Basic Principles and Calculation in Chemical Engineering
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Module-03
Lecture-10
Material Balances On Combustion Reactions

Welcome to massive open online course on basic principles and calculations in chemical engineering. So, we are discussing about fundamentals of material balance under module 3. Under this module today will describe about the material balances on you know chemical reaction process especially for combustion reactions.

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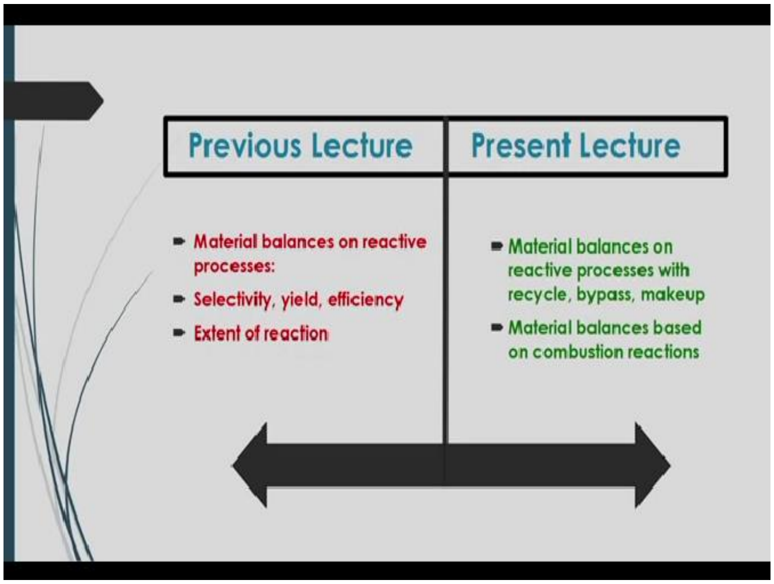

And in the previous lecture we have discussed and also solved the problems of material balances on reactive processes especially with selectivity yield efficiency and extent of reaction. Now, we will discuss some more about that material balance of chemical processes of a reaction will be involved. But, in this case will describe something about the processes, which will be involving chemical reactions as well as you know, bypass recycle.

And you know parts with makeup also and then next part of this lecture will describe about the combustion processes and also try to you know solve some problems about that combustion reactions and how to do that material balance with those combustion reactions.

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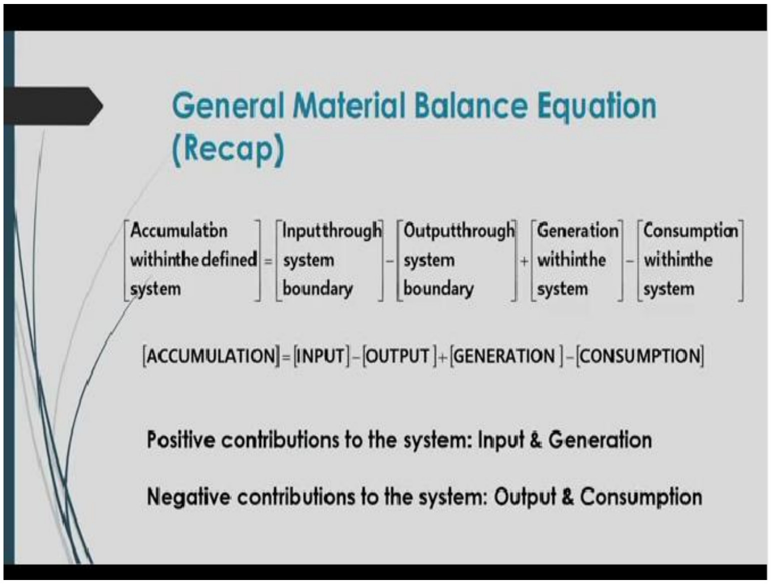

So, let us first discuss about did you know that material balances with reactions based on that recycle bypass, makeup and purge. So, before going to that, we of course recall that you know, general material balance equation, which is basically that accumulation = input - output + generation - consumption and since this material balance involving with that chemical reactions, here, we have to consider that generation and consumption terms. But if this reaction processes is at steady state condition, then we can see that accumulation will be equal to 0.

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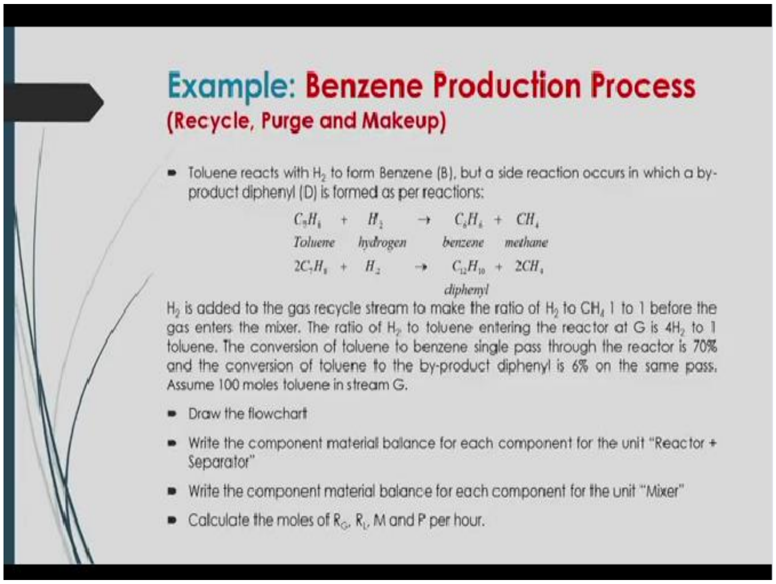

So, let us have this problem of that you know chemical engineering processes which will involve these chemical reactions here like if we produce a gene from the you know toluene then how this process will be executed with different processing needs.

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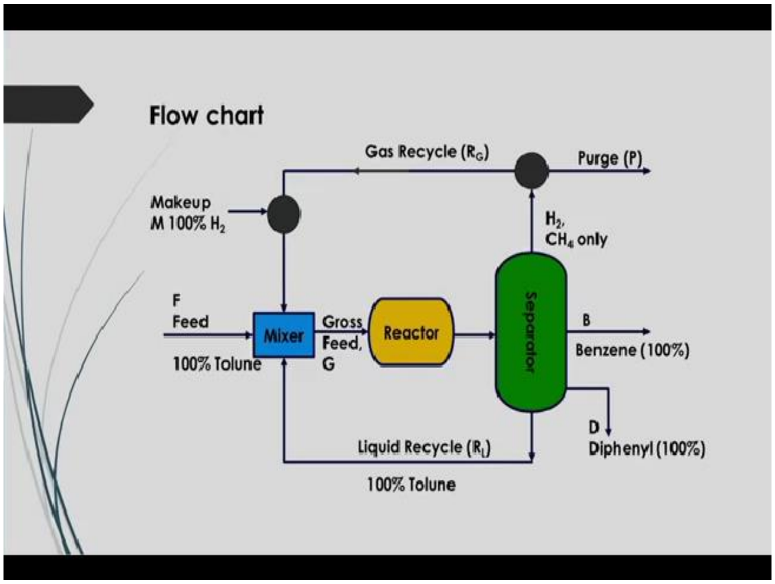

Let us have this process unit here, there are several process you need to be you know utilized here for this you know Benzene production from the Toluene, here some mixer, reactors, separator you know that divider and then you can see that mixer will be used after makeup there. Now, what is that actually for that reaction process with this actually going on during that engine production process.

In this case, Toluene will react with hydrogen to form Benzene. But a side reaction will also occur in who is a byproduct like diphenyl as denoted by D here is formed as far reactions. Here the reaction is given ah like, you know that in this reactions a toluene is reacting with hydrogen and will give you that you know benzene and you know methane and this production of this you know that benzene production along with that there will be some byproducts will be produced.

In that case this you know Toluene have been will be reacting and then the byproduct will be coming out as a diphenyl along with that methane. Now, in this case hydrogen is added to the gas recycle stream to make the ratio of hydrogen to methane that is 1 : 1 before the gas enters the mixer. Now, this ratio of hydrogen to Toluene that enters the reactor at you know, at a certain amount let it be G here as per problems given and that will be equal to 4 times of hydrogen to 1 Toluene.

Now, this reaction conversion of the toluene to be engine will be single pass to the reactor that is 70%, we have described the definition of you know overall conversion of the reactant and also single pass conversion of the reaction that is you know that for the particular process unit is given in the previous lecture. So, as for that you can see that the conversion of conversion to benzene in a single pass to the reactor will be 70%.

And the conversion of toluene to the byproduct that is diphenyl is 6% on the same pass, in this case you can assume that 100 moles of toluene in the stream G. So, what should be the flowchart first you have to draw and also the flowchart you have to write the component material balance for each component for the unit reactor + separator. Write the component material balance for each component for the unit mixer.

And then calculate the moles of you know, R G R L M and P per hour. So, here in this slides, these you know, flowchart of the you know process is given here. So, here see that mixer, the mixer you know the feed is coming that is 100% toluene, that is pure toluene is you know coming to the mixer and in this mixer some you know gas will be entering as a gastric cycle along with his makeup.

And also liquid recycle also will be entering here in the mixer and after that from this mixer gross amount of feed as G will be you know coming into the reactor and after that reaction you will see that several products will be coming out like you know that is part reactions sort of our components will be coming out along with the byproducts will be there. After that those you know productive streams with the different components with product and byproducts it will be you know saying to the you know separator.

And after that some processing of separation, you will see that it will be you know divided into several components, here that the product will be coming as 100% you know pure benzene as a B and byproducts will be you know taking from that separator as a D here, that will also 100% diphenyl will be taken at separate a stream and then some amount of you know gas like you know whatever gas is produced there that is methane gas.

Along with unreacted gas like hydrogen gas you know that that will be you know recycle back to the mixer, but if there is some you know that unreacted materials are there or inert materials will be there that will be pas as a P here from this you know outlet and the gaseous cycle as amount R G it will be you know going to that mixer along with some you know that some amount of hydrogen gas has a makeup to be given.

Because some you know that hydrogen gas may be you know lost because of some leakage or some other you know dispute of that instrument there and after that also whatever liquid product as you know that will be you know after separation will be taken out as you know byproduct and then you know that some liquid recycle that is toluene that is unreacted toluene of the liquidity will be recycled to the mixer again.

And after that, from that mixer the you know that stream as a grass feed are denoted by G it will be against you and back to the reactor. So, in this way this whole process is going on. So, we can you know that, you know specify that you know stream amount what will be components are there and we have you know given here in this slides in the picture here, see this is total you know flowchart of that process.

Now, for this particular process you have to you know do the material balance based on that general you know material balance equation. Now, let us do that material balance one by one, here one important things that you have to remember here not only single unit multiple units will be you know considered for the system at a time even sometimes to you know that units, process units will be considered as one single system.

Even only one single system or single process unit will be considered as one single system there. So, based on who is sometimes for convenience of your calculation, you have to consider that more than one process in it will be as a you know process system there.

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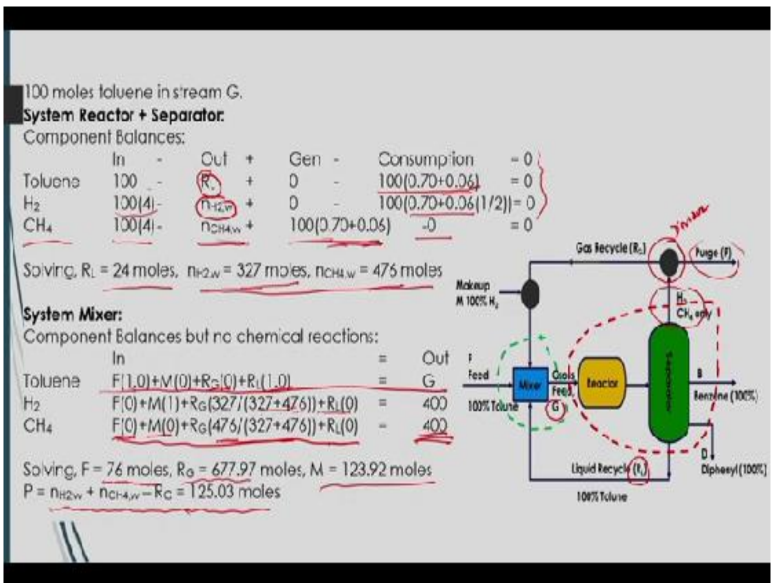

Now, let us you know solve this problem one way here like if we consider that 100 moles of toluene in stream G after you know mixer here, then if we consider the system as reactor and separator and considering both the units here as a system and then if we do the you know material balance for each component here, then what we can you know write. Now, as per material balance equation we know that if there is a steady state operation then we can simply write there in - out + generation - consumption.

So, here since reaction is going on, we can consider that generation and consumption there, but some reactions maybe there will be no generation but consumption will be there, some others you know that there may be generation there will be no consumption like this. So, let us have this here, if we consider fast to the toluene then what will happen that what would the input of that toluene.

This is given that toluene is coming as 100 moles there as a G. So, we can write here this you know that toluene as 100 here in and then out what do the output of that toluene since here from this system, this toluene is coming out as a recycle here, then what happened this recycle amount is considered as R L here. Since it is not known to you we are considering that that amount will be R L. So, simply we are keeping that you know symbol as R L here that amount.

So, 100 – RL, now then + generation Now, what will be the amount of generation of toluene since here there is no formation or generation of toluene, this is only supplied but there is no by you know formation of or generation of toluene based on the reactions. So, we can write simply generation of toluene = 0 and consumption now since there is a reaction based on that reaction equation toluene is reacting you know that with what is that hydrogen.

And it will give you that benzene and the methane, so we can write here that consumption of that toluene will be what, since this toluene is going to that reactor. So, one pass you know conversion is given 70%. So, here 100 into 0.7 this mass of amount of consumption of toluene will be there, but along with that there will be other consumption there that here it is said as per your problem that.

Here you know some conversion of toluene will give you, you know that byproduct diphenyl which will be 6% on that same pass. So, you have to consider that 6% of conversion of toluene there in the consumption term. So, it will be coming as 100 into 0.7 + again 100 into that is 0.06. So, this total consumption of the toluene will be like this 100 into 0.70 + 0.06. So, this is the equation we can write for the component toluene.

Similarly we can write the balance of the component for hydrogen like what should be that you know, amount of hydrogen is coming into the you know, system that is for that combination of reactor and separator, we can simply write here that since G amount is 100, but they are you know that it is said in your problem that you know that hydrogen is added to the gas cycle steam to you know that make the ratio of hydrogen to methane will be 1 : 1 before the gas enters the mixer.

And also it is told that that ratio of hydrogen to toluene entering the reactor at G will be 4 times of hydrogen to 1 or more of toluene. So, in that case we can simply write that hydrogen amount will be you know, 4 times of that toluene amount. So toluene is 100 whereas this hydrogen then will be equals to what is that this 4 times of 100 that play 100 4 like this here.

So, it will be your in and what will be the out that outlet amount of hydrogen it is not known to you. We can simply assume that this amount of mole of hydrogen at this outlet will be equals to what this is NH2 here and also we can see that here the separation in the separated you will see that a precipitated this hydrogen will be coming out as this amount and then what is the generation terms of that hydrogen.

Since, you know that there is no hydrogen is you know generic during that reaction we can simply say that generation term will be equals to 0. Whereas consumption of hydrogen will be there since there is a reaction with that hydrogen. So, hydrogen consumption will be is equal to 100 into 0.702 into 0.06 into 1 by 2, why that 0.06 into 1 by 2, because 1 mole of toluene is you know required you know that a half moles of hydrogen in the second reaction production of byproduct.

So, that is why we can say that here 100 into 0.70 and + 100 into 0.06 into half mole of hydrogen is required for and it will be considered as a consumption there and that will be equals to total here this as for this equation it will become 0. So, all these equations it is coming 0 because that you know accumulation term is 0. Similarly, you can do that methane balance it will be in the 100 into 4 that is in PR and methane that is coming out from that separator here.

It is not known to you let us see that this will be is equals to n methane there and here what is that this you know generation terms of the methane because this methane is produced after reaction. So, that is why generation of this methane will be considered there. So, what is the amount of generation of methane will be is equal to per 400 mole what should be that amount because conversion is 70%.

And also they are you know 6% of by product is produced based on that you know reaction with hydrogen gas. So, 1 mole of hydrogen is required to give you that it is 6% of that diphenyl. So, accordingly you can see that total you know, how you know, many moles of that methane is required for the generation of each methane gas and also consumption in this case methane is not consumed, because there is no you know participation of the methane for the reaction only. It is coming out as a product.

Now, solving these you know, 3 equations of this material balance of components, we can have this R L = 24 moles and hydrogen moles that is coming out from the separator as 327 moles and within gas which is coming out from the separator that will be is equal to 476 moles. Now, up to that there will be other you know variables to be you know estimated based on the material balance like you do not know what will be the amount of feed in the mixer.

So, based on the you know consideration of the system of you know mixer unit, we can also do the same component balances but there will be no chemical reactions. So, accordingly we can say that they are only the material balance equation will be is equal to n will be is equal to in – out. So, based on that toluene will be is equal to what toluene balance will give you that what will be the amount of toluene is coming into the mixer.

That will be F into you know 1 why 1 because here 100% toluene is there, there is no other component in this mixer. So, that is why you can write there this you know fraction will be simply 1. So, that you know that F into 1 and there you know that other part of that in is what is that here as a makeup some amount of you know, what toluene whether it is coming or not.

Since makeup is only for 100% hydrogen there is no makeup amount of what is that toluene there. So simply we can write that M into 0. Here N is that amount of you know toluene sorry amount of makeup is considered here and also other quantity, which is coming to the mixer is you know the amount of gaseous cycle there that is R G, but in that R G what will be the amount of toluene since there is no toluene is coming out from the separator, we can say that in the gaseous cycle stream, there will be no toluene. So, that is why it will be 0 because R G into then 0 and then other part is coming into the mixer is liquid recycle.

Now, in that case as a liquid recycle amount is R L, but it this recycle stream will not contain other components except you know, toluene, there 100% toluene is coming to this stream. So, they are we can say that simply that amount of toluene will be equal to R L into 1.0 because 100% toluene there so, that why we can write here 1.0. So, we can do this material balance for the toluene in this mixer like this.

Now, this is your total in, but what from the out, out of course will be that you know, outlet amount will be G. So, that is why this equation can be written as a material balanced for the toluene. Similarly, we can do the material balance for the hydrogen, what is the amount of hydrogen is coming in into the mixer that is as a feed it will be 0 because there is no hydrogen is coming into the mixer from this feed mixer.

And then what is the makeup amount there of course, there 100% hydrogen will be supplied as a makeup they are so we can write simply in there and R G they are here in this case, R G that is gas recycle, what will be the fraction of that hydrogen will be containing into that R Z, that simply you can calculate because you know that what the mole of hydrogen and mole of methane in the mixer that is coming out from the separator here in this gaseous cycle stream.

Now that fraction will be is equal to simply that moles of hydrogen divided by total moles of hydrogen and methane. So, accordingly hydrogen mole fraction you can simply calculate based on this you know amount at as it is you know pound by solution from this material balance of component in the system of reactor and separator. So, we can write here R G into 327 by 327 + 476. Why 327 + 476.

This is the total mole of hydrogen and methane and since this 327 by total mole this 327 is for you know hydrogen. So we can write here hydrogen mole fraction. So, R G into hydrogen mole fraction that will be your total amount of hydrogen that is coming into the mixer and then liquid recycle their R L since there is no hydrogen they are in the you know liquid to recycle. So, you can simply write that to a fraction will be close to 0.

So R L into 0 simply that there will be no hydrogen gas in this liquid recycle. So finally, you can write that hydrogen balances F 0 + M 1 to RG into what is that this faction + RL that will be is equal to 400, why 400 here because the amount of hydrogen that is coming out from this you know that mixer in the G stream as 400 because 1 mole of toluene will carry along with that 4 times of its amount. So that is why that is 400.

Similarly, methane balance if we do for this mixture what we can get that what is the feed amount of you know that methane there. So methane since there is no methane amount in the feed mixer we can say that simply to be 0 then you can write here F into 0 and similarly in the makeup stream there will be no methane. So, we can write here M into 0, but in the R G that is a gas recycle stream we can say that there will be a some you know fraction of methane in that you know gaseous stream that is coming out from the separator.

So, in this case, we can write similar fashion that earlier we have told that the fraction can be written as here, what will be the amount of methane out of total moles of that meet methane and hydrogen. So, this is simply 476 divided by 327 + 476 as per that is the amount that we got from that material balance by considering that system of reactor and separator and what will be the amount of methane that is coming out from the separator as a liquid recycle there.

Because the liquid recycle there will be no you know methane we can write that R L into 0 that means 0 amount of methane there in the liquid recycle. So, finally, this is your total in and what will be the out similarly, that it will be 400 because, again as part problem that you know 1 mole of toluene will produce you know that 4 times of its methane according to the reaction, so, it would be simply you know 400.

So, we can write here to this you know material balance for this mixer system and after you know, substitution of these are R L, it is required of course, there it is required in this equation and also that you know other moles of hydrogen and you know that methane amount there and solving these equations there again we can get this F = 76 moles, R G = 677.97 and M = 123.92 moles.

So, in this case we can then have what to be the makeup amount what will be feed amount and also you know that what will be the particularly that total amount of G that we can get there. Again we have to find out what should the purge. Now, this purge basically that if we do the material balance, so what this system here in the divider, this is actually this divider we can write.

So, this divided if we say that, this total amount of you know purge will be basically that what is the amount of you know, mixture of methane and hydrogen is coming from the separator into this divider and then what would the amount of you know, gases recycle to the mixer here. So, if you subtract out the total amount of gas mixer you know gas recycle from this gas mixer then you can easily calculate what is the purge.

Basically you can do the material balance here in this divided. So, it will be simply overall material balance it will come as here P you know that + R G that will be basically that mixer of that total amount of hydrogen and methane because here inlet will be is equal to outlet amount. So, in that way you can simply write that here P = n mole of hydrogen + n mole of methane - this R G.

You know this R G already you have calculated based on that material balance and then finally, you can have this you know, purge amount is you know 125.03 moles. So, this problem is, you know that is a very good example of material balance, how to do the material balance with chemical reactions with you know 1 purge reactions and also you know that with multiple units also you can say that is there any bypass or not is there any you know that you can see that recycle or not or is there any purge or not or is there any makeup or not.

So, based on all those you know components you can you know practice this problem and you can have the idea how to do the material balance here.

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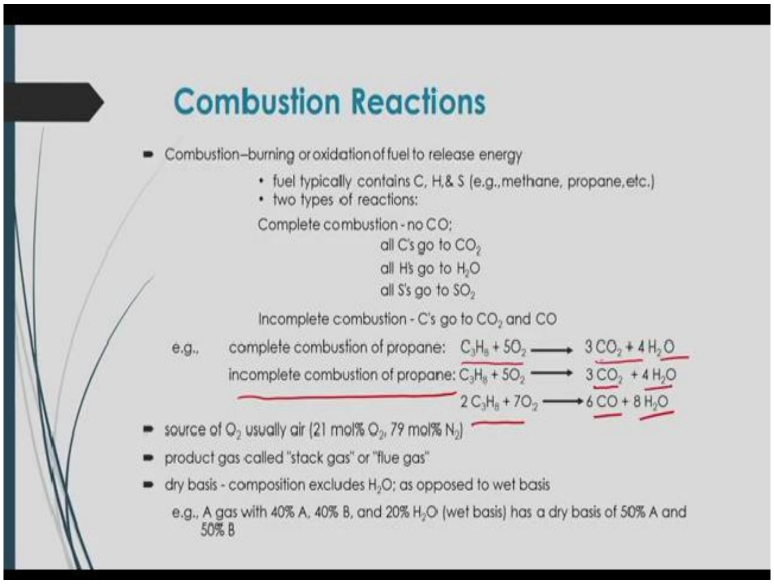

Next we will consider the you know material balance based on combustion reaction, you know before going to that you know material balance based on the combustion reactions you have to know that what is that combustion basically. So, combustion basically is a burning or oxidation of, you know fuel to release energy and fuel typically contains carbon, hydrogen and sulpher even sometimes methane, propane etc. 2 types of actually reactions are in combustion reactions.

One is you know complete combustion or there will be no carbon monoxide and also you can see that all carbon will be converted to carbon dioxide, all hydrogen will be converted to you know water and sulpher will be converted to sulpher dioxide. So, as per complete combustion will not have any carbon monoxide in the outlet streams as a product and also we can say that there will be no you know there will be a complete you know combustion of carbon to the carbon dioxide complete combustion of hydrogen to the water and complete conversion of sulpher to the sulpher dioxide.

Whereas another reactions it is called that incomplete combustion reactions where you will see that the all carbon will go to the carbon dioxide as well as carbon monoxide, that is incomplete reactions okay. So, whenever you will get that carbon monoxide that means, you can assume that there will be an incomplete reaction. So, complete combustion of propane here an example is given that this you know propane after oxidation it will give you that you know carbon dioxide and water.

Similarly, incomplete combustion of propane it will give you that carbon dioxide and water but again this you know that propane will be you know reacting with oxygen and it will give you that carbon monoxide and water. So, basically it is an incomplete reaction. Now, for this oxidation reaction for the combustion you will see that source of oxygen will be usually air which will contain 21 mole percent of oxygen and 79 mole percent of nitrogen.

And product gas that will be you know coming out after reaction it will be called as stack gas or you can see that flue gas and you can you know, consider that, you know mixer as dry basis for air the composition excludes water whereas, you know that wet basis it will be there where this composition of this flue gas or stack gas will become contains, you know water there. So, a gas with 40% A 40% B and 20% water will be called as wet basis, you know combustion.

Flue gas combust flue gas and also, you know if is there only 50% A and 50% B there is no moisture is there you can see that there will be a dry stack gas or dry flue gas. So, this is the basic concept of that complete combustion and incomplete combustion and these are the reactions you will see that. So, based on which we will do some you know calculation as per material balance equation.

Now, for this you know that oxygen will be supplied and by that oxygen you know combustion will be there. Now, what will be the amount of you know that theoretical oxygen will be required for complete combustion and accordingly what should be that actually air to be supplied and if suppose, certain amount of you know oxygen in excess to be required for the complete combustion in the feed stream that also you have to calculate.

So, for that you have to define that you know how to you know estimate or calculate that you know excess air or do you know that excess oxygen the air on.

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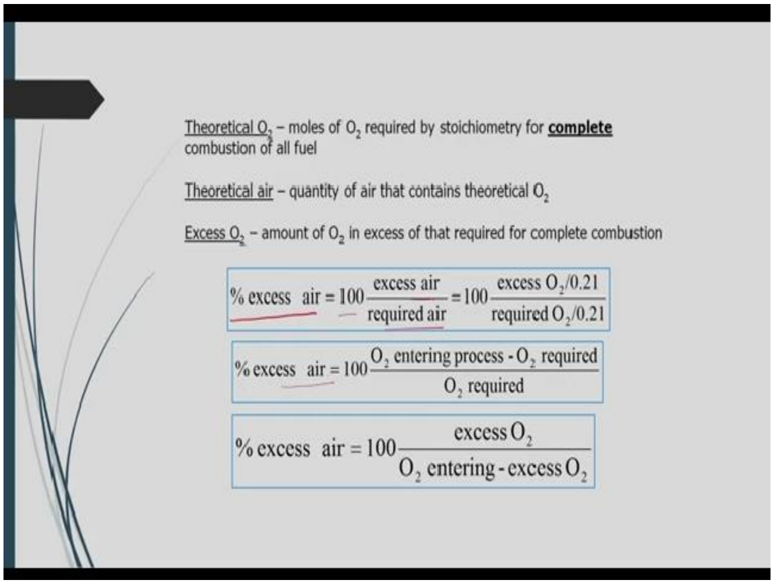

So in that case excess oxygen will be defined as the amount of oxygen in excess of that required for complete combustion and theoretical air which is required that is quantity for air that contains theoretical oxygen there and theoretical oxygen will be moles of oxygen that will be required by stoichiometry for complete combustion of all fuel. So, these 3 definitions you have to remember.

Accordingly we can say that the excess air will be defined as 100 into excess air by required air. This is percentage excess air so to be 100 into excess oxygen by 0.21. And by required air that means in terms of oxygen it will be oxygen by 0.21. Why that 0.1 because air contains 21 mole percent of oxygen. This excess air also you can expressed in terms of you know that what the you know, entering amount and also required amount of oxygen that you can express in that way.

So, it is defined as 100 into oxygen entering the process minus oxygen required divided by oxygen required. Similarly, percent of excess air can be calculated based on that excess oxygen also like 100 into excess oxygen divided by oxygen entering minus excess oxygen like these. So, these you know definition you can use for you know further calculation for your material balance.

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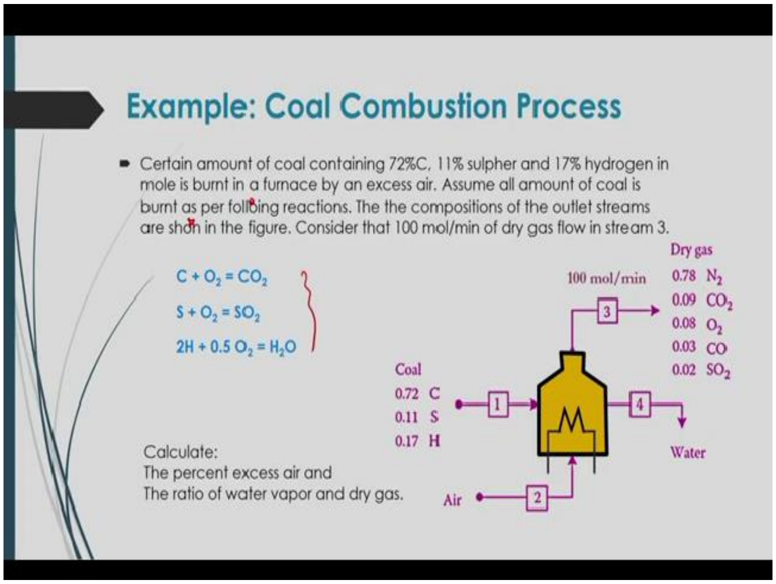

Let us have an example for coal combustion process and for this coal combustion process, how to you know do the material balance based on this you know combustion reaction. In this case let us say that certain amount of coal that contains 72% carbon, 11% you know, sulpher and remaining that is 17% hydrogen in mole that will be burnt in a you know furnace by an excess air. Assume all amount of coal is burned as part you know following reactions.

The compositions of the outlet streams are you know that are shown in the figure here. And also in that case you have to consider that 100 mole per minute of dry gas flow in stream 3 as shown in you know figure are in the slide. In this case, we can see that coal contains carbon sulpher and hydrogen and if you burn this coal there will be a combustion reaction.

Now, the combustion reaction can be represented by this equation here that is carbon will oxidized to give you a carbon dioxide, sulpher will oxidized and it will be giving you sulpher dioxide and hydrogen will convert it to the potential. So, in this way of internal combustion reaction, if you consider that 100 mole per minute of dry gas that is flowing in the stream you know 3 as a dry gas.

They are based on which you have to calculate, what should be the percentage excess air is required and also what should be the ratio of water vapor and dry gas they are in this particular process.

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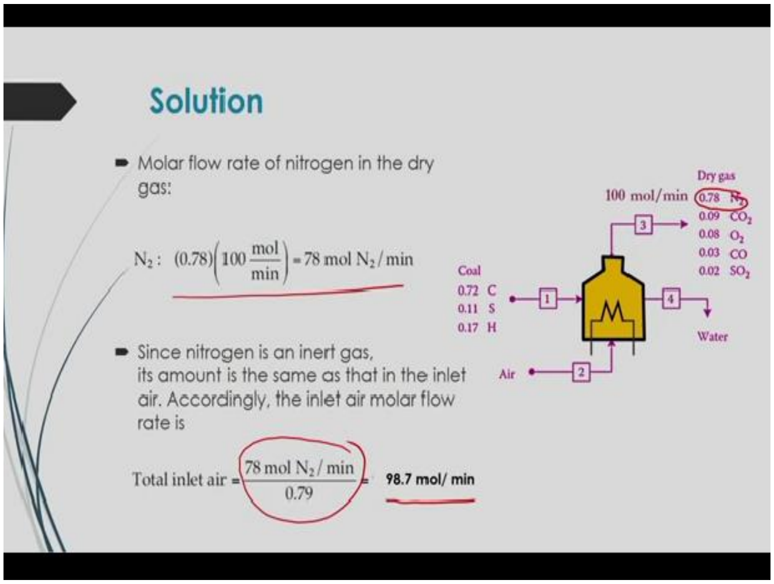

So, the solution we can say that first of all you have to find out what should be the molar flow rate of nitrogen in the dry gas, nitrogen in the dry gas that will be you know that you know that 78% that is in mole percent of nitrogen is in the you know that air stream. So, it will be you know nitrogen amount will be you know 78 mole of nitrogen per minute, but here, if we do not consider that the airstream.

In this case very simple that in the dry gas you will see that they are it is given that only 78% you know of nitrogen they are in the stack gas. So, here total amount of nitrogen will be here since the you know flow rate of you know gas in the stream are 3 is 100 mole per minute. So, there will be a nitrogen will be is equal to 78 mole of nitrogen per minute it will be flowing air. Now, this nitrogen gas is coming from actually air which is supplied in the you know that that finish.

So, each amount is the same as that in the inlet air. So, accordingly the inlet air molar flow rate will be is equal to what, since it is the nitrogen amount and since nitrogen contains in the you know nitrogen in the air is 70 you know that 9%. So, we can see that air it will be you know that 78 mole of nitrogen per minute divided by 7.79. So, it will be simply as 98.7 mole per minute.

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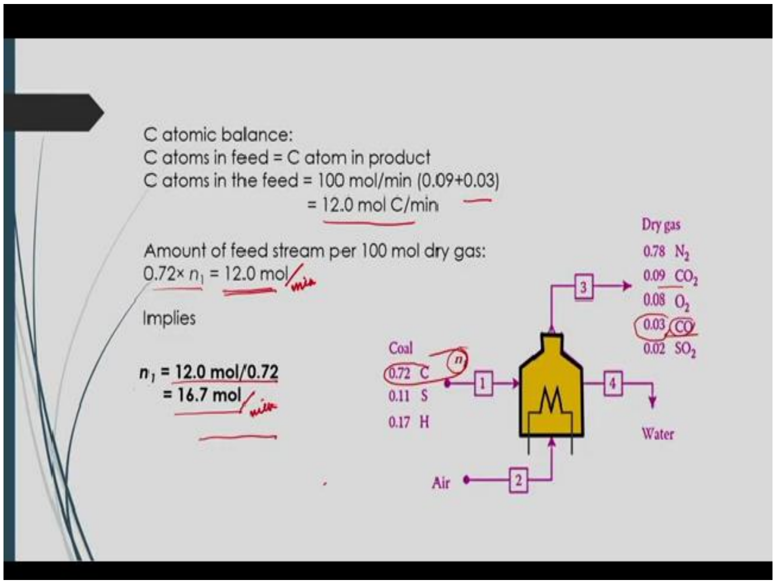

And then, if you do the carbon atomic balance for this you know system that carbon atoms in the feed that will be equal to carbon atoms in the product. So, this is you yield equal to out for that carbon atoms. Now, these carbon atoms in the feet, what is that amount it is you know that of course, will be equals to what is that 100 moles into 0.09 + 0.03, why because in the outlets steams that carbon is coming as carbon dioxide and carbon monoxide.

This carbon dioxide and carbon monoxide is basically coming from the source of that coal in the you know that feeds stream. So, what will be that you know carbon dioxide in there by you know stream and what will be the carbon atoms there that will be basically 100 into 0.09 and similarly, other the carbon is coming from that you know that coal steam as a carbon monoxide here in that dry gas.

And its production since it is 0.03 out of that you know, 100 moles of, you know, rate. So, we can simply say that total amount of carbon will be is equal to 0 that 100 into 0.09 + 0.03. So, it will be amount of 12 moles of carbon per minute. Now, this carbon of course, it will from that you know feed stream. So, what will be that then feed stream you know flow rate that you have to you know calculate.

See that this feed stream flow rate is n 1. So, we can simply write that this you know carbon balance for that. So, we can write n 1 into 0.72 that will be actually equals to that you know h carbon in the you know dry gas. So, it will be simply 12.0 mole, which implies that n 1 will be equal to what this here, like this. So, this is per minutes we can write here per minute. So, here it will be per minute.

So, here we can have here as per material balance that what will be the, you know, feed stream flow rate in the stream 1 that will be equal to n 1 and it will be equal to 16.7 mole.

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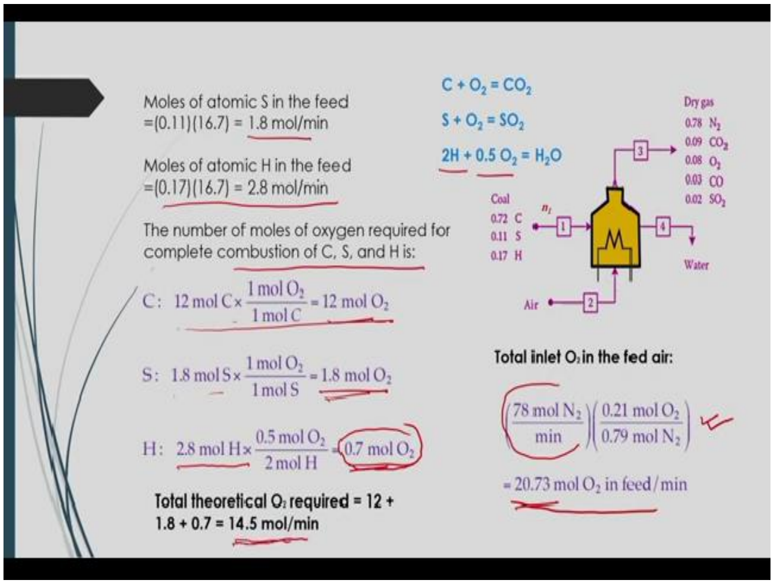

And after that, if you do the atomic sulpher balance, then you can say that, you know the moles of atomic sulpher in the feed will be equal to 1.8 mole per minute and moles of atomic hydrogen in the feed will be is equal to 2.8 mole per minute and accordingly the number of moles of oxygen that will be required for complete combustion of carbon sulpher and hydrogen that basically as for this equation.

Because here 12 mole of carbon you know that will require how you know many moles of oxygen simply here to be to 12 mole of oxygen because 1 mole carbon requires you know, 1 mole of oxygen. So, that is why basically 12 mole of carbon will actually require 12 mole of oxygen. Similarly, since here 1.8 mole of sulpher is in the feed stream we can say that, for this 1.8 mole of sulpher will require similarly, here 1.8 mole of oxygen.

Because 1 mole of sulpher will require 1 mole of oxygen, similarly 2.8 mole of hydrogen in the feed stream. So, this 2.8 mole of hydrogen will require 0.7 mole of oxygen here in this case as for reactions you will see that you have 2 mole of hydrogen will require 0.5 mole of you know oxygen as per reaction. So, accordingly we can see that 2.8 mole of hydrogen will require you know that 0.7 mole of oxygen.

So, total theoretical oxygen will be required for the complete combustion will be close to this to 2 L + 1.8 1.8 + 0.7. So, it will be total 14.5 mole per minute, this is your theoretical oxygen, but total inlet oxygen in the feed air, what will be that, you know that total inlet oxygen in the feed air that will be equal to you know that calculated based on that what would be the nitrogen amount there in the feed stream and accordingly it will come.

Because in the air you will see that 79% mole of nitrogen will be having along with that what is that 21% of oxygen and so if there is 78 mole of nitrogen there in the air stream, so, we can say that how many moles of oxygen will be in the feed stream. So, it will be simply by 20.73 mole of oxygen in feed by minute. So, this is where you can calculate it for to be the total you know that inlet of oxygen in the feed air.

So, once you know these that you know supplied oxygen in the feed air is 20.73 whereas theoretical oxygen required for the complete combustion in the burner or you can find this that will be equal to 14.5 mole per minute.

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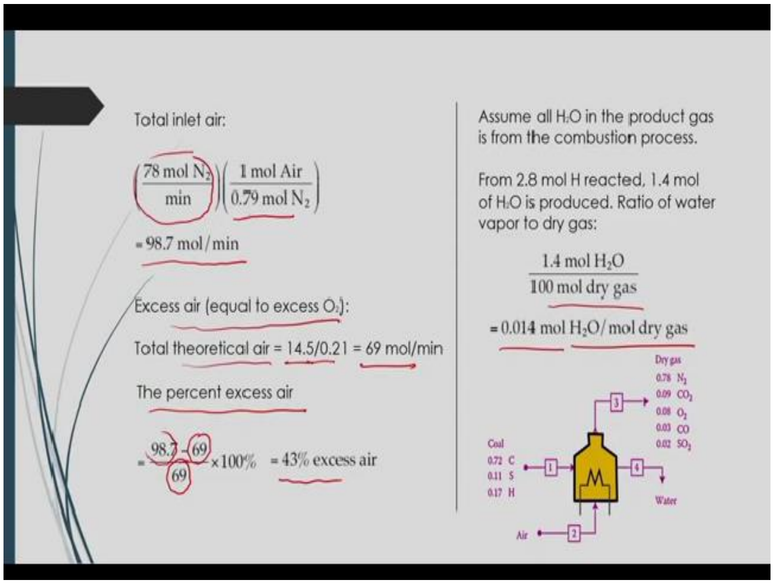

And based on that, you know that you can calculate what should be the percent oxygen there and then what should the percent excess air also there. Now, if you know calculate that percent air then you have to you know consider that what the amount of excess air is required there. Now, total inlet air is you know that since you know that only nitrogen amount 0.79 mole of nitrogen is having in 1 mole of air.

So, 78 mole of nitrogen will be having in how many moles of air, it will be simply air as per calculation 98.7 mole per minute. So, excess air that is equal to excess oxygen okay. So, according to that total theoretical air will be equal to that is 14.5 is the theoretical oxygen required. So, you have to convert it to what to be the amount of theoretical air to be required just by simply dividing this 14.5 by this you know 0.21 of oxygen fraction.

So, it will be simply 69 mole per minute. So, percent excess air will be equal to air excess air definition that is what to be the supplied amount and what is the theoretical amount of air supplied is 98.7 and theoretical is 69. So, divided by theoretical air required. So accordingly, it will be coming as 43% of excess air required for this complete combustion. Now, if you assume that all water in the product gas is from the combustion process.

Now from you know that 2.8 mole of hydrogen that is reacted 1.4 mole of you know hydrogen will be produced based on that reaction, then ratio of water vapor to the dry gas will be simply

1.4 divided by 100 mole of dry gas. So, it will be simply 0.01 per mole of hydrogen per mole of dry gas. So, in this way, we can you know that do the material balance for the combustion reaction.

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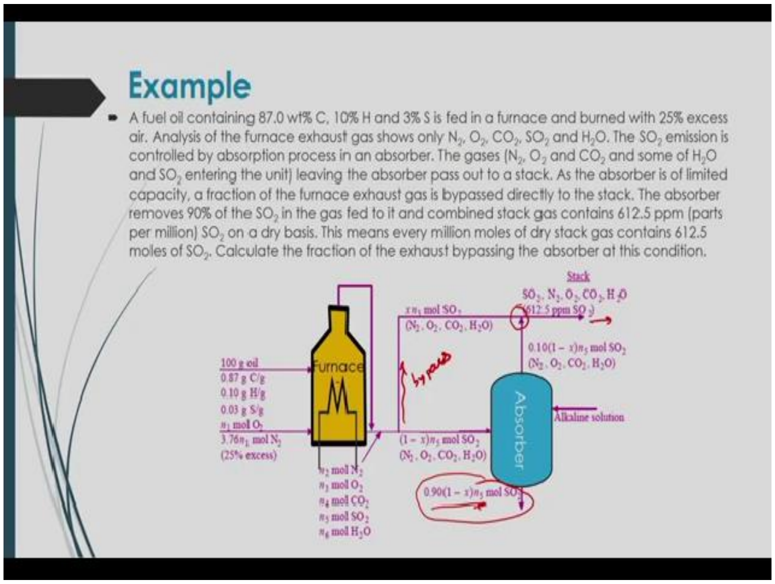

Another example we can say that if fuel oil containing 87% wt% carbon, 10% hydrogen and 3% sulpher that is fed in a furnace and burned with you know 25% access air. Now analyzes of the furnace exhaust gas results only nitrogen, oxygen, carbon dioxide, sulpher dioxide and water. The sulpher dioxide emission is actually controlled by some absorption process in and you know absorber.

So, in that case the gases like nitrogen, oxygen carbon dioxide and some of that water and sulpher dioxide that is entering to the unit that will leave the absorber and pass out to a you know stack and as the absorber is of limited capacity, you see that a fraction of that furnace exhaust gas would be bypassed directly to the stack there and you will see that the observer removes 90% of the sulpher dioxide in the gas feed to it.

And combined stack gas contains you know 612.5 ppm it is called parts per million that sulpher dioxide on a dry basis. Now this means that every million moles of dry stack gas contains you know 60 sorry 600 12.5 you know most of sulpher dioxide. In this case you have to calculate what should be the fraction of the exhaust bypassing the observer at this condition.

Now, see here the you know flows out of the problem is given here, this is one furnace and in the furnace you know 100 gram of oil is coming with it is composition here like carbon, hydrogen, sulpher and oxygen and n mole of oxygen is supplied here in the furnace whereas 3.76 into n 1 mole of nitrogen as 25% excess will be supplied to the furnace for the combustion and after combustion you will see that there will be you know it just gas from the furnace will be containing you know N 2 amount of nitrogen.

And N 3 amount of oxygen in N 4 amount of carbon dioxide, N 5 amount of you know that sulpher dioxide and N 6 amount of water. Now, from this you know mixer some amount of this you know mixer will be you know bypassed here like this as shown here this is bypass they are this is bypass that observer unit and some fractions will be you know allowed to pass to the observer to absorb some you know that gases.

And then outlet gas from that absorber again will be mixing with that you know bypass amount and it will go to the stack and you know some amount of that you know gaseous product as a sulpher dioxide it will be you know taking out from that absorber. You know after the absorption as you know this amount as shown here in the figure in the flow chart. Now, accordingly you have to calculate what should be the fraction of that just bypassing that observer at this condition.

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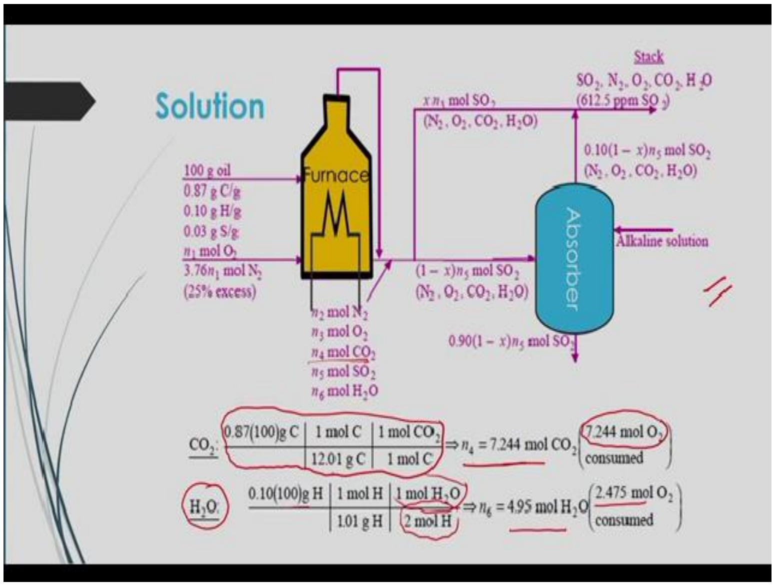

Let us solve this problem here. So, this is your you know you know flow chart give in details. Now, if you are considered that carbon dioxide past to do that material balance, now, you will see that this carbon dioxide that is in the feed stream it is 87%. So, if it is 100 moles of total feed then it will be you know that carbon will be you know 0.87 into 100 this gram of carbon.

And since the molecular weight of carbon is 12.01. So, amount of you know carbon in terms of mole, it will be this divided by 12 and again 1 mole of carbon you know converting to carbon dioxide that will be 1 mole. So, basically you can say that this input whatever it is coming out from that furnace as a carbon dioxide this amount will be exactly the same of this you know 87% of carbon in the feed stream.

So, according you can say that this N 4 = 7.244 after calculation and for this 7.244 mole of carbon dioxide will require how many moles of oxygen for its you know combustion or this you know complete reaction. So, it will require 7.244 mole of oxygen. Similarly, for water if you consider that what will be the amount of water that is you know supplied in that, you know furnace as a feed stream that will be you know 10% of that as hydrogen.

And that hydrogen, if you convert it gram to mole and then 2 moles of hydrogen will give you that you know 1 mole of water that means air this amount of water is actually being supplied there, but N 6 you will get this moisture will come from that furnace as N 6 mole, so, N 6 is equal to like this. Now, for these N 6 of course, you know that how much oxygen will be consumed there, it will be you know that you know according to that reaction, it will come out 2.475 mole of oxygen.

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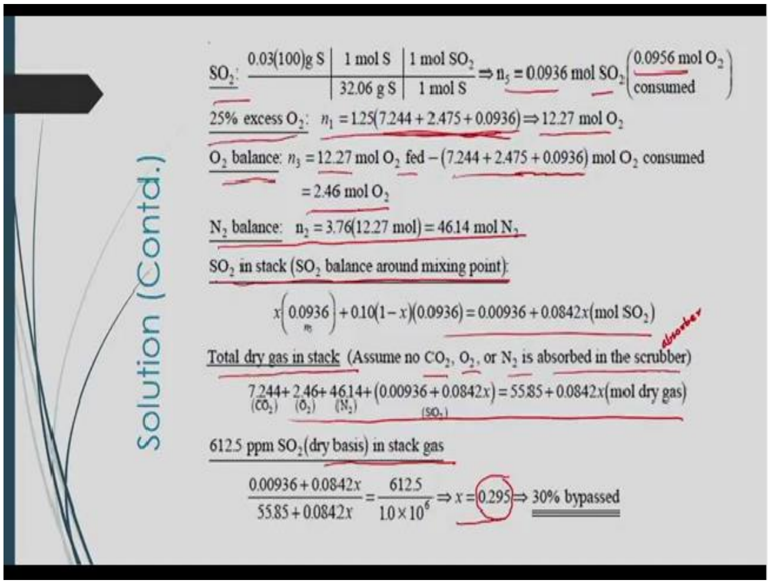

Similarly, you can do the same way for sulpher dioxide and in that case this N 5 as the sulpher dioxide it to be 0.0 96 mole of sulpher dioxide which will require 0.0956 mole of oxygen in for its consumption for the reaction. Now, since there is 25% excesses there of that oxygen, we can say that this n 1 will be is equal to ask for this, you know, here in this n 1 what is that n 1 here. This n 1 is here basically that mole of oxygen in that is supplied to the furnace. So, that n 1 can be calculated this is you know required oxygen and since it is the sorry 25% of excess.

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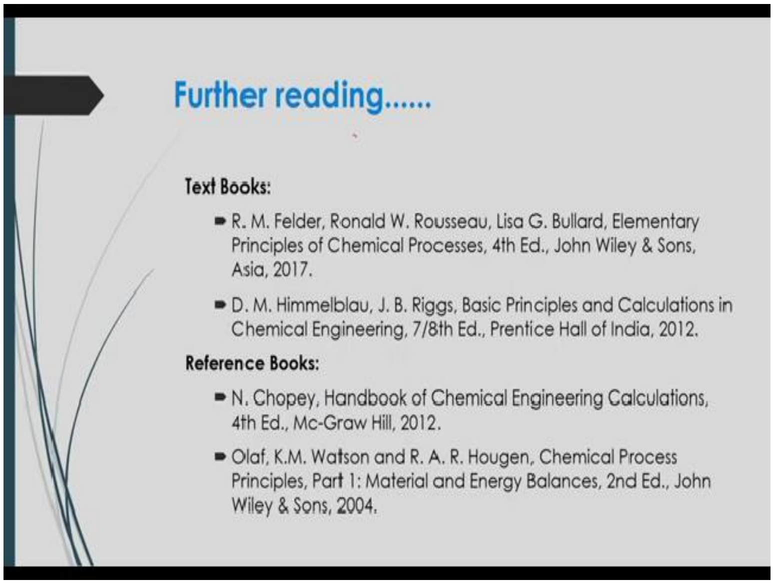

So, it will be you know simply you have to multiply by 1 point you know 25 with this you know that what is the oxygen consume for that complete combustion. So, it will be coming as 12.27 mole of oxygen. Similarly, if you do the you know oxygen balance for n 3 then you can say that these n 3 will be equal to what basically this n 3 will be is equal to here what will be the mole of oxygen is coming out, you know from the furnace that will be coming out from the feed stream.

After the reaction consumption and then and then we can write that this amount will be is equal to your 12.27 that is actually the excess amount of feed of oxygen, whereas required amount is 7.244 + 2.475 and 0.0936 as per that oxygen consumption based on that, you know that reaction. So, accordingly you can see that this oxygen balance that is n 3 which is coming out as you know unreacted oxygen this will be equal to 2.46 mole of oxygen.

Similarly you can do that nitrogen balance here and also sulpher dioxide instead sulpher dioxide balance around that mixing point, in the mixing point if you considered that here in this case at this location we push stack so, we can have this you know that you know sulpher dioxide in the stack like this. Similarly, total dry gas in stack assume there will be no carbon dioxide oxygen or nitrogen in the absorbed in the scrubber or scrubber you say absorber we can see write here observer.

So, we can see that you know this total dry gas a balance if you do that, in this way, you can simply calculate what should be the, you know amount of you know fraction of x, they are for the sulpher dioxide they are you can easily calculate them. And since 612.5 ppm of sulpher dioxide drivers in this tear gas. So, we can see that this fraction of bypass will be equal to you know that 0.295 as far that dry basis.

So, this is you know that one example by which you can see that how to do the material balance for the combustion reaction and also you can you know do the material balance for this combustion reaction with excess oxygen with excess you know air and how to calculate that theoretical oxygen, theoretical air and based on this how to calculate that excess oxygen is required for that you know combustion reaction or also what will be the you know, excess amount of air to be required for that complete processes.

So, I think this will be helpful to understand the, you know how of the material balance for this combustion processes and also I think you will get the idea to you know do the material balance further with some other problem. So, I would suggest to follow this textbook given in this slides for further understanding of the material balance with this combustion process.