Lighter Than Air Systems
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Lecture - 36
Parameters affecting Static Lift

Good morning. We start from where we left last time. Last time in fact we have 2 lectures in which we looked at the basic methods and formulae for estimating the static lift generated by any LTA system. First, we derived the basic formulae and then we try to simplify them and also apply them to specific LTA systems, like rigid airship and then a balloon. And also, super pressure balloon. Now what is more important for us to know what happens to this static lift when there are variations.

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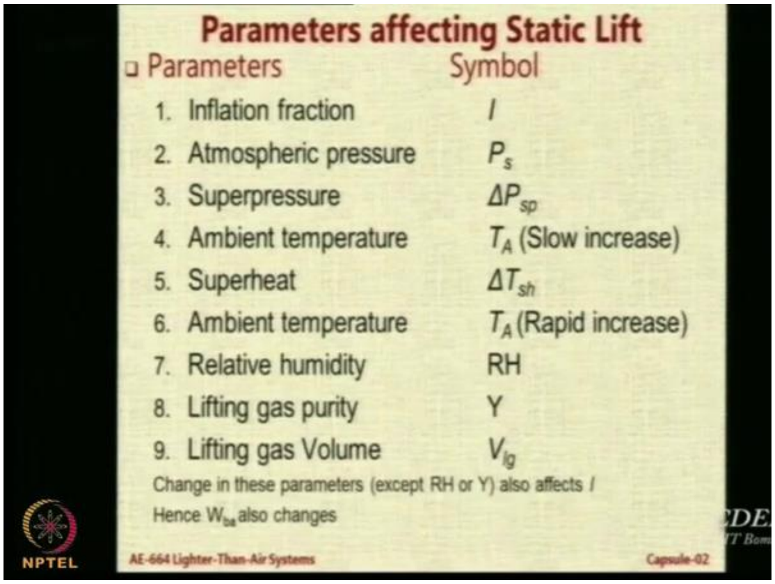

Today we are going to look at several operational parameters and their effect in the changing values of static lift or to be more precise what is the methodology to calculate the variation is static lift as these parameters change? The first parameter that we will look for is inflation fraction. This inflation fraction, the first parameter that will look is inflation fraction. This I hope you remember is the ratio of the lifting gas the occupied in the volume upon the total volume of the envelope.

So, if there is no ballonet this fraction is one. Then we will look at the change in the atmospheric pressure? I do not call it as P_A but P_s because P_s is the standard pressure. We will look at the effect of change of super pressure P_s which if you recall is the pressure above the atmosphere, which is or if the envelope is filled with gas at a higher pressure, then ambient that pressure additional pressure is super pressure.

We will look at what happens when there is slow in increase in the ambient temperature when I say slow increase, I mean we give time for the system to come into equilibrium and we assume that the heat transfer takes place through the envelope. We will look set of super heat, which is exposure to the envelope to temperatures higher than ambient. Then we will look at what happens when you suddenly bring an LTA system into high temperature without giving time for the system to equalize that is called a rapid increase in the ambient temperature.

We will look at the effect of humidity, we will look at the effect of listing gas purity and finally, we will look at the effect of changing the lifting gas volume. So, our mandate for today is for all these 9 parameters one by one what is the variation in static lift as one by one these parameters change that is our mandate for today. Remember that all these parameters are changed except for the in the last second last and the third last that is the humidity and purity of the gas.

When these parameters change the amount of air inside the envelope will also change either because the amount of air in the ballonet increases or hence for some other reasons. So, the inflation fraction I will also change when these parameters change. Then that happens the weight of the air in the ballonet will also change. For every case we might have to calculate the effect of the change in the ballonet air also.

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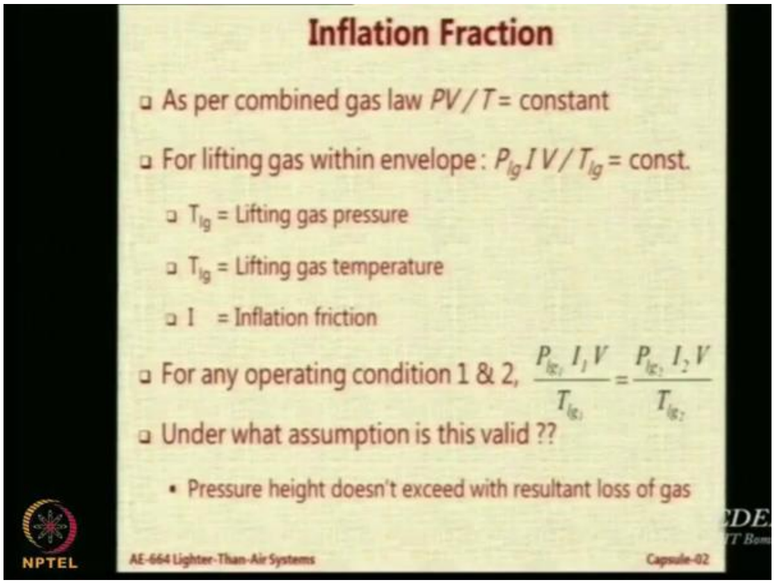

Let look at the first of these factors which is the inflation fraction I. Now applying a simple gas law which says; that PV/T is equal to constant. For any lifting gas inside a closed envelope, we can always say that $\frac{P_{lg}IV}{T_{lg}}$ is a constant. Why do we say this because I into V is the multiplication of inflation fraction with the volume? Now in my previous slide I have used V_{env} for the envelope volume because there is a mix up in velocity also.

But then we are in aerostatic, so therefore whenever you see V now on you understand that it is the envelope volume. So, I have dropped the superscript env. One reason is it makes the formulae very large unnecessarily as you will see the formulae which we will be deriving are any way very large. So, if I remove env there should be no confusion there is no velocity here there is only volume. Pressure of lifting gas into inflation fraction into V divide by T of lifting gas that will be constant for the lifting gas and if there is any operating condition one and from there you go to condition number 2.

$$\frac{P_{lg,1}I_1V}{T_{lg,1}} = \frac{P_{lg,2}I_2V}{T_{lg,2}}$$

Then $P_{lg,1}$ that is the pressure of the lifting gas in condition 1 into I_1 into V upon $T_{lg,1}$ will be equal to the same things for the second condition. But keep in mind that is a very very big assumption we are making when we equate these two quantities. So can you now think and tell me what are you assuming when we are seeing that $\frac{P_{lg,1} I_1 V}{T_{lg,1}}$ equal to the values for the second operating condition.

Or specific questions under what conditions will this equality be invalid? Density variation will take place, no density variation is implicit. So, you cannot say but this will be true only at the same altitude or in the same. So, density variation is permitted. Envelope volume will not change because there is V on both sides. So, yes, you can say that assuming envelope volume remains constant. In all our analysis we are assuming envelope volume remains constant.

Externally the volume remains constant internally the volume available for the lifting gas might change correct mass. The mass of the lifting gas is the same. So even though the ballonet is inflating or deflecting the volume available for the lifting gas may change but its mass is not changing. Under what condition does the mass remain constant. Right, but which operating condition will ensure that mass does not remain constant?

One is leakages so with time there will be leakages. So, we are look at the quasi-study situation. So, we cannot take care of time-dependent changes in the mass. So that is another assumption that we are looking at a particular instance. We are looking at constant outside envelope volume. So, can you recall, is there any condition operating condition which makes you throughout the lifting gas, if you want to exceed the pressure altitude? Do you remember the concept of pressure altitude.

When you are on ground you have air in the envelope and a ballonet and the ballonet is full on the ground. As it goes up the ballonet air is being pushed out. You reach an altitude at which the ballonet is flush. If you still want to go higher up then the only option you have is to throw out some gas. So, we are assuming that we are below the pressure altitude. So that is the key assumptions that we do not exceed the pressure height during this analysis.

So as far as operating from any operating condition to pressure altitude this equation is valid. For a constant out of envelope gas envelope shapes hence the volume.

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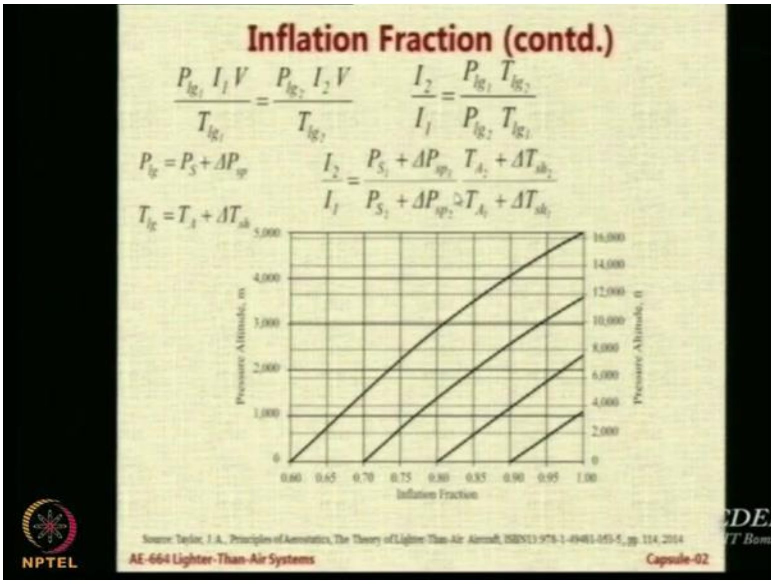

Now let us continue, so the same formula I have reproduced here for continuity. Now what you can do is you can take the ratio of I_2/I_1 by rearranging the formula.

$$\frac{I_2}{I_1} = \frac{P_{lg,1} * T_{lg,2}}{P_{lg,2} * T_{lg,1}}$$

this is the ratio of the inflation fractions. Now P_{lg} is the pressure of the lifting that will be equal to the pressure at which you are operating plus the super pressure that you will provide.

Now why do you provide super pressure? To maintain the shape to give a pressure slightly more than atmospheric so that in case of any dynamic pressure acting on the balloon the shape; so, if you want to keep V constant and you need to ensure that there is some pressure inside. So that is why P of the envelope will be ambient pressure or the standard pressure operating altitude + ΔP_{SP}. Similarly, T of the lifting gas that is the temperature of the lifting gas will be equal to the ambient temperature plus any super heat that is present.

There look at the screen just do it yourself. So, in this particular expression you replace $P_{lg,1}$ and $P_{lg,2}$ with $P_{s1} + \Delta P_{SP1}$ and $P_{s2} + \Delta P_{SP2}$ because at two operating conditions super pressure may not remain same. Similarly, the ambient pressure also will not be the same it will be P_1 and P_2. So, if you do that the expression becomes as shown on this screen and further if I plot the variation from sea level to higher altitudes.

Now, this is a double scale figure so figures on the right side are in feet pressure attitude in feet and scales are shown by the dotted lines or that scales in dotted lines, the figure, the number on the left pressure altitude in meters. So, from 0 to 5000 meters or 0 to 15000 feet approximately is the altitude variation here. And on the X axis you have the inflation fraction varying from 0.6 to 1. So will someone tell me if the inflation fraction is 0.7. What will be the percentage volume occupied by ballonet at sea level?

If the inflation fraction is 0.7 look at this point if it is 0.7 or let us say 0.6 at sea level inflation fraction is 0.6. You are at sea level 0 altitude and inflation fraction is 0.6 what will be the volume occupied by the ballonet Percentage wise? 40% inflation fraction 0.6 means 60% of the envelope is full of the LTA gas therefore remaining 40% which is filled of the ballonet which is the air and as we go higher up and if we move along this line.

We see that for an airship with inflation fraction 0.6 at sea level as the altitude is increased or you can also say as the ambient pressure is decreased you reach a stage here at around 5,000 feet where the inflation fraction become one which means what has happened? Sunil, what has happened? Which volume is zero? The ballonet, the entire envelope is full of the same amount of LTA gas, we have not increased the LTA gas.

LTA gas mass is same but the volume availability has been changed. We did that because he pushed out some ballonet air. We pushed it out because we wanted the envelope not get overstressed. So, what can you say about the pressure height of this particular airship? 5000 meters is the pressure height of this airship because the inflation fraction becomes equal to 1 at 5000 feet. And therefore, in normal circumstances we should not go beyond above 5000 meters.

If you have to go you have to throw some LTA gas out only then will be able to go up. So, keep this mind inflation fraction 0.6 sea level condition it becomes one almost one at 5000 meters. So that much is what we have to learn about the effect of inflation fraction. What we have learnt is that as the Ambient pressure decreases because of change in the altitude or increase in the altitude the inflation fraction increases till it hit is equal to 1.

And the line which it follows depends on from where it started. These are almost parallel lines almost. So, follows a non-linear but I should say slightly non-linear variation.