Lighter-Than-Air Systems

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Lecture - 60
Discussion of Practice Questions

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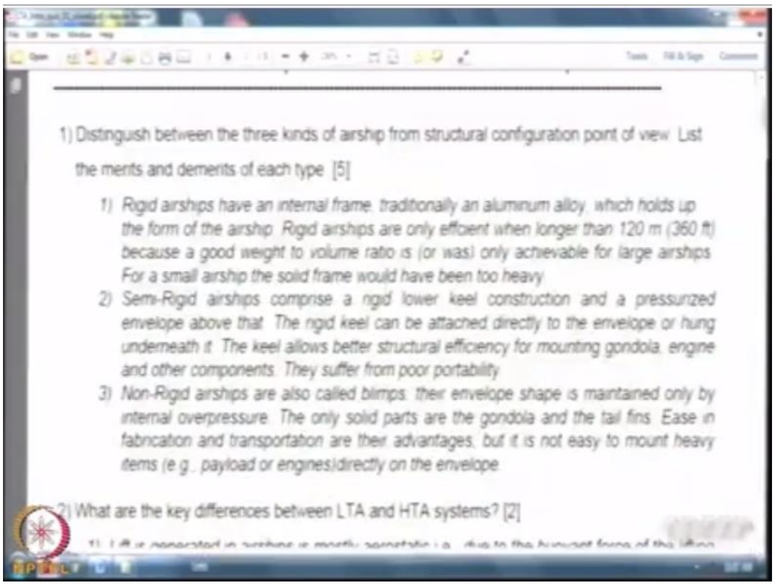

So let me start off by showing you the model solutions. So the first question was basically just a starter. All of you I am sure will be able to address the difference between rigid, semi-rigid and nonrigid. What is important is to understand the merits and demerits of each type. Rigid airships are actually structurally most efficient if the size is large. So some studies have shown that if the size exceeds around 120 meters or even 100 meters.

Then the payload fraction or the empty weight fraction of these airships tends to be the best compared to the other types. Another advantage is that the passengers can be seated inside or the cargo can be placed inside the envelope. So, the drag is reduced. So, these airships generally have very high speeds. Semi-rigid airships essentially are useful because you can mount some items such as the power plant directly on the structure.

In a non-rigid airship, you are constrained to mount everything on the gondola which is suspended below the envelope because it is difficult to locally load the envelope. But in a semi-rigid airship because there is a framework you can use the framework to mount engines. If you look at Zeppelin NT, which is the currently available semi-rigid airship for flight operations, passenger operations, we noticed that there are 9 frames.

And before and after each major structural element they have put a framework. For example ahead and behind the gondola, ahead and behind of the horizontal tail and vertical tail because they are in the same plane. Similarly, in the front also they are inserted. And also the engines are mounted on a frame on the sides of the airship because you can use the framework to mount the propulsive devices.

In a non-rigid airship, you are forced to put the engines only on the gondola and therefore the moment arm between them will be very small. So, you cannot use it for any turning performance enhancement. Whereas if you mount the engine on the side of the fuselage at the maximum diameter location on the framework not only you get large moment arm, you also get very good aerodynamic location to mount it.

So, the semi-rigid airship was brought up because of that reason. Another reason why Zeppelin NT company went for semi-rigid airships is that please recall historically the name Zeppelin is associated with failure, with fire, with bad design which is not true actually. So when they tried to revive the airships and they wanted to get German certification for passenger carrying airships. If they have gone for a non-rigid framework, they would have had to explain many more new things.

So but if you have a structural framework that takes the main load, it inspires confidence in the minds of the reviewing agencies or regulatory bodies plus it is also safer. Depending only on the envelope for passenger carrying airships and large airships with large payload may not be a good idea. The problem with semi-rigid is that they cannot be folded, they cannot be transported.

So when Zeppelin NT company delivered an airship to Japan, they had to fly it to Japan. And flying into Japan from Germany involves a huge logistic issue because everywhere down in the road or along the path you need to have places to store it, to refuel it, to service it. So it is a logistical nightmare to transport a semi-rigid airship that is one reason why a team of students is trying to design a transportable semi-rigid airship.

Something which can be dismantled, packed and taken away. Now, are there any other points which you would like to be included in this as far as the type and merits and demerits are concerned? If not, then let us go ahead.

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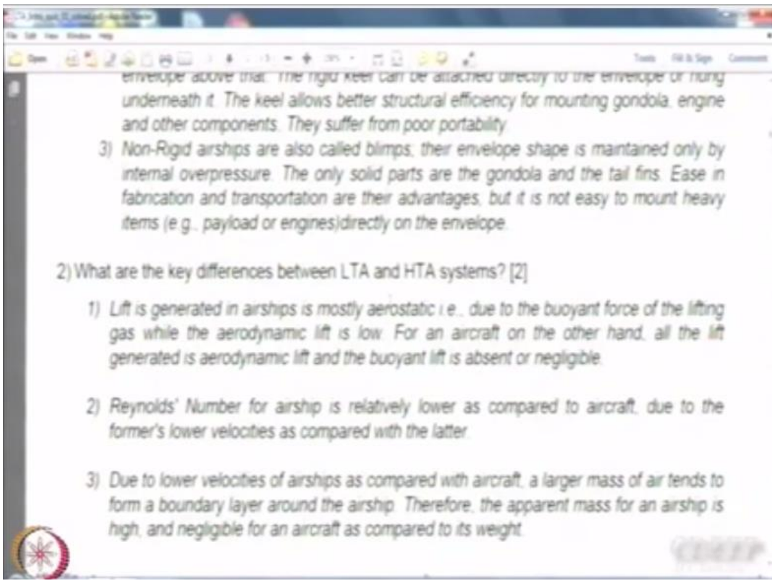

Between LTA and HTA systems, the differences are clearly mentioned in the notes. The first and foremost is about the nature of lift transition. Aerostatic lift is available in LTA systems. The Reynold’s number of the airships tends to be large because of the large dimension, although the speeds are low but the dimensions are quite large. So, for an aircraft we normally had Reynold’s number in terms of 6 million, 10 million.

In airships 10 power 8, 100 million, 200 million are commonly thought about and they were large sized passenger carrying airships. And secondly, airship is essentially practically zero mass system, practically its net mass is zero because buoyancy is fighting the gravity. So, it is a very lightweight body large in size which is moving, therefore it does not cut through the air rapidly like an aircraft. So, a large mass of air actually moves with the airship.

So, when the airship moves there is a huge amount of air collected in the front of the airship which actually moves with it. This is called as the added mass or apparent mass. Apparent mass is equal to airship mass plus added mass. So, this apparent mass is also present in aircraft. Even in an aircraft when the aircraft moves, some amount of air will move with the aircraft, but the quantity is far small compared to the aircraft weight.

So, in aircraft you can say literally cut through the air without too much of air being attached to it. So, the apparent mass could be half percent one percent negligible. In the airship, the other mass could be 40%-50% and that changes the whole dynamics. We will study about apparent mass later on. These are the three main differences. Any other point that you think should be included here as a difference between LTA and HTA worth mentioning.

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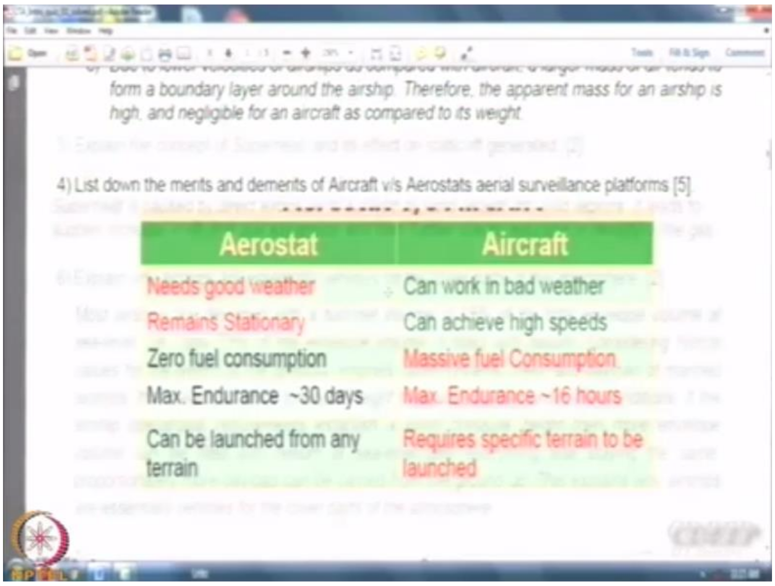

These are just taken directly from the screenshot of the notes. Aircraft versus aerostat for surveillance platforms. The two main problems with aerostats are they are weather dependent and they remain stationary.

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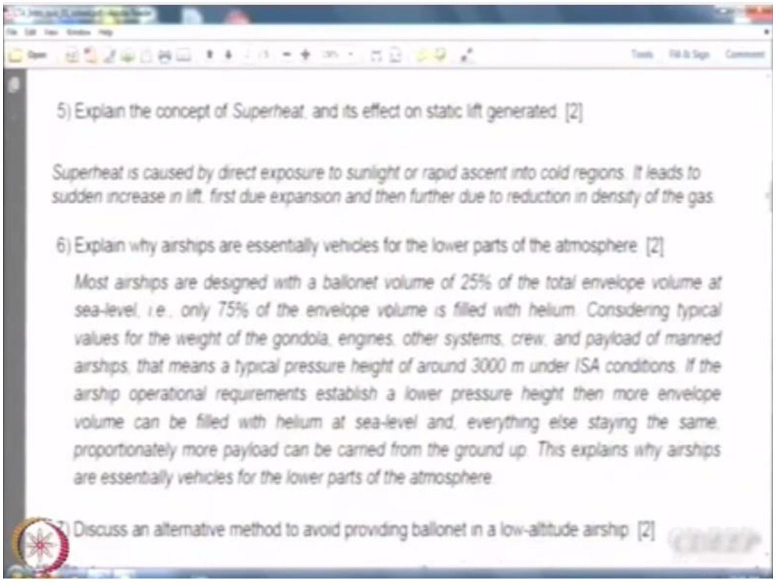

So superheat many people misunderstand it is basically the change in the buoyancy caused because of direct exposure to sunlight or rapid ascent into cold regions. It goes both ways. You can have negative superheat. By pushing an airship or an aerostat into a very cold region suddenly it leads to certain increase in lift if you have a positive superheat first because of the expansion of the gas and then because of the density reduction.

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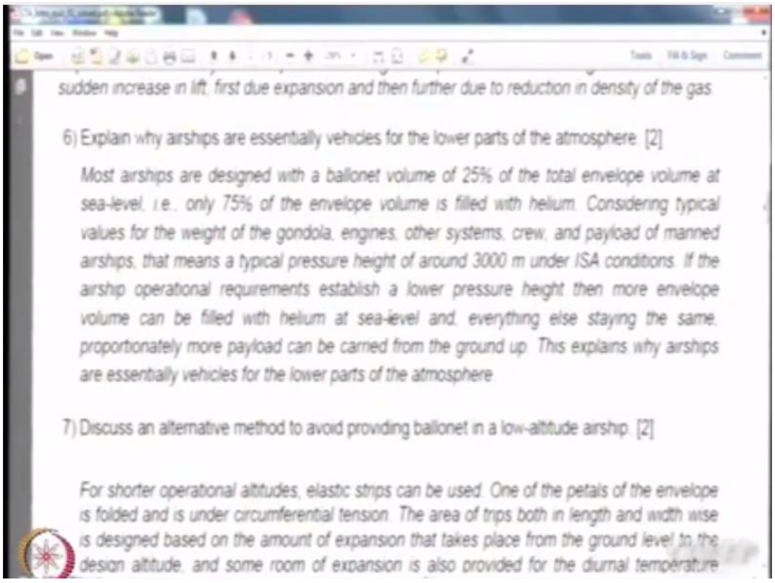

Why are airshps essentially vehicles for the lower parts of the atmosphere? Why we cannot use them to operate at very high altitudes? The reason is that the volume of the ballonet that you have in the airship is decided by the ΔH and if you have high ΔH larger percentage of the envelope will be ballonet because we need to control the buoyancy as we go from launching altitude to operating altitude.

So, if ΔH is small then you have more volume available for the gas and less volume is to be kept as a ballonet for the air. Hence it is better to operate them only at low altitudes. Now this is a lesson that we learned when we did a study for operating airships for Uttarakhand that is how this whole activity in IIT Bombay started in the year 2000-2001 we started a project.

Our idea was why not use airships for transporting goods and passengers over hilly terrains because there are a lot of transportation issues. When we did the calculations and when we actually went around meeting people, we realized that they will work very well if they are launched from a higher altitude to a slightly high altitude. But if you launch them from the plains of Uttarakhand to the heights of Uttarakhand, the volume occupied by the ballonet was very large.

The inflation fraction was very small and hence it was considered to be untenable. No airship in the world available is able to handle the load of let us say one and a half tonnes. So this is something that we learnt a hard way. But if you want to operate from sea level to 1 kilometer altitude let say Mumbai Pune for example, sea level to 1 kilometer altitude or if you want to operate from some altitude to a slightly higher altitude. If the ΔH is small airships are very good.

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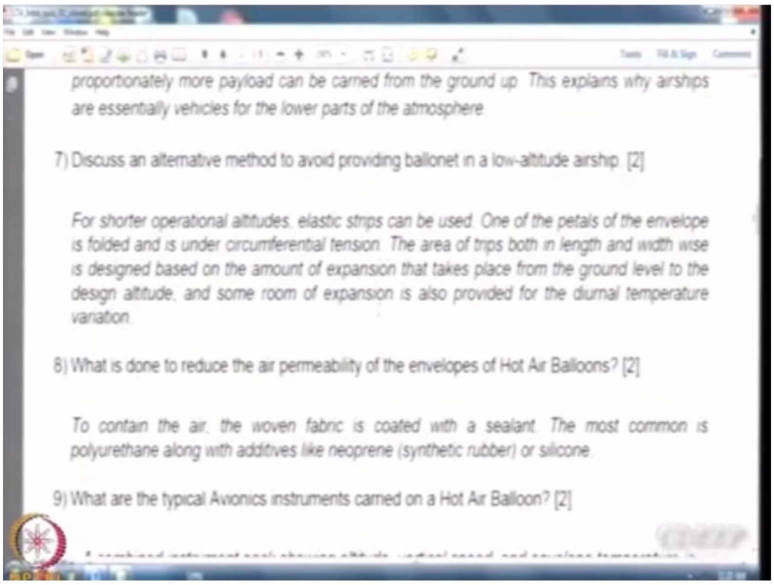

This alternative method for providing the buoyancy control, I had actually mentioned in the classroom and I actually showed you also, but did I show you a picture of this? When we operated aerostats we realized that one can, I actually mentioned just like we have a bootstrapping, you can put an elastic cable on the bottom of the envelope and you can tighten the envelope.

And as the airship envelope wants to expand either because of superheat or because of any other reason, maybe ΔH the elastic cordage can allow the envelope to expand and when the temperature falls or when you want to bring it down to lower altitudes, the elastic forces will try to because then the envelope tends to reduce in volume, the elastic cordage helps in controlling that.

So, in all the airships and aerostat that we have built so far we have never used ballonet because ballonet is a very complicated system. It is not a simple system to design a ballonet. Can somebody answer this question what is done to reduce the air permeability of the envelopes of hot air balloons? Coating. So, you coat it with what? Yes, the most common thing is neoprene.

So, this is what some of you could have tried in your lanterns if you knew and if these silicon coatings would have been available. You could have just coated that from inside to reduce the air permeability.

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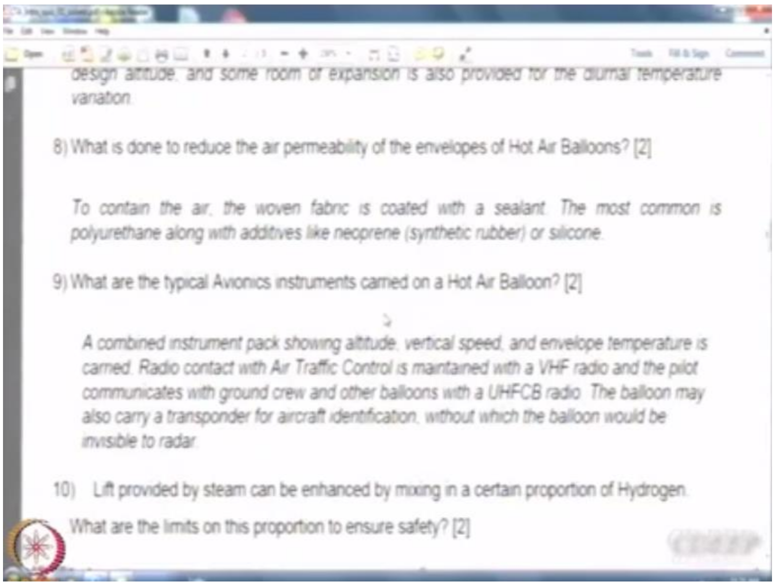

So, what are the typical instruments that are carried for the avionics? What is it? Why do you need a transponder? Correct to help the air traffic controllers identify your location because a hot air balloon is going to be a slow moving and drifting vehicle. So the air traffic controller should know where they are. So the easiest way by which the ATC can know about the location of a flying object is by a transponder, which continuously transmits its unique code called as a squawk code.

It transmits it uniquely and when it is intercepted by the screen the ATC know where this particular vehicle is. So yes, one is a transponder when what else Yes, you need to communicate with the air traffic controller because it is of course, they cannot say maintain so and so altitude or go so and so because you have no control on it. Perhaps you have some control on the height by adjusting the buoyancy.

But if there is an imminent threat, the ATC can warn you or you can warn the ATC that we are losing control, our height is increasing rapidly, so channeliz traffic away from us. So you need a communication system, anything else? That is a communication system, UHF VHF is a radio for communication. Anything else is needed if you are on a hot air balloon? See, the pilot should know the location of the balloon.

So an instrument that shows altitude, vertical speed and envelope temperature is very important. The temperature of the envelope directly affects the buoyancy. If it is exceeding some limits, there is a danger of envelope tearing and people coming down crashing. So, one instrument that you need is to measure these important parameters. Then, you can communicate with the ground people using a UHF communications radio and you may have a transponder for identification, right.

This is all mentioned in the notes. I have actually copied and pasted from the notes directly some of the answers. This also is mentioned in the notes. You can use superheated steam for a hot air balloon because superheated steam has got a very good buoyancy, but the problem is to maintain that superheated steam at that particular temperature. So, Germans will come up with a very interesting fabric which can hold superheated steam.

And some people have suggested that you can further increase the buoyancy by mixing it with hydrogen, but hydrogen is inflammable. So, there is a certain proportion after which it becomes inflammable. That proportion is around 12%. So, initial mixture of 15% hydrogen and 85% water is progressively diluted by air and 12% hydrogen if you add you will have a safe mixture. Beyond this it will become prone to ignition. This is also given in the notes in the hot air balloon chapter.

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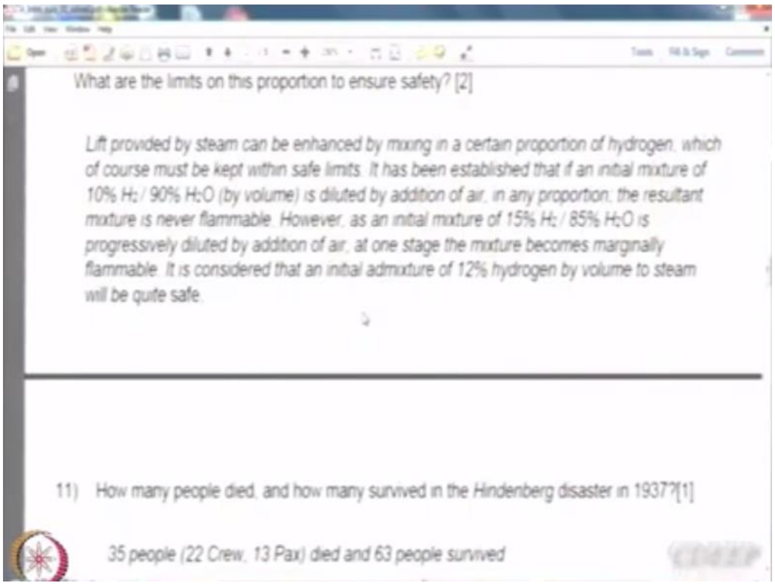

This is something which many people may not remember, but I wanted to highlight this so that from now on you remember. Anybody knows the answer? 35 people died, yeah so 22 of them were crew members, remaining 12 were passengers and correct 63 people survived. So the number of people who survived, now if you are off by 1 or 2 people are not going to penalize you.

So 35 people died and 63 people survived and of the people who died most of them were crew members. So it is just 13 passengers.

“Professor – student conversation starts.” What did you write? because you think airships are unsafe. Right. **“Professor - student conversation ends.”**

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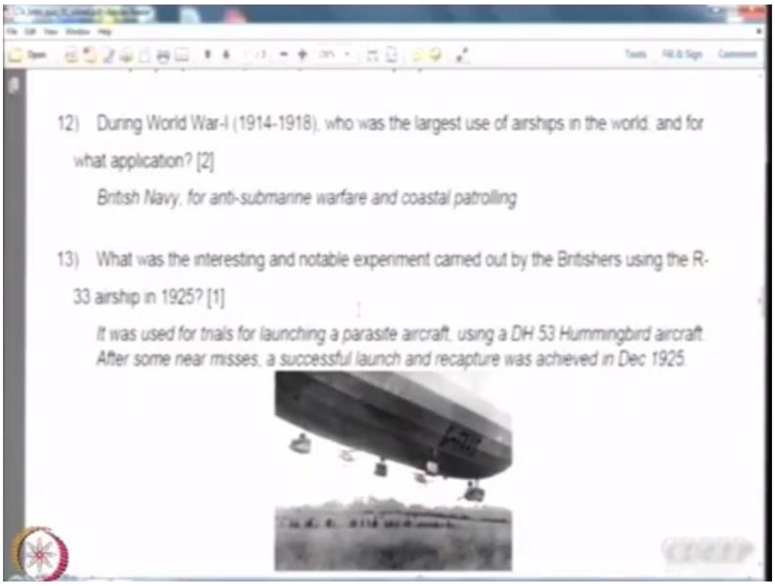

This is a very interesting question. During World War 1, there was one agency which used airships for a very specific application. Anybody has any answer?

“Professor – student conversation starts.” British. British what? British airforce, British? British Navy. For what application? Yes. Anti-submarine warfare and coastal patrolling. **“Professor – student conversation ends.”**

Last year, not last year few years ago I was invited by the Indian Navy for an anti-submarine warfare workshop in Kochi.

So, there was a presentation on how in the past airship, they had no idea. They are experts in anti-submarine warfare. They had no idea that there is something called airship and it was used by the US by the British Navy. So I made a presentation to them. And then I said why not we try to revive airships in India? So, hopefully someday we will hear Indian Navy also using airships for coastal patrolling and submarine warfare.

Experiments carried out by Britishers using the R 33 airships in 25? This is again going back to history. This was the world's first aircraft carrier. The first aircraft carrier of the world was not on a ship on the water, but on a ship in the air. So, what they did is they carried aircraft on the airship. So they are called as parasite aircraft. So the first one used was this DH 53 Hummingbird aircraft.

And this aircraft would actually it will be launched from the airship and it will come back and reattach after doing its mission. Very challenging and very exciting. There are many failures, but ultimately there was a success in December of that month. So, this is a very unique application. You can see there are these two aircraft hanging below the airship. Now, this might sound very odd and peculiar.

But you will be surprised that now there is a rethink on this whether we can use an airship for attaching MAVs which can be taken to our location, launched and reattached. So, there is some thought and some people have approached me to write a proposal for designing a mother airship which can carry UAVs or MAVs which can increase the range and capability of these MAVs. There will be having a docking station where you can charge them also.

So, you can take the airship and make it fly, then these small babies are launched. They do their work and they come back, get recharged, refueled and again launched. There is a possibility we will take a project in that area.

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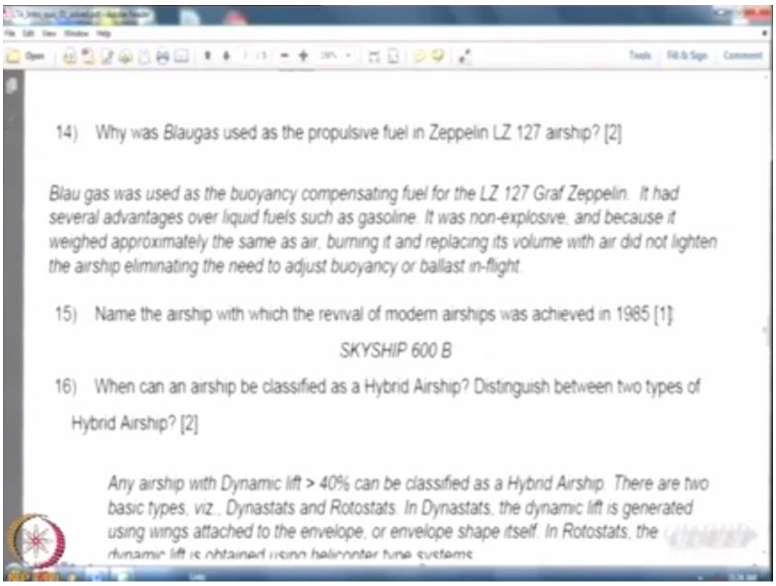

Blau gas, anybody remember this? What is Blau gas? What is special about it? Yes, same density as air. So very beautiful. So fuel whose density is same as the air. So, you can consume it and put it back. There is no loss in buoyancy. So, all these heavy and complicated methods to control buoyancy are not needed if you do not have change in the density. So this is a very remarkable idea.

It said buoyancy compensating fuel for the Graf Zeppelin. And non-explosive, therefore safe to handle. And you can use it without a change in buoyancy. So this was the secret weapon of the Germans in the war that they can use. This anybody can answer? Skyship 600 B is the answer. The airship which was used to revive the technology in mid 80s. Alright, so let us look at the next question which is about hybrid airships.

The question asks how do you classify an airship as a hybrid airship? And also there are 2 different types, so how do you distinguish between them? So does anybody know the answer? When does an airship classify as a hybrid airship? Yes, come on I am sure you know the answer of this question because many of you have answered it, alright. So, basically when the dynamic lifts exceeds 40%. Now, there is no fixed number available in literature.

So, this is not something which has been accepted by everybody. The general feeling is that if you can produce more than 40% lift by non-static means or non-buyonant means, then it is considered to be hybrid airships. The two basic types are the Dynastats and Rotostats depending on whether you use the relative motion between the airship.

And the air to generate that dynamic lift either by changing the shape of the envelope to a flattish envelope, just like we have seen in P 790 or by attaching wings to a balloon. In Rotostats you attach rotors and with those rotors you produce vertical force or lift which exceeds 40% of the total.

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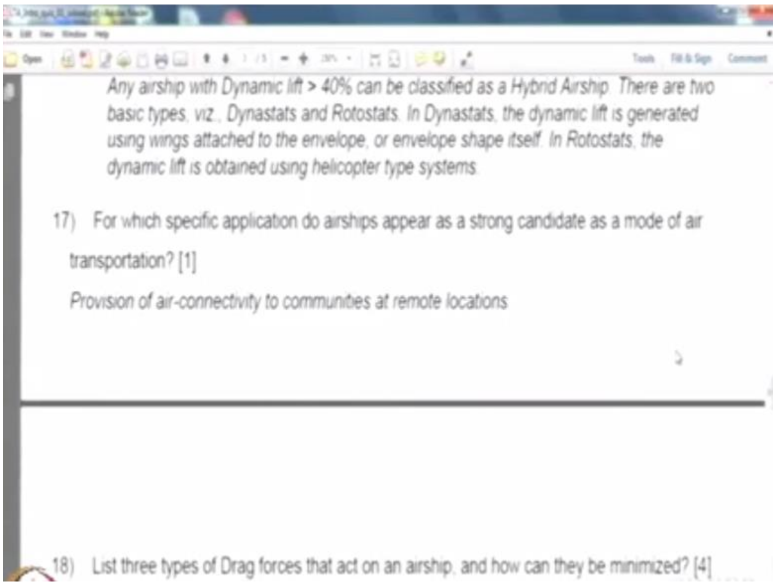

Now there is a question which many people want to know and that has to do with very specific application where airships can be used as a mode of air transportation. We cannot use airships in those scenarios where we need high dispatch reliability and all other operations because you know that they are not able to operate in bad weather conditions.

But when you look at connecting remote communities where other modes of transportation are pretty bad or very expensive or sometimes even infeasible, in those applications if we can provide airships it will be a very good solution. I will be presenting to you a case study of airships versus helicopters for connecting remote communities in in Uttarakhand, which was done by me a few years ago and it has appeared as a chapter in one textbook on providing air transportation to remote communities.

Moving ahead let us look at the theory of drag forces that act on the airship and also how to minimize them. So, can somebody name these 3 forces? What are the 3 types of drag forces which act on an airship. Scale friction because it is a very large body which has got a huge surface area. Yes, induced drag because it generates lift and therefore there will be some induced drag and the third is the profile drag.

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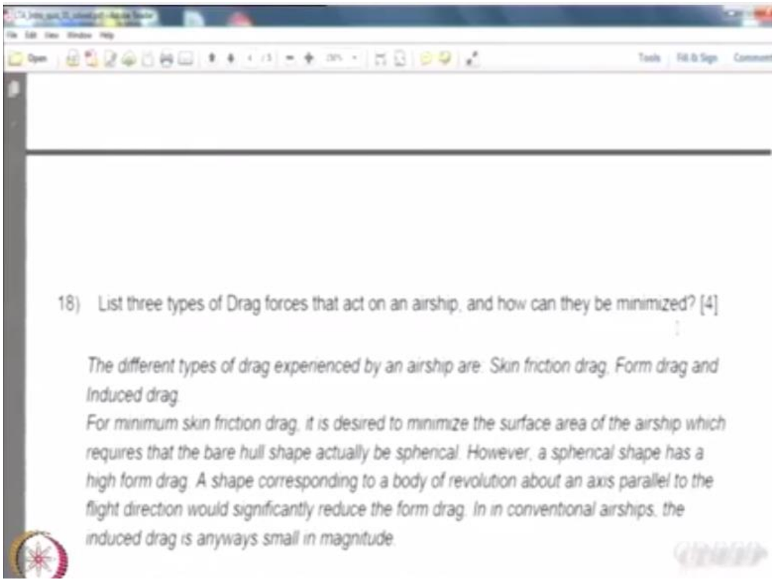
18) List three types of Drag forces that act on an airship, and how can they be minimized? [4]

The different types of drag experienced by an airship are: Skin friction drag, Form drag and Induced drag.
For minimum skin friction drag, it is desired to minimize the surface area of the airship which requires that the bare hull shape actually be spherical. However, a spherical shape has a high form drag. A shape corresponding to a body of revolution about an axis parallel to the flight direction would significantly reduce the form drag. In in conventional airships, the induced drag is anyways small in magnitude.

So, the three drags are skin friction form and induced. Form and profile are interchangeable. Now, for minimum skin friction drag you just try to go for minimum surface area, but spherical shape is the best for that. However, it has got extremely high form drag. So, the compromise will be an oblate spheroid type of shape. Then if you want to really worry about form drag more than skin friction, then you can go for elongating the body and making an axisymmetric body of evolution.

So, the longer you make it, higher the L/D more than a surface area for a given volume, but lesser is the form drag. So, depending on which component is more important depending on the Reynolds number, operating conditions, speeds you can decide. Anyway the induced drag is always very small because the lifts produced by the body is around 15% in the non-hybrid airships. So, there are 9 requirements for airship structure given in the notes, any 5 of these could be used to answer this question.

And let us look at this is a slightly trick question. It talks about location of the fin on the envelope. If you have a fin located far back, smaller area hence less weight will give you the required moment arm. If you move it forward, then for the same moment arm you need larger area hence more weight. But as you keep moving back, the cross sectional area of the airship envelope reduces especially the tapered portion.

So, if you do it very much behind then it is difficult to adapt to structurally because that area tends to be on low pressure. So, there is a compromise between these two and what we have found with our experience is that the location where you mount the aerodynamic center of the fin is roughly 70 to 78% of the length of the airship. This is what we have observed based on our experience and also a study of the existing airship.

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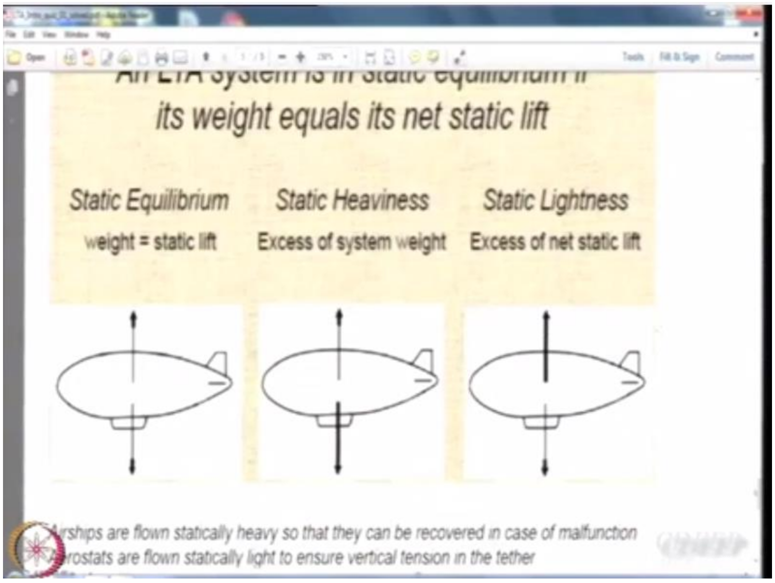

This is something that many people know static heaviness. When the net lift is not zero, when it is more than zero. So, airships are flown statically heavy because we want them to come down and aerostats are statically light because we want tension in the tether for it to remain afloat and not start sagging.

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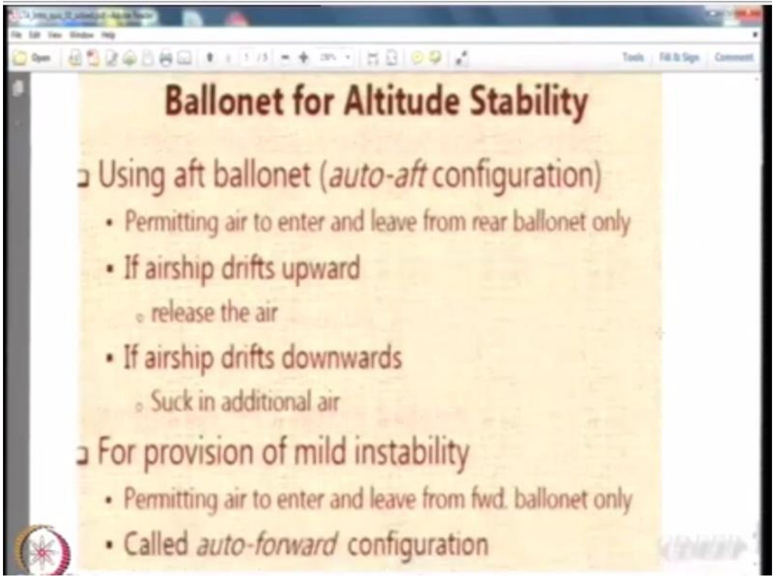

Now ballonets can be used to provide altitude stability by using the aft ballonet. So, because you can have more than one in this case two ballonets the rear ballonet alone if it is adjusted, it can be used to create the required pitching moment to trim so that is what it is.