Fuels, Refractory and Furnaces

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Lecture No. # 35
Miscellaneous Topics: Atmosphere In Furnaces

In the course on the fuel refractory and furnaces I had included flu few miscellaneous topics which are also important. So, some miscellaneous topics which I will be going to cover in the next few lectures one is atmosphere in furnaces, atmosphere in furnaces and second I am going to cover temperature measurements, temperature measurements because many a times temperature measurement is also an important issue and one should know the principle and operating detail of temperature measurements.

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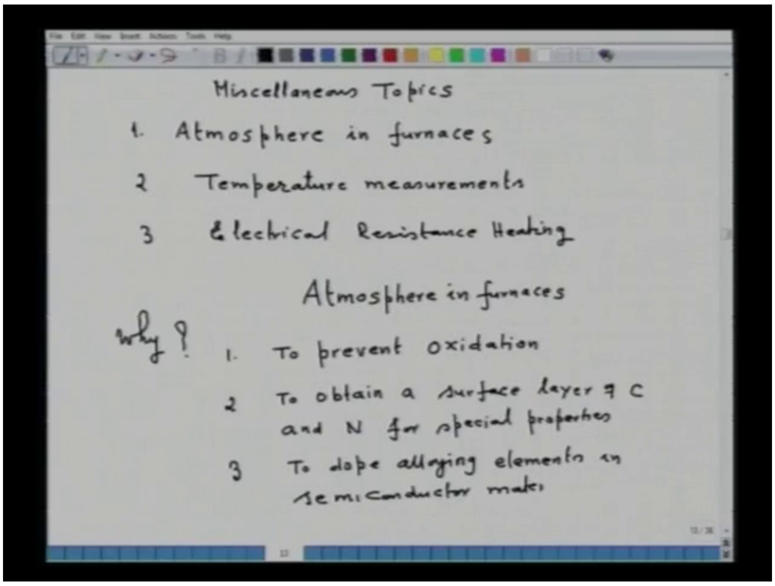

Third that I am will be including on electrical electrical resistance heating, so, as such let me first start with the atmosphere in furnaces. Atmosphere in furnaces, now, I had always said that a furnace is thermal enclosure and is used to employ heating of the object to the required temperature.

Now, in this connection in many application it is required that the certain is specific type of atmosphere in the furnace should be maintained for doing certain special type of jobs. So, why we need atmosphere in the furnaces? Why we need a special atmosphere of the furnaces, in the furnaces? Now, when I say atmosphere in furnaces then I mean fuel, fire furnaces or electrical furnaces because both are used for heating and in many situations one does require a special type of atmosphere. So, why we need? The first reason to prevent oxidation, to prevent oxidation. Now, this is particularly very much required when you are heating for example, a steel alloys below their melting point for thermo mechanical processing or for heat treatment purposes then oxidation is important because if you heat them in the atmospheric oxygen then certain amount of oxidation will occur. Then accordingly scale formation will be there so either you remove the scale or you avoid the oxidation atmosphere.

Another important function of the atmosphere say to obtain a surface layer, to obtain a surface layer of carbon and nitrogen for a special properties, for a special properties.

Because you know the process is called carburization and nitrid- nitriding the they are the two important case hardening method where an appropriate atmosphere is created so that the carbon and nitrogen of the atmosphere, it diffuses into the surface of the steel and accordingly surface is case hardened. Third for many semi-conductor applications or to produce semi-conductor material, doping of alloying element is also done. With the doping I mean that elements which are very very small concentrations are put in the atmosphere and they are allowed to diffuse into the semi-conductor material and that is called doping.

So, the third objective to dope, to dope alloying elements, alloying elements in semi-conductor material, semi-conductor material

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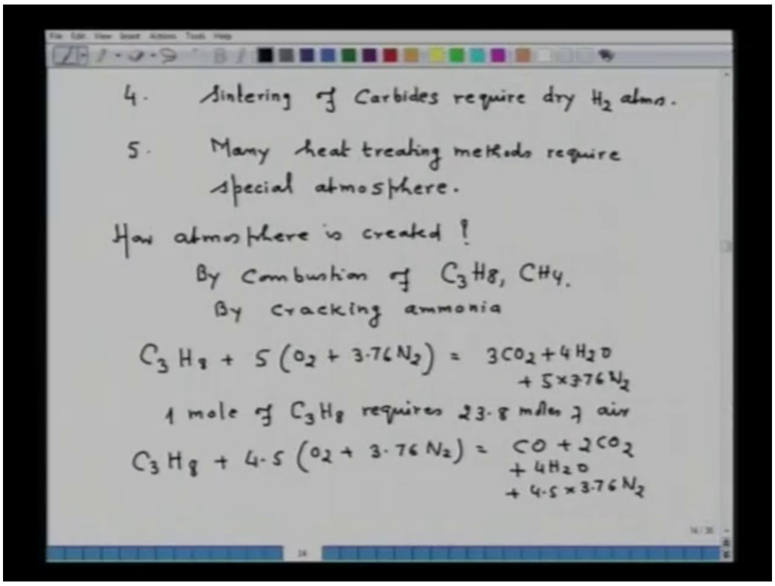

Now, fourth objective we also carry out sintering. Sometimes sintering of carbides it requires dry hydrogen atmosphere. So, sintering of carbides, sintering of carbides requires dry hydrogen atmosphere. Also as I said many heat treating methods, many heat treating methods, with the heat treating methods I mean annealing, normalizing, quenching, tempering, mar tempering, house tempering and so on to create a special micro structure in the steel for a special application these materials also requires a certain special type of atmosphere, could be neutral atmosphere, could be reducing atmosphere or whatever the cases I am writing many heat treating methods require a special atmosphere, require a special atmosphere. Now, naturally the question comes how the various atmospheres are created.

That is how atmosphere is created, is created. Now, essentially an atmosphere means the presence of gases. So, when we say atmosphere in the furnace we mean the presence of certain type of gases, to the gases which are relevant for the atmosphere are hydrogen nitrogen and then H2O, CO2, CO a alone or their mixtures. So, depending on the requirement for example, if we require a reducing atmosphere we try to have a carbon oxide or hydrogen atmosphere, if you want a neutral atmosphere we want to have a nitrogen atmosphere or if you want to de-carburize the steel, they are the solid steel at high temperature then we may like to oxidizing atmosphere for example, CO2 or we would like to have a hydrogen atmosphere. So, when we say atmosphere means that means you are creating or you are providing a mixture of gases or single gas for example, if you want to create inherit atmosphere only nitrogen over the piece of material which we are heating that is what means the atmosphere. So, it is created say by combustion of propane.

For example C_3, H_8, CH_4 or by cracking ammonia. Now, for example, if we take say a combustion of C_3, H_8. So, if we take C_3, H_8 and if we completely combust say for example, we take 5 O_2 plus 3.76 N_2 that is this much amount of stoichiometrically if we take then we are going to get 3 CO_2 plus 4 H_2O plus 5 into 3.76 N_2. So, if we combust completely propane with the stoichiometric amount of air then the atmosphere will consists of CO_2, H_2O and Nitrogen. Now, in this stackometric amount so what we need a one mole of C_3 H_8, one mole of C_3 H_8 it requires 23.8 moles of air stoichiometrically. Now, if our objective is to create an atmosphere which is the mixture of CO, CO_2, H_2O and N_2 then naturally what we have to do we have to use air less than the stackometric amount of air. Now, if we use air less than the stoichiometric amount of air as you recall from the knowledge of the combustion which I have given in the lectures nine to twelve.

You know that amount of air less than stackometric will lead to production of CO, CO_2 mixture along with H_2O and nitrogen. Now, we can we can bring back those knowledge and put it here if you want to create an atmosphere of CO, CO_2 proportion, the proportion we have to specify, then by controlling the combustion and mixing with the right amount of air we can create that particular CO upon CO_2 ratio in the atmosphere. So, that means suppose if we want to create an atmosphere of say one mole of CO_2 to two mole of CO_2 then what we have to do, we have to take air less than the stackometric amount of air that is certain. So, for that case we take the C_3 H_8.

If we combust with 4.5 O_2, 4.5 O_2 plus 3.76 N_2 then I will be getting CO plus 2 CO_2 plus 4 H_2O plus 4.5 into 3.76 N_2. So, this is my atmosphere will consists of if I take air less than the stackometric amount of air. Now, if for some reason I need only CO and CO_2 then I must have a mechanism where I can remove H_2O and nitrogen from this product of combustion, there are methods are available. So, second important thing is to note that the reaction C_3 H_8 plus 4.5.

It is a an incomplete combustion and accordingly less amount of heat will be generated. So, lesser will be the amount of air we take I mean lesser than the stackometric amount of air we take, more CO will form, but the reaction will be endothermic. So, one of the important requirement to create an atmosphere of increasing proportion of CO upon CO_2 two things are required, one, you should have amount of air less than the stackometric, one and second you have to provide a external source of heating because the reaction with less than the stackometric amount of air, they are endothermic in nature and accordingly external heating is required.

And also it is required that the CO and CO2 they are I mean they are say analyzed and prepared for the particular atmosphere.

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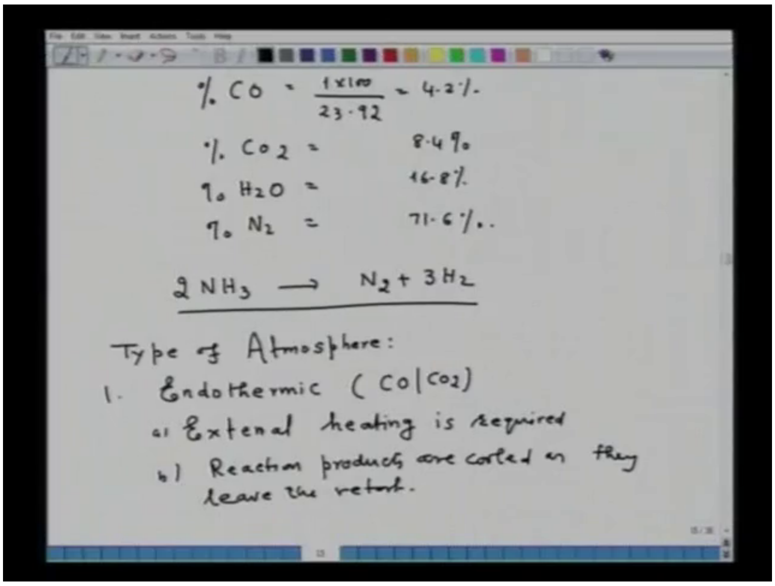

So, in this particular case what will be having say percentage CO, percentage CO will be equal to 1 upon 100 into 23.92 that will be equal to 4.2 percent, percentage CO2 similarly, you can calculate 8.4 percent percentage H2O, that is equal to 16.8 percent and percentage nitrogen that is equal to 17 71.6 percent. So, this is one of the method of creating of the different atmosphere using air less than the stackometric amount. Similarly, for this purpose methane can also be used and accordingly the proportion of air can be adjusted depending upon the type of the atmosphere that is needed. Now, in a similar way for example, NH3, a 2 NH3 can be crack into N2 plus 3H2. So, you have an atmosphere which contains nitrogen and hydrogen. Now, based on this different proportion of CO, CO2, nitrogen and all these things, the we can say what are the different types of atmosphere. Now, we can put type of atmosphere, type of atmosphere. Say, one we have endothermic atmosphere.

Endothermic atmosphere and this endothermic atmosphere consists of mainly CO and CO2 ratio that is main CO upon CO2 ratio is higher. Now, as the name suggests this endothermic atmosphere means the reaction at the time of conversion of propane or whatever the gas into the products of combustion which constitutes the atmosphere they are endothermic in nature, that means by the name endothermic atmosphere it suggests that the mixture of air and fuel that means the amount of air is less than the stackometric amount of air and accordingly one has to heat air gas mixture in a metal retard which is externally heated, if it is not externally heated then the endothermic atmosphere creation is very difficult because the reaction is endothermic in nature. Another (( )) one important thing is that external heating is required, one important thing is that external heating is required for the reason already I have said because the reactions are endothermic and hence you have to (( )) externally and that is an important thing, second important thing is that the reaction products, reaction product are cooled as they leave the retard, leave the retard.

Now, why it is so because you know as CO it decomposes back to CO2 plus C at lower temperature therefore, a abrupt cooling of the products of combustion is required in order to retain the amount of CO in the atmosphere.

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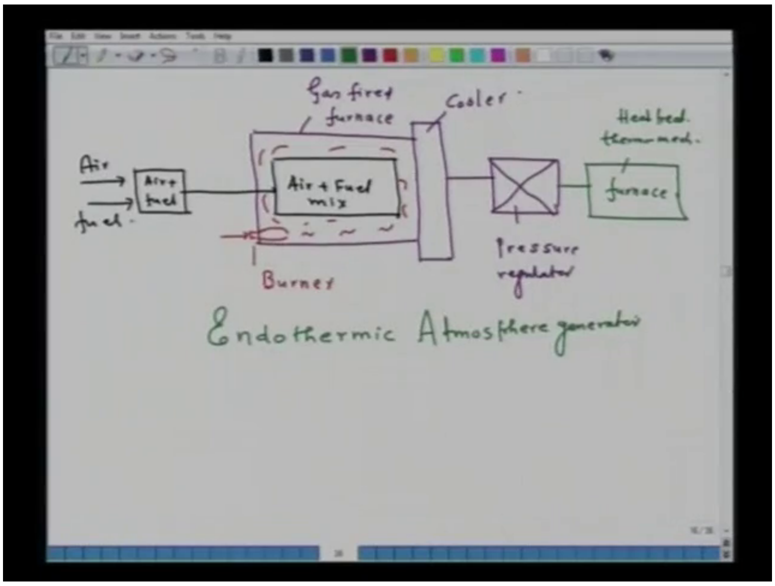

So, I try to sketch a typical diagram for example, if we have, this is the air fuel mix (( )) this is air plus fuel mix and it is surrounded by, it is surrounded by a gas fired furnace. So, this is a gas fired furnace.

This is a gas fired furnace, this is a cooler and here, here say you have a burner and this produces a flame, here the products of combustion they circulate so, that the external temperature of the air fuel mix retard is kept at a particular temperature. So, this is a burner, then you need a system where you can supply air and fuel. So, you have here a system which is say air plus fuel. So, here you are supplying air and here you are supply fuel. Now, at this site you have, you have a sort of pressure regulator, this is a pressure regulator, pressure regulator and then you have a so called furnace where now this furnace could be for heat treatment purposes or heat treating or thermo mechanical processing or whatever the objectives. So, this is the way, this is the endothermic atmosphere generator.

Endothermic atmosphere generator and these atmospheres they are connected to the furnace.

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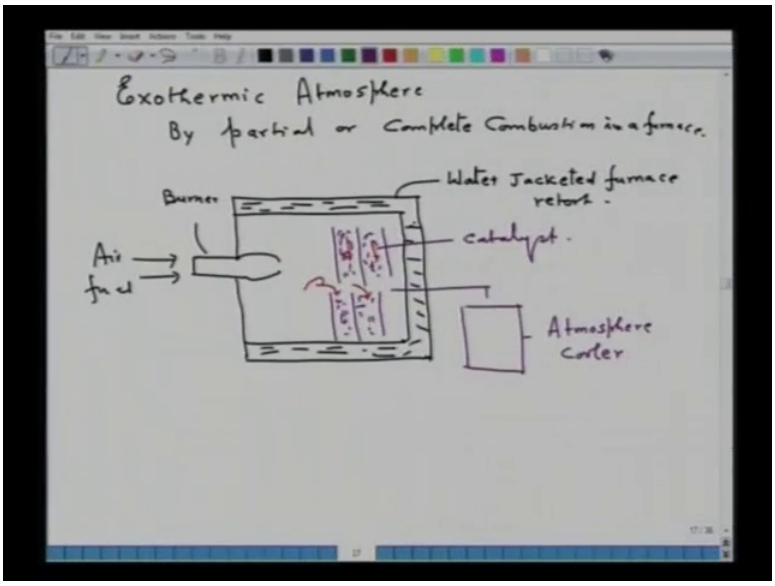

Now, another type of atmosphere is called exothermic atmosphere, exothermic atmosphere. Now, the name suggests in the exothermic atmosphere the amount of air increases gradually from less than the stackometric if you go towards a stackometric then the heat will be produced and accordingly they are called exothermic atmosphere and the closer we to the stackometric amount of air more CO2 will be produced and less CO will be produced. So, that is why they are called exothermic atmosphere and the exothermic atmosphere are produced by partial or complete combustion or complete combustion in a furnace. Now, say if we have, this is say a burner which is producing a flame, this is an outer say water jacketed furnace, this is here, this is all, this one is a water jacketed furnace retard, this is a burner, you are supplying here air and here you are supplying fuel.

Now, another important thing here the catalyst are used. So, I am showing the catalyst that is say catalyst, they are filled with the catalyst to catalyze the reaction so these are the catalyst, these are the catalyst and here the products of combustion they flow to here to here, here and here. This is the flow of products of combustion and then eventually from here say the output here, it is here, this is a system for atmosphere. Atmosphere cooler and then eventually it is taken into the furnace. So, this is how an exothermic atmosphere it works. Now, another is the as I said that the ammonia can be dissociated and to create an atmosphere of nitrogen and hydrogen.

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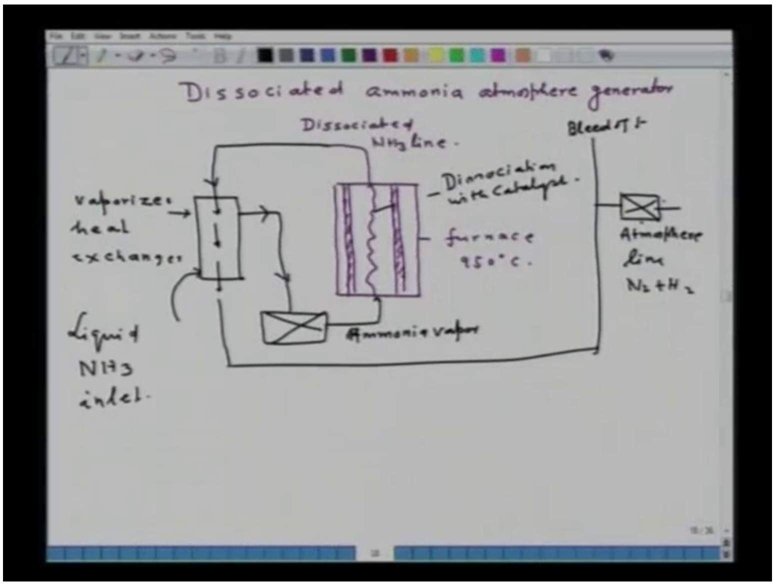

So, it looks like this I will show here that dissociated, dissociated ammonia atmosphere generator, atmosphere generator. So, it looks something like this I have here a reactor, a reactor and this is the flow of dissociated ammonia line and here I put on this side and this side.

These are the electric heaters and this one is the dissociated NH3 line, dissociated NH3 line this is a furnace which is maintained at 950 degree celsius. So, somewhere here we have an heat exchanger, this is the heat exchanger. So, this one is a vaporizer heat exchanger. Here you have liquid NH3 inlet and here passes through a valve system, ammonia vapor, ammonia vapor and this dissociated line back to the this particular thing, this is about the extra amount of (( )) and through a system of valves this atmosphere line, this is the atmosphere line, atmosphere line which contains nitrogen plus hydrogen to the furnace. Now, this one is the dissociated dissociation having with catalyst. So, the whole thing is that you maintain a furnace at 950 degree celsius, ammonia dissociates and that is it you get this the atmosphere which consists of nitrogen and hydrogen.

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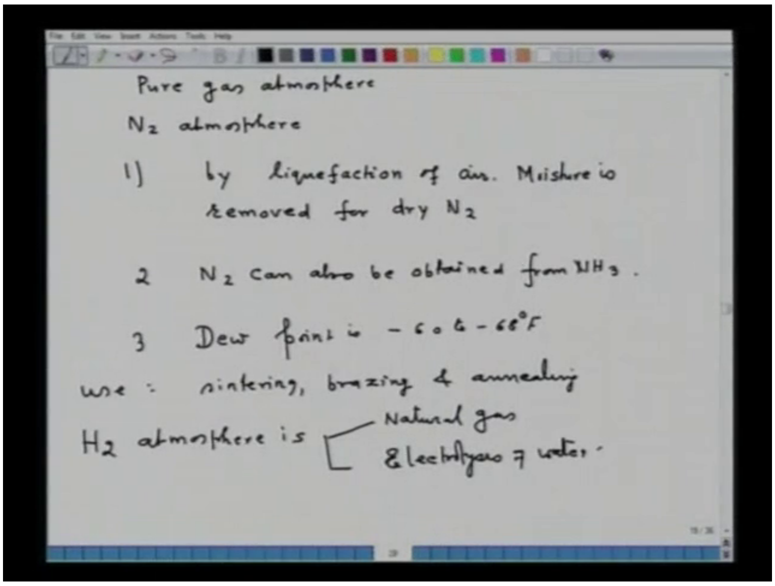

Now, many of times we also need pure gas atmosphere, we need pure gas atmosphere. Now, earlier we have seen that atmosphere consists of mixture of gases, the pure gas atmosphere for example, we need nitrogen atmosphere. We need nitrogen atmosphere. Now, nitrogen is produced by liquefaction of air, by liquefaction of air and moisture is removed, moisture is removed for dry nitrogen production, second nitrogen can also be produced, nitrogen atmosphere can also be obtained from NH3 also. Now, important point to remember in case of nitrogen atmosphere that the dew point of nitrogen, dew point is minus 60 to minus 68 degree Fahrenheit and the use of nitrogen atmosphere is say for sintering, brazing and annealing. Then another atmosphere for example, hydrogen atmosphere, hydrogen atmosphere you know it is a reducing agent. So, hydrogen atmosphere is produced from natural gas or by electrolysis of water, electrolysis of water. Hydrogen typically provides a reducing atmosphere. Now, you must know hydrogen is very explosive and it requires very careful handling, another important point is that many steel alloys are susceptible for hydrogen and hence they may cause hydrogen embrittlement therefore, one should use it wherever it is required and also to be known it is very strong decarburizer they, if you use carbon and steel if you use hydrogen atmosphere then C plus 2 H2 it forms a methane, a very strong decarburizer and hence should not be used for carbon steel.

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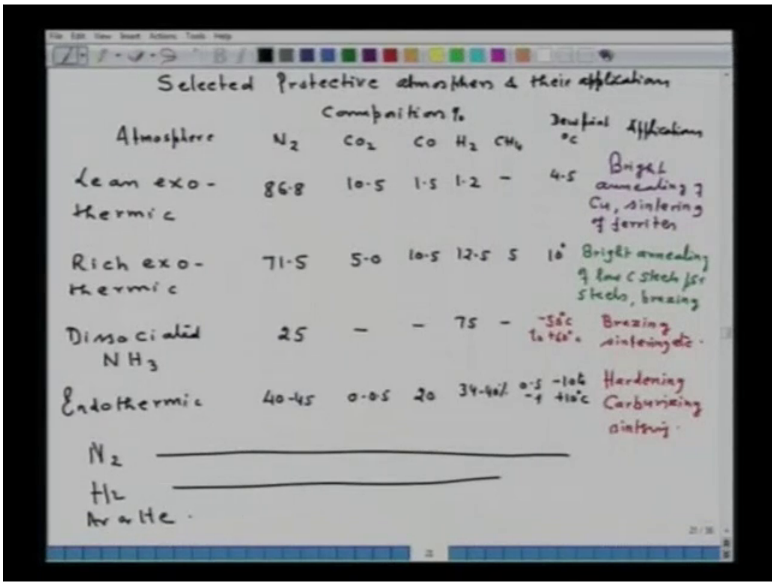

Now, it is mainly used hydrogen atmosphere it is mainly used mainly used say first for annealing of say for annealing of say low carbon steels, electric and stainless steels and stainless steels it is also used as I said earlier sintering of carbide, sintering of carbide. So, these are some of this say another say many of times you require the helium and argon atmosphere, helium and argon atmosphere by nature all of us, all of us we know that hydrogen and argon they are inert and their applications for example, use for tig welding, heat treatment of the special high temperature high strength alloy and nuclear applications.

Now I will, I will tell you now some of the selected protective atmosphere, some of the selected protective atmosphere, you can also consider the atmosphere which we are discussing they are also protective atmosphere because they protect against certain thing, selective protective atmosphere and their applications, I will just make a table for you so that you get a feel the type of atmosphere, their composition and relevant application. So, I will put first of all an atmosphere followed by its composition and in composition I will put nitrogen, CO2, CO, hydrogen and methane. Then I will put another that is the dew point, remember dew point is a very very important in case of atmosphere because it is the temperature at which a gas begin to condense and applications, few applications I will give you more you should consider the books and find out. So, one atmosphere it is a lean exothermic atmosphere, lean exothermic. Now, lean exothermic it has 86.8 the composition are all volume percent 86.8 percent nitrogen 10.5 CO_2, 1.5 carbon oxide and 1.2 hydrogen, CH_4 is nil, Dew point is 4.5 degree Celsius and their application for bright annealing, bright annealing of copper and sintering of ferrites, sintering of ferrites. So, this is one particular lean exothermic atmosphere. Now, say another is let us say is a rich exothermic atmosphere, rich exothermic atmosphere, the difference again in the proportion of CO_2. So, here you have 71.5 percent CO_2 5 percent CO_2.

In the rich exothermic atmosphere nitrogen is 71.5 percent, CO_2 is 5 percent, CO is 10.5 percent H_2 is 12.5 percent and methane is 5 percent and it is dew point is 10 degree so its application are again bright annealing, bright annealing of low carbon steels, low carbon steels, silicon steels and it can also be used for brazing, sintering also one of the applications. Now, third is one say dissociated ammonia, dissociated N h 3, now this has 25 percent nitrogen and 75 percent hydrogen and nothing and its say dew point is minus 50 degree C to plus 60 degree C and it is used in brazing, sintering etcetera. Now, still another atmosphere they are the endothermic atmosphere, in the endothermic atmosphere nitrogen varies from 40 to 45 percent, CO_2 0 to 0.5 percent.

CO is 20 percent note that CO is 20 percent hydrogen is 34 to 40 percent and CH_4 is 0.5 to 1 percent and minus 10 to plus 10 degree C that is its dew point and it is used for hardening, carburizing, sintering and several other type of functions, another say important type of atmosphere they are one is the nitrogen atmosphere, there is nothing except 100 percent nitrogen, it is a neutral wherever its required for annealing is one of the purpose then hydrogen again 100 percent hydrogen, it is a reducing atmosphere and argon and helium, they are inert atmosphere. Having studied the different types of atmosphere now let me address little bit about the heating of the protective atmosphere furnaces because once you are applying the furnace with the atmosphere now heating is to be done very carefully that means you can do one is the indirect heating, you cannot heat now directly, second you can also heat with the radiant tubes and third of course, on the electric heating, but if you heat a fuel than it has to be indirect heating.

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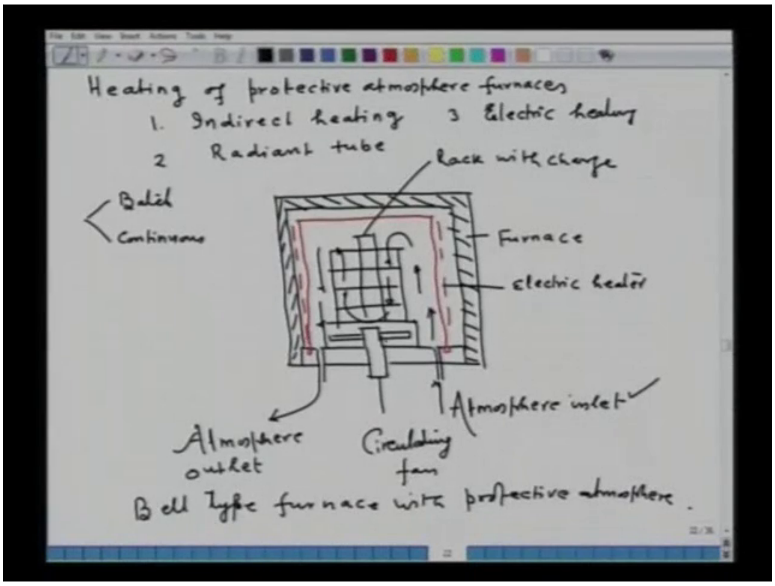

Now the furnaces are of two types one you have batch furnace and another you have a continuous furnace. Now, this particular diagram which I drawn for you is a bell type furnace with a protective atmosphere, this is typically a batch type of furnace where you have electric heater as you are looking for it heats the charge which is inserted into the furnace. So, the atmosphere enters in that is inlet and here is a circulating fan and this fan circulates the atmosphere above the or around the charge which has been put on a rack, this is the rack with the charge. So, this is how a sort of a batch furnace look. Now, similarly, you can visualize in a continuous type of furnace the atmosphere has to be continuously in and it has to be continuously out because of the nature of the continuous furnaces.

Now, this gas which is going out of the furnace it is hot and it can also be used for preheating of the charge. So, batch type and continuous type now the operation in this both the furnaces are first of all filled with the atmosphere and the process is on.

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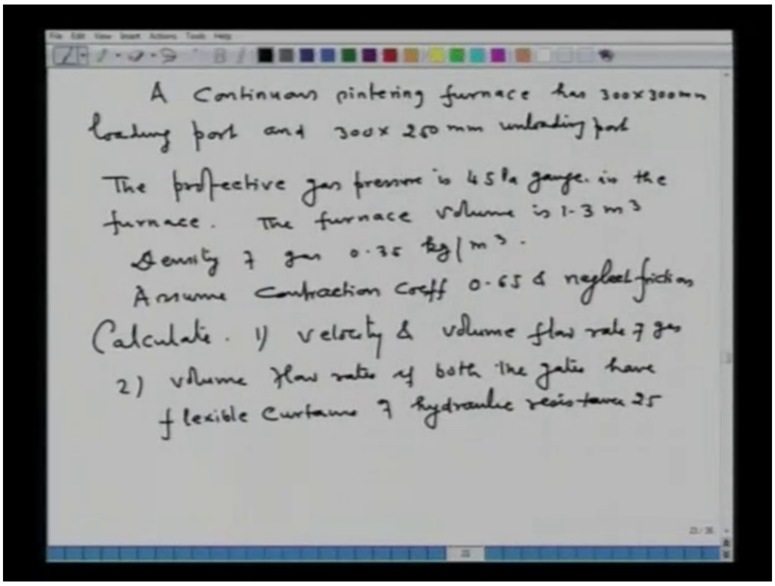

Now, a simple calculation will illustrate you the about the velocity and volume flow rates now for example, a continuous sintering furnace, sintering furnace has 300 into 300 mille meter loading port, loading port and 300 into 250 mille meter unloading port because for a continuous furnace continuously you load it and continuously you have to unload it. So, from one cross section atmosphere will enter and another it will leave the furnace. Now, the protective gas pressure, the protective gas pressure is 45 pascal gauge that means about the atmospheric pressure in the furnace, in the furnace. Furnace volume, furnace volume is 1.3 meter cube, density of gas is 0.35 kilogram per meter cube.

Now, assume contraction coefficient, assume contraction coefficient 0.65 and neglect friction what you have to do calculate velocity and volume flow rate of gas, velocity and volume flow rate of gas flow from the furnace port and second you have to calculate volume flow rates volume flow rates if both the gates, both the gates have flexible curtains of hydraulic resistance, they get 25. So, this type of thing we have already done when I was doing the fluid flow in the furnaces and there you recall that the velocity of gas I hope you must be remembering velocity of gas that is equal to 2 into delta P upon rho now by substituting the value of delta P and rho the velocity will be getting 16 meter per second.

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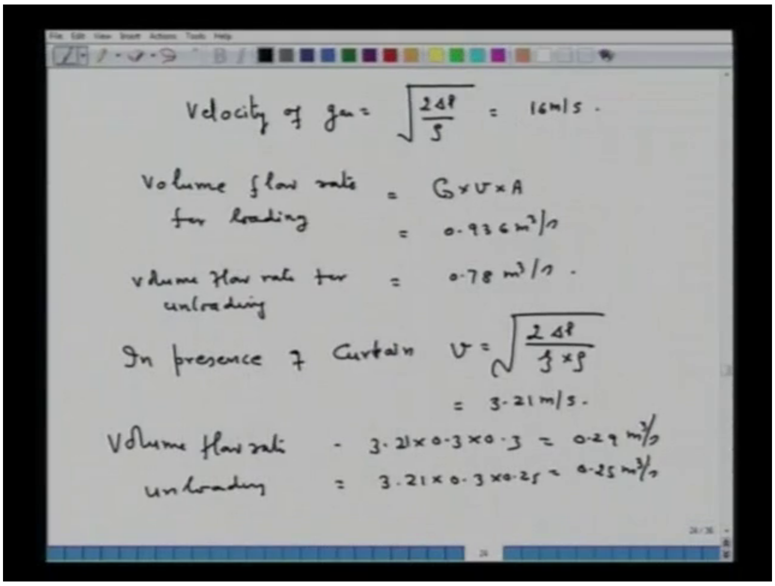

Now, immediately we can find out volume flow rate. The Volume flow rate for loading port that will be equal to C D into v into A which is given to you discharge coefficient that will come out to be equal to 0.936 meter cube per second you see that much amount of gas will be requiring and volume flow rate, volume flow rate for unloading port that will be equal to same way you can calculate C D v into A v is the same area you know it comes out to be 0.78 meter cube per second. Now, in presence of curtain, the curtain offers the hydraulic resistance. So, in presence of curtain, in presence of curtain velocity v 2 into delta P upon the hydraulic resistance into density if you substitute all the values the v you are getting at 3.21 meter per second. Now, we can calculate similarly, the volume flow rate when curtain is there you have to multiply 3.21 into 0.3 into 0.3 and for unloading volume flow rate for unloading port that will be equal to 3.21 into 0.3 into 0.25 so one will be equal to 0.29 meter cube per second and another will be 0.25 meter cube per second.

What I have tried to illustrate that the earlier lecture which I delivered on fluid flow in the, in the furnaces they can equally be used here also to find out what is the flow rate of the gas is required, what is the velocity of the gas which is there as an information for improvement of the working of the atmosphere.

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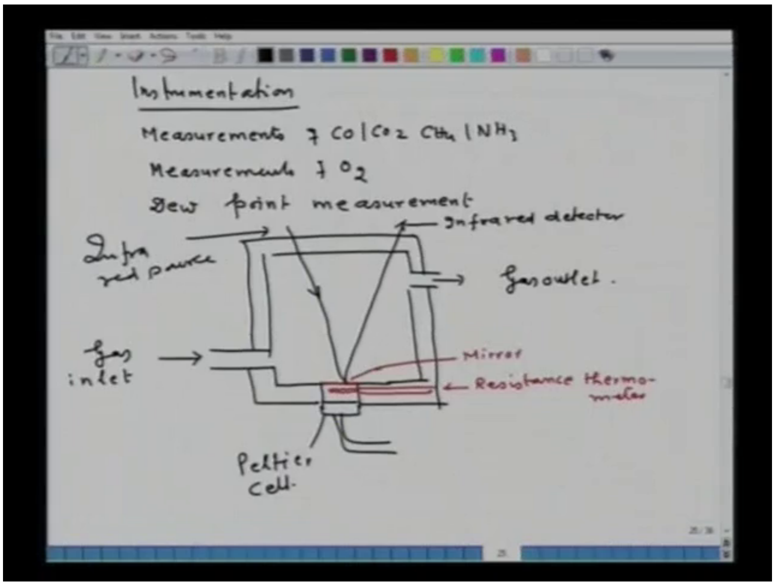

Now, the another important thing which is here is so called instrumentation. Now, in the instrumentation one requires measurement of CO, measurements of CO, CO2, CH4 and NH3, now the online measurements are available by using infrared analyzers or continuously analyzing the atmosphere. So, one type of instrumentation is the measurement of CO and CO2 and here the infrared detection technique is used to find out a percentage CO, CO2, CH4 and so on and another important as and when it requires measurement of oxygen, measurement of oxygen. If oxygen is present for that solid electrolytes sensors are used to measure the oxygen content and third which is the most important in case of atmosphere is the dew point measurement, is the dew point measurement and this dew point measurement I will discuss here which I draw a sketch for you the instrument which measures the dew point that is have, let me draw the sketch.

This is say from here a gas inlet, gas inlet here, we have gas outlet, gas outlet and here we have say this is when after enclosure and this one is the resistance thermometer, resistance thermometer and this one is the I will call this, put it here, this is the mirror, this one resistance thermometer, thermometer, this is a Peltier cell. So, a this is the infrared source, it hits the mirror and here you have the infrared detector. So, this is the infrared detector, infrared detector, here infrared source, infrared source. Here is the gas inlet and there is a gas outlet. Now, a light beam if it strikes the mirror and it reflected from the mirror and detected by the photodiode that means you have a detector in the source. So, a light beam it strikes the mirror and it is reflected.

Now, if the gas passes a atmosphere passes and a some amount of steam or is condensed or if there is a condensation occur then accordingly the amount of reflected beam rather its intensity will be influenced and accordingly the temperature will be measured and that is called the dew point. Now, mirror is also heated or cooled by a so called solid state Peltier device. So, that is how a system for measurement of dew point it works and infact this dew point measurement is very important because if gas condenses during the process then it is considered to be producing a hazardous effect.

So, with this lecture I think I have said sufficient on the atmosphere and the atmosphere in the furnaces and towards end of the few lectures I will give the references so that you can go and read further about the atmospheres and furnaces.