Plant Design and Economics
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Lecture No-13
Cost Components in Capital Investments

Welcome to lecture 13, Plant Design and Economics. In this week, we are talking about analysis of cost estimation. Now today we will talk about cost components in capital investment.

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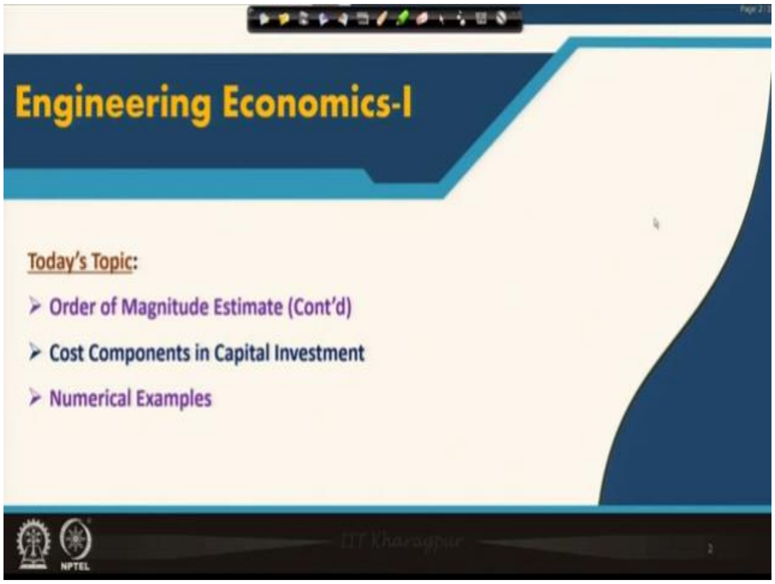

So in previous lecture we started with order of magnitude estimate. So we will continue with that in this lecture and then we will talk about cost components in capital investment. Then we will take few numerical examples.

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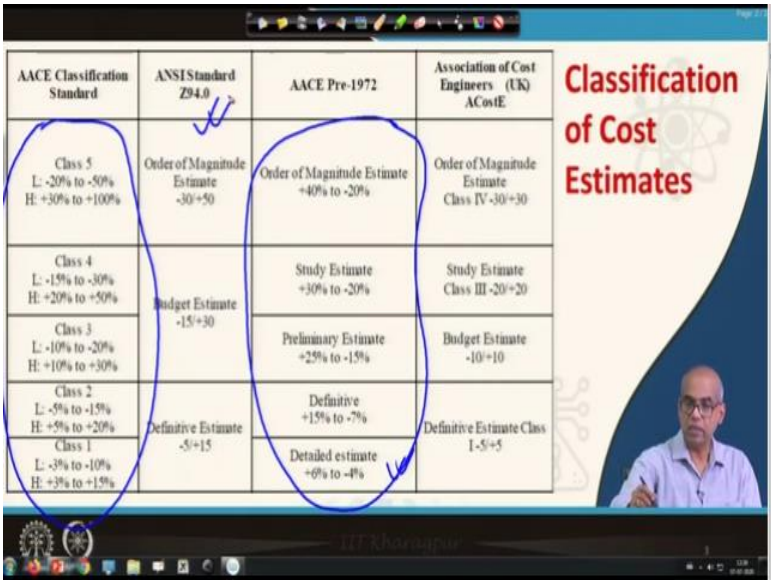

In our previous lecture, we talked about classification of cost estimates we talked about five different estimates which can be used depending on the purpose and the degree of accuracy required. Now this slide is just to tell you that there are various other estimates. We have talked about Order of Magnitude Estimate, Study, Estimate, Preliminary Estimate, Definitive Estimate and Detailed estimate and corresponding AACE classification, which goes from class 5 to class 1.

Class 1 is the highest accuracy and class 5 is a lowest accuracy. Apart from that we have ANSI standard, we also have Association of Cost Engineers, UK Estimate. So this is just to tell you that there are various estimates available.

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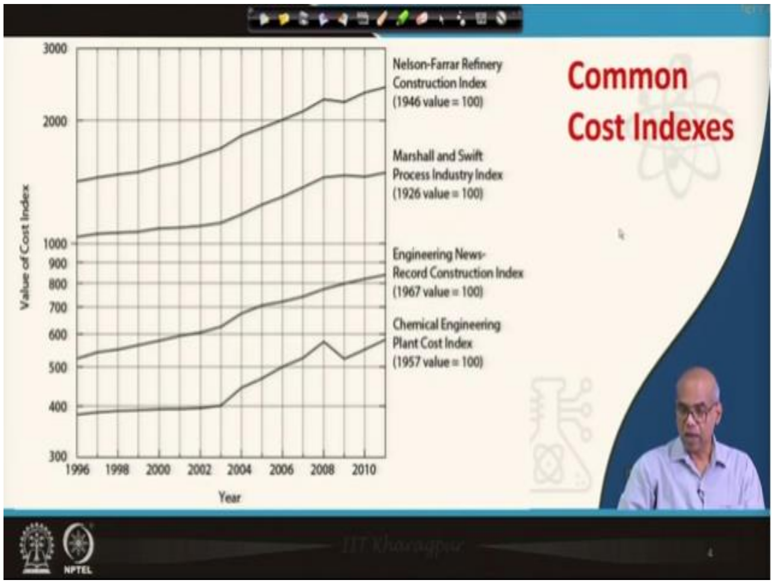

We have talked about some of the common cost indexes. So this figure just shows you Nelson-Farrar Refinery Index, Marshall and Swift Index, Engineering News Record Construction Index and Chemical Engineering Plant Cost Index for the period 1996 to 2010.

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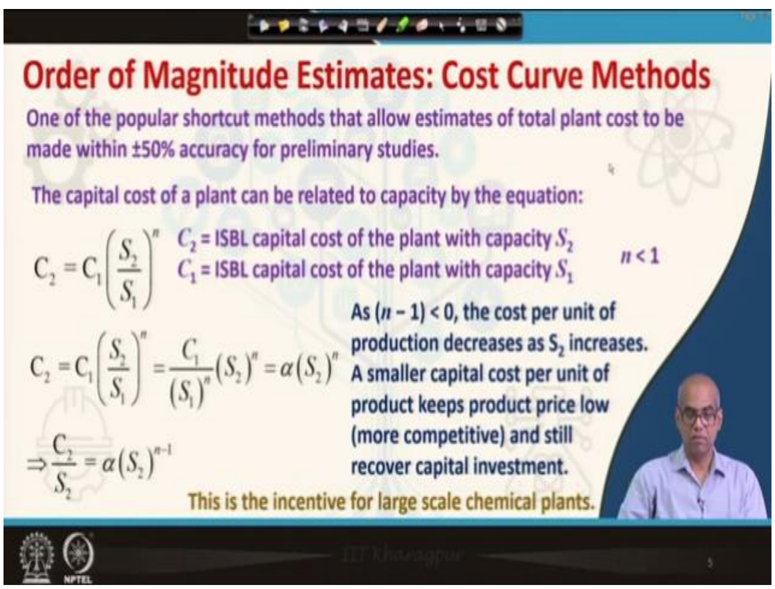

Now, let us continue with our Order of Magnitude Estimates. We talked about cost curve methods in our previous lecture. This is one of the popular shortcut methods that allow estimates of total plant cost to be made within plus minus 50% accuracy and this can be used for preliminary studies. So you have mentioned about this equation, that the capital cost of a plant can be related to the capacity by the equations C2 = C1 into S2 by S1 to the power n.

Where C2 represents inside battery limit capital cost of the plant with capacity S2 and C1 represents inside battery limit capital cost of the plant with capacity S1, n has values less than 1. Now let us rearrange this equation. So you can write as C2 = C 1 by S1 to the power n into S2 to the power n. Let us represent C1 by S1 to the power n by some quantity alpha then you can write C2 by S2 as alpha into S2 to the power n - 1.

Now that S2 to the power n can be written as S2 into S2 to the power n minus 1. So that is why we have written the C2 by S2 equal to alpha into S2 to the power n - 1. Now N is less than 1. So n - 1 is less than 0. So the cost per unit cost of production will decrease as S2 will increase. So what it means is that a smaller capital cost per unit of product is possible to achieve, if you increase the capacity.

A smaller capital cost per unit of product will help the manufacturer to keep the product price lower. So in the market, it will be more competitive and the manufacturer will still be able to recover capital investment. So, this is the incentive for building chemical plants with larger capacity.

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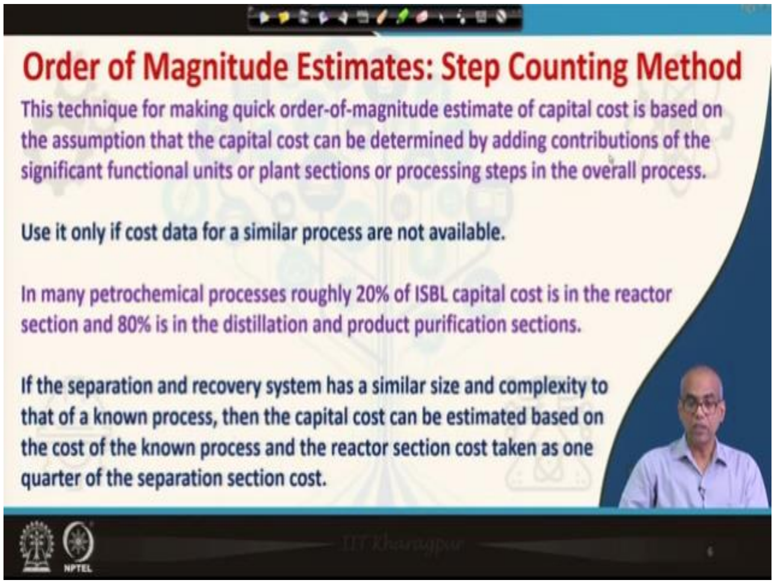

Next we talk about another order of magnitude estimates, known as step counting method. This is another technique for making quick estimate of capital cost and it is an order of magnitude estimate. This technique is based on the assumption that the capital cost can be determined by adding contributions of the significant functional units or plant sections or processing steps in the overall process.

So look at the functional units or plant sections or processing steps in your process look at their contributions and you can have an order of magnitude estimate of capital cost by summing up these contributions. You can use it or better you should use it only if cost data for a similar process is not available. In many petrochemical processes roughly 20% of ISBL capital cost is in the reactor section and 80% is in the distillation and product purification section.

You know that, distillation product purification is very important operation in petrochemical processes. So, roughly 20% of the ISBL capital cost is in the reactor section, whereas 80% is in the distillation and product purification sections. If the separation and recovery system has a similar size and complexity to that of a known process, then the capital cost can be estimated based on the cost of the known process.

And then the reactor section cost can be considered as 1/4th of the separation section cost. So this is where we use that the contributions of Functional units of plant sections to have an order of magnitude estimate of the capital cost.

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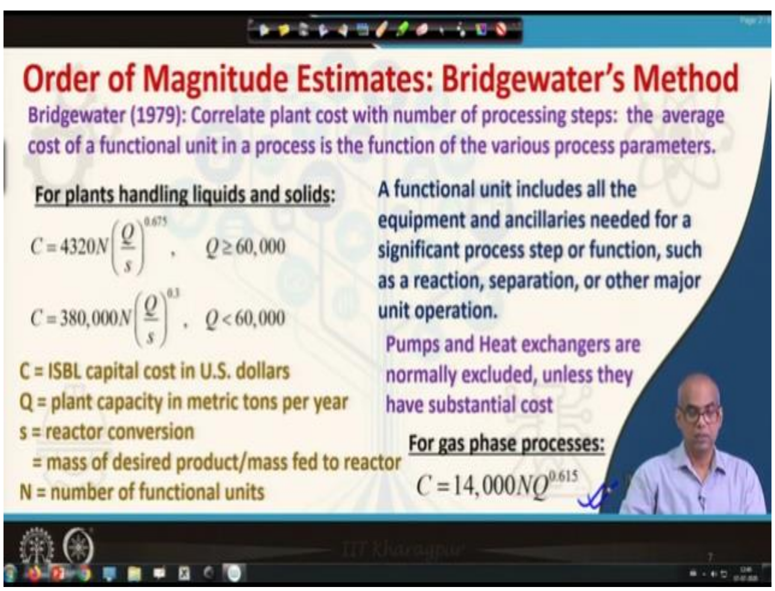

Now, alternatively we can use Bridgewater's method. Now Bridgewater's proposed that the average cost of a functional unit in a process is the function of the various processing parameters and presented a correlation of the plant cost with number of processing steps. A functional unit includes all the equipment and ancillaries needed for a significant process tape or function such as a reaction, separation or other major unit operations.

So, functional unit includes all the equipment and ancillaries needed for a significant process state or function. For example; a reaction, separation or other major unit operations. So what are excluded from functional unit? Usually pumps and heat exchangers are excluded normally unless they have significant amount of cost, otherwise will exclude. See pumps heat exchanger have significant or substantial amount of cost then they may be included otherwise they are normally excluded.

So, these are the correlations for plants handling liquids and solids. Here Q is the plant capacity in metric tones per year and C represents inside battery limit capital cost in US dollar. N is number of functional units and s represents reactor conversion, which can be obtained as mass of desired product divided by mass fed to the reactor. Now depending on the plant capacity we have two correlations.

So one correlation the first one can be used when the plant capacity in metric tone per year is greater or equal to 60000 and the second correlation can be used when the plant capacity is less than 60000 metric tones per year. So this is these two correlations apply to plants that handle liquids and solids. For gas processing plants or gas phase processes, we have a simpler correlation which is shown here C = 14000 into N into Q to the power 0.615. Note that, the capital cause that will be obtained is in US dollar.

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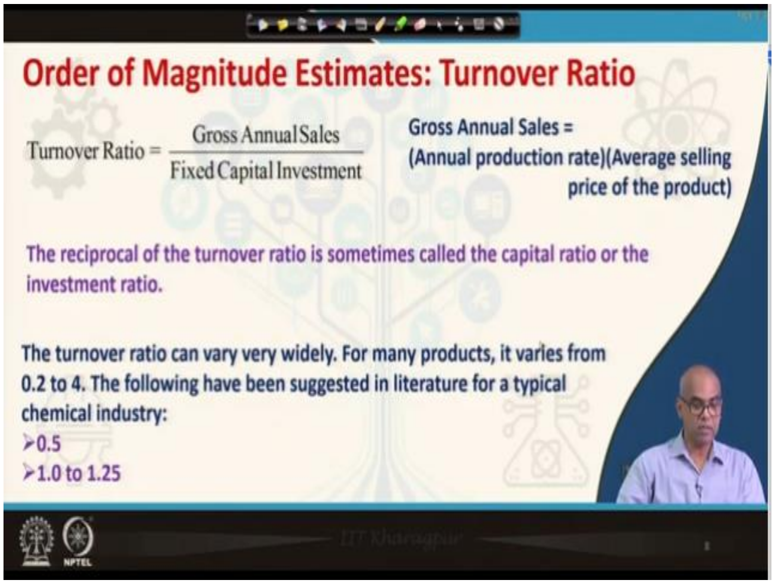

Now, another order of magnitude estimate is obtained from Turnover Ratio. Turnover Ratio is defined as gross annual sales divided by fixed capital investment. So if you know Turnover Ratio, you will be able to have an estimate of fixed capital investment. What is a gross annual sales? So gross annual sales is the cross earning, which you can compute as the product of annual production rate multiplied by average selling price of the product.

So your annual production rate multiplied by average selling price of the product will give you gross annual sales. Note that we are assuming here that the all products are sold. The reciprocal of the turnover ratio is sometimes called the capital ratio or the investment ratio. The Turnover Ratio generally varies widely, for many products it varies from 0.2 to 4. In literature for a typical chemical industry, these values are reported as 0.5 some other literature reports as 1.0 to 1.25.

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Now, let us talk about various cost components in capital investment and we start with; Estimating Purchase Equipment Cost. The foundation of a fixed capital investment estimate is the equipment cost data. So equipment cost data is very important because it works as the foundation of estimation of fixed capital investment. From this information through the application of factors or percentages based upon the estimators experience the fixed capital investment is developed.

These cost data are reported as purchased equipment cost, delivered purchase equipment cost or installed cost. Purchase equipment cost represents the price of the equipment at the manufacturer's plant. So wherever the equipment was manufactured, so purchase cost represents; price of the equipment at the manufacturer's plant. Delivered cost represents purchase price plus the delivery charge to the purchaser’s plant.

So the equipment needs to be delivered from the manufacturer's plant to the purchaser's plant. So delivered cost represents purchase price plus the delivery charge to the purchases plant. Install cost means the equipment has been purchased delivered and placed on a foundation in the purchaser's plan. So you have purchased it, it has been delivered and it has been placed on a foundation in the purchasers plant.

It does not include cost for piping, electrical, instrumentation, insulation etcetera. So these are the typical cost data associated with equipment. Now based on this purchase equipment cost data, capital investment estimate can be made. We consider certain factors or percentages based upon designer's experience and then fixed capital investment is developed from the cost data of the equipment.

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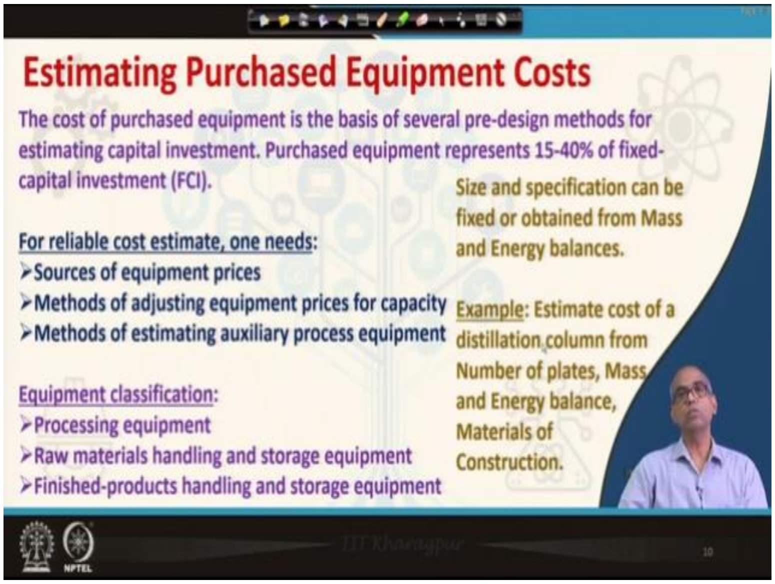

The cost of purchase equipment is the basis of several design method for estimating capital investment. Purchase requirement represents 15 to 40% of fixed capital investment. For reliable cost estimate as a designer, you will need sources of equipment prices, methods of adjusting equipment prices for capacity, methods for estimating auxiliary process equipment. You can classify decrement as follows; Processing equipment, Raw materials handling and storage equipment, Finished- products handling and storage equipment.

The sizes and specifications all this equipment can be fixed or can be obtained from mass and energy balance equations. For example you want to estimate the cost of a distillation column. So you can find out the number of the plates, then the number of the plates once you find out using the various methods that are familiar with and you correct it using the efficiency of the plates.

This information along with mass and energy balance and the materials of construction will allow you to have an estimate of the distillation column.

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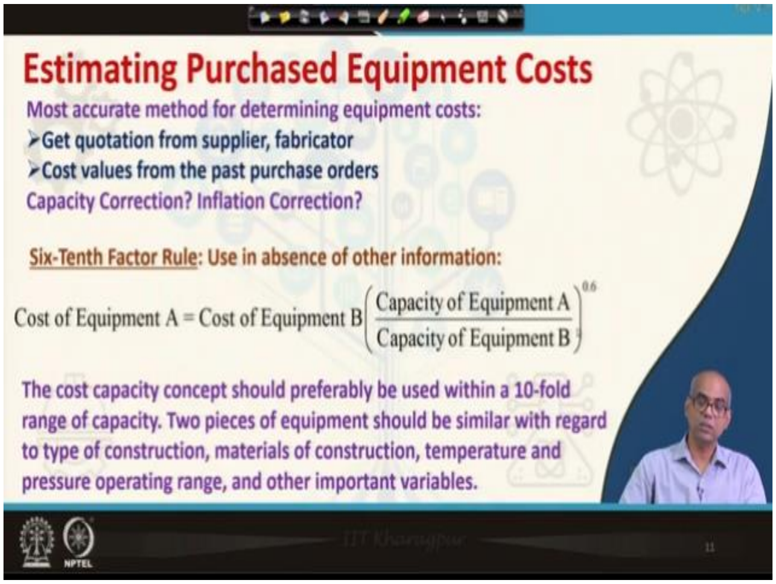

What can be the most accurate method for determining equipment cost? It may be that you get quotation from supplier or fabricator. So the supplier will give you the current price of the equipment. It can also be that you determine the cost values from the past purchase orders. So, the best option will be that you get quotation from the supplier so you will get the current cost. Second best option can be that cost values can be obtained from past purchase orders.

Then you have to make capacity corrections may also have to make inflation corrections. Capacity corrections can be made by making use of Six-Tenth factor rule. We are already familiar with this that cost of equipment A equal to cost of equipment B multiplied by capacity equipment a divided by capacity of equipment B to the power 0.6. We have talked about this in previous class that the exponent 0.6 works well for wide range of chemical process industries and that is why it is known as Six-Tenth factor rule.

The cost capacity concept should preferably use within a 10-fold range of capacity. So if the capacity does not exceed by more than 10 we should use it beyond that is not recommended. Two pieces of equipment should be similar with regard to type of construction materials of construction temperatures and pressure operating range and also with respect to other important variables.

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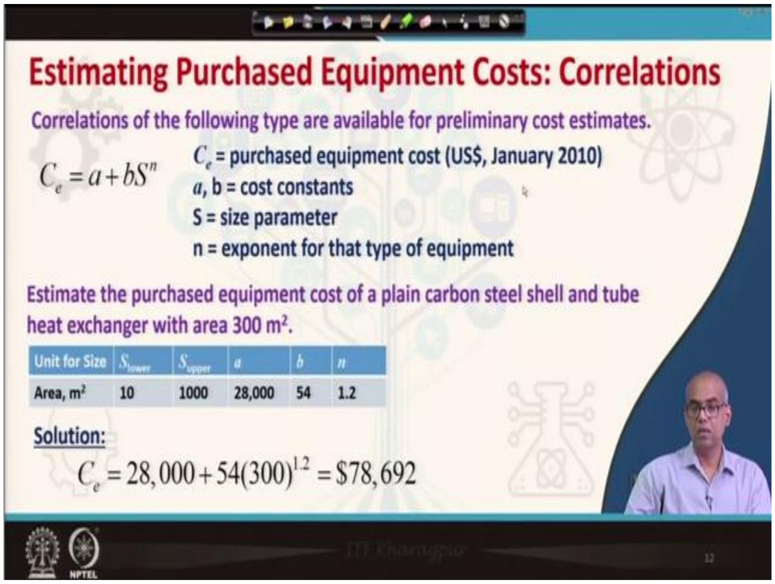

Correlations are available for making preliminary cost estimates and you can use such correlations, when you do not have any other information. One such correlation is shown here Ce is purchased equipment cost equal to a + b into S to the power n, S is the size parameter. Ce equal to purchase equipment cost in US dollar January 2010 basis, a,b are cost constants and n is the exponent for that type of equipment.

So similar type, such correlations are available and then the values of a,b,n are given in tables. For example; look at this table, Unit for size is area in meter square. The value of a is 28,000 value of b is 54 value of n is 1.2. So you can estimate the purchase equipment cost of a plane carbon steel shell and tube heat exchanger with area 300 meter square. So this table, which is a very, very small part of the tables that are available in literature, gives you this data.

Now this equation or correlation can be used, when the size varies from 10 meters to 1000 meters and then you can use the value of a, b and n as 28000, 54 and 1.2. This table is taken from the reference book by Touler**.** So now you can easily estimate the purchase equipment cost of a plane carbon steel shell and tube heat exchanger with area 300 meter square. So it will be straightforward application of this equation 28,000+ 54 into 300 to the power 1.2, which will give you 78,690 dollar, note that this is January 2010 basis.

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Let us now talk about other cost components in capital investment. First, we talk about direct costs; Purchase equipment delivery. Purchase equipment prices are usually quoted as Free On Board or FOB which means that the purchaser pays the freight. Freight costs depend upon the weight and size of the equipment distance from source to plant and method of transport. For pre-design estimates, it is recommended that 10% of the purchase equipment cost be allocated under this head.

Purchase equipment installation; Installation of process equipment involves cost for labour foundations, supports, platforms, construction expenses and other factors directly related to the erection of purchase equipment is recommended that 20 to 60% of the purchase equipment cost may be allocated.

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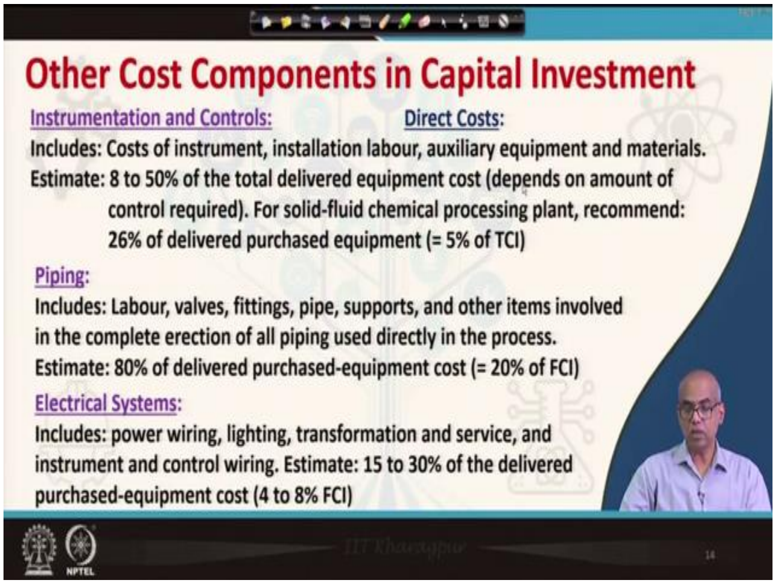

Instrumentation and controls, this will include cost of instrument cost of installation labour cost of auxiliary equipment and materials. 8 to 50% of the total delivered equipment cost can be allocated but it depends on the amount and degree of control that is required in your process. For solid-fluid chemical processing plant recommendation is 26% of delivered purchase equipment, which is about 5% of the total capital investment.

Piping includes; labour, valves, fittings by supports and other items involved in the complete erection of all piping used directly in the process. Estimate is 80% of the delivered purchase equipment cost under this head, which is about 20% of fixed capital investment. Electrical systems includes power wiring, lighting transformation and service and instrument and control wiring.

It is estimated that 15 to 30% of the delivered purchase equipment cost be allocated under this head, which is about 4 to 8% of the fixed capital investment.

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Startup expenses after plant construction has been completed, it is generally seen that there will be some changes before the plant can operate at the maximum design conditions. These changes will involve expenditures for materials and equipment and thus will result in loss of income while the plant is shut down or the plant is operating with partial capacity and allowance of 8 to 10% of the fixed capital investment for this startup expenses is satisfactory.

In the overall cost analysis startup expense may be represented as a one-time expenditure in the first year of the plant operation, because next year onwards it is expected that your plant will run with maximum design capacity. So in the overall cost analysis start up expenses may be represented as a one-time expenditure in the first year of the plant operation or as part of the total capital investment depending on the company policy.

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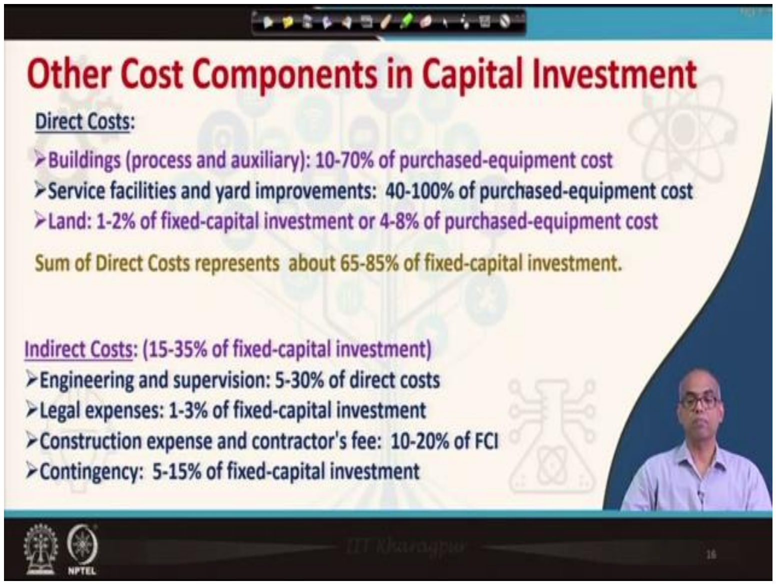

These are some other direct costs; Buildings, buildings may be process buildings, auxiliary buildings, so 10 to 70% of purchase equipment cost may be allocated service facilities and yard improvements 40 to 100% of purchase equipment cost may be allocated. Land 1 to 2% of fixed capital investment or 4 to 8% of purchase equipment cost may be allocated. Some of all the direct costs represent about 65 to 85% of fixed capital investment.

Now, what about indirect cost? The total indirect cost represents about 15 to 35% of fixed capital investment. The different heads engineering and supervision you can allocate 5 to 30% of direct cost legal expenses 1 to 3% of fixed capital investment. Construction expense and contractors fee 10 to 20% of fixed capital investment and for contingency 5 to 15% of fixed capital investment.

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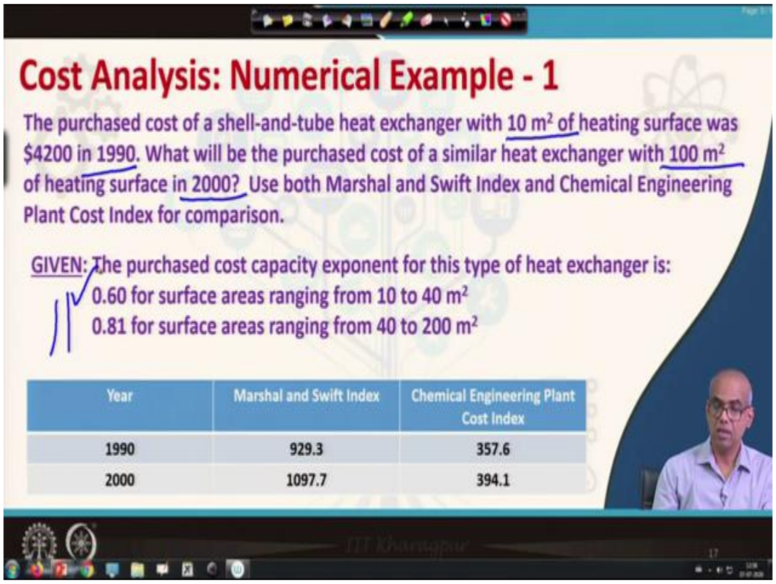

Now, let us take few numerical examples. The first problem says the purchase cost of a shell-and-tube heat exchanger with 10 meter square of heating surface was 4200 dollar in 1990. What should be the purchase cost of a similar heat exchanger with 100 meter square of heating surface in year 2000? Use both Marshal Swift index and chemical engineering plant cost index for comparison.

Given the purchase cost capacity exponent for this type of heat exchanger is 0.6 for surface areas engine pump 10 to 40 meter square and 0.81 for surface areas ranging from 40 to 200 meter square and both in year 1990 and 2000 the Marshal Swift index and chemical engineering plant cost index are given. So what should be noted here is this. So what is known is the cost of 10 meter square heat exchanger in 1990.

And we have to estimate cost of 100 meter square heat exchange in the year 2000. But note that, the exponent the capacity exponent that value n, the capacity exponent 10 to 40 meter square is 0.6 and from 40 to 200 meter square is 0.81, so you have to take care of this fact. So, how do you solve it?

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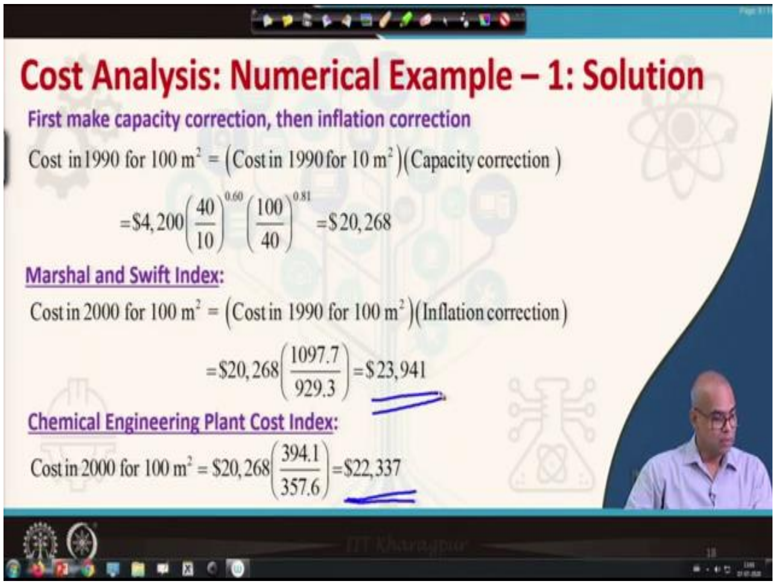

So first make capacity correction and then we will make inflation correction. Inflation correction is due to year change and capacity correction is due to change in capacity. So, cost in 1990 for 10 meter square is given, so what will be the cost in 1990 for 100 meter square? It will be cost in 1990 for 10 meter square multiplied by capacity correction. So for capacity correction, you have to go into steps; ten meter square to 40 meter square and then 40 meter square to 100 meter square.

So this needs to be understood. So then you get the cost for 1990 for 100 meter square heat exchanger. Now, we do correction for inflation. Let us first make use of Marshall and Swift index. So cost in year, 2000 for 100 meter square is cost in 1990 for 100 meter square multiplied by the inflation correction which comes from the table given; The Marshall and Swift index in the year 2000 divided by Marshall and Swift index in 1990.

So you get the value 23,941 US dollar, repeat it with the chemical engineering plant cost index. So the plant cost and index in 2000 divided by chemical engine plant cost index in 1990. So this gives you 22,337 dollar. So these are two values you get from two different index. So note that estimates are close, they are comparable.

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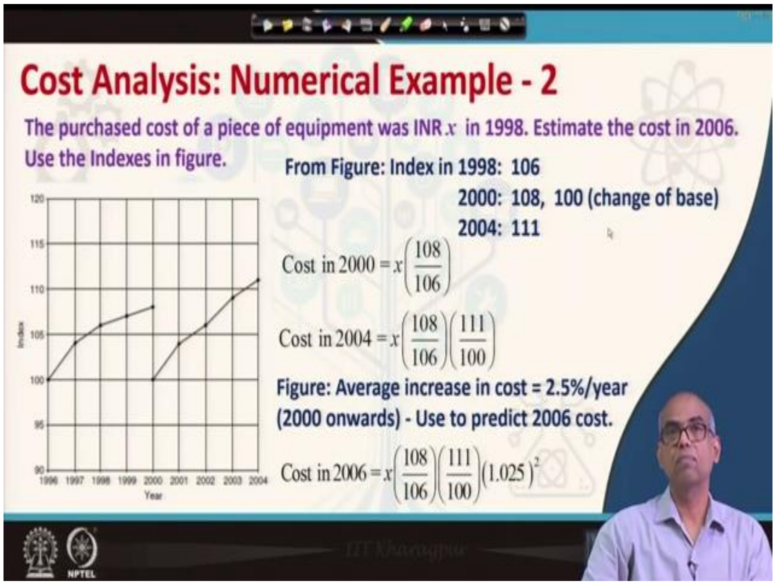

Now, let us take another example the purchase cost of a piece of equipment was x rupees in 1998, estimate the cost in 2006 and you have to use the indexes given in the figure. Now, look at the figure from 1996 to 2004 is given, so the data is given in 1998. Data of the piece of equipment as rupees x and you have to estimate it in 2006, but there is no index for 2006 and there is a change of basis in year, two thousand.

So in 1998 the index was 106 in 2000 it is 108 and 100 change of basis. Then in 2004 it is 111. So first find out cost in 2000 because there was change of basis in 2000 so that can be obtained as x into index ratio. Then cost in 2004, now I have data in 2004 but I need cost in 2006. So if you look at this figure, you see that the average cost roughly increases as 2.5% per year. So use this information to predict the cost in 2006.

So cost in 2006 will be cost in 2004 multiplied by 1.025 squared, because there is 2005 and these 2006. So this is how we can estimate.

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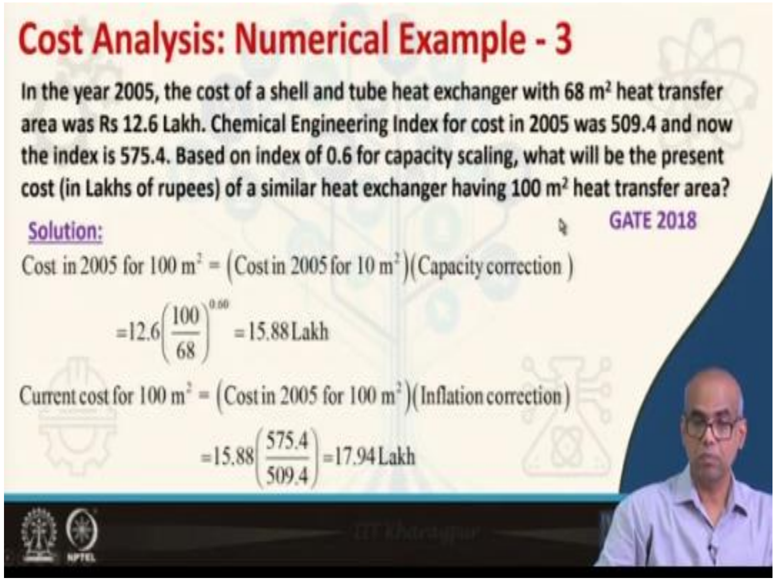

One more problem in the year 2005 the cost of a shell and tube heat exchanger with 68 meter square heat transfer area was rupees 12.6 lakh. Chemical engineering index for cost in 2005 was 509.4 and now the index is 575.4 based on index of 0.6 for capacity scaling what will be the present cost in lakhs of rupees for a similar heat exchanger having 100 meter square heat transfer area? So this is a straightforward problem.

What you should do is you find out the cost in 2005 for 100 meter square first. So take the value, in 2005 for 10 meter square and then multiply by correction factor, so I get as 15.88 lakh. So now you make correction for inflation. So you multiply 15.88 with the cost index. Current time divided by cost index in 2005, this gives you 17.94 lakh as estimate of current cost for 100 meter square area of heat exchanger.

So this way you can solve the problems that are related to equipment cost mostly have to make corrections for capacity and inflation, with this we stop our discussion here. Thank you for watching.