Lighter-Than-Air Systems
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Lecture - 95
Design Constants in Aerostat Design Methodology

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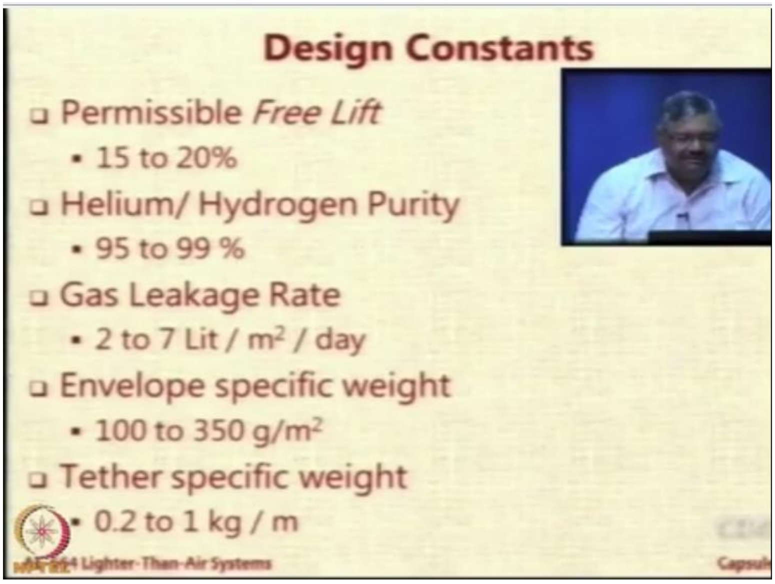

Then there are some constants. This is a very important parameter and this is the most misunderstood parameter. So, all of you pay attention. There is something called as free lift. Of course, nothing comes free, you have to have an envelope volume to get the lift. But then what is this free lift? And why the value is 15 to 20%? So, can somebody help elaborate? **"Professor – student conversation starts."** Have you heard this word before?

Yes, so what is it if you have heard before? No that is dynamic lift. The lift that comes because of aerodynamic forces is aerodynamically for dynamic lift. Free lift occurs even when there is zero velocity zero ambient wind. Then might be static light with heaviness. Yes, static light with heaviness, correct. Very rightly said, very good, I am happy on the use of the technical word static lightness. **"Professor – student conversation ends."**

Exactly. So, permissible free lift or free lift is basically amount of static lightness and we are saying it should be typically 15 to 20%. This is purely by experience or by the norms. There is no mathematical reasoning for this. But what is the need to get static lightness in an aerostat?

In order to get the tether remain tense. So the tether remains reasonably taut, tense will be a problem because if there is too much tension then you are reducing its life.

So, but if you do not give free lift, then it will be a very prone to disturbance kind of system. So, we want it to be tight, taut. So, typically 15-20% extra. This also allows you to take care of differences. So, day and night temperature changes, static lift changes. You know if I am deploying for a long time, there will be rain, humidity will change, superpressure will change. So, to ensure that under all conditions, there is always some darkness in the road we provide so much of free lift.

Then, what is the purity of the gas that we use? You have studied about the effect of loss of purity it is quite substantial. Now if you go and buy hydrogen or helium commercially, you will get various grades. One grade is called as a commercial grade, it is typically 95 point some percentage pure, remaining is impurity, Impurity will be nitrogen gas or whatever. Then you have what is called as laboratory grade gas which is 99.999% pure.

So, obviously it will be more expensive because you are purifying it taking out all the impurities. So, typically we assume that the gas will be 95% or 99% or in between that is the typical value of practically available gas for aerostat use and the numbers will differ. Gas leakage rate through the envelope, this varies. It depends on the envelope material and its permeability. Typical values are between 2 and 7 liters per square meter per day.

So, you measure the total area and per day per square meter the gas leakage will be between 2 and 7. So, one envelope that we have tested it was 3.75 liters per square meter per day. We got it tested that is the permeability of the yellow fabric that we have. Envelope specific weight; this again depends on the material. It depends on what is the base fabric, how many coatings, what kind of coatings. So, the value varies from about 100 gsm.

Now if you work in LTA lab or some other laboratory with a very small lightweight indoor aerostat or something, you can even use thinner material of 50, 60, 70 gsm. But most practical numbers would be between 100 gsm to around 350 gsm. More than 350 gsm is very heavy fabric. But some of the fabrics used by ADRDE Agra for very large aerostats are 350 gsm, so much is the weight per unit area. Then you have tether specific weight.

From a simple nylon cable to a multilayered conducting cable it could vary from 0.2 to even 1 kg, 0.2 to it will be probably 0.3, 0.2 to 0.5 kg per meter that would be the maximum generally.

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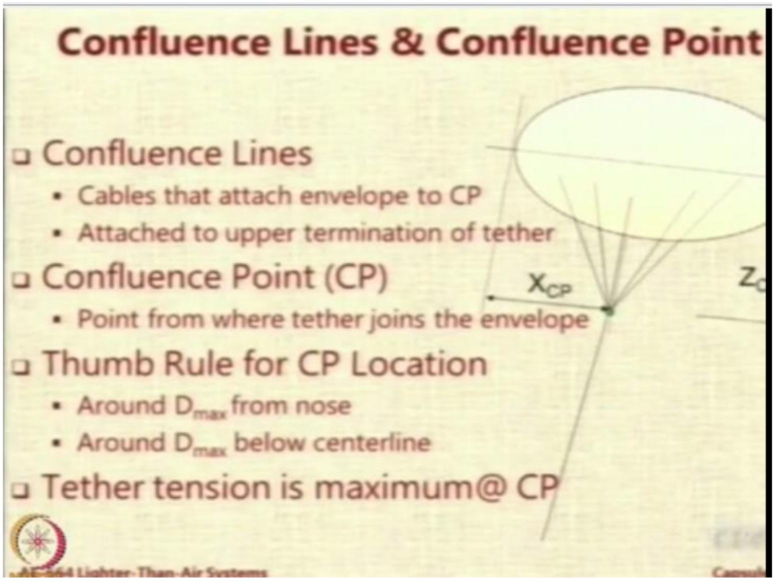

Now we need to understand a few concepts before we take up the design of the aerostats. Two important points are the confluence lines and the confluence point. So here is an envelope of an aerostat, I have just chosen to show you an oval shape, but the same thing is applicable to all shapes. So, these are these cables which attach the envelope to the confluence point, they are called as confluence lines.

And basically they meet at the upper termination of the tether. So below this will be the tether. So, this confluence point it is a very important point. When you fly a kite, it is very important that the distance between the top knot and the bottom knot and the knot where the rope is attached there is a triangular dimension. And when we flew kites, we learn that you hold it hand and take it on the top and the bottom.

A good maneuverable kite will have around one finger gap from the knot to that. So, this is all basically thumb rules for proper stability of kites. So, similarly this is exactly the same concept for an aerostat or a balloon. You have these confluence lines which meet at a point called confluence point and the location of this confluence point is important because that is the place where all the ropes will terminate and from below that you will have just a single tether.

So, there are thumb rules for the location of confluence point. These thumb rules are based on experience and they are helpful in determining what would be the location. So, one is the location of the x coordinate of the confluence point from the leading edge of the balloon that is x confluence point or X_{CP} and then the Z_{CP} will be the vertical location between the axis of the balloon and the confluence point.

So, basically experience has shown that both these numbers should be around maximum diameter. So the confluence point should be located max diameter below the center line or you can say radius below the balloon if it is almost spherical. And it is also located approximately max diameter behind the nose. If you do this, you will get a reasonably stable aerostat. So also important point is that the tether tension is going to be the maximum that confluence point because it is the place where everything meets.

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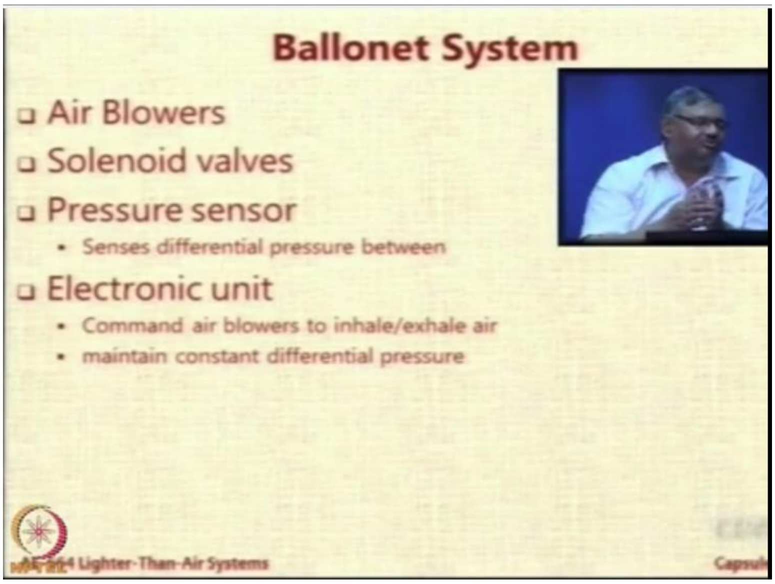

Alright, now you know that typical aerostats have an integral or an in-built ballonet system. The ballonet system actually consists of many subcomponents. There are air blowers in the ballonet on the bottom. There are solenoid valves and there are pressure sensors. And there is an electronic unit which basically commands the blowers. So depending on the pressure sensed by the pressure sensor, the air inside the ballonet is either sucked in or thrown out depending on the requirement.

So, tell me what will happen if for instance there is a loss of temperature? Ambient temperature falls, it becomes cold because it rained. So, what will happen? Will ballonet take more air or it will expel air? It will take more air. Why will it take more air because a loss in temperature is going to create shrinkage of the balloon not because of thermal conduction but becaue of loss in buoyancy.

But balloon has to maintain its shape, otherwise it will not displace air. So you pump air into the ballonet to keep it tight. Reverse will happen when you deploy aerostat in the morning and then in the bright sunlight for after 2 hours or so, there will be superpressure. So at that time air will be thrown out of the ballonet to release the pressure. So, there is an electronic unit which does this automatically.