Introduction to Flight
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Lecture 17: Number 02.1
Air speed measurement – Pitot Static Tube

Now, let us go for Air Speed Measurement. Now, for the Air Speed Measurement we use a system which is called as a "Pitot Static System" in respect to a scientist called Pitot who was very much active in pneumatics. So, this is a system that is used to measure the aircraft's air speed. We will see in detail how the system works but in principle you can see that there is a tube, which is the one on the bottom, the L shape tube, you take the ram air or the ambient air, you bring it to rest isentropically, connect it and then there is also a static pressure. So, let us see how the system work then we will be able to talk about it in more detail.

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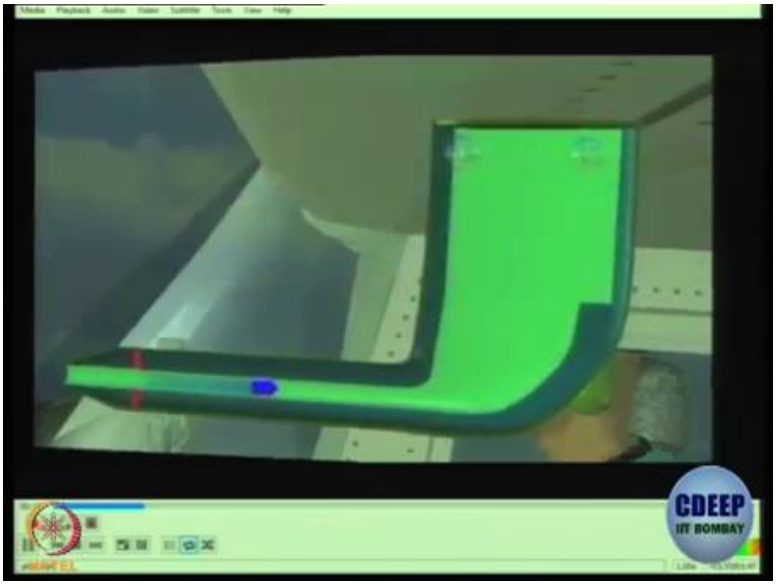
The pitot-static system is an essential component


The Cessna 172's pitot tube...
N1234




The anatomy of a pitot tube
Pressure Chamber
Static chamber
Baffel plate
Pitot tube
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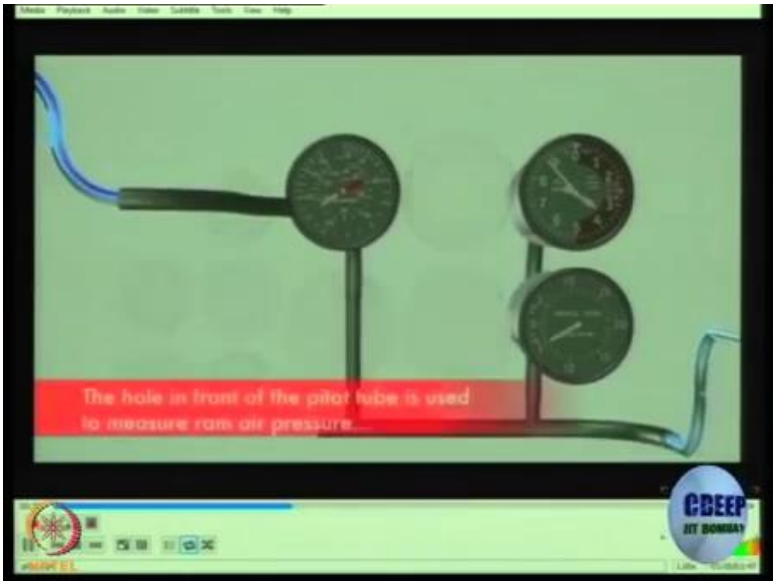
The hole in front of the pitot tube is used
to measure ram air pressure.
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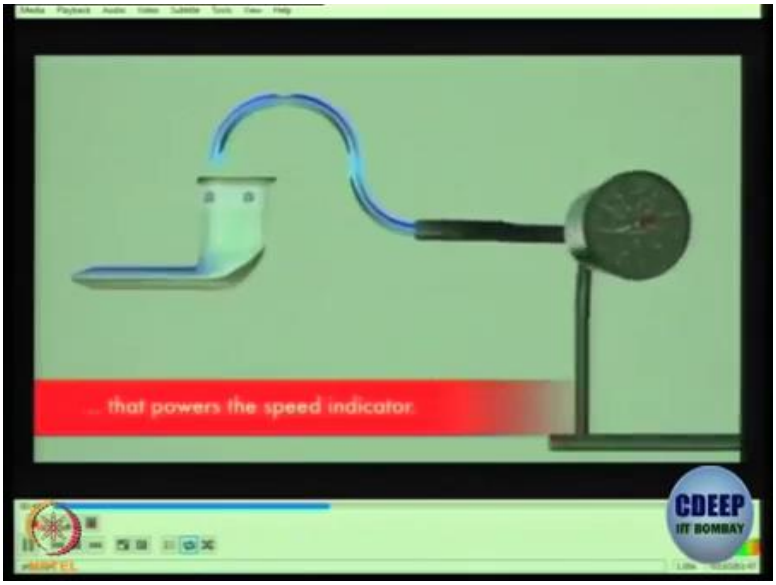
... that powers the speed indicator.
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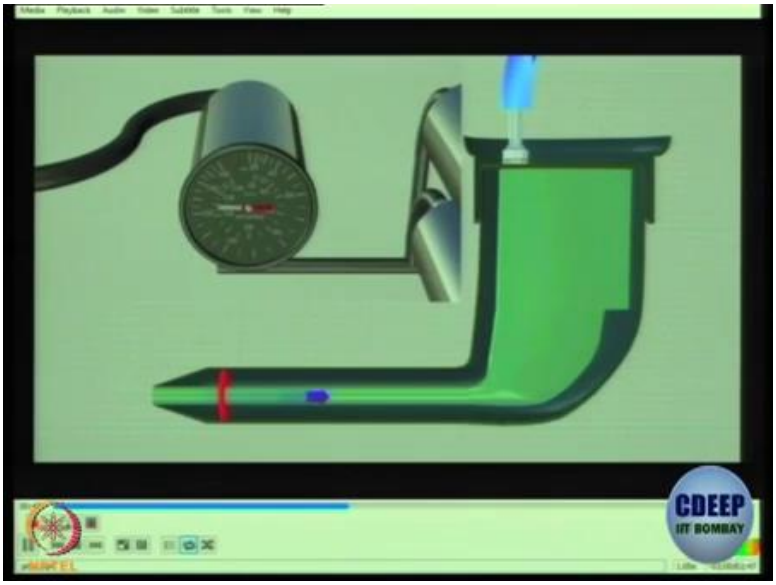
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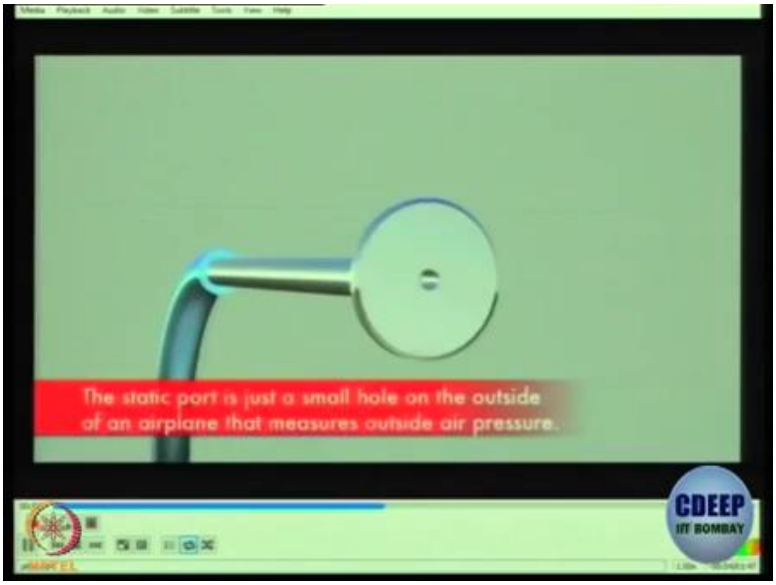
The static port is just a small hole on the outside
of an airplane that measures outside air pressure.
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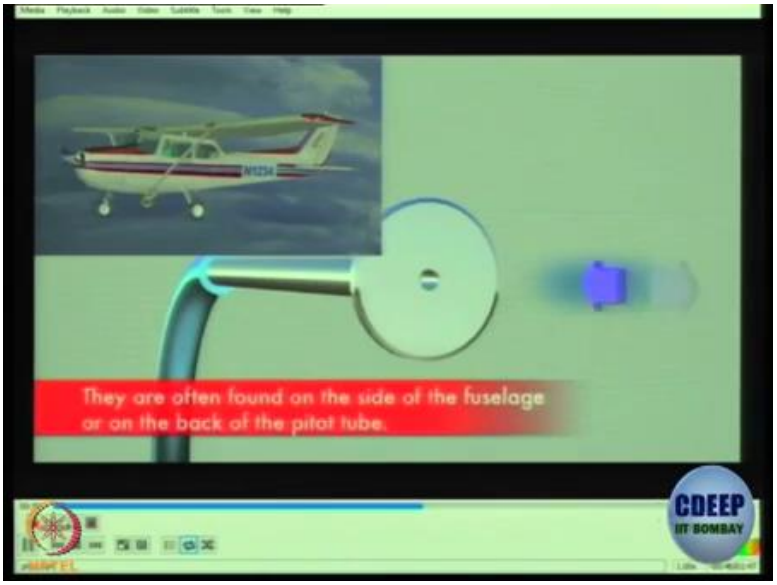
They are often found on the side of the fuselage
or on the back of the pitot tube.
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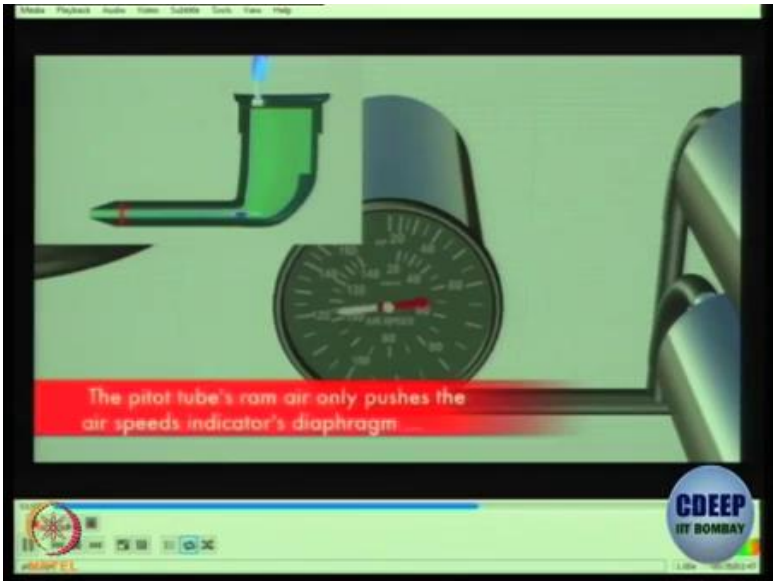
The pitot tube's ram air only pushes the
air speeds indicator's diaphragm
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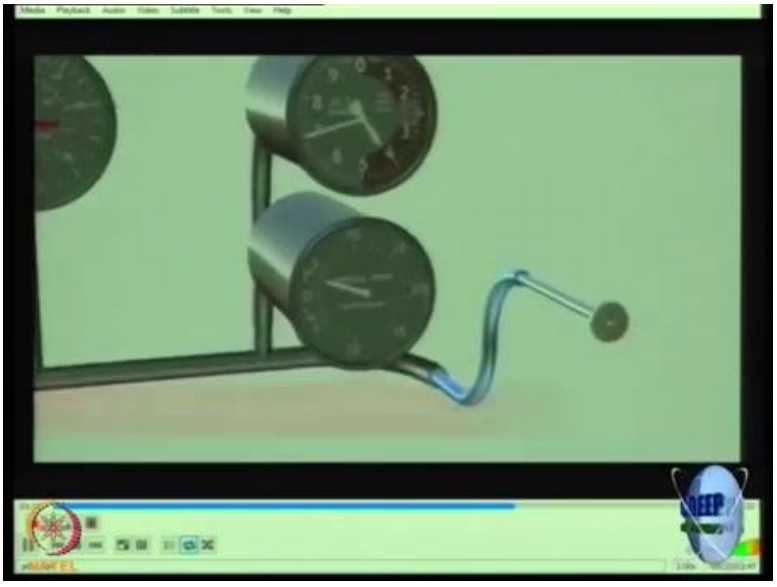


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Both the static port and pitot tube are prone to multiple failures.
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The pitot-static system must be inspected every twenty four months.
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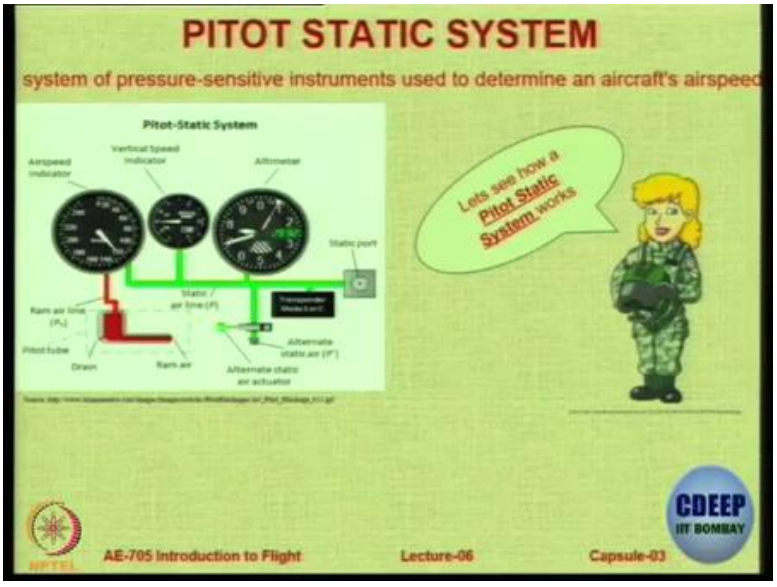
PITOT STATIC SYSTEM
system of pressure-sensitive instruments used to determine an aircraft's airspeed
Pitot-Static System
Airspeed indicator
Vertical speed indicator
Altimeter
Static port
Ram air line (Pt)
Static air line (Ps)
Pitot tube
Drain
Ram air
Alternate static air actuation
Alternate static air (Ps')
Lets see how a Pitot Static System works
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AE-705 Introduction to Flight
Lecture-06
Capsule-03

Video: The pitot static system is an essential component that powers three vital flight instruments. The pitot static tube contains the baffel plate, the Pitot tube, the static chamber and the pressure chamber.

Professor: These are mechanical instruments.

Video: The hole in front of the Pitot tube is used to measure ram air pressure that powers the speed indicator. The static port is just a small hole on the outside of an airplane that measures the outside air pressure. They are often found on the side of the fuselage or on the back of the Pitot tube. The Pitot tube's ram air only pushes the air speeds indicator's diaphragm. The air does not flow past the speed indicator. Static port pressure is fed through internal tubing where bellows expand and contract that powers both the vertical speeds indicator and the altimeter.

Professor: We will study about them later.

Video: They indicate climbs, descents and changes in altitude. Both the static port and Pitot tube are prone to multiple failures. The pitot static system must be inspected every twenty four months.

Professor: Twenty four months is just an indication actually it's inspected more frequently. Ok!

So the voice in the video was that of Siddharth Joshi who actually made this presentation. So we saw that the system consist of a pitot static tube, which measures actually it has an intake which directly measures the total pressure and the static pressure comes from the side of the aircraft through the static holes which we will see very soon. So the difference of them can be shown as the dynamic pressure or half rho v square and therefore you can get the value of v.

The other two instruments the vertical speed indicator and the altimeter work only on the static port; because they are only going to measure the parameters based on the static pressure which changes. Ok!

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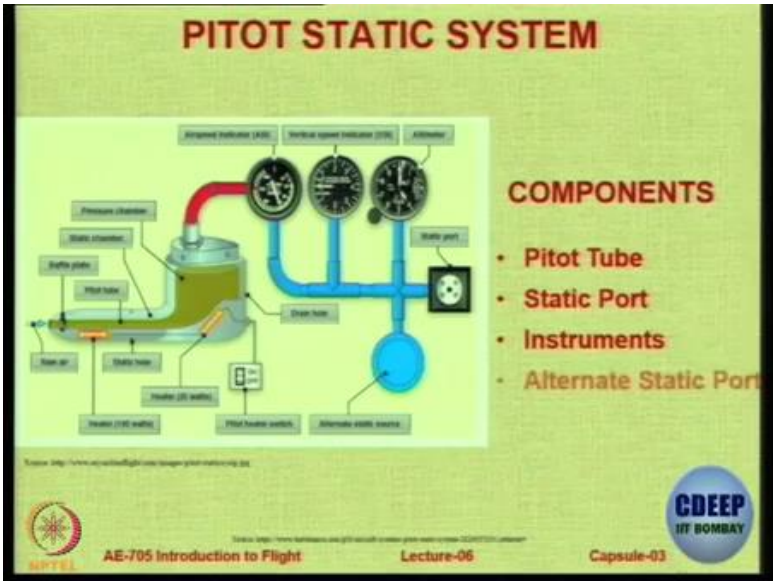

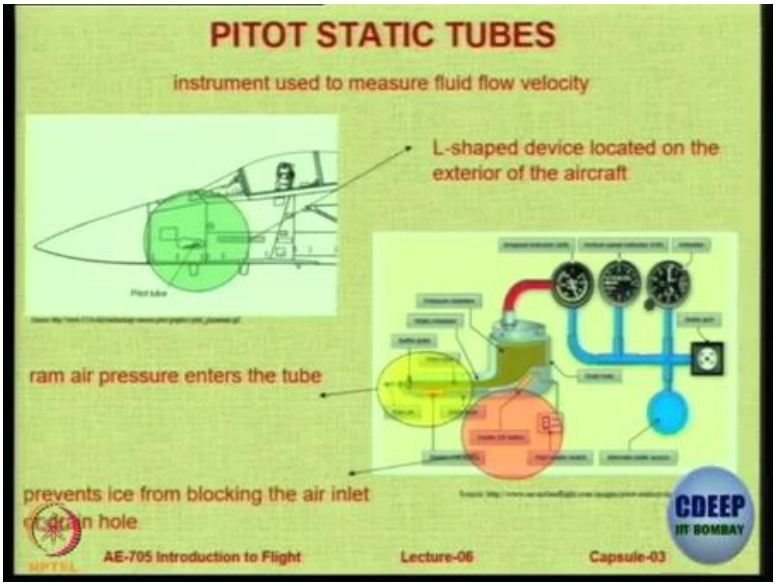

So this is how the pitot static system works. So there is a pitot tube, there is static port. There are instruments and there is alternate static port for removing the errors or any blockings, because of any blockage or any error there could be mismatch so there are backup. So you can see in this particular example the Pitot tube is mounted on the fuselage. It could be in the nose. There could be a boom coming out in the front with the pitot static tube. There are many many locations. And the location is decided based on the different aircraft to remove an error which we will study about called as the position error.

Basically we want it to be in substantially undisturbed flow. We want it to be like that. Alright, so ram air pressure enters the tube and it prevents ice from blocking the air inlet to drain hole etc.

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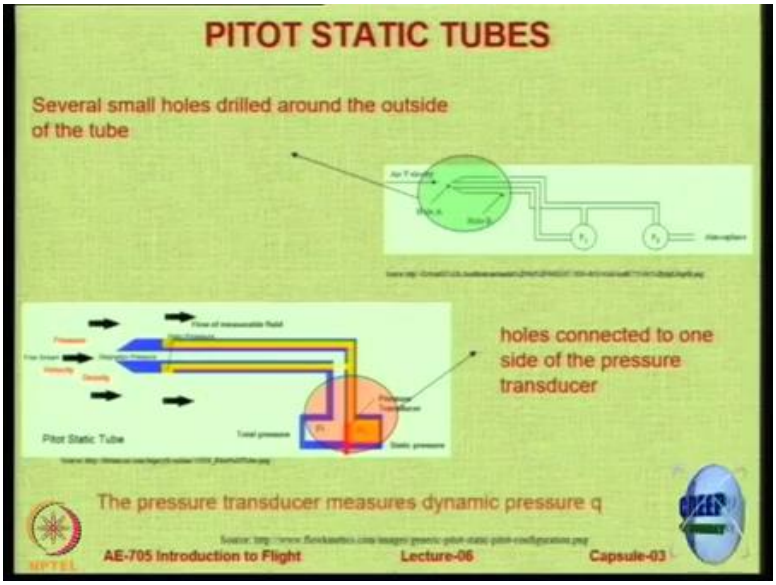

We have already seen this this is the simple explanation and I am putting this in the presentation merely to allow you to use it for self-study. I think the system is very standard.

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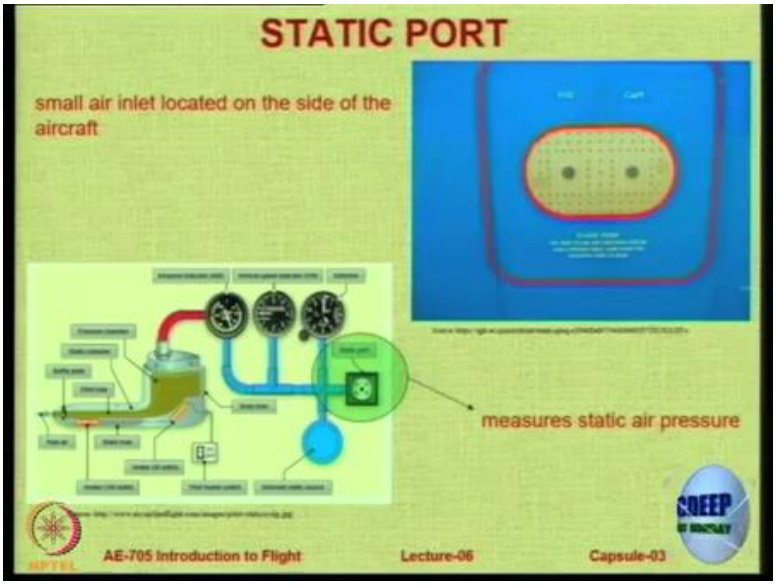

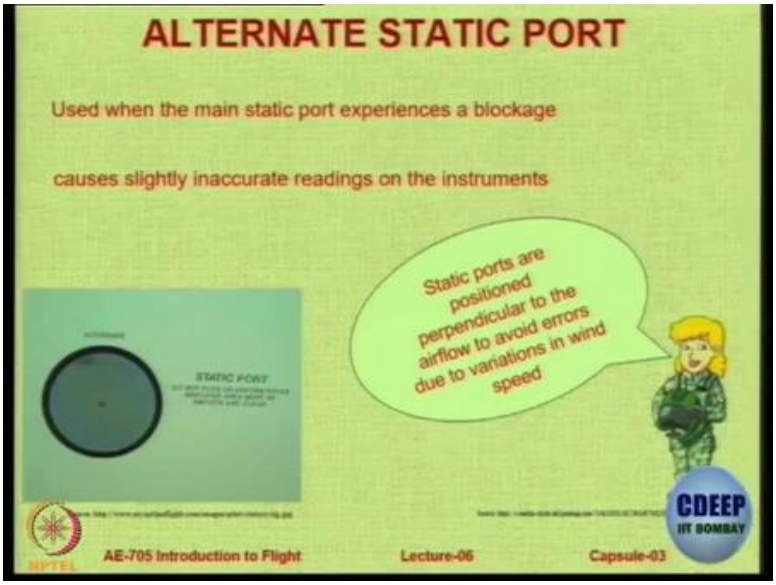

So this a photograph of a static port which is on the side of the fuselage. So these are small air inlets which are on the aircraft side and they are the ones which are conveying the static pressure to this particular system. Alternatively you also need to have some other static ports to ensure that if there is blockage you don't get any false reading. So there could be static ports on the other side of the fuselage there could be static ports at some other place; but the important point to be kept in mind is, that there should not be a location of static port which causes errors. It should actually be in such a place where it is perfectly perpendicular to the oncoming free stream. So you could put it on the side of the pitot static tube itself which is done most of the cases or you could put it at some other locations on the aircraft. Ok!

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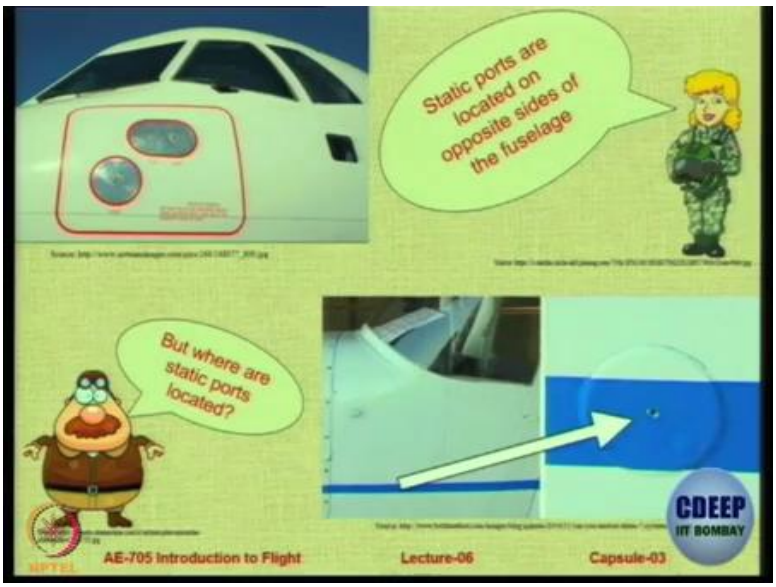

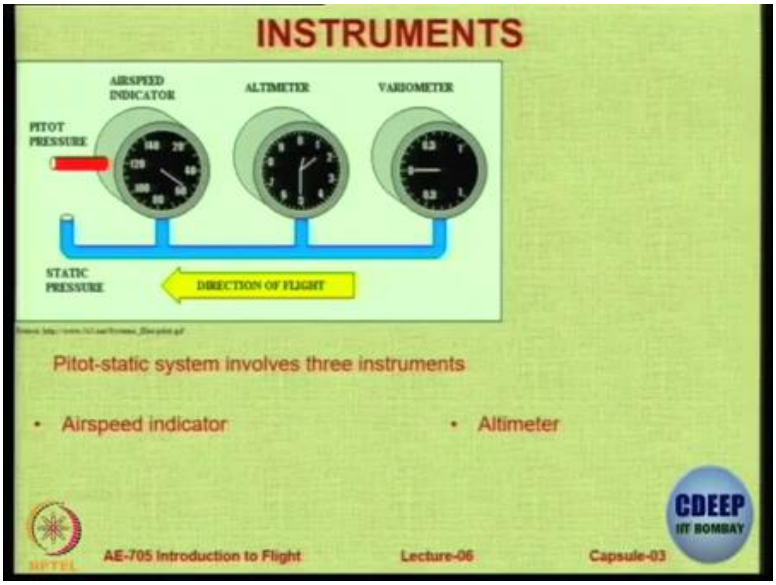

So where are they located? So you can see here these are the examples of the main and the backup static ports on one transport aircraft and this is the another example of the location of static port and these are actually sign posted very clearly. Ok! So these are sign posted. So there is the pitot static system which actually involve these three instruments. Variometer is basically the indication of the change in the height.

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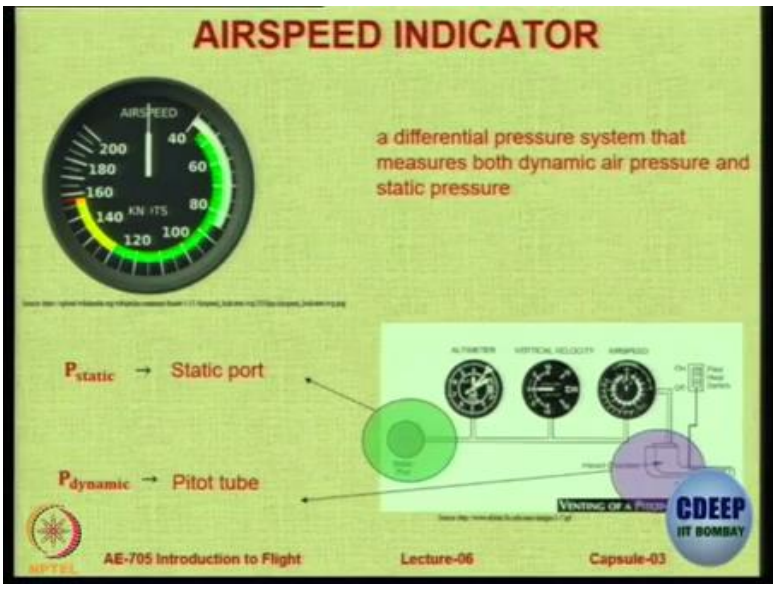

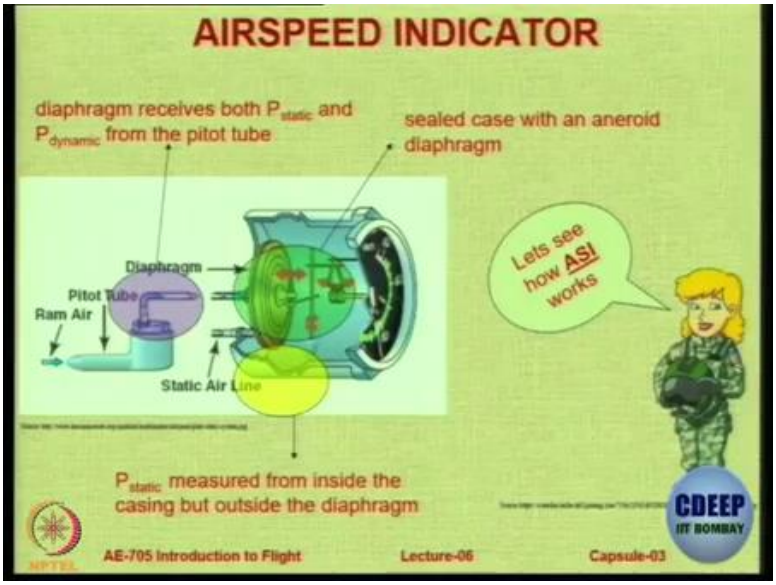

Let us look at the Air Speed Indicator first. It's a differential pressure system which measures both dynamic air pressure and static pressure. So, the dynamic pressure is converted. So total pressure its wrong, the total pressure comes from the Pitot tube and static comes from static port and the difference is going to push. So interestingly the air does not go through the instrumentation.

Yes, there is a question?

Student: Sir as static ports are perpendicular to the flow where air flow, then do not you think when air will flow the local pressure just above the static hole will get down so we will get ball sitting.

Professor: Why do you think so?

Student: Sir, because according to Bernoulli's principle when the velocity dynamic head is high then the static we get the static low static reading.

Professor: So, when I say perpendicular to the flow what I mean is that if the air is flowing like this I put it like this. So when I put it like this, dynamic pressure is not conveyed to that port.

Student: But Sir, local pressure will get reduced.

Professor: Why? There is there is a stream let us say there is a streamline, on that streamline you have a flow of velocity v, so if I put the probe along the flow direction opposing it, then I am going to bring it to rest isentropically or maybe it does goes through, then I can get

understand; but if there is a flow stream this way and the port this way then it is going to measure only static pressure. How will Bernoulli's principle make any difference on this?

Student: Actually I thought that the total energy must be constant up that a pressure head plus dynamic head must be constant.

Professor: Right!

Student: So, if dynamic head is rising, then the;

Professor: Why, why is it rising?

Student: Because sir, there is a velocity of the air so the dynamic head is there.

Professor: Yeah. So, there is a dynamic head it is not rising. The dynamic head see as I said, you locate these instrument at a place, where the velocity is roughly equal to the free stream velocity. That means the velocity is constant, if I put it at a place where there is a bulge in the aircraft then I understand your point that because there is bulge in the aircraft the local velocity there may not be equal to free stream velocity. Then there can be errors but the location of the static port is at those places on the aircraft where we do not expect too much change in the ambient velocity. There will be a change, see the presence of anybody definitely will affect; but how much? So instead of putting it right let's say below behind the propeller, then it is a wrong reading because the propeller is going to give some dynamic pressure. Or if I put it in the wake region where there is a reverse flow or if I put it at some other place where the flow is separated. So I put it in a location where I expect the flow to be attached. Ok! I expect the flow to be may be a slightly more than the ambient or almost equal to ambient and undisturbed. So the direction is such so that's why on the fuselage sides below the cockpit not very much ahead not not too much behind, Good! Any other question anybody has? Yes, mic please.

Student: Sir, myself Venkat Salve.

Professor: Yes.

Student: Sir, the boundary layer effect it will show some stagnation and static pressure also.

Professor: Definitely! Definitely it will. So, the thing is this either you keep it projected out like, I will show you some example, where there is a lateral gap between the fuselage and the pitot static tube. The purpose of that is as long as you clear the boundary layer you will not be.

So, the boundary layer is going to slowly build up, okay. So, that is why the location of the static ports is such that we do not expect, it is normally located at the point before the expected transition point. So, there will be boundary layer but it will be perhaps laminar or the disturbance because of that will be minimal; but still we will correct for it. We will not take that direct pressure reading. We are always doing a compensation, which I will talk about.

Student: Sir and one more doubt.

Professor: Yes.

Student: Sir I want to add a point to his argument. Yes. Sir let us consider aircraft is flying at a some altitude.

Professor: Yeah.

Student: Fixed altitude.

Professor: Yeah.

Student: And as the aircraft speed increases aircraft speed increases, the dynamic pressure increases.

Professor: Yes.

Student: So there may be chance of decreasing static pressure and we make it wrong altitude value.

Professor: No no no, if the dynamic pressure is increasing why should static pressure decreased.

Student: I mean ask for as per Bernoulli's principle, the velocity increases the static pressure decreases as far constant pressure.

Professor: Is it is it is it really true? Is it a long, Do you agree with this? So let we see if somebody can clarify this point. Yeah take the mic please.

Student: Sir the error in his assumption is because it is not the fluid that is flowing, so it's not its energy that is we have to consider it. The relative velocity, dynamic head that is the fluid is getting in, because of the motion of the aircraft. So the relative velocity just we cannot assume

that, because the velocity is increasing the static pressure is decreasing. The pressure of the air is constant. It is the speed of the aircraft that is increasing thereby there is increase.

Professor: Ok! Anybody else would like to add?

Professor: Yes.

Student: My name is Devansh Sharma.

Professor: Yes.

Student: So I think, in this case when the aircraft is increasing its speed the flow is not steady. So we cannot apply Bernoulli's principle in this case we need to account for the energy change also.

Professor: No, why do you think the flow will become unsteady? Is it going to a flow is unsteady, when there is a time component to flow.

Student: Yeah.

Professor: So this unsteadiness is a is present… no I do not agree with you, the flow can be still steady. When I am in, let us say I am in a cruising flight, I maintain a velocity and then I accelerate. It does not mean that the flow is unsteady. Unsteadiness is present in a flow, only when there is a time related component of the flow.

So it is not because of the flow is steady or unsteady, and anyway unsteady flow we cannot apply Bernoulli's principle. So there is no question of saying that, the flow is unsteady and hence Bernoulli's state something; Bernoulli cannot be applied. So unsteadiness is not the reason or not the not the justification. Ok! Think about Anybody, you also had a point just next to you there is a person.

Student: Sir my name is Amogh.

Professor: Yes.

Student: Sir, we are placing the pitot tubes at positions where there is like like where the speed of the aircraft is not affecting the wind speed outside the aircraft. So even if, we are accelerating the stream velocity of the wind is not changing. Therefore I do not think there will be any change in static pressure.

Professor: Yeah. I would said, do not try to doing any Bernoulli's principle here, okay. Do not think that because we have studied Bernoulli's principle we have to put it everywhere. This is a very simple thing now you are locating as far as possible these sensors in the area where the conditions are equivalent to the free stream conditions. So, the free stream has some static pressure, simply because of the altitude. And the free stream has static pressure a dynamic pressure because of its velocity. So, as long as I do not mess up with them. I will not be getting too many errors in the instrumentation. Okay. Shall we go ahead? Convinced? Ok. Yes.

Student: Hello!

Professor: Yes.

Student: Sir, my name is Vibhushi.

Professor: Yes Vibhushi.

Student: And my question is that will the pressure measured it will it differ with the speed of the aircraft. Could it change?

Professor: The you mean to say that, which pressure static pressure or dynamic pressure?

Student: Static pressure.

Professor: No, static pressure is a function only of the altitude. So, what is static pressure at that altitude because of the weight of the atmosphere above it? What is the load acting on an element above and below and we showed in the first class I think or in second class. First class was just course introduction. In our first lecture on atmosphere, we showed that, the static pressure basically is a function only of location in the atmosphere. So, if an aircraft is flying at any speed, now if you bringing supersonic flow, shock waves shock waves, boundary layer interaction, then things might change slightly; but let us keep it away. Let us say we flying from marked number point one to point two to point three, static pressure will have no change. The only change will be the dynamic pressure. Ok!

Student: Sir.

Professor: Yeah mic.

Student: Sir my name is Vardhir and my doubt is that, when we say pressure altitude then we look at the reading of the pressure and we compare with the standard atmosphere and we said, the we are at this altitude. So, when we read the pressure reading will it be a total pressure or static pressure or dynamic pressure?

Professor: What do you think?

Student: I think total pressure.

Professor: Why? Why are you bringing in velocity effect? Total pressure is dynamic plus static.

Student: Yes.

Professor: Why are you bringing in the velocity factor into consideration? We want to measure the pressure in the we want we want to find out what is the pressure that the aircraft is facing? And that pressure is faced by an aircraft under the ISA table at so and so altitude. So, it is static pressure. So when we, yeah so altitude, I will show you very soon altitude measurement. Altitude measurement is only using static pressure. Ok! It is a static pressure. We will not use total pressure for altitude measurement. Ok. So let us now see how this Air Speed Indicator works. So very short video.

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How It Works
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How It Works
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How It Works
PassFaaExams.com
Source: https://www.youtube.com/watch?v=lyyc_CurfUs
asi.mp4
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Video: As you fly through the air faster and faster as shown by the animation. The air striking the Pitot tube enters more rapidly and this expands the diaphragm further and further. The diaphragm connected to the sector for levers which rotate it and in turn this rotates the hand of pinion that is directly connected to speed dial and displays the current speed. As you fly through the air faster and faster as shown.

Professor: Ok! It is very simple. As the speed of the air coming in that pitot static tube or a pitot tube keeps on increasing. The bellows are going to expand more because they are under higher pressure. And there will be a static pressure acting opposing to it. So the difference will be the dynamic pressure. So this is how the ASI work. So you have one line you have static pressure from inside and outside the diaphragm they cancel out. Ok! So the change in the air speed is shown by the needle. Ok! So now we have to look at corrections because whatever is measured by the instrument one should not blindly believe it. Ok!

If the aircraft is flying, at a reasonable speed and you know its flying because you can see things going passed you and the air speed indicator shows zero.

It does not mean that the speed is zero. Ok! Can it happen in a flight? Do you think it can happen in a flight, that aircraft is flying and the indicator shows zero? What could be the reason? Under what condition can you have?

Professor: Yes.

Student: My name is Atharv.

Professor: Yes.

Student: The opening of the Pitot tube blocked.

Professor: So will it shows infinite speed or zero speed?

Student: Zero.

Professor: Why? If the opening is blocked, the opening is blocked so what will the instrument read?

Student: momentum transfer.

Professor: Where is a momentum transfer into the instrument?

Student: We stop the air, so.

Professor: No, the opening is blocked, so there is no sensing now. The opening is blocked. Since the opening is blocked then the pressure convert is how much? Ok! At what height do we have zero pressure? Where? In space, so it will show that you are in space, because it does not get any pressure. Ok!

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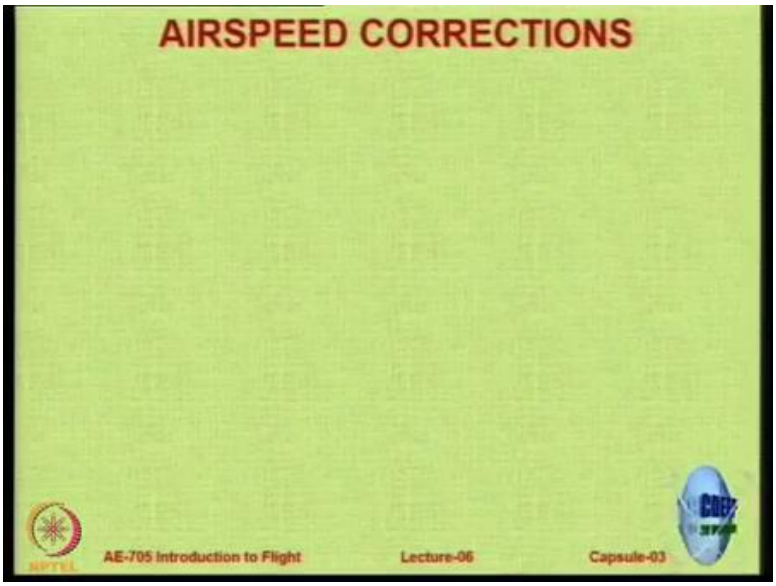

So when can, when can you see it zero? Yes when we will see the pressure is zero, a value, when that reading is zero?

Student: Sir if the opening is blocked then how come it will show the infinite pressure.

Professor: No not infinite pressure. It will show zero pressure.

Student: Sir how come it will show zero pressure?

Professor: Where is pressure zero in atmosphere? Where is a pressure highest in the atmosphere?

Student: Sir ground level.

Professor: So if we go up pressure reduces reduces reduces reduces. Where do you get zero pressure?

Student: outside the atmosphere.

Professor: Correct. So that means if the if the indicator is blocked, it should show the infinity right. It should show that you are in outer space, where there is no pressure. The instrument does not know where it is sensing or where there is a mistake.

Student: Sir, but there will not be the vacuum inside the instrument.

Professor: There will be some air inside the instrument, though that air is stationary and now the intake is blocked. So the pressure acting on the bellows by a stationary fluid in a tube is zero.

Student: If the fluid will have some pressure?

Professor: Why it will have a pressure.pressure from the fluid come either because of motion or because of the altitude? Now you have a tube containing air and you blocked it.

Student: Sir the pressure.

Professor: No you try it out, take a tube. Ok! Put a pressure gauge and just block. The pressure will be zero and pressure is zero at infinity altitude, in the atmosphere.

Student: Sir it only measures pressure when it it's changing.

Professor: No no no not that. It measure it measure the pressure which is conveyed to it. If it if that if you remove the block suddenly it will get some pressure because now the now the static pressure is going to be conveyed to the instrument. So if you remove the block it will show the correct pressure and that correct pressure will move the instrument to the correct value. Ok So now the question is when it will show zero?

Yes anybody can answer or you want to do it on moodle. Yes what do you think? When will the instrumentation show zero speed?

Student: Sir my name is Namya. When the wind speed is same as a speed of the aero plane, there is no net difference between the speed ratios zero velocity air speed.

Professor: What do you think? Are we measuring relative speed in the instrument or the real, total or the actual speed?

Student: Sir I did not get that part like when the wind affect the ends.

Professor: I am asking the question to everybody in the class. It's a good point. Do you think if the if the speed, so do you think do you think the instrument is showing you the true air speed or the relative air speed? You answer yourself. You are saying that, if the aircraft is flying at speed 'v' and the wind is coming from the front at speed 'v' opposite direction, then the instrument should read zero; but the instrument in the instrumentation did we ever say measure the speed of the aircraft, measure speed of the wind do the cancellation and then display. We did not. So what we are measuring is only the ambient wind speed. Think about it.