Technologies for Clean and Renewable Energy Production
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Lecture - 21
Gaseous Fuels: Properties and Routes for Energy Production

Hi friends, now we will discuss on the topic gaseous fuels, properties, and routes for energy production. In this course, so far we have discussed on the utilization of coal and petroleum which are fossil fuels, and solid and liquid in nature, but now we will be discussing on the gaseous wells and how this can be used in a more cleaner of sense, most conventional routes and how it can be processed through a more cleaner routes. So, that we will discuss in this class.

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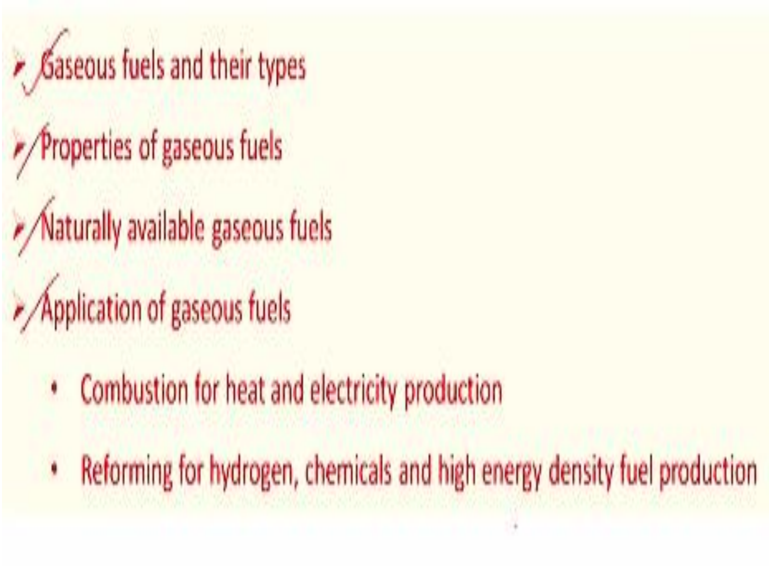

The content of this; the gaseous fuels and their types, properties of gaseous fuels, naturally available gaseous fuels, application of gaseous fuels in combustion for heat and electricity production and reforming for hydrogen, chemicals and high energy density fuel production. So we will see at first what are the conventional routes, that is, basically that gas can also be used for the production of heat and electricity. It can be used in transport sector as well as for electricity productions in power plant.

We may converts gaseous fuels to syngas and syngas to different types of chemicals or liquid fuels so that energy density will be high and we can moreover get hydrogen from this syngas or from this methane or natural gas, so that will be one cleaner option for its utilization. Now, we will see the gaseous fuel types.

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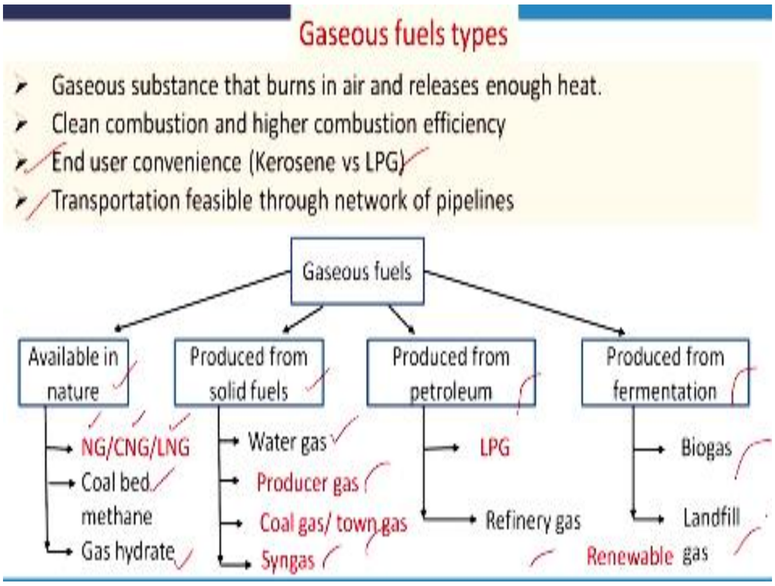

So what are the types of gaseous fuels that we will see here and this is the fuel in gas phase and it burns and gives heat, this is the definition of gaseous fuels. So, the gaseous substance that burns in air and release enough heat. Indeed clean combustion and higher combustion efficiency it has and the use of gaseous fuels user convenience and you see some example kerosene and LPG. Obviously, we will prefer the use of LPG for cooking purpose and then transportation feasible through network of pipelines.

So, gas can be transferred from one place to others with pipeline. If we see the types, so one is available in nature, some gaseous fuels which are available in nature; so natural gas, compressed natural gas, liquefied natural gas, those are available, coalbed methane is also one naturally available gas and gas hydrate. So these are the naturally available gaseous fuels. We can produce from the solid fuels like say water gas, producer gas, coal gas and town gas, and syngas.

Already we have discussed these things how the coal gas, producer gas, syngas, etc. can be produced from the coal and petcoke and produced from petroleum. From petroleum, we can get LPG and we can get refinery gasses. Produced from fermentation, from fermentations in anaerobic digestions, we can get biogas, we can get landfill gas. So these are different types of gaseous fuels, which we can get and we can use these resources for energy production in cleaner route. We will discuss how this can be used in a cleaner process or cleaner routes.

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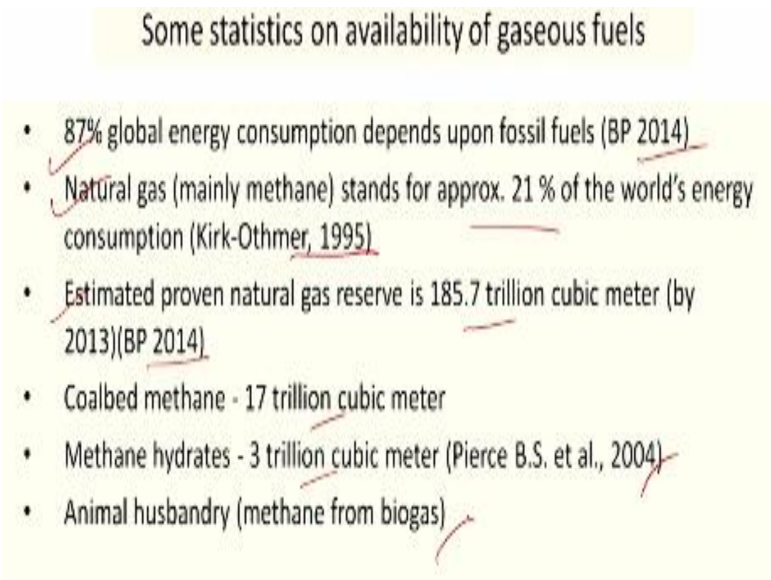

Now this slide shows us some statistics, the availability of gaseous fuels, say 87% global energy consumption depends upon fossil fuels as you know. The natural gas stands for approximate 21% percent of the world's energy consumptions as per this reference. Then it is estimated the proven natural gas reserve is 185.7 trillion cubic meter, this is the British Petroleum 2014 report; and coalbed methane is 17 trillion cubic meter.

Then methane hydrates 3 trillion cubic meter, that is as per 2004 data, and then animal husbandry, the methane from the biogas, so that is also one good source of the gas, biogas from the cow dung or other animal manures or any other animal rejects. Now we will see the basic properties of gaseous fuels. So like coal and petroleum, these gaseous fuels will also have some specific properties and some of those properties are very very important to consider it as a very good candidate for energy production.

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Basic properties of gaseous fuels

- Composition
- HCV (Q_s) and LCV (Q_i) , MJ/m³
- Density ρ, kg/m³ and dimensionless density d_v (Relative density)
- Wobbe No., W_b (Wobbe index)
- Temperature of dew point and moisture
- Explosibility limits, %
- Stoichiometric air
- Octane number (ON)

So some of those properties are composition, then high calorific value and low calorific value, then density and dimensionless density or relative density, and then Wobbe number and Wobbe index, then temperature of dew point and moisture, explosibility limits, stoichiometric air, octane number; so all those properties are important to consider the gaseous fuels as energy candidate.

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Composition

Gas	Typical Composition	Typical Heating value MJ/m³
NG	CH_4 92%, HC 5%, Inert 3 %,	41
LPG	Propane 20 %, Butane 80 %	117
Coal gas	H_2 48 %, CO 5 %, CH_4 34%, CO_2 13%	20.2
Producer gas	H_2 13-19 %, CO 18-22 %, CH_4 1-5%, CO_2 9-12 %, Heavier hydrocarbon 0.2-0.4, N_2 45-55 %, H_2O 4 %	4.5-6
Syngas	H_2 20-30 %, CO 40-60 %, CH_4 0-5%, CO_2 5-15 %, N_2 0.5-4 %, H_2O 8-12 %	9.3-14.9
Water gas	H_2 34-38%, CO 23-28%, saturated hydrocarbons 17-21%, unsaturated hydrocarbons 13-16%, CO_2 0.2-2.2% and N_2 2.5-5%	4.5

High caloric (example: with high methane content, HCV = 39 MJ/m³),
Low caloric (example: with high nitrogen content, HCV <= 27 MJ/m³).

Now here we see the typical composition of different type of gas; so natural gas, LPG, coal gas, producer gas, syngas, water gas. So if we see here in these gases, the composition is different, so somewhere we are having CH4 92% for natural gas and higher hydrocarbon 5% and inert 3%. So here we see heating value is 41. Then you go for LPG, propane and butane higher hydrocarbon we are having here and also we are getting very high heating value, whereas coal gas we have hydrogen 48%, CO 5%, CH4 34%, CO2 13%, but its heating value is 20.2 megajoule per meter cube.

Producer gas is further it is less, very less heating value it has, and your syngas we are having up to 9.3 to 14.9, for this case is hydrogen 20 to 30%, carbon monoxide 40 to 60%, CH_4 5%, and CO_2 5 to 15% like this. So in this case also, the heating value is not very high. Water gas also has very low heating value. So to be energy candidate, obviously the heating value is very important and we see that the LPG is having the highest heating value among others followed by natural gas.

So which one is having higher heating value and which one is lower heating value that demarcation has been made by this one that the high calorific we can consider and high heating value in 39 megajoule per meter cube or more and then it is less than 27 megajoule per meter cube, it is considered as low calorific value containing gas.

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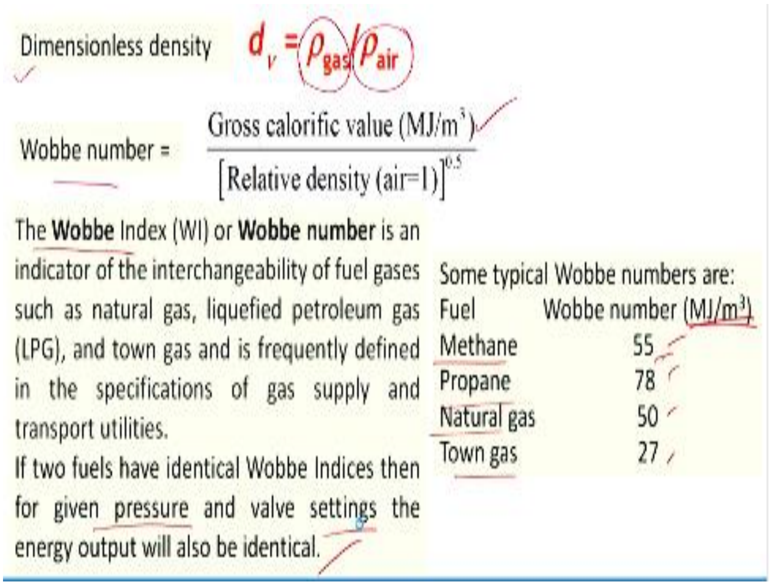

Then we see the density, what is density yow that mass/volume and then dimensionless density = density of gas/density of air at the same conditions, so that will be the relative density. Then Wobbe number is defined as that gross calorific value that a high calorific value in megajoule per meter cube unit divided by relative density to the power 0.5, so this is the Wobbe number definition.

Then, this will be coming into megajoule per meter cube unit and these are different components, different types of gas, which are having different Wobbe number. So what is the significance of this number? You see say I have a gas mixture, I am using it for a particular application, I want to change one component from the mixture, see is it possible that can be decided by Wobbe index, Wobbe number. So similar Wobbe number means the similar amount of energy is released by unit volume of gas.

So, if I want to change one component by other, then if both are having the similar Wobbe number, then there will be no problem during the combustions to meet the heat requirement for the process. So that is the importance of Wobbe index or Wobbe number. So if 2 fuels have identical Wobbe indices, then for given pressure and valve settings, the energy output will also be identical. So that is one important parameter.

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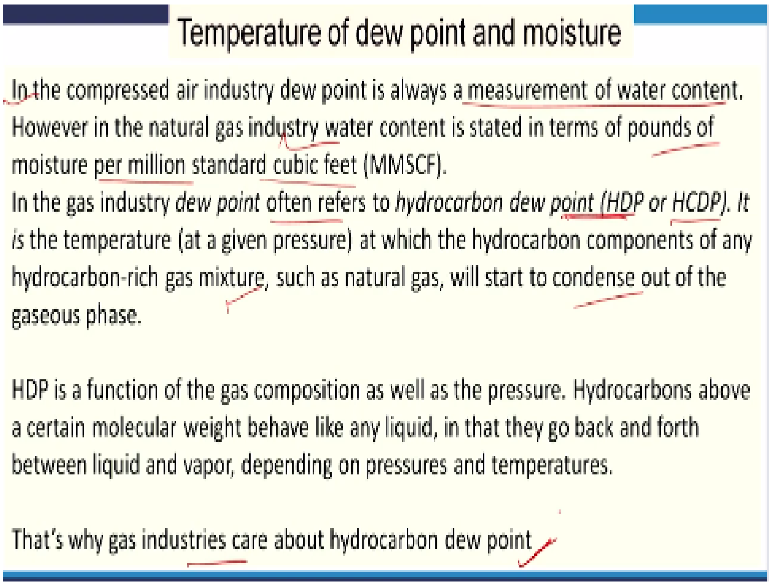

Now temperature of dew point and moisture. So this is the dew point definition the significance is different for different cases. So if we consider the compressed air industry, then dew point is always a measurement of water content, but in this gas industry and natural gas industry, water content is stated in terms of pounds of moisture per million standard cubic feet. Dew point often refers to the hydrocarbon dew point or that is HDP or HCDP.

It is the temperature at which the hydrocarbon components of any hydrocarbon rich gas mixture such as natural gas will start to condense out of the gaseous phase, so minimum temperature when it will start to condense, the hydrocarbon gas will start to condense. So this is your dew point. So we have seen that higher molecular weight hydrocarbon is giving higher heating value, there is LPG having higher heating value, and in this case liquid and air transfer is also possible depending upon the pressure and temperature.

So the industries care about the hydrocarbon dew point. So dew point will influence how much molecules will be in gas phase, gas phase means it is easy to use, and liquid phase is giving us higher hydrocarbon is giving us more heating value. So the hydrocarbon dew point is important that it will decide whether the hydrocarbon will be in gas phase or in liquid phase, that is why this hydrocarbon dew point is considered by the gas industry.

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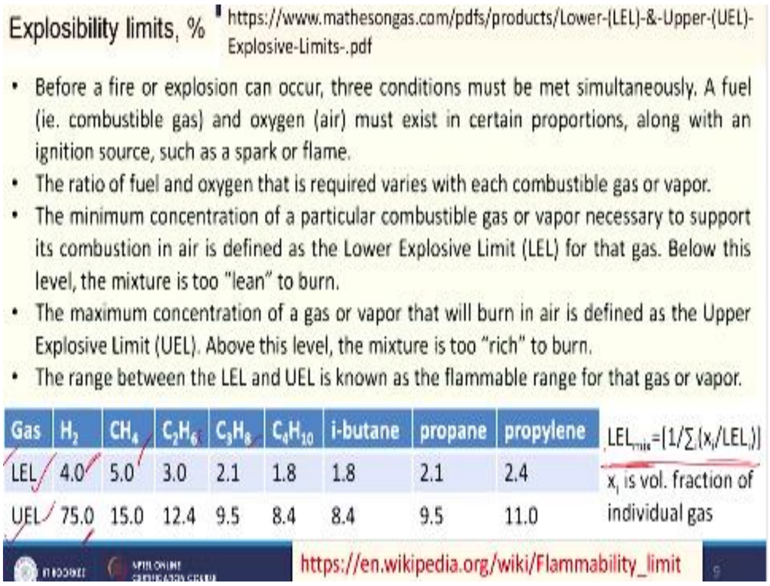

Now explosibility limits. In explosibility limits as you know if we want to get explosions or say firing from any material, then we need 3 things; that is your oxygen, fuel, and your sufficient heat or some ignition source. So these things are required, that is, fire triangle also we can say. So if we have sufficient amount of gas, oxygen is less, so we may not get firing. So for the explosion, for catching fire, we need oxygen and gas and some temperature.

So what will be happening, there will be one lower limit and there will be an upper limit for the concentration of gas in the air mixture. So gas and air, below certain concentration of gas, it will be a lean gas, so it will not be able to burn, and after certain concentration of the gas in the mixture, it will be rich in gas, and also there will be no burning or combustion in this process. So the upper concentration is upper limit and the lower concentration is lower limit. Within this upper to lower limit, the gas explosion will take place.

So some examples are given here. Low explosion level and upper explosion level for hydrogen is 4, this is for 4 and this is for 7.5, so 4% hydrogen and 75% percent hydrogen, so these are the limits. Similarly, for methane 5 to 15, C2H5, 3 to 12.4, and 2.1 to 9.5 likewise. So now if we have a mixture, then what will be the LEL and what will be the UEL if we have a gas mixture. Then, we have to consider the individual gas mixture and their LEL and UEL and we can put this in these expressions.

So, that is LEL mixture is equal to 1divided by sum of xi by LELi, then what is the mass fraction of particular component divided by LELi of that component plus, similarly if you have n numbers we have to add n in this, this, this term that is xi by LELi, then we will be getting the overall LEL of the mixture.

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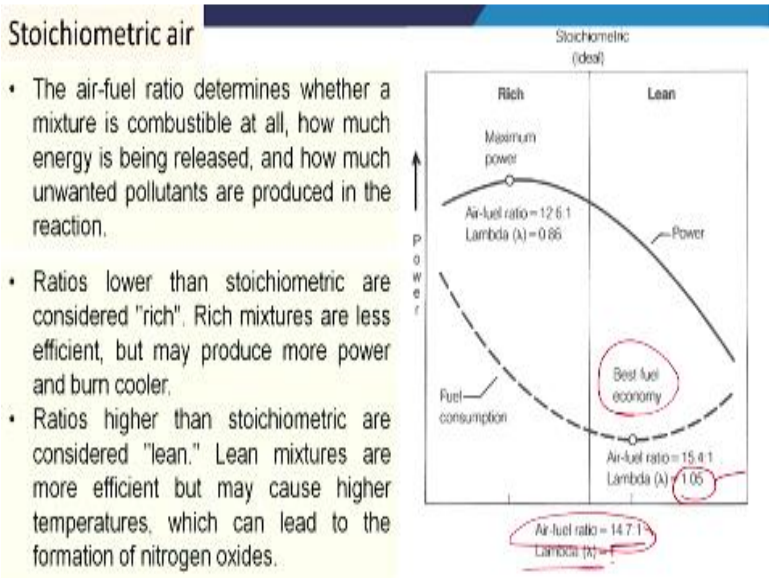

Then stoichiometric air requirement, that is also important properties that for a particular gas fuel what is the air requirement stoichiometry, so some example is given here. It say that if air is very high, air is more, then air will be in excess, so there will be heat loss; and air is less, complete combustion will not take place. So there will be some optimizations and people have worked on it and found out that 14.7 to 1% this air-fuel ratio is required for stoichiometric conversions, but if we provide stoichiometric air, then the process will not be that efficient.

We need some excess amount of oxygen and that oxygen the excess amount is defined by lambda. So lambda 1 is stoichiometric. If it is more than one, that means you are getting some excess oxygen. So it is found that this 5% excess oxygen, it gives the best fuel economy. So, we will see what is the stoichiometric ratio and then what will be the oxygen required for the combustion of this fuel that we can determine if we can know the stoichiometric air requirement. So this is one important property of gaseous fuel.

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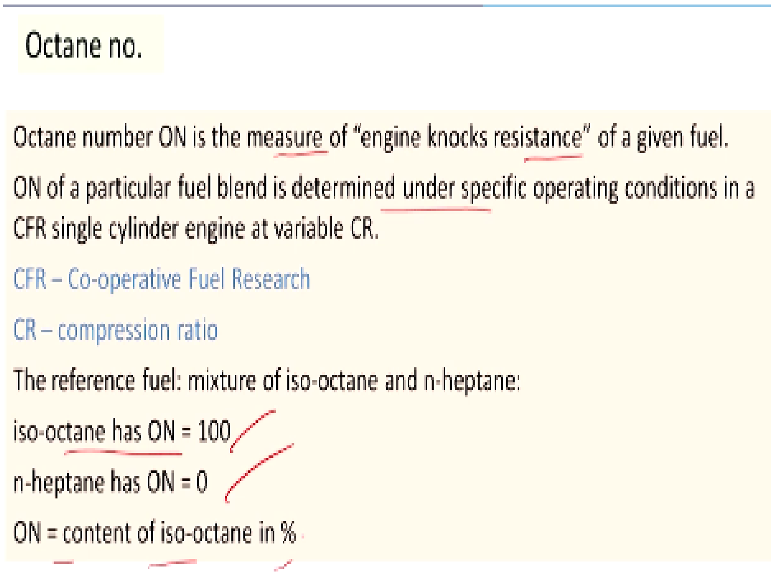

Octane number we have already discussed that it is related to the antiknock property of that. So octane number is the measure of engine knocks resistance of a given fuel and octane number of a particular fuel blend is determined under specific operating conditions as you have discussed in case of petroleum and its different petroleum products, particularly for gasoline.

So similar test is done for testing the knocking property of this gaseous fuel and here the same definition of octane number as we have discussed iso-octane has 100 and then n-heptane has 0 and octane number is equal to content of iso-octane in percentage in the mixture which has the similar type of knocking property of that particular fuel.

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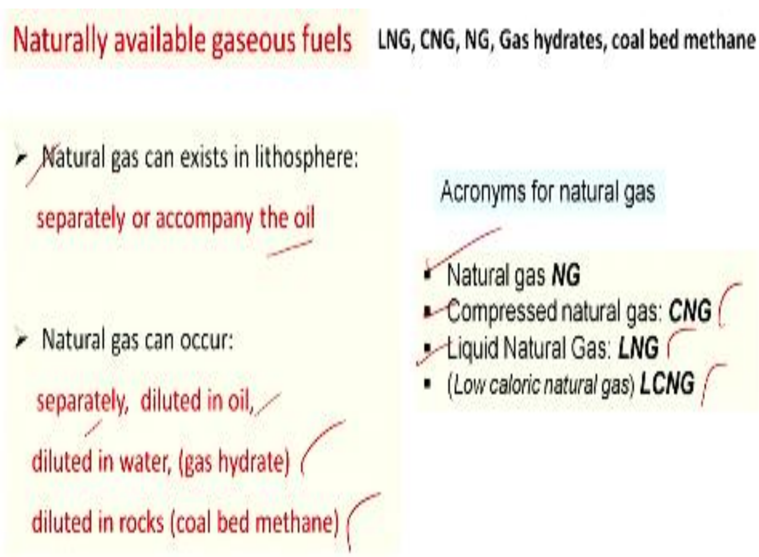

Then we will see the naturally available gaseous fuels. So naturally available gaseous fuels we have already discussed. We have natural gas, which can exist in lithosphere, separately or accompany the oil, it may be separately gas or may be along with the oil, it is naturally available, that is natural gas. This natural gas can occur separately, diluted in oil, and diluted in water that is gas hydrates, and diluted in rocks that is coal bed methane.

So, these are the natural source of gaseous fuels and this natural gas can exist in different forms and some acronyms are natural gas NG, then compressed natural gas CNG, liquefied natural gas LNG, and low calorific natural gas LCNG. So these are the acronyms of natural gas.

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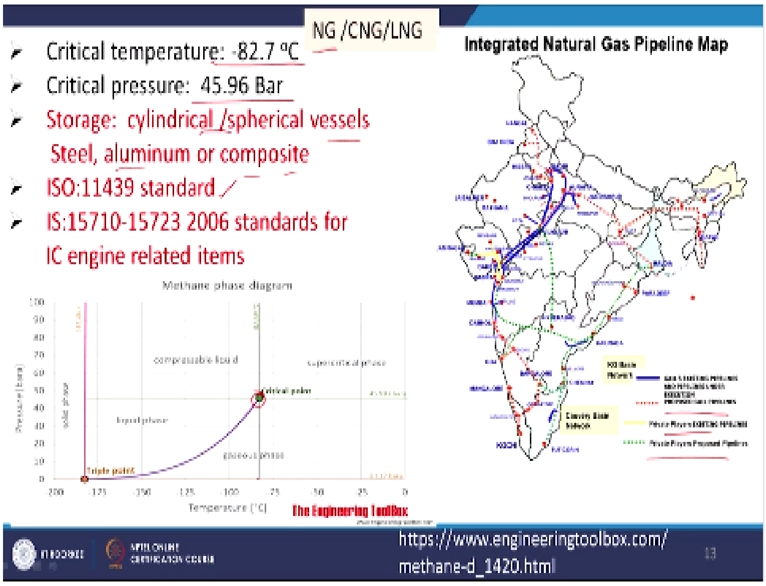

Now we will see what NG, CNG, LNG are? So you know that natural gas at ordinary temperature and pressure, normal temperature and pressure, it is in gas phase. So if we can change the temperature and pressure, it can be converted to liquid phase or it can be compressed. So some pressure temperature curve shows that this is the critical point for this, this is the critical point for the natural gas. The critical pressure is equal to 45.96 Bar and temperature is -82.7, so we have -82.7 and this is your 45.96 Bar.

So our temperature is normal temperature is say 30 degree, so in that case, it comes into gas phase. So how we will store it, that this can be stored in cylindrical or spherical vessels, steel, aluminum or made of some composite and those standard, these are defined by the standards. It should have some quality as mentioned in the standards. You see this natural gas net in the country. So, this we have on dotted line so that is your GAIL's existing facilities.

So, GAIL, Gas Authority of India Limited, so this is one Indian company Navratna company, so this company is exclusively involved for the gas business and this is their existing plant. This is the pipeline for the transport of gaseous fuels and there are some expansion programs. This is your proposed GAIL pipeline. So this red or the proposed gas will be supplied through this line different parts of the country, it will be connected through this pipeline.

Then private players, there are some private players also who are involved in this business, and these private players' proposed pipelines. So these are the proposed pipelines of gas supply for the private player. So this is the availability of natural gas in the country, and we will give some information here.

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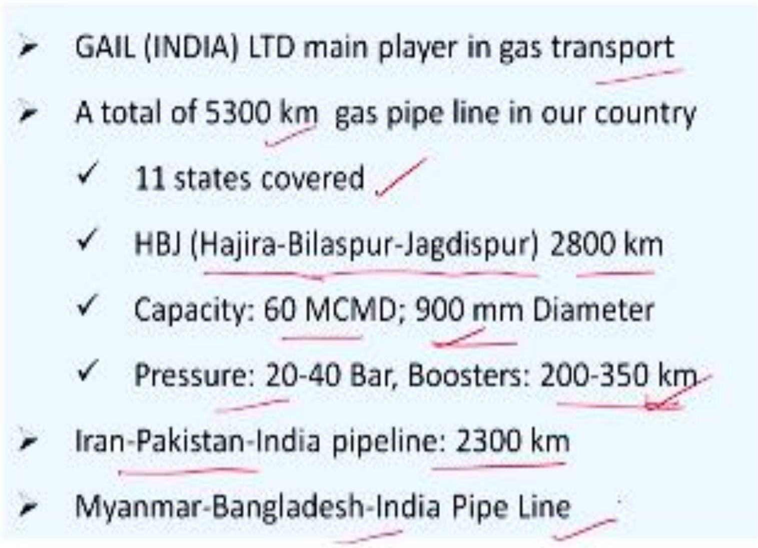

So we will get some information here, that is GAIL India limited main player in gas transport. A total 5300 km gas pipeline is available in the country in 11 states and Hajira-Bilaspur-Jagdispur 2800 km. It has a capacity of 60 MCMD and 900 mm diameter and pressure 20 to 40 Bar and there are some booster pumps at 200 to 350 km away. So, the gas is transferred through pipelines.

During the transfer, it loses its pressure, so some booster pump is required to generate further pressure to pressurize it to movement from one place to other, so that is the role of the booster and this is the pipeline specification. Apart from this, we have Iran-Pakistan-India pipeline 2300 km and Myanmar-Bangladesh-India pipeline.

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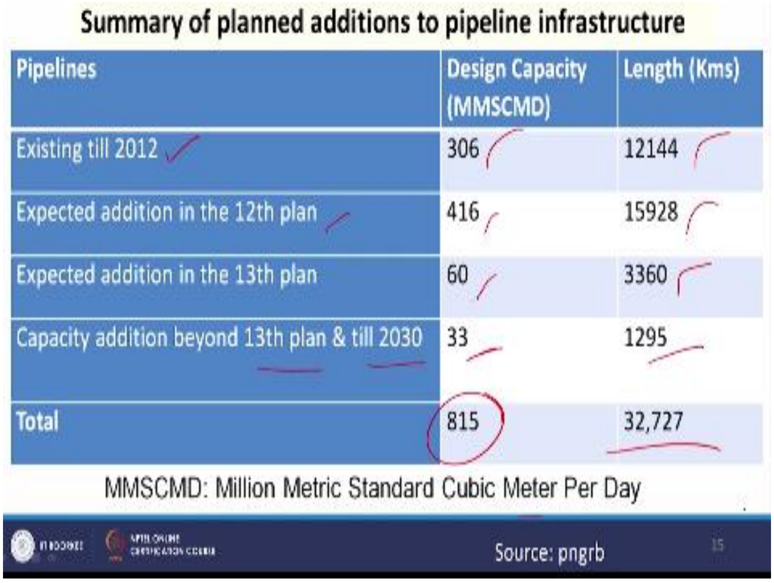

Summary of planned additions to pipeline infrastructure

Pipelines	Design Capacity (MMSCMD)	Length (Kms)
Existing till 2012	306	12144
Expected addition in the 12th plan	416	15928
Expected addition in the 13th plan	60	3360
Capacity addition beyond 13th plan & till 2030	33	1295
Total	815	32,727

MMSCMD: Million Metric Standard Cubic Meter Per Day

Source: pngrb

So these are the summary of planned additions to pipeline infrastructure. Say existing till 2012, we had 306 million metric standard cubic meter per day MMSCMD and then length is 12144. Then we have expected addition in 12th plan, 416 that was 15928 km kilometers and then expected addition in 13th plan that its design capacity 60 in this plan and then it is 3360 km pipeline addition.

Capacity addition beyond 13th plan and till 2030 that is beyond 13th plan we are having this and this is 1295 km of pipeline addition. So, total 815 MMSCMD capacity with 32727 km pipe length is under proposal.

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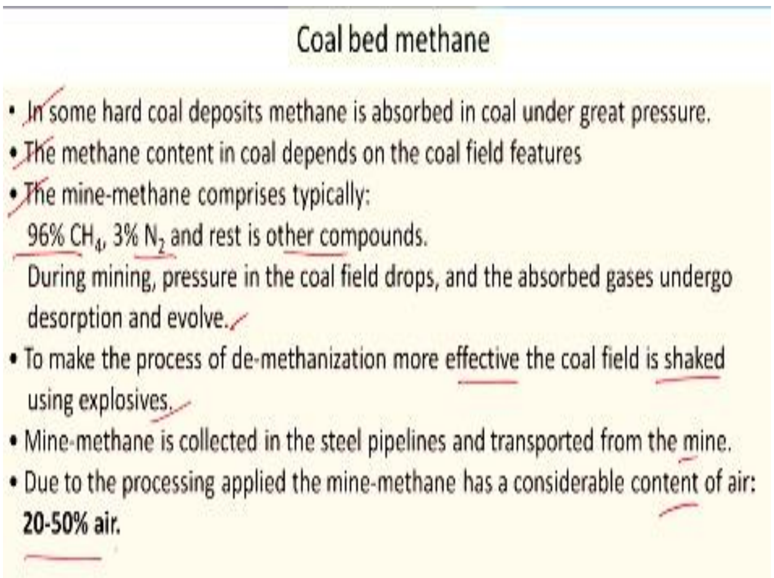

Then we are coming to coal bed methane. So coal bed methane, obviously the name indicates that it is available in the coal seam, it is coal bed. So in some hard coal deposits, methane is absorbed in coal under great pressure. So, the methane content in coal depends on the coalfields' features and the composition of this coal bed methane in basically 96% of methane and 3% nitrogen and rest is other compounds.

During mining process, the pressure reduction takes place, so once the pressure is reduced, then the absorbed gas comes out or dissolved, so we can get the coal bed methane by that way. To make the process of de-methanization more effective, coal field is set by blasting or by using explosives. Then mine-methane is collected in the steel pipelines and transported from the mine, and we will see due to the processing applied, the mine methane has a considerable content of air, it contains around 20 to 50% of air.

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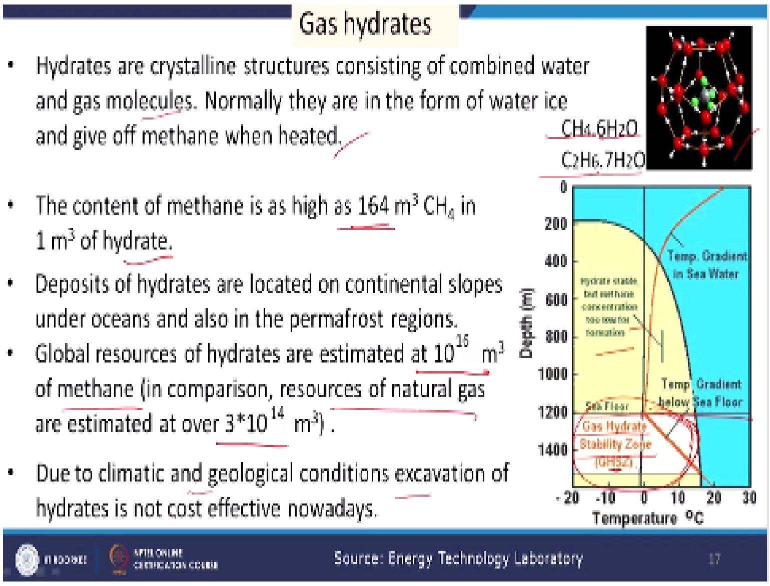

Then gas hydrates is another type of gaseous fuels available in hydrate forms and see this is the structure of gas hydrates. It has a crystalline structure and methane are higher and higher hydrocarbons associated with water molecules are present in hydrate form as a solid form and then if we can break this, then we can get methane. So, the hydrates are crystalline structure consisting of combined water and gas molecules. Normally they are in the form of water ice and give off methane when heated.

So thing required, so this figure shows that this is our sea floor, so below the sea floor the gas hydrate stability zone we are getting, so above also we can get some hydrate, but this hydrate stable, but methane concentration too low for formation, so methane concentration is very less in this, so this part is very useful. So methane gas that is available here can be extracted, but this is not a very matured technology, investigations are going on how to use these gas hydrates as energy product.

In India also, we have some reserve in a Godavari basin then that can be used and government of India is also investing good amount of money for the research on this area. The content of methane is as high as 164 meter cube methane in 1 meter cube of hydrate, so 1 meter cube hydrate can give us 164 meter cube of methane. Deposits of hydrates are located on continental slopes under oceans and also in the permafrost regions, already we have discussed.

Due to climatic change and geological conditions, excavation of hydrates is not cost effective nowadays, so this is not a very cost effective option to use this commercially, but research is going on and in near future, this resource may also be used.

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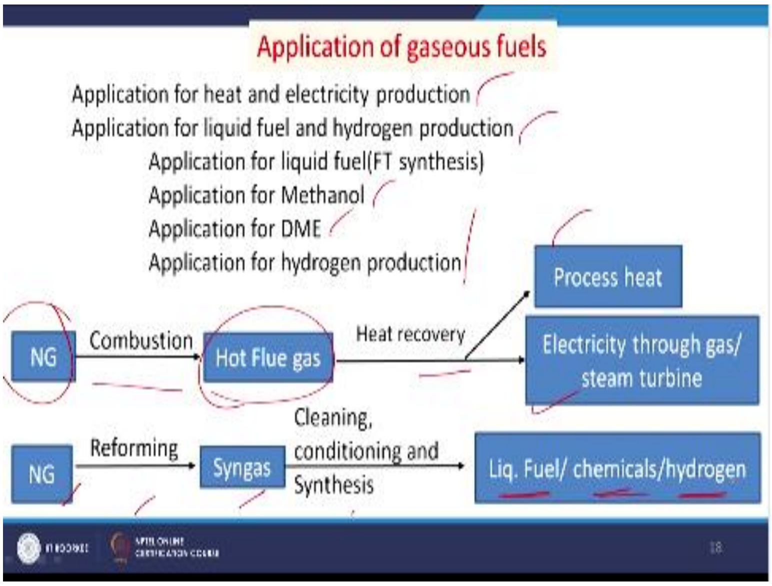

So now we will see how these various types of gases can be used and conventionally used. So this can be used for heat and electricity production, very conventional method. An application for liquid fuel and hydrogen production, in application for liquid fuels, methanol, DME, and hydrogen these can be produced. So we have natural gas say, so we will follow the combustion route, we will get hot flue gas, and then heat recovery, it will give us process heat and electricity through the steam and gas turbine.

So, this is a very conventional method, but we can use this natural gas through reforming, then we can get a syngas, then syngas cleaning and conditioning, it will be the feedstock for different type of products, may be liquid fuel, maybe chemicals or maybe hydrogen. So that way, these routes are not well explored, so research is going on for the development of new technology, even in small scale technology, for the utilization of natural gas through these routes.

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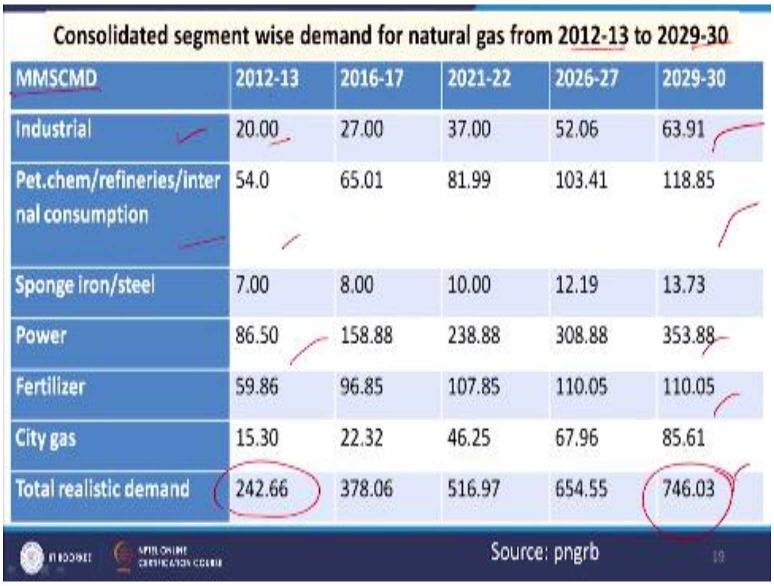

Consolidated segment wise demand for natural gas from 2012-13 to 2029-30

MMSCMD	2012-13	2016-17	2021-22	2026-27	2029-30
Industrial	20.00	27.00	37.00	52.06	63.91
Pet.chem/refineries/internal consumption	54.0	65.01	81.99	103.41	118.85
Sponge iron/steel	7.00	8.00	10.00	12.19	13.73
Power	86.50	158.88	238.88	308.88	353.88
Fertilizer	59.86	96.85	107.85	110.05	110.05
City gas	15.30	22.32	46.25	67.96	85.61
Total realistic demand	242.66	378.06	516.97	654.55	746.03

Source: pngrb

This is a segment wise demand for natural gas from 2012-13 to 2029-30. So industrial sector say 20 MMSCMD in 2012-13 is expected to be 63.91 MMSCMD. Similarly for all sectors, it is expected the natural gas utilization will increase in near future, for everywhere we are getting increase and significant increase, total 242.66 MMSCMD to it is expected that it will be 746.03 MMSCMD.

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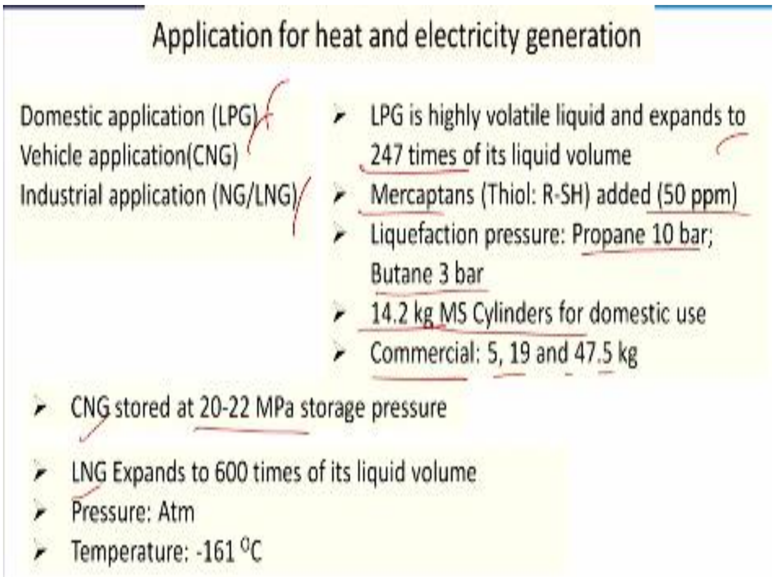

Conventionally, we use the LPG, we use CNG or natural gas or LNG we use. An LPG as you know that it is highly volatile liquid and expands to 247 times of its liquid volume and

Mercaptans are available in it, say 50 ppm. Liquefaction pressure, propane it is 10 bar and butane 3 bar, propane propane and butane are the major components of the LPG we know and in this case 14.2 kg MS cylinders for domestic use it is available, but for commercial, we have 5, 19, and 47.5 kg cylinder.

Compressed natural gas, the natural gas is compressed which is called CNG and is stored at 20 to 22 megapascal storage pressure, so 200 to 220 atmospheric pressure. So LNG, similarly liquefied natural gas, the natural gas can be liquefied if the temperature is reduced to -161 degree centigrade, and when it expands, it can expand to around 600 times of its liquid volume. So this is the application for electricity production as you have discussed for coal and other fuels, also the petroleum.

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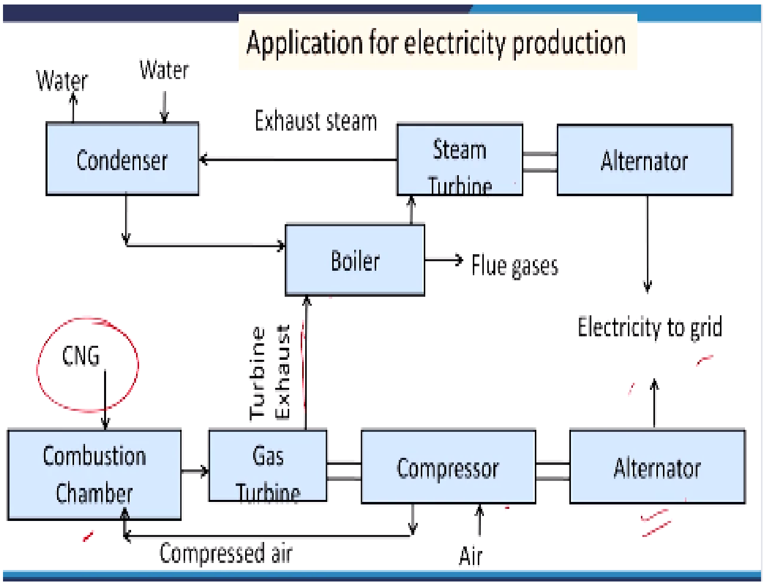

Also, the similar way the gas can be used for electricity production through the combustion route. So combustion, then flue gas, then heat turbine and turbine, and then this is going to your alternator and we are getting the electricity. Similarly again, the exhaust from the turbines can be used in machine to boiler for heat recovery and then steam turbine and then electricity and from this, condensed water can come here and it is again go to the boiler.

So that way in a conventional route, the gas can be used for the production of electricity and heat. So now, we will see in the next classes how the gaseous fuels, particularly the natural gas can be used for the production of chemicals, liquid fuels, and hydrogen. Thank you very much for your patience.