Cryogenic Hydrogen Technology
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Week - 02
Lecture 10
Hydrogen Production

So, welcome to this lecture on cryogenic hydrogen technology. We were talking about the cryogenic about the hydrogen production and there we have already learned about the different you know processes of getting the hydrogen. ah You may remember that we were I mean in the last lecture we have talked about the hydrogen production from the coke oven gas and there we have talked about the source of what is ah the source of this coke oven gas and what could be the possible composition the typical composition of the coke oven gas and how we could possibly get ah hydrogen you know from the coke oven gas. So, you may remember that ah the difference in the boiling point of hydrogen with the rest of the components was ah you know basically quite high there is a large difference in the boiling point and that is how you know we have been able to separate out this ah hydrogen from the mixture. And we have talked about the Linde-Bronn process where we have used ah or take help of the liquid hydrogen in a condenser evaporator where we have tried to separate them out. And now we will be talking today about ah I mean it is a continuation in continuation to that process of generating hydrogen from the coke oven gas.

Today, we will be talking about another in the popular process called ah l'Air liquide process for separating hydrogen from the coke oven gas. Now ah this is another I mean cryogenic you know process where ah we will be seeing how we could take help of this ah I mean harness this difference in the boiling point, but this process will be different from the earlier one in terms of providing the refrigeration. So, in the Linde-Bronn process that was mainly meant for as I ah told you earlier that that was meant for producing ammonia. So, we had a composition of hydrogen and nitrogen and that finally, you know someone if wants to ah you know separate out hydrogen from nitrogen it is again they have quite ah difference in quite different you know boiling normal boiling point and that can again be separated out using a condenser evaporator.

So, here we will try to ah first of all you know talk about that l'Air liquide process and before that just we will try to give you a overview of what we have learned earlier. This is say I mean coke oven composition of ah you know taken from the Barron's book and these are the typical normal boiling point just to recapitulate. And you can see that the normal boiling point of ah nitrogen is quite ah different from the rest of the gas the nearest possible

one is the methane sorry nitrogen. And ah all of them are you know quite higher than that you know and the most of the higher boiling sorry the higher hydrocarbons like you know ethane, propylene and ethylene. So, those are also present in this ah if there are present you know in small quantity that can also be separated out.

And they are quite ah you know their boiling points are quite different from the boiling point of hydrogen. So, this can be ah you know utilized in again in this process. So, this is another ah coke oven gas composition which we have talked in the earlier class. And then we have you know learned about this Linde Braun process where we have said that you know we have a compressor where we have compressed this coke oven gas. And finally, that was cooled with the help of LN2 in this you know condenser evaporator.

So, this condenser evaporator the was ah giving us the ah I mean finally, of course, we had to ah separate out this nitrogen and ammonia. And you know the CO mixture was there and from there we have used CO scrubber because it was having some amount of CO present in this. And finally, we got this you know nitrogen and hydrogen mixture. So, ah it it was quite elaborate process you have might have noted that there are different you know heat exchangers ah. And I mean starting from ah 2 stream exchanger cooled with the ammonia we have 3 stream exchangers also we have 2 4 stream exchangers. And apart from ah condenser and evaporator that is again another kind of heat exchanger and phase CO scrubber. But the main idea is that you know we have the coolant which is coming from ah I mean it is not like you know ah ordinary thing that is available ah. But of course, we need some you know ah when it needs when it is needed in bulk quantity we have to look for an air separation process. So, from the air separation process or cryogenic air separation process we get this liquid nitrogen. And that liquid nitrogen will be you know supplying the necessary refrigeration in this process that is what is the Linde-Bronn process.

But is there any possibility that this refrigeration can be ah provided within the process itself. And that is how you know this air liquid process has evolved ah it was done by Claude. And later on, we will learn when we talk about the cryogenic liquefaction process we will see ah it will be I mean ah better understood at that time. So, at this moment you just go through this process. And again, we will be coming back or you will be able to understand this process better probably when you have learned about the cryogenic liquefaction cycles. So, here comes this you know coke oven gas we start with the coke oven gas. And first of all, you know we compress it to ah nearly about 25 atmospheric pressure. So, this is about 2.5 MPa. And from there we take it to ah directly into one three stream exchanger we will try to identify the other streams which are you know cooling this high-pressure ah coke oven gas.

Then comes ah as I have you know told earlier also this will come to I mean if it is cooled to a sufficient level you know it is coming to nearly about minus 65 degree centigrade. So, at that temperature you will find some propylene will be condensing. So, this propylene will be taken out from here and the rest of the compressed coke oven gas will come. And that will come to another heat exchanger that is again another 3-stream heat exchanger. And this will continue to ah you know pass through another phase separator where mostly the ethylene, ethane and some portion of methane will also get condensed.

But not you know ah everything will be getting condensed here. So, all these components are like as I told you the methane ah a part and ethylene and ethane they will be coming over here and they will come out ok. But what is about this compressed coke oven gas? This will continue to the flow through this and then we will put it in a again ah condenser evaporator. So, on this part we will be putting it you know as a compressed bond and it is coming over here. So, this is coming to this side and this will produce ah basically it has to be cooled right. But as we have understood that earlier this cooling was provided with the help of ah liquid nitrogen, but we do not want to use liquid nitrogen. So, then we have to arrange for something you know which will provide the necessary refrigeration here. So, what we have here ah imagine that we have produced some amount of methane here liquid methane. So, this liquid methane and along with other components it will be not only liquid methane only. So, that will come out from here and then again, we will expand it and you will put it back to this side.

So, if we have been able to create some amount of liquid methane we will see how it really has been produced. So, we will put it as a refrigerant on this side on the on I mean one side of the tube. And ah once we have provided that refrigeration. So, what we will find is basically the hydrogen will be coming out in the form of gaseous hydrogen and this gaseous hydrogen it is under pressure and this because we have not expanded this hydrogen right. So, this is coming from here and we have taken it into this tube side and here on this side you know this methane is getting methane along with say CO and other hydrocarbon would be there in this and they will be you know coming over here and it is expanded and it will be providing the refrigeration.

So, on this side you have the gaseous hydrogen. So, this gaseous hydrogen which is under pressure. So, we will try to put it in an expander. This is this expansion process is different from this expansion process. This is the J T expansion we will talk in details later on while talking about the liquefaction part, but this is what is called an isentropic expansion or isentropic expansion and that means, it is entropy remains constant.

Whereas, this is isenthalpic I mean expansion where the enthalpy remains constant in this process, but there are certain advantage of this you know expanding the things with the isentropic expansion particularly for gases like hydrogen. So, this gas will be expanded and it will you know generate nearly about when it comes out it will be nearly about minus 205 degree centigrade. So, this gas will you know come out from here and it will be taken as the hydrogen you know product that will be mixed with certain amount of impurities which can always be you know separated out using the PSA based system. Now, ah what is about this ah I mean gas which is there on top of it you have this mixture as ah let me change the color of it. So, this is where you have this gaseous vapor on this side or you can say here this is you know this ah basically this part is ah the vapor part of this CO and CH4 and that is quite you know cold and that will you know be taken out from here as a methane plus CO mixture.

So, before it is it is in cold condition. So, that cold will be retrieved basically before it you know goes back to the I mean since it is methane and CO mixture it can always be used as a you know ah fuel. So, but it is cold fuel. So, basically you can understand that we will take it is cold to you know cool the incoming high-pressure gas when it was coming to this ah you know condenser evaporator. This CH4 CO part that is which has been liquefied basically this refrigeration has come from here.

So, initially when the process is getting started you do not have any you know liquid over here, but some portion of the gas you know at that pressure this high pressure will be collected over here and then it will be expanded and then you know it will provide you the some amount of cooling which will be cooling the high high pressure incoming gas and then in the steady state process you will find that it is providing you the methane plus CO mixture. So, that is how we are trying to I mean separate out the methane and CO and hydrogen and basically get this hydrogen in the form of gaseous hydrogen this is still at in the gaseous condition and that is why it is collected on this top part. Whereas, this liquid part you know this methane CO which has become liquid that is collected as liquid at the bottom part of this condenser evaporator. So, this part is getting condensed and you know a part of it is again here this is getting evaporated that part was basically this is at this point this is pressurized one on this side when it has come it is under low pressure because we have expanded as I have told you here this is a JT expander. So, this JT expansion is done and finally, it is coming as you know low pressure liquid.

So, that is providing the refrigeration, but the main refrigeration is basically has been created by the help of this expansion engine. It is unlike that ah Linde-Bronn process where liquid nitrogen was supplied from outside here this high-pressure gas you know because of

this expansion in the isentropic ah JT isentropic expansion it will produce the necessary refrigeration. So, this is how this l'Air liquide process is meant for you know producing the hydrogen from the coke oven gas. Now, in both the l'Air liquide as well as in the Linde-Bronn process we have seen there is something called condenser evaporator. So, it is of course, our 2 D figure which may be bit difficult for you to you know ah realize.

So, let us first of all you know let us look into this l'Air liquid process as a whole. So, this is how it is. So, we have the you know coke oven gas it is getting compressed and then it is cooled with the help of this 3-stream exchanger. Then we have separated out you know some portion of the propylene etcetera and here you know again it is cooled into this 3-stream heat exchanger and finally, before it comes to this condenser evaporator all this ethylene ethane and methane will be separated out from here that will be taken out from this you know process. So, here ah it is top heat built you know as I told you that this is the high pressure this coke oven gas it is coming on the tube side and here we have the gaseous hydrogen.

This is still under pressure. So, before it goes you know it will be expanding and this will come to nearly about 205 degree centigrade and it is finally, coming out as hydrogen in the form of gas, but before it goes out you know in at room temperature or atmospheric temperature it is ah you know first of all it is atmospheric pressure this was at 25 if there is no you know pressure drop in the system. Then it is coming to ah atmospheric pressure, but this is at quite low temperature. So, this low temperature or this cooling will be you know ah basically that cooling will be taken by this high-pressure incoming gas and before it goes out into the atmosphere. On the other hand, as I told that this methane and co mixture will be expanded and that will be coming over on top of it on the condenser evaporated part that will be collected over here and provide the refrigeration for this methane which will be you know collected over here. So, this methane part a part of it will also be you know ah I am sorry this will be taken back this evaporated part and that will again be at low temperature.

So, that has to go back you know before that we will take out it is cooling. So, this is CH_4 plus CO and ah that will come out of the system. So, this is how it looks like ah this liquid air process ah l'Air liquid process ok. So, what is common in both these 2 systems is ah this as I told you that this condenser evaporator which has been drawn in ah 2D. So, let us ah have a you know look into this in detail ah I will just show you ah small you know ah video here that will tell you how this is how it looks like.

Of course, the ah piping etcetera is not shown here ah just you know the structure is given

here. So, this is what is that you know tube bundle you can see and this is the 2 you know vapor domes ok. I am showing it once more this is how this condenser evaporator looks like this is what is that tube bundle and this is ah you know top cover, this is the bottom cover and this is the cylindrical part and this is another top cover of it ok. So, now let us look into this ah I am sorry ah fine. So, these are the 3D structure as I told you that this is the tube bundle.

So, on top of it we have one cover this is that this part and on the bottom part of it is you know if we look at it or identify it with this this is the bottom part we have covered this on this side also. Now, ah this is that annular ah I mean part ah where we have you know on this side we have provided the I mean that liquid ah nitrogen was poured in from here in the Linde-Bronn process we said that you know we are putting liquid nitrogen. So, this is filled in with the liquid so that means, all these tubes were basically cooled by the liquid nitrogen. So, here in this space we were filling it up you know from this part and this inner part which you know is basically coming or you know all the gas high pressure gas is coming over here and there you know coming in contact passing through this ah you know tubes are getting collected over here this gaseous part will be collected over here collected over this part and the liquid part you know the refrigerant part is on this side on this outside this tube. So, they are not getting mixed with each other on this side in the Linde Bron process we said that we have this N2 plus H2 plus CO and we were providing the we were providing on top of it ah basically ah I am sorry this was not this was the top product from here I am sorry this is you know the top product which was coming from here and then it went to ah it went to the CO scrubber and outside this we had liquid nitrogen we have provided liquid nitrogen in the Linde-Bronn process.

So, this was the one which has been collected from this dome and this was taken to the ah LN2 scrubber, but for the ah for the what is called this ah l'Air liquid process. So, this was basically the methane and CO this methane and CO was ah here this was you know at this I am sorry. So, at this point it was coming as H2 plus CH4 and then we had the CO this 3 things were coming out of that this H2 was you know collected at the top whereas, this methane and CO was under pressure and they were you know getting collected over here or getting liquefied and this gas you know high pressure gas was expanded as we have learned in the liquid air process air decade process. So, this was high pressure gas we have expanded it and put it on this side. So, this will be collected over here on this end you know this is providing outside this tube we have this liquid methane plus CO and inside we have the vapor where this CH4 plus CO will condense it will collect it will be collected over here the hydrogen gaseous form you know it will be collected from the top.

So, this is still at high pressure in the ah you know in the in case of ah l'Air liquid process.

So, this is how it looks like ah in both the Linde-Bronn process or in l'Air liquid process. Now, we have a question that if it could be you know either be it liquid hydrogen or say be it liquid nitrogen or ah I mean in the l'Air liquid process we have used this I mean we have used that expansion engine. So, why did we do such an elaborate scheme say if ah in the Linde Bron process also ah we had that coke oven gas and we could have you know put directly ah into it ah and cool it with the liquid nitrogen or this coke oven gas we have compressed it we could have directly put into this condenser evaporator and everything was you know getting condensed here except this hydrogen. So, why it was necessary to have such an elaborate scheme of you know putting so many heat exchangers and then you know ah ah I mean 2 stream exchanger, 3 stream exchanger then 4 stream exchanger in case of Linde Bron process and in case of ah of course, the air liquid process which is much simpler in ah you know nature, but still we have at least 2 3 stream heat exchanger apart from this condensate evaporator.

So, was it really necessary to use all these components and then you know to have this kind of you know ah generation of ah this ah H2 in the process for generating H2 from this process. So, basically the answer to that question is was yes, it is necessary because it is not only the hydrogen ah, but we have another ah I mean all these components ah where we have seen that be it methane be it you know the CO or other components like ethylene. Ethane though it was present in small quantity, but those are very ah I mean useful things. So, the ethylene for example, you know we are making polyethylene. So, that kind of component if it was not collected earlier it would have come you know along with this mixture and finally, it would have gone as a waste.

So, in order to retrieve all these components one by one ah you know we have ah that elaborate process ah where you could understand that every ah you know useful quantity ah which is there in meaningful I mean ah amount basically it should not be such that you know ah after separation ah this product is such that it is price is more I mean less than the ah separation process. So, the separation process should not be costlier. So, if we are able to retrieve a meaningful amount from this process we should you know try to separate the amount. So, that is how we have seen that the ethylene ethane those components are to be separated from those process along with that you know we should try to ah get this hydrogen. So, this is about ah this ah I mean ah this is ah about this separation of hydrogen from the coke oven gas this has been taught mostly from the cryogenic systems by Barron.

So, here comes this ah conclusion that again ah this is potential source of hydrogen if we have the coke oven gas coke anyway is necessary for you know the ah steel making process and ah along with that this coke oven gas can be a potential source of gaseous hydrogen and moreover ah we have earlier talked about this ah Linde-Bronn process now we have

learned about the l'Air liquid process. This l'Air liquid process is basically based on then ah expansion engine whereas, the other one that Linde-Bronn process is based on the supply of liquid nitrogen. So, with this ah we know we come to ah ah I mean an end on the ah hydrogen production part and ah in the next class ah I mean hydrogen we have talked about ah the hydrogen production part from the conventional fossil fuel or fossil resources. In the next class we will try to look into the non-conventional ah or renewable energy resources ah mostly that will be you know water splitting that we will take up in the next class. So, thank you for your attention.