Cryogenic Hydrogen Technology

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Week - 01
Lecture 01
Introduction

Welcome to this online course on hydrogen technology, cryogenic hydrogen technology to be very precise and by this time all of us are familiar with the terms hydrogen technology, hydrogen economy, hydrogen energy, but there is an additional term cryogenic, but this cryogenic is not an adjective to hydrogen rather it should be read as hydrogen energy and what is the role of cryogenics in it. So, let us look into it and this is an introduction course today. So, we will give you a brief introduction with the course outline and we will try to understand what it means. So, these are the keywords hydrogen energy vector and cryogenics. So, let us start with the deep milestones of hydrogen and we will find that some of the major milestones starts with the ah I mean invention of hydrogen when it was first generated ah. It is known that Robert Boyle ah generated hydrogen for the first time by dissolving iron into in sulfuric acid.

Later on, ah Henry Cavent is specifically or I mean precisely measured its density and specific weight and subsequently ah LaBeau-Siere named it as hydrogenium because this hydrogenium is ah named because it is a mixture of hydrogen and oxygen gives or produces water and from there this hydrogenium from this hydrogenium this symbol H finally, arrived. So, it was James Dewar in 1898 ah first time liquefied this hydrogen and it was at that time during that time I mean it was known that some of the ah so called this gases are so called permanent gases like nitrogen, oxygen, helium ah and say hydrogen all these gases cannot be liquefied just by ah applying pressure and later on it was found that the concept is not correct and they were able to liquefy hydrogen ah James Dewar is the person who liquefied and not only that he liquefied it in a good quantity and he could ah preserve it in a container basically a double walled container and still that container is in use that concept of that container is still in use for storing the cryogen and it is named as small Dewar and ah it was in 1998 subsequently ah in 1926 we found that the Frischertrop ah process came for production of liquid hydrocarbon and sub and we have seen that this hydrogen ah weld rocket was fired by USA in the year 1963. So, that means, it has the long if these are some of the ah milestones it has a long history and we are now in the 21st century trying to figure out this hydrogen economy or hydrogen technology for our future application. So, let us try to look what is new in it.

So, the present scenario is that hydrogen is used ah in many chemical and oil refineries

and they are using they are being used as reducing or hydrogenating agent for example, that if we have to use ah ah I mean reduce or hydrogenate ah the fatty acids sometime it is or I mean edible or inedible and depending on that ah this will be producing the either soap or you know ah mayonnaise or in oil refineries both it is produced and as well as consumed and for space application we know that the you know hydrogen is used as well. So, this hydrogenating agent means ah in case of say ammonia production for example, this is a mixture of nitrogen and hydrogen and this again say for example, in oil refineries if we have to ah remove say the ah sulphur we need to hydrogenate it and as synthesis gas this is a combination of CO and H2 that is again used in plenty in several chemical industries and oil refineries. So, ah these are already known to us and in the future what we want to do is that we want to ah use hydrogen as fuel though it is has though it has limited applications in space we want to use it as fuel for running our car, running our buses train etcetera I mean for everywhere where the diesel or the petrol is in use we want to replace those with hydrogen. So, not only that we want also you know this generation of hydrogen from the non-fossil fuel. So, that means, when we are talking about generation of hydrogen from non-fossil fuel that means, hydrogen is it not available freely in air or in atmosphere the answer is no we do not have hydrogen in available in air, but rather it is available as you know PPM level.

So, if we go some something like 100 kilometer above the earth surface this is linear and that linear is mostly you know contains hydrogen, but nobody is going to pick up this hydrogen from 100 kilometer above the atmosphere. So, what is the source of hydrogen then? We have a stable compound on atmosphere or in earth on earth that is water, but as I have said that it is a stable compound if we have to get hydrogen from water we need to break it up. And so, what are the other you know I mean sources of hydrogen other than this water we have have talked about the application of hydrogen in chemical industries say or in oil refineries. So, what is the source of hydrogen in all these chemical plants or industries? So, these are basically the coal, crude oil, natural gas these are basically the fossil fuels you can understand that this civil industrialization started with coal subsequently crude oil you know was discovered and natural gas came in picture. So, these are the sources of hydrocarbon.

So, sources of hydrogen these hydrocarbons are the sources of hydrogen. So, as you can understand that these are some stable compound and if we have to free hydrogen from this stable compound we need to have energy. So, that means, hydrogen is not a I mean free source of energy, but we have to free this hydrogen from some compound. That means, we have to use some energy to get this you know hydrogen or hydrogen energy from you know hydrogen. So, that means, it is the energy vector just like electricity this electricity will not be available freely you have to spend energy to create this electricity.

Similarly this hydrogen energy if you have to get you have to first spend some energy to you know generate it from water or coal or crude oil or natural gas. But what are the ah let us look into the C by H ratio that is carbon to H ratio for all these materials or the hydrocarbons. Say coal is having nearly about 2 carbons per hydrogen, crude oil is having nearly 0.5 and natural gas is having 0.25 and with the hydrogen there is no carbon.

So, what does it means because when we are trying to convert all these hydrocarbons into or trying to generate hydrogen out of this hydrocarbons there would be co-generation of CO 2. That means, you know the amount of carbon present in these compounds will also matter. So, if there are more you know carbon present in these compounds obviously, there would be higher CO 2 co-generation ok. So, these are ah I mean the first 3 of this you know compounds are basically fossil fuel and you know from there if we try to generate the hydrogen we will find that there is co-generation of CO 2 except for hydrogen. Since it is not having any ah carbon in it so, there would be any co-generation of CO 2, but why CO 2 is not good? CO 2 is not good for the environment as we all know that it is causing global warming ok.

So, we have to reduce the carbon emission or CO 2 emission into the atmosphere and that is why we find that you know this ah hydrogen is the best fuel among all these elements ok. But we are still bound to use this ah you know fossil fuel and that is also you know depleting with time and we have to reduce our dependency on this ah fossil fuels in future for the generation of the hydrogen. So, we will ah you know look for an alternative source of this hydrogen other than this fossil fuel. So, we have understood this hydrogen is the future fuel. So, let us look into it ah we have said that it is ah cryogenic hydrogen technology.

So, we have understood about the hydrogen and hydrogen technology ah. Now why cryogenics is coming in picture? So, before that we need to understand what is cryogenics? So, cryogenics is a science and technology dealing with the production maintenance and and utilization of low temperature below 123 Kelvin in terms of degree centigrade it is minus 150 degree centigrade, but usually in cryogenics we always talk in terms of Kelvin. So, we have to now look into this cryogenics ah ah and it let us just you know briefly ah look into the ah cryogenics and what is its role in the modern society. So, in steel making I mean in larger or ah ah tonnage steel making you will find there is enormous application of cryogenics. Whenever this steel is made you will find that it needs oxygen that oxygen comes from the air separation where you need ah I mean large cryogenics application or large cryogenic engineering applications.

Then in medical science if someone has ah you know fallen sick and he has to do the MRI that MRI needs a very large magnet or ah strong magnet which is often generated using the

superconductivity a superconducting magnet or superconducting wire that superconducting wire has to be cooled with liquid helium often and there also you have the application of cryogenics. Then you know for biological sample preservation be it ah what is called the stem cell preservation or any biological samples often you will find that they are cooled to ah 77 Kelvin for storing the biological samples. And ah also you know the blood preservation and body tissue ah preservation are done at low temperature mostly in cryogenic condition. Then there is a application in the strategic and other two strategic sectors one is space and there is defense. So, in space you know we have learned about the Hubble telescope then we have the James Webb space telescope our knowledge about this universe is mostly you know dependent on these cryogenic applications for space.

And also say in defense you will find that when the missiles are fired it has a higher ah sensors which is to be again cooled using liquid nitrogen or some small cryocoolers. So, in everywhere you know ah by enlarge in modern society you will find applications of cryogenics and particularly with respect to this hydrogen you will find that it is basically this liquid in the form of ah I mean liquid hydrogen is basically a cryogenic fluid. So, let us now move to the I mean ah when we are when we have decided this that you know the hydrogen is the future fuel. So, what is what is that ah infrastructure that will be necessary to use this hydrogen as a future generation fuel. So, we have learned that hydrogen is not freely available in atmosphere we have to generate it from the hydrocarbons at present.

So, in future maybe you know we have to generate it using the non-fossil fuel using renewable energy preferably. So, first of all we need to generate hydrogen. So, either it is at this moment we are generating it using fossil fuel and there is co-generation of CO 2 if we have to you know basically develop ah hydrogen infrastructure that has to be and it has to be free from CO 2 then we need to look for the non-fossil fuel as well as the renewable energy. So, hydrogen generation ah it will be you know ah I mean along with that we have to look for its storage as well as distribution. So, you can understand that this hydrogen is basically ah it it comes on the it is the first element in the time a periodic table.

So, in the periodic table that if it is the first element that means, it is very light weight. So, obviously, if we want to store it in the gaseous form it will occupy a very large volume. So, often it may not be you know ah practical to store it in the gaseous form. So, either we have to compress it or we have to liquefy it and then finally, this stored or you know ah stored liquid has to be distributed to different you know ah I mean wherever we want to use this liquid or you know gaseous hydrogen. So, there are different you know hydrogen generation processes at this as this moment there is coal gasification then partial oxidation of the crude oil then steam reforming which is mostly the methane and or the natural gas and then you have water electrolysis.

So, this first 3 ah coal gasification, partial oxidation and the steam reforming all these processes are based on the ah what is called the fossil fuel. The water electrolysis is of course, not ah you know depending on the fossil fuel, but it is still an energy intensive process we have to look into it ah in details when we talk about this hydrogen generation in ah in the future in future. So, there is also this hydrogen generation we have to look into that is ah using as I have said that using the renewable energy resources. Then comes the storage and distribution. So, as we have learned that this hydrogen is the lightest element and obviously, we have to compress it to densify or to increase its density and then you can of course, you know transfer it ah by the pipeline, but other option is ah to liquefy it and when we liquefy this hydrogen it is a boiling point would be in the cryogenic domain.

So, if it is in the ah you know gaseous form and if it is compressed ah it will densify it to certain extent and then we can you know transfer it through the pipeline from one end to the other end of the country. Then it can also be ah transferred by bundle trailer that means, we have high pressure cylinders like ah you know we transfer the oxygen from one end to the other end of the country or the cities. So, similarly where the hydrogen is getting generated you know it can be compressed and put in a cylinder like that and it can be put on a trailer to bring it to the point of you know use. The other option is you know storing the liquid in a ah I mean in a container and like you have seen on the highway that when ah you know you are passing by you will find that there is liquid nitrogen container, but you know in a truck or the liquid oxygen is being transported. Similarly ah from the point of generation of say this hydrogen where it will be liquefied it will be transferred to the point of use like ah if you know someone wants the liquid ah hydrogen driven car to be filled he has to go to a filling station where liquid hydrogen will be available and that filling station has to be supplied with this liquid hydrogen coming from different station or you know it will come ah I mean it will be on board or it will be ah generated in that filling station itself.

So, subsequently it comes ah its utilization part say be it ah a car personal car or you know bus or train or you know the aeroplane. So, probably ah this liquid hydrogen would be ah the only option for some of the applications though some of the buses and you know cars are these days running in Europe you know with the compressed ah gaseous hydrogen, but for ah aeroplane application or you know this ah air I mean aeroplanes the probably the liquid hydrogen is the only option. So, apart from that we have ah you know onsite production and storage of ah hydrogen that is also possible, but if it is in a large-scale ah application ah probably we have to look for the cryogenic storage and transportation of this ah hydrogen. So, now let us look briefly into the course content ah as we have already discussed that we have to look into the different hydrogen production techniques both existing and the futuristic because the successful implementation of this hydrogen energy

will be dependent on the ah production and as we have learned that it is an energy vector we need to spend energy to generate the hydrogen. So, we have to have energy efficient process for generation of hydrogen.

So, for generating hydrogen it should not be that you know we spend energy more than what it is you know can give. So, that we will look into. So, what are the available or what are the existing ah hydrogen production processes from the fossil fuel and what is the role of cryogenics in that hydrogen production. And then of course, there are different hydrogen storage means mostly we will look into the compressed as well as the liquefaction or liquefied hydrogen and when it is liquefied hydrogen as we have learned that it is in the cryogenic domain. So, it is storage it is you know ah I mean liquefaction process it is I mean it is completely different from the ah other refrigeration processes.

So, we will look into that cryogenic liquefaction process and then there are other ah storage means like ah you know storing hydrogen in metal hydride cryosurption storage then cryo compressed hydrogen is also you know those are all futuristic methods and we will try to look into it ah from it is ah utilization point of view. So, for utilization ah we will you know ah look into ah mainly hydrogen as a fuel ah where this hydrogen will be using ah at present it is it has limited application in the space technology or you know ah cryogenic rocket or cryogenic engines. And other than that if we have to use this liquid or gaseous hydrogen for running a car we have to either I mean look into ah suitable engine or you know where the gaseous or liquid hydrogen will be directly injected or we have to look into the fuel cell where you know this hydrogen will be injected or you know supplied ah in the form of liquid and finally, it has to be gasified and utilize it ah. So, other than that we have the safety the part you know ah whenever we talk talk about the liquid hydrogen as such liquid hydrogen since it is in the cryogenic temperature there is no problem, but as we try to you know store it in a closed container or in a ah confinement. So, it it may you know because of the heating leak it may get pressurized and create ah you know safety hazards.

So, we have to look into the safety aspects of using the hydrogen. Other than that, what it is important before we you know start this discussion on this cryogenic hydrogen ah we have to look into the hydrogen properties there are very peculiar properties of hydrogen ah both in particularly in low temperature. So, we will be looking into it in details ah in the coming ah lectures. So, let us ah look into the references. So, mostly we will be talking ah about the cryogenics from cryogenics part of hydrogen from cryogenic systems by R. F. Barron then there is one more book by Thomas Flynn there are plenty of cryogenic books these days available and this is about the safety part. So, these are some of the references what it came to my mind at this moment. So, later on I will also tell about the other ah references. So, let us try to conclude. So, in conclusion we can say that we have

learned that hydrogen is a prospective fuel and hydrogen energy hydrogen is the ah energy vector and hydrogen infrastructure ah is necessary to create it as a ah you know future fuel and there is a role of cryogenics ah has an important role in this hydrogen ah technology ok.

So, thank you for your attention. Thank you once again.