Multiphase Flow
Prof. Gargi Das
Department of Chemical Engineering
Indian Institute of Technology, Kharagpur

Lecture No. # 39
Measurement Techniques for Two-Phase Flow Parameters - Void Fraction Measurement (Contd.)

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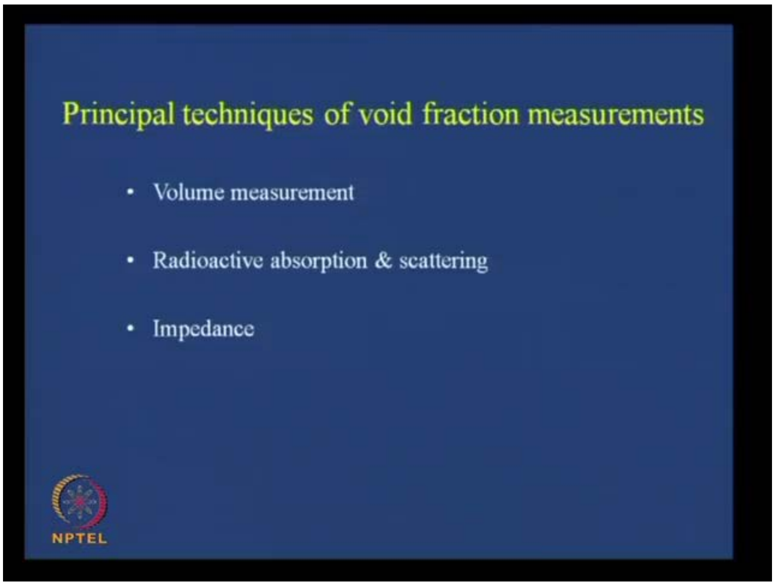

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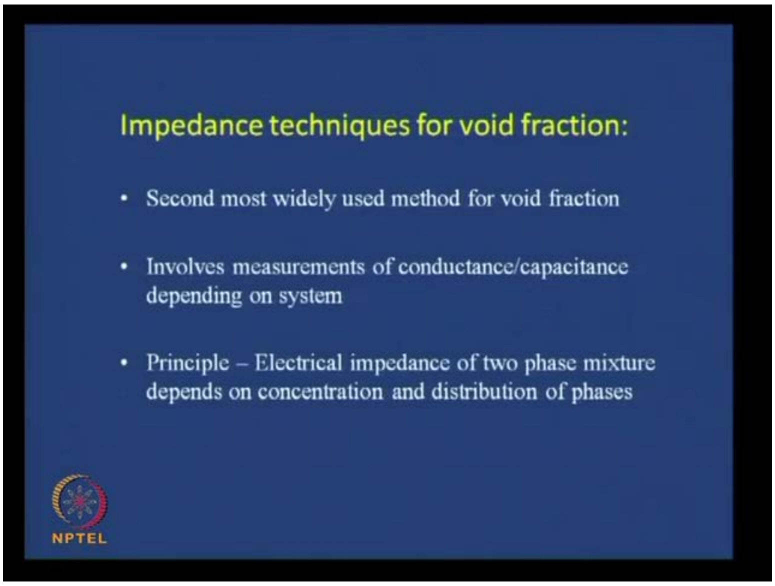

So, will continue with our discussions in the last class what we did, we started or rather we were discussing void fraction. And I told you that the most common techniques, which are used is the volume measurement, radioactive absorption and scattering, it is usually the radiation attenuation techniques, it is better known as. And then the other technique which is very commonly used is the impendence technique, because very frequently what we find, we find that the electrical conductivity of the of the two phases I usually different or the electrical capacitance of the two phases are usually different.

So therefore, it is very common or rather this technique is also, it is a second most widely used method for void fraction measurement, in this case, it involves the measurement of either the conductance or the capacitance depending upon the system. If you are operating at a higher frequency, then capacitance is dominating in that case, the method works on the difference in the dielectric constants of the two phases or and if you are operating at lower frequency, then it is based on the difference in electrical conductivity of the two phases. Usually for air water system, we prefer conductivity probes, but for certain other systems, it is better that we depend on the dielectric constant difference.

Remember one thing, the only problem it is easier to design the circuits for conductivity probes. The only problem is as we all know that conductivity it is; it is very difficult to maintain a constant conductivity of the liquid, is it not? The conductivity varies even if you take tap water every day in fact, after half an hour, if you measure you will find the conductivity changes. It depends upon the dissolved solids, the dissolved gases, the temperature pressure, depends on a large number of factors. So, therefore, it is a much more variable as compared to the dielectric constant.

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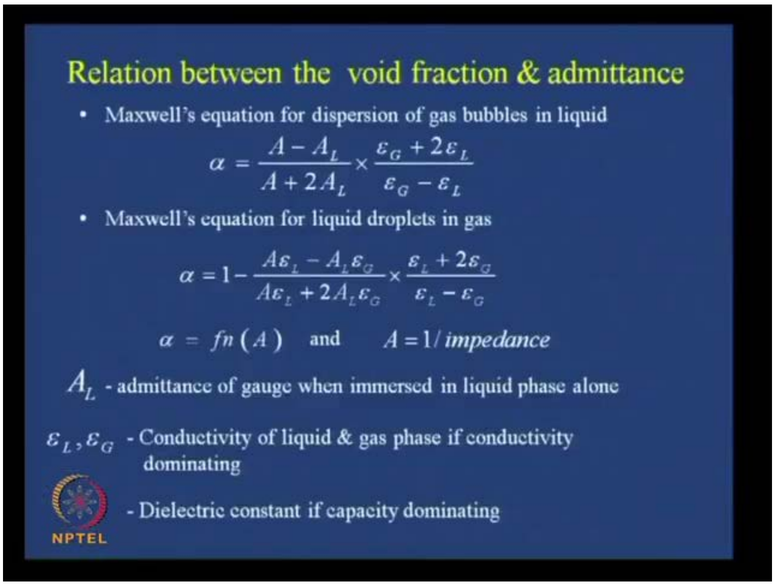

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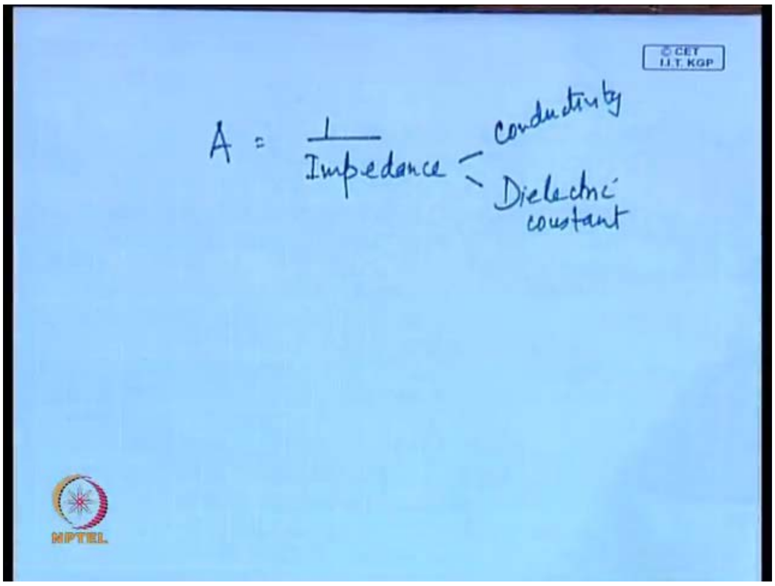

So, far more accurate measurements very often, we would prefer to explode the difference in dielectric constant as compared to difference in electrical conductivity. Now, when we are using it, what we have to do? We have to measure, say the again the same thing the conductivity when, the tube is full of water, may be the conductivity when the tube is full of air, if it is a air water mixture and then, we have to find out the conductivity when the two phase mixture is flowing. Do you mean to say that, after we measure the conductivity, we have to convert it to the void fraction, because our final aim is to find out the void fraction is it not.

So, if we have to convert the conductivity to void fraction, we need some sort of a relationship usually Maxwell's relationships are used for this particular purpose, because the admittance which is nothing but 1 by impendence this I believe you already know is it not. Admittance A it is equal to 1 by impedance where this particular impedance it can be conductivity or it can be dielectric constant. So, the point is, if this particular admittance has to be related to void fraction then, they has to be some particular mathematical relationship for it is it not. Now, any particular mathematical relationship if we used, this relationship definitely firstly, it will not be a linear relationship and secondly, it cannot be same for different flow patterns. Is it possible that the relationship between impedance and void fraction that you obtain for annular flow, the same relationship cannot be used to find out the void fraction for bubbly flow? Definitely, it is not possible. Because the relationship between void fraction and impendence or admittance which is the reciprocal of impendence, this has to be different for different distributions when, we are dealing with dispersed systems then, we can use the Maxwell's equation for this.

If you see the Maxwell's equation you find that, this particular Maxwell's relation it is the admittance, it expresses alpha in terms of the admittance of the two phase mixture, the admittance when the tube is full of liquid. And the dielectric constants of the conductivities, when the tube is full of water and when it is completely empty or full of gas. We find that, when the dispersion of gas bubbles in liquid this is the relationship, when it is liquid droplets in gas this is the relationship. So, we find that even for dispersed flow also, if the dispersed medium and the continuous medium are interchanged keeping everything else constant under that condition also, alpha is different for the two cases. We have different expressions for alpha when gas bubbles are dispersed in liquid and when there are liquid droplets dispersed in gas.

So, therefore, you can very well understand that, the only hitch in finding out alpha from your impedance is, we have to know the distribution of the two phases in order to find out a relationship between alpha and admittance or alpha and impendence, this is the first thing, never the less this technique is very, very attractive. Can you tell me why? Any electrical technique is very attractive firstly definitely it is cheaper as it safer cheaper as compared to radiation techniques. The other thing, the advantage of all electrical techniques is it gives an almost instantaneous response. So, therefore, the due to it is fast response it is always very attractive.

So, the thing is, we find that even for dispersed flow, when we dispersing and the continuous medium are interchange, we have different relationships. And definitely, totally different relationships will be there, when we are having dispersed flow and when we are having separated flow. Even for separated flow the same relationship cannot apply for stratified cases and annular cases.

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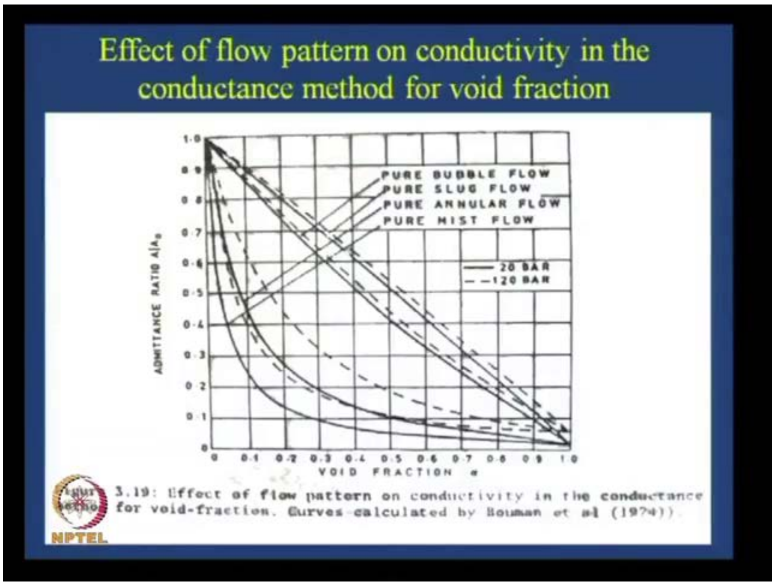

Now, this particular figure, this is going to show you the effect of flow pattern on conductivity. From here, you can very well see that, even for the same void fraction, we get sorry even for the same admittance ratio, if we have bubbly flow, we have one void fraction, if we have annular flow we get another void fraction. So, for the same admittance if you see, we find that for an say admittance ratio is 0.3 for that particular case when it is annular flow, the void fraction is 0.2 and when it is bubbly or slug flow the void fraction is say almost 0.7, 0.75. So, therefore, if we have to know really what is the void fraction within this particular wide range then, we have to know the distribution of the voids are the flow patterns. Without an apriary knowledge of the flow pattern it is not possible to find out the void fraction or the quantitative value of void fraction very accurately by using the impedance technique, this particular path we have to remember.

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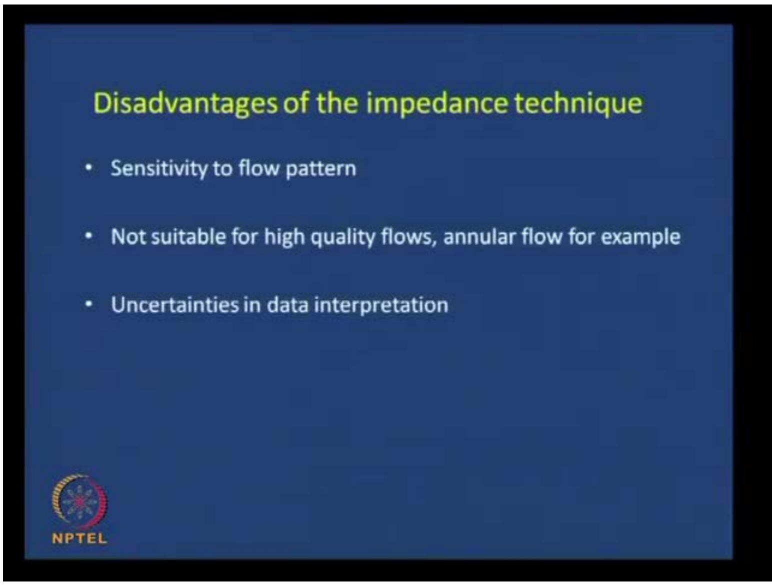

So, what are the advantages definitely, the first advantage is almost instantaneous response and it is obviously, very accurate if a apriary knowledge of flow pattern is there. What are the disadvantages? Firstly, it sensitivity to flow pattern definitely, the other thing is, try to keep this in mind. See suppose, we are using the conductivity probe, which works on the basis of difference in conductivity of the liquid and the gas. Now, remember one thing, when we are having a larger proportion of the liquid smaller proportion of gas it is fine. Liquid see, we are having a high conductivity moment gas is been introduce gradually conductivity decreases decreases decreases, then when we have large amount of gas or something the conductivity become zero.

Now, for greater amount of liquid or in other words, when liquid forms the continuous phase then, what happens the liquid more or less it gives a path for the electrical circuit to be completed. But if gas becomes the predominant phase, then in that case what happens, the liquid they will be dispersed. So, therefore, under that circumstance the gas is not going to give a continuous path for electrical circuit to be completed. So, therefore, if the flow patterns change, but the gas is the continuous phase, but or the gas is major quantity in for high quality flows what happens, we find since circuit is not completed it is going to give you zero output, no matter even if the flow pattern changes or even in the void fraction changes is it correct.

So, remember one thing, most of this techniques they work well only when, we are doing for low quality flows, it can be bubbly, it can be slag, it can go up to churn as well. Sometimes in annular flow it gives more or less good results why you know, because since there is a continuous liquid fill. So, around the liquid fill more or less a path is provided. But usually we find wherever, whenever we go for high quality flows, this techniques they are not suitable at all, this has to be kept in mind, they are suitable only primarily for low quality flows. And the other thing definitely uncertainties in data interpretation, unless you know the flow pattern, unless you have a proper mathematical expression, it is very difficult. Even if you do not have a mathematical expression also incitive calibration is possible, just like the way I was discussing for radiation absorption. We can take up on incitive calibration.

We find out the conductivity, when it is full of water, zero conductivity when it is full of air see what is the conductivity for the two phase flow? Definitely, this conductivity will change or it is a very sensitive function of void orientation, the void distribution and so on and so forth it is going to be highly effected by this. But one good thing about this is, see in radiation absorption always you get a chordal average void fraction is it not. Volume averages always get a volume average void fraction. But in this impedance technique, we can design the probes to suite our purpose such that, if required we can obtain an idea about the volume average, if required we can find an idea recording the area average, if required we can find have an idea about the chordal average or the time average as well.

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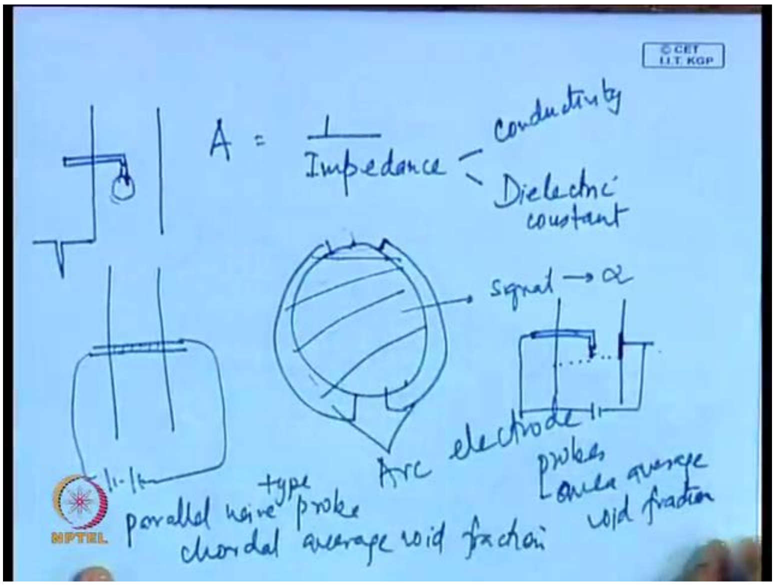

For example and remember one thing this conductivity probes were not very popular or the impedance probes where not very popular, even about fifty years back also, why, because the design of electrodes is very important. So, with advance designs the entire efficiency depends on how well you design the electrodes that is very, very important. So, therefore, it is very flexible, we can use it to our advantage, if you have a master you over the designs and the circuits that is what is important. For example, suppose, you want area average, what will you do? We can take say arc electro probes. But people have been using them, these are known as arc electro probes. What they do? They are more or less, they are mounted on diametrically opposite valves, they span the entire tube valve and then from here, through the electrical lines more or less they give us an idea about the area average void fraction.

There are definitely some problems here, the most accurate thing we will be getting if more or less the entire cross section is covered, but that is not possible. Because we have to ensure that the electrical path takes place through the two phase medium, see they touch here then the thing is gone remember that. So, this and this the advantage of this arc electrode probe is, that it is non intrusive, it does not disturb the flow passage. And the this advantage, remember one thing see these things exactly it is difficult to get in any text books, the problem is slides also they do not provide you everything. So, the best thing you here it properly understand it, ask me questions and then, if you want, we can it form informal discussion. So, that I can clarify what ever doubts you have, where ever you understand the you rise your hands and then, I will be explaining it once more. So, therefore, this arc electrode probes the advantages definitely, it is non intrusive and it gives us an area average value.

This advantages firstly, converting it is signal in to voidage, that is not very easy it requires very extensive mathematical manipulation, but if that can be done, then it is what that. There are certain other in accuracies here, for example, just like I was taking in radiation absorption towards the valves there are some amount of fringing effects, towards here and here. And the closer these two can be made the more accurate area average, we can get instead of this a much more simpler thing is, if you want a chordal average void fraction, we can take two wires very closely paste and then they can be connected to any particular circuit. Now, in this case what happens since, the wires are very closely paste the electrical path from this wire to this wire it goes through the space between them. Depending upon the conductivity of the two phase mixture here we can get an idea about the chordal average void faction. This chord it can be traversed over the entire tube cross section and it can give us an area average void fraction as well.

Now, here the advantages that the circuit is much more simpler and getting a the estimate of void fraction, form the output data is simpler in this particular case. So, instead arc electrode, we very often refer the wire probe, it is now as parallel wire probe, parallel wire type probe which gives us the chordal average void fraction. This gives you the area average void fraction. I do not know the students we ever missing to this class it will be difficult for them slightly. The other thing which we can have is, we can have a point electrode sort of a thing, we can have something of this sort, where there is a wire here, a larger wire here. Here this gives us the point average of the time average void fraction. Whenever there is a bubble coming here, it gives us a zero output or else it gives us a continues output when water is flowing here. This particular probe it can be traversed throughout the cross section to give us the voidage profile.

Now, this can be other way also, we can have it in this particular way also, we can have a wire here and we can have another electrode here. So, that between these two, we can have a complete circuit so in that case it gives us void fraction between the two. So, here also, we can have more or less we can be traversed and we can have an idea about the voidage profile. But when this particular probe, we can not only measure the voidage profile, we can also measure the frequency as well as the size of the disposed phase as well.

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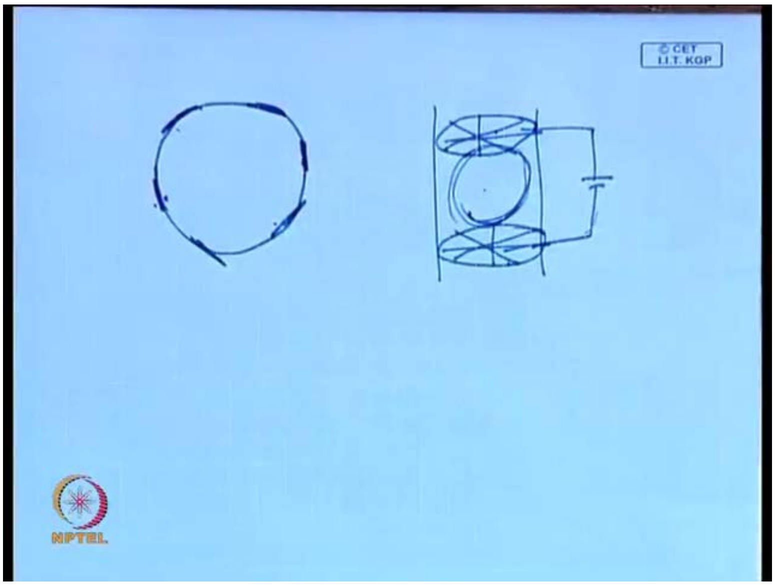

Now, instead of this arc electrode probe, there is one other probe also which people have used and they have got quite good results very interestingly. See they have put six electrodes along the valve and alternate electrodes are energized sub simultaneously. So, therefore, once these two, once these two, once these two are energized and then from a proper average we get an idea about the cross sectional average void fraction.

So, the what I want the emphasized to you is that depending upon the design of the probe, this particular technique can be use for a wide range of purposes. And suppose, we want to measure the volume average, what will we do? We can just have one particular wire mesh probe here, we can just have one particular wire mesh probe here, just like the strainer through which you strain t, just like those two we can have on both the ends and this can be connected our complete to a circuit. So therefore, depending upon the two phase, this is usually use for bubbly flow for measuring bubble velocities etcetera. So, the depending upon the two phase mixture here, we can obtain a idea about the your volume average void fraction.

But this as you can see this is very much intrusive this obstructs the flow to a large extent, to abstraction can be minimize by making wires very thin such that they disturb the flow to a minimum extend. But naturally any volume average method it is going to abstract the flow, we cannot help it at least you do not have to stop the flow or do something in this particular case.

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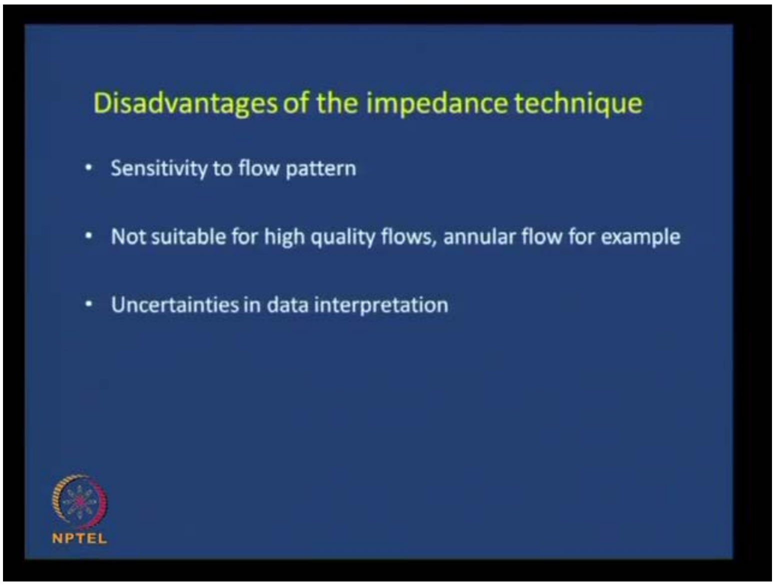

So, what I wanted to tell you was that, this impendence technique it has got a wide range of applications depending upon the design and the more mastery we gain over the design of this circuit and the design of the probes. As well as the better, we understand electrical engineering in other to convert the impendence or the admittance signals in to the void fraction, we can use it for a wide verity of advantages. This is something which I wanted to say.

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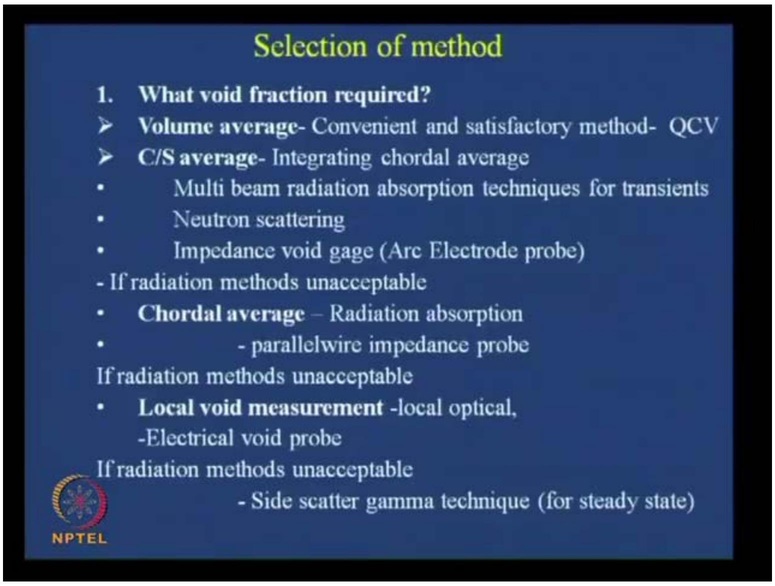

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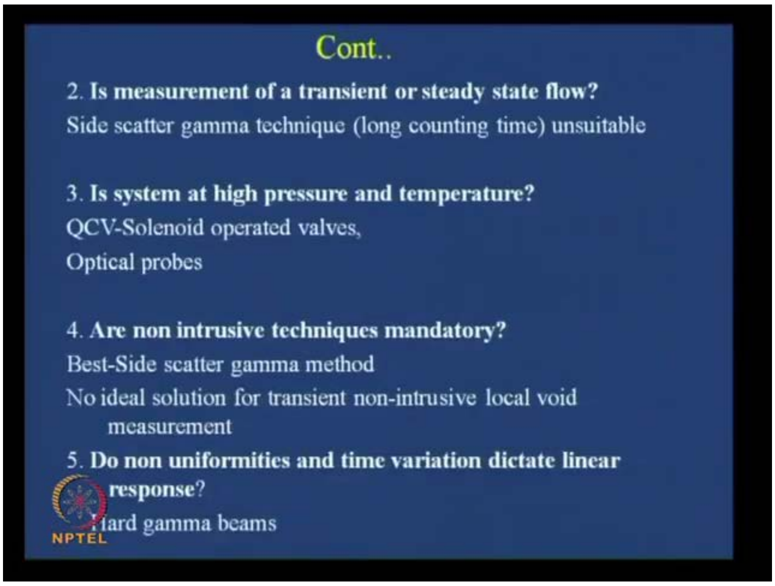

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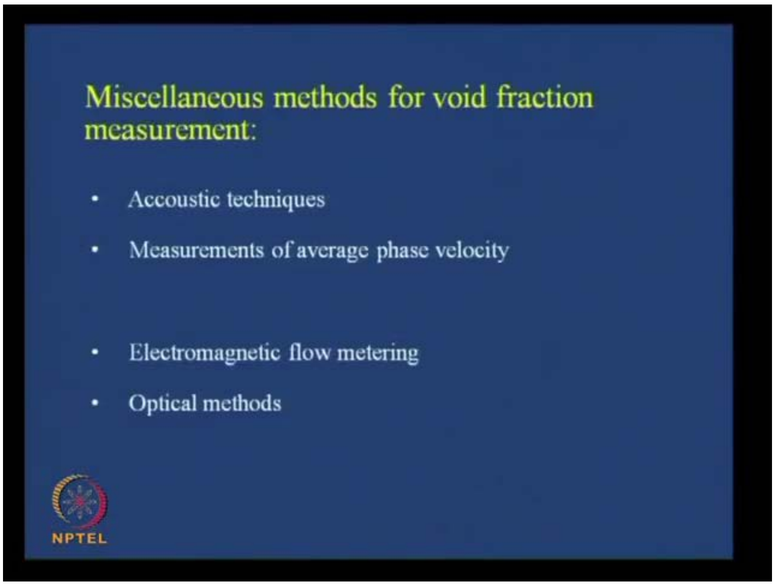

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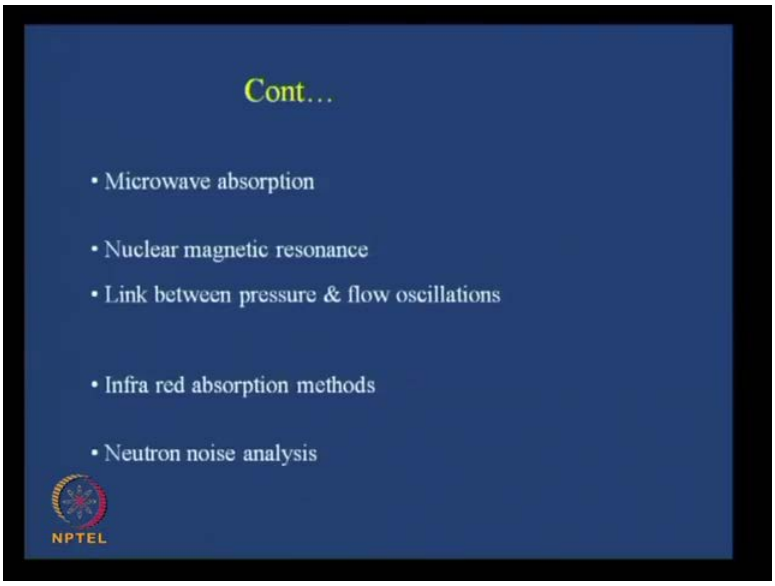

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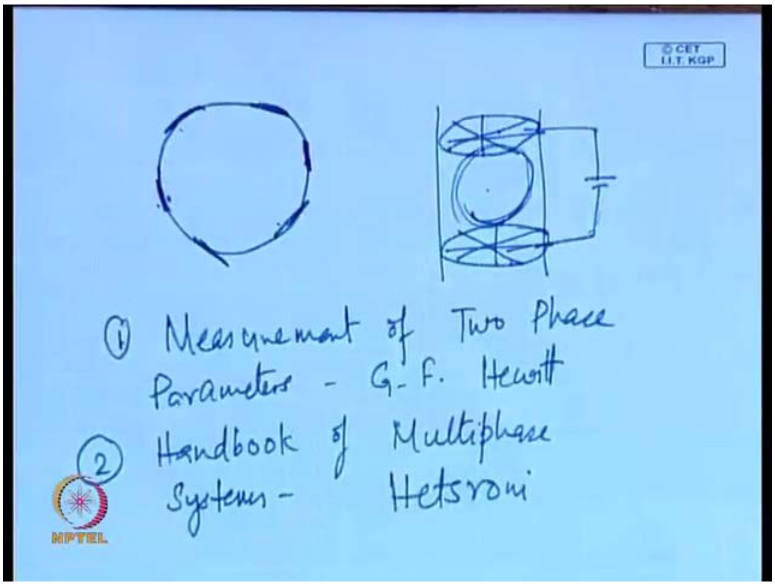

Now, after this I would like to use or rather I would like to discuss certain other techniques which and not so very common also. But they are more or less they are being use to now more and more and they have got or rather in the modern times, they can be exploited more for obtaining and idea about the void fraction. See, first thing which I told you was radiation absorption, usually we use gamma rays instead of radiation absorption, we can use microwave absorption this does not have the hazards of radiation. So, this is one very good thing about microwave.

Now, remember this microwave these things details you can get from the book by G F Heuritt, it is the measurement of two phase parameters, whatever you do not understand you can come to me, measurement of two phase parameters. And, another book is also there in the library you can go through this because see in exams more or less you will be getting logical questions from here, whatever you think and do. Definitely, I will not tell you to right down the advantages of this technique, disadvantages not a very direct question definitely. Hand book of multiphase systems (No audio from: 22:35 to 22:42) you can note down these two books, more or less from these two books if you study, it is going to be slightly easier for you.

Well now to continue instead of you are radiation, we can use microwave absorption. Now, remember this microwave absorption this is particularly applicable to organic reactor coolant systems for such organic reactor coolant void fraction measurement microwave absorption is very, very useful, the amount of microwave which is absorbed, that gives a measure of alpha. This is also has also being used for finding out the void fraction, during hydrogen vapor liquid mixture flow some known; see these techniques usually are used for non conventional situations, for air water we do not have to do so much trouble, for kerosene water slightly problem is there. But air water and all this normal systems so much moment we have, we are encountering newer and newer applications of two phase flow; newer and newer two phases or newer and newer geometries for two phases occurring that miscellaneous techniques are becoming important.

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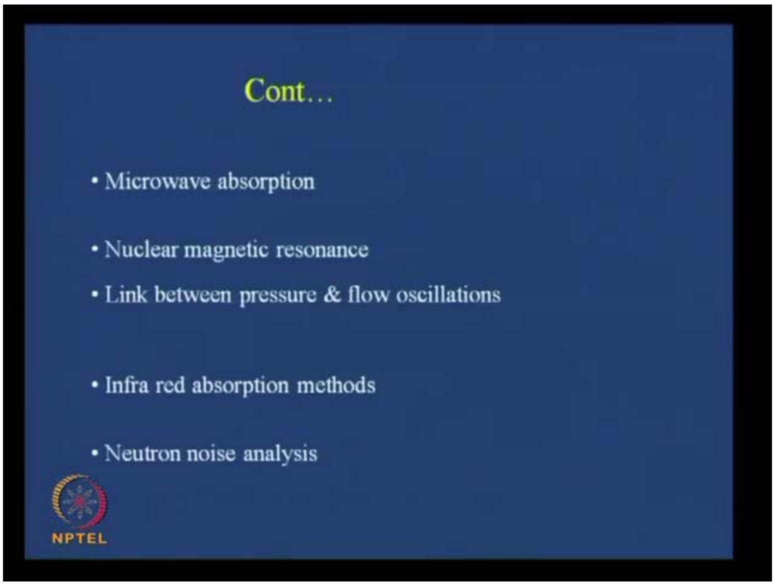

So, this microwave absorption this is used in organic reactor coolant system it is also used for measurement it has been used for measuring the void fraction during hydrogen vapor liquid mixture flow and interestingly it has been used to measure the water content of margarine for that purpose also this microwave absorption has been used.

Then, there is another thing infra red absorption. Instead of gamma rays, we can go for infrared absorption techniques. Now, what is the beauty of is technique? See, most of the techniques I have told you, they are very good for water continues systems or liquid continues systems, for high quality full flows most of the things, they do not work well. Because why? Because the absorption of the attenuation of radiations, they are maximum for water they are much less for air. So, when there is a large amount of air water was small water amount is there that does not much effect the attenuation process. Electrical impendence again works for low quality flows, the beauty of infrared absorption is this works for high quality flows.

So, therefore, if you have to go for high quality flows, it is very good for air water, steam water and such flows this is one. The other very interesting thing is, see this neutron noise analysis, they are alpha nuclear reactors. Where alpha is obtain from correlating the analysis of signals from neutron detectors, from neutron detectors just as a I was mentioning from neutron detectors, the amount of neutrons which has been emitted that, it can be related to alpha by some correlation that is number one. Another interesting thing is say suppose, you use say sodium liquid vapor system, normally we do not use them, but now with this difference etcetera this has come.

For sodium liquid vapor system which technique will you use? Radiation absorption is not a very good technique, because both of them they are have having more or less comparable amounts of attenuation, impendence techniques going to fail, conductivity is high for both of them. So, for such systems, what will you use? What people have observed is that, if we can induce some pressure fluctuation in to the system or if you can induce sorry; the some flow fluctuation in to the or some pressure fluctuation into the this system by a pomp or something, they cause some flow fluctuation. And, this particular flow fluctuation that depends upon alpha the void fraction.

So, this particular the this particular technique which I have written link between pressure and flow oscillations, this is primarily used for sodium liquid vapor systems. By using a pump, we impose some amount of pressure oscillations from this pressure oscillations some flow oscillations are induce, this flow oscillations depend upon alpha, this is one. Certain other techniques if you see, if you can use the amount of radiation absorbed, we can also use the amount of sound wave, which is absorbed. We can find out the velocity of sound, we very well know the velocity of sound is a function of the medium through which it is travelling, this is a very well known fact. So, therefore, through water it will travel fast, through air it will travel slow through two phase mixture it will be something intermediate. So, we can measure the velocity and we will try to find out alpha there.

But again in this particular case remember that the velocity, it depends upon not only the void fraction and also on the void size, void orientation number one. Number two, sound frequency keeping it constant is very difficult, just like maintaining high zero was important there here also the initial sound frequency has to be maintained.

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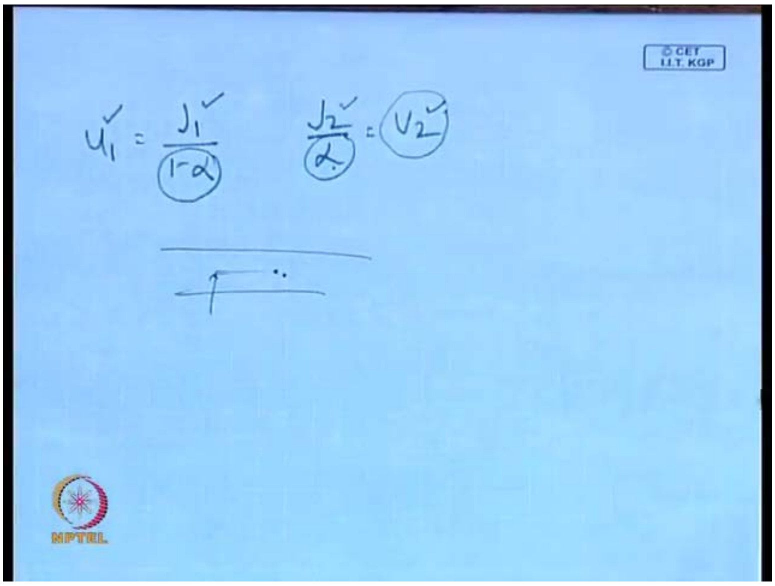

Maintaining a constant sound frequency is difficult here, this you remember. The other technique is see we can measure the inlet velocity it is given by J 1 and J 2. Suppose, by any means, we can measure the incitive velocity U 1 then once we can measure U 1, we can measure J 1 we can find out one minus alpha or in other words. So, if you can measure J 2, if you can measure U 2 you can find out alpha. So, by some particular localized measurements, if we can measure the incitive local velocity then, it is very easy to find out alpha.

Now, what can we do? Suppose, two phase flow is accruing here, we simply inject a radioactive tracer, this radioactive tracer will be flowing at the incitive velocity of the continues phase or the phase which absorbs it. So, accordingly, we can measure the incitive velocity of that phase yes or no. So, this is one particular technique, which I have returned as measurement of average phase velocity, which can be done by a radioactive tracer technique.

There is another way also of measuring the incitive velocity that is an electromagnetic flow metering device. I do not know whether you know what an electromagnet is.

Electromagnet it is mounted, I do not know whether you have seen, if you go to a laboratory you can see, they are simply mounted on vertical pipes, the vertical pipes they are mounted on it and what they do? They generate an electrical field within them; this electrical field is professional to the velocity of flow or the flow rate. So, depending upon the electrical field generated it gives us a measure of the flow velocity. Electromagnetic flow meter is a very well established flow measuring device in vertical systems for conducting fluids. For non conducting fluids, it is not going to server purpose, for conducting fluids at in vertical systems it is very good.

So, suppose, we install the electromagnetic flow meter and at least one of the phases are conducting then, in that case the reading will give us, the flow rate of the conducting phase provided that is the major phase or that is the continues phase. If that is not the continues phase electrical fields will not be generated and will not get a reading of the velocity neither of the continues nor of the dispersed phase. But if conducting one of the phases are at least conducting and the conducting phase is the major phase then, in that case and estimate of the average phase velocity can be obtained by this electromagnetic flow metering device, clear to all of you.

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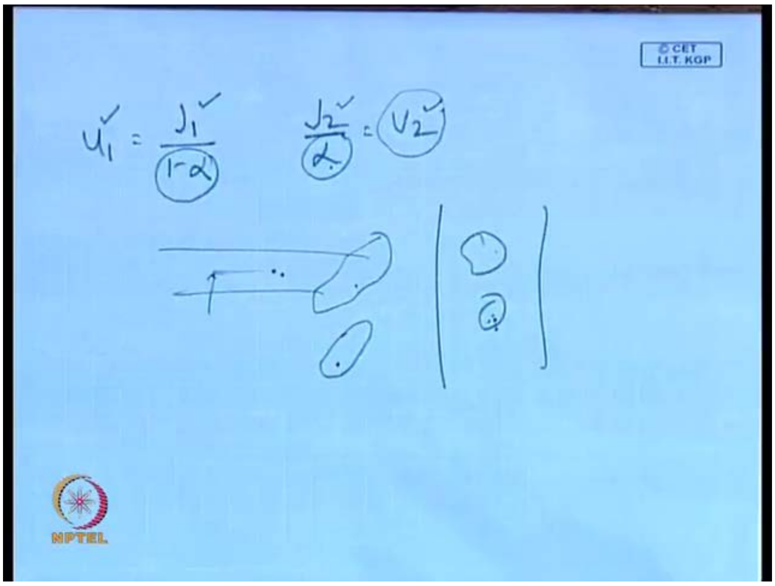

And definitely, the last method optical methods, a very tedious method, you take a series of photographs, analyze the photographs and try to find out the void fraction. A very safe method definitely, but it is very, very difficult you it may seem to that well there is no problem in it. Just seeing the photographs is fine, but getting out something mathematical from the photographs is very, very difficult. Getting good photographs us definitely a challenge particularly, when the flow velocity is very high everything is oscillating and small, small problems which will not realized.

Suppose, even if it is bubbly flow, with a large number of bubbles, first thing is when you take the photograph, we will take it from an angle. So, definitely, this bubble the shape will become deformed in your photograph. So, there has to be a calibration to convert this shape to this shape and then this shape may be will something of this sort. So, for each particular thing you need a calibration and then it is all; it is very very is tedious, but it is not the people have and done it. See, they; if they have to find it, if they find none of the other methods are suitable, they have to go for it.

Or in other words, there is another optical method which is very good, what is that, if you use lights scattering. See, lights scattering is much less as I does and much cheaper and much easier to handle as compare to radiations scattering. We can use light scattering, it depends upon the difference in the refractive index or it depends upon the difference in the attenuation of the two methods. In fact, I will tell you one thing, what we had done in our lab was, for air water it was not a problem, after air water we started liquid systems flow systems it started with water kerosene system. What we found? See, radiation absorption staying here, it is not possible will never get the permission. We were using impendence probes of different designs, for different the air water systems. We went on devising designs and we try to use them for circular pipes no problem, for annuals the flow passage is abstracted.

So, how to ensure a continues flow between the two electrons? So, taking that into consideration, we designed probes it was suitable annuals as well as. We try to device a large number of conductivity probes for different situations.

Next one, we went for kerosene water, nothing intrusive could work, because the kerosene was sticking to it. And movement see suppose, kerosene comes in contact with the probes sticks to it there when water comes the kerosene is still sticking. So, it cannot detect the flow of water, do you understand. So, therefore, nothing intrusive could work here we could not use any sort of impendence probes. So, what was the next thing that we thought of? We thought, suppose, we use optical method, we had used ultraviolet rays, we had a source, we had a detector and then an ultraviolet ray was passing and then, this particular ray while it was passing naturally it was absorbs more for kerosene it was absorbs less for water.

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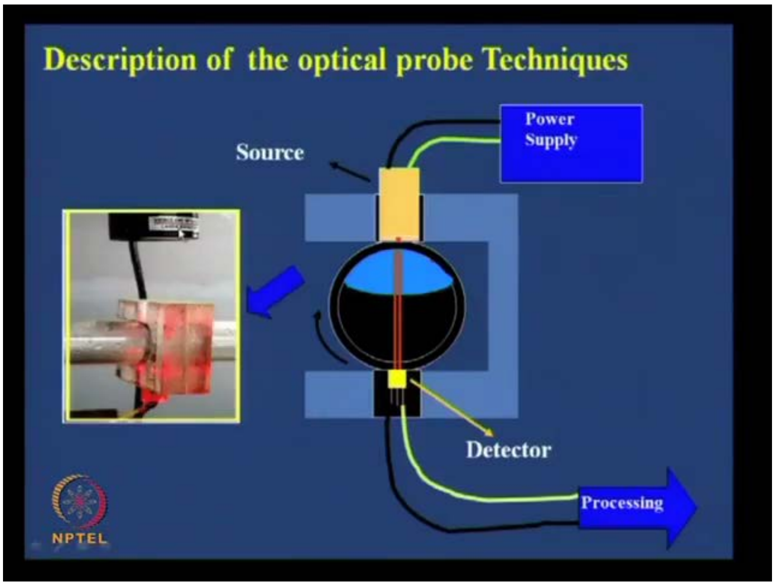

So, the and the other thing was. So, therefore, depending upon the proportion of kerosene and water, we got a higher signal, when more amount of water was there in the flow passage less absorption took place, we got a lower signal when less amount of kerosene was present in the flow passage sorry more amount of kerosene was present in the flow passage. And accordingly, we could find out the void fraction, in this particular case, this was very unique so in fact, we have patented it because it is it was completely new.

But the important point is, we could not use visible light, why? Because visible light is entering from all sides into the flow passage, we have to use something which is not entering from all sides, you can use visible light, but in that case you have to keep in a block box so that light from extend your sources do not enter there. We had tried infrared probes also, that did not work much ultraviolet source worked better. I do not know whether I have a photograph then, I can show you let me see if I have a photograph of this.

This is the optical probe which was there, there was a source here, there was a detector here, if you see there was a detector here, the situation is shown here, a very narrow beam is ejected. And then, what happens is, see it was very interesting it could give us flow pattern and void fraction both. What was happening? Here, the entire two phase mixture was distributed, may be kerosene is distributed in water or something. And while it was travelling when it comes in contact with kerosene more amount of light was attenuated, when it came in contact with water less amount of light was attenuated. So, therefore, the transmitted signal it depended on how much of kerosene and water are present this was number one.

Number two interestingly, see we could also understand how this kerosene was distributed, if they were distributed as bubbles then, in that case what happened, large amount of scattering; we use to take place is it clear. And when it was stratified flow kerosene top water less then, very less amount of scattering was taking place.

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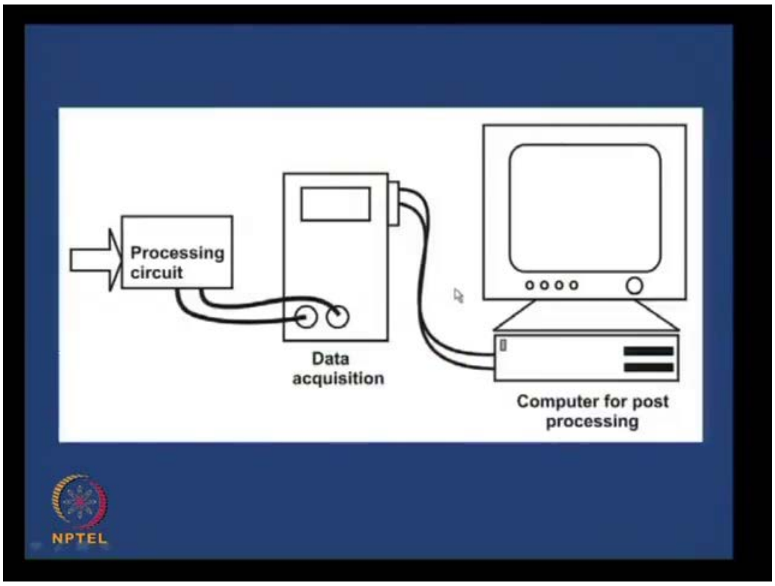

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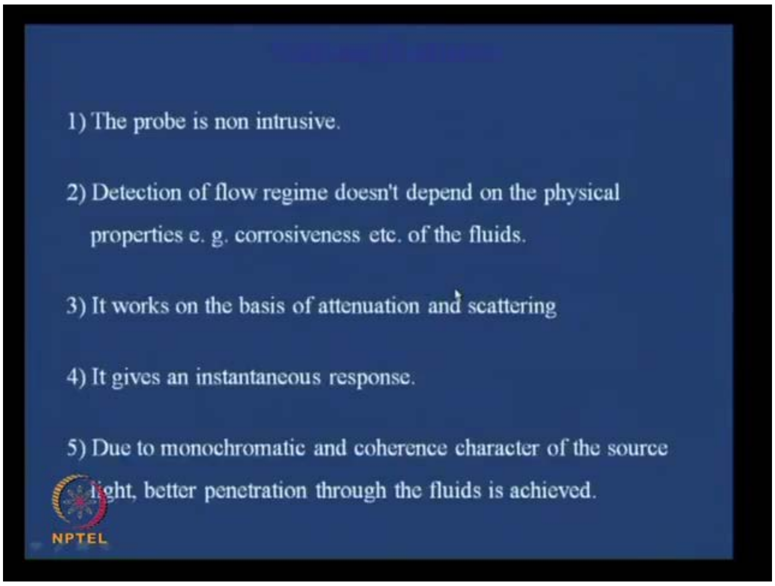

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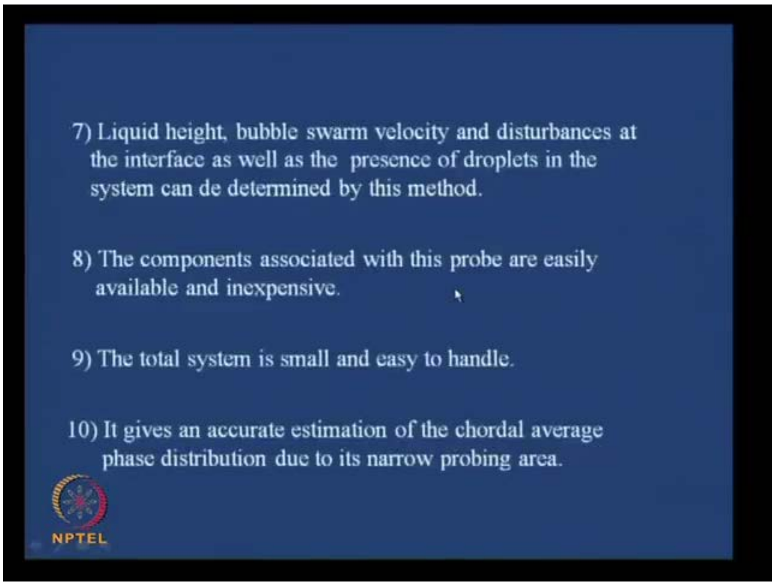

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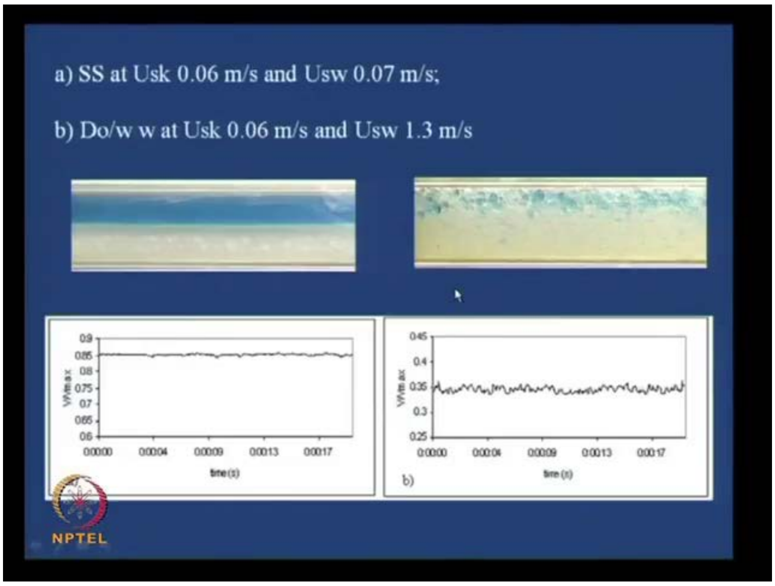

So, therefore, I thing I have, you just see, when it was stratified flow, see here large amount of kerosene is here, here small amount of kerosene is there for large amount of kerosene what we had? We had got a higher voltage value. sorry very sorry usk [FT] sorry here, less amount of water large amount of kerosene correct. So, therefore, we got a higher voltage value. Moment, we had larger amount of water, we had a lower voltage value, is it correct. What we were doing, the amount which was transmitted that was converted to a voltage signal. How it was converted? The voltage signal was high, when water was the continues phase it was low when kerosene was the continues phase, this circuit was designed in that particular way.

So, therefore, we find that whenever water is in larger proportion, we have a lower voltage, whenever kerosene was in larger proportion, we had a higher voltage. Not only that, if you observe the signals we find that, when the inter phase was smooth, we obtained an almost straight line signal. On the other hand, when there were bubbles when each particular bubbles surface or droplet surface behaved as a reflecting surface, they were reflecting the light is it not. So, therefore, the undulations were much more for dispersed flow. So, therefore, the two things were important in our case, one was the average value of the voltage that we are getting, the other was the amount of fluctuations which we were receiving here.

So, depending upon these two, we could find out not only the doduative proportion of the two phases in the mixture, but we could also obtain an idea regarding the distribution of the two phases here. So, this was the beauty of the optical probe that we had used in this particular case, it had a power supply, it had a detector, in this it was a photo diode sort of a thing. Now, what happened, moment light was incident it was converted into an electrical signal, this electrical signal through a processing circuit it was send a data acquisition system and then it was recorded in the computer. And as I have told you for higher values, we get for higher kerosene we got the higher voltage, for lower kerosene we got a lower voltage. So, this was one particular thing, which we used for this of course, we will be studying slightly more if when we take up the void fraction thing. So, these were the different techniques that are used.

So, there are acoustic techniques there are optical methods then definitely, measurement of average void fraction either by radioactive tracer or electromagnetic flow metering devices. Then there are other radiation absorption techniques, which can be microwave absorption, infrared absorption, nuclear magnetic resonance, neutron noise analysis and so on and so forth.

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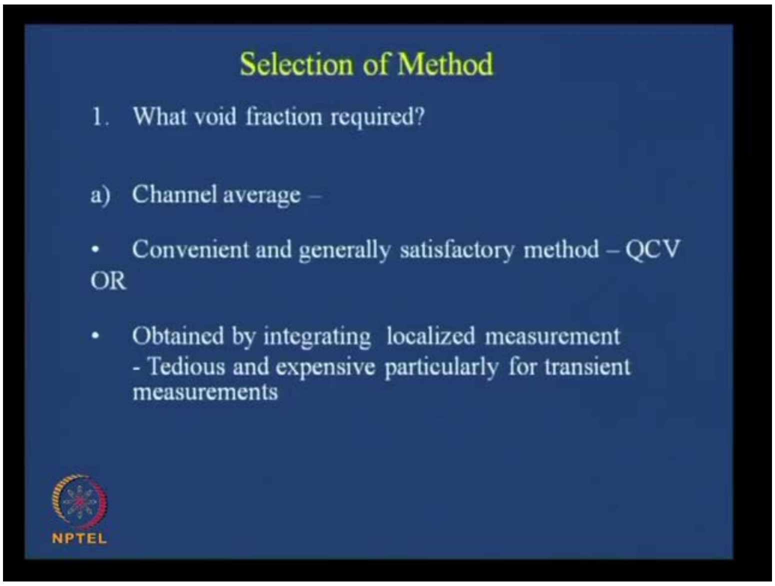

Now, before I conclude the void fraction measurement, I would just like to, we just in a nutshell I would like to discuss in the remaining time, what are the different methods which I used under different conditions. See, the technique we will select according to the requirements which we have, which void fraction do we have to measure? If it is a volume average, only thing we can do is quick closing valve technique here, if you see this transparency it is written down or else what we can do? We can get a large number of chordal averages as I was telling and then we can transfer it to the volume average value this is of course, very tedious very expensive and transient measurements it is not possible. Remember one thing quick closing valve is a very accurate technique, but it is only for steady state situations, otherwise it is not very accurate.

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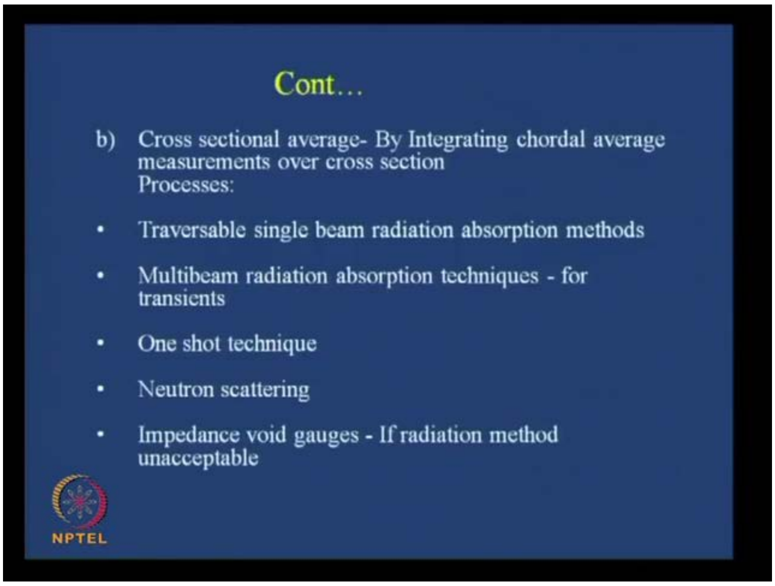

Next is for cross sectional average, void fraction I have already discussed. What are the different ways by which we can obtained cross sectional average? It can be either by radiation absorption or it can be by impendence techniques, we have to integrate chordal average measurements over the cross section. And what are the different methods? I have already told you either you can traverse a single beam radiation or a multi beam radiation at one time. This multi beam radiation it is useful for transient measurements or the one short technique which I was telling that a large source can be used with special colinatives and accordingly this one short technique can be used. Neutrons catering can be done and impendence void gauges can definitely be used when radiation methods are un acceptable, which was the case for my particular situation.

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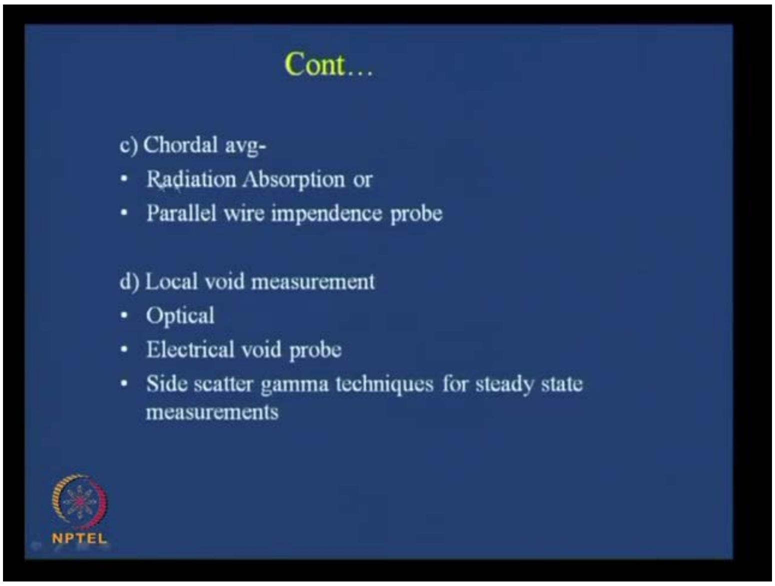

Chordal average, again you can either use a parallel wire type impendence radiation absorption. For local void fraction, again a local point electrode probe can be used; sides scatter gamma techniques can be used. But the sides scatter gamma technique can be used only for steady state measurements, transient measurements cannot be done by this case, transient either optical or electrical void can be used, other thing is have the measurement to be a transient or a steady state. I have already told you some techniques like quick closing valve techniques sides scatter gamma technique they are unsuitable for transient measurements. Since, they require a long counting time these cannot be used.

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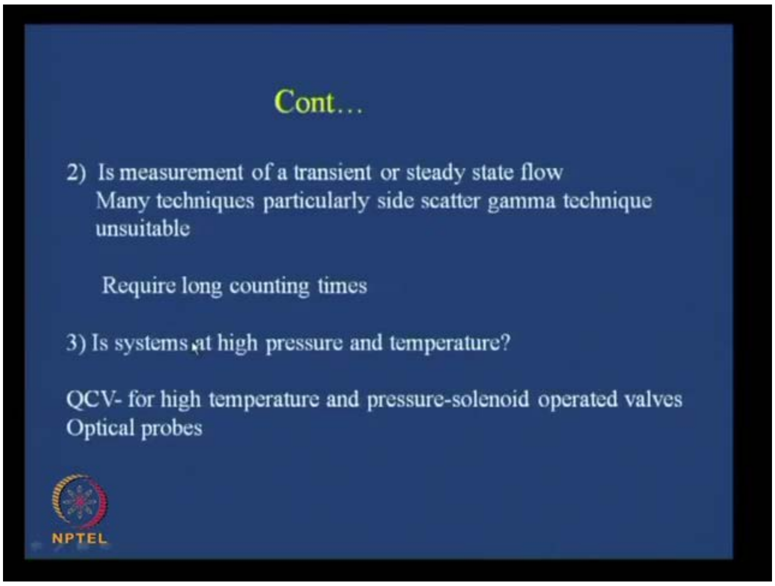

Next very frequently, we have to deal with systems which are at high pressure and high temperature. For such cases the only option is quick closing valve technique. For high temperature and pressure of probes, we cannot use bal valves and things like that we have to operated from a remote distance. So, therefore, solenoid operated, electrically operate valves at the only things. Optical probes if they are suitably designed can be used for these particular purposes.

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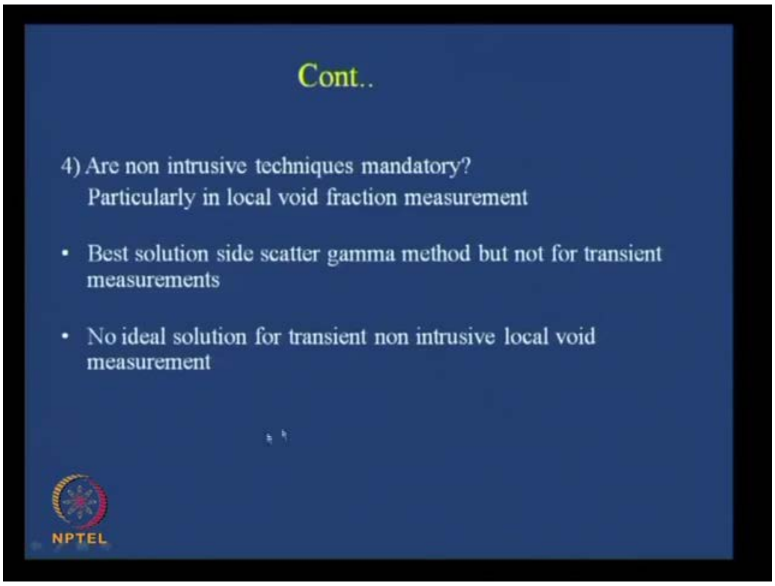

Now, suppose, the fluid such that, we cannot approach the fluid or non intrusive techniques are mandatory, may the fluid will get it is of high quality it will get contaminated, if any sort anything is inserted there it can happen. Particularly, for local void fraction measurement, these intrusive techniques are almost the only ways by which we can do. So, if non intrusive techniques are mandatory, what is the best method? Your sides scatter gamma technique, where some amount of gamma radiations, they scattered and this scattered beam that is being recorded by a detector. Again remember this cannot be done for transient measurements it requires a long counting time. Remember one thing which is very important, if you want to measure the local void fraction by non intrusive technique and transient, there is no ideal solution. This is very very important no ideal solution for transient non intrusive local void fraction measurement, remember this.

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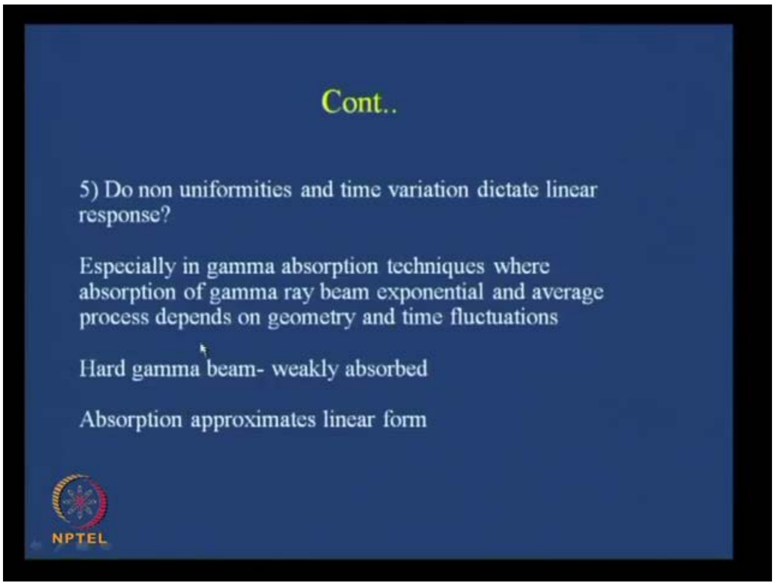

Other thing is, if suppose, the times variation and non uniformities are there in the flow under that condition usually, we would like to have a linear response as I was telling in slug flow etcetera, if the response is not linear it is a problem. So, for linear response what you have to do, if it is radiation attenuation technique? The only thing is to use a hot gamma source, as I have said, which is weakly absorbed, when it is weakly absorbed naturally absorption approximates the linear form. This is the only thing that can be used under this particular condition.

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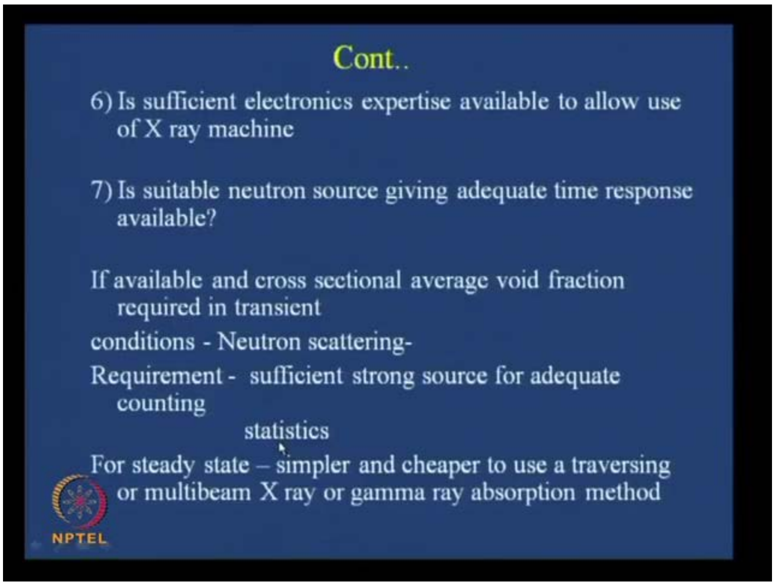

Next is, if sufficient electronics expertise is available, because see X ray machine is everybody cannot use, just now I and you we cannot use the X ray machines. So, therefore, if sufficient electronics is not available then, x ray machine is cannot be used otherwise X ray machines can be used. Same thing applies for neutrons scattering techniques also, if suitable neutrons source is available, which is quite an expensive affair and if adequate time response is available, then in that case we can use the neutrons scattering. Available and cross sectional average void fraction is required under transient condition, then definitely neutrons scattering has to be used. Under these circumstances, sufficient strong source has to be used for counting statistics that reduction of fluctuating error a strong source has to be used.

For steady state of course, if it is not transient, if it is transient neutrons scattering is the only technique. For steady state definitely, we can use a multi beam X ray or a gamma ray absorption technique. For transient measurements of course, we can also use a one short technique as well.

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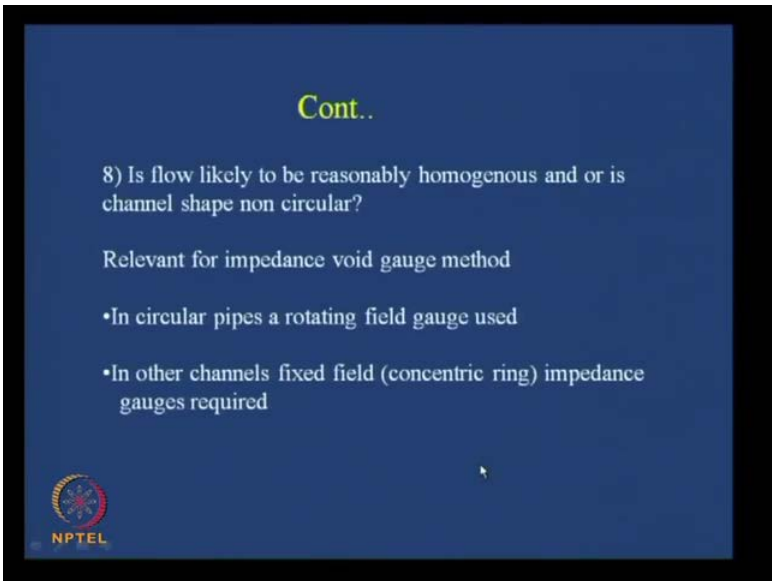

What are the other things that we have to can see, because we have to work over a wide range of flow situations, a large number of factors have to be considered for selection of the criteria. If the flow is reasonably homogeneous fine, if it is bubbly flow, if it is not homogeneous, then definitely becomes a problem. Particularly, if the entire flow passage it is abstracted by something suppose, you have to work on two phase flows where large number of things are inserted, such applications are there. A two phase flow through rod bundles, a two phase flow through concentric annulus, there the entire flow passage is not free for your measurements, under these conditions, it becomes a problem. Other thing if the flow passage is circular it is fine, if it is not circular sometimes for different types of geometries also it becomes a problem.

So, for non circular cases and when your the flow field, the flow passage it is not homogeneous not for constant cross section definitely, impendence void gauges can be used, if you design it properly. The design is very important for this particular case. And for circular pipes, I had already shown you this rotating field gauge, this is more or less useful.

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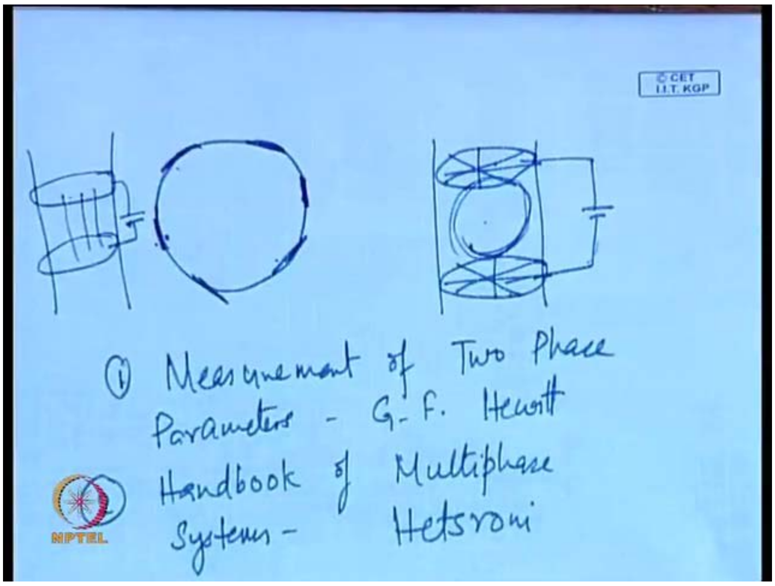

We can use something of this sort as well. And if it is a non circular channel, then definitely this rotating field sort of a thing, because this symmetry does not hold it is not possible; under that condition, concentric ray impendence gauge. That means, we can have something a flow passage like this, we can have a ring here, we can have a ring here and just rings, two rings, they are non intrusive. And between these two rings maybe, we can have a circuit between these two rings, the electrical path is provided by this particular process. This can also be thought of under these circumstances.

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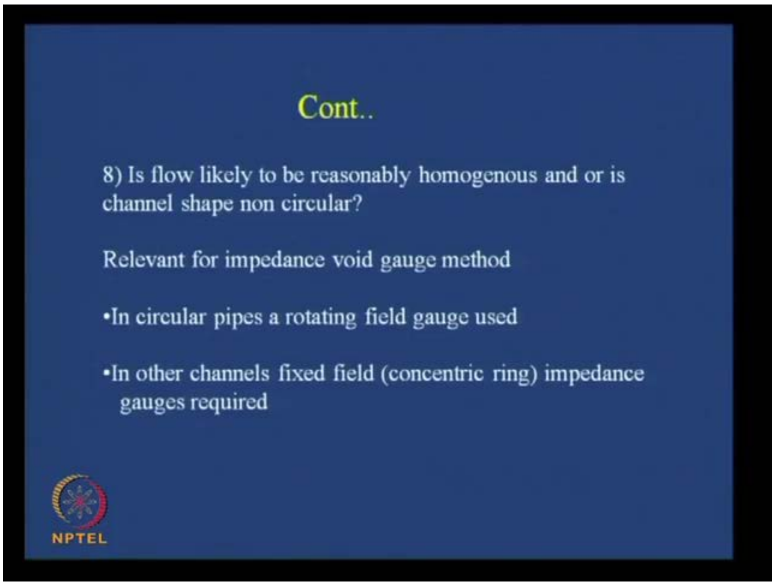

Well so, with this we conclude the void fraction measurements, we find out that in void fraction measurements, the most important three techniques are volume measurement, radiation attenuation techniques, it can be absorption, it can be scattering or radiation techniques you can write, it can be absorption, it can be scattering to some extent, it can be emission of a consequent radiation and impendence gauges. Impendence gauges are popular just, because they can be made to adjust to a wide verity of flow situations simply because by the design of the probes as well as the circuits. Other techniques which we have discussed they are coming up and depending upon the applications etcetera, we can use them for a large number of cases.

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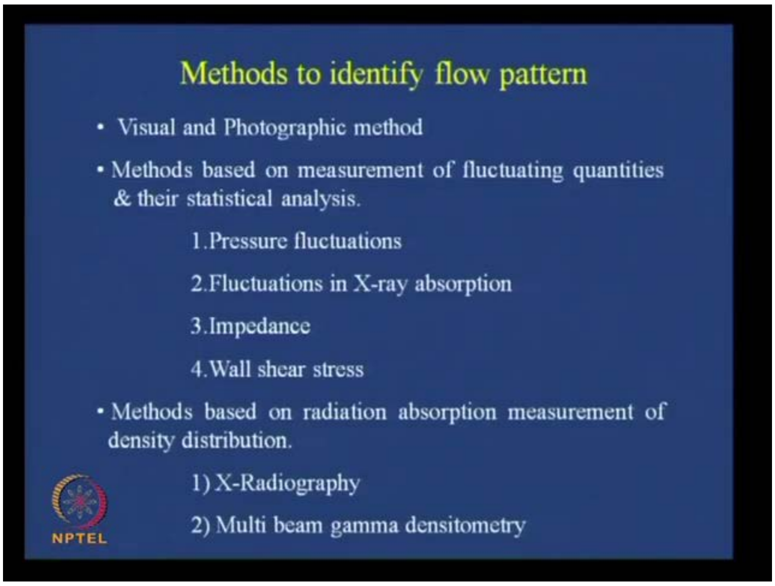

So, this completes our void fraction measurement, in the next class, we will be discussing ways to identify flow patterns. Now, remember one thing what is flow pattern it is simply, the variation of voids, how they are distributed. Instead of the average value, we need to record the variation; the variation can be across a cross section the variation can be at a point anything. More or less the techniques which are applicable for void fraction, the same techniques will be applicable in that case also, visual is definitely one, but it is not a very good technique.

Then naturally gamma your radiation absorption can be one, impendence can be one. So, definitely, we are not going to repeat this techniques, what we are going to do is. We will be seeing more or less certain like pressure drop fluctuations etcetera, they cannot be converted to void fraction data, but they can definitely be recorded for showing the fluctuations in the signals. We will be doing a small amount of them, and then we will discuss a detailed conductivity probe design, for estimating the flow patterns in a horizontal and a vertical tube.

And remember one thing, just by seeing recording of this signals, it is not always to possible to identify flow patterns. Sometimes, we have to perform some statically or other analysis; if time permits, we will also study a few basics of the probability density function. And the psdf analysis of analyzing the random probe signals, these are the few things, which will be doing in the last class and that it will end up our studies or a discussions on multiphase flow. So, thank you very much.