Inorganic Chemical Technology

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Lecture - 05
Fuel Gases

Welcome to the MOOC course Inorganic Chemical Technology. The title of today's lecture is Fuel Gases. This week and coming next week what we will be discussing we will be discussing about the production of fuel and industrial gases. So, why do we need to study about the fuel and industrial gases production process, rather directly jumping into the production process of different types of inorganic chemicals, which is the main content of the course?

Because, any plant if you take there are several cases not only inorganic, but organic chemicals manufacturing plants if you take what happens there are several cases where these industries inorganic and organic industries depends primarily on fuel and industrial gases for different purposes.

Different purposes such as like process heating or heat treatment or for synthesis of different types of inorganic and organic chemicals like that that is the reason rather directly going into the production process of different types of a inorganic chemicals, what we are doing we are going to see a few basics, few details not only basic few details like manufacturing process etcetera, reactions etcetera for the production of fuel and industrial gases.

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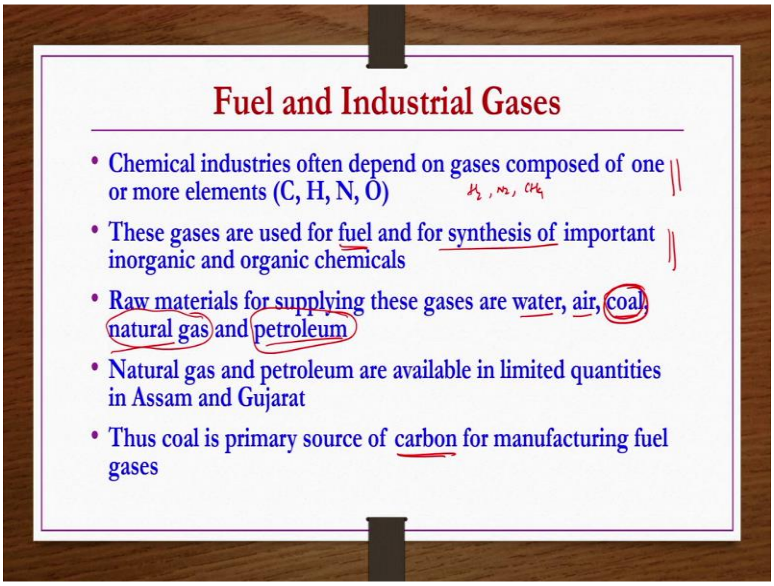

So, chemical industries often depend on gases composed of one or more elements of C, H, N, O single element you know gases are something like H 2, N 2 etcetera. Two element gases something like CH 4 etcetera are these are often used in chemical industries very often used in chemical industries. These gases are used for fuel purpose also and for synthesis of important inorganic and organic chemicals as well that is the reason it is essential to have a have a adequate information or knowledge on the production process of these fuel and industrial gases from UG curriculum point of view right.

So, raw materials for supplying these gases are naturally available water, air, coal, natural gas and petroleum right. So but however, the natural gas resources and petroleum resources are very limited in India very very limited we have a few resources in Assam and Gujarat for the natural gas etcetera, but other place we don’t even have such minimum limited resources also right.

So, because of that one coal is treated as a primary source of a production for this fuel and industrial gases in India especially ok. So, thus coal is a primary source of carbon for manufacturing fuel gases ok. So, now, before going into the production of different types of fuel and industrial gases what we do? We will have a kind of a classification of these gases. Let us start with fuel gases.

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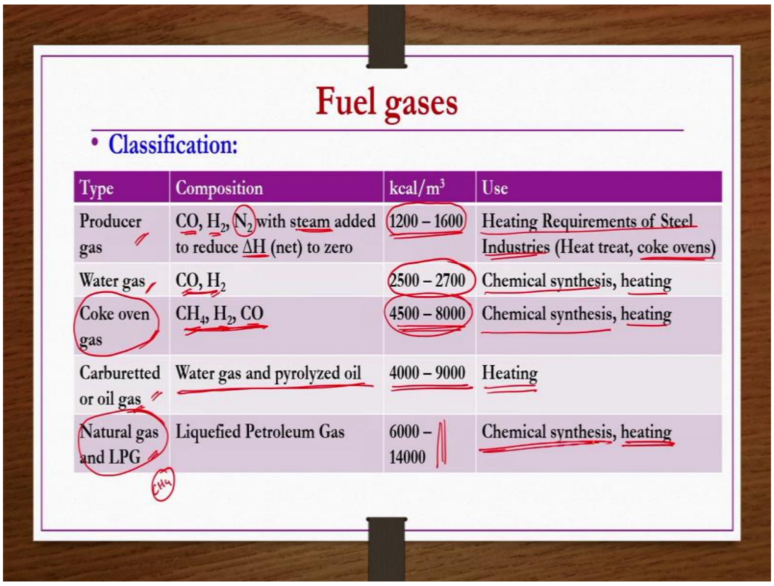

Fuel gases classification there are a different types of fuel gases are there. Now we are going to see different types of gases their composition, their energy content and then application where we often use them. So, different types of fuel gases that we are having are producer gas, water gas, coke oven gas, carbureted or oil gas, natural gas and LPG right.

If you see composition of a producer gas it consists of CO and H 2 in addition to inerts like N 2 plus steam if required to reduce the delta H of the process to zero; net delta H of the reaction if you wanted to make it to zero then you are supposed to add steam to this producer gas composition. Otherwise, primarily it consists of CO, H 2 and N 2. Steam is added or required to add only if you wanted to make delta H of the process to become zero ok.

The energy content if you see per meter cube of gas, the energy content of the producer gas is around 1200 to 1600 kilo calories. Now, the question is that why so much of variation in energy content of this producer gases, if you take only a meter cube of the producer gas? That because as the variation in the composition of CO, H 2 and then steam added to it if required then accordingly the energy content varies right.

Because the CO how much percent it is there H 2 how much percent is there in the gas that makes you know variations in this kilo calorie per meter cube of energy content and the given gas right. It is often used in heating requirements of steel industries especially coke ovens. Coke ovens are used to produce coke from the coal ok or upgraded coal. So, these coal are you know processed in coke ovens in order to get the coke that coke is again used in steel industries especially iron making etcetera, steel making kind of processes it is used.

So, in this process the coke oven gas is a byproduct also. So, coke oven gas is not produced individually in general. So, it is produced as a kind of byproduct of a process ok; that we are going to see today anyway. Next is water gas which is having a CO and H 2 only right. The energy content of this water gas if you see per meter cube if you take it will have energy content approximately 2500 to 2700 depending on the composition of CO and H 2 variations in CO and H 2 makes variations in this energy content of this water gas.

Then it is often used for chemical synthesis and heating purpose also most of these gases are used for heating and then chemical synthesis purposes. Then coke oven gas it consists of not only CO and H 2, but also methane CH 4 right. So, its energy content you see the variations are too much 4500 to 8000 kilo calorie per meter cube of coke oven gas.

So, now these many variations, the variation such a large variation is coming in the energy content or calorific value of the coke oven gas is coming because of the variations in the components CH 4, H 2 and CO that are present in this gas. If you have more CH 4, it is possible that you know more calorific value per meter cube of coke oven gas you may get. It is also used for chemical synthesis and heating.

Then carburetted or oil gas which is nothing, but water gas and pyrolyzed oil which is used for heating in most of the you know petroleum industries and then the energy content of this gas varies between 4000 to 9000 kilo calorie per meter cube of the oil gas ok the variations again because of the variations in the compositions. Then natural gas and LPG compositions are liquefied petroleum gas, if it is primarily methane and then a few fraction few percentage of other hydrocarbons then it is natural gas.

If you have a liquefied petroleum gas then mostly you have propane and butane kind of alkanes that are present in the gases ok. So, these two are you know the same process can be used to produce both of them that is also we are going to see. Now, here again you can see their energy content is varying a large from 6000 to 14000 kilo calorie per meter cube because of variations in the compositions ok.

Because what we understand from these gases any of the gases that you produce you know in the subsequent slide we are going to see the reaction. So, there you can see from the same carbon let us say coal is a source for the carbon and then you do certain kind of reaction more than one component CO, CO 2 are possible. In general sometimes you know depending on the what is the other reactant CH 4 etcetera also possible right. So, when these reactions are taking place so more than one components are forming.

So, then depending on how depending on the degree of purity subsequent after the reaction that you are doing based on that one the composition is going to vary. So, that accordingly their energy content is going to vary and then these gases are also used for heating purposes and then chemical synthesis.

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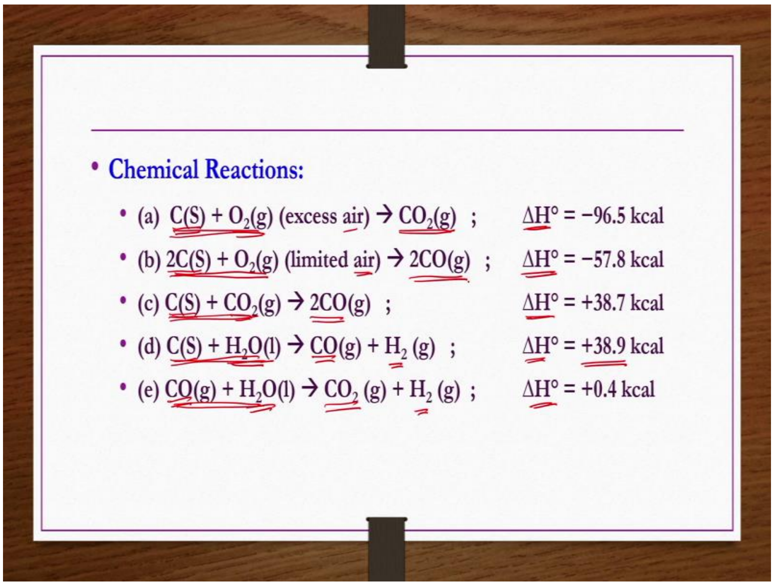

Now some of the common chemical reactions occur while we have this fuel gases production processes. What are they? That we are going to see now. The first reaction, let us say if you have a solid carbon and then you react with a gaseous oxygen with excess air then you get CO 2 gas carbon dioxide gas you get with delta H naught minus 96.5 kilo calorie right.

So, now, this delta H is coming negative; that means, the enthalpy of the reactants is higher compared to the enthalpy of the products; that means, it liberates the energy and then its called its an exothermic reaction. Its an exothermic reaction right. So, when this reaction takes place whatever the energy is there that one can recover and then use for the different process like process heating etcetera ok.

If you have 2C and O 2 C in a solid form and then O 2 in gaseous form with limited air then you get 2 moles of carbon monoxide gaseous form. And then this delta H naught here again is minus 57.8 kilo calorie minus so that means, here also the enthalpy of the reactants is higher compared to that of the product; so that means, it liberates the energy.

And when this reaction occurs, the energy is liberated that energy can be stored or you know recovered or processed further to use in different purposes that is the advantage. But, now if you take another reaction C plus CO 2 then it gives 2 moles of CO right, but the energy if you see here delta H naught is plus 38.7 kilo calories.

Now, here the energy delta H naught is positive right; that means, the enthalpy of the reactants is less than that of the product so, that reaction is not going to occur until and unless if you supply some energy or sufficient amount of energy to the reactants. So, these are the endothermic reactions.

Similarly, C is not going to react with water until and unless you provide sufficient amount of energy adequate energy for this reaction to occur; because the delta H naught for this reaction is also positive, it is also endothermic reaction. Here we get CO and NH 2 as products.

Similarly, if you have CO and then try to react it with water then also reaction does not occur until and unless if you provide adequate energy to the reactants. So, that products CO 2 and H 2 O to form because here again delta H naught is plus 0.4 kilo calories positive ok.

So, now here some of the reactions are exothermic, some of the reactions are endothermic when C reacts with oxygen or air and then H 2, H 2 O and then CO 2 etcetera. So, then these details are given. So, depending on the process conditions and then what kind of input are you taking.

Let us say oxygen is required. How pure oxygen are you taking what is amount of oxygen that are you providing to the reactor. So, that the reaction take place is it sufficient amount, limited amount or excess amount. So, based on those things these reactions are going to change ok.

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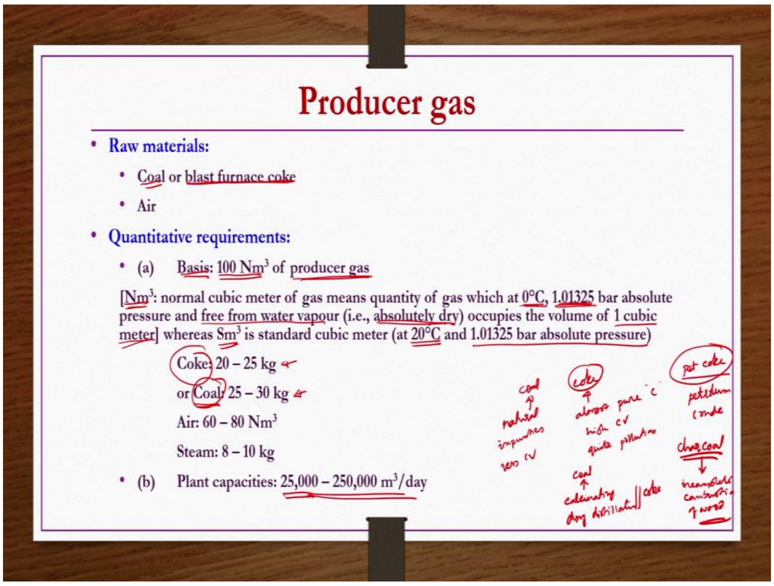

So, now we see producer gas production process. Raw materials are nothing but coal or blast furnace coke. So, this coke as I mentioned coke ovens are there so, this coke ovens are used to make coke from the processed coal right or upgraded coal you use in coke ovens right. So, that to get coke and this coke is often used in the different types of furnaces ok.

One such kind of furnace is blast furnace coke where you produce the coke and then that coke you can use for the production of you know you can use in the steel industry ok. So, that coke you can directly use for producing the producer gas. Air is the other raw material and then quantitative requirements; what do you mean by quantitative requirements?

That is how much coal you need? How much air you need that depends on how much product you need? How much what is the quantity of the producer gas product that you want in the process? So, accordingly you have to take the coal or coke accordingly you have to take and then air also you have to take.

So, those material and energy balance calculations you might have already done in your process calculations course or the same course is also known as material and energy balance course in some other universities as well. So, according to that one if you take basis what is this basis? Basis is that you know required quantity of the product that often we take as a basis right.

Let us say if you wanted to produce 100 normal cubic meters of producer gas then how much coal or coke is required or how much air is required in addition to that one how much steam etcetera required those things you know is nothing but you know quantitative requirements of the process.

So, for that these quantitative requirements that we are going to have for almost all process and then the basis is this one; basis is that you know per k g or per tone of the chemical that you produce. Now, here in this case if you want to produce 100 normal cubic meters of producer gas how much coal or coke are required in addition to the air and steam right.

So, this Nm cube is normal cubic meter which is actually sometimes it is a confusion between Nm cube and then Sm cube Nm cube is nothing but normal cubic meter of gas means quantity of gas which is at 0 degree centigrade, 1.01325 bar absolute pressure and free from water vapour, that is, completely absolutely dry basis on dry basis occupies the volume of 1 cubic meter.

Because we know these gases depending on the size of the container and depending on the size of the temperature and pressure at which we are storing the volume changes; the volume changes. So, that is the reason the specification of temperature and pressure is very much essential if you are specifying a volume of a gas.

So, if you take dry gas at 0 degree centigrade and then 1.01325 bar of absolute pressure whatever that dry gas occupies the volume is of 1 meter cube then that is that standard unit is nothing but 1 normal cubic meter, right. Whereas Sm cube is standard cubic meter that is at 20 degree centigrade and 1.01325 bar absolute pressure.

So, if you wanted to produced 100 normal cubic meter of producer gas then you need 20 to 25 kgs of coke and or if you are taking coal as a source of C, then 25 to 30 kgs of coal is required air is required 60 to 80 normal cubic meters and then steam 8 to 10 kgs. Plant capacity is in general 25000 to 250000 meter cube per day for most of the existing plants.

Now, what is the difference between coke and coal? Right. The coal is the one you know natural resources that we get naturally with so many impurities. So obviously, it will be having less calorific value whereas, the coke is processed one almost pure not pure, but almost pure carbon source in this one.

So obviously, its energy is going to be high. So, high calorific value would be there, but it is also quite polluting pollution because of the coke is very high compared to the coal ok. So, that is the difference and then there is also something like pet coke or petroleum coke what it is.

Actually how do you get coke? Coke also you get from the coal only. What you do? You properly you know do some kind of processing like calcination or dry distillation or destructive distillation etcetera that you do. Then, you get almost like a pure coke. Similar process if you do for a petroleum crude then whatever the coke that you get that is known as the pet coke or petroleum coke.

And then in addition to this one you also may be having heard of the term charcoal. Charcoal is nothing but if you do the incomplete combustion of wood, then whatever the coke that you get that is known as the charcoal ok. These are the terminology we may be often using in this course. So, that is the reason it is essential to know a few basics or differences about them right.

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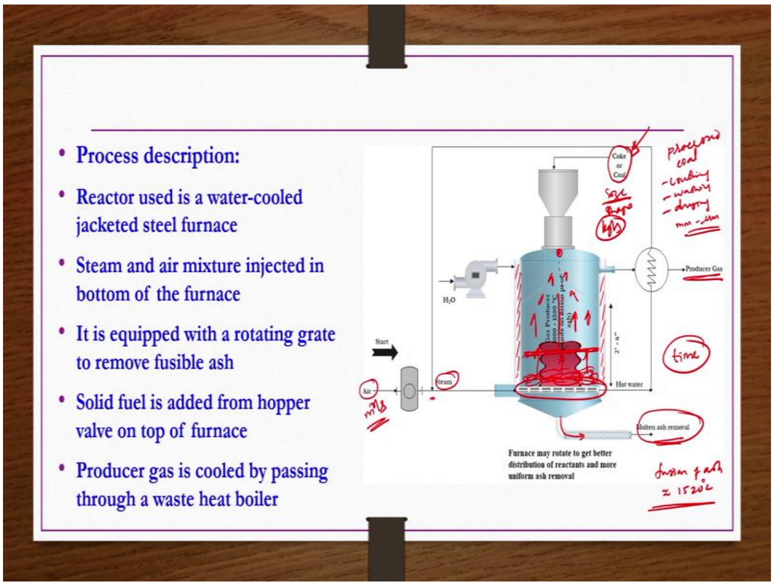

Now, how do we produce producer gas from the coke or coal? That is what we are going to see now here. So, let us say we have a we need a reactor here actually that is a furnace ok. In order to produce producer gas from the coke or coal you need a furnace right. So, that furnace is jacketed with you know provision. So, that one can do the water circulation also if required alright. So, to this reactor from the top coke or coal is taken a processed coke.

Processed means what? You know a natural process we get big lumps etcetera. So, then that we cannot put them in the furnace so, then what we do. We do you know crushing whatever unit operation that we discussed and then washing then drying these kind of processes you do so that you get fine particles of few mm or few micron size. So, those dry coal particles of such small sizes that you put from the top here to the reactor right.

And then from the bottom what you are giving? You are giving air and steam to the reactor and then this furnace is operated at temperature range of 1000 to 1500 degree centigrade depending on the fusion point of ash. Fusion point of ash is very much important, it is approximately 1520 degree centigrade. So, you have to operate this one as temperature at temperature less than the fusion point of the ash ok.

So, you do not want this fusion of ash to take place otherwise it is going to hinder the process right. So, such a way that you have to you know operate. And then why then why not at 1500 degree centigrade why at 1000 why at 1000 degree centigrade? That may be a question. These are the process variable one has to operate, one has to do the a prior calculation and accordingly decide which temperature is suitable for a required product quality right.

So, now this also is very essential for the particle to combust. So, now, what happens let us say for example, the carbon particle is coming from here at the top. This is the top most position for the carbon particle. So, by the time it reaches the bottom of the reactor it should completely burnt with the air that is coming in from the bottom. So, this air is moving up like this right.

So, in the inside the temperature is very high temperature is maintained. So, what you want by the particle it comes to the bottom, it should have a sufficient time or the contact time between the carbon particle or coal particle and then air should be sufficiently large enough that you know by the time it reaches to the bottom of the you know a reactor it should be completely burnt. So, the under these conditions under at this temperature pressure condition that are prevailing in the reactor one has to do a kind of a you know settling velocity of the particle etcetera.

So, it also depends on the size of the particle and then shape of the particle also that is there. So, now, see all your you know fluid particle you know interactions that fluid particle mechanics whatever that you study in fluid mechanics all that are coming into the picture here. Accordingly you have to decide. So, and then also you know based on the time required it should not be actually the time should not be calculated time required to reach the bottom of the reactor.

It should be some more above height something like this why? Because why as the time progresses; obviously, some ash will form because when coke or coal when you combust because of the impurities inorganic impurities present in that sample; obviously, whatever the cleaning that you do there will be definitely be there. If you wanted to make its 100 percent pure so, then its process is not going to be you know economically feasible that is another different problem ok.

So, that ash when forms it will be accumulated at the bottom. So, now, some portion of the bottom of the reactor is occupied by the ash. So, that is the reason you cannot take the bottom most layer of the reactor as the point to calculate the time required for the particle to reach from the top of the reactor to the bottom of the reactor. It should be something some above point like this. And then at what rate kgs per second should you feed the coke that is again going to have a role right.

And then at what rate of you know at what volumetric flow rate are you allowing air to flow through. That is again makes in you know difference here right. So, all these are the process engineering problems that one has to consider while designing the you know reactor for this particular process. Similar problems may be there in almost all kind of chemical production units. So, one has to be careful like this. So, now, these are some of the problems right.

The uniformity of the particle is required that is one problem. Size and shape has to be uniform then only efficiently the process will take place. And then the time the required time that is there for the particle to reach from the top to bottom that should be sufficiently high enough at especially high temperature right.

Those calculations are also very difficult all these fluid particle you know fluid particle mechanics those calculations you have done at the room temperature you know atmospheric pressure etcetera ok. That is the second issue time. Third issue is that what about this ash that is formed? Right. This ash has to be continuously removed that is another issue.

So, for that reason what we have? We have some grid at the bottom right which rotates. So, while rotating this grid there are two advantages the reactants may be a mixed properly for a uniformity and then another one the same grid is useful to drain out or take out the ash from it right. So, the time is why the time is very much essential?

Because now to this point when you are feeding the reactor by that time itself you have spent a enough number of unit operations, enough amount of money, enough amount of labor to get these particles right. So that means by to get this raw material itself you have spent enough money and time labor etcetera right. Now, that particle comes through and then let us say if does not react properly. If does not if it is not able to burnt by the time it reaches to the bottom of the reactor what happens? It will mix with the ash.

So, you may be thinking that if whatever the unreacted carbon or coke is there that you may be taken out from the ash and then recycle it, but that is not going to be easy because this ash is very fine, very fine particles inorganic particles are there right. So, these are very fine inside and then if the coal is mixed with that one or coke is mixed coke particles mixed with that one it will be very difficult to separate, if it is in dry conditions.

If it is in wet conditions now you should forget about separation of such unreacted coal particles such difficulties separation of coal or coke particles from the molten ash. So, that is the reason these problems are very essential engineering problems for a chemical engineers to handle while designing these reactors ok.

So, from the reaction chemistry point of view how simple it is just you know coke or coal is coming and then air and steam are joining inside the reactor and then certain high temperature is maintained and then reaction is taking place you get the producer gas. So, simple from the chemistry point of view, but from the chemical technology point of view see how many things you need to worry about it ok.

So, now, whatever the producer gas that you get from the reaction that is occurring inside this furnace that will be collected from the top. And then this hot producer gas would be passed through a waste boiler to recover the energy and then producer gas cold producer gas is stopped. So, while recovering the energy from the hot producer gas so you know you will be supplying the water.

So, then that hot water you can you know convert into the steam and then further join with the air as a recycle amount and then feed to the reactor ok, that is how. So, not only that water, but also the processing water in order to keep the reactor at required temperature you know you are supplying water through the through these jackets also. That water also you can you know use as a you can recycle after you know making it suitable for the recycling in the form of steam like this to this process ok.

So, now this is now this is the simplest one probably that we are going to study in this course. Later on as we are going into the you know different types of inorganic chemicals production, the flow sheets are going to be more complicated. Now, when you have only one single furnace and then designing and all that you are doing so many things are there.

Now, if you visualize you know when there are so many things are happening prior to the reaction and then after the reaction purification etcetera that entire flow sheet how many engineering problems would be there? How much thorough chemical engineering knowledge you need to become a successful chemical engineer you can realize ok.

So, reactor used is a water cool jacketed steel furnace, steam and air mixture injected in bottom of the furnace. It is equipped with a rotating grid to remove fusible ash and then solid fuel is added from hopper wall on top of the furnace. Producer gas is cooled by passing through a waste heat boiler.

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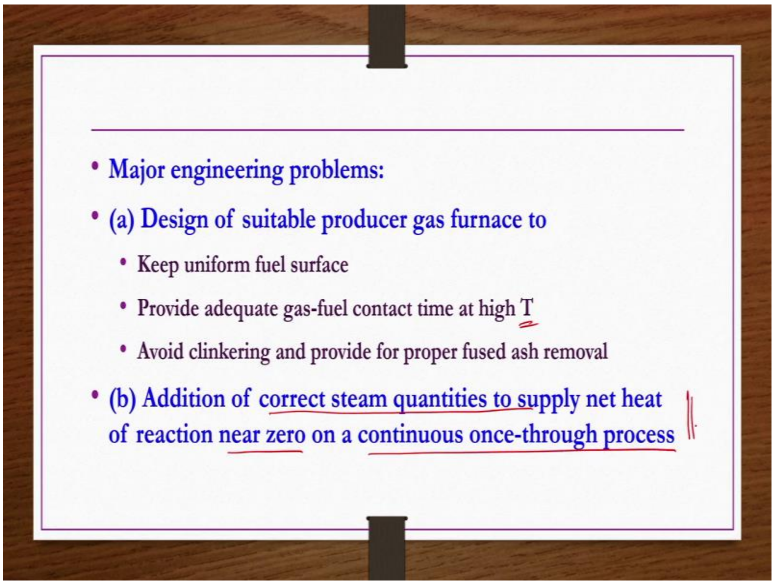

Now major engineering problem one is the design problem. Design of suitable producer gas furnace that should able to handle a three important problems as I mentioned. Keep uniform fuel surface and then provide adequate gas fuel contact time especially at high temperatures. And then avoid clinkering and provide for proper fused ash removal ok.

When lot of ash is formed and then it is accumulated at the bottom of the furnace that is going to be forming clinkers and then once the clinkers are forming the removal of such ash is become is going to become much more difficult. Then another one is this one. Addition of correct steam quantities to supply net heat of reaction near zero on continuous one through process is another problem. Now, we see water gas right.

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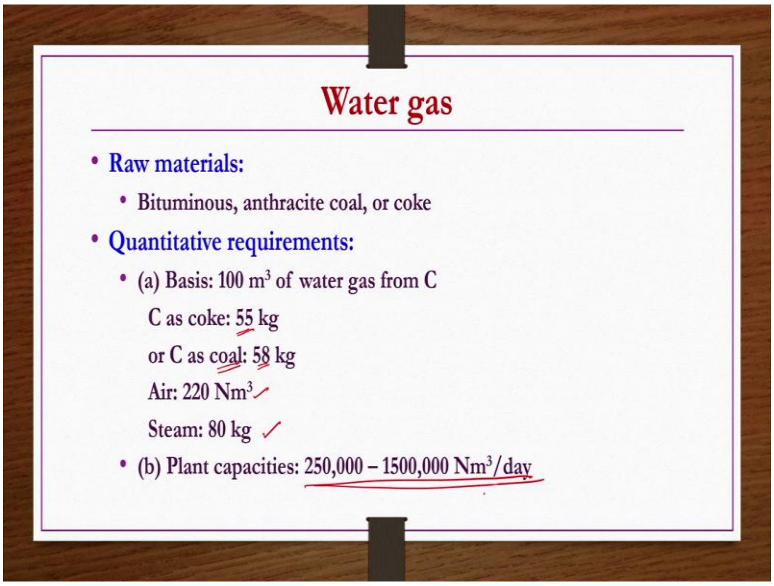

Raw materials for production of water gas or bituminous, anthracite coal, or coke then quantitative requirements; if you wanted to produce 100 meter cube of water gas from C source for C can be coke or different types of coal. Then if you are using coke as source for carbon then 55 kgs are required.

If you are using coal as source of carbon then 58 kg of coal is required. Then air is 220 normal cubic meters of air is required. Steam 80 kgs required. Plant capacity such as water gas production plants are having high capacity something like 250000 to 1500000 normal meter cubes of water gas per day.

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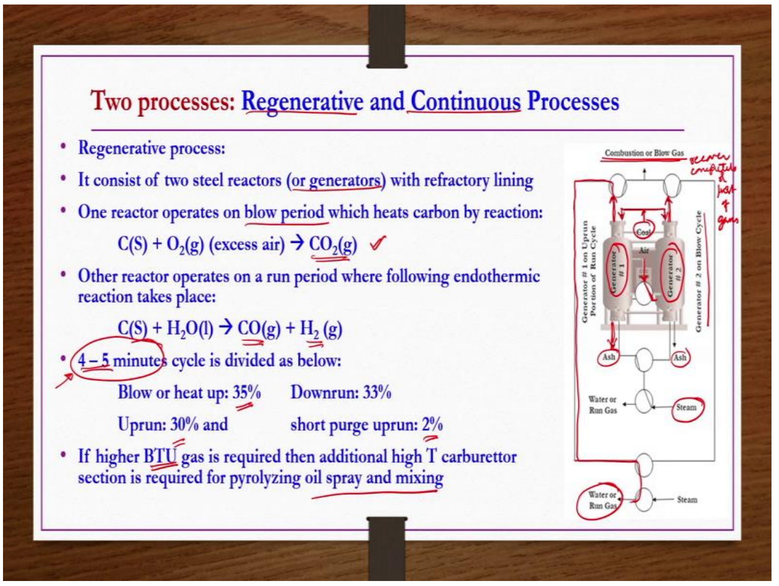

There are two process to get water gas a from C sources using air and steam they are regenerative process and continuous process. We see both of them. Let us start with the regenerative process. In the regenerative process is consists of two steel reactors or generators with refractory lining one reactor operates on blow period which heats carbon by the reaction C S that is C in the solid form plus oxygen in the gaseous form with excess air you can get CO 2.

This reaction occurs in one generator or reactor. Other reactor operates on a run period where following endothermic reaction takes place. We have already seen this reaction is exothermic previously you know when we are discussing about the chemical reactions few slides before we have seen this is exothermic reaction.

But in the other reactor which operates on a run period of endothermic reaction that is C in the solid form plus H 2 O in the liquid form when reacts together it gives CO gaseous form and H 2 gaseous form right. The cycle of this process is 4 to 5 minutes and then it is divided as below.

Blow or heat up 35 percent whatever the cycle time is there out of which blow period is 35 percent taken down run 33 percent is taken up run 30 percent is taken and then short purge up run is 2 percent. Purging in the sense you know you during the process you remove some of the things in order to make the material and energy balance you know suitable as per the requirements.

If higher BTU that is British Thermal Units gas is required then additional high temperature carburetter section is required for pyrolyzing oil spray and mixing. So, this is the regenerative process. If you see the pictorially what you can understand here as described here we have a 2 generators, generator 1 and generator 2. This generator 2 is on blow cycle to which you know for this both the reaction whatever the coal or coke that you have taken that is provided from the top like this ok.

This coal right and then in the generator 2 that is reactor 2 or you know reactor which operates on blow period. So, that here we are calling generator 2 to that one air is supplied air is supplied like this right. So, now this carbon and then this oxygen reacts with because excess air is there. So, then CO 2 would be forming.

So, now, these when this reaction occurs; obviously, gases are there and then ash would also be there. This ash is collected from the bottom like this ok whereas, the gases is there they are collected from the top like this ok and there you know what is the difference between blow period and then run period? Blow period or you know blow run.

Here, blow cycle what we can do we can recover. Recover or recycle completely or part of gases actually. That we can do. So, you can recover some of them and then subsequently you can use right. You can recover them and then use them as combustion or blow gas ok. Then other reactor or other generator that is generator 1 is on up run cycle right.

So, here what happens? In this reactor you know the endothermic reaction takes place. Generator 2 exothermic reaction is taking place. So, there is a heat liberated ok. There is a heat liberator, but generator 1 endothermic reaction that is CS plus H 2 O giving rise to CO plus H 2 O is taking place. So, this reaction will not take place until and unless you provide sufficient amount of energy to this one. So, from where this energy is coming? That is the question right.

So, one is that you know coal is coming from the top for this reactor also. Another one is the steam that you process through this one H 2 O right. So, and then going to this one and then energy whatever energy is required that energy you can take it from the whatever the blow cycle whatever the energy is liberated that you can send it to this reactor and then that energy would be helpful for the second reaction to take place; because the second reaction in the generator 1 is nothing but is endothermic reaction ok.

So, here also in this reaction also there would be some amount of ash forming. So, that ash has to be collected from the bottom right and then this process you can do you know as a cycle as a complete cycle you can do. Its a kind of regeneration is taking place by recovery or you know recycling of some of the gases ok. So, that is what you know that is the reason this process is known as the regenerative process regenerative process here.

So, whatever the energy required for both the reactions to taking place are you know not required to give energy from the outside much whatever the energy is there from the generator 2 that can be used in generator 1 ok. So, that is the process right. So, now, this process whatever the producer gas CO plus H 2 has formed coming from the generator 1 or the reactor that operates on a up run period.

So, then that those gases are you know mostly consisting of CO and H 2. They can be collected as water gas or as run gas as shown here ok. Now, the problem in this one this cycle the most important is that the cycle that operates is a total cycle is 4 to 5 minutes right.

Making this 4 to 5 minute cycle and then appropriately giving the coal feed rate and then giving the appropriate steam volumetric rate etcetera is going to be very tough one. So, that is another challenging issue about this regenerative process. Now we see continuous process.

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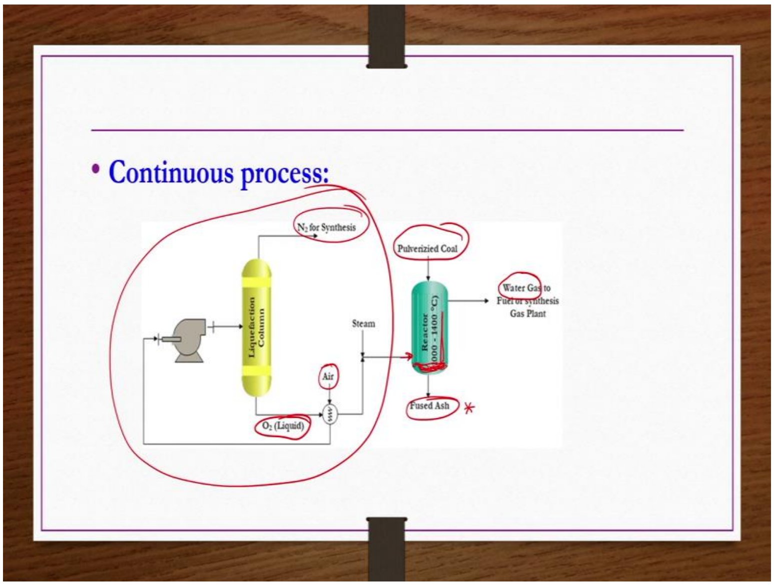

So, continuous process to produce a water gas is simple what we have, we have a simple reactor as shown here which operates between 1000 to 1400 degree centigrade to this reactor from the top you are sending pulverized coal or coke whatever you wanted you are using as a feed and then from the bottom you are sending air along with the steam right.

So, that the required reaction takes place and then you get water gas this water gas you can simply use as a fuel or you can take it to the synthesis plant; as per the requirement. And then whatever the ash that is forming because of this reaction inside the reactor, that ash is collected at the bottom and then that has to be continuously taken out.

So, continuously removing ash from this reactor is the major engineering problem of this process. Now, here the problem is that you need you know steam plus O 2 right along with the air right. So, how do you get O 2? So, if you have pure O 2 sufficiently. So, that can be taken as per the you know reactions reaction as per the stoichiometric and then see all this material and energy balance when you do you calculate all these streams different streams what is the carrying mass rate or volumetric rate and then at what temperature they should be provided and all those things you do the calculation appropriately you have to use them here.

Some people directly what they to they do? Some plants what they do? They take the air normal air and then they do they pass it through the liquefaction columns. So, that to get liquefied oxygen and then that along with the steam they take to the reactor whereas, the nitrogen they take it for the synthesis that is another option anyway ok.

So, this is the continuous process. So, before the reactor whatever this process is that you know depends on the process. If you directly having you know sufficiently pure enough oxygen and then steam directly you put them in the reactor otherwise one has to go for this one which is economic.

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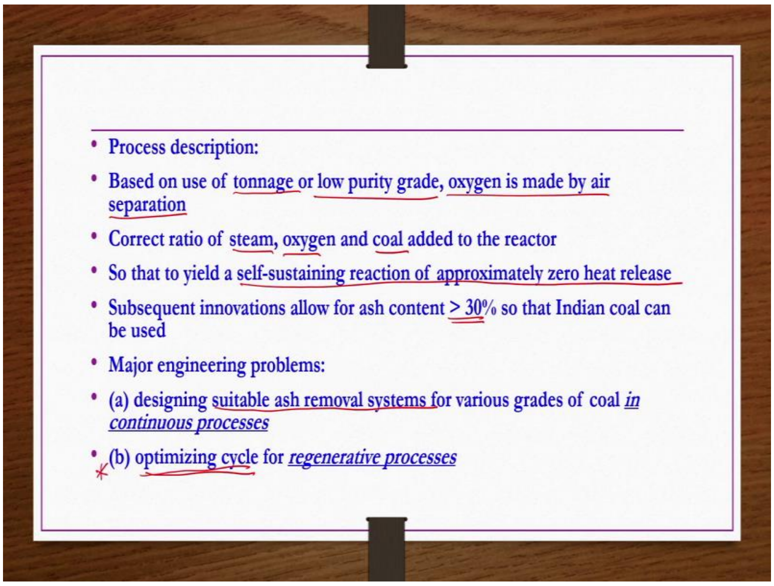

Process description it is based on use of tonnage or low purity grade oxygen is made by air separation right and then correct ratio of steam oxygen and coal added to the reactor. So, that to yield a self-sustaining reaction of approximately zero heat release self-sustaining reaction in the sense the delta H naught should be close to the zero. Subsequent innovation allow for ash content more than 30 percent also.

So, that Indian coal can be used. Now, the basic process is that one whatever the flow sheet is shown. So, now, one can add up and then make modification as per their requirements ok. There are several innovations are there some of them are such a way that you know Indian coal, Indian coal is the one where you know lot of you know ash contents are present in the coal up to 30 percent even more 40 percent also there.

So, you know such innovations are also there anyway. So, major engineering problems in the continuous process is the designing suitable ash removal systems for various grades of coal. In the case of regenerative process optimizing the cycle whether it is 4 to 5 minutes, 4 minutes, 5 minutes or 6 minutes what it is that optimization is you know another big engineering problem for regenerative processes.

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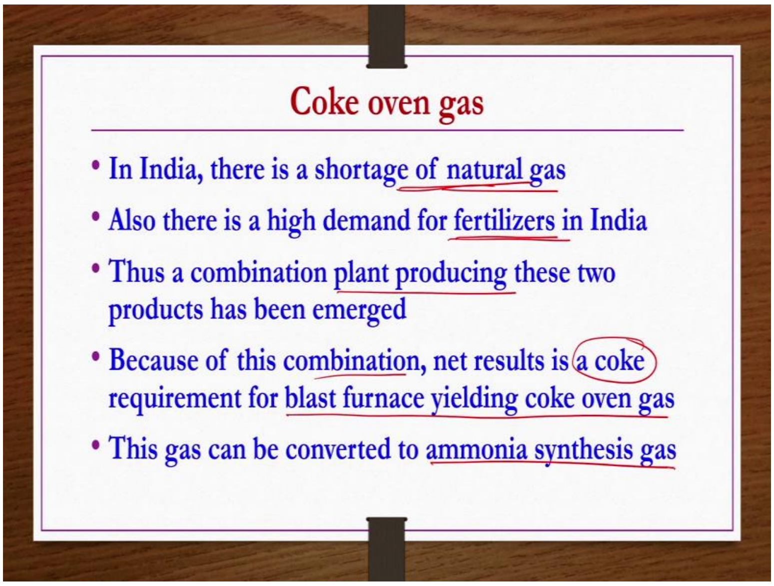

Now, we see production of coke oven gas. In India there is a shortage of natural gas also there is a high demand of fertilizers. So, now, because of that reason what we have? We have a processes where a combination of these two is occurring. You are doing the fertilizer production as well as you are producing some amount of natural gases.

So, thus a combination plant producing these two products has been emerged and then because of this combination, net results is a coke requirement for blast furnace yielding coke oven gas yielding coke oven gas ok. So, how it is that is what we are going to see. This gas can be converted to ammonia synthesis gas as well.

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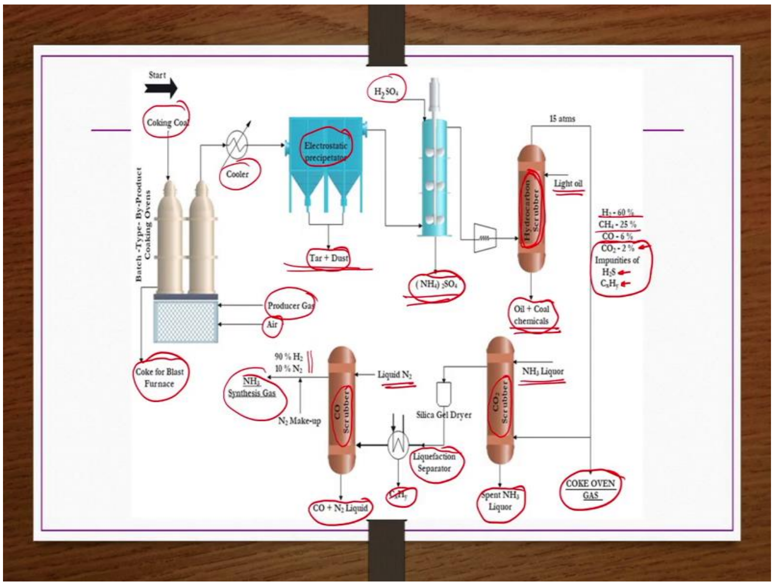

Now, the process if you see here what we have we have a byproduct coke oven shown here to this one coking coal whatever the upgraded coal is there that is fed from the top right and then in this one the coking takes place. In order to coking takes place what you have to produce? You have to produce you know what you have to do? You have to supply energy and that energy supplied by producer gas. The heat requirement taken care by this producer gas along with the air.

So, now in this batch type byproduct coking oven or coke oven, once the coking process is done the coke is collected from the bottom for the blast furnace. Whereas, the gases there those gases include the coke oven gases. Those gases include the coke oven gases along with some impurities. They are passed through a cooler. Then they undergo different types of separation purification steps. All these are the purification steps.

So, first purification step is the electrostatic precipitator so, that to remove tar, dust, ash kind of contents if anything are present in the gas. They should be avoided or removed by applying the electrostatic precipitation principles. Here, in the electrostatic precipitators. This is one of the one type of unit operation that we have not studied in our Week 1 anyway ok.

So, now here from the coke oven gases whatever the tar, dust etcetera have been removed using the electrostatic precipitation principle those gases are further taken into sulfuric acid H 2 SO 4 sulfuric acid H 2 SO 4 scrubbing units. So, here these gases are put from the bottom and then from the top H_2SO_4 is supplied. So, that scrubbing of the gases takes place and then because of that one during the process ammonium sulfate also forms ammonium sulfate also forms ok.

So, after this H_2SO_4 scrubbing whatever the gases are there they are passed through a compressor at 15 atmospheric pressure and then it that passes through hydrocarbon scrubber. Hydrocarbon scrubber you know here by the name you know it scrubs the hydrocarbon and it separates the hydrocarbons from the gaseous mixture because gaseous mixture is not only having CH_4 H_2 and CO. It is also having CO_2 and then hydrocarbons H_2S etcetera these kind of things right.

So, whatever the hydrocarbons are there those things are removed in this hydrocarbon scrubber. For that you need to have a light oil in which these hydrocarbons are dissolving easily that they can be dissolved ok. So, once the hydrocarbons are separated out scrubbed out from the gases those gases would be collected would be having you know 60 percent of H_2 and then 25 percent of CH_4 and 6 percent of CO.

CO_2 is impurity H_2S is also impurity and then C_xH_y is nothing but hydrocarbons these are also impurities. Though you are doing so many process to remove. It is not possible to remove completely. There will be some amount would be there right. So, from the bottom of the hydrocarbon scrubbers you will get the spent oil along with the coal chemicals right.

They may also be having some value NH 4 NH 4 twice, SO_4 is also having some kind of a market. So, they can also be used even tar and tar may also be used for some purposes ok. So, this if you are ok with the little amount of CO_2 and then H_2S and then little amount of you know hydrocarbons in your coke oven gas then you can take them as a product coke oven gas alright.

If you want further purification because you want like you know these products these gases if you wanted to use for the you know fertilizer industry or for production of fertilizers what you have to do? You have to remove CO_2 completely. So, that what you have to do this coke oven gas with minor impurities whatever are there that you have to pass through CO_2 scrubber carbon dioxide scrubber which is you know to which gases are supplied from the bottom and then from the top ammonia liquor is sprayed.

So, in the counter current way these two are interacting. So, once the CO 2 is removed the spent NH 3 liquor spent NH 3 liquor ammonia liquor is collected from the bottom from the top whatever the gases are there they will be passed through silica gel dryer. So, that to remove any amount of H 2 S etcetera or CO 2 etcetera remaining there itself there again ok especially H 2 S etcetera.

Then after this you know you pass it through you pass those gases through a liquefaction separator where hydrocarbons are liquefied and separated out hydrocarbons are liquefied and separated out. And then remaining then what you are having? You are having you know H 2 CO and these things are only you are having CH 4 these things are only you are having.

So, that you those gases you further process through or send through CO scrubber to which liquid nitrogen is spread from the top and then from the bottom these gases are you know going. So, counter current way they interact and then from the bottom what you get CO and then N 2 liquid form you get.

So, whatever the top gases is there that would be pure in 90 percent of H 2 and 10 percent of N 2, so that is sufficiently pure enough for ammonia synthesis right. So, these gases you can take to ammonia synthesis gas production unit ok.

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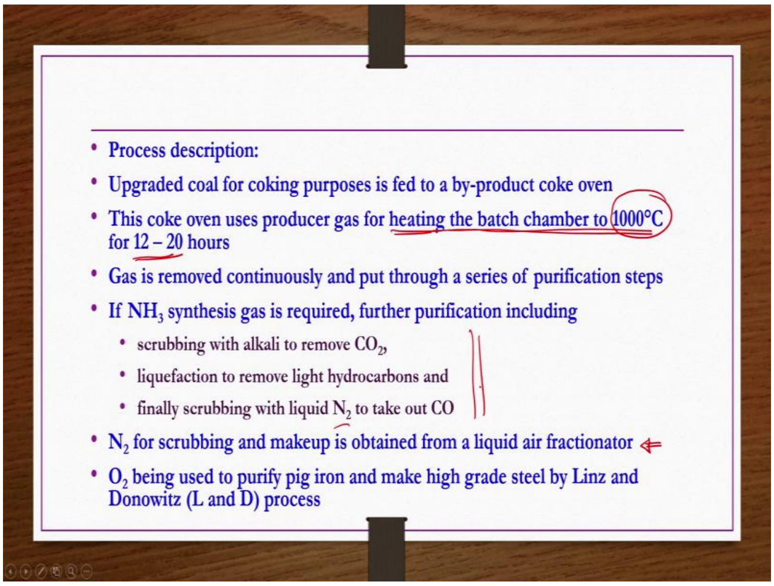

Same thing is explained here upgraded coal for coking purpose is fed to a byproduct coke oven. This coke oven uses producer gas for heating purpose the batch chamber whatever the batch chamber that is we are using for the heating purpose, you know that operates at 1000 degree centigrade and for 12 to 20 hours gas is removed continuously and put through a series of purification steps.

If NH3 synthesis gas is required further purification including scrubbing with alkali to remove CO 2 liquefaction to remove light hydrocarbons and finally, scrubbing with N 2 to take out CO. N 2 for scrubbing and makeup is obtained from a liquid air fractionator separately. This is not shown in the process. So obviously, see now we are concentrating only on the coke oven producing coke oven gas production and then ammonia synthesis gas production so, only required things only we are showing here.

We are not discussing about how N 2 is coming how H 2 SO 4 coming they are separate process. We are using them here ok. If at all it is required to produce onsite then you have to produce onsite also. O 2 being used to purify pig iron and make high grade steel by Linz and Donowitz process ok. So, all these steps we have seen I discussed in the previous slide anyway.

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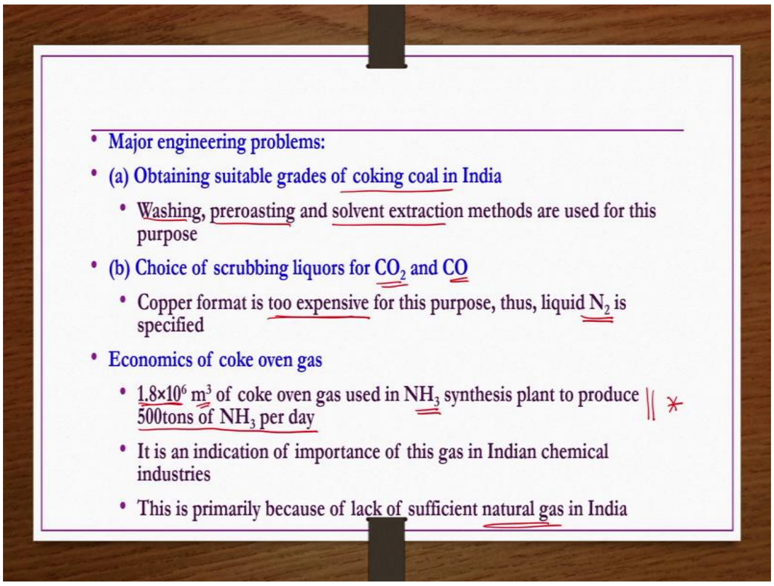

Major engineering problems associated with this process are obtaining suitable grades of coking coal in India that is one big issue. Because, washing, pre roasting and solvent extraction methods has to be applied for that coke and then they take lot of you know efforts, time labor and then capital cost everything right.

So, not only operation cost. So, then because of that one process may become economically expensive. Then choice of scrubbing liquors for CO 2 and CO is another issue. One has to go for cheaper ones or economic ones. Copper format is a best option, but it is too expensive for this purpose. Thus liquid N 2 is specified and then economics of coke oven gas, if you take 1.8 multiplied by 10 power 6 meter cube of coke oven gas used in ammonia synthesis plant to produce 500 tons of ammonia per day.

You can now seeing this number you can see how much important is coke oven gas combined with the fertilizer industry ok. It is an indication of importance of this gas in Indian chemical industries especially from fertilizer industries viewpoint. This is primary because of lack of sufficient natural gas resources in India.

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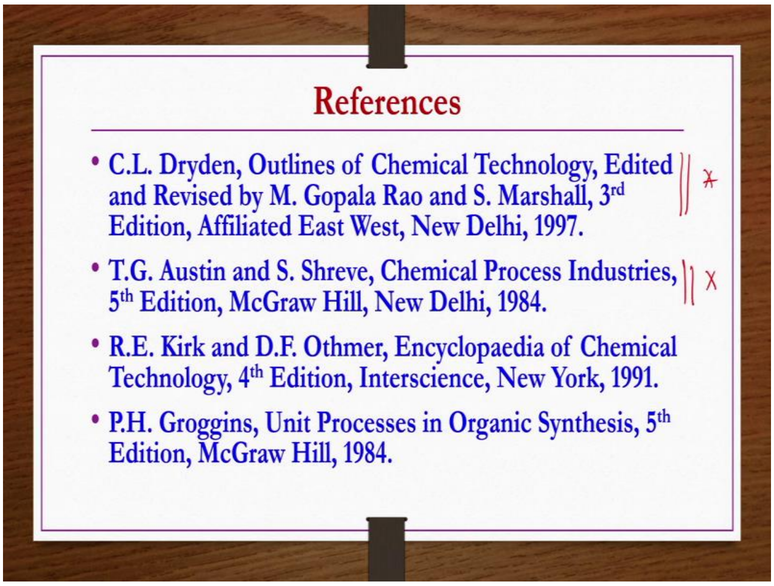

The references for today's lecture are provided here; however, most of the details you can find either in this book or in this book.

Thank you.