Steam and Gas Power Systems
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Module No # 03
Lecture No # 12
Draught

Hello I welcome you all in this course on steam and gas power systems and today we will discuss draught.

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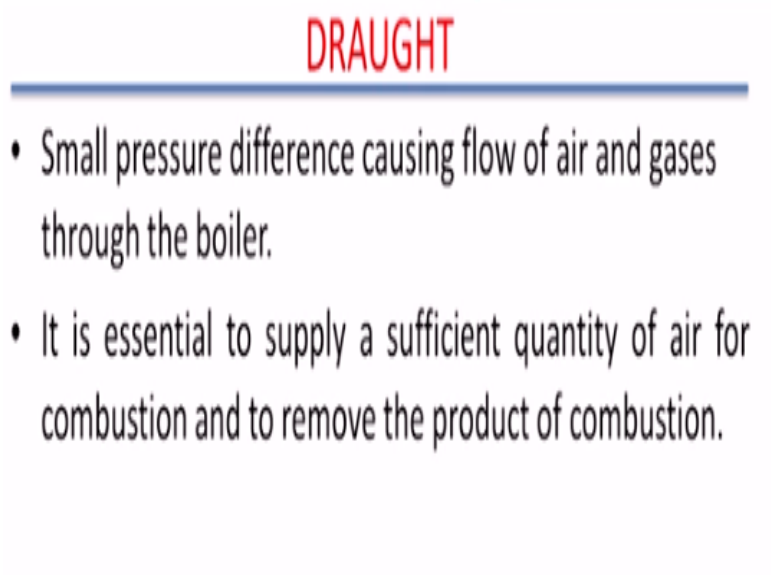

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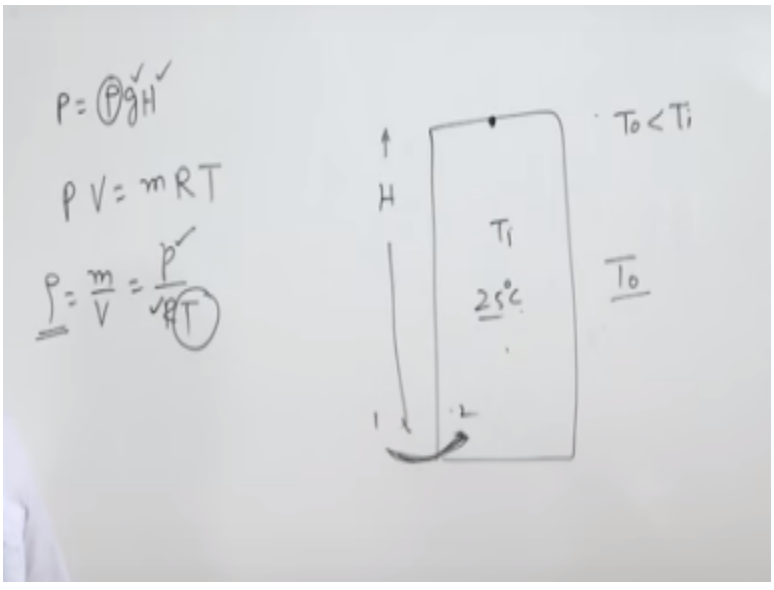

Draught is small pressure difference causing flow of air and gases through the boiler it is essential to supply sufficient quantity of air through the grate because fuel is burnt in the grate and designer have to ensure that there is sufficient amount of air which is available in the grater otherwise the fuel will not burn and efficiency of the boiler will may go down.

In order to provide sufficient burning of the or complete combustion of the fuel in the grate the air circulation as to be maintained there are two ways of circulating air one is we provide a pump or fan at this side or on this side or we may provision for natural circulation of air. Natural circulation is always preferred because it does not consume any energy right it may have some fixed high initial cost but recurring cost is zero in case of we use natural methods of circulation of air in the grate.

You must have observed in your house that during winter season when temperature inside is let us say 25 degree centigrade if it is air conditioned house right. In any case outside temperature is lower than the inside temperature TO is lower than TI. Now in winter you must have observed the air outside air enters the house from the openings at the bottom of the structure like from the bottom of the door or bottom of the window and this air comes into the room because of the reason of pressure drop between outside and inside air.

Outside air is at lower temperature lower temperature is if you look at the density of the air because the pressure is in a fluid is function of the density. So pressure is RHO GH H is the height of the room right G is constant H is constant in ideal gas PV = MRT. P is pressure V is volume R is gas constant T is temperature absolute temperature and density = M by V = P by RT.

If pressure is remaining constant this is constant this is constant for air if we reduce the temperature the density will increase. So density is the function of temperature outside temperature is lower than the inside temperature. So that is why the density of outside air is larger than or will more than the density of air which is inside the room. And if we go by this equation the pressure at point one which is greater than pressure at point two right air will enter.

But when we are moving in upward direction the reduction is pressure outside will be more than the reduction pressure inside because density of the air is large and for this reason when air reaches hot gases reaches here they reach here then pressure at this point is larger than the pressure with the surroundings. Now let us take case of chimney if chimney is the vertical structure may be circular or hexagonal or square it is not necessary to be circular.

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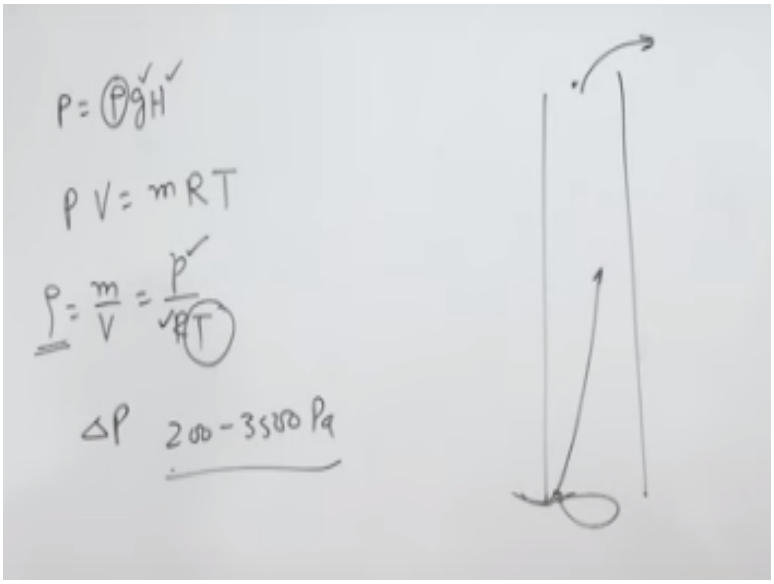

So if you take the chimney here the fuel is burnt air is coming from outside air is coming in when it is reaching at the top it is reaching at the top with certain velocity and with certain higher pressure and it is leaving at the top. Now here in this case height of the chimney becomes important because if you increase the height of the chimney this pressure difference will also change.

So if you make the chimney higher and higher I mean if you keep on increasing the length of the chimney or height of the chimney the pressure difference will increase but there is a limitation because in the boilers the pressure drop can vary this is known as draught and this pressure difference may vary from 200 to 3500 pascal right but if you want to have the chimney for 3500 pascal the length will go in hundreds of the meter that we will discuss later on.

First of all we will discuss the chimney for the natural circulation of air right that is known as draught and the height of the chimney is crucial here so we will first of all we will calculate the

height of the chimney before we go for such calculation let us understand the theory of combustion. Normally in fuel it is carbon or hydrogen up to 80% it is carbon 75, 85 % or it can go up to 85 %.

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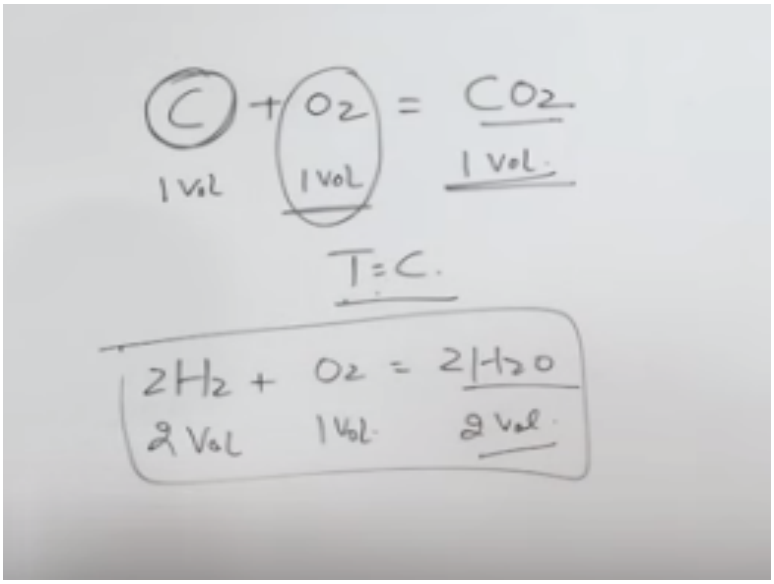

So carbon is burnt with oxygen and forms CO2 so one volume of carbon, one volume of oxygen will give you one volume of carbon di oxide right. It means say this is not very significant it means the volume of air because nitrogen does not participate in the combustion process. So volume of the air is equal to the volume of flue gases right and volume of air is equal to the volume of the flue gases in the case when temperature is same.

If the temperature will vary then volume will vary so normally flue temperature gases temperature is high but if you take both of them at the same temperature the volume is going to remain same. Second part is hydrogen is burning then then it is oxygen and then H2O then two then two. So two volumes of hydrogen one volume of oxygen is two volume of H2 two volume of water hydrogen oxide.

But here in this case hydrogen is only 4 or 5 % it is fuel it is not significant portion is significant fraction is carbon. So we will not take into account where doing the calculation right and we will take we will assume that same temperature the volume of air is equal to volume of flue gases for calculating hydrogen because density is function of temperature.

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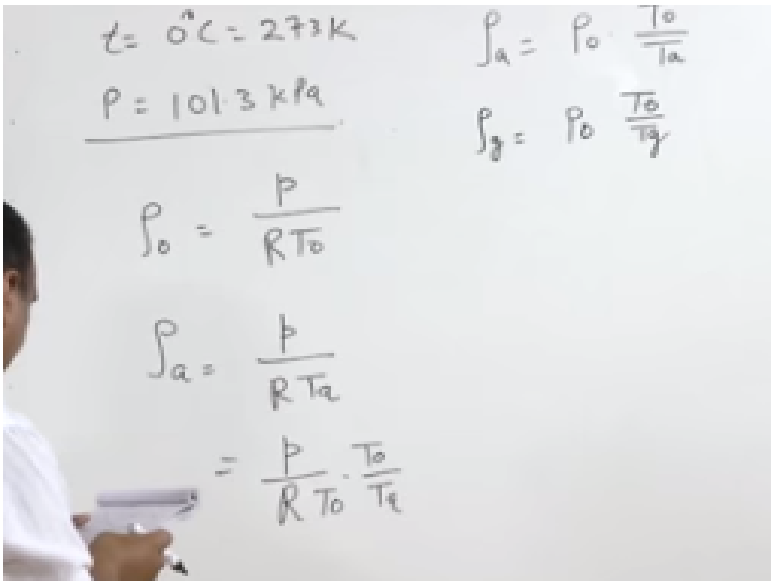

So we will have in order to find the height of the chimney we will have a reference value of density right and this reference value is temperature zero degree centigrade that is 273 kelvin and pressure is 100 and 1.3 kilo pascal right. So if we take temperature 273 kelvin the volume of flue gases should be is call the density of flue gases should be equal to or volume of the flue gases should be equal to the volume of air.

So the density reference density O = PRT so here we can take density of air RHO A = P over RTA or we can say that this is P this P is same. We will take here also P over R TO multiplied by To by TA we are taking this as a reference density. So density of air RHO A = RHO multiplied by To by Ta similarly for at temperature TG this is temperature of the hot gases right.

Temperature of the hot gases the density is RHO To by TG volume of air volume of air is equal to gases at the same temperature. If air is brought to the TG PG then density of the air going to be like this.

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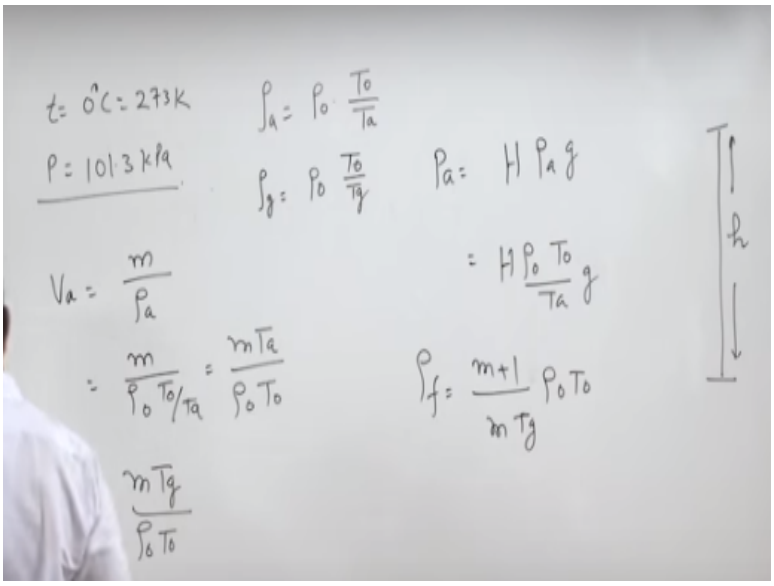

Now velocity sorry volume of air now we have density now volume of air is equal to mass of the air divide by density of air now mass of air means mass of air for the combustion of 1 KG of fuel one KG of coal or KG of fuel. So M is the mass of air which is required for combustion of one KG of fuel so the volume of air is going to be this much or it is going to be M by RHO TO by TA or MTA right.

Volume of the gas it is going to be MT RHO O by T because temperature air is increasing to Tg that will become the (()) (11:02) gas because we have already established that the volume of the air is equal to that the volume of the gas at the same temperature. Now pressure of the air pressure of the air is H RHO G where H is the height of the chimney we have assume certain height of the chimney H right and pressure of the air is H Rho AG = H Rho O To by TA into G right.

Now density of flue gases now density of air density of flue gases density of the flue gases is mass of the flue gases divided by the volume of flue gases. Mass of the flue gases is not M, M is the mass of the air Mass of the flue gases is M + 1 this is mass of the flue gases because M AG of the gas is used for burning one KG of fuel. So mass of the flue gases is M + 1 volume is this.

So density is M + 1 divided by M TG Rho TO is it clear now we have density of flue gases, flue gases is moving in the chimney we have density of air we will use the formula Rho GH and if we use the formula Rho GH then.

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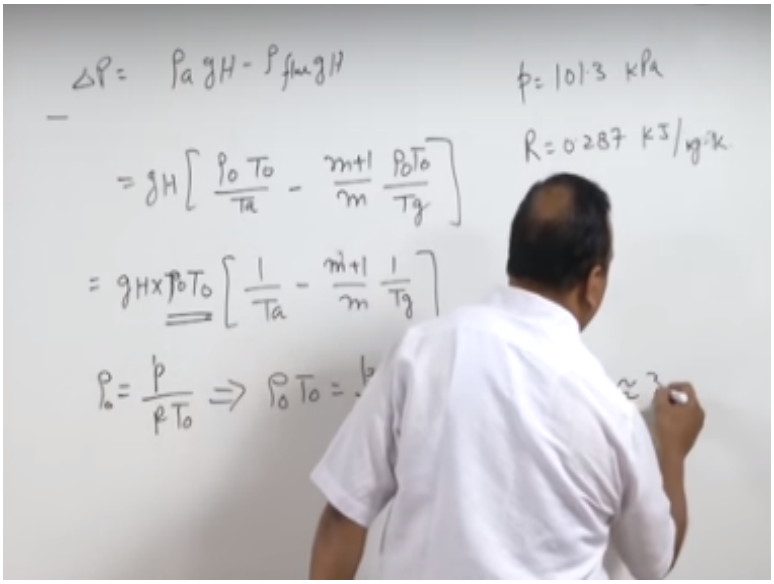

So the delta P will be Rho AGH - Rho F flue gases GH, GH will come out and we will get GH will come out and then we will get what we are going to get Rho TO by Ta that is Rho A - M + 1 by N Rho O To by T is it clear. Now this TH again multiplied by Rho O TO then we will get one by Ta - M + 1 by M1 by T.

Now here the main thing is calculation of density of flue gases so in order to find the density of the flue gases first of all we have assumed or it is established that the volume of air is equal to volume of air is equal to volume of flue gases volume of the flue gases at the same temperature then we calculate volume of air at temperature TG that is temperature of the flue gases right and that becomes the volume of the flue gases also.

Mass of the flue gases is M + 1 it is not M so that is how we are getting this expression now Rho To is Rho = P over R To. So Rho TO is P over R P is the constant P = 101.3, R = P Rho .287 and it is kilo pascal this is P = 101.3 kilo pascal and R = 0.287 this is for air is kilo joules per Kg kelvin sorry Kg kelvin this Kg is small K Kg kelvin.

So we have taken this ratio if we take this ratio hundred 1.3 divide by .287 it comes around sorry hundred and 1.3 divided by .287 it comes around 352.96 or approximately 353. So we can re write here that this pressure difference is into 353 and this is pressure difference right now H is the height of the chimney now pressure difference in sometimes it is taken in millimeter of water and millimeters of water it is earlier practice.

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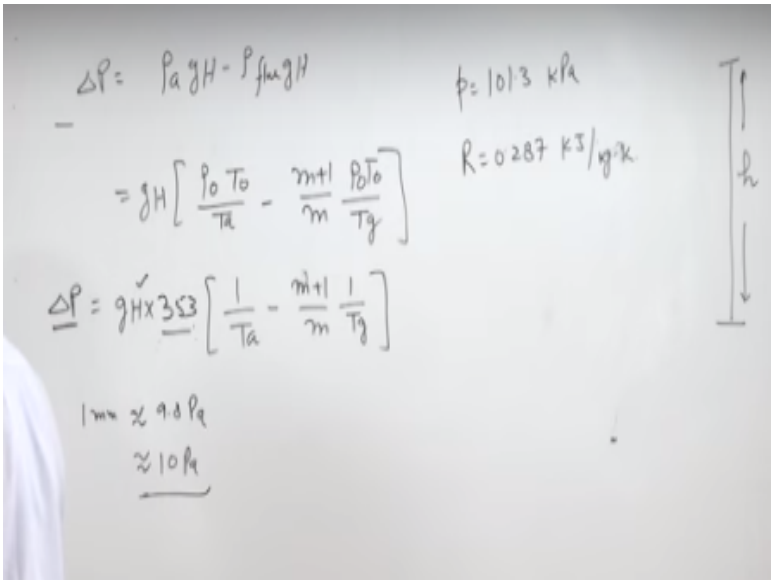

But normally 1 millimeter of water one mm of water is approximately equal to 9.8 pascal or it is approximately 10 pascal. Because in SI system we do not use this system millimeter or centimeter earlier in each point system it was inches of water half, half inch of water or quarter inch of water but now a days pressure difference is expressed in terms of pascal only.

So we will take in terms of pascal so this is the pressure for the pressure difference or the draught developed in chimney of height H. It is a function of now here it we can make some interpretation out of it because main thing is interpretation it is a function of TG and TA and M + 1 by M it is ratio. So if we are using chimney for one boiler are two boiler or three boilers if there are identical boilers.

We are increasing the number of boilers this ratio is remaining same if there are identical or if they are same boiler if we have burning more fuel. If we are burning more fuel then this ratio will remain same because it is M is the mass of air required for burning 1 KG of fuel right.

So but the cross section area will increase cross section of the chimney will increase because it will have to recommended more flue gases but the height of the chimney will remain the same for this pressure difference. Now we can take one example if we take example I think the understanding of phenomena will be clear.

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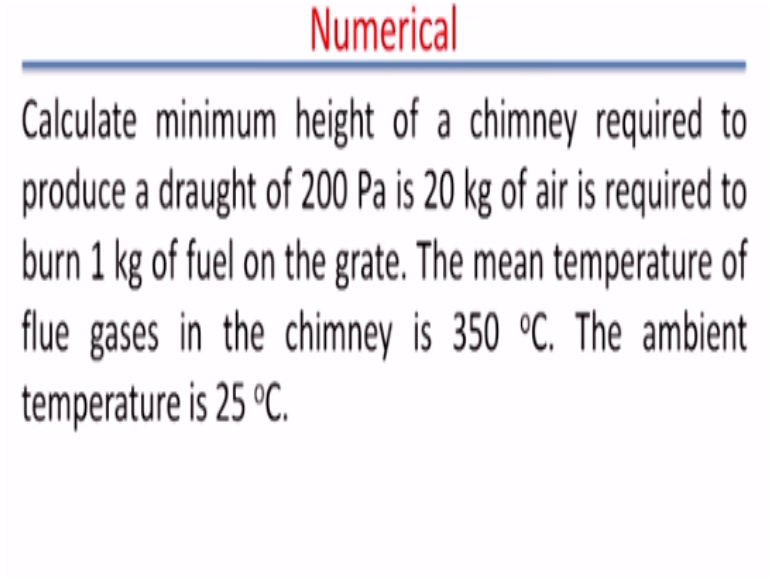

Calculate minimum height of the chimney required to produce a draft of 200 pascal. If 20 KG of air required to burn 1 KG of fuel on the grate the mean temperature of the flue gases is in the chimney is 350 degree centigrade the ambient temperature is 25 degree centigrade.

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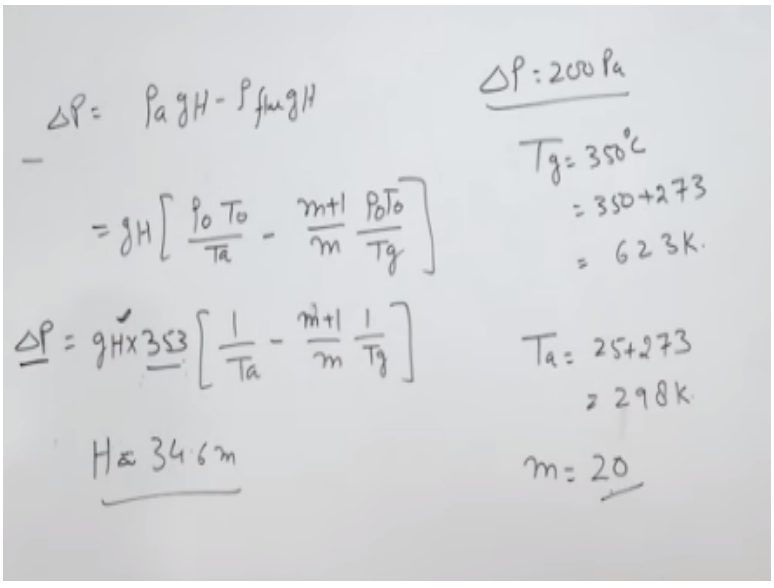

It means that delta P is 200 pascal in terms of millimeter it come around approximately 20 millimeters right. So delta P is 200 pascal temperature of hot gases it is 350 degree centigrade. So it has to be converted into kelvin this one should not forget so 350 + 273 = 623 kelvin.

Temperature of (()) (19:42) is again 25 degree centigrade it is 25 + 223 = 298 kelvin now we have value of TG we have the value of TA. M is 20 KG we can put this values here and height of the chimney minimum height of the chimney as to be calculated. Delta P is 200 I think we have all the information except H.

From here we can calculate the value of H and H will be approximately 34.6 meter approximately or we can take 350 meters. I mean 34.6 is minimum so height of the chimney is more than this. So it can be 36 meters so that proper draft is produced for the circulation of air through the grate through the top of the chimney.

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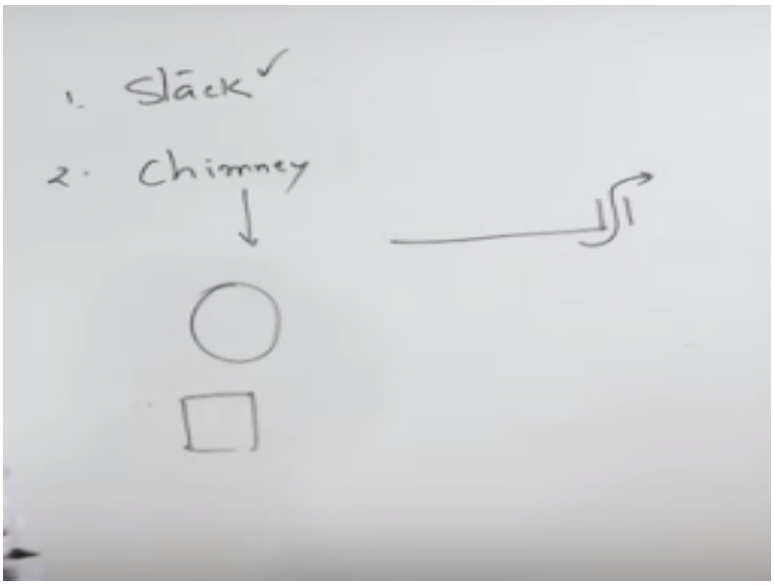

There are two things one is chimney sorry the chimney another is stack and another is second is chimney. Now chimney normally has brick work I mean it can have any shape here circular or it can be a rectangular or hexagonal but it has brick work. If stack is by click and for chimney we can go for greater height than for a stack even in locomotive engine you must have seen stack in a locomotive engine M at the top it is project where from the flue gases are coming out in steam engine that is the stack.

In the boiler also static boilers also so stack is used but the stack is used but the height of the stack is not it is not comparable with the height of the chimney. Height of the chimney is normally more than the height of the stack. So for a light load application normally a stack is used and we can use chimney for higher load (()) (21:52).

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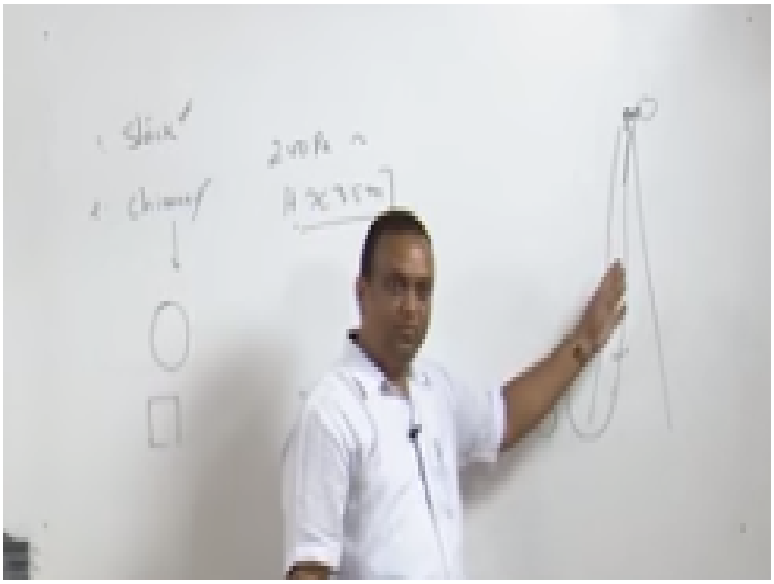

But chimney for natural draught you must have seen that is that the top it is tapering it is not straight normally it is tapering. Tapering is provided just to increase the velocity of the flue gases that is one thing second thing is for the centigrade we calculated that for 200 pascal the height of the chimney was approximately 35 meters right.

If you calculate the height of the chimney for 1000 pascals it will be will be very large and even 35 meters means approximately 10 or 11 storage building it is quite large. So for high pressure high draught chimney is not a feasible solutions or natural circulation also chimney is there but natural circulation of chimney is there. Chimney has to be there to remove the flue gases but natural circulation of flue gases is not a feasible solution.

So induced draught is produced so for induced draught fence are provided so fence are provide suppose there is grate fence can be provided at the inlet where air is supplied or pressure inside the chimney is positive pressure. So the system is pressurized another is at the end of the

chimney the fan is provide this fan sucks the air through the chimney so the vacuum is created and when the vacuum is the grate is created air automatically rush in from surroundings or from the outside.

So either it can be induced draft circulation of air in the system or a force draught or mix of two we have arrangement we have we are forcing air through the grate and the same time we have pulling out air through the chimney and from the grate as well so combination of this two is also possible ok. So the draught we can have induced draught or natural draught for natural draught we have already calculated the height of the chimney because a particular height of the chimney is required to produce certain amount of pressure difference because it is game of pressure difference.

So pressure difference can be provided by providing a chimney right and by natural pressure difference due to virtue of temperature difference inside the chimney outside the chimney circulation will takes place that is known as natural draught and if we are providing the fence then it is artificial draught. In artificial draught external (()) (24:44) is required natural draught no external (()) (24:46) is required some (()) (24:48) has to be there fence here will be subjected to very high temperature.

So bearing and all have to be one jacketed for the cooling purposes so this type of arrangement have to be made for the circulation of air in the grate that is all for today from the next class we will start with the performance of boiler.