and pumps cannot be sized until the energy balance for the plant is completed. The final energy balance depends upon the energy conservation measures to be employed and the plant layout; that means the final energy balance will depend on the energy integration that you are going to adopt for your plant as well as on the plant layout. But all other equipment can be sized reasonably accurately at this stage. There are many approximate methods or equivalent sizing available in textbooks.

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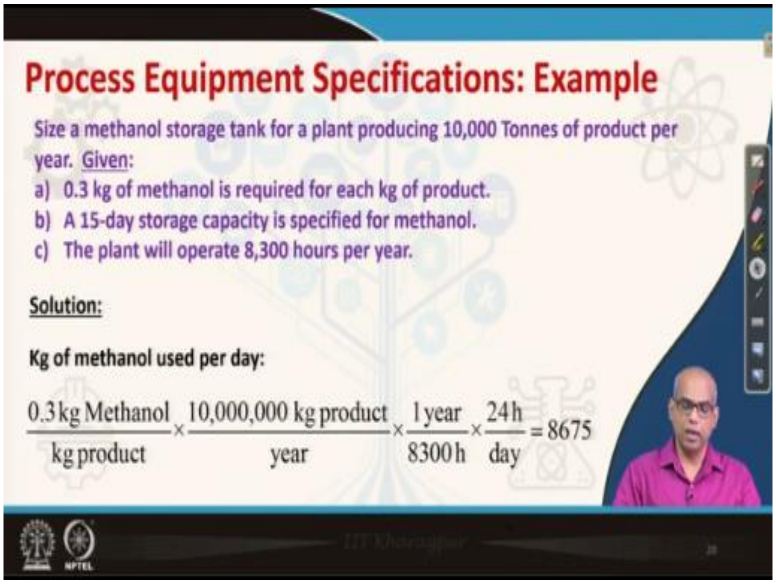

We will take a small example here; let us size a methanol storage tank for a plant which produces 10,000 tonnes of a particular product per year. Given 0.3 kg of methanol is required for each kg of product. A 15 day storage capacity specified for methanol. The plant will operate 8,300 hours per year. So how do I size the methanol storage tank? Now let us use our process calculation principles.

So, Kg of methanol used per day can be obtained as 0.3 kg methanol per kg product, multiplied by 10,000 tonnes of product per year. Then you have 8,300 hours in a year and you have 24 hours in a day. So if you multiply these quantities, you get kg of methanol used per day as 8,675. So 8,675 kg of methanol will be used per day.

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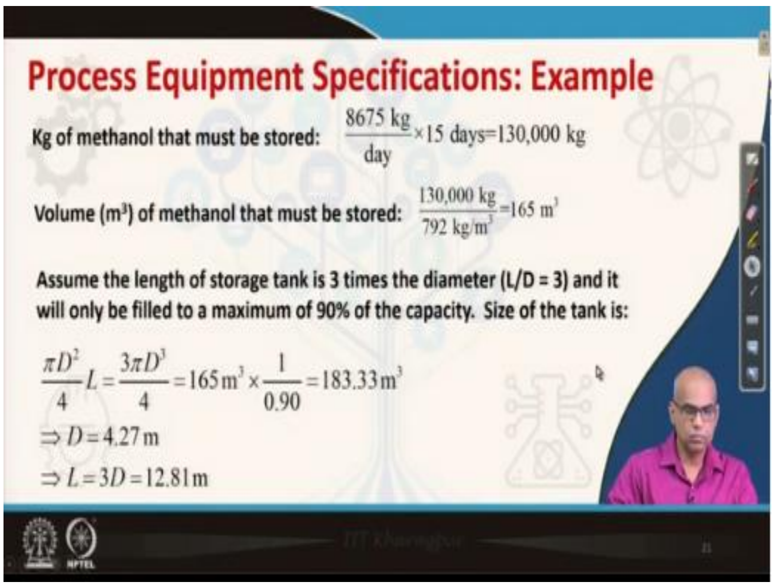

Now the amount of methanol that must be stored over 15 days can be found out simply by multiplying with 15. So that gives me 130 into 10 to the power 3 kg of methanol. So the volume methanol that must be stored can be obtained by dividing this quantity with the density of methanol, which is 792 kg per meter cube. So, I get 165 meter cube volume of methanol that must be stored. Now, let us assume the length of the storage tank is 3 times the diameter.

So L by D is 3 and it will only be filled to a maximum 90% of the capacity. So the size of the tank can be easily obtained. So pi D square by 4 into L which when you put L by D equal to 3 will be 3 pi D cube by 4. So this quantity will be equated to 165 by 0.90. So the diameter of the tank can be obtained as 4.27 meter and L can be obtained as 3 times of it, which is 12.81 meter. So this is how you can design, you can size the tank.

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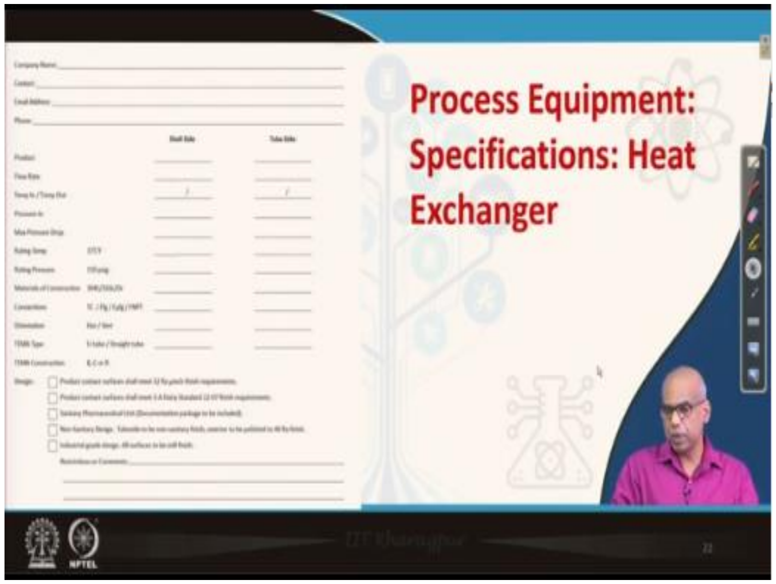

So, this is a typical example of specification sheet for heat exchanger.

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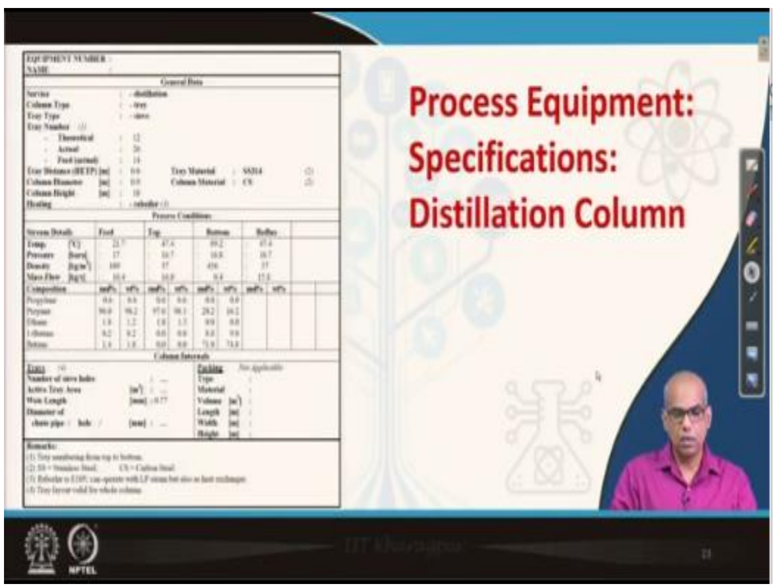

Another specification sheet, for the distillation column.

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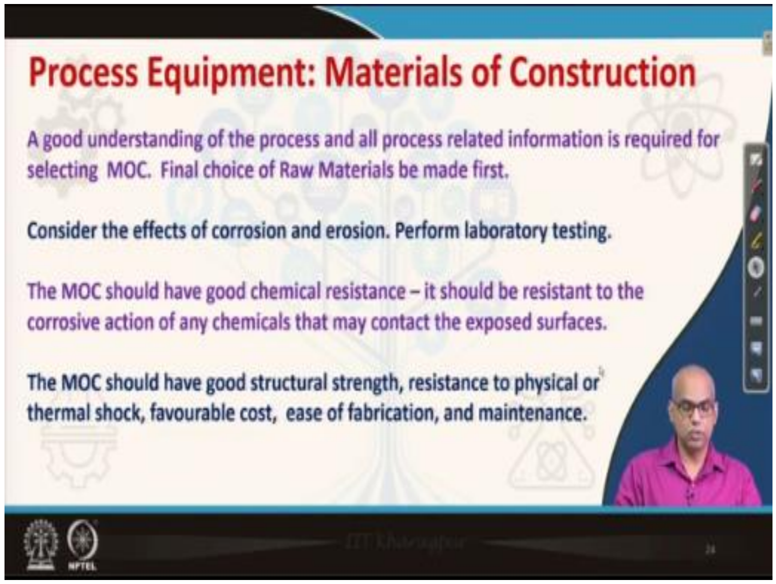

Now, let us quickly talk about materials of construction process equipment, a good understanding of the process and all process related information is required for selecting materials of construction. Final choice of raw materials must be made first before you try to select the materials of construction. Consider the effects of corrosion and erosion perform laboratory testing if necessary.

The materials of construction should have good chemical resistance; it should be resistant to the corrosion action of any chemicals that may contact the exposed surfaces. The materials of construction should have good structural strength, resistance to physical or thermal shock, favourable cost, ease of fabrication and maintenance.

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So, here are certain guidelines for selection of materials of construction. Preliminary selection can be done based on experience, manufacturers data, literature, availability, laboratory testing. Then properties mechanical and physical properties, tensile strengths, stiffness, toughness, hardness, fatigue resistance, corrosion, erosion resistance. Now after doing preliminary selection, you perhaps will select a set of equipment, a set of materials of construction which are probable candidates.

Then this will go final screening. So final selection will be based on both technical factors as well as economic factors, fabrication method effect of temperature pressure agitation, possibility of impurity, material cost, production cost, probable life of equipment product, degradation liability of special hazards, etcetera. So, these are the factors which you can use as guidelines for selection of materials of construction.

So, with this we will stop our discussion on selection of process equipment. Thank you for watching.