Lighter Than Air Systems
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Lecture - 31
Effect of Lifting Gas Purity Super pressure and Super heat

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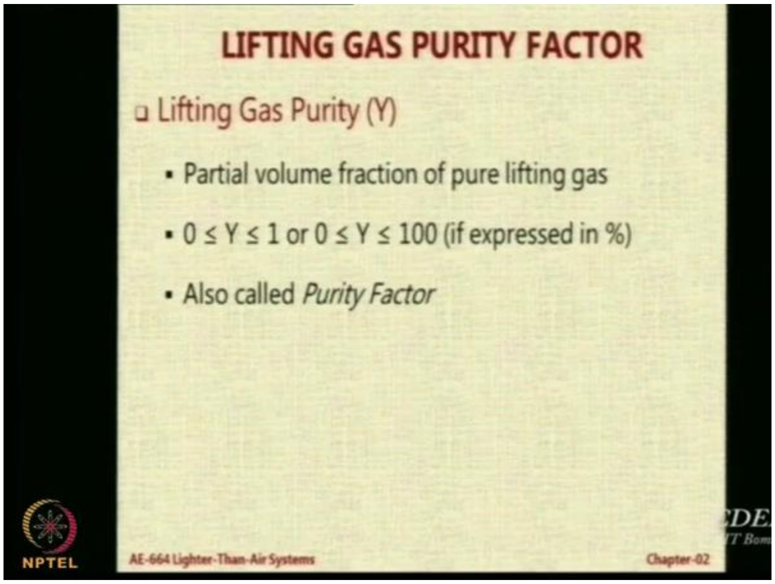

Now we have to look at one more effect. One more effort has to be studied; the gas that we use inside the envelope it need not be pure gas. After all it is a gas which comes from any commercial establishment it will have some impurity. So that also is going to affect the gross and then net lift. So, we define lifting gas purity Y. So, in any gas container you will have the gas and air as a impurity.

So, this factor, Y is called the purity factor now typically airships are not operated when this factor falls below 90%. Some companies insist 95% from safety point of view. And when you start your never have 100% it will be 99.7%, 99.5% even when you have a fresh fill. And practically speaking if it is a large envelope, it is very difficult to take out all the air from any gas bag. We have tried in our lab several times.

Some amount of sir always remain inside whatever suction pressure is it to use, some amount of air will always remain inside. Secondly as airship operates this water vapour is actually a very small molecule. It also goes inside the envelope. It might not go to high rate but it will go inside. The gas inside will also go out slowly with time I told you 1 liter per square meter per day is considered to be a good material property or acceptable material property.

People are trying to making is lesser and lesser. So, some LTA gas will go out and some moisture will come inside envelope. So, this purity will be lost over a period of time. So, Y will be volume occupied by pure lifting gas upon the total lifting gas volume.

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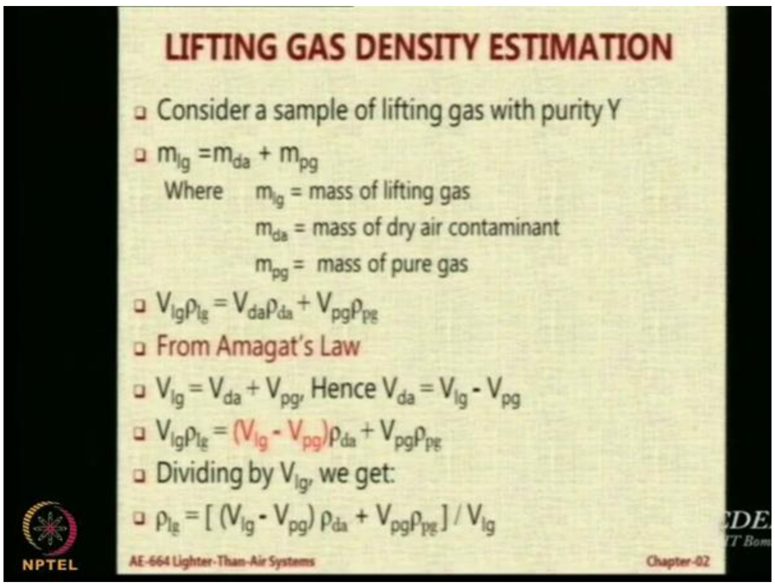

So, let us see. So, we just assume that you are putting gas with purity Y inside. So, the mass of the lifting gas will be equal to mass of the dry air which is the impurity. Now do not try to bring in wet air also in this because that is going to complicate the thing further than you have to do calculations inside calculations. So let us now assume that there is dry air which comes in and add to the mass of the pure gas.

Now it is also mixture. So same thing will apply

$$V_{lg} * \rho_{lg} = V_{da} * \rho_{da} + V_{pg} * \rho_{pg}$$

So, Amagat's law applies so the volume fractions will add up. So, volume of lifting gas will be volume occupied by the dry air plus volume occupied by the pure gas. There is container it has some volume; total volume will be equal to the volume of each of them. So, therefore volume of dry air is equal to volume of the lifting gas minus volume of the pure gas.

And you can then put this in the expression and then you divide by V_{lg}, so you will get ρ_{lg} that is the density of the lifting gas.

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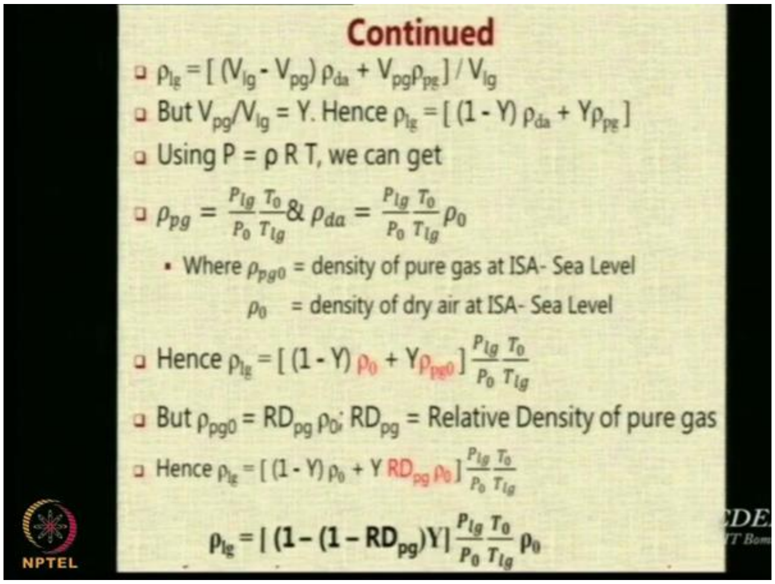

So, I just copied that now $\frac{V_{pg}}{V_{lg}}$ that is defined as the infraction, volume of the pure gas divided by volume of the total lifting gas. Lifting gas means gas which also contains air impurity. Therefore, you can replace that by $\left[(1 - Y)\rho_{da} + Y\rho_{pg}\right]$. Now $P = \rho RT$, the same thing rho of pure gas and ρ of dry air you can relate it to the pressures and temperatures. And using the same law you can relate it to pressure at sea level standard condition.

So therefore, ρ_{lg} that is density of the lifting gas, so you need this is number to calculate the net static lift that will be equal to

$$\rho_{lg} = \left[(1 - Y)\rho_0 + Y\rho_{pg0}\right]\frac{P_{lg}}{P_0}\frac{T_0}{T_{lg}}$$

So now apply the same gas constant. Again, bring in the same concept of relative density. So, you replace ρ_{pg0} that is density of the pure gas under the ISA conditions with the relative density of the pure gas into the density at sea level condition.

So, the same thing we bring it down to the sea level. So, you get a formula which gives you the value of density of lifting gas. Earlier we got a similar formula for air and water vapour. Now we got similar formula for lifting gas and air now air is the impurity in this case. So, once again it will be inside the value of Y will be inside. So just for your information this is will be available to you obviously. So, the same formula comes here.

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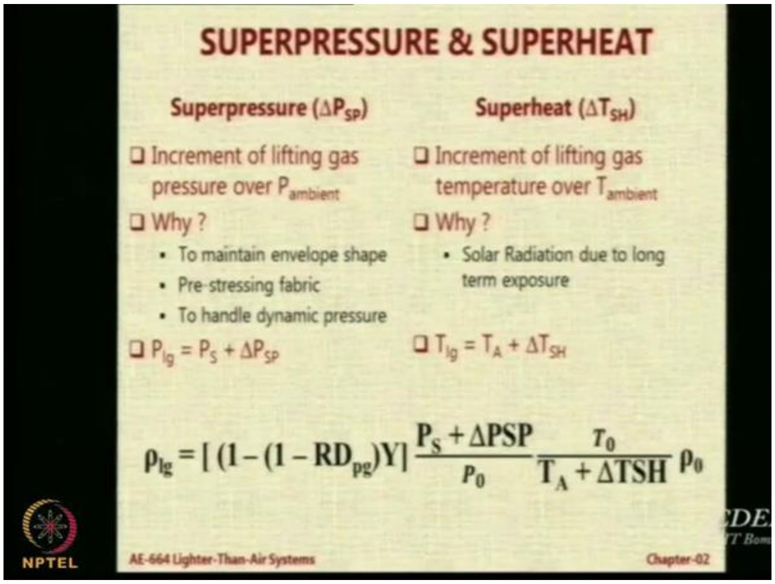

We notice that the relative density of helium is 0.1382 and Hydrogen is 0.6995 compared to the air so 1 minus will be also calculatable, so you get 2 simple formulae for calculating the density of helium and density of the hydrogen gas. Now finally the last thing to be considered is called as super pressure and super heat. So, the ambient air will not always be at the condition. The temperature of the lifting gas will remain same as ambient air there will be some heat transfer over a period of time.

So, if I take a balloon with gas inside keep it in the atmosphere after some time there will be heat transfer through so the air will also get heated up. Now much time it takes that is the function of the property of the envelope material but we assume that there is some temperature increase of the gas inside that is ΔT_{SH}. Similarly, the pressure of the balloon inside is not going to be kept same as pressure outside.

We have to keep slight over the pressure, why? Because we need to have the, envelope tight if I have the pressure inside same as outside and if I move balloon the nose will bulging you experience this in one flight. If you observe carefully one of my video shows that the nose was bulging inside.

So therefore, pressure inside of the gas will also be more than the ambient by an amount ΔP_{SP} this number is normally kept between 400 to 500 Newton per meter square.

Now if it is more ΔP_{SP} you are stretching the membrane also the structure will also have problems there will be more chance of tearing. If there are pinhole they will open up. This is what happened in R101 the pinholes opened up. So, the formula then gets modified by the P will become $P_s + \Delta P_{SP}$ and $T_s = T_A + \Delta T_{SH}$ and with that you can calculate the lifting gas weight.

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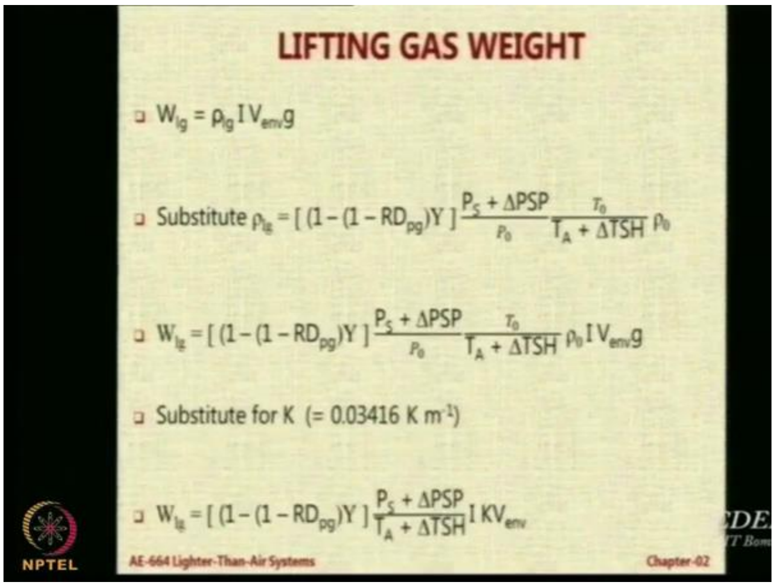

Now lifting as weight is what? minus the ballonets so you just put it I into V_{env} you get the lifting gas. So, the same formula will now be created with the value of I. So now you just have IKV_{env} outside for weight of our lifting gas.

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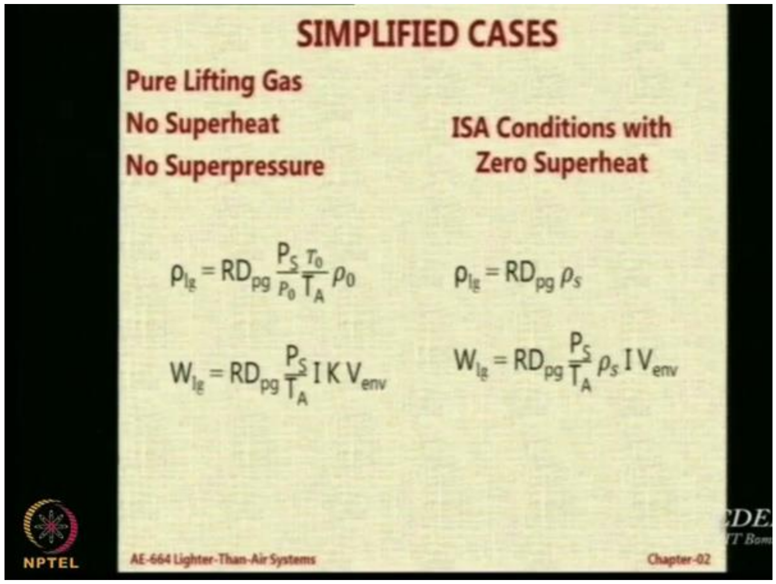

Now just 2 simple cases before we wind up one is assumed pure lifting gas so now Y is equal to 1 no super heat, no super pressure, simple expression. ISA conditions and no super heat P will be equal to directly related to; ρ will be directly related to the values and from there you can get the values of the gas as well as weight.

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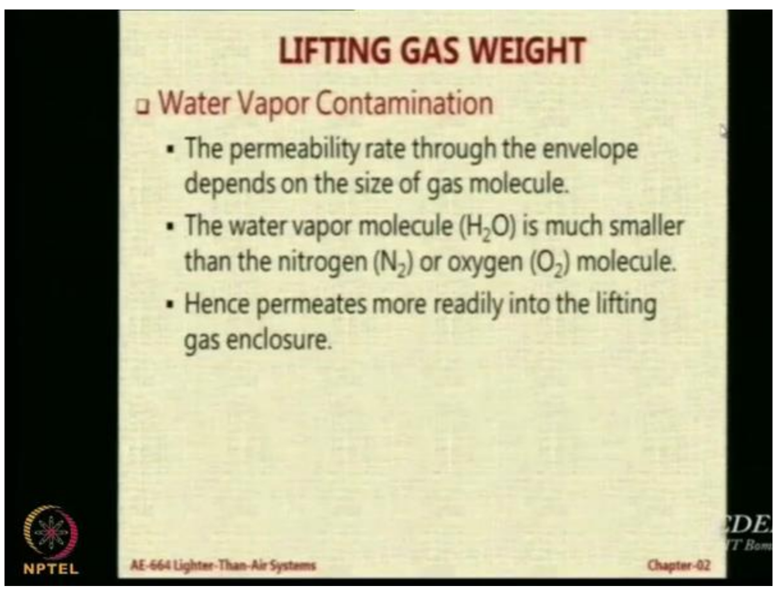

Now I already mention to you that the water vapour contamination takes place. The gas molecule is very small. In fact, water molecule is much smaller than nitrogen and oxygen so it permeates much better.

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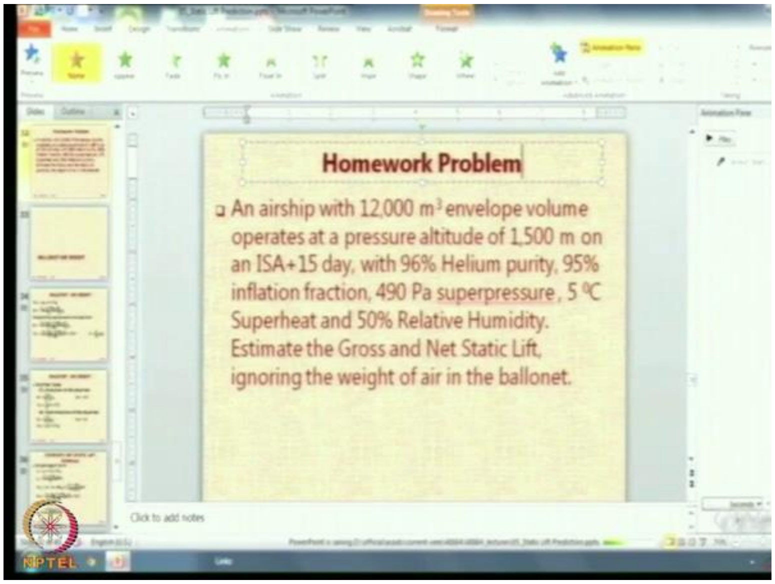

Now this I will skip right now basically it is just a question of; basically, the idea is the effect of atmospheric air coming in is like the effect of humidity. So, this is one problem, which I would like you to do, now do not do it you do not have time. This is something which I would like you to note down and I will call it as a homework problem rather than together do the problem. So, I am going to put this on Moodle page.

You no need to copy down it will come on a Moodle page. So, this will take care everything that was seen today altitude, ISA plus 15, helium impurity, inflation fraction, super pressure, super heat, humidity and all these effects what is the lifting gas calculation.