Two Phase Flow and Heat Transfer
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Lecture No: 10
Measurement of Void Fraction and Signal Analysis: Part-01

Hello and welcome in the tenth lecture in the course Two Phase Flow and Heat Transfer. In this lecture we will be giving you an idea about measurement technique in Two Phase Flow and how the signals obtain from the measurements can be analyzed. Now in this lecture we are having 2 parts which will be also continue in the next one that means the eleventh 1. So here I will be discussing the first part only.

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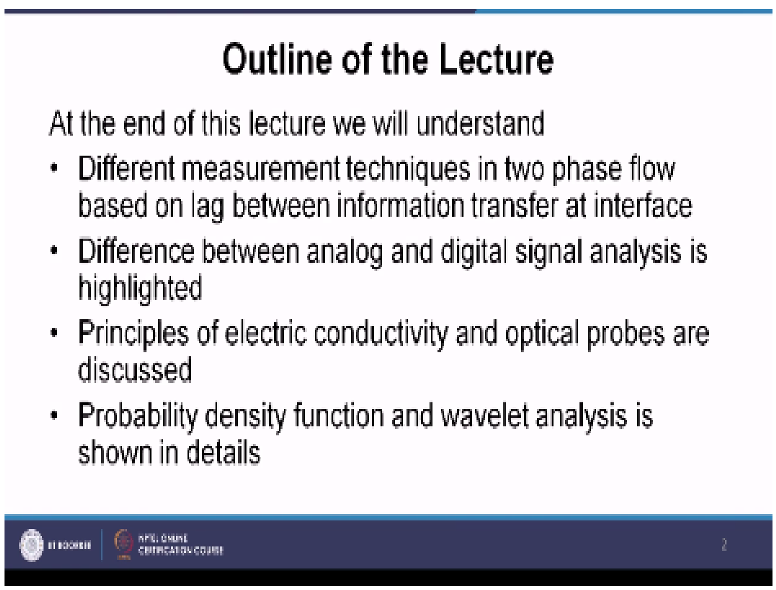

So at the end of this lecture we will understand different measurement techniques in Two Phase Flow based on lag between information transfers at interface. So as it is Two Phase both the fluids will be having different properties to transfer the information through it depending on that we are devising different measurement techniques. So you will be discussing about those. We will be discussing about the different analog and digital signal analysis.

So how primitive analog signal analysis and at present modern digital signal analysis differ in principle those things will be discussing. You will be also giving you idea about electrical conductivity probe and optical probe. We will be also showing you that how signal analysis from this conductivity and optical probe can be done by a probability density function and wavelet analysis okay. Now to begin with, let us see what are the different principles sensing method are available in Two Phase Flow.

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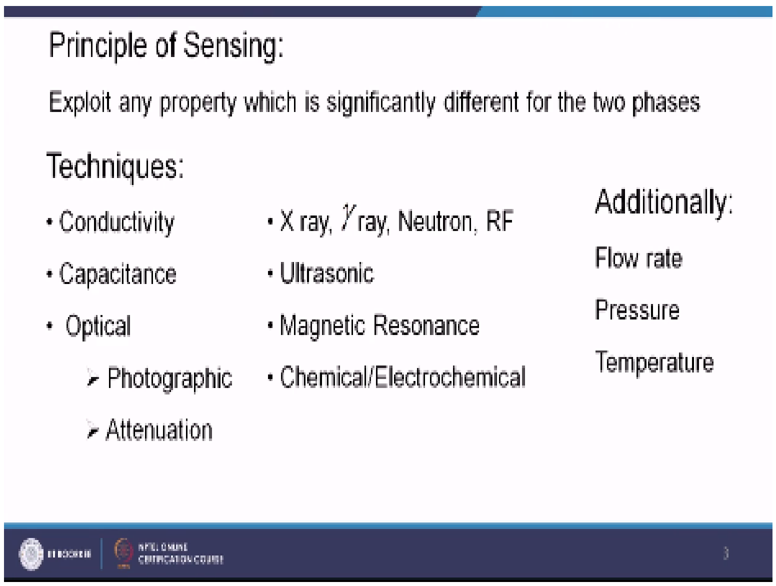

So what will be doing for measurement of Two Phase Flow, we will be exploiting any property okay which is significantly different for the phases okay. So let us say we are taking 2 phases as gas and liquid. So you can take any fluid property or exploit any fluid property okay which will be behaving differently amongst this gas and liquid phases okay.

For example here I have named few technologies for example let us see this right hand side first. Flow rate pressure and temperature so here you will be finding out for a given pump the flow rate for the gaseous liquid phases will be different. Because that fluid properties like viscosity density those are different. So obviously you will be finding out for a given input the flow rates for both the phases will be different.

So by knowing the or by calibrating those flow rates before hand and later on for some unknown flow rate we can find out what phase is going on inside the pipeline okay. In a similar fashion pressure drop okay and temperature also can be utilized for sensing the flow characteristic inside the pipeline. Now let us see some modern techniques.

So in the left hand side I have shown electrical conductivity, capacitance, optical these are also different methodologies using which you can measure the 2 phase parameters. For example conductivity this is electrical conductivity. So gas phase and liquid phase they are having different electrical conductivities. So if we pass electricity between the 2 phase mixture depending on the presence of gaseous phase in the liquid you will be finding out that signal is differing okay.

So using the electrical conductivity of the medium where both the pressures can be present you will be finding out the 2 phase measurements. So that type of technique is called electrical conductivity measurement. In a similar fashion if you use capacitance principle of the fluids okay. We know that capacitance of gaseous phase and liquid phase will be different.

So depending on the capacitance property if you define or if you describe some probes okay which will be picking up the information of capacitance in the Two Phase Flow, you will be finding out that it can measure the 2 phase parameters. Similarly optical parameters, so light will not be passing in a similar way in gas and liquid. So you will be finding out that depending on the attenuation okay.

There will be lots of difference at the interface. So in presence of interface can be found out whenever optical ray is passing an attenuate from the interface. Obviously optical can be used for photographic purpose also. Using normal camera we can take a photography with the (()) (05:02) and we can find out what different type of Two Phase Flow is occurring inside right.

Few modern technologies are also like this x ray, gamma ray, neutron and radio frequency. So both the phases are behaving differently in the presence of x ray, gamma ray, neutron and radio frequency. So depending on these principles also probes can be developed okay. So nowadays at now researches are going on for development of x ray, gamma ray, neutron ray and radio frequency force.

We can use ultrasonic properties so sound speeds are not same in liquid phase and gaseous phase. So depending on the sound speed also we can generate some amount of probe. So, ultrasonic probes are also very popular for measurement of Two Phase Flow. Magnetic field also behaves differently in both the phases. So we can develop magnetic resonance probes okay for measurement of 2 phase parameters. And we can also see chemical and electrochemical behaviors of the phases.

Let us say we are going for some chemical reactions now that chemical reaction will be enhanced if the substances are in liquid phase and it will not be that much active if the substances are in gaseous phase. So obviously you will find out that depending on the chemical and electro chemical potential the fluid can be identified okay. So all these techniques nowadays people are using for measurement of Two Phase Flow.

Now first I will be showing you the measurement of Two Phase Flow what is the most primitive technique okay. Primitive means quick and you know many a times you use in your lab so what we can find out let us say here I have given 1 idea or a schematic of the tube inside which you are having 2 phase.

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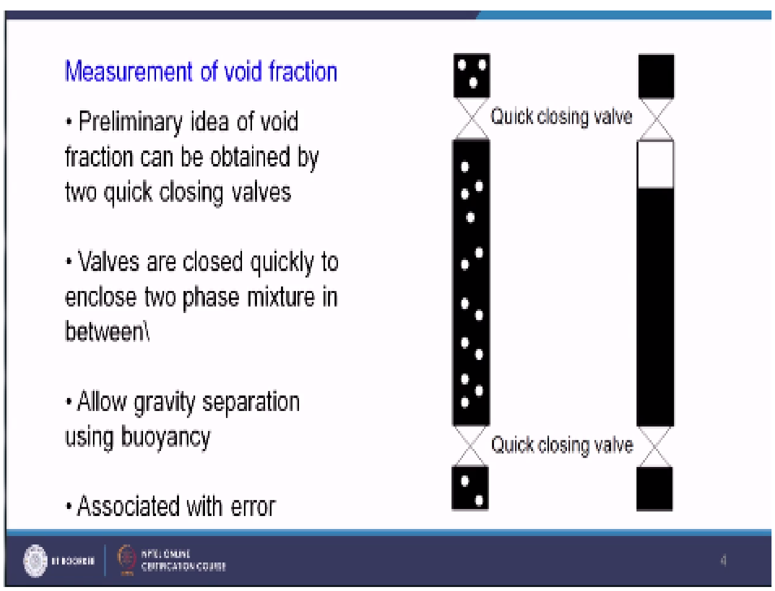

Here the white color circles are resembling let us say the gaseous phase and the black colored background is showing you the liquid phase right. So eventually you can consider that inside a pipe you are having bubbly flow. Now what will doing for measurement of void fraction, you will be having 2 quick closing valves over here okay. So in the general conditions the valves will be opened so that flow can be there inside the pipeline okay without disturbing the void fractions.

Now what we can do as we are using quick closing valve quickly both the valves will be closed simultaneously. So in that way you will be entrapping some amount of 2 phase mixture in the intermediate pipelines okay. Now you know that both the phases are behaving differently in the presence of gravity. So gas will be moving up and liquid will be falling down.

So you will be finding out that after sometime you are having some stratified layer of liquid and gas over here so if you will just measure the length of this 2 then you will be finding out volumetrically what is their ratio. And once you a get the volumetric ratio for a constant diameter pipeline, finding out void fraction is not difficult okay. So this is a primitive methodology or not primitive methodology.

I should say this steel, we are using this is not that much accurate so it is associated with the error because we will be having manual error when you will be closing the valves okay. But this steel we are using for quick measurement of void fraction okay. Then let us try to see that nowadays whatever probes are senses you are using, those are having 2 different dimensions okay. First dimension is that we are having analog type okay and another one is digital type. So let us try to understand what are these 2 modes analog mode and digital mode.
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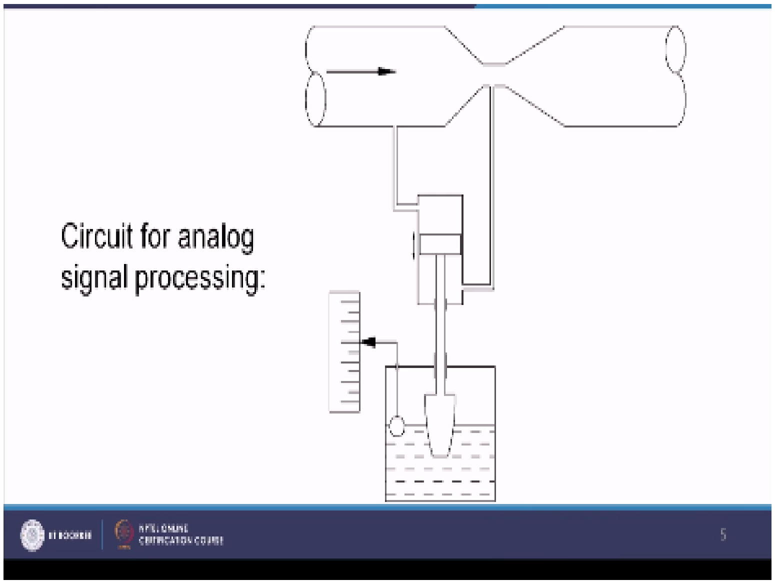

So what I have given you over here, a figure which shows you circuit for analog signal processing okay. So essentially this is a pipe so you can see this is a pipe carrying some flow. This can be single phase flow also or Two Phase Flow depending on the flow configuration, I have given the example using single phase flow.

And it is somehow is having eventually so some restricted flow part is there okay. So now, what you can find out, you can tap the liquid from the smaller cross section portion and from the pipe then we can connect those 2 taps around a piston. So this is a piston so you can find out it is connected in the upper side, this is connected in the lower side okay. Now depending on the pressure drop here and here you will be finding out the piston is moving up and down right.

So depending on the flow velocity you will be finding out the pressure drop between these 2 points are vary. And as I said, you will be finding out piston is moving up and down okay. So this pistol movement can be correlated with the velocity of the pipe right. Now as we are having this piston movement that can be easily converted to a stylus movement via some weight floating on the liquid.

And you see, here you are having the ball valve and that ball valve will connect with stylus. So that means if you having reciprocating portion over here, this (()) 10:11 will be actually moving as a result that ball valve will be also moving and the stylus which is connected with this ball valve will be also moving like that. Now if this stylus you actually pressed against one graph paper okay or you can say some sheet then you will be finding out that this reciprocation of the piston can be represented in the graph paper.

That means the velocity fluctuation in the pipeline can be represented here in the sheet or graph paper. So this was the earlier methodology of, you know obtaining signals for some variable input. Here the velocity of the variable input and that has been obtained in the graph paper right. But what happens here, I have given you some sort of you know idea of analog system. So here you see this is for Two Phase Flow, here you are having gaseous bubble in the periphery of you know liquid.

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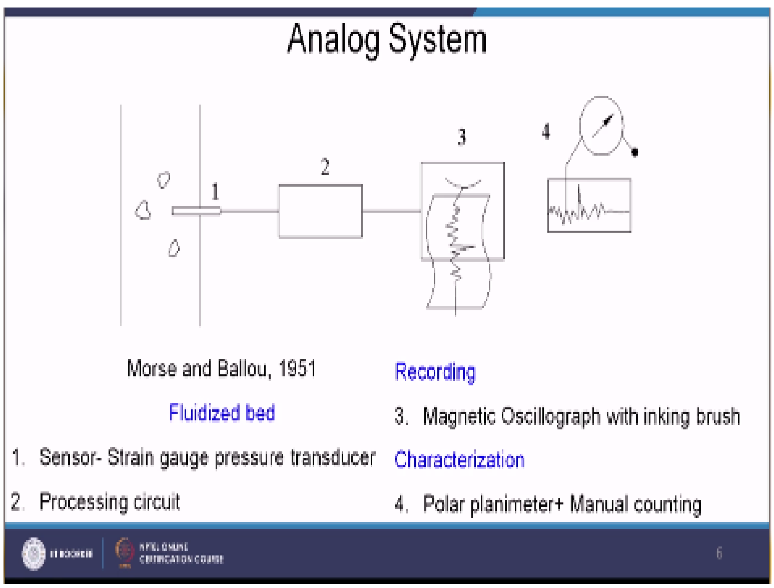

So this is a sensing element so this is sensing something so here you have given strain gauge pressure transducer okay which will be sensing and it will be giving some signal. So then we are having some processing circuit over here. This processing circuit can be any mechanical arrangement here the mechanical arrangement was this system cylinder device okay. After that it will be giving signal to some magnetic oscillograph with inking brush okay.

So this is the magnetic oscillation oscillograph with inking brush. In a previous figure that was replace by a stylus and the paper okay. And finally from this graph paper we need to find out some information. So what we do we use some polar planimeter and manual counting. So if you have the graph paper, you can count how many pix and values you are having in the fluctuation of the graph paper manually to get some information. Or you can use a polar planimeter which will be giving you that what is the area under the graph okay.

And that can be used for some information. So this was the typical analog system used earlier. Here I have shown you 1 old experiment okay. So here you see this was the experiment of rewetting.

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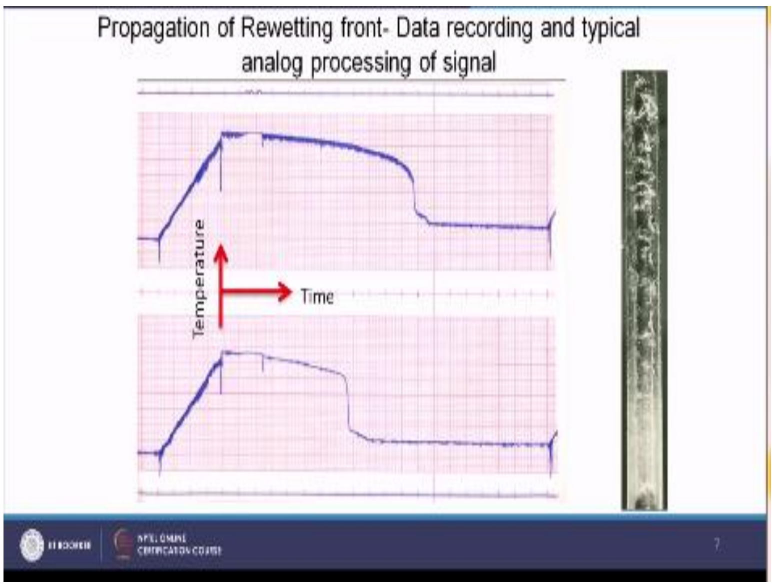

So this was a heated rod around that we have actually sprayed liquid. So let us say you have a heated rod and you have sprayed liquid from surroundings. So you will be finding out that first that liquid will be flooding the liquid this heated rod. After certain period, when boiling will be starting will find out that the liquid is jumping from the solid heated wire okay.

So that is actually called rewetting, rewetting why because after jumping once again it will be touching so in between some portion will not be touching the heated rod. So here we have shown the propagation of rewetting front okay using our analog signal so this is once again the stylus recording on a graph paper.

So you can find out over here that from here to here we are having actually no contact between the liquid fronts on the heated wire okay. Now as time progresses you can find out so here you can find out that as here we are given 2 signals like this 2 different conditions. You can find out that the area under this (()) 13:21 is reducing that means that 2 different conditions whenever you are heated rod is 2 different temperatures.

We can find out that what is the different temperature by comparing these 2 graphs. So obviously, this is having low temperature of the heated rod and this is having higher temperature of the heated rod okay. So, these kinds of comparative graphs earlier (()) 13:42. Okay, next let us see the modern technology nowadays whatever we were using that is called digital system. So here in this digital system, sensing element remains same okay.

Those who was from the principle are difference in thermodynamic or fluid mechanics properties, as I have mentioned in the previous slides different properties we can use. So, sensing element remains same. So you see which is the sensor okay.

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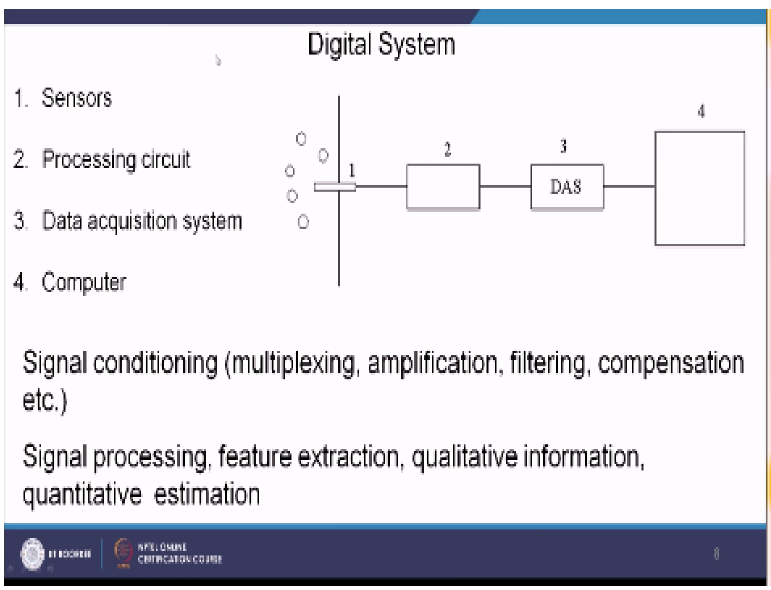

And after that you are having processing circuitry also. Earlier that was in case of analog that was mechanical processing circuitry, now it is we are converting that 1 into digital processing circuitry okay. So these are actually electronic processing circuitry. Then after that you are having here data acquisition system, these data acquisition systems are having typically few features.

For example it will be for storing then it will actually filtering then it will be amplify and lots of you know post processing also we can do using this type of data acquisition system. And finally the data acquisition system will be sending the signal to store in a computer okay. So these are typical components of a digital system whatever we are having now.

Now for a signal conditioning, so here in data acquisition system we have system conditioning as I have already told you it will be handling amplification it will be handling filtering if you have some unwanted data (()) 15:08 those, it will be filtering okay. It can also do multiplexing that means let us see you are having multiple probes. And data are coming from those multiple probes.

So what you can do those data, you can club in a single channel and you can do some subtraction, multiplication or division so those are called multiplexing. So using this data acquisition system you can also do multiplexing right. And at the end you can go for some compensation we know that for some sensing element like thermocouple (()) 15:40 device you have to go for compensation for thermocouple that is called core junction compensation.

So using this data acquisition system we can do those compensations electronically okay. In case of analog those compensation needs to be done manually right okay. And after this data acquisition system in the computer, we can go for signal processing feature extraction and then qualitative information and subsequently quantitative estimations. So after you get the signal it is very easy to rule the post processes okay and obtain some sort of qualitative and qualititative information okay.

Next let us try to see that how we are obtaining these informations, quantitative and qualitative informations. So you have to go for techniques different techniques for signal analysis. Now these signals can be of 2 different types. If you are taking the signal using a camera, the signal will be coming in the form of image pixilated image. So you can have an image processing techniques okay from image you can extract some amount of information.

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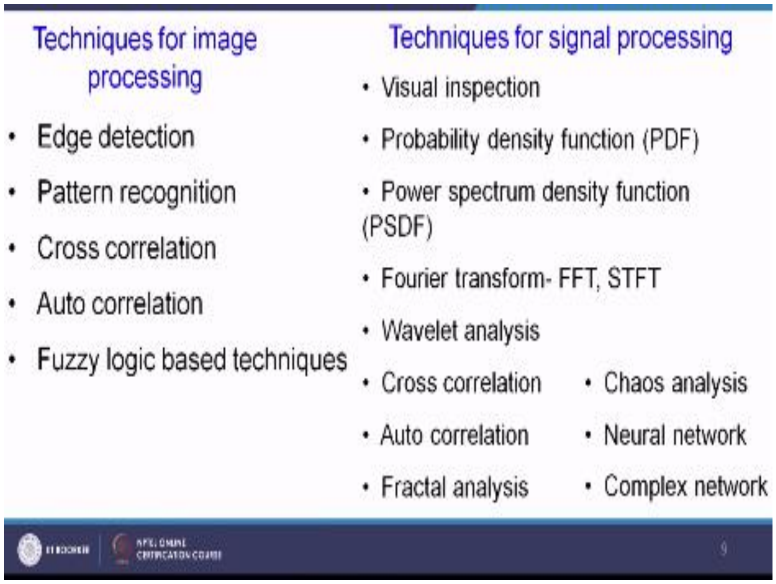

On the other hand some probes are there which will be giving as an electric signal. So we can have techniques for the signal processing also. Let us go through what are the techniques for image processing, for example first 1 is edge detection as you are having let us say interfacial configuration and you are taking a photograph.

So first task is to find out where is the interface. So you can do edge detection, edge detection means you can typically identify where liquid is and where gas is and the intermediate is actual the interface on edge right. So you can go for edge detection and find out the interface. Similarly, we can go for pattern recognition, cross correlation, auto correlation and some modern day fuzzy logic based technique also using in edge right.

So these cross correlation, auto correlation and fuzzy logic those are mathematics based topics we are not going in detail of this one. But nowadays tools are available with cameras using which we can go for cross correlation, auto correlation and fuzzy logic based techniques okay. Now for a signal analysis, electrical signal analysis first 1 obviously, you can see the raw signal which is called visual inspection. So from visual inspection we can find out that if you are getting some pictures or not.

Then you can quickly next we can go for probability density function for the signal okay. I will showing you some signals over here with probability density function. You can go for power spectrum density function PSDF, so PSDF is once again a mathematical tool using which you can analyze some time data okay. You can go for fast Fourier transformation FFT okay or STFT okay. We can go for wavelet analysis also I will be showing you what is wavelet analysis.

And some typical signal analysis processes like cross correlation, auto correlation, fractal analysis, chaotic analysis, neural network and complex network some of these I will be telling you in the next lecture okay. So first example you will be taking is a gas liquid up flow through concentric annulus okay. So let us say you have the annulus section where, gas and liquid is flowing in the upward direction okay.

So it is not a pipe is actually 1 annular section. So inside a pipe you are having a solid concentric tube okay. So the gas and liquid only can flow in the annular regime okay.
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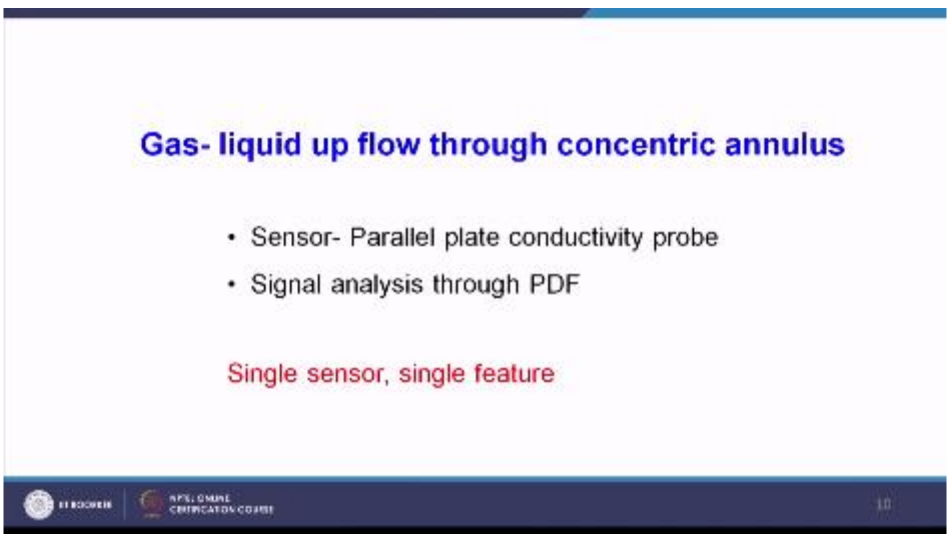

So here in this experiment what we have done, we have used parallel plate conductivity probe okay. So electrical conductivity probe, parallel plate electrical conductivity probe as sensor and for characteristics analysis we have done for signal analysis through PDF okay. So this is typically a single sensor, single feature application okay. So let us see what are the different types of conductivity probe, electrical conductivity probes are available.
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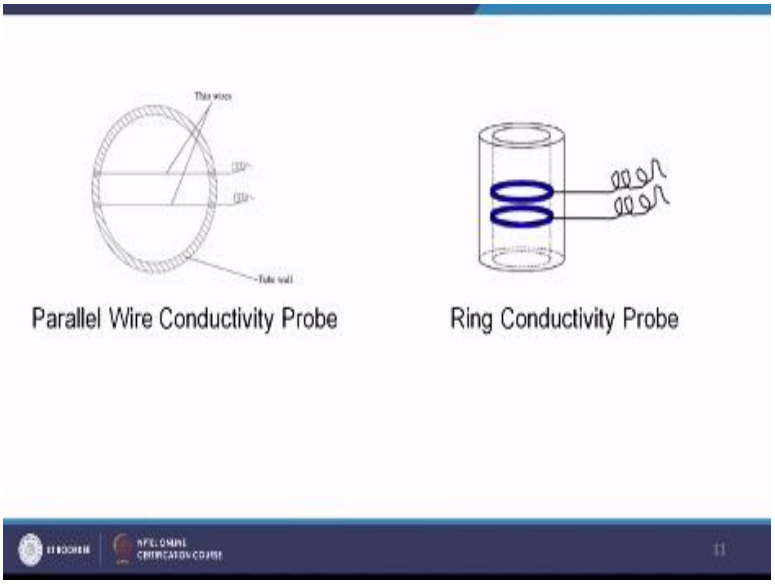

So first here you see you are having parallel wire conductivity probe so this is cross section the pipeline. So what we will do, we make holes like this okay face to face holes like this okay. And we pass the electrical wire so this can be copper wire or this can be you know aluminum wire okay. So through which we can pass electricity.

So what we will be doing. 1 side of this wire will be blankly fixing in the pipeline and other side will be taking out okay. And this 2, you will be connecting with, you know some power supply. Now depending on the medium presenting between okay as (()) 20:35 not connected okay so these are blankly fixed with the pipe wall. So there is no physical connection between these wires okay.

Only connections between these wires are through the medium okay in between the wires. So depending on the medium whatever you have, the circuit will be closed and resistance overall resistance will be determined okay. If you are having air in between these 2 wires, you will be finding out that you are having a huge resistance in the circuit.

And if you are having some liquid let us say water over here connecting these 2 wires then you will be finding out that you are having very less amount of resistance okay. Now if you try to give a constant over here okay and if you try to find out that what is the voltage across some small section using 1 volt meter then we will be finding out that depending medium means that the pipeline the voltage is actually fluctuating right.

In a similar fashion, so this is actually called parallel wire conductivity flow as the wire for parallel. In a similar fashion, we can have ring conductivity probes also. Here the wires are parallel but here what we do in the wall of the tube we keeps some parallel plates okay. So this is actually the blue color thing is actually parallel plate so each plate is connected with the wire okay.

And whatever medium is here in between this parallel wire, parallel plates are actually consoling the resistance in between these 2 open circuits okay. So depending on the medium we can also use what type of voltage will be coming from this ring conductivity probe. Now to give you example, as we know all the flow regimes this 1 parallel wire conductivity probe will be very, very helpful for bubbly flow or slug flow kind of thing but ring conductivity flow will be very, very helpful for your annular or a core annular or (()) 22:32 kind of thing this will be very, very helpful.

So let us see that what is the details of the processing circuitry.

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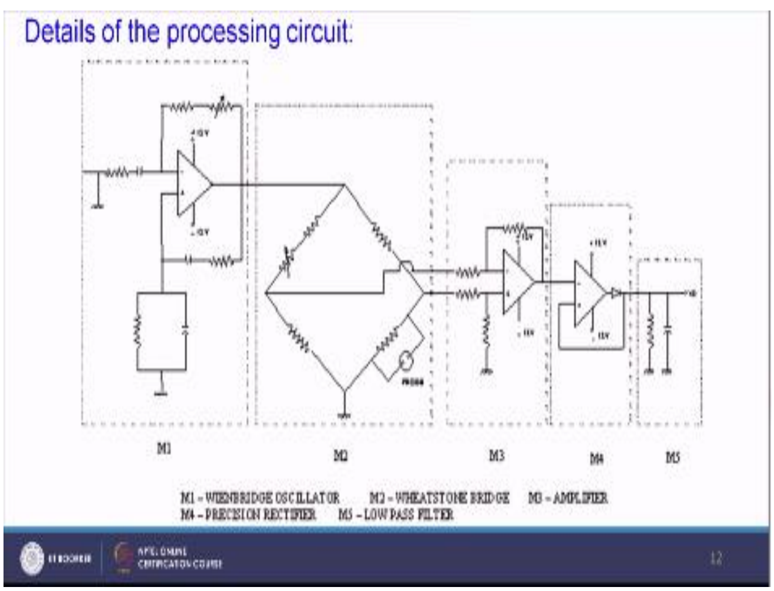

So here we will be finding out that we are having few components in the processing circuitry. First one is 1 WIENBRIDGE oscillator will be having 1 WHEATSTONE BRIDGE also throughout this connected in 1 arm of the WHEATSTONE BRIDGE. Next for the filtering and rectify we are having 1 AMPLIFIER and then PRECISION RECTIFIERS over here.

So this is the amplifier section this is the rectifier section and finally you are having some low pass section low pass filter section okay. So whatever probe signal you were getting over here, we are doing AMPLIFICATION, RECTIFICATION, and FILTRATION and finally store that in the computer okay. So this is the typical processing circuitry as I have told, this will be constructed by electronic so this is typical processing circuitry signal.

Okay next let us take some example, let us say I was discussing about annular pipeline.

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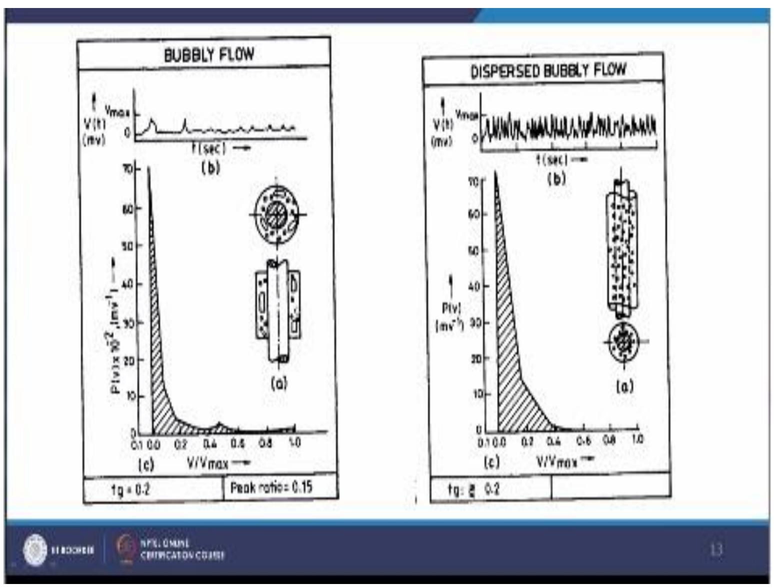

So let us say this is the annular joule we have shown 1 cross section. So you see in this typical section so this is the cross section this is the front view of the pipeline. So you can see lots of bubbles okay are there in the cross section okay. So this is actually a bubbly flow situation. Now if you take the signal using electrical conductivity probe, you will be getting a raw signal like this.

So in the axises we are having time over here and in the ordinate you are having the voltage okay. So you can find out a erratic signal like this okay. And now if you go for signal analysis first one is nothing but I will be using the probability density function. So this signal we have actually obtained the probability density function.

So you can find out after doing this probability density function you will be getting a very sharp peak near low voltage because most of the time the pipeline is occupied by liquid. As a result resistance is very low right, as a result you will be finding out a high peak near the 0 voltage okay. The situation actually differs in this case, wherever we are having dispersed bubbly flow. You see in case of disperse bubbly flow diameter of the bubbles are smaller compare to this one okay.

So here you will be finding out that lots of small bubbles are over there which probably not being tackled using your probe okay. So the signal, typical signal will be like this, voltage verses time and in a same fashion you will be getting a peak also over here near 0 but there are differences between these 2 peaks. This peak will be very sharp okay because we are having small number of bubbles in this case were as a very large number of smaller bubbles over here in dispersed bubbly flow case okay.

So this peak will be little bit flattened compare to the bubbly flow peak okay. System will be changing whenever we are finding out a slug bubble okay. Here you see a typical slug bubble around one annular cross section.

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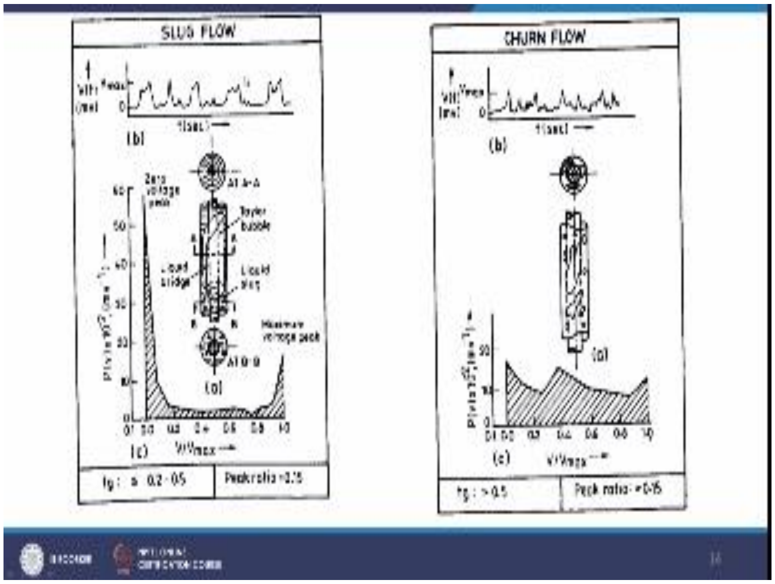

So you see this is the slug bubble, open slug bubble basically. So you will be finding out the signal is showing lots of peaks and valleys okay. And if you go for signal analysis probably density function you will be getting two peaks first peak near the 0 voltage and second peak near 1 voltage. Remember this voltage is we have actually normalized okay.

So here you can find out sometime, we are having presence of gas whenever we are having you know contact of the probe with the gaseous phase. So we will be getting a peak also over here okay. And for the liquid contact we are getting a peak somewhere over here okay. So if you see the signal and the PDA, probability density function for both the phases slug flow and the bubbly flow, we can understand that which type of flow regime is occurring inside the pipeline.

Similarly in case of churn flow, as we know churn flow is very much erratic that is no fixed configuration in the pipeline. So you will be getting a signal like this okay the erratic flow signal kind of thing. And if you go for the probability density function, you will be finding out no peak at all right. So that shows that you are having typically churn flow or chaotic flow kind of thing inside the pipeline right.

Okay, next let us try to go for another experiment where, you will be showing simultaneous flow of 2 miscible liquid. So this is actually liquid, liquid flow immiscible liquids.

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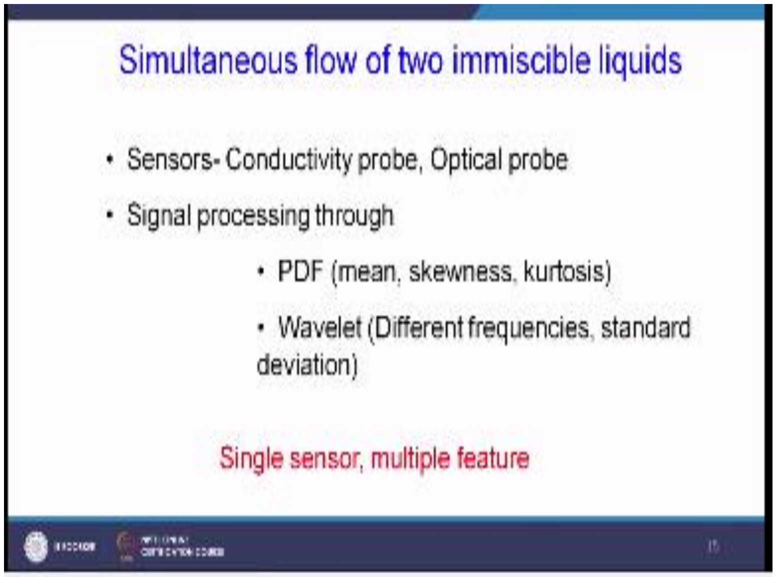

So, here you have used both conductivity probe and optical probe okay. And we have actually process the signal for using PDF okay, PDF already I have shown in the previous experiment and here new thing we have done is actually wavelet okay. So this is single sensor but multiple features okay. So this is a typical example with the set up. So here we have used both optical probe as well as electrical conductivity probe.

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So as I have already given you idea about conductivity probe, let me tell you something about optical probe.

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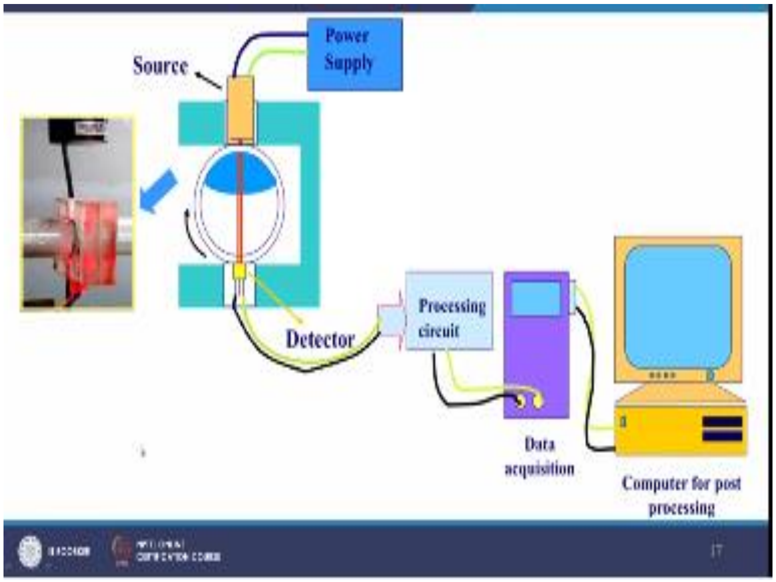

So here let us say this is the pipeline okay. And here we are having the laser force which will be giving you the light. And the other hand side of the pipeline, we are having 1 optical receiver which is essentially 1 for photodiode okay. Depending on the light intensity coming out of the other side of the pipeline, the photodiode will be energizing and generating some voltage signal right.

So here schematically I have shown let us say 2 liquids we are having water and kerosene. Water is white in color and kerosene is blue. So you can find out the laser light whatever it is giving some portion is coming in the detector and detector after energizing, it will sending some signals to the processing circuitry via data acquisition system that can be coming to the computer okay.

So this is a typical example so you can see the processing circuitry over here okay.

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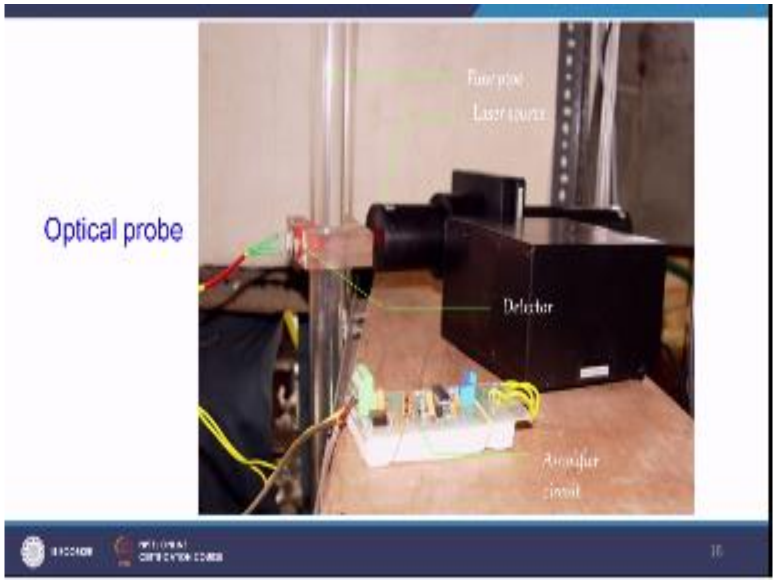

Here we are having the detector, in this side we have the laser force okay. Now as I have told that I will be telling you about wavelet analysis. So let us see that features of wavelet analysis.

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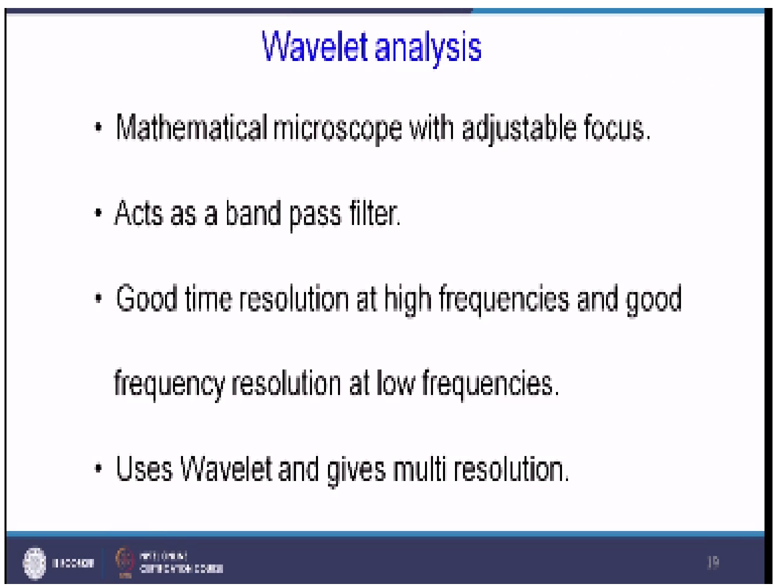

So this is actually mathematical microscope with adjustable focus. It acts as band pass filter; it is having very good time resolution at high frequency and good frequency resolution at low frequencies okay. And you will use a wavelet to obtain multi resolution okay. So let us show you a typical wavelet analysis. Here this is the raw signal s.

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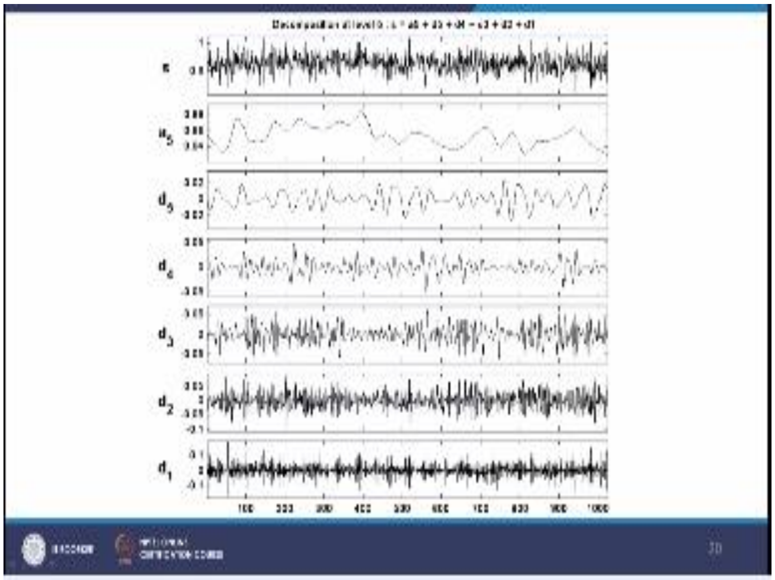

So in the axis we are having time, in the ordinate we are having raw signal. So you can find out this is the raw signal from your pipeline, liquid, liquid flow pipeline. So what we do, we decompose this signal into 1 a5 and then d5, d4, d3, d1, d2 okay. So all these d's are plotted over here and all at this a5s over here. So this is basically a fifth order wavelet analysis so you can go for higher and lower order respectively you will be getting the equations and the signals.

So here you see this d1 is actually the major signal from here okay. So if you subtract s -d1, you will be getting d2. Similarly, if you subtract s- d1 -d2, you will be getting d3. Something like this if you continue, finally you will be obtaining a5 right. Now after decomposition what we will be doing for a typical signal, you will be finding out the probability density function or standard deviation for all those d1, d2, d3, d4, d5 and a5 along with the raw signal s.

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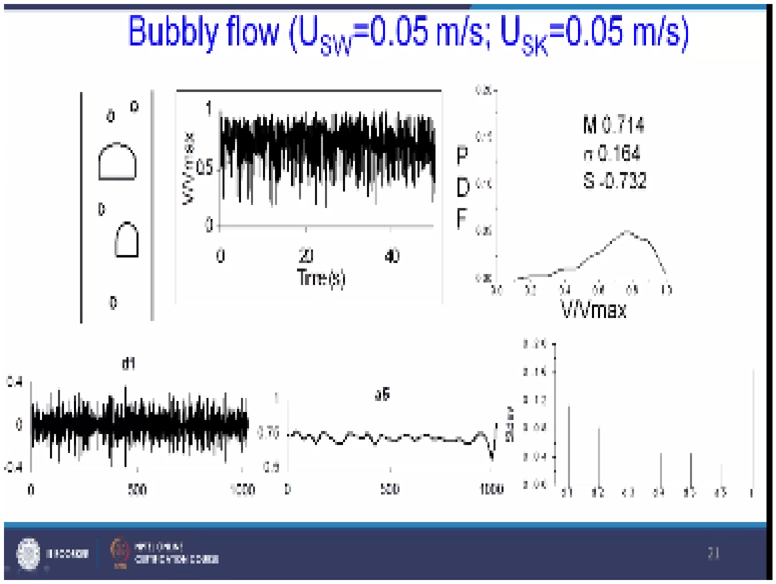

So you see here along with the conductivity probe signals we have shown you the optical signals also. So this is a typical signal with respect to time whenever we are having bubbly flow and we have shown here the probability density function from the conductivity probe signals and d1, a5 from the wavelet analysis and their corresponding standard deviation over here. So you can see for bubbly flow.

You will be getting a falling nature of all these intermediate frequency standard deviation. The system changes whenever you are having turbulent flow. So you can see the PDF was like this for bubbly flow but for churn turbulent flow PDF is shifting towards 0. But we are not having any difference in the standard deviation of the wavelets okay. So using both the things, we can recognize actually a difference between bubbly flow and churn turbulent flow.

So the wavelet analysis is not giving the difference but PDF or conductivity probe is giving us the difference okay. But that will be important whenever optical probe signal will be important. In case of core annular flow, we see you can find out the complete reverse nature of the standard deviation of the wavelets d1, d2, d3, d4, d5.

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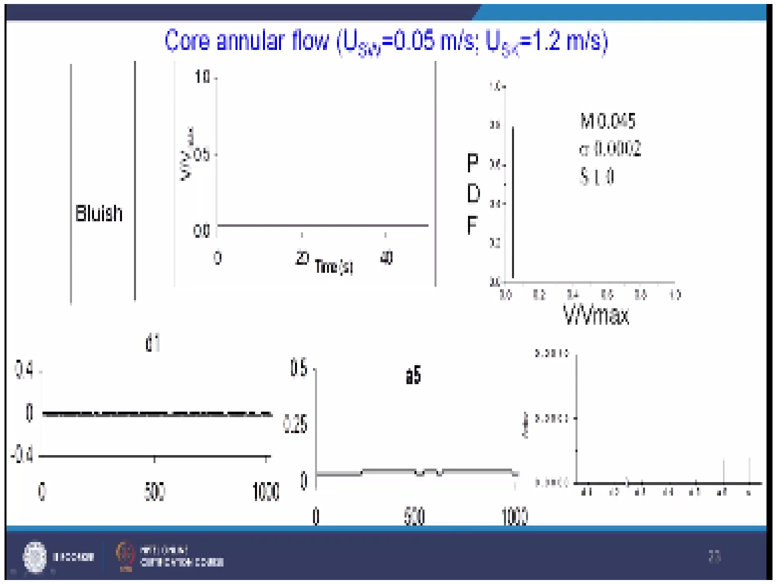

You see earlier it was falling nature, now it is continuously increasing nature. So using the wavelet you can find out that what is the difference between the core annular flow and bubbly flow or your churn turbulent flow okay.

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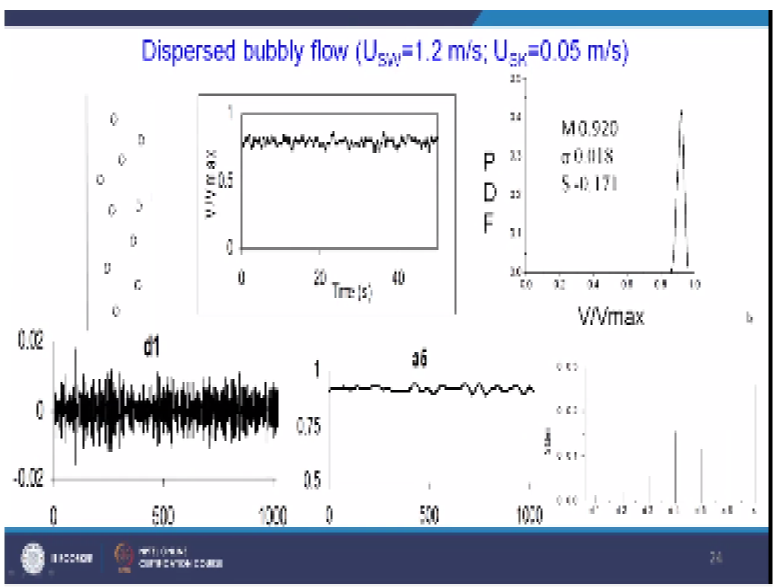

Similar thing can be seen for dispersed bubbly flow. Here you see the random erratic nature of the signals okay. So standard deviations of all those decompositions okay. PDF shows the similar kind of thing okay whatever we have seen in case of your electrical conductivity probe. Now to summarize in this lecture, we have listed down all possible techniques for measurement of Two Phase Flow void fractions.

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We have shown construction and working principle for the electrical conductivity probe. And we have also shown you the optical probe construction and working principle. For signal analysis we have shown you the probability density function and wavelet analysis. How those are important for recognizing the flow regime inside a pipeline okay. Let us try to test our understanding, so you are having 3 questions over here.

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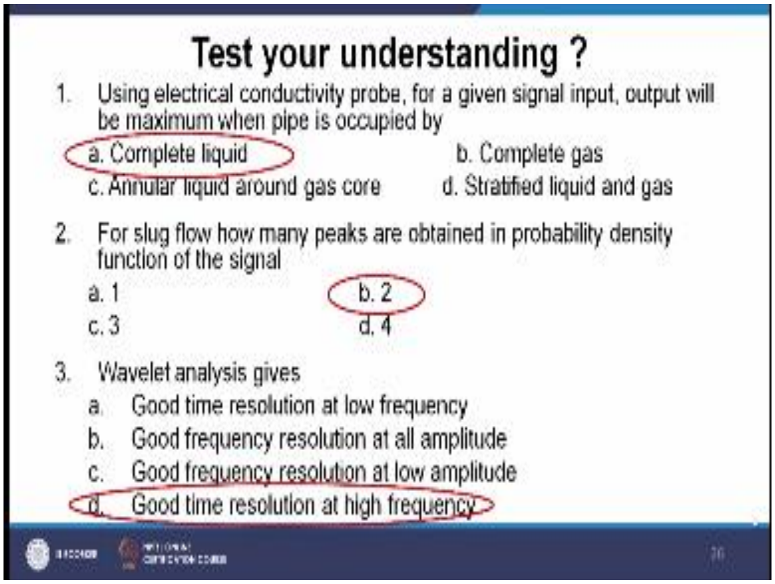

Using electrical conductivity probe for a given signal input output will be maximum when pipe is occupied by? 4 options you are having, complete liquid, complete gas, annular liquid around gas core and finally answer d is stratified liquid and gas okay. So from the principle of the conductivity probe we can find out that answer will be complete liquid okay.

Question number 2, for slug flow how many peaks are obtained in probability density function okay. So answers are 1, 2, 3 and 4 okay. All of you know answer will be 2 right. Next third question wavelet analysis gives, Good time resolution at low frequency, Good frequency resolution at all amplitude, Good frequency resolution at low amplitude and finally for d Good time resolution at high frequency okay.

So already we have given you the characteristics of wavelet analysis please go through that one once again. I think you can get the answer, last 1 is the answer Good time resolution at high frequency. With this I will be ending this lecture, thank you.