Adiabatic Two-Phase Flow and Flow Boiling in Microchannel

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Lecture – 10
Experimental Identification of Flow regimes (Contd.)

Hello everybody. Let us continue with a discussion on the flow patter identification by optical probes in micro systems. In the last I already explained to you the principle of measurement and how it can be identify the different patterns on the basis of the amount of light absorbed and scattered. Now, we are going to see one particular application of this particular probe in micro systems.

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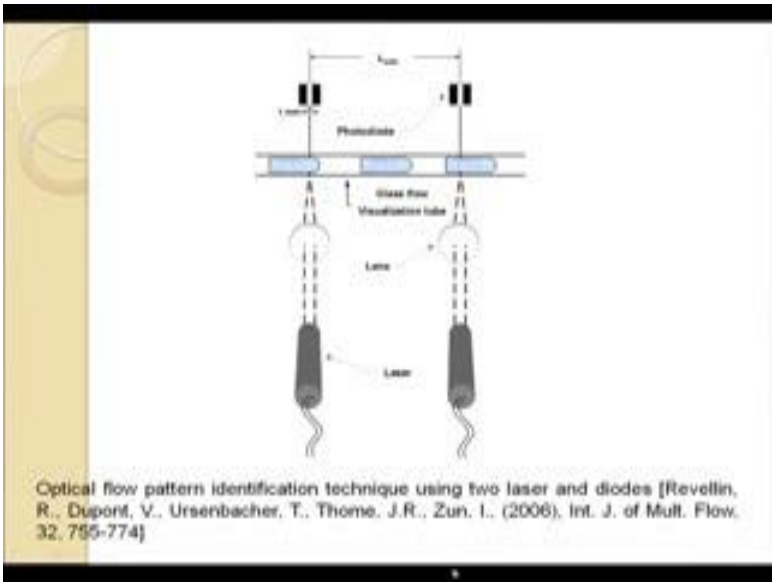

The reference of the paper from which this particular or the workers who have taken this particular technique is also there and you can refer to this for further reading. Here, what do we find we find that in this particular case 2 micro lasers are used this is one thing we have to keep in mind the efficiency of this particular method will be dependent upon the intensity of light. Because, if the intensity of light is very high then in this small volume whatever amount will be absorbed attenuated can hardly be detected.

Therefore, if the strength of the laser source is less then it is going to be much more better and in this particular case the researches what they have use is 2 micro laser beams, because they wanted to measure the velocity of the of the moving Taylor flux

also. They have used 2 micro laser beams where the light passes through the glass tubes and the fluid at 2 different additional location and they are also used a pair of lenses one lens for each particular source.

This particular lens it focuses the laser beam on to the middle of the micro tube. So, that we can understand the reflection etcetera occurs in the center of the tube and observing that we can know the cross sectional distribution of the words and you on the diametrical opposite point 2 photo diodes are used which record the intensity of light and the signals they are used to identify the different flow patterns or rather the different distribution whichever happen in this particular case.

And, the signals as we have seen in the previous cases signals they are recorded by means of some particular data acquisition system and in this particular case its certain things are important. One is the lens and then the intensity of the light and then a micro positioning system is also very important to align the laser beams with the lenses and photo diodes. Since, everything in a very miniature scale.

Therefore, much more accuracy is necessary in this particular case and in this again the same thing as in micro system the laser beam it interacts locally with the structure of flow and by suitable signal processing. It is possible to determine not only the distribution of the phases, but also the velocity, the length and also the frequency of the vapor bubbles ok.

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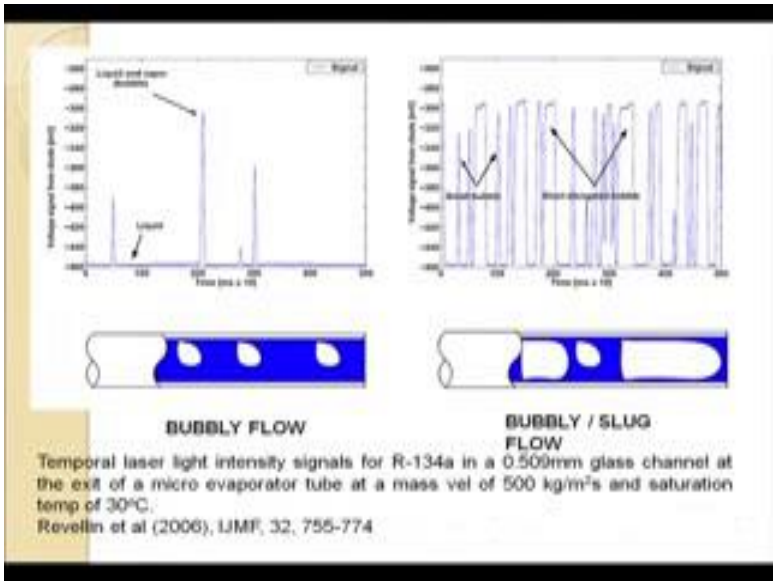

And. Let us see the different types of signal which has been recorded we need to remember one thing in order to one thing I will let me tell you that the probe which had been developed in the multi phase flow laboratory this particular probe it was developed for primarily for kerosene water systems. The neat arose because none of the intrusive techniques could be used for oil water systems because oil will stick to the probe and then naturally after that we were unable to get particular signals. The other thing is it was very effective for oil, water, because the absorption coefficient of kerosene and water were very different.

These particular researches we have used it for air, water, systems. Now, when we are using it, it is very important to maintain a proper threshold such that you can identify the noises from the fluctuations. For example, we have to threshold it in such a way that we can identify that it is not a noise, but it is a bubble.

Therefore, in this particular case what do we see in air water system when it is filled up with the liquid then naturally a greater amount of signal is absorbed and when it is filled up with air lesser amount of signal is absorbed. So, therefore, the transmitted amount of light or rather the incident amount of light on the photo diode is going to be lower when water or any other liquid is in the predominant phase it is going to be higher when a gas comes on path of the light.

Naturally, if you observe the raw signals what do we get for bubbly flow pattern? More or less since liquid is the predominant phase we get or almost continuous signal at very low voltage. And whenever, the bubble comes in the path of the light we get small spikes which denote the passage of occasional bubbles of sizes smaller than the conduit diameter which shows that liquid is the continuous phase and bubbles traverse this particular path.

Now, as we increase flow rate and we approach the transition from the bubble to the slug flow pattern as we know it is marked by elongated bubbles and this is immediately shown in the random signals that have been recorded. This case we find that the apparent difference between the bubbly and the slug flow or the transition between bubbly slug flow is immediately evident on comparing these 2 particular raw signals.

Here, we find that instead of almost study signal at low voltage at the fuse spikes the signal now exhibits alternating values and peaks. And, we find that in the values some

spikes are there which show the presence of gas bubble in the continuous liquid slug and the consistent peaks which we get they show the passage of elongated bubbles.

And, in this particular peak region the small disturbances which we get they are due to the presence of the liquid film between the bubble and the conduit wall.

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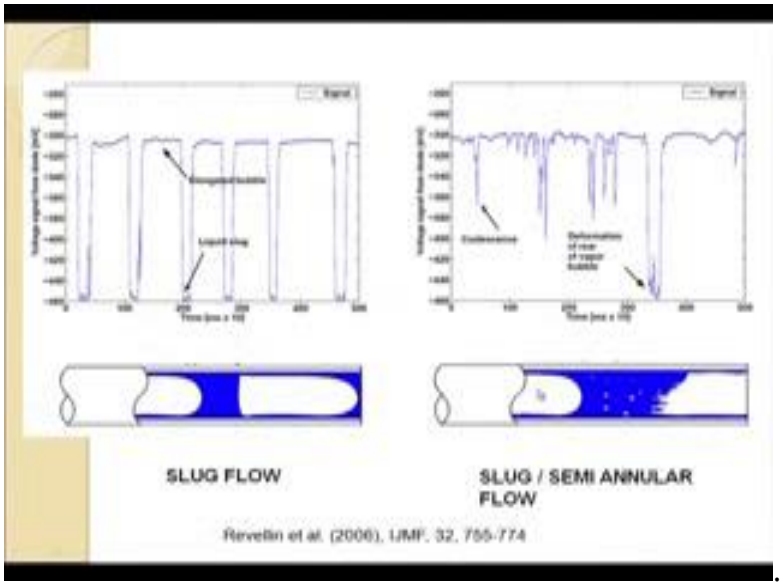

We find that from the bubble slug as we approach the slug flow pattern we find the intermediate pattern is very clear. And more important I would like to say since the liquid slugs are almost unrated. As a result what happens we find that it is almost square wave type of a signal if the noises can be eliminated it becomes almost square wave type of signal where we can very well see large peaks and small tapered valise. Which naturally shows that now large Taylor bubbles and short liquid slugs are passing through the rather are traversing the path of the laser ray or the laser narrow beam.

Now, if we compare this particular signal with the bubbly slug signal certain things are evident. Number one: that the proportion of the gas phases increases because the signal now lies for a greater proportion of time in the higher voltage region. Secondly, more or less all the bubbles are elongated bubbles and thirdly there are lesser disturbances in the liquid slug.

Therefore, from this it is the comparison immediately shows us how erratic the transition zone was compared to the fully developed zone. Now, as we go for higher velocities for

people observed were I would like to tell you that in micro channels your annular flow is not very evident and this particular group of researches they also approve something like this slug of the semi annular flow pattern with occasional liquid paging they could not approach they could not get a pure annular flow.

How, is this evident if you if you observe this particular signal if your transition from slug to annular or semi annular whatever you say we find that now for the signal is for a greater fraction of time it is in the high voltage area. So that shows the definitely gas is passing the flow passage or gas is traversing the path of light for a greater fraction of time and there are short spikes in the opposite direction which shows that rear the rear bubble it is getting deformed or may be some amount of smaller satellite bubbles getting from the rear bubbles. As, a result of which there are some spikes in the downward direction when short liquid slug come in the path.

If you just compare this particular your signal with bubbly signal you will see that both of them are almost mirror images and this shows that air is the predominant phase in this particular case and water was predominant phase here and in the intermediate region comprising of bubbly slug and slug flow both of them were more or less comparable with water being a larger proportion here air been a larger proportion in this particular case.

Therefore, in this particular way we find that optical probe was one particular technique which was used wide or other features as been used with some particular success in micro channels. Now, the next technique which is also been used to some extent in micro systems is the impedance probe technique.

What do we observe in the evidence probe technique what does it do exactly it is quite a popular technique in macro systems the reason for its popularity being. Firstly, it is cheap, it gives an instantaneous response and it can be fabricated in a large number of designs in order to suite what our purposes we want to serve.

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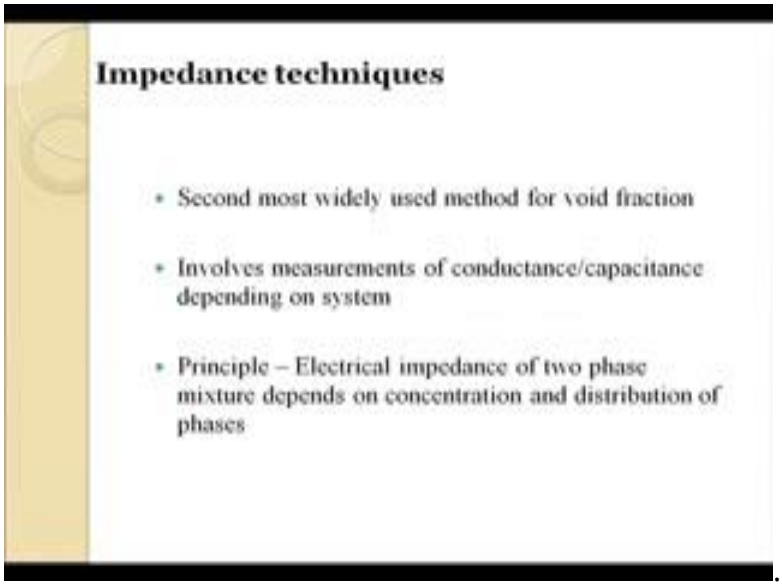

And therefore, the impedance probe it is the second most widely used method not only for void fraction measurement, but also for the estimation of wide fraction or other void distribution.

Now, what does it do basically? It basically, measures the difference in electrical conductivity or electrical impedance of the 2 phase mixture. Therefore, in this particular case what happens is it measures the electrical impedance or the electrical means the thing is that when there is a 2 phase mixture flowing.

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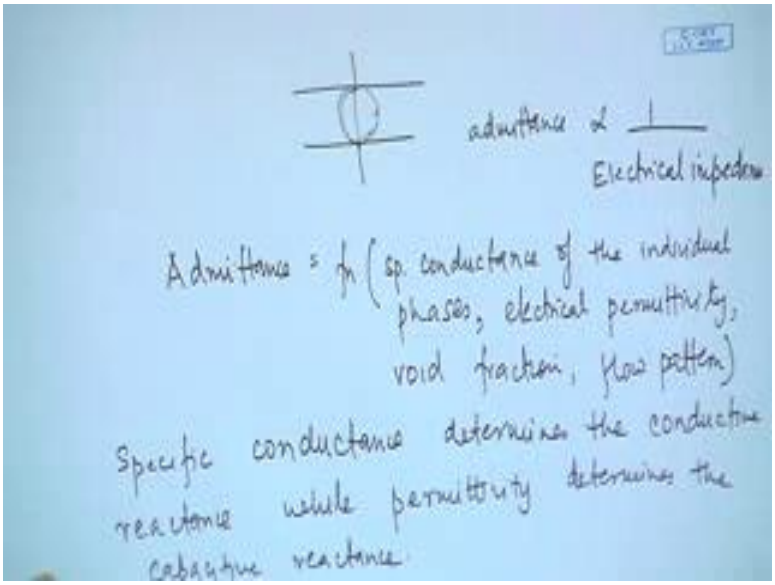

Then and we have 2 electrodes may be located at the 2 walls then the electrical path is through the 2 phase mixture or rather it is through the fluid medium. Therefore, in this particular case the resulting admittance it is more or less of your, it is the reciprocal of electrical impedance.

At this particular admittance or A if we call it this particular admittance, it is going to be function of firstly, the specific conductance of the intervening medium, which in case of 2 phase flow is the specific conductance of the individual phases, then it is also a function of electrical permittivity or in other words it is a function of the electrical properties of the 2 phases then, it is also a function of void fraction and your flow pattern right.

Therefore, we find that in this particular case the thing which happen is that suppose we have any particular probe then that the depending upon the composition of rather depending upon what are the 2 phases which are present here the net electrical admittance is usually measured.

And this electrical admittance this is the inverse of the electrical impedance of the 2 phase mixture and this is a function of the material properties which are nothing, but this specific conductance of the individual phases and the electrical permittivity. It is also a function of void fraction and flow pattern.

Now, if the 2 phases are fixed. Naturally the material property is become fixed and that case it is just a function of void fraction and flow pattern it is a coupled function for one particular flow pattern it has got some specific relationship with void fraction and if the flow pattern is known then we can find out we can have an estimate void fraction from the admittance which can be either the conductance or the capacitance of 2 phase mixture.

But in order to find measure void fraction from admittance we need to have an (Refer Time: 15:12) knowledge of the flow pattern. This particular specific conductance this determines the conductive reactance while permittivity determines the capacitive reactance.

It means that if you are operating in the conductance mode or in the conductive mode then the specific conductance of the 2 phases will be determining the conductive

reactance while if you are operating capacitive mode then permittivity will be determine the capacitive resistance. Now, for a given geometry what we find is that the measured admittance if it is appropriately normalized this will be a function of void fraction and your flow pattern.

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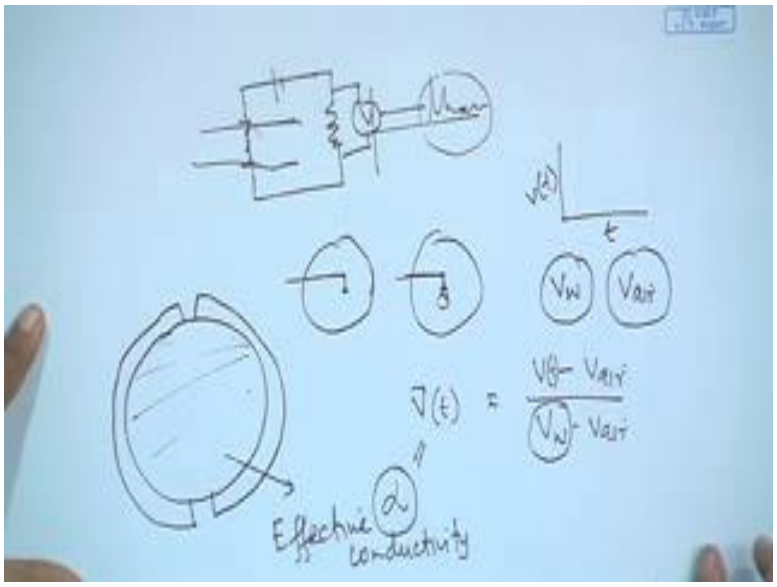

Therefore, the next thing is that once this particular specific conductance so the principle of measurement is that we have 2 electrodes on 2 sides of say any particular channel right. And between whatever is the composition and the distribution depending on that we would be getting some particular signal.

The signal can be due to the difference in the conductivity of the 2 phases it can also be due to a difference in the di-electric constant or permittivity of the 2 phases. We have to decide which particular property we would like to exploit depending upon the system and then we have to work accordingly.

For example, if it is a kerosene air mixture of course, for that possibly we will be not using electrical or impedance probe, but for that case a conductivity meter or conductivity probe not going to serve the purpose because both of them are more or less non conducting, but for air water system conductivity probe is a very efficient and very widely used technique because air and water have widely different electrical conductivities well.

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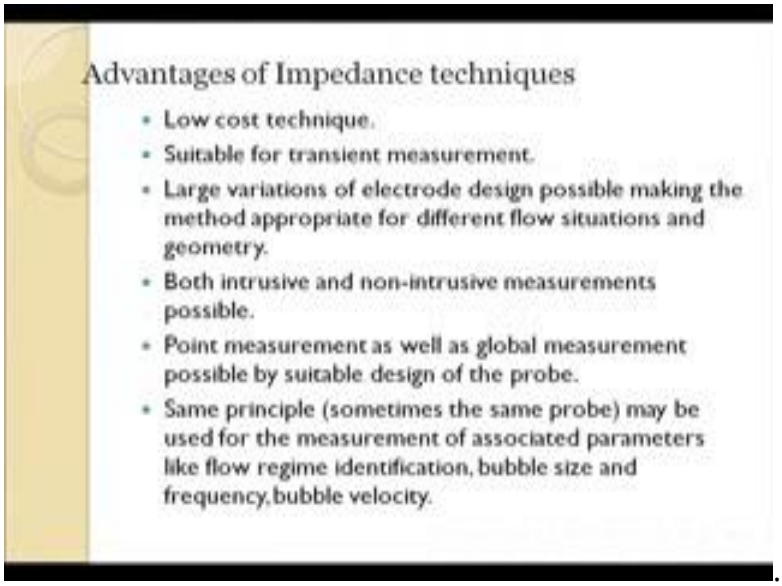

So, the advantages which we have are number one low cost techniques then the other thing is very suitable for transient measurement because what it does is more or less it gives us a time varying voltage signal rather across a resistor.

The basic principle is that from here more or less the current features passing through this that is passed through a known resistor and the voltage across the resistor is measured and this then recorded as a function of time and this gives us an idea about the current which was passing and this current is a function of the composition of the 2 phase mixture.

Therefore, it is quite suitable for transient measurements and as I have already said large variations of electrode design is possible. Now, usually it can be intrusive it can be non intrusive as well how mostly it is intrusive where what we have is we have may be one particular electrode which is emerged here and may be the wall is another electrode or maybe we can have 2 electrodes of slightly different dimensions where the current between the 2 is measured and the circuit is closed when water comes in contact with the 2 electrodes.

And when moment of bubbles comes in contact the circuit is broken and that is shown by a drop in voltage and from recording those drops we can find out a distribution.

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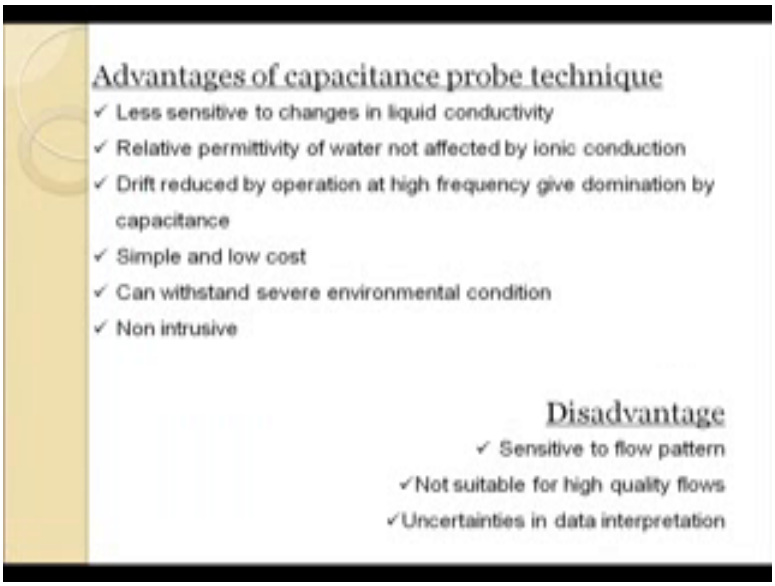

Any how this is quite an attractive technique and mostly for the micro channels the capacitance probe technique has been used.

Now, the capacitance probe although the circuit is not very it is slightly more complicated, but there are certain advantages of the capacitance probe firstly, if we have to make any particular quantitative measurement. How the signals are recorded is that just recording the signals just from the voltage time signal we are not going to get anything unless it is properly normalized now how is it normalized initially what is done the voltage when the system is full of water is recorded say the signal is VW.

And then the voltage for the flow passage completely empty or for air flow is recorded. Therefore, we know the 2 extremes when the circuit is closed and when the circuit is completely opened. Now when we record the voltage signal during air water flow it is going to be lay between the 2. Therefore, this particular signal it is normalized as V minus V air by VW minus V air this is the normalized voltage this is function of time so naturally in this way you get the normalized voltage and this is the voltage which is measured as a function of time in order to obtain the void fraction data.

Therefore, it is quite evident that this particular normalized voltage signals from where we would want to have data on alpha or we would like to find out the distribution of the 2 phases that definitely depends upon the voltage which we which we receive from the test passage is full of water and naturally so it is depends upon the conductivity of the

liquid which is their inside.

Now we know that conductivity is quite sensitive to the amount of impurity to temperature etcetera. Therefore, almost for every experimental run conductivity will be different and. Therefore, if any particular measurement is highly based on the liquid conductivity and if the liquid conductivity is changing so much then in that case normalization or getting if we just want to have an idea regarding the qualitative nature of this signal and to identify flow patterns it is fine.

But if you really want to have some quantitative idea regarding the estimation of void fraction or the incentive composition then this dependence of conductivity on several other extraneous parameters which are not under our control becomes slightly difficult.

Naturally when we are operating in the capacitance mode the first advantage is it is less sensitive to changes in liquid conductivity. The other thing is relative permittivity of water is not affected the ionic condition which again means the same thing and definitely it is simple and low cost can withstand severe environmental condition and the important part is design which has been used in literature, but they use it is a modified version of the arc electrode probe.

What the arc electrode probe does? It has 2 electrodes which are flush mounted which the wall of conduit and by means of electrical lines of forces between the 2 arc it measures the effective conductivity of the 2 phase mixture. Therefore, this is something quite commonly used in micro system

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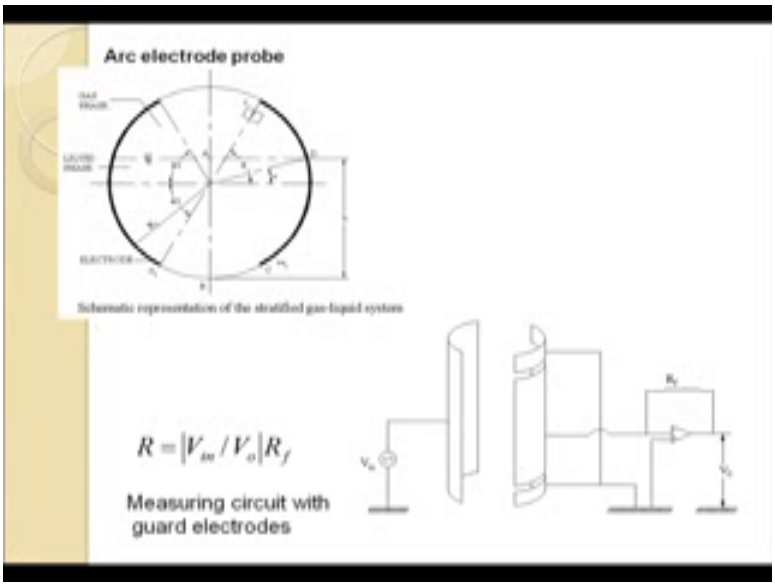

And 1 particular group of researches this is the thing which I was telling that while using arc electrode probe there are 2 electrodes which are flush mounted now in this particular case few problems arise. First, thing is there is a fringing effect near the edges and the 2 arcs cannot be brought very close to one another so therefore, this fringing effect exists.

Now to eliminate this very frequent thing which is done is use 2 guard electrodes at the 2 ends. Those fringing effects are taken care of by them and more or less the measurement zone is free of this.

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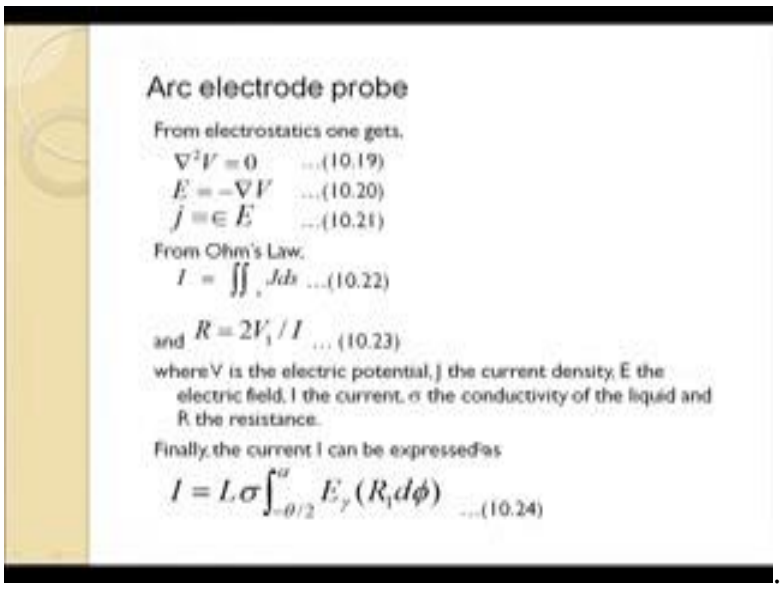

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And the electro statistics it is there and no point in going to great details from here, but from this particular side we can understand how the current can be expressed in terms of the current density voltage and all those things.

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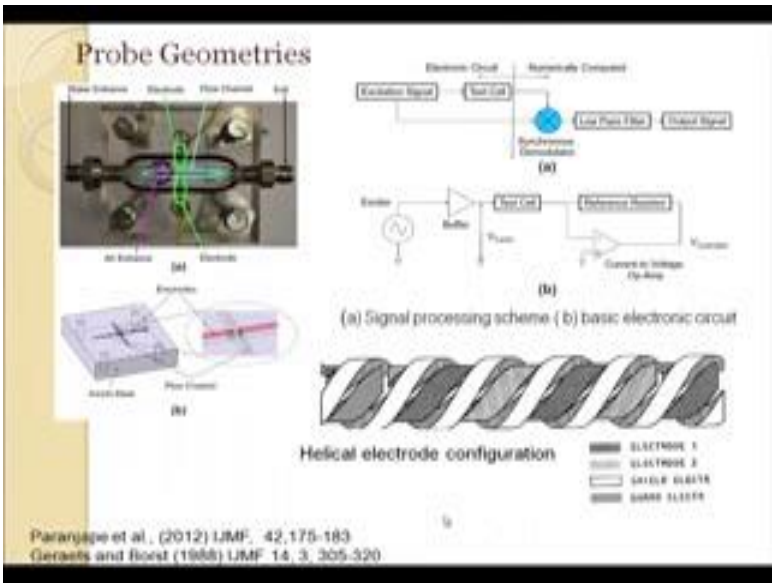

And so a variation of this arc electrode probe has been used by this particular group of researches. What they have done they have used a rectangular micro channel and in this particular micro channel they have used 2 stainless steel electrodes which are embedded in the base plates ok.

And this 2 stainless steel electrode are such that the phases of the electrodes are flush mounted with the 2 walls a better way to represent is this as you can observe that this is the channel and the 2 stainless steel electrodes they are flush mounted with the 2 edges of the rather of the 2 walls of the channel.

Such, that it can measure the electrical field between the 2 electrodes right and in this case also an auto balancing bridge method is used as I have already mentioned in this particular auto balancing bridge what is done is the there is an (Refer Time: 26:59) operates in the capacitance mode so therefore, an exciter signal is passed and then this particular current which moves to the test cell it is send through a reference resistor and from the reference resistor the voltage across the reference resistor is measured and that gives us idea regarding the amount of current which was flowing through the this particular cell.

And along with the raw signal attempts were also made just like other researches in order to perform the probability density function analysis of the signal such that we can obtain a better idea regarding the flow distribution.

We are going to discuss it in the next class we continue our discussions on experimental techniques of flow pattern measurement and void fraction measurement in the next class.

Thank you very much.