Process Design Decisions and Project Economics

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Module - 1
Nature of Process Synthesis and Analysis
Lecture - 1
General Introduction to the Course and Syllabus

Welcome. This is the NPTEL course on process design decision and project economics. My name is Dr. V.S. Moholkar. And I am a faculty of chemical engineering at IIT, Guwahati. Let me first give you a brief introduction to the genesis of this course and the course syllabus. This course appears in the final year of b-tech curriculum in most of the universities. This course is also about coupling the chemical engineering principles to the principles of economics, because the economic success of a chemical project is very important for the viability of the industry. And therefore we have to always see the economics of any decision that we make for the design of a particular process.

There are several NPTEL courses on a heat exchanger, heat transfer, mass transfer, chemical reactions engineering. And there is also course on equipment design process equipment design. But this course is different from those, because it gives a overall view of all of these principles from developing a process or, from the view point of a potential chemical project, chemical project play a special role in the sustainable development of the society. In our day to day life, we use chemicals in various forms; such as pharmaceuticals, textiles, soaps, detergents, cosmetics, fertilizer, fuel, metal and plastics. Without chemicals, life is very difficult to follow.

A chemical plant can be identified as a facility for physicochemical or, biological transformation of raw material into value added products with various resources. Such as; man power energy, water space and money. Various factors that influence the design of a chemical process for manufacture of a chemical product, so chemical process or chemical plant is judicious combinations of various unit operations and unit processes. Like for example, in a petroleum refinery, crude oil is separated into various fractions, such as; LPG, Anpha petrol, kerosene, diesel, soft wax and a series of distillation columns are used for these separations. And you have studied displasion as a unit operation in mass transfer course. Conversion of Naphtha into aromatics such as,

benzene, toluene, Xylene that is called as aromatization is used as a process preceding extraction and distillation as unit operations for recovery of aromatics.

The objectives and priorities in a process design are influenced by the market into which these are being sold. Chemical products are usually classified into 3 broad classes; first is the commodity or bulk chemical. Second one is fine chemicals and third one is the specialty or a functional chemical. Commodity chemicals are produced in large volumes and they are sold on the basis of composition of purity, which determines their price.

And examples of these chemicals are; sulphuric acid, nitric acid, nitrogen, oxygen, ethylene and chlorine and many other such chemicals, fine. Chemicals are produced in smaller volumes relatively, but like commodity chemicals are sold on the basis of composition and purity which determines their price. An example of chemicals in this category are; chloropropylene oxide used for manufacture of epoxy resin, ironoxy resin, dimethylformamide which is used as the solvent in reaction medium an intermediate pharmaceutical manufacture and butyric acid which is used in beverages flavoring fragrances etc.

And finally, the specialty and functional chemicals are manufactured for a particular or specific application. And it is the first functions of these chemicals, which determine their price rather than the chemical composition. For example, perfumes, flavorings or pharmaceuticals products. Even a simple chemicals, such as; various mosquito repellants that we use, in at home or domestic cleaners so all of these are chemicals we rarely bother about their chemical composition. But we are mainly assessing their function as how effectively they clean? Or how effectively they repel mosquitoes in case of mosquito repellant or even in simple pharmaceutical products, such various syrups those are available in the market. So, we rarely bother about their composition, but we see mainly the functions. They repel mosquitoes in case of mosquito repellant or even in simple pharmaceutical products; such as various syrups that are available in the market.

So, we rarely bother about their composition, but we see mainly the function. The specialty or functional chemicals are manufactured for a particular or specific application. And it is the function of these chemicals that determines their price rather than chemical composition. And examples are; chemicals in this category are perfumes flavoring, simple pharmaceutical products such as; syrups that are available in the

market, some tablets are available in the market for simple diseases, like headache or, cold or, cough or, it could also be the domestic cleaner that we use or, the mosquito repellants that we use.

So, we are not bothered about the chemical compositions of these products, but mainly see their function. And another distinction between the various chemical products is in the form of differentiated and undifferentiated product. The commodity and fine chemicals can be purchased on the basis of chemical composition alone. And they are classified as undifferentiated products. On the other hand specialty chemicals are purchased on the basis of their effect or, function and hence they are classified as; differentiated products, but the terms differentiated and undifferentiated should be thought as relative terms rather than absolute terms. Because there is certain specialty chemicals like polymers which are manufactured in terms of their mechanical strength. They are classified as undifferentiated product, although they are manufactured for a specific purpose or, for a specific function ok.

The scale of production also differs between the 3 classes of chemical products. The final chemicals tend to be produced in volumes less than 1000 tons per year, on the other hand the commodity chemicals tend to be produced in much larger volume than this. Again this distinction is also not so clear; like the polymer products which we were talking about, they are produced in quantities higher than 1000 tons per year. But they are still classified as the specialty chemicals.

The chemical projects differ from other projects such as automobile, hydro power, highway and dam construction projects. In that, they transfer one substance into totally different substance. Like example is, natural gas which is converted to methanol after steam reforming of methane so that is distinct case of one phase chemical being converted another phase chemical. When a new product is introduced into the market, the sales grow slowly until the market is established and very rapidly once the market is established. If the product is protected by patent then no other manufacture will be able to produce the product till the patent expires.

However, competitive products are introduced by other companies in the market and they may reduce the sale of a particular product. The sale may become so low in some cases, that the company may withdraw the product from the market. Now, different class

of products have different added value, which is the difference between the selling price of the product and purchase cost of raw material the value addition of commodity chemicals is small while that of specialty chemicals is high. However, the scale of production of commodity chemicals is much higher than that of specialty chemicals. And due to this while designing the process for commodity chemical, it is desirable to keep the operating or production cost as low as possible. The capital cost of such process could be high due to large scale of production. On the other hand while designing process for a specialty chemical or, functional chemical priority is given the product and not the process because the functionality of the product has to be protected and functionality of the products is what matters.

In this case, the operating cost could be high, yet the capital cost is low due to small scale of production. The time required for actual marketing of the product since, its invention thorough basic research is also important factor in overall feasibility of the project for the functional chemicals. Thus the priority of process design are different for the 2 types of chemicals; commodity and specialty chemicals. In commodity chemical there is little product innovation, because product is already established in the market, it is a well known product. But the greater focus is on process innovation. How we can make the process better like reducing its energy consumption or, using raw materials which are cheaper or, using less harsh conditions. So, the emphasis is on process renovations to make process better and cheaper and safer. However, in case of the specialty chemicals, it is the otherwise. That it is the product innovation matters more than process innovation.

In some cases, the some certain stringent conditions or instructions on the product composition have to be made. And therefore you may have to adopt the process which is more energy intense, which has more operating cost. But still to meet the certain specification of the project. You have to follow the process which is not optimized and that restricts the process innovation in case of specialty chemicals. For commodity chemicals, the process equipment is exclusively designed for a particular process step. Therefore, the life of equipment is more or less same as that of the product or the life of process operation. However in case of specialty product, you have certain flexibility the manufacture of fine on specialty chemicals involves low scale production. And therefore;

sharp product life cycle and sharp time to market, thus the process development has less time and essentially the product and process development have to go handle.

The manufacture of fine and specialty chemicals is often carried out in multipurpose equipment. And different chemicals might be produced in different parts of the year. The life of equipments makes it significantly therefore, the life of the product. Because the product of the company may keep on changing but same equipment is used for that particular product. Then development of pharmaceutical product involves concurrent safety and clinical assessments studies while process development. Along with process development pharmaceutical production represents an extreme case of process design in which the regularity framework controlling the product makes it difficult make process changes. As I just said, that certain in case of specialty functional chemicals you have to meet certain specification of the product. The product has to function to the expectation of the consumer.

And, therefore to make the product you may have to adopt a process which is not optimum, which is more energy intense, which has more operating cost, but still you have to make the product through the same process. And therefore methane process changes even during the development stage of the product, is rather difficult. So, these are some basic guidelines of the chemical products and chemical process. The chemical engineering design of new processes and expansion and revision of existing processes requires use of engineering principles and theories combine with a practical understanding of the limiting posed by environmental safety and health concerns. And this is where the chemical engineering design differs from the individual unit operations here.

When you learnt mass transfer, when you learn heat transfer, you need not consider these aspects. But in this course, we are going to consider these aspects and within with constraints of these aspects we are going to see as how best we arrive at a design of a chemical engineering project. Development of new processes from concept evaluation to profitable reality can become complex since the process design problems are open ended problems.

In many cases, you may not have information that you need. In that case you have to either generate information or do some intelligent guess work of the information with of

course, some iteration. And then arrive at a suitable design. Thus, there are many process design and solution, which are profitable even if they are not optimal. So, the solution that you obtain may not be the unique solution, it may be profitable but it is not optimal. And hence there is an improvement for the design.

Now, let us see how a chemical engineering design problem is formulated, before we start a process design, we must formulate the design problem. And this begins with the product specification, if a well defined and a well established product is to be manufactured then the product specification is straight forward. However, for a specialty product to be manufactured, the functional properties are more important than chemical properties. And hence we have to go for product design step prior to process design.

The chemical project is design of a chemical project or chemical process is like a painting. How does a painter draws a painting initially on a canvas, he marks and he decides what to draw in the first place then on a canvas he marks broadly marks, the regions where he will draw a different parts of the painting and then he first makes a rough sketch with pencil and then a little fair and then fairly adds colors and this how a painting is developed. And painting is never finished when a painter stops drawing painting, when additional effort does not yield necessary redraws that means, when you have drawn the painting to the fullest.

Now, putting additional colors etcetera is not going to make painting any better, significantly better and that is a point where the painter stops and there that is point where the painting is finished. So, process design is very much similar so we will start first with a broad idea and then arrive and keep on conversing on various aspects and then finally, making a design. But let me first give you some information about chemical projects.

The chemical projects are broadly classified; as either grassroots project or an add-on project. The grassroots or green field project is a plant which is constructed from 0 level and almost barren land. And here the project will start from activity such as, land procurement. Add-on projects are different; they are built within an existing complex or built around the main project. And such projects could be an addition of a new facility or, a backward or, a forward integration or, altogether a new product line around and an existing or, expanded structure of utilities.

Now, what is forward and backward integration? Forward integration is essentially a propose project using products or, byproducts of existing plant as raw material. And backward integration is the manufacture of the raw material of an existing project. If the project owner decides to manufacture the raw material for existing project, it is known as backward integration. The expansion of project capacity depends on market forces, suppose the entrepreneur does not want to start a new product but just to expand in the existing facility keeping product same. Then that decision is governed by the market forces. The market potential needs to be established for the proposed product, by thus study by consulting some experts. If the market for a particular project is predicted to grow then the production should increase.

But we should keep in mind that the time that is required to build additional facilities or, to reach the enhanced production in that period some competitors might enter the market in this period and then the market share of the company may go down. And you need some intelligent and guesswork, intelligent analysis for this from experts to decide the expansion of the plant. If your product is making lot of profit then it attracts other manufacturers and then they enter the business.

They start production; more of the products come into the market demand remaining the same price falls. So, many companies deliberately try to sell their product at lower price, just to discourage the competition in the market. There are certain pre project activities like; defining project in many cases, in itself is a project. This task is addressed by the entrepreneurs and managers who are engaged in the corporate planning. The main questions to which these people have to find the answer are first what to produce that is identification of the product or a series of products now, these could be the same as I said the commodity chemical specialty chemical etcetera. Then of course, this requires extensive foresight and market knowledge. We have to not see just today's market for the product but the predicted market when our plant actually starts to functioning. It takes typically 3, 4 years to build a plant. So, we should always see the predicted market than the current market.

One needs entrepreneurship as an individual or, as an organization at corporate level. Then the question comes; how much to produce? This decides the size of the project this is determined by the market share of the product as I just said. And the economy plant capacity below which the price of the product is not attracted to consumers.

Now, this is there is something called as the economy of scale, when you design a plant for certain scale of production. Let us say 100 tons per day and when you want to double the capacity, you consider plant with twice or thrice or even 5 times capacity. Then the cost does not rise linearly; the cost rises with certain exponent which is less than 1 that we are going to see in this course in greater detail. When we study project economics and because of that the unit cost of production or unit cost of product falls as the scale of production increases.

Therefore, the production capacity is governed by this economy of scale; as well as the market analysis. And market analysis comes before, more primary than economy of scale. This is could be easy for an established product but not so easy for new product. So, if you are manufacturing an established product like sulphuric acid, nitric acid any commodity chemical, that is already in the market then making this kind of analysis is rather easy then a completely new product.

Then, the question is; how to produce? And this requires the selection of technology for the process. If the entrepreneur has his own technology then the efforts on this issue are saved. However, if one has to use license technology then we have to find the answers to the two questions. First is there any better technology available. And secondly is there any new technology underdevelopment which could be available in near future. All new technologies have to meet the SHE compliance, the safety health environment SHE, then the energy conservation N con philosophy, resulting in total quality management operation.

And, when the above questions are answered the more important question about the project; cost and financing will have to be addressed. The project cost and working capital decide the total capital outlet of the project and then financing can come from various sources. It could be the entrepreneur's own money, it could be the debt borrowed from some financial institution like HDFC, it could be partly debt entrepreneur's money and part money you borrow from people public in the form of shares. So, that is essentially the next question that we have to address.

Now, let us see how a project grows like milestones of a project from concept to commissioning. A project goes through various steps or sequences before final implementation, before finally you start producing a product. And significances stages

or, my stone in this journey in the projector the first the project conception that why the idea of project has come up. This could be considering from business in market opportunities, it could be new material or, technologies are available which are in demand, which could be consumer feedback, it could be opportunities made available from global politics. Or, in some cases it could be the simply statuary compulsions that conceive the project idea. Like tetra ethyl lead was used as oxygenate in petrol but because of pollution the tetra ethyl lead was bang and then empty bean methyl ((Refer Time: 23:03)) was used as oxygenate.

But now even empty bean is banned in many countries, because empty bean is formed to be a very severe pollutant and the currently used oxygenate is ethanol. So, this is how the project idea is conceived. Somebody would like to start a new project on ethanol just to make it as an oxygenate for the petroleum industry. Then next is the market potential that needs to be established, before you decide on the project.

Then, the technology search which I just said that you have to look for a new technology or, what is a best technology in existing among the existing options. Adequate technical data has to be obtained to evaluate the profitability at primary level. The preliminary feasible report needs to be prepared to aid the investment decision. Then the detail technology search and evaluation this task could be undertaken with the help of a project engineering company. Then is the step of site selection you have to search a proper site for the project after careful evaluation of all the sites that are available.

Then, comes the preparation of detail techno economical feasibility report which is presented to the board of governors of the company and once it is approved then you have to go for a statutory clearances or, approval such are needed for the project implementation from both central and state government. You have to do the hazard analysis, the hazard operability study called Hazop. And then the environmental impact assessment this study needs to be undertaken with the help of the techno economic feasibility report, because all of these is going to affect the economy of the process. Then after this is completed; then you have to go for detailed engineering then contract should be signed with the process licensor for supply of know how.

The contract should also be signed with the detailed engineering contractor; next step is project financing as I just said, that you can obtain finances through various sources;

either through bank or entrepreneur's own money, own investment or, through equity shares or a combined of these 3. And after you complete these 10 steps then the project construction starts including the detailed engineering procurement is installation of equipment. And once it is installed then the project is commissioned after completion of construction. First there is mechanical commissioning project and that is followed by process commissioning.

So, this is how is the journey of a chemical project at each and every stage you have to make sure that you have a profitable process. so that technique economical process feasibility report is a major milestone because that essentially gives you an idea of the profitability of the process. Now, let us see some aspects of the chemical process design. What we have seen so far is a chemical project as a whole, but when we are developing a process before it becomes a project.

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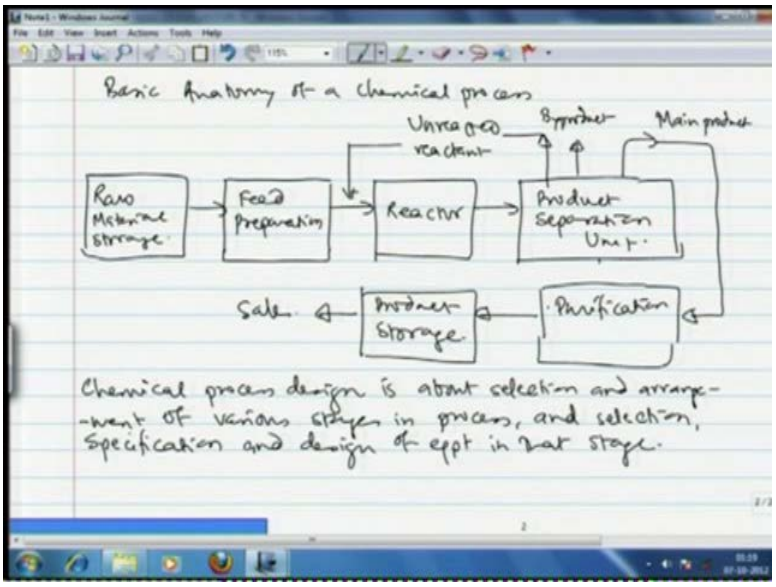

What are the guidelines that we have to follow or what are the basic steps that we have to see the basic anatomy of a chemical process is as follows; how do you give a general picture of chemical process? You have certain raw material which you store at particular location then you have to go for feed preparation, if your raw material does not need the required specification purity or, particle size or, concentration and so for then you have to prepare the feed before it enters the reactors. So, after feed preparation there is a

reactor, the streams emerging from reactor contain mainly products, byproducts, waste products and UN reacted reactant.

So, the stream emerging from the reactor has to go to product separation unit. This removes the byproducts, the main product and also the un reacted reactant which is recycled back to the reactor and then the main product further goes to purification unit. And after purification it goes to the storage.

And finally it is sent to the market. So, this is a basic anatomy of any chemical engineering process, a very general design not all of these steps will be there in all chemical process and then the complexities of each stage will depend on the nature of the process. The process design is essentially concerned with selection and arrangement of these stages and specification and design of the equipment that is required for each stage. So, that point I note here; that chemical process design is about selection and arrangement of various stages in the process and selection specification and design of the equipment in that particular stage.

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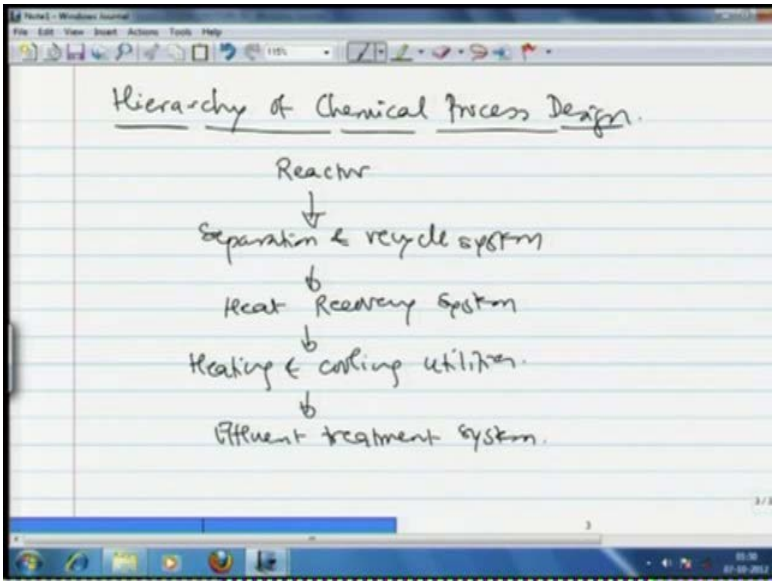

Now, how does a chemical process design start or, the hierarchy of chemical process design. I just mentioned to you; that designing a chemical process like drawing a painting, that you first mapped the canvas with certain areas. Where you will draw a certain parts of your painting and then keep on filling these with greater and greater detail. Every process transforms the feed into product; in the most cases the feed may not

react completely, the UN reacted reactant needs to be separated from product for recycling. Moreover the product itself needs to be purified, as I just showed in the anatomy diagram and this gives the guidelines for separation system design. Depending on if you have the knowledge of the stream emerging from the reactor that is a starting point for the separation system. The separation system consists of various operations like flash or flashing drums, distillation column, extraction unit, absorption, absorption unit etcetera.

Now, many separations in unit require large energy input like for example, distillation column. The re-boiler of the distillation column has to be operated and that is the unit which is highly energy intensive. Distillation column also requires a cold utility to operate its condenser. So, that energy distillation is a highly utility intensive operation it requires both hot and cold utility.

If all of these heating and cooling requirements are to be met, by the hot and cold utility for example, the steam and cooling water are the most frequently used hot and cold utilities. That creates a large burden on the utility and also the economics of the process. And that renders the process rather inefficient, in terms of economics. Therefore, we have to carry out the energy integration. Energy integration is nothing but meeting the deficit of energy in one part of the process by surplus of the energy to another part of the process. And this issue you have already seen in the NPTEL course of process equipment design.

And, therefore; energy integration reduces the load on utilities making the process more economically favorable. The synthesis of heat exchanger network for the integration of process requires knowledge of all the flow rates composition heat capacities and temperature of the streams. And this intern requires all the material energy balance and design of reactor and separation system to be done a prior. So, when you undertake heat integration process, you have to know everything about the process; what are the components of separation system? What is composition of the stream that is emerging from the reactor? And what are the overall material energy balances of the process.

So, energy integration is can be considered as the last step of the design. Because it requires knowledge of all the previous steps so that is the last stage in the design. So, changes in the reactor could also be possible, making the reactor size large, increases the

residence time of the reaction mixture or using another catalyst than the existing one that changes the composition of the product stream that is emerging. And therefore; the extent of the conversion achieved in the feed also changes not only the yield, but selectivity of the products of the changes.

Now, this intern increases the amount of like product in the exit stream. If you make reactor large the residence time of the reaction mixture increases that makes the reaction to go to higher extent. And then the amount of product increases, but rarely will you have a single reaction going on in the reactor, there are always several side reactions and therefore; the quantities of byproducts of the process will also go up.

And, this intern affects the design of the separation system, because the purification needs of the product; how to be made separation of by products has to be done and therefore you may need some additional separation units or, you may have to change the equation of separation of products, when the reactor configuration changes. Now, with change in the separation system, the heat integration network also changes.

So, with all of these variations in the design and process parameters, you can generate a large number of flow sheets and each of these has gone for further improvement with heat integration. You have certain variables with permutation and combination of variables, large number of flow sheets may be possible. And then you have to evaluate all these flow sheets to minimum extent. Like you cannot; let us say, if you have 1000 possible flow sheets, all of them may be profitable but to greater or less extent and then you have to screen these process alternatives and then you have to arrive at certain set of best possible design.

It could be; let us say 10 out of 1000 but you cannot find out a single possible flow sheet. And the final flow sheet that you need may be a combination of all these 10 sheets. The complexity of the chemical process synthesis is 3 4, first to identify all the major equipment in the process by identifying the unit of oppression. Then optimize each of the operation with optimal interconnection between them and finally, optimize the whole process ok.

Now, you will often find optimization of one set of equipment does disturb the minimum condition for the second equipment. And therefore; as I said you have to optimize the process as a whole, rather than optimizing 1or 2 sections of the units. If a chemical

process is to be designed from scratch, it is helpful to develop a methodology, for this design. So, after choosing the exact reactions for synthesis of the product and raw material that is a first stage; the designs start from the main reactor of the process and this is the place where the raw materials are converted into product. What is the type of reactor, the space velocity temperature pressure of the reaction is finalized then we get the idea of stream that is emerging from the reactor.

That contains the products and byproducts and the UN reacted reactant and with this it is easier to design the separation system and the recycle structure of the flow sheet. Recycle structure of the flow sheet is very important; because the recycle causes significant rise the operating cost. Especially, if you have the gaseous reactant recycles then you require compressor. And compressor is equipment which is high in terms of both capital cost as well as operating cost.

The reactor design the separation system recycle structure together defines the heating and cooling duties of the process. Thus, the heat exchanger network comes next. And after heat integration of the process those heating and after you do heat integration process; you may still require some heating or, cooling duties like, some heating and cooling the process cannot be still satisfied with heat integration. And then you use the utilities only for those heating and cooling duties that will reduce the load on utilities significantly. There are various hot and cold utilities; for example, the furnace heating steam at various pressure levels, steam generation, cooling water, air cooling refrigeration ok.

So, the utility selection follows the design of heat recovery system. And after design of all of the above; we get an idea of the various discharges that may occur from the process. Now, process we generate all three kinds of fluids; solid, liquid and gas. And this affluent needs to be treated before they are discharged to the surroundings. For example, if the process is generating a purge stream containing pollutant gases like socks, nox, sulphur oxide, nitrogen oxide. Or, if it has harmful organic vapors, we need to design gas absorption or vapor recovery steam before the purge.

Similarly, if an affluent stream is being generated from the process that needs to be treated for lowering the BOD and COD values before discharging into the water bodies like, river and lake. So, the design of the affluent treatment plant comes the last; so the

hierarchy of chemical process, design could be written as follows. First you design the reactor, then comes the separation and the recycle system. Then comes the heat recovery system; then comes the heating and cooling utilities selection of the heating and cooling utilities, then comes finally, the affluent treatment system.

Now, in this course we are going to see all these aspects of chemical process design. And then we are going to couple that to the chemical project economics. Because we have to develop a profitable process; it should also be a safe process, it should be also energy efficient process, it should be environment friendly process. So, all these things we are going to address in this course.

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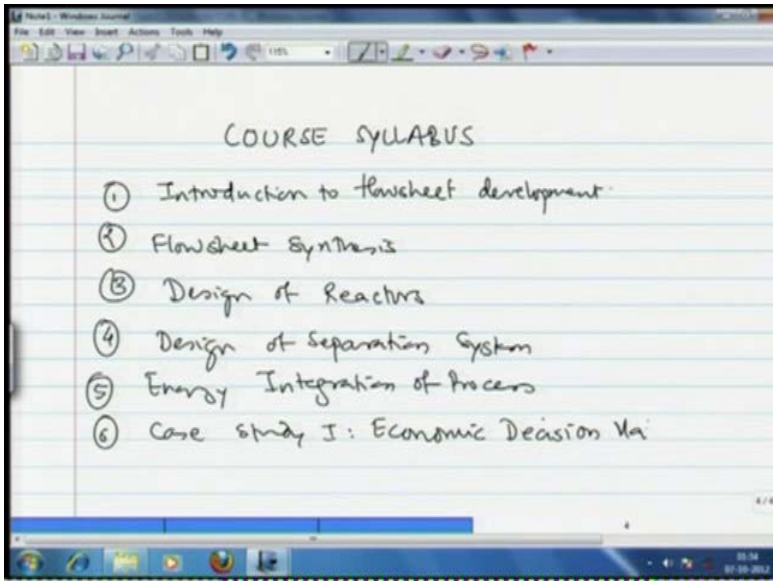

Now, let me give you the syllabus for this course. We have essentially 8 modules in this course. And the contents of these modules are as follows. Course syllabus; the first module is about introduction to flow sheet development, where we shall see some basic aspects of design of the flow sheet essentially, the same thing which we have seen today but when greater detail then next comes the module of flow sheet synthesis.

The sub topics that we are going to see here are; input information for the process like, batch versus continuous; then input output structure of the flow sheet, recycle structure of the flow sheet. Then we are also going to have tutorial sun mass and energy balance the process and the recycle structure of the flow sheet. Then will be the module of the design of reactors. Here, we are going to see the design principles for catalytic and non-

catalytic reactors of pluck flow reactor, continuous stuck tank reactors or C S T R R batch type of reactor.

And, then we shall also have; tutorial on design and costing of the reactor. So, some portion of this module you have already studied in the NPTEL course of chemical reaction engineering. But here, we shall couple it to the economics; we shall also see the costing of the reactor along with the design. Then comes the module of design of separation systems; we shall review the general separation systems for homogenous and heterogeneous mixtures. You have already had introduction to these systems in the NPTEL course of unit operation, mass transfer operations.

So, this will be more or less revision. Thereafter, we shall see the design of the distillation column, but from practical point of view, we shall see, what are the easy steps for calculation of number of plates, the multi-component method, you have seen in the course of mass transfer, but we shall see some simpler and quicker methods for multi-component mixtures. In addition to this; we shall see how we can calculate the height and diameter of the column.

Then, we shall see the sequence of the distillation column, when we have to separate multi-component mixtures. What are the principles governing and deciding the sequence of columns and finally, we shall see the heat integration of the sequences. And then we shall also have the tutorials. Then comes the module of energy integration of the process, the fifth module will be energy integration of the process.

Here, we shall see the principles of energy integration again; this will be some repetition of whatever you have learnt PED3 Process equipment design 3 NPTEL course. Then how like composite cursor are constructed, how energy targets are identified, the cost targets are identified minimum and minimum hot and cold utility. Then the problem table algorithm and finally; we shall see the pinch technology for the design of the heat exchanger networks.

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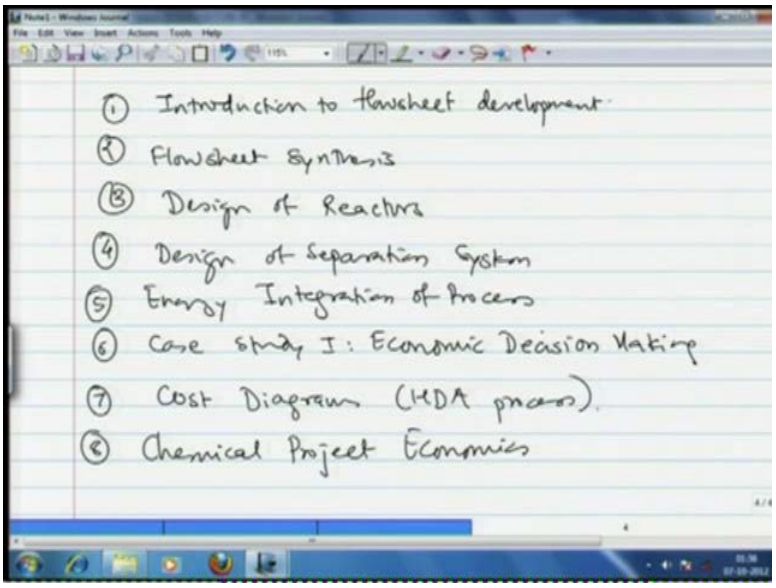

And, we shall also have tutorials on all of these aspects. Later, we shall have 2 case studies; case study 1 will be that of economic decision making. We will see the design of a gas observer, but from economics point of view like, gas absorption is also a topic that you have studied in mass transfer operation. But now, we shall see the economic aspects of this particular process and how economics governs the design of the gas absorber.

So, this will be a case study one that is the sixth module. The seventh module will be the cost diagram; which is another case study of hydro de alkylation process, H D A process hydro de alkylation process. Here, we shall see as how we can screen different process alternatives. As I just said that this chemical process synthesis about generating process flow sheets ok. So, you may generate very large number of flow sheets and you may have certain process alternatives.

So, how you can assess the economic implications of these alternatives, that issue will be addressed in this particular case study like, cost diagrams. We can see as how the cost information and process information can be represented in the same diagram? And how simple diagram, simple calculations can help us assess various process alternatives, where economic implications of various process alternatives.

So, after these 2 cases studies; the final module will be that of chemical project economics. And here we shall see various aspects of economics project economics. Now, these principles that we are going to learn in this, apply equally to other projects as well

it is not chemical project economics, but you can say it will be project economics. Because the basic principles of economic evaluation projects, that we are going to learn apply equally well to other projects also and the topics in this are; first the introduction then the process selection, site survey, project cost estimation, time value of money, the concepts of interests, depreciation, project finance and finally the profitability analysis.

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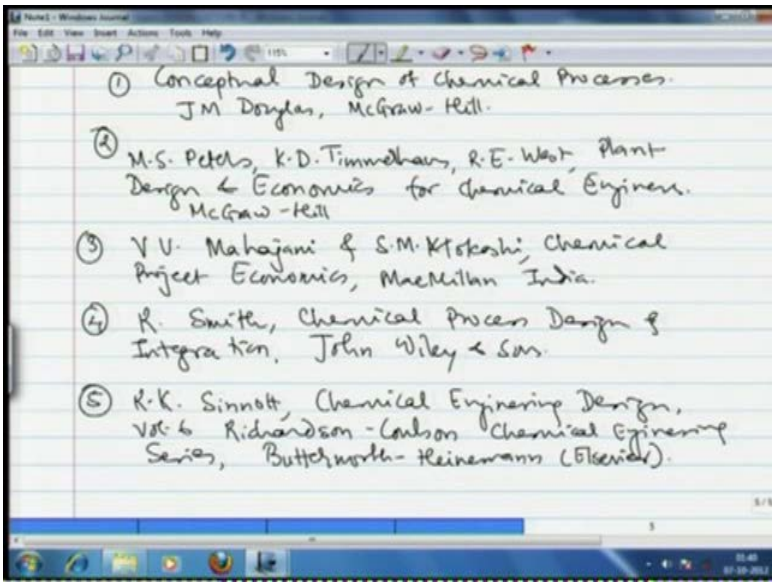

So, we have a syllabus of 8 modules, spanning 46 lectures. I am going to refer to 5 books while teaching this particular course. And I am giving here with the names of these books along with the authors. The first book that I am going to use or, refer to is the conceptual design of chemical process. This is very widely used book in many universities. Conceptual design of chemical processes by J M Douglas and the publisher of this book is M C Grow hill international. Then the second book which I am going to refer to is the standard text of M.S peters and K.D.Timmerhaus. This is already in the fifth edition vary widely, very popular text among undergraduate students as well as practicing engineers M S Peters and K.D.Timmerhaus and R E West plant design and economics for chemical engineers. This is again published by M C Grow hill.

The third book I am going to refer to is by Doctor V. V. Mahajani and Doctor S M Mokasani. The title of this book is chemical project economics and it is published by Macmillian India. Then the fourth book I am going to refer to is also quite popular text among undergraduates; the book of Robin smith chemical process design and

integration. This is published by john Wiley and sons. And finally, the fifth book is that of R K Sinnott chemical engineering design. This is volume 6 of Richardson Carlson chemical engineering series. And the publisher of this is Butterworth Heinemann which is a part of Elsevier. So, these 5 books I shall be mostly referring to while teaching various modules of this course. So, I hope you will enjoy this course, because as I said in the beginning this is a sort of a pinnacle of chemical engineering curriculum; where you will learn applications of various principle that you have used, that you have learnt in all other NPTEL courses for designing a chemical process. Then converting that process into a project and finally, evaluating economics of this project.

Thank you.