Lighter Than Air Systems
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Lecture - 41
Effect of Slow change in Atmospheric Temperature and Superheat

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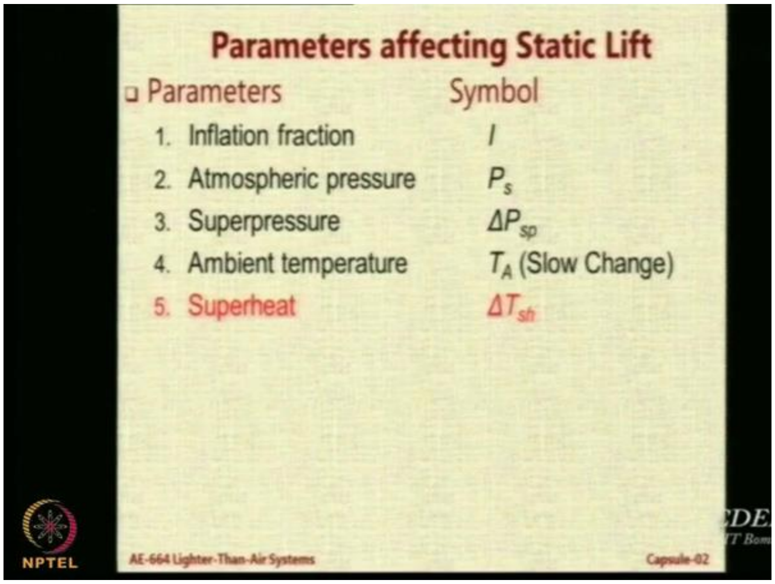

So, we have looked at the inflation fraction we have looked at the atmospheric pressure and the superpressure. And now the next thing to look at will be the ambient air temperature other thing remaining same. When the ambient temperature changes and changes slowly the first expression. So, when it changes slowly you are giving enough time for the thermal equilibrium. We know that if you give enough time, there will be a conduction.

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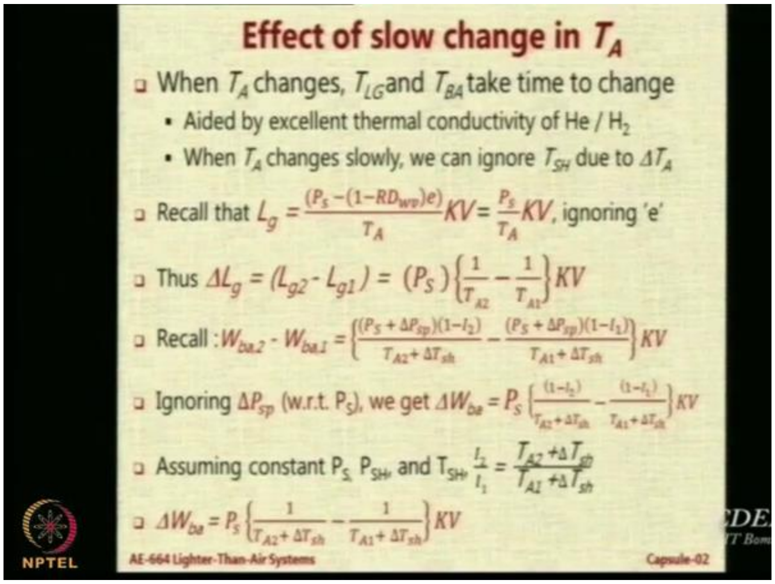

So, when T_A changes or the ambient temperature changes the temperature of the lifting gas and the ballonet air, they also change but they take time to change. However, there are two things one is that both Helium and hydrogen which are commonly used LTA gases they are excellent in thermal conductivity. So, quickly help in the temperature equilibrium to be reached and when the T_A slowly then the superheat that is created because of change in the ambient temperature can be ignored.

Because superheat basically means when there is temperature which has not been absorbed or which has not been equalized over a period of time that is what is the superheat. So, we recall that the net lift is basically given by this expression required since so many times. If I put e equal to zero it becomes $\frac{P_S}{T_A} KV$ therefore the gross lift change will be just because of T_{A2} and T_{A1}.

So, it will be

$$\Delta L_g = P_S * \left(\frac{1}{T_{A2}} - \frac{1}{T_{A1}}\right) KV$$

Now, also recall that the ballonet their weight difference we say it last time is

$$\Delta W_{ba} = \left\{\frac{P_S + \Delta P_{SP}(1 - I_2)}{T_{A2} + \Delta T_{SH}} - \frac{P_S + \Delta P_{SP}(1 - I_1)}{T_{A1} + \Delta T_{SH}}\right\} KV$$

So let us ignore the ΔP_{SP} with respect to P_S because P_S is a large quantity and ΔP_{SP} is a small quantity. So, to make things simple because remember you are looking at changes in one parameter and other one not changing.

Others are not changing or ignoring the minor changes. So, we knockoff ΔP_{SP} in this expression so you put ΔP_{SP} equal to zero you will get as

$$\Delta W_{ba} = P_S \left\{ \frac{(1 - I_2)}{T_{A2} + \Delta T_{SH}} - \frac{(1 - I_1)}{T_{A1} + \Delta T_{SH}} \right\} KV$$

Now suppose we assume that P_S is constant T_{SH} is constant T_{SH} is constant because we are looking at only change in the T_A now.

So other things remaining constant. this pressure will get cancelled out because the pressures are same P_S. So, the pressure term will get cancelled out. The only thing will be the temperature terms. And now if you see with this you can say this I_2 you can replace for I_2 here and replace for I_1 here and all figures do cross multiply term inside.

You can show that they will cancel out and ultimately you will get need expression which will say that the change in the ballonet is going to be

$$\Delta W_{ba} = P_S \left\{ \frac{1}{T_{A2} + \Delta T_{SH}} - \frac{1}{T_{A1} + \Delta T_{SH}} \right\} KV$$

So, this is only because we are ignored the superheat contribution. We are allowing it to slowly equalize. Later on, we will see what happens if you do not allow this to happen when it is sudden.

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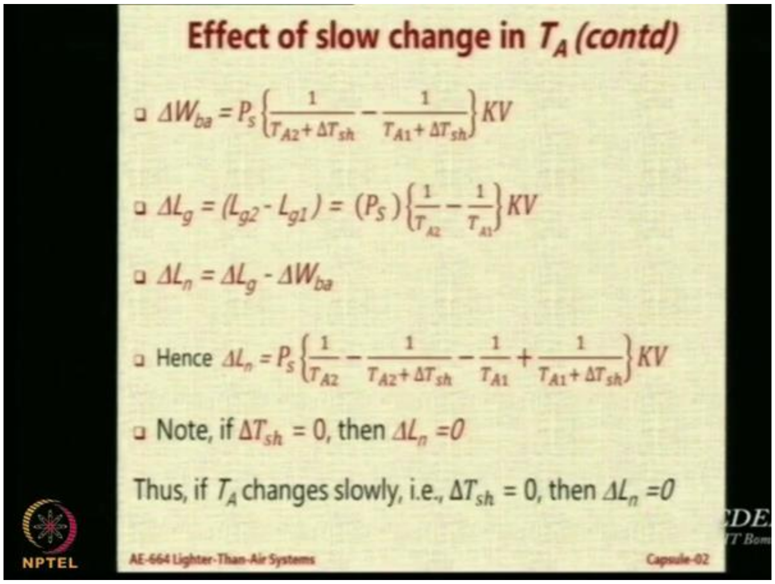

So, I am just copying and pasting the two expressions from the previous slide and the net lift is the difference between the gross lift and the ballonet air. So, all of them are not neatly in terms of only the temperature and the superheat. So, once again if you ignore superheat, what do you get? What happens if you ignore superheat? Zero if $\Delta T_{SH} = 0$ then there is no net lift increase that there is a direct compensation.

So, if you change T_A slowly the net lift will not change. You allow an airship to stand. There is an airship which is standing outside, the temperature of the ambient air changes. If this temperature is conveyed beautiful inside the system and it both the LTA gas and air in the ballonet get to the same temperature there is no net lift change. Because there will be a cancellation of the increase, but if you look at only the LTA gas weight only the ballonet air there may be differences.

But the net lift we will remain the same and that is what matters to you. So, we have looked at that all these factors next one we look at is superheat. Everything else remaining same, we just look at now the effect of superheat. So, just like superpressure the same expressions you only change ΔT_{SH} and you ignore no changes in T.

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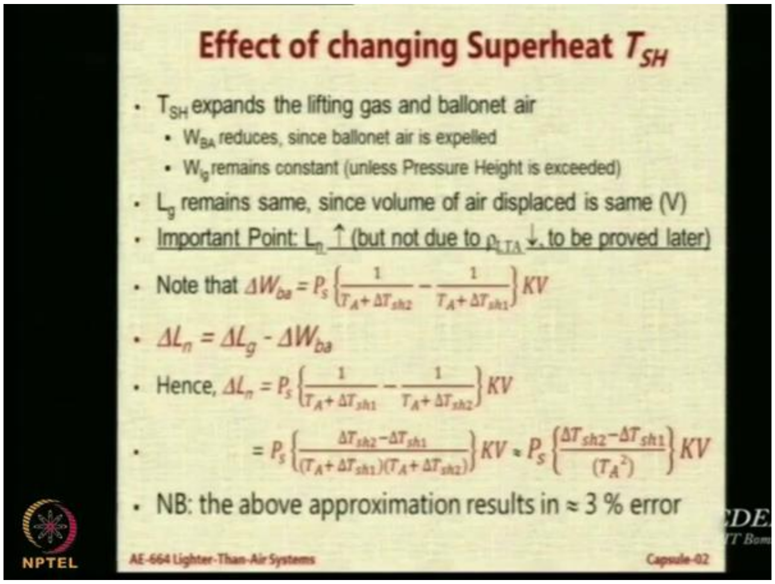

So, if you have super heat, what is superheat? Temperature increase because of exposure to high temperature. So, both the ballonet and the gas inside are going to expand because of that increase in the temperature. So interestingly ballonet air weight will be reduced because the ballonet gas will be expanded but W_{lg} will remain the same the weight of the lifting gas; gas not been thrown out its weight will remain the same.

Weight of the ballonet air will reduce but weight of the lifting gas will remain the same outside volume remains the same the only difference is on the temperatures. So, since we are not displacing heavier or lighter air therefore gross lift remains the same. So net lift will change now many people they have this impression that the net lift changes because you are pushing the air out from the ballonet. Therefore, there is more volume available for LTA gas.

Same mass of LTA gas occupies more volume so there is density decrease and because of this the difference in the density between the ambient air and the density inside increases and hence the lift increases this is a fallacy. This is something which many people assume. The mechanism is not this I will show you in the next slide. So once again I will repeat the fallacy so that you can understand and you see this in books also and this confused me a lot in the beginning.

They are all also believed that you have airship and you have a ballonet and now you are superheat. So, the lifting gas inside is going to expand and hence it pushes the ballonet air out. So, the volume available for the LTA gas increases the mass remains the same density reduces so rho A minus rho g difference increases net lift increases. No, we will see the mechanism is bit different. We just copy the formula from the last time the weight of the ballonet air is the difference of the 1 by temperature terms into P_s into KV.

And the net lift is equal to gross lift minus the change in the ballonet air. So, the net lift will be equal to P_s the same expression that you saw. And here what we are doing now is simplifying it. If you simplify it, you will get

$$\Delta L_N = P_s \left\{ \frac{\Delta T_{SH2} - \Delta T_{SH1}}{(T_A + \Delta T_{SH1})(T_A + \Delta T_{SH2})} \right\} KV$$

Now if you look at the relative value of T_A , ΔT_{SH1} and ΔT_{SH2} you can actually ignore.

Just to get the order of magnitude analysis, you can ignore. So, if you do that you are approximate this value as just the change in the superheat divided by the square of the ambient air temperature. And between the term on and the middle and on the right the difference because of this ignoring is not more than 3%. So, if you are happy with 3% error in general, the numbers will change depending on P_s and all that but generally the error is around 3%. Therefore, without much loss of accuracy, we can get an expression for net lift change.

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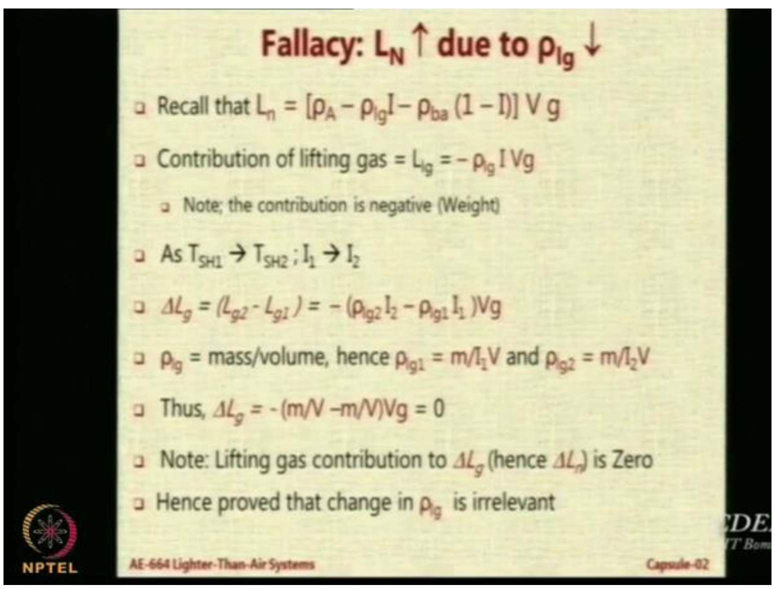

Just look at fallacy, just look at why there is a mistake. So, we recall that the net lift is basically because of the three terms are there. First term is the gross lift which is $\rho_A * V * g$ what is this?

This is the weight of the air displaced. So, because you brought the airship from somewhere to this place air of density of ρ_A ambient air density times the V and this g is just for the units. So, the first term $\rho_A * V * g$ is the gross lift.

The second term minus $\rho_{lg} * I * V * g$ is the weight of the lifting gas which has been put in space created by bringing the airship. You brought the airship along with the airship got the envelope blah blah all those structures plus you also get; right now, we are ignoring everything else. So, you are you are getting in lifting gas in the envelope and getting air in the ballonet. So, $\rho_{lg} * I * V * g$ is where I into V is the volume occupied by the lifting gas into the lifting gas density ρ_{lg}, it will subtract from the gross lift.

Then (1-I)V is the volume occupied by the ballonet. Ballonet also has some gas air inside which has got density. That is ρ_{ba} that is ρ of ballonet air. In general, you cannot assume it to be same as air density. We do not know. It may be same as ρ_A we do not know right now. We give the term as ρ_{ba} density of the ballonet air. So, with this we get the net lift. But this is not payload.

Net lift is what is the vertical force you get now you subtract the weight of the system? Blah, blah then you will get the payload. Is this point clear to everybody? Now what is the temperature of the lifting gas? Lifting gas contribution is the first part, the middle part sorry, which is negative contribution is actually a weight. So, it is not giving you a lift it is taking away from some lift so that contribution is negative ρ_{lg} times I into V.

Now as the value of T_{SH1} approaches T_{SH2} so we know that the inflation fraction depends on pressure and temperature. So, the value of T_{SH1} approaches T_{SH2} the inflation fraction I_1 will approach I_2 values. So now what will be the gross lift difference? It will be the difference between the inflation fraction I_2 and I_1. So, when I change T_{SH}. there will be a change in the lifting gas density. It will become ρ_{lg2} from ρ_{lg1} therefore the inflation fraction will become I_2 from I_1.

And the difference in the lifting gross lift, gross lift will change only because of the difference between the gas. Now ρ_{lg} is the density of the lifting gas that is equal to mass upon volume.

Therefore, $\rho_{lg1} = \frac{m}{I_1 V}$ and $\rho_{lg2} = \frac{m}{I_2 V}$ where I_1 and I_2 are inflation fraction at condition 1 and 2. The mass of the gas remain constant we are not throwing out gas. So put the value of ρ_{lg1} and ρ_{lg2} into this expression.

If ΔL_g is zero then the lifting gas contribution to ΔL_g is zero. So, lifting gas does not contribute anything to the net lift when there is a change in the superheat. Because it undergoes a change in the density and through that it simply cancels out.

Therefore, change of the lifting gases irrelevant so when people say that density of the lifting has reduced it is actually irrelevant. We have seen here that the density of the lifting gas its change is going to play any role in the net lift calculation. Now we come to the next point. What is left now? No, you are looking only at a change in T_{SH}, see do not make a system suddenly opened and suddenly closed and then expect to have the same relationship valid.

We are looking at only the contribution of the lifting gas. I is changing from I_1 to I_2. I is changing it was I_1 earlier it became I_2. But while becoming I_2 the density also has accordingly. So that is what we are trying to say but changed in the inflation fraction will take density change. Therefore, density change is not the mechanism of generating the net lift. We need to figure out why the net lift is changing.