NOC: Introduction to Airplane Performance
Prof. A. K. Ghosh
Department of Aerospace Engineering
Indian Institute of Technology, Kanpur

Lecture - 28
Take off: Warm-up Lecture

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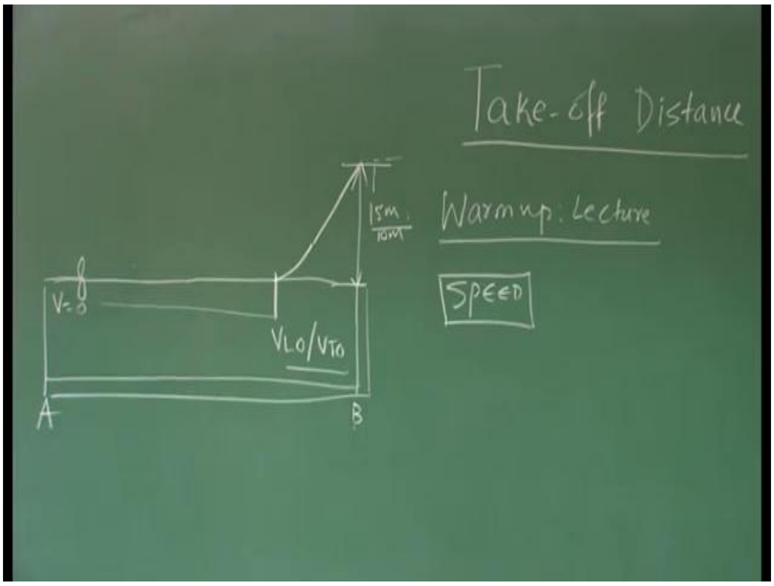

Hello welcome friends, as we have seen we are warming up ourselves to be ready to understand, how to estimate Takeoff distance. And you, by now also know, how it is important that we should design an airplane and try to ensure that the takeoff distance is as low as possible. What do we mean by takeoff distance? Loosely, I want that length of airstrip, where I can equal to zero to V equal to certain speed and I should be able to takeoff in a loose sense.

But, as you understand and if you see history of aviation, there are plenty of accidents during takeoff and landing. And that is why, if you see an aircraft manual, you will find for a pilot instruction there are so many types of speeds are defined. What I mean is, if I am starting from here V equal to 0, I start the engine; I do the engine check, control check, etcetera, etcetera. Then, I start moving and that speed will go on increasing to a certain speed I want.

I call it V liftoff, V takeoff, that is the speed at which I should be able to generate enough lift by rotating the airplane by small angle and I should be able to climb that is, I come here, I rotate the plane and then, climb and then do whatever I want to do. Theoretically speaking, takeoff distance is defined as from the start to a point, where the airplane has cleared 15 metre or 10 metre depending upon type of airplane.

So, this distance from here to here that is A B subject to, it has cleared this height which is 10 or 15 metres depending upon type of airplane, which is also called screen height, then only we say the takeoff is done. Now, as I come back to my earlier discussion that, if you see lot of history of aviation, you find lot of accidents happened during takeoff and landing. And that is why, you will notice if you see physically a pilot manual, which is used by pilot for flying, there are lot of different speed definitions are there.

For example, at what speed the elevators will be effective? At what speed the rudder will be effective? Imagine, on the ground I want to steer the nose wheel, I want to turn on the ground. How do I do that? I use rudder and turn the nose, but for rudder to be effective, there has to be some speed, some defined speed, so that the pilot should know. Then, if it is a tail dragger, you will soon see while he is going for taxiing he will lift the tail through elevator; that means there is a requirement of knowledge at what speed he should push the elevator up.

Similarly, you will find there are limitations like you cannot exceed a particular speed. All these things are done, there are many such speeds you will find for twin engine, there are another class of speed checks are there. Guidance is there, you do this at this speed, you try to obey the landing gear, you will forward general aircraft at this speed only. If you are doing a maneuver, then what is the speed limit he should be very careful.

All those descriptions are given in pilot manual to ensure, that there are no human errors. But, for a designer it means that your design should be able to satisfy, whatever the pilot requirements are there and more importantly, a good design is such designs which helps the pilot to learn in adaptive manner. It should not be too sensitive or it should not be, you know too sluggish. So, all these things will come into the mind of a designer when he is designing an aircraft for any machine.

That is, what our initial lecturer have told you that, when you are designing an aircrafts, please remember somebody like you and me or a human being will be flying. So, you have to make him first most comfortable. So, why I am stressing all these speeds? The speeds are so important to ensure that a proper guidance is given to the pilot. So, he is not crossing those limits and safely, he is flying taking off, touching down, doing manoeuvre and have fun.

So, the whole stress goes on speed. How do I give the feel of speed to the pilot? We have already discussed about airspeed indicator, I will again go back to this concept of airspeed indicator and see, how it functions and what are the sources of error and what are it is implication for a pilot.

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Lecture - 28
Airspeed Indicator and Altimeter: Pilot Perspective

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So, you can see this is the airspeed indicator; there are various coloured markings in this airspeed indicator. First of all you can see the red line, which is the maximum speed or it is the never exceed speed, we call it VNE. The airplane should not be operated beyond this speed. Then, you can see the yellow markings, from here to here you can see the yellow markings. This is the caution range, in which the airplane has to be operated with caution in smooth air conditions only.

Now, from here to here you can see this is the green range, which is the normal operating range. Here, you can see this is the white range, right from say see from 60 till around 110, it is white range that is, the airplane can be operated with flaps down within this range of speed.

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It is basically a differential pressure gauge, which measures the difference between the static pressure and the pitot pressure. The static pressure is the pressure of the atmosphere around the aircraft, the pitot pressure is the impact pressure what develops in the pitot pressure tube due to the motion of the aircraft.

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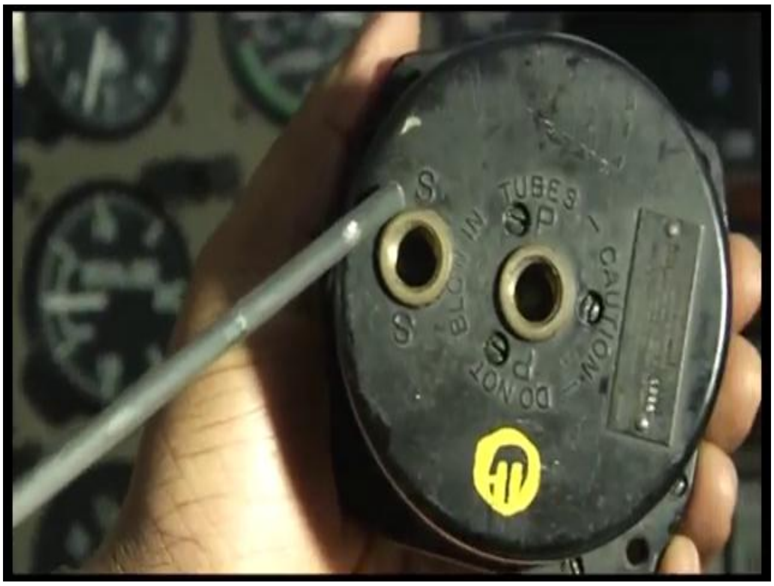

It consists of an air tight case. At the back of with, there are two connections one for static pressure. You can see, this is the opening for the static pressure and the other for the pitot pressure, you can see S written and P written here.

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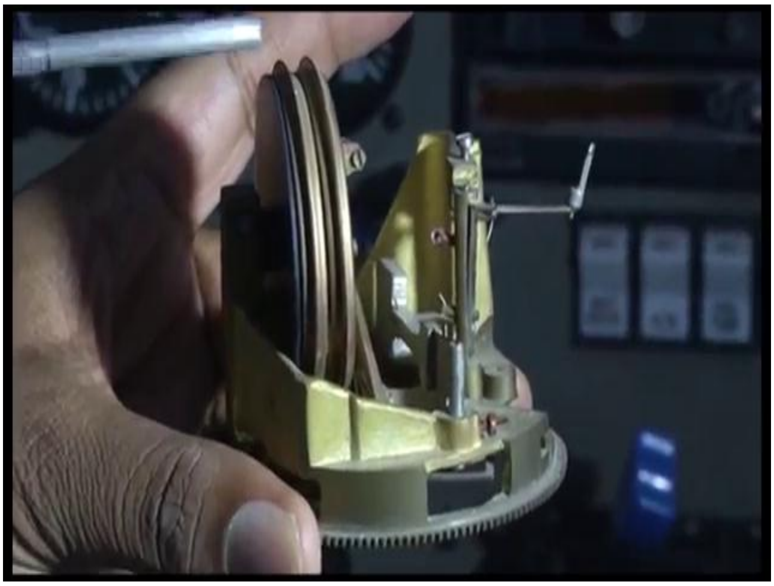

This is an instrument inside, this is a specially treated metallic corrugated diaphragm made of nickel silver or phosphor bronze, which is fitted inside the case on a frame. You can see that, it is fitted on a frame.

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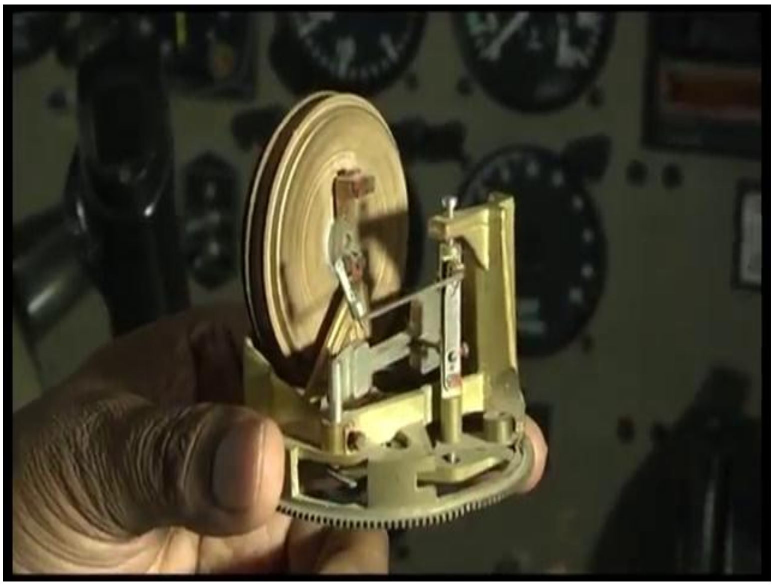

This diaphragm is connected to the pitot pressure, the pitot pressure enters the diaphragm from this hole.

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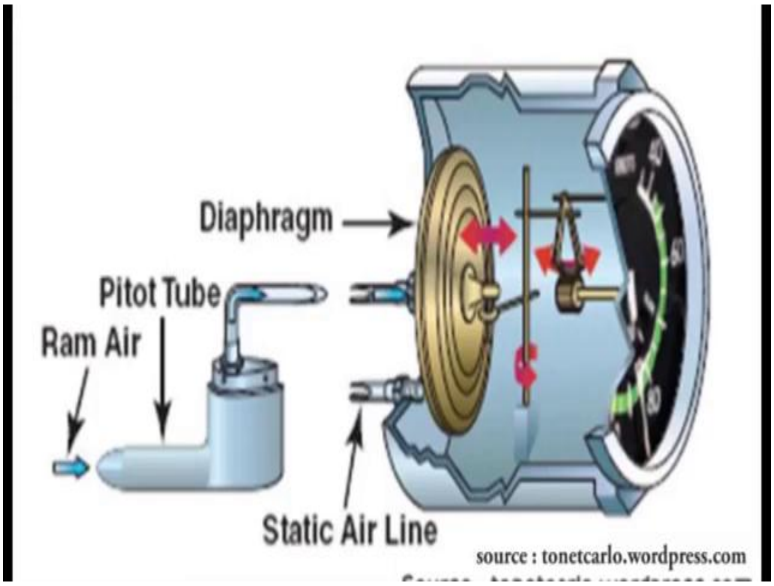

You can see in the diagram, the pitot pressure enters the pitot tube. Through the tubing, it enters the diaphragm through the centre hole. So, inside the diaphragm is the pitot pressure, outside the diaphragm, but within the casing is the static pressure, which from the static vents through the tubing enters the instrument and acts, outside the diaphragm. The movement of this diaphragm ((Refer Time: 08:25)) is transmitted to the pointer by mechanical linkages consisting of link, rocking shaft, vertical bimetallic arm, sector and pinion.

There is a hairspring also fitted to remove the backlash error. As the differential pressure increases, the diaphragm expands and rotates the rocking shat which through the sector and pinion moves the pointer across the instrument dial.

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So, now we will talk about altimeter, this is the altimeter on the instrument panel. The altimeter works on the aneroid barometer principle, which is calibrated to read height. The altimeter is used to give a continuous indication of height on an aeroplane above any reference point.

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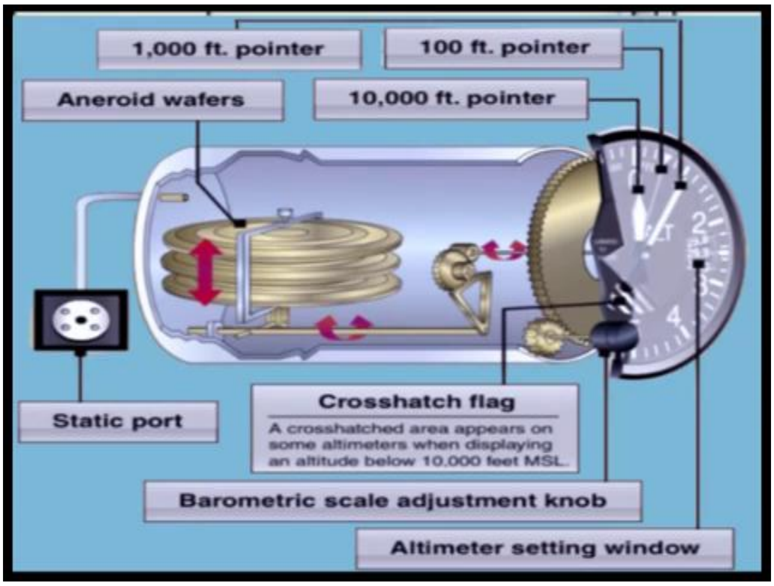

The altimeter is connected through the tubing to static vents, the static pressure through the static vents and the tubing enters the static port.

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This is an altimeter, you can see.

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The altimeter at the back has got one port only through which the static pressure enters. This instrument is inside the casing; the static pressure enters through that port and acts over this capsule. When the airplane climbs, the atmospheric pressure inside the case that is outside the capsule decreases, this causes expansion of the capsule. This movement of the capsule is transmitted to the arm, magnifying lever, sector, pointer pinion and pointer.

These are all the mechanical linkages between the capsule and the pointer and the pointer finally, moves over a dial, which is calibrated in feet. ((Refer Time: 10:19)) The geographical location is not a datum for the altimeter, it is the pressure value which is the zero datum for the altimeter. The altimeter will read the height above the pressure level set on the subscale, there is a small window here and there is a small window here. So, these are the subscales, one is in inches of mercury and one is in millibars.

So, these are the subscales, so whatever pressure is set on these subscales is the zero datum for the altimeter to read. To find the height above a particular point, set the pressure at that point on the subscale. See there are three pointers, number one number two and number three, this is the long pointer which indicates altitude in 100 feet. This is slightly shorter, this indicates the altitude for 1000 feet and the third one indicates the altitude for 10,000 feet.

In order to find the height above a particular point, set the pressure at that point on the subscale. Suppose, we need to find the height at this point, where we are standing we need to set the pressure here or here. At the moment, the pressure here at this point is around 290 inches of mercury, which I am going to set. You can see, this is the nob through which we can adjust the subscale in the Kollsman window.

So, I am adjusting the pressure prevailing at the airfield now to 290 inches of mercury, which is almost equivalent to 990 millibars. You can see, the altimeter is reading 0, so this is commonly called QFE setting.

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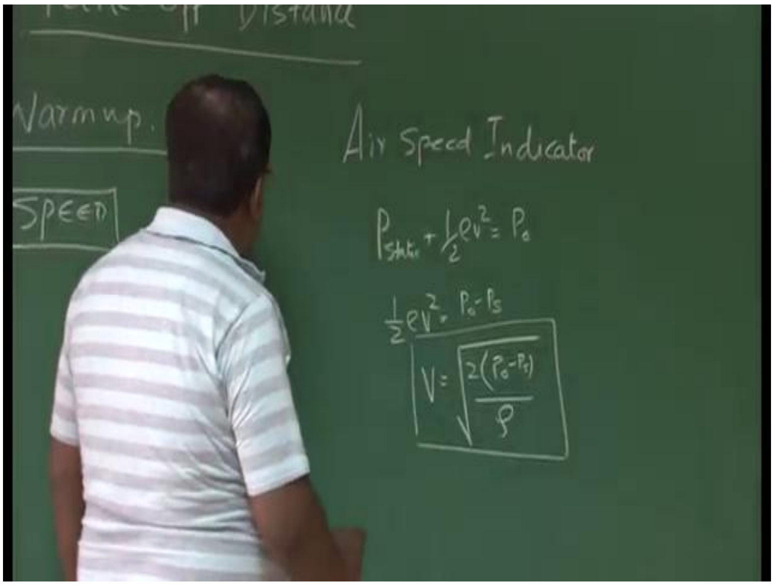

So, let us revise, we remember that we are using airspeed indicator and the principle was basically, I know P static plus P dynamic which is half rho v square is P total, P naught and we also know from here, that half rho v square is P naught minus P static. So, V is 2 P naught minus P S by rho under root. And we have seen that in an airspeed indicator, there are two inlets, one inlet is for static pressure and one is for total pressure and the difference is sensed by a diaphragm.

So, it contracts expands like this and this motion gets translated using a lever and you see, the readings on the dial gauge. It is as simple as this as principle is concerned. But, let us see what is this V, this v is basically the true airspeed.

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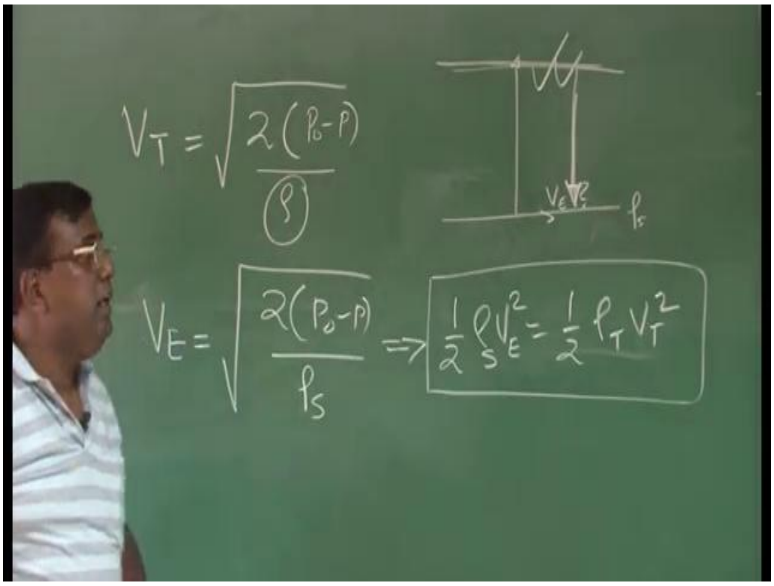

So, this V is basically true airspeed, because rho is the actual density at the altitude you are flying. But, for calibration purpose you could understand, every altitude getting density and all, then calibration will be a difficult thing. So, we have defined some speed V E, where this is same dynamic pressure; however, rho is rho S which is the sea level standard atmosphere value. Now, if I again see this expression little carefully, what does this expression means to us?

This is equivalent to say half rho standard V square equal to half rho true V true square. You could see easily here, P naught minus P you replace P naught minus P by dynamic pressure and then, you can see this nothing but, half rho S V equivalent square half rho true V true square, we have seen this. What is the meaning of this? Meaning, thereby is that if I am flying at an altitude, some pressure altitude I am flying and I am noting down, what is the dynamic pressure there, true dynamic pressure.

And I am now trying to fly at rho S standard density, standard atmosphere at sea level and try to see, at what speed I should fly. So, that the true dynamic pressure here and this, at this altitude is duplicated. Is it clear? So, I am flying at a altitude, where dynamic pressure is half rho true V true square, now I am flying at sea level condition, standard atmosphere and I want to see what is that speed required to duplicate this dynamic pressure, which is sensed at this altitude. So, this is the concept of equivalent airspeed and that is, what is used in airspeed indicator.

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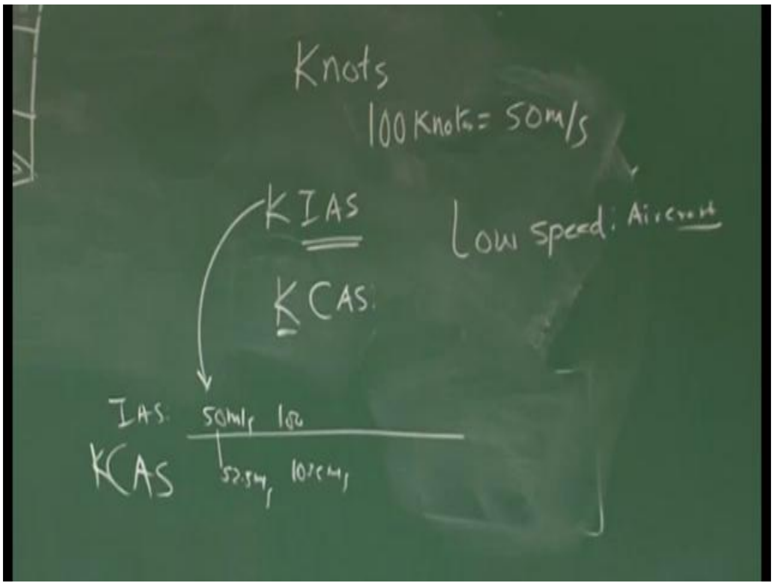

If you see a airspeed indicator, you will find routinely they are using unit knots and 1 or 100 knots is roughly equal to 50 metre per second. This is the unit around 0.51 metre per second, roughly it is this. Also you will see that, they use term like K I A S, I A S for indicated airspeed, which is equivalent airspeed, K is in knots, so K I A S. They also use something called KCAS, which is called Knots Calibrated Air Speed. What is calibrated airspeed for low speed aircraft? I will be on discussing.

Please understand, we are mostly focused on low speed aircraft. This is typically less than 0.3 max, so that flow is incompressible. So, what is the need to define calibrated airspeed? Let us understand that.

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Suppose, this is the airplane, now first problem what we face. When we try to find out a point, where I can tap the static pressure, which is the static pressure if the aircraft was not here as a free stream condition. What will happen, you see depending upon the contour, the static pressure will go on changing at different points. So, it is through experience, we try to find out some point mostly in fuse large, where you give an inlet from where the static pressure is tapped.

You will also find, there is also a method to install pitot's tube at the wing tip and this wing tip is like this, I am exaggerating this tube. So, this is the inlet for total and there will be some gap here, where from static input will go. So, basically there should be two tube like this, from here whatever is going inside is total and from here, if I keep opening here, slight opening, so this static pressure could be measured. There are many variants, but what is important.

Depending upon where we have put these things, here or here or somewhere here, because it is positioned, you will find some wrong measurements are coming. So, they are calibrating in a tunnel and find out, what is that point where you get exactly what you are supposed to get or other way it is, you have no other option to put at some particular point, because of other consideration.

Then, you calibrate this way wind tunnel or other measurements that is, the meaning is whatever you are reading in the KIAS or the airspeed indicator, there will be a chart calibrated airspeed. So, suppose this is 50 meter per second, IAS what you are reading from. Your ASP indicator, it will give please read this as 52.5 metre per second. Suppose it is 100, there will be something 103.6 metre per second.

So, this calibration chart is available to the pilot to get an exact feel of what is the relative airspeed he is flying with. Please understand, these are not giving very true airspeed to the pilot. Although, if you are flying at low altitude, these two speeds are not much of a difference, but the most of the information for flying the machine, pilot will be using almost all will be using this KCAS calibrated airspeed which is nothing but, equivalent airspeed.

To get little more depth into this, as I have mentioned in one of the lecture, it is not only know how, but it is also do how. So, that you can one day celebrate it is show how. Show how happens, when you design an aircraft and make it fly the way you want. So, we solve an example.

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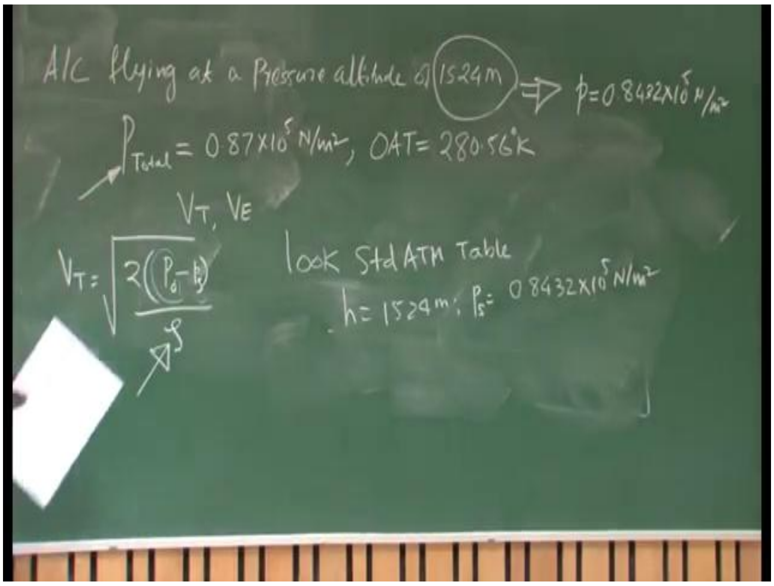

Let us say one aircraft, which is flying at a pressure altitude of 1524 metre. The aircraft flying at a pressure altitude of 1524 metre and P total, let us say the aircraft measured was 0.87 into 10 to the power 5 Newton per metre square. Please understand, this is the P total that is a central tube of the pitot’s tube. Let say, it was measured to be 0.87 into 10 to the power 5 Newton per metre square, calculate V true and V equivalent.

You could see that it needs one more information. Because, I know that let us also add one more information that the outside air temperature, which was measured through independent measurement, it was 280.56 degree Kelvin. Now, the question is, calculate true airspeed and equivalent airspeed. This example will give you a feel for numbers that is the purpose, why we are solving this example. We know that V true is nothing but, 2 times P naught minus P by rho.

Please notice here, when I am calculating V true I want density of air at that altitude, where it is flying. What is the P naught there? P naught there is nothing but, given here as 0.87 10 to the power 5 Newton per metre square. The next question is, what is this P now? P means P S that is static pressure. How do I find out? At that altitude, at the pressure altitude always gives static pressure. So, I will now look standard atmosphere table and check, at h equal to 1524 metre, what is the P, which is P S.

And if you check that, you will find that P S is around 0.8432 into 10 to the power 5 Newton per metre square. So, is it clear, what we have done? The aircraft was flying at an pressure altitude of 1524 metre and once I know this, I check standard atmospheric table and I find that, that P was 0.8432 into 10 to the power 5 Newton per metre square. P naught is given, but I do not know how to find rho, but for rho what I will use.

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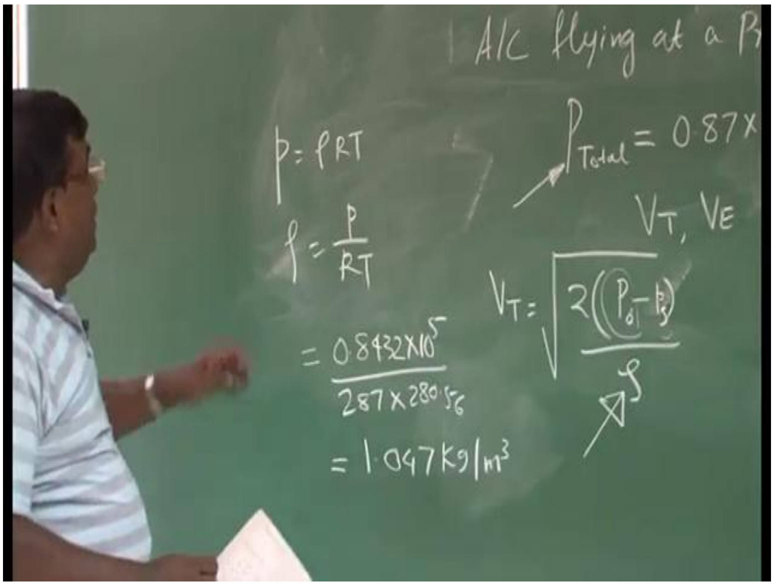

P equal to rho R T, so rho is P by R T and if I substitute the value, I will get 0. into 10 to the power 5, R is 287 and temperature is 280.56. Please understand here, I have taken

0.8432, because this value I have got from where, from the pressure altitude that I will be using, not the total pressure. So, this will give me rho as 1.047 kg per metre cube. So, what is this 1.047 kg per metre cube? It is the density of air, where the pressure altitude was 1524 metre and what I have used. I have used additional information, whatever was the outside air temperature at that altitude.

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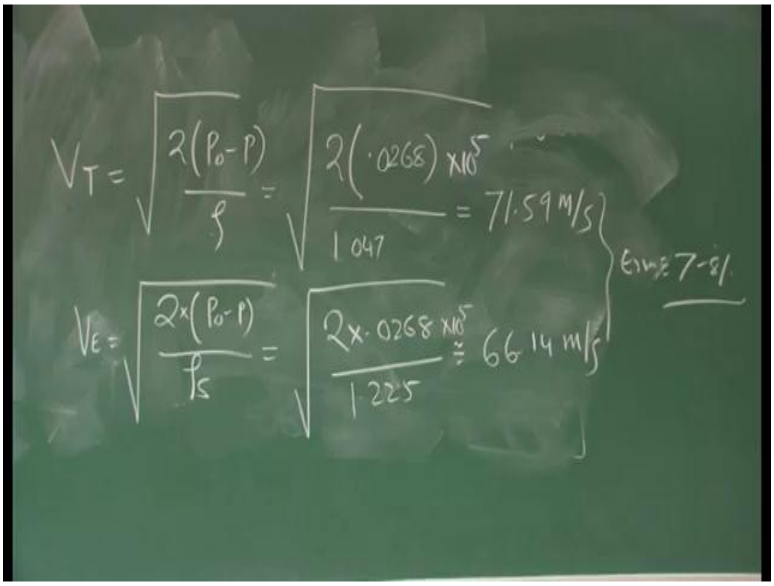

So, I have to find V true. V true, I know it is 2 P naught minus P by rho. By now, I know the value of rho, so I substitute this is 71.59 metre per second. Now, let us find out the equivalent airspeed. What will be equivalent airspeed, that will be same thing 2 into P naught minus P, instead of rho it will be rho S, sea level standard value of density. So, what is the message? Message is through air relative speed is 71.59 metre per second, but V equivalent air relative speed is actually what I am seeing in the dial gauge or airspeed indicator is 66.14 metre per second and roughly, the error is of 7 to 8 percent. This will help you in calculating equivalent airspeed and true airspeed.