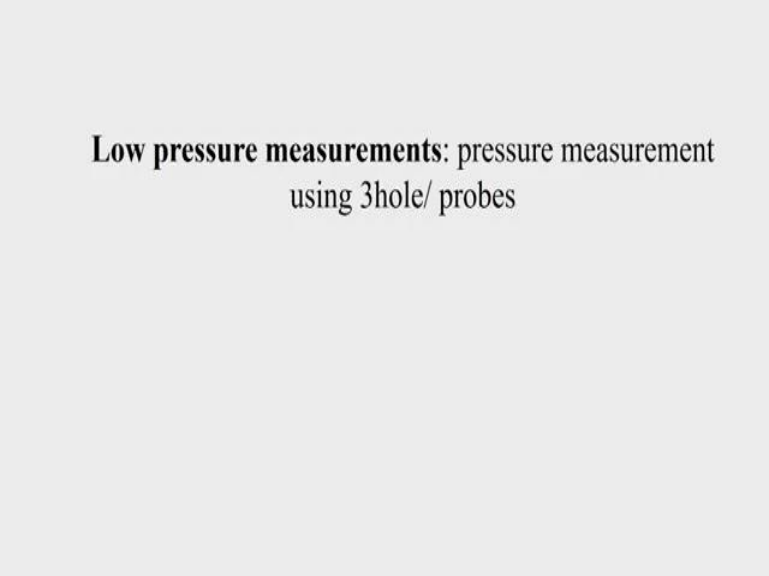
Experimental Methods in Fluid Mechanics
Professor Pranab Kumar Mondal
Department of Mechanical Engineering
Indian Institute of Technology Guwahati
Module
Lecture 16
Pressure measurement using 3 holes probes Contd

(Refer Slide Time: 0:37)



Good afternoon, I welcome you to the session of Experimental Methods in Fluid Mechanics, and in continuation of my last lecture on multi-hole probes, today I will discuss about the difference between 3 hole and 4-hole probes and we will see that the extra feature that is there with the measurement of 4-hole probes and many a time we need to place 4-hole probes to measure extra flow parameter which we cannot measure using 3 hole probe.

If I can recall correctly, in my last lecture, I have discussed about the pressure measurement using 3 hole probe and we have seen that as compared to other instruments, which we used to measure pressure, multi-hole probes are used and in places where you know, we need to have simultaneous measurement of static pressure, stagnation pressure and also the flow angles. In particular I can tell that this multi-hole probes are very important to measure flow parameters in the flow field in a turbo machine.

Where in addition to the static pressure total pressure, the flow angles are very important, direction of flow is very important. Now, we have seen that the probes are basically 2 types; static pressure probes and stagnation pressure probe and I have discussed that stagnation pressure probe or static pressure probes are very, we need to place them accurately in the

flow field and there are a few conditions which you need to maintain which you need to consider while placing those probes in the flow field like their orientation.

And if I can recall that perhaps, I have discussed about the you know one important problem that is there with the measurement of pressure using stagnation pressure probe that the stagnation pressure, I mean when you place stagnation pressure probes in the flow field, inevitably the probes you know disturb the flow field near the measurement points.

And fortunately if the flow is uniform and steady then the stagnant points you know stagnation occurs so rapidly that the effect of temperature and heat transfer and frictional effect can be ignored. And if we can ignore if the flow field is uniform and steady then the measurement that the measured when using flow will be the correct one.

Now, this may not be the case always, in fact, it is very difficult to have uniform and steady flow always and when we talk about the flow is uniform and steady perhaps I mean this is one assumption but it is not the case. In fact, it is not the case when we use probes to measure for parameters in turbo machinery or in the flow field of turbo machinery. Now so, what will be the problem?

So, that means, if we use stagnation pressure probe, again I am telling that the flows are very useful, because these probes are having a few advantageous features that we have discussed in my last lecture. So, in particular this if we place the stagnation pressure probe in a flow field, I mean where we have a steep stagnation pressure gradient, say within the boundary layer where streamlines are deflected in the region velocity is less.

In that case the measured of pressure using stagnation pressure probe we will overestimate the pressure because the measured value will be higher than the pressure which is actually there in the measured zone. So, and we have seen that if we use 3 hole probe to measure flow parameters say static pressure, stagnation pressure and using this static and stagnation pressure we can measure flow velocity component that I will discuss in detail in one of my lectures, while we will discuss about the flow velocity measurement.

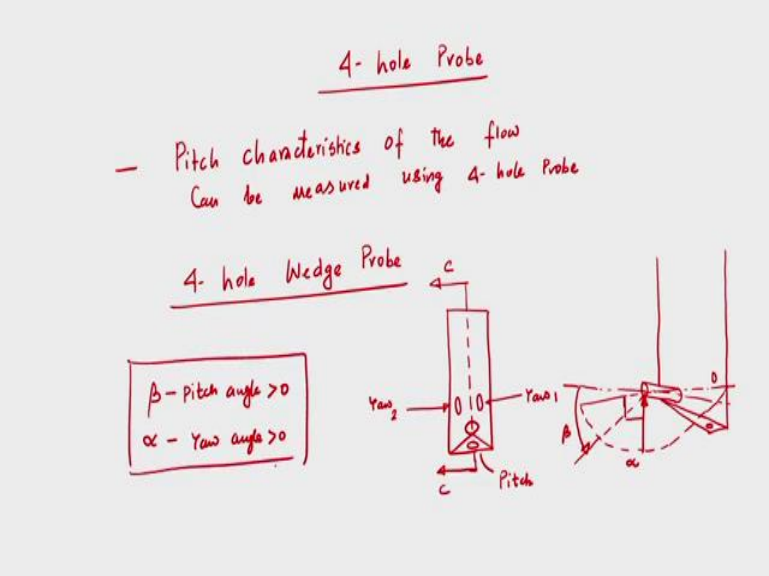
Now, the 3 hole probe is having limitation that it cannot measure the pitch angle, rather the pitch characteristics of the flow cannot be measured by the 3 hole probe and to overcome that if we use 3 hole probe in particular in turbo machine, in that case the pitch characteristics of the flow cannot be measured, but which is very important.

Now, to include that feature so that we can measure pitch angle on the top of the yaw angle that is which is measured using 3 hole probe, there is another probe that is 4-hole probe and today we will discuss with a schematic the constructional feature of a 4-hole probe and how using a 4-hole probe we can measure pitch characteristics additionally, because other 3 parameters like static pressure, stagnation pressure and the yaw angle can also be measured.

So, now, we will discuss that the construction of a 4-hole probe and this 4-hole probes are basically used in places where flow field is 3-dimensional and that is what I have discussed I have pointed out in my last lecture. Now, today, we will see that these 4-hole probe are also having, you know, additional features which, you know, make it much more applicable in the experimental fluid dynamics in particular experimental turbo machinery.

Now, if I try to draw a schematic of a 4-hole probe we will see that there are two different you know, see probes are basically different types you know kind of that is what I have discussed that you know cylindrical probe, rectangular probe, so that depending upon the you know geometrical shape, this can be classified but I will take only the cylindrical probe today to describe the working principle, and from there we will just try to see that how we can measure the you know, static pressure, stagnation pressure and also from there how we can measure the velocity component that is very important.

(Refer Slide Time: 8:16)



Now so, today we will discuss about the 4-hole probe. So, if I compare this flow with the 3-hole probe, then we will see that this probe having an advantage that it can measure the pitch characteristics. So, pitch characteristics rather pitch angle, pitch characteristics of the flow

can be measured using 4-hole probe. So this is one. Now since, this extra flow feature can be measured using this probe, construction wise it is slightly different than the 3-hole probe.

That means to measure this extra feature using this probe, we need to have another extra probe that is obvious because the name itself suggests that the name itself implies that this is 4-hole so, we will have extra hole that is used to measure the pitch characteristics. Now, so, just today I will describe the constructional feature. Again I am telling depending upon the geometry of the probe, it may be cylindrical, it may be wedge type probe, the probe may conical type.

So, that is basically geometrical traction of the probes but the operational principle is more or less same for all the cases. So now, taking one example, say if I try to draw a 4-hole cylindrical probe, and then we will see that even if we use 4-hole cylindrical probe, that probe is not useful to measure flow parameters very close to the boundary. So, we can measure, rather we can use that probe to measure flow parameters, but we need to place the probe away from the boundary.

So, again, this is another one limitation. So, to circumvent that, there are other you know, other type of 4-hole probe that is the wedge type flow which can be measured the flow parameters, even in the zone which is close to the boundary. Now, I am drawing a 4-hole wedge prob. So, again I am telling these probes are you know having several advantageous features I mean, because of what these probes are very commonly used to measure flow parameters in particular static pressure, stagnation pressure.

And if I talk about flow features in turbo machinery flow field then of course, the pitch angle and yaw angle will come, but because of this you know robustness, simplicity in the structure and ease of insertion we can easily insert. So, this you know 3 important advantageous features is rather features are allowing 4-hole or 3-hole probe to gain huge popularity in the experimental research where simultaneous measurement of several flow parameters are important.

Now, so this is if I look at so now there will be 4-holes because name is 4-hole probe so there will be probes multi-hole, we have 4 hole, this is wedge type, so we will have one hole here and another here. So, this is used pitch this is used to measure yaw angle, yaw 1, and I can say this is used to measure yaw angle 2 and this is pitch 1. So, this is basically the, I am

drawing the schematic of the probe and the special feature is that we can measure pitch characteristics which you cannot measure using 3-hole probe.

So, now if I try to see the probe in a different view then it will look like this, and in fact, now this is one hole that is also one hole if I see from this side. Now, so if the flow, this is the flow direction now say so this is the flow direction and this angle beta and so this is the flow velocity and this angle is alpha. So now, this beta and alpha, so this beta and this Alpha, see this beta that is very important and to measure this beta we need to have this additional hole.

So, this beta is the pitch angle, pitch angle which is greater than 0 and alpha that is, we have seen in that is there wherein for the 3-hole probe configuration and this alpha is the yaw angle which is also greater than 0. Now, the additional hole which is there in a 4-hole probe allows us to measure pitch angle, which cannot be measured using the 3-hole probe. We will see that when we measure flow parameters using 4-hole probe then there are 4 different holes we have identified.

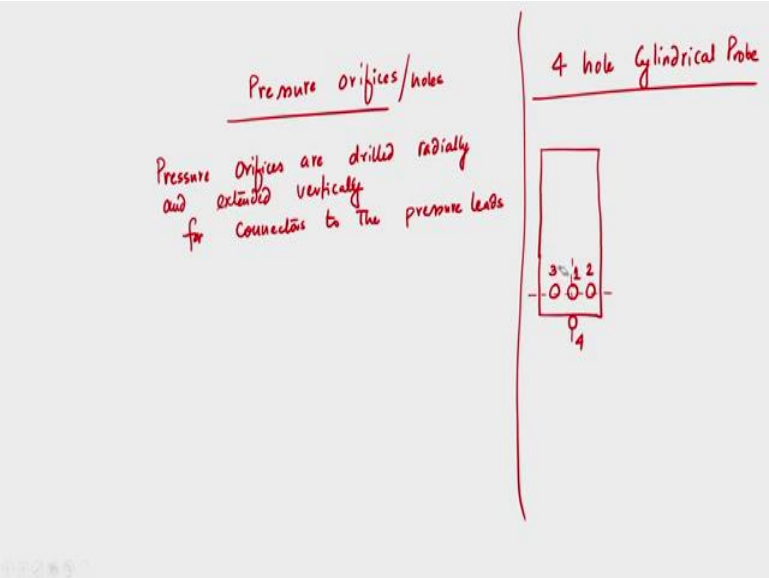
Now, pressure taps are connected rather these holes are drilled radially and the pressure taps are connected to the pressure leads and those leads are connected to, pressure taps are connected U tube manometer. Now, the probe is erode until the, you know this one, two, these two are connected I can say that the pressure leads are connected to the U tube manometer rather projection manometer and to projection manometer and one U tube manometer. And the U tube manometer two limbs are connected the orifices that is point 2 and 3. Now, the probe is you know until the pressure at point 2 and 3 are become equal.

And this is I mean whenever you are using rather we are inserting this probe in any flow field, we need to ensure that the pressure at point 2 and 3 will be equal and the probe is erode until the pressure at the orifices 2 and 3 are same. And this is done at least for within the interval of different you know angles say at interval of 5 degree from plus minus 45 degree.

And the operational principle of the 4-hole probe, how we can measure static pressure, stagnation pressure and the pitch and yaw angle that we will discuss and we will discuss in detail in the context of measuring flow velocities. But for the time being, we should know that this is the geometrical structure of a 4-hole wedge type probe where additional hole is responsible to measure the pitch characteristics of that each angle that is shown in the figure.

Now, in this context at least we should know that we have seen there are pressure orifices. So, this pressure orifice where the pressure holes are drilled radially and extended vertically for the pressure leads. They are connected to the pressure leads.

(Refer Slide Time: 20:46)

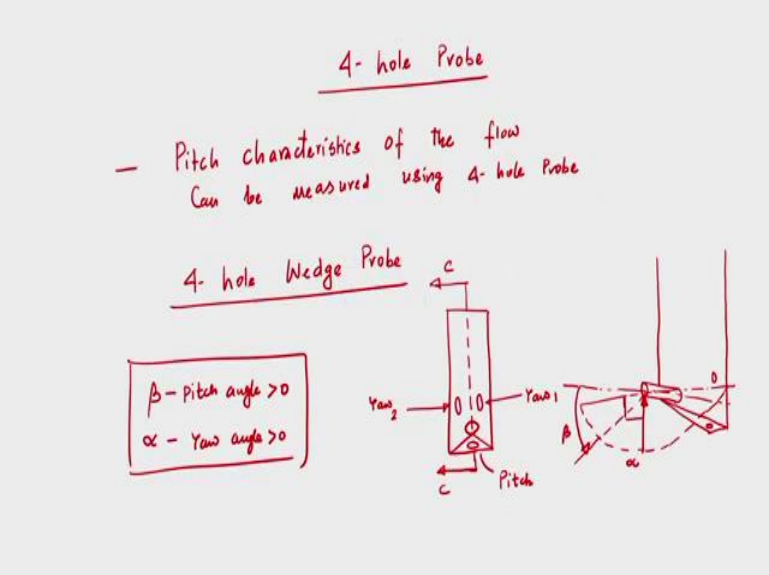


So, I am writing that pressure orifices we have seen that we have and this pressure orifices or holes this pressure orifices are drilled radially and extended particularly for connectors to the leads to the pressure leads. Now, when we talk about this, at least here we will see that what will be the geometrical structure of a 4-hole probe which is cylindrically shape.

And if we use a 4-hole probe shape you know, rather then it will be clear what are the you know connector, what is pressure lead and the drilled holes as I have written here, those are drilled radially and these are extended vertically for connector to the pressure leads because eventually we need to take tap or we need to connect the pressure leads to the projection manometer and U tube manometer from there we will get the reading.

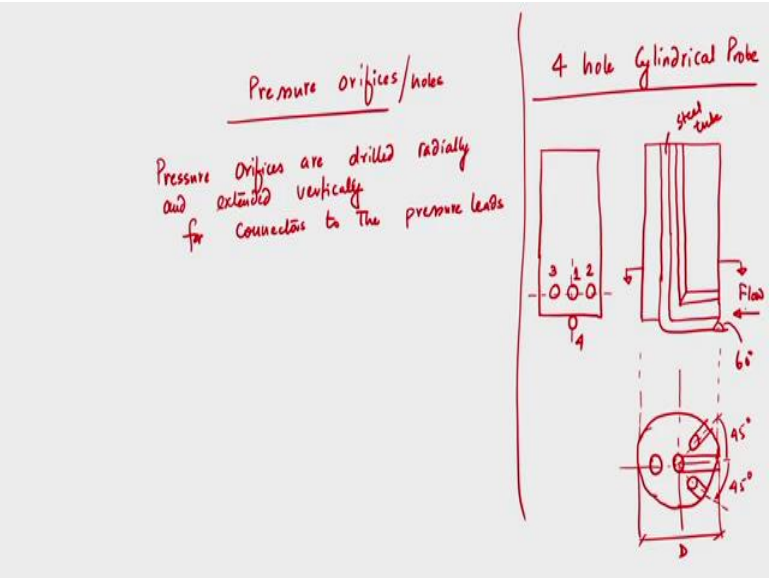
Now, if I try to draw the 4-hole cylindrical probe because the limitation of cantilever type or wedge type probe is that that these probes cannot be directly placed in the reason which is close to the boundary. So to overcome that difficulty, the new configuration that is 4-hole cylindrical probe came and now it is again, very straightforward and I am now drawing that. So, one hole, one orifice is here, one is at the centre location, other two are, you know the air from the centre location. So this is 1, this is 2, this is 3, this is 4. Now, this 1, 2, 3 and 4, 2 and 3.

(Refer Slide Time: 23:53)



If I go back to my previous slides then yaw 1 and yaw 2 that is these two are used to measure the yaw characteristics; one is as usual that is there to measure that is there even in you know 3-hole probe, but the 4-hole probe the final, the 4th number of hole that is used to measure the pitch characteristics.

(Refer Slide Time: 24:13)



Now, just now, I have written that pressure orifices or holes are drilled radially and extended vertically for connectors to the pressure lead. Now, if I draw another view of this 4-hole probe then we can see that what are the pressure leads and all those things. Now, so we have one central hole, one similarly and this extra hole is responsible for to measure the pitch characteristics. Now these are placed if angle is 45 degree, this angle is also 45 degree.

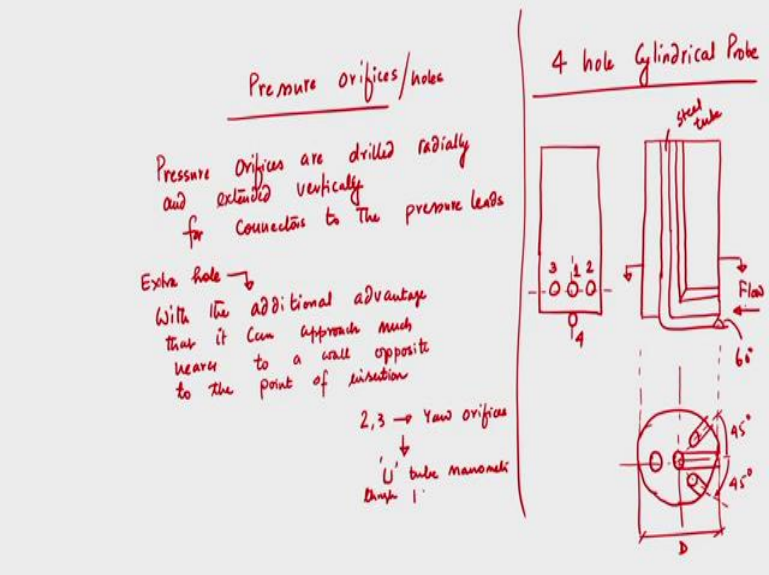
So, and this diameter of the cylinder that is capital D. Now you know, if I draw that this is the fourth hole, this is the fourth hole this angle is 60 degree. So, this fourth hole so this is drilled radially and then extended vertically to connect the pressure leads and those leads are connected to, the taps are connected from rather from the pressure lead to connect with the projection manometer and U tube manometer. So these are basically similarly, another one hole, just I am drawing here.

So now, this is the flow direction this is the flow direction, and the view which is shown at the bottom is like this. So, if I try to look at from the top, it will look like this and if the flow is operating like this in the directions shown by arrow then the additional hole which is drilled radially and then extended vertically and to the pressure leads and then ultimately these pressure leads will be connected to the manometer which is responsible to measure the pitch characteristics.

And this drilled hole radially drilled holes are housed in a brass head and the tubes which are as I say said you the pressure leads I mean drilled holes those are connected to the steel tube. I mean these are holes are drilled in the brass head and then steel tubes are you know these are steel tubes so basically this is steel tube. So, the holes are drilled radially and extended vertically through which steel tubes are placed.

Now, we will see that this 4-hole cylindrical probe is even better as compared to the wedge shape and you know cantilever type 4-hole cantilever type hole, cylinder cantilever type, because this can be placed even in the region which is close to the boundary. So, we will discuss in detail that today just I have we have seen that the geometrical construction of the probes now when this we will see that using this probe if you would like to measure that flow is approaching.

(Refer Slide Time: 30:09)



Now, flow even if I go back to the previous slide, so this is the flow velocity flow velocity. So now, then, if that is placed because many times the probes are placed where flow axis is perpendicular to the probe axis. And if it is not the case we have seen that there will be a few problems, but normally these flow axis probe is placed in such way that the probe axis will be parallel to the flow axis.

We will see that these probes are normally calibrated and that is the calibration is done in a wind tunnel, but if it is otherwise we cannot measure flow parameters when we directly after manufacturing it is calibrated. Now, the operational principle that is very important how we can measure several flow parameters. Till now we have understood that fine using 4-hole probe or multi-hole probes, we can measure static process, stagnation pressure, as well as the flow angles, but we need to know the operational principle.

The moment we insert probe in the flow field, then what are the procedure you need to follow to have the measurement of static pressure, stagnation pressure and the flow angles and that is very important and we will discuss that aspect in detail when we will be discussing about the flow velocity measurement using the multi-hole probe. But for the time being we have seen that geometrically 4-hole probe is better as compared to 3-hole probe in the context of you know, one important flow parameter measurement that is pitch angle.

And 4-hole probe are largely suited where flow field 3-dimensional and we have seen that this additional hole you know having an additional hole in the probe is not again I am telling you know, fabrication wise it is not so easy, but this is important this should have to have,

you know, the measurement of pitch characteristics, but this 4-hole probe again can be classified based on their geometrical construction.

Wedge type probe we have seen and also the 4 orifice cantilever type cylindrical probe that is also not suitable for measuring flow parameters which is very, you know, I mean we cannot measure flow parameters using those probes in a zone which is very close to the boundary. Instead, if we use 4-hole cylindrical type probe, this probe is much more suitable for measuring flow parameters in zones close to the boundary.

Now, this 4-hole probe as I said you that additional hole, so I am writing with the additional advantage that it can approach much nearer to a wall opposite to the points of insertion, so this is the additional advantage. What is the additional advantage? The equipment of additional hole. So, extra hole with the additional advantage that it can approach much nearer to a wall opposite to the point of insertion.

Now, as I said that here we have 1, 2, 3, 4; 4 different holes. The pressure leads, the extent vertically for connectors to the pressure leads. The pressure leads are connected to projection manometer and to two projection manometer and one U tube manometers. The U tube manometer, of course, we can see two projection manometer means the 1 and 4, these two are connected with the two projection manometers and 2 and 3, these 2 pressure leads are connected to the U tube manometer because these 2 are the yaw orifices.

So here 2 comma 3, these 2 are the yaw orifices, and these yaw artifices are connected to U tube manometer through pressure leads. So, through pressure leads these two orifices are connected to the U tube manometer and a reference (())(36:36) tube rather (())(36:38) probe used to measure the total pressure. And again I am telling that part I will discuss in detail again that the probe is yawed until the pressure at orifices 2 and 3 that is the pressure the probe will be yawed until the pressure at point 2 and 3 becomes equal.

So, until they are not becoming equal, the probe will be yawed, and this is done at an interval of 5 degree of the yaw angle and that part, the operational principle and how we can eventually calculate the total pressure, static pressure and from there, the flow velocities that is very important. We will discuss in detail in one of my next lectures.

So, today we have discussed that the 4-hole probe are used in places where flow field is really, I mean largely three dimensional because the 3-hole probe cannot measure the pitch characteristics of the flow. To measure these extra features rather the pitch characteristics of

the flow on the top of that, other measurements like static pressure, stagnation pressure and the yaw angle, we need to have an additional hole that is why this is 4 hole.

But the placement or placing of an additional hole in the structure is an advantage because, the additional advantage is that we can place the probe which is close to the wall opposite to the direct opposite to the point of insertion. Now, that means we can measure floe parameters in a zone which is close to the boundary which is not possible using other 4-hole probes that is 4-hole wedge type probe and the cantilever orifice for orifice cantilever type probe.

Now, that is why this 4-hole probe cylindrical probe came into the picture. Now, the pressure orifices pressure holes those are drilled radially and extended particularly, so that the pressure leads basically steel tube are connected to the probes and from there tapping is taken to connect those orifices or holes to the manometer. There are four different holes 1, 2, 3, 4; 2 and 3 are the yaw orifices which are connected to the U tube manometer through pressure leads.

And the orifices 1 and 4 these are connected to the two projection manometer. So, from these two projection manometer we will get reading. Using those reading how we can calculate the flow velocities, in particular flow angle is very important in the context of turbo machinery, flow angle this is done and yaw orifices are connected to the U tube manometer.

One important point is that when we are measuring probe parameters using multi-hole probes, these are in 4-hole probe, the probes will be yawed until the pressure at orifices 2 and 3 are become equal. And this is continued with an interval of 5 degree yaw angle to check the, you know to calibrate the probes. So with this, I stop my discussion today, and we will continue our discussion in the next class. Thank you.