Machinery Fault Diagnosis and Signal Processing
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Lecture - 52
Eddy Current and Acoustic Emission

Well as you know, some of the non destructive test techniques which are used for evaluating the condition of a machinery component like ultrasonics, dye penetrant test, Eddy current, acoustic emission thermography, these are some of the techniques which they are not online, unlike vibration monitoring or moto current signature analysis, but usually when we do a NDT which is known as non destructive test technique to decide on the quality of the product.

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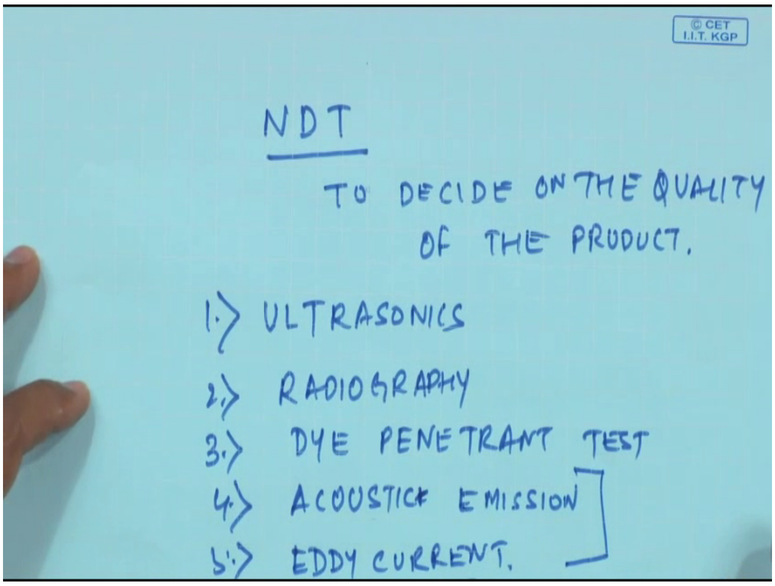

So, some of the NDT techniques which we have covered so far; ultrasonics, then we have this radiography and dye penetrant test and then, today we will look into acoustic emission and Eddy current ok. So, let us see in this lecture, what is this acoustic emission and Eddy current and how it is used for finding out the faults in a machinery on the product quality usually, they are used as a go, no go test technique for quality control.

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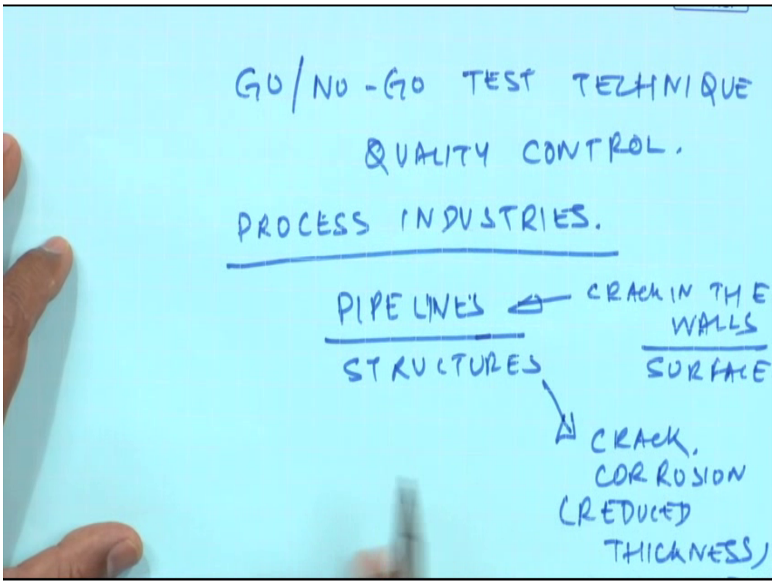

But in many process industries, beta chemical plant, beta oil refinery menu, the parameters like particularly pipelines or structures, they may undergo defects now what could be the defect in pipeline as you all know could be crack in the walls or the surface and another in structures, we may have a crack corrosion which leads to reduce thickness.

All these can be very easily measured by either Eddy current or acoustic emission.

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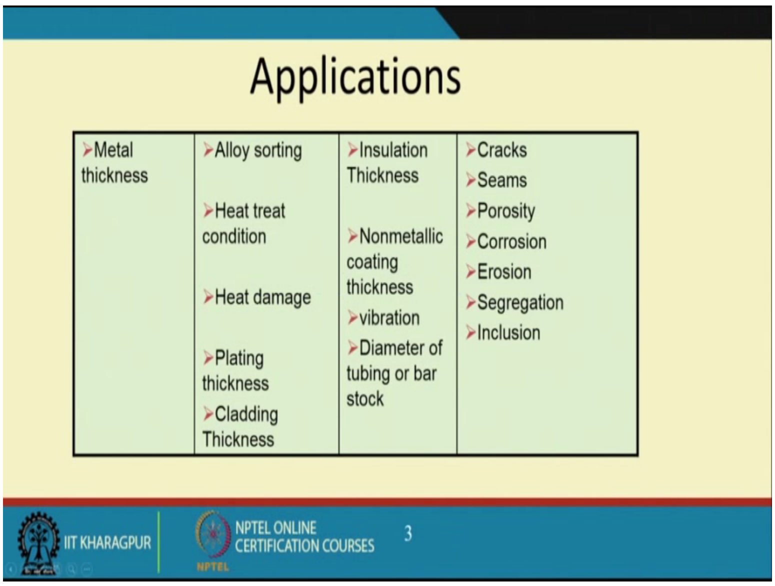

So, what is this Eddy current testing we will see say they can be used for all these applications to measure the metal thickness to find out the heat treatment condition, plating thickness, cladding thickness, insulation thickness, diameter of tubing or bar stock, cracks, seams, porosity, corrosion, erosion, segregation, inclusion, etcetera and you recall when we discussed about vibration monitoring Particularly of journal bearings.

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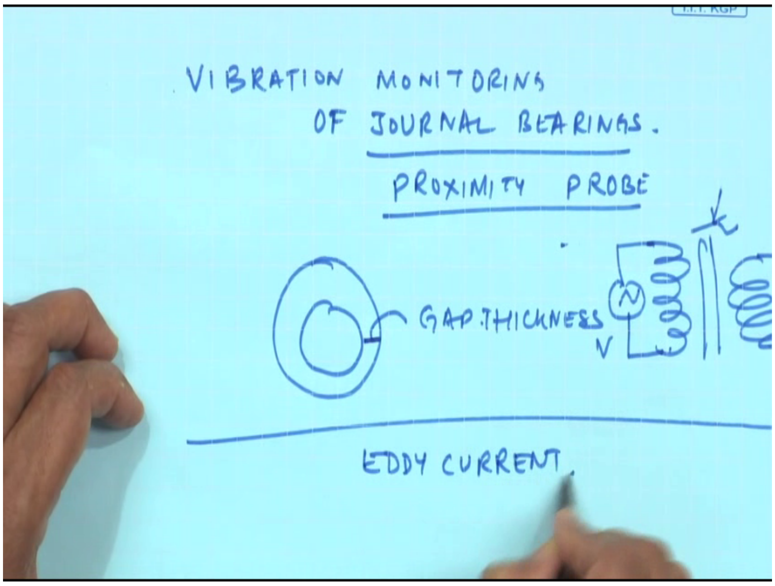

We used proximity probe, this actually dependent on the gap thickness here. So, we give a primary excitation to a and then we got a secondary voltage depending on the magnetic reluctance. So, this is a proximity probe, but here we are talking about and Eddy current probe when we take a coil to a conducting material and ac coil has been given and then it produces a magnetic field.

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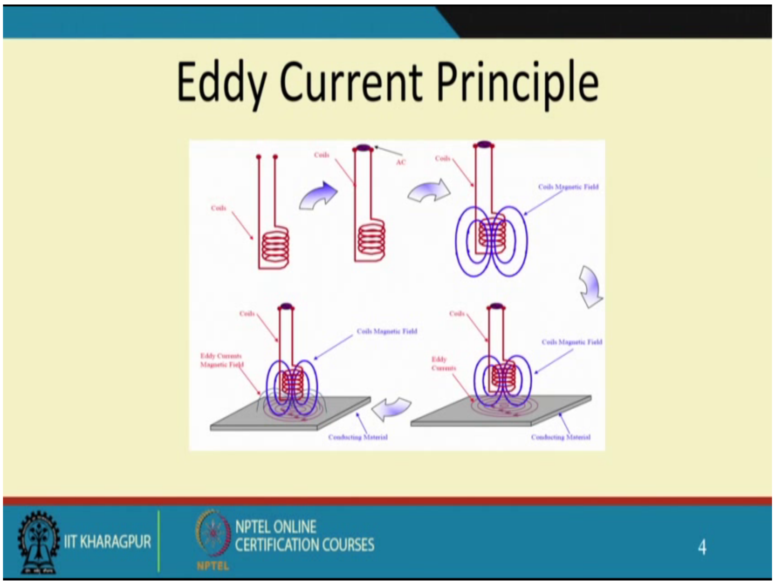

So, in this conducting material because of the presence of this magnetic field very closed to it, Eddy currents of the geometry and this material has to be conducted.

So, all are test materials have to be conducted. Now if there is a surface defect, crack, it is Eddy current intensity is going to change and if I can sense this Eddy current in the magnetic field due to the Eddy current, I can indirectly get; what is wrong in this material or in the surface which has created a change in the generated Eddy current, ok. So, this is basically the principle, but the material has to be conducting unlike ultrasonics, where the ultrasonic wave can pass into any material, it did not be conductive of course, the power of the ultrasonic waves would change, but in Eddy current that is not the case.

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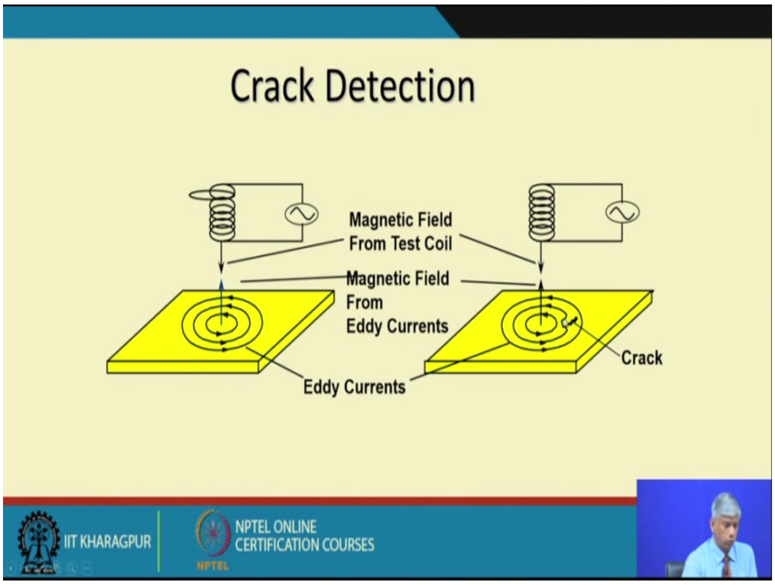

So, how is Eddy current used to detect a crack? If you will see here, I have a magnetic field from this test coil which I move close. So, the magnetic field from the Eddy current will be generated ok. Now if there is a crack, the intensity of the magnitude of this Eddy current is going to change qualitatively.

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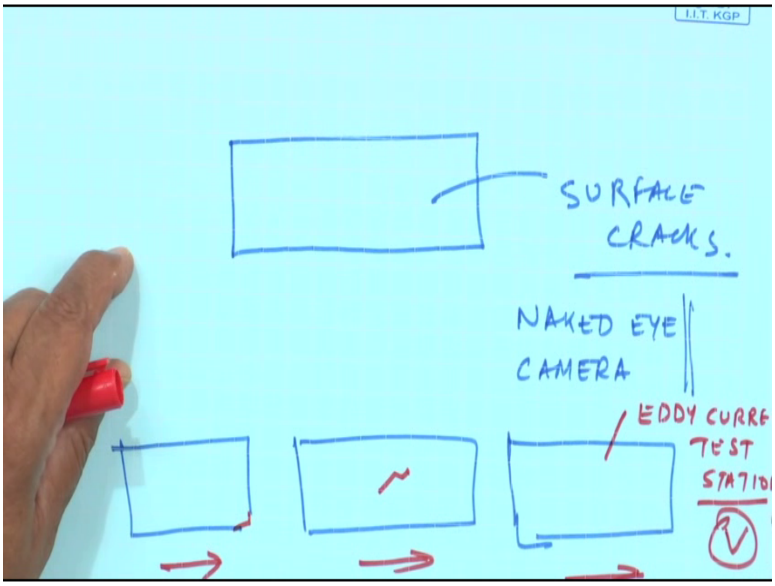

So, this could be sense in the voltage measuring device which you have. So, this and is a very easy way to find out surface cracks of course, you know surface cracks can easily be seen sometimes under naked eye or today with you know help of vision base systems cameras and so on.

But they are sometimes time consuming, they required to be focused so, but then if you have for example, you have producing large number of components. So, they can go to and Eddy current test section and these are moving maybe in a some system. So, you can have in automated Eddy current a system. So, if there is a defect on the surface, they will be change in the voltage. So, this is going to give us an indication. So, you see such techniques are very good for crack detection for surface defect detection and so on.

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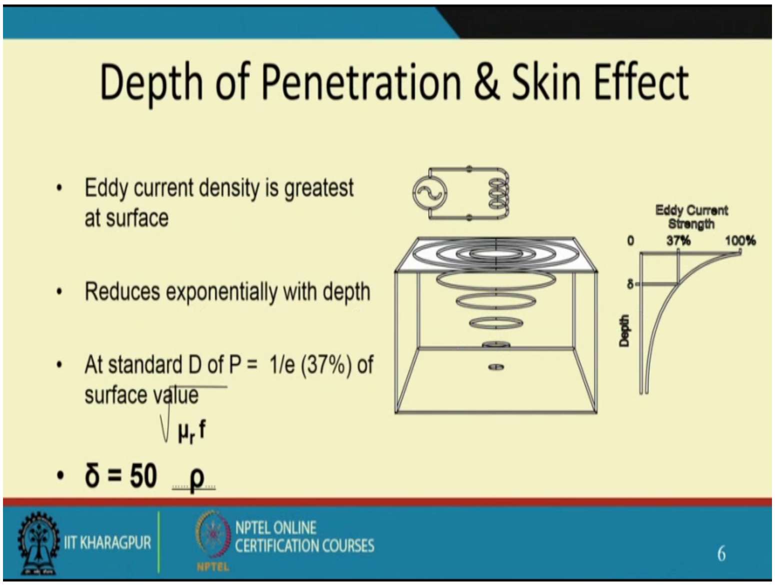

But then one has to keep in mind, certain parameters ok. So, Eddy current density is greatest at the surface and it decreases with depth ok. So, this depends on the material property. So, one has to be careful about how thin or how thick a material should be measured, we have going to measure on the surface and so on.

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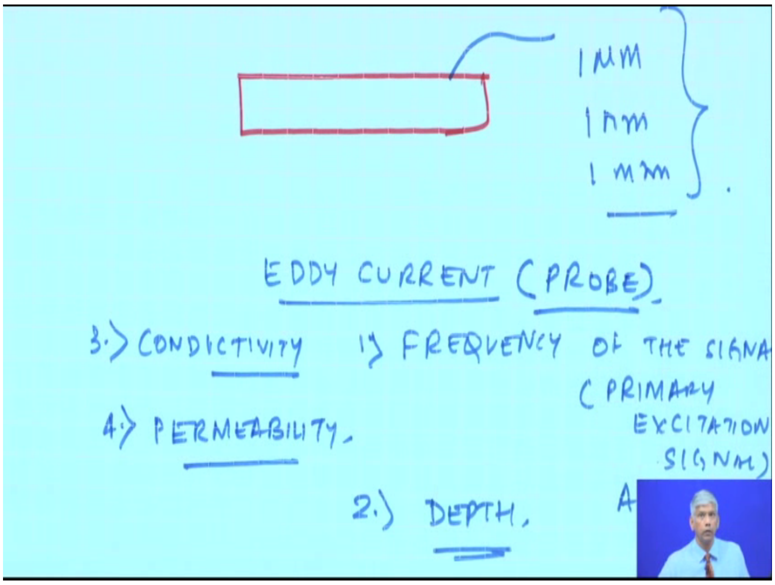

And how fine can you A crack B, I mean are you talking on a surface are you talking about crack, earlier of 1 micron or 1 nanometer or 1 millimeter, based on that your Eddy current power would change.

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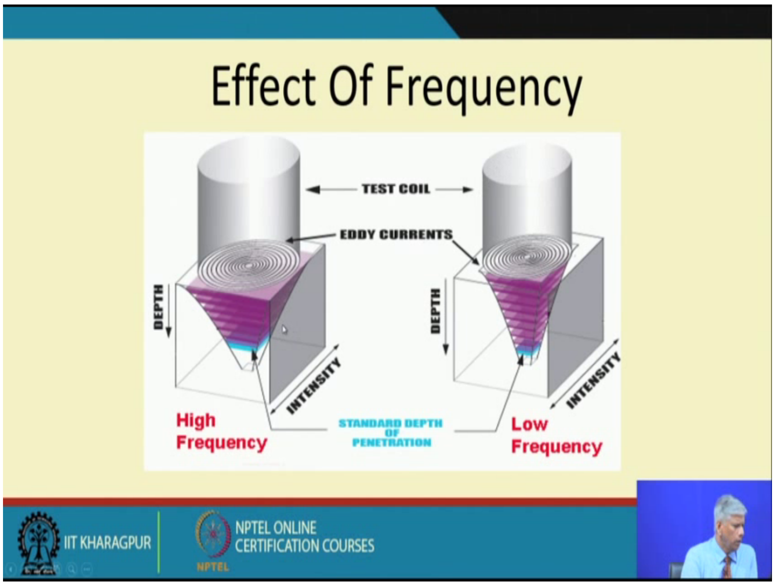

So, as you know the; for high frequency and for low frequency the intensity is going to change ok, if the depth is more than density would reduce and so on right. So, we have a larger intensity if the depth is less and particularly at high frequencies and so on. So, when we select Eddy current probes, one has to be careful about the frequency of this signal that is the primary excitation signal which again has to be an alternating current signal because it will produce a magnetic field and next is the depth to which we want to measure.

Of course though it has to be conducting the effect on good conductor or a poor conductor is also influence and that is come from the magnetic permeability the effect of permeability is also there. So, all these factors will also influence conductivity and permeability, they will influence your selection of the Eddy current probe, all right.

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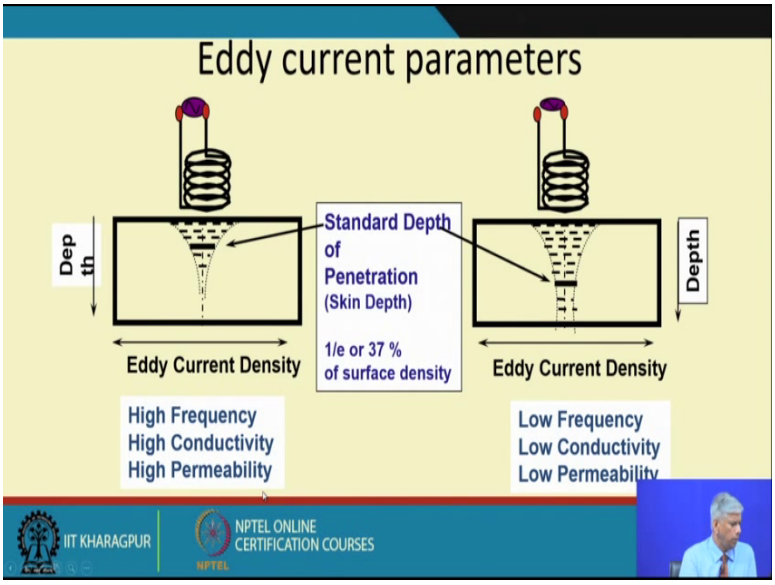

So, some of the parameters high frequency high conductivity high permeability you get an effect like this as a function of depth, but for low frequency low conductivity and low permeability the standard depth is more.

So, this parameters one has to decide ok.

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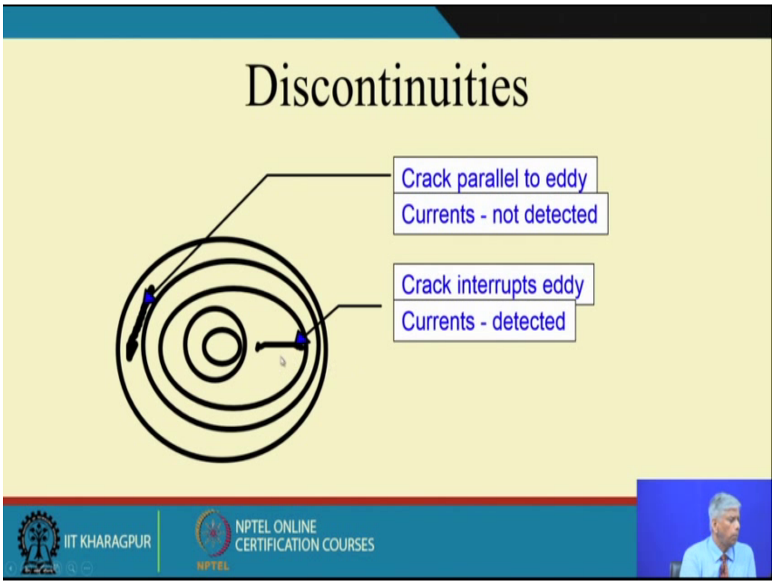

But when we talk about detection of discontinuity is using Eddy current with the crack is parallel to the Eddy currents, it is not detected. So, one has to be careful how to row them in the direction, but if they are perpendicular to the Eddy current which is being generated on the surface they can easily be detected.

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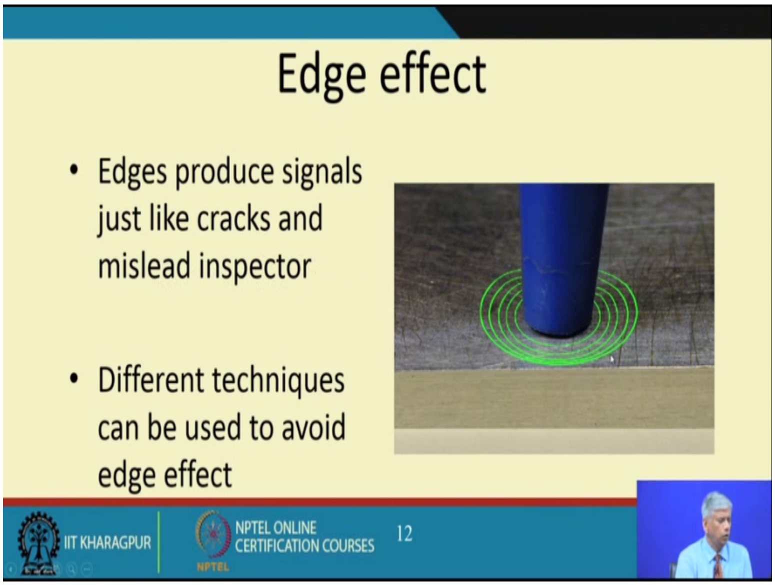

So, one has to be careful in the orientation and sometimes you know edge effects, you know earlier practically using signals, you know very close to the edge, they can give out signals which will miss lead the NDT inspector that crack has occurred.

So, certain techniques exists to avoid such as effects.

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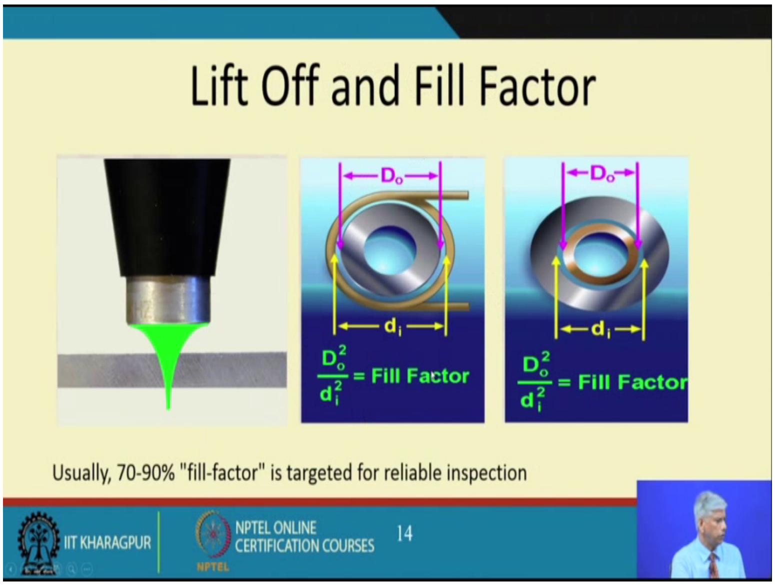

So, the inductive coupling actually happens here, we have a primary magnetic field and the secondary magnetic field as adjustment seen to you, but there is a lift off and a fill factor. So, lift off is defined by the diameter D 0 square by D 1 square and the usually the fill factor is we should go for a 70 to 90 percent of fill factor, ok, how much we should expose that area for Eddy current testing.

So, this is what we have to target.

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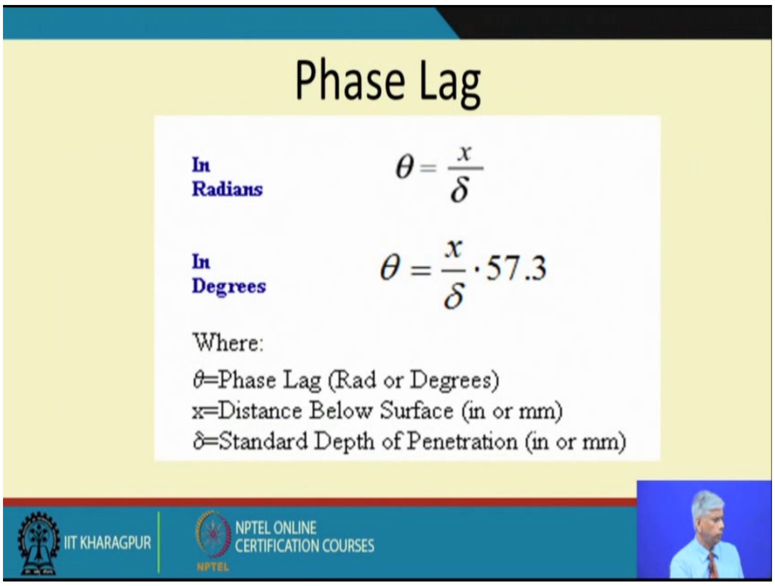

So, for different sizes may be you have to row the Eddy current probe or we have to find a different Eddy current probe. So, there is a phase lag which can be measured as the function of the penetration depth.

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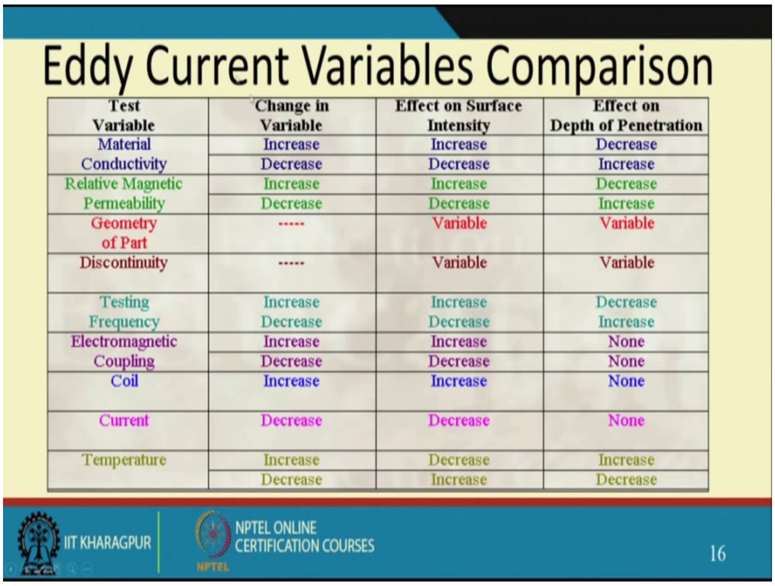
Eddy Current Variables Comparison

Test Variable	Change in Variable	Effect on Surface Intensity	Effect on Depth of Penetration
Material	Increase	Increase	Decrease
Conductivity	Decrease	Decrease	Increase
Relative Magnetic	Increase	Increase	Decrease
Permeability	Decrease	Decrease	Increase
Geometry of Part	-----	Variable	Variable
Discontinuity	-----	Variable	Variable
Testing	Increase	Increase	Decrease
Frequency	Decrease	Decrease	Increase
Electromagnetic	Increase	Increase	None
Coupling	Decrease	Decrease	None
Coil	Increase	Increase	None
Current	Decrease	Decrease	None
Temperature	Increase	Decrease	Increase
	Decrease	Increase	Decrease

So, some of the; so, as you see in Eddy current there are many test variables ok. So, it has an effect on the surface intensity and depth of penetration. So, to a normal user you see unless you are very sure with the test protocol.

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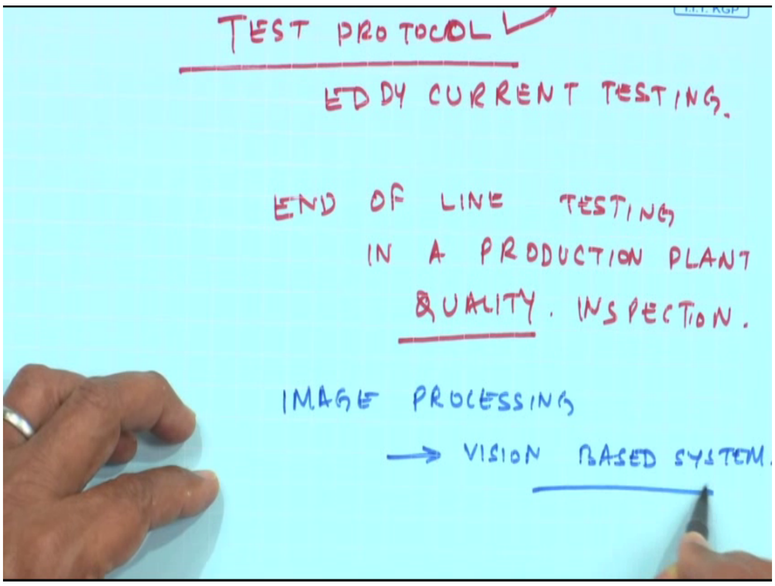

You may get different results ok. So, that is why because there is so many variables which will affect your Eddy current the material conductivity relative magnetic permeability geometry discontinuity testing frequency electric magnetic coupling coil current temperature. So, if I change variables which are there are many, it will affect the surface intensity and the depth of penetration. So, we need to have a test protocol for Eddy current testing. So, for one of a kind measurement Eddy current sometimes, we may get a value which may be difficult for you to compare with, but when you have a end of a line testing in a production plant for quality inspection.

So, Eddy current is a very good application of course, the product has to be mentally conducting.

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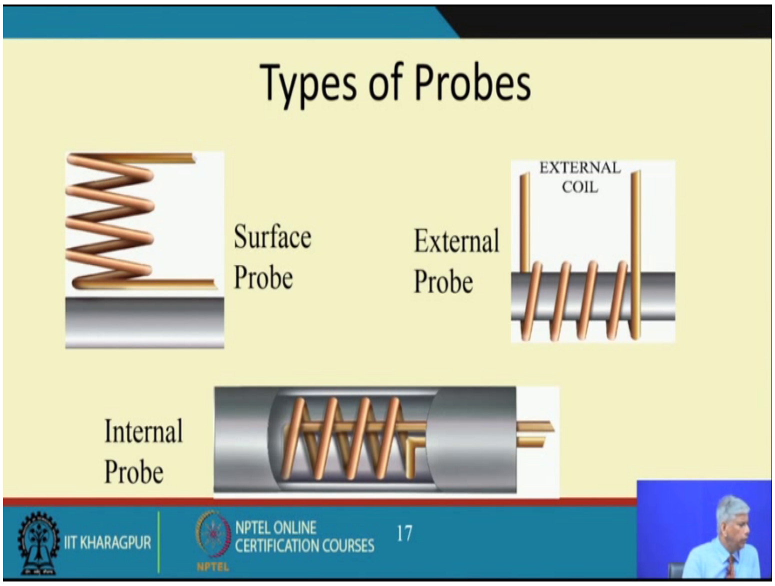

So, some of the probes which will see here external probes internal probes, you know external coil. So, the probes can be arrange and all necessary what happens is this material has to be conducting and there has to be a certain ac signal flowing though this coil.

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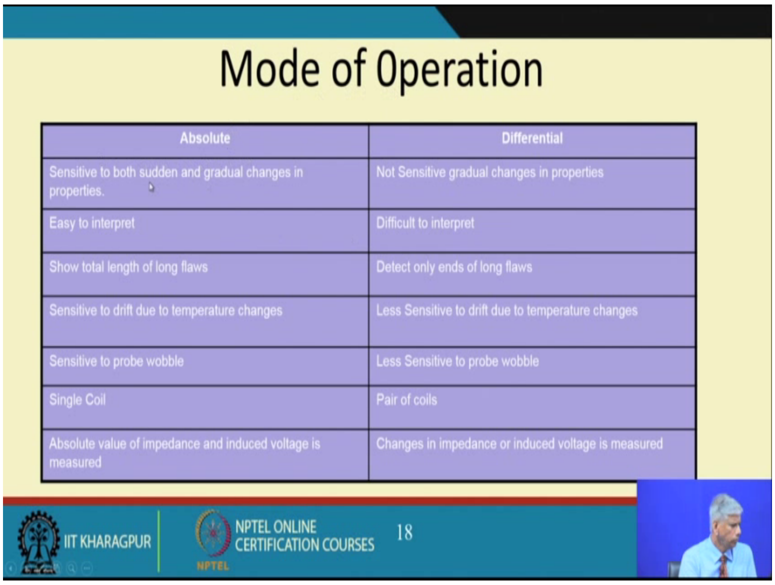

So, sometimes mode of operation could be absolute or differential then. So, this is pretty a comparative and differential is when we have a pair of coils.

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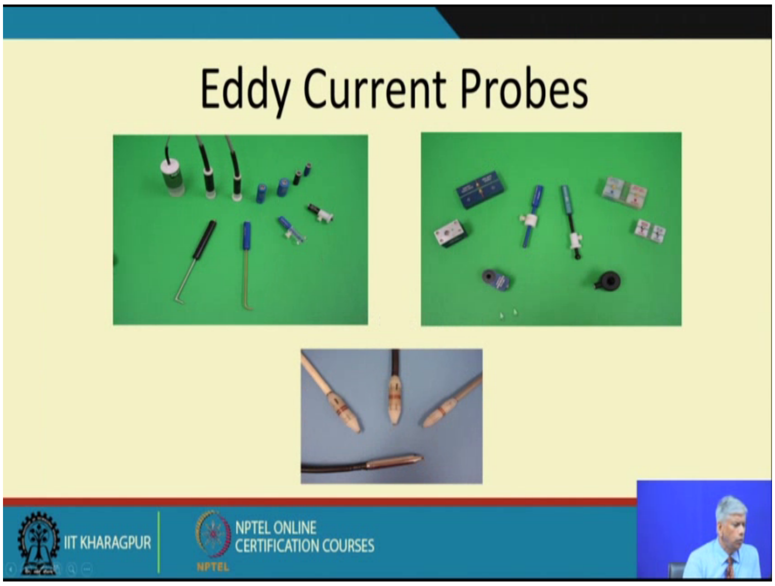

So, we can see the difference. So, typically this is how particular views of some commercially available Eddy current probes the common different forms and all you require is a Eddy current test equipment with multi frequency equipment and then you have an analogue meter and then recurrent probe.

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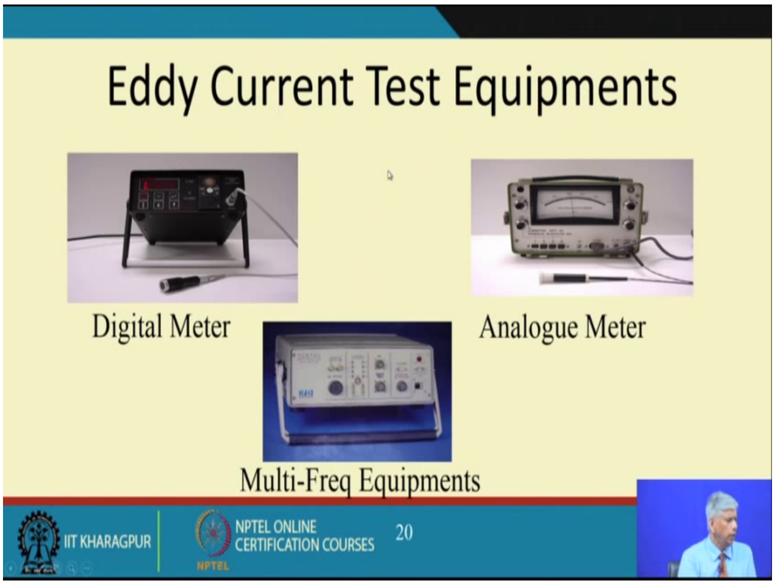

So, the secondary voltage magnetic field which is inducing a secondary voltage can be sensed and then you can use it for a quality testing.

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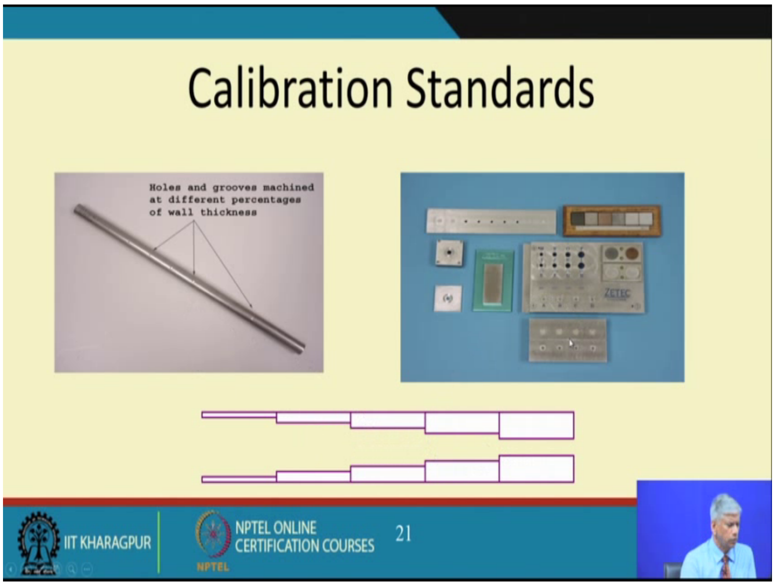

Of course, there are certain calibration standards for example, holes in a tube holes are made of different diameters ok.

And as a percentage of the wall thickness is certain calibration standards are there. so that we can calibrate the voltage level corresponding to the diameter which is being measured ok.

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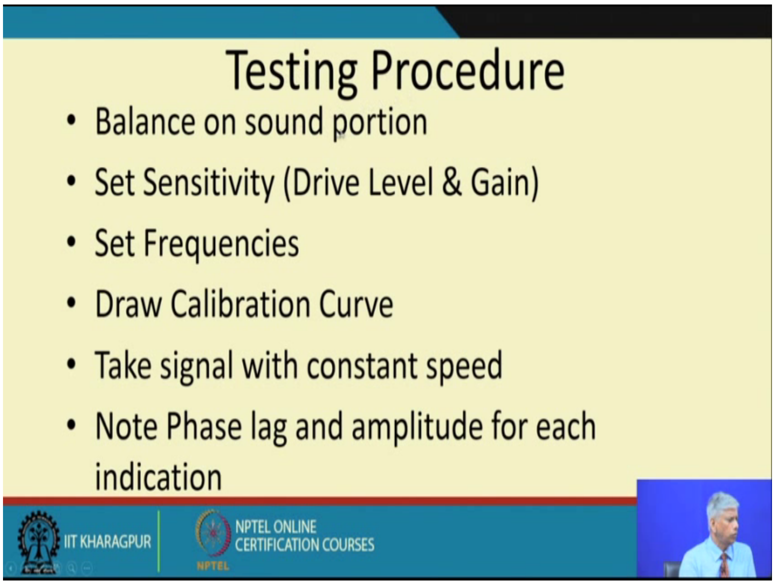

So, some of the testing procedure balance on a sound portion set sensitivity set frequency draw the calibration curve take signal with constant speed because when a when he when he moving the probe speed has to be constant and note the phase lag and amplitude for each indication ok.

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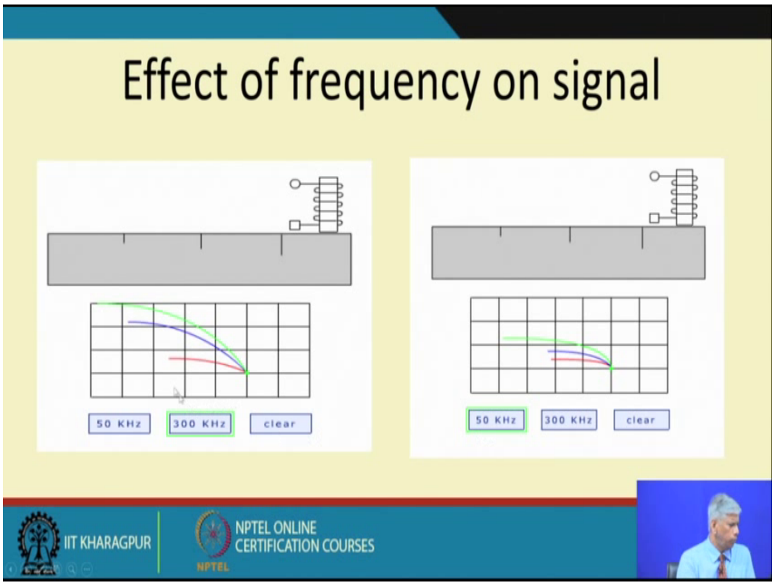

So, sometimes as you have seen with frequency they will get affected and so on. So, we can use and typical frequencies of Eddy current 50 kilohertz, 300 kilohertz and so on.

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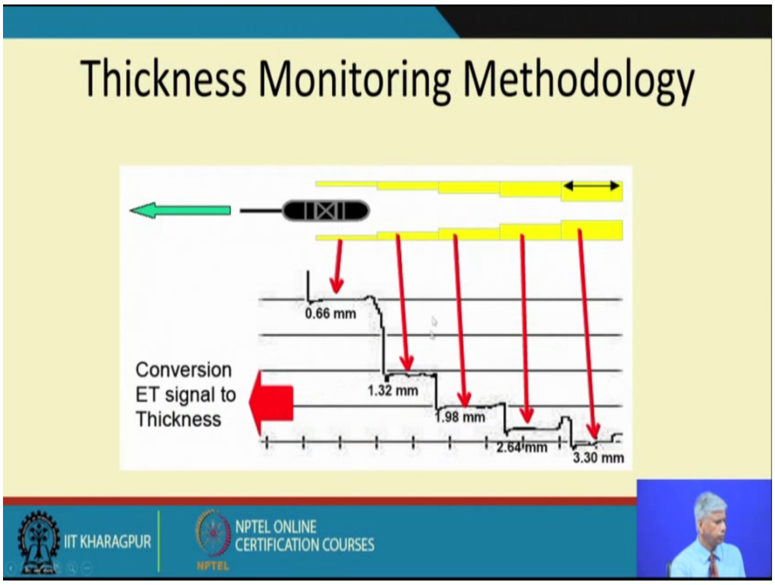

You see which this is a calibration standard to monitor the thickness you are moving the probe and conversion of the Eddy current signal to a corresponding thickness as you can see qualitatively, if you have seen here 3.3 meter. So, 2.46 meters, it is the thickness of the pipe and that has changed if I am moving this probe.

But then whatever voltage is coming you need to know that this corresponds to 3.3 mm this when the probe is here it corresponds to 2.64 mm. So, such thickness monitoring methodology or calibration needs to be done before even we apply the Eddy current probe for an interesting.

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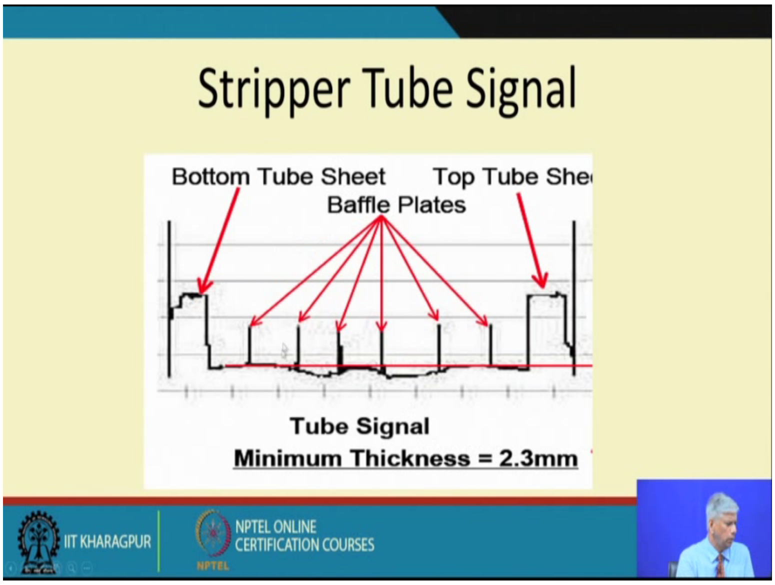

Similarly, in tube signals in a, with a bottom of the tube sheet and then there is the minimum thickness, etcetera.

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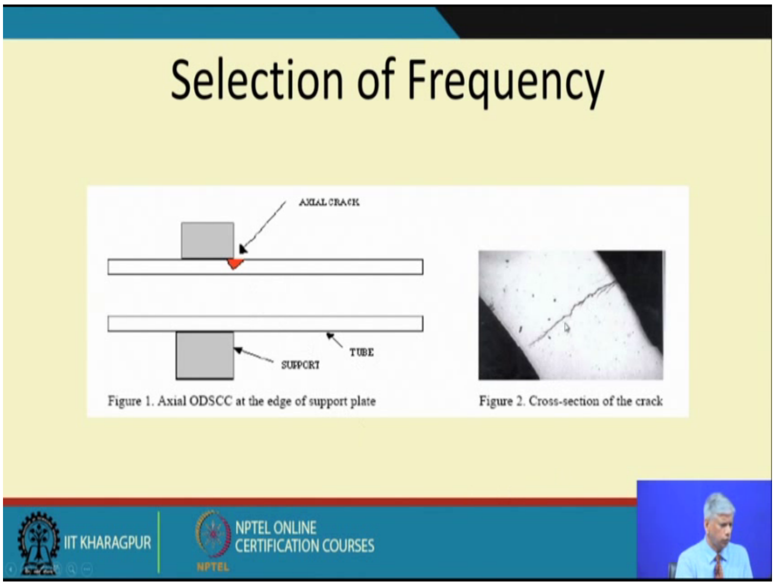

A crack has occurred and then you see cross section of the crack.

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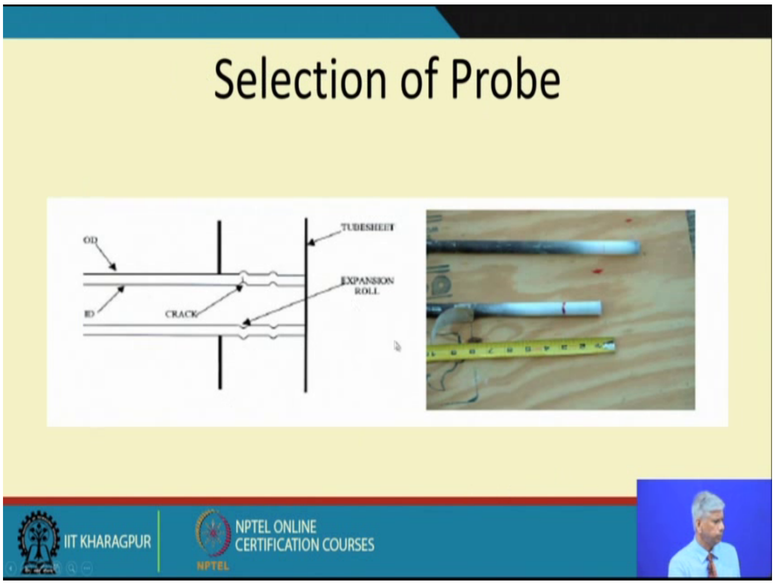

So, this can be used to measure selection of the probe depending on the crack location how thick the diameter should be.

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And sometimes as you will see such surface defects, it if we can see in this images, there are many surface defects on the pipe of course, to our visualize we can see it and of course, you know today the technology such that you can do image processing by having a vision base systems, but Eddy current can be used to also altered them.

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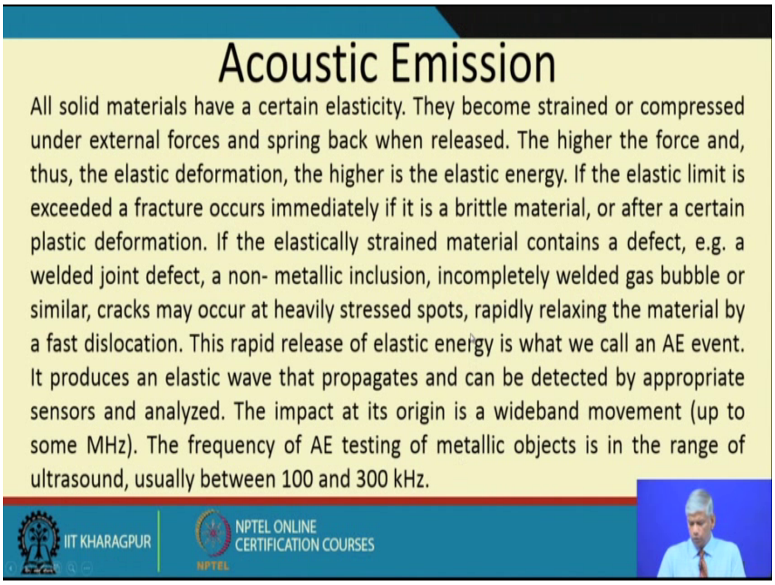

So, now we will talk about another technique which we had told in the beginning.

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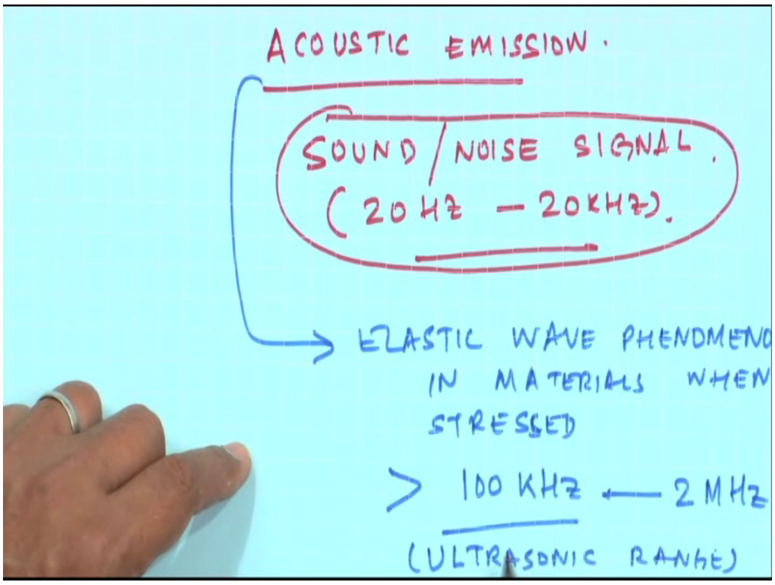

This is acoustic emission the definition of acoustic emission or a brief paragraph I have included here that all of you can perhaps read, I am just going to read it out for the benefit of all solid materials have a certain elasticity they becomes trained or compressed under external forces and spring back when released the higher the frequency and does the elastic deformation the higher is the elastic energy, if the elastic limit is exceeded of fracture occurs immediately, if it is a brittle material or after a certain plastic deformation is the elastically strained material contains a defect like a welded joint defect.

A non metallic inclusion in completely welded gas bubble or similar cracks may occur at heavily stressed points, rapidly relaxing the material by a fast dislocation this rapid release of elastic energy is what we called an AE event or the acoustic emission event, it produces and elastics wave that propagates and can be detected by appropriate sensors and analyzed, they impact at its origin is a wide band movement up to some megahertz the frequency of AE testing of metallic objects is in the range of ultrasonic usually between 100 and 100 kilohertz.

So, with this explanation of acoustic emission I must tell you, this is not the same as sound or noise signal which we have talked in the audible range from 20 hertz to 20 kilohertz ok, acoustic emission is an elastic wave phenomenon in materials when stressed and they are at frequency more than 100 kilohertz, they are in the ultra sonic range maybe even up to 2 megahertz. So, we are talking about a very very high frequency acoustic wave ok. So, being high frequency they are directional, it has nothing to do with noise control of machineries or human hearing ok. In fact, they are in the ultrasonic range.

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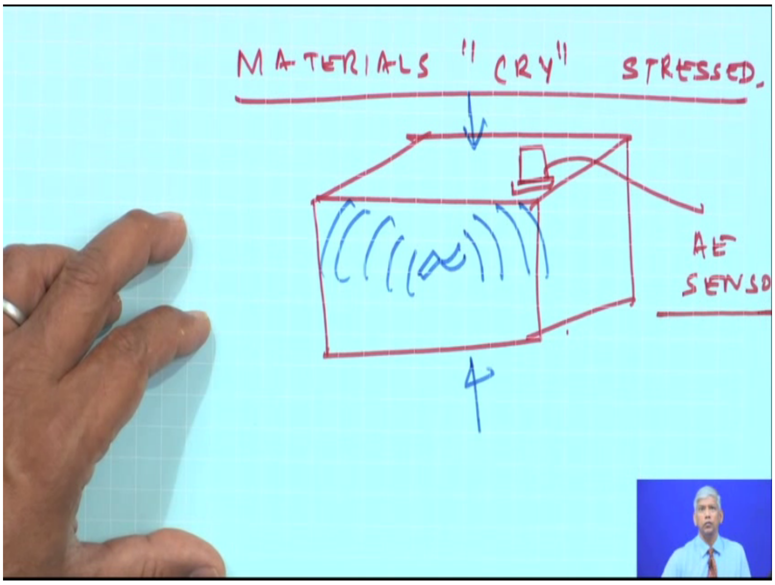

So, human being can never here acoustic emission, but what I can say is materials cry when they are stressed. So, this can be used to find out the condition of the defect in the material imagine a body where in there is a crack. So, if loads are applied. So, they are going to give out waves in all directions and if I put a AE sensor, I will get this signal and this can be used to know the condition, So, application of acoustic emission again non destructive testing of heavily mechanically stressed components or structures.

Particularly and materials research in inspection and quality assurances monitoring of welding and wood drying processes real time leakage test and location within various components particular the corrosion was occurred tank leaks and high voltage partial discharge even enlarge transformers.

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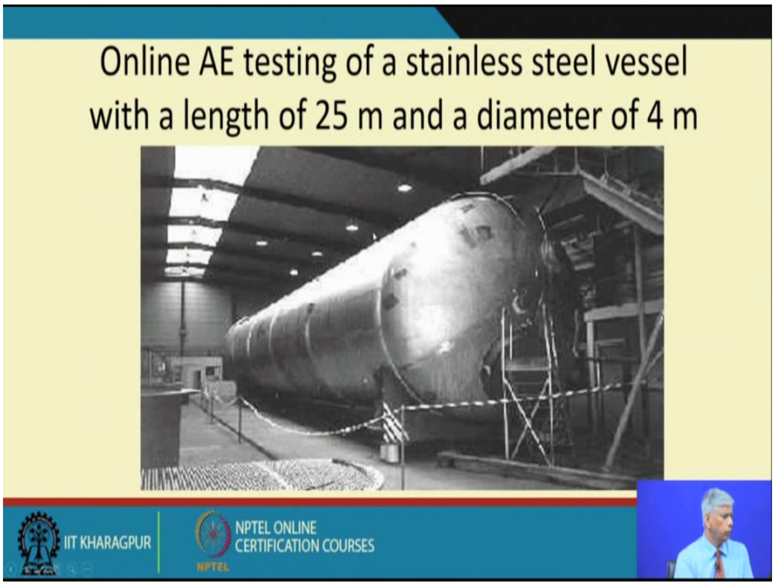

This is a view of a large pressure vessel of diameter four meter length 20 meter doing acoustic emission testing.

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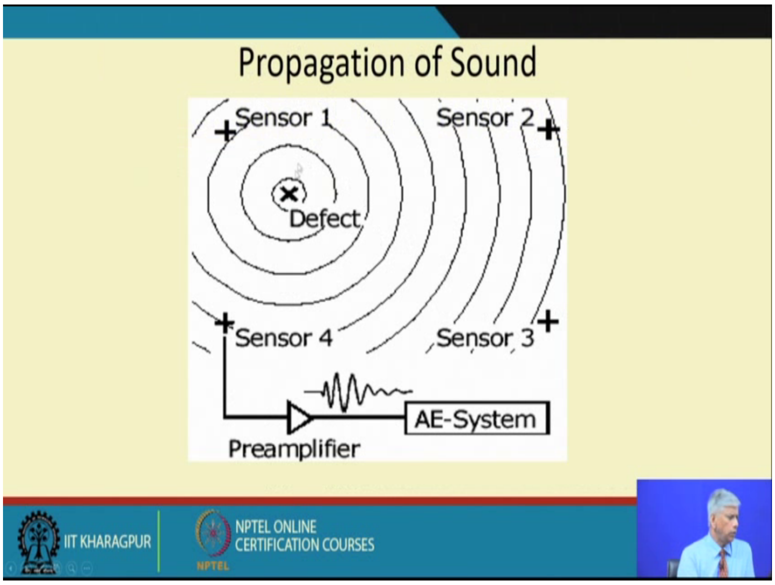

So, what happens if a defect has occurred and a on the surface I have put 3-4sensors basically like I was mentioning the case of ultrasonics.

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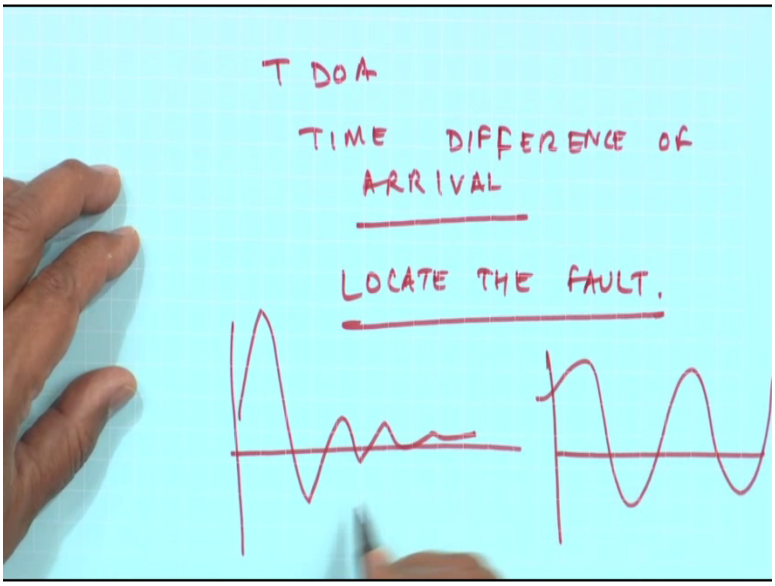

The TDOA time difference of arrival of the signal can be used to locate the fault ok.

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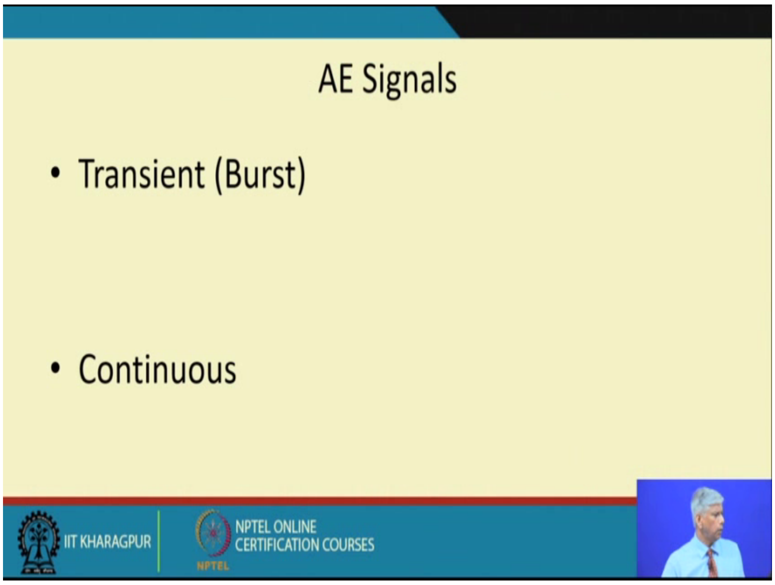

But only problem is the acoustic emissions are high frequency signals. So, they come out in burst. So, they can be either burst or continuous signals ok. So, transients occur as an burst or in containers. So, this is a typical acoustic emission look at the value here this is in microseconds.

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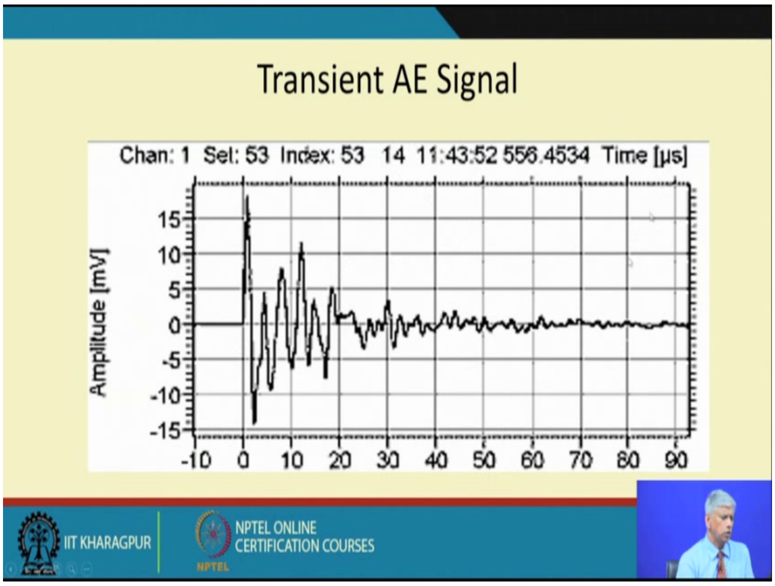

So, this is a very very high frequency phenomena. So, there is a challenge to analyze these systems that the modern data occasion systems we are not able to sample this signals at high sampling rates.

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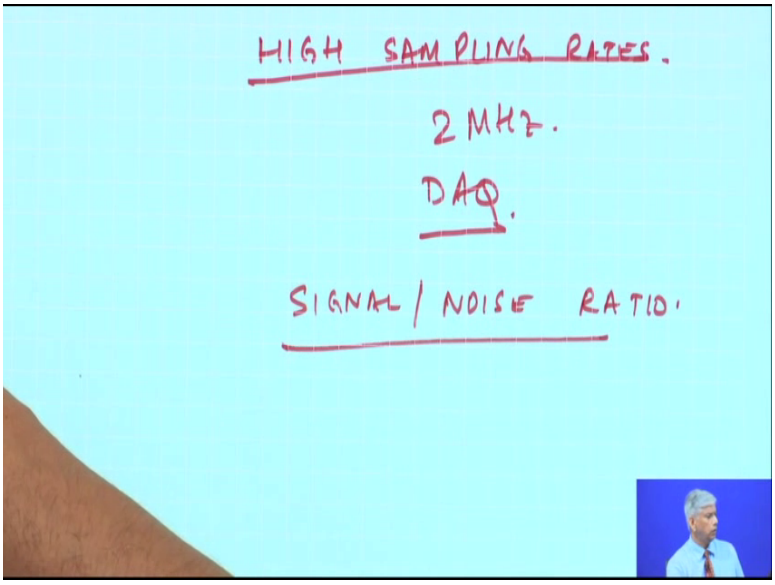

Of course, today and that is why they were not popular, but today we when we have DAQ systems with can sample high frequency signals they can be used.

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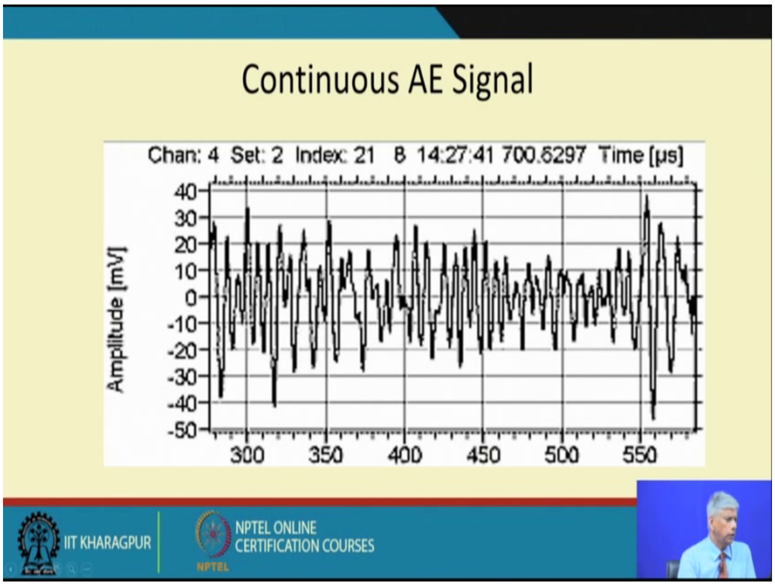

And this is a typical continuous burst AE signal and there is an Kaiser effect in acoustic emission ok.

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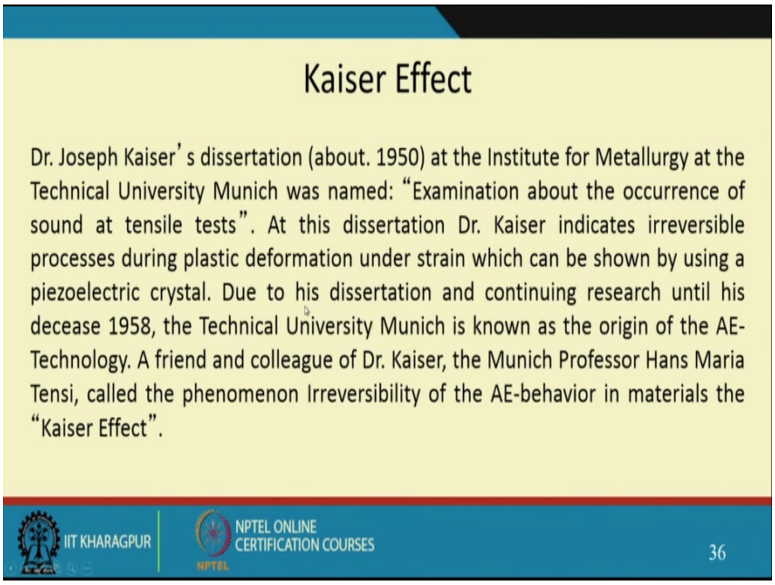

So, at this the Doctor Kaiser recess due to indicates and irreversible process during plastic deformation under strain which can be shown in a piezoelectric crystal.

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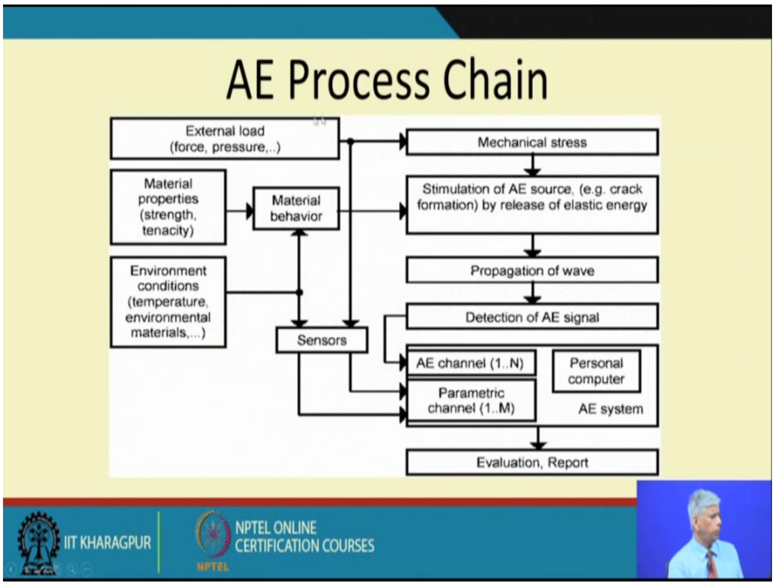

So, particularly in an and this is this piezoelectric crystal which is sensing this AE signal with basically the sensor is again and piezoelectric crystal ok.

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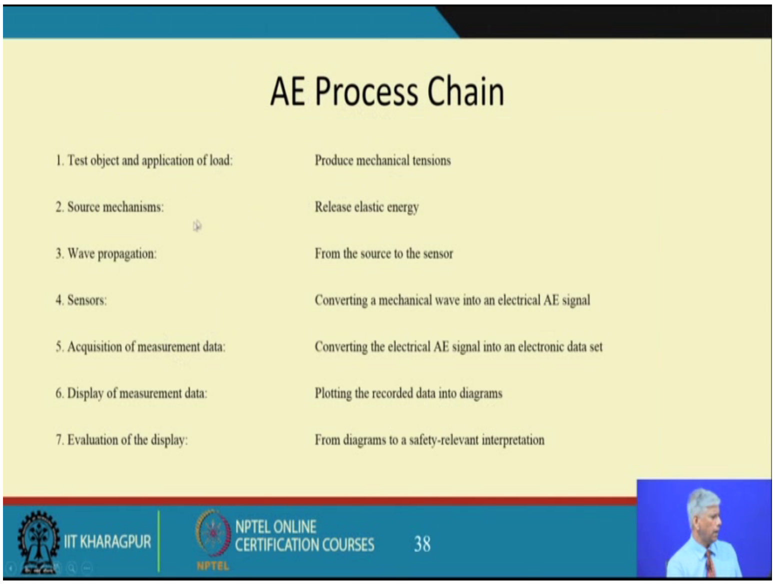

So, we have the test mechanisms in the process chain we are the test object resource where is being generated, we have an AE sensor and then the data acquisition units.

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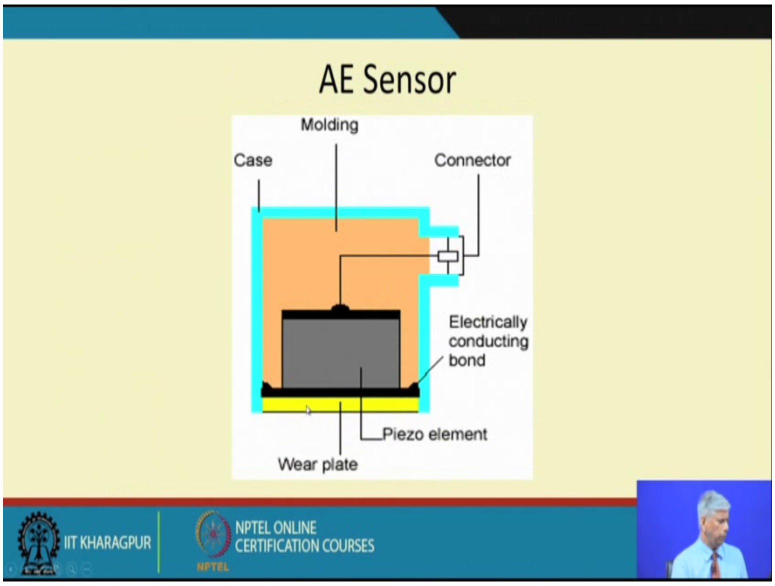

So, this is the typical acoustic emission sensor, we have a air plate the sensing element and we have a sensor.

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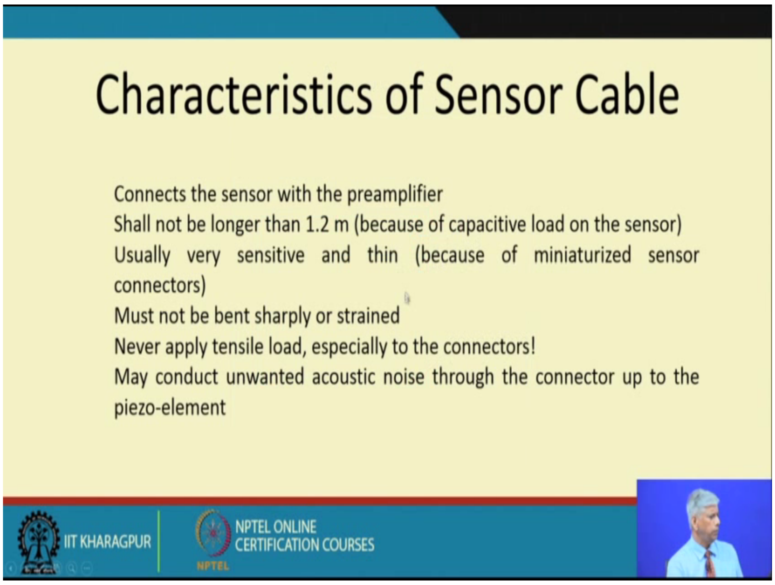

But then because this is being a very high frequency signal to noise ratio is an very big issue in AE measurements and one has to be careful about of course, the signal again being very low there is a pre amplifier which is used to amplify the signal.

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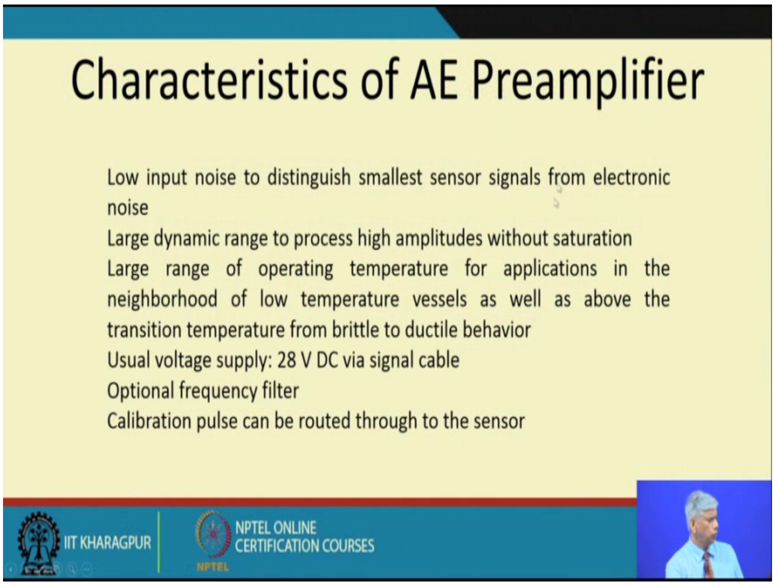

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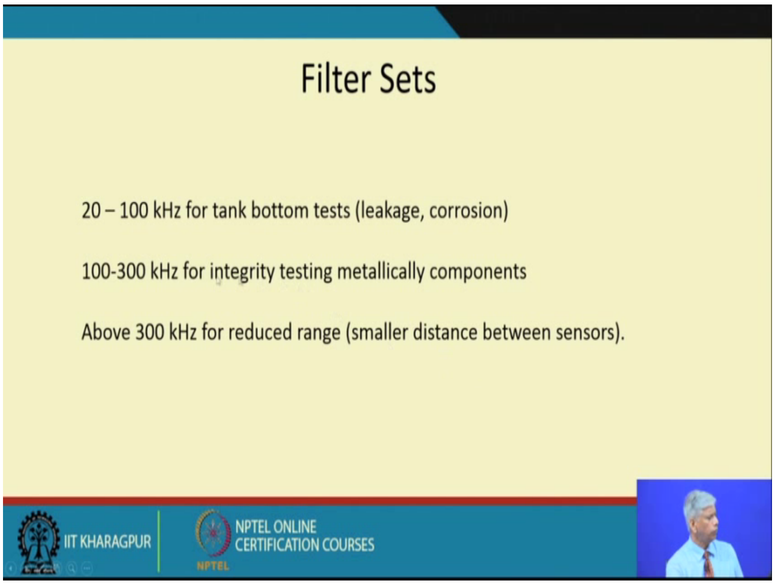

And of course, you can use a filter sets depending on your application because if digital signal processing is not available at high frequencies, we can use analogue filters ok.

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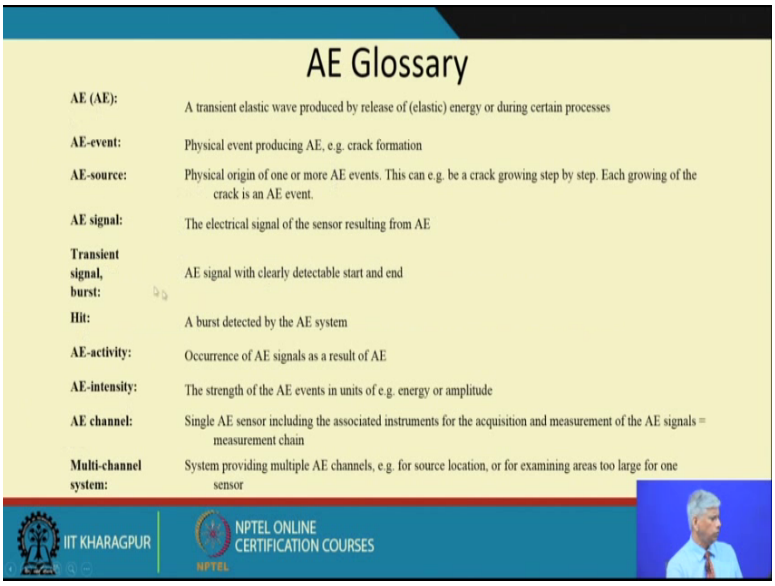

And some of these glossaries we can find the details here in these slides.

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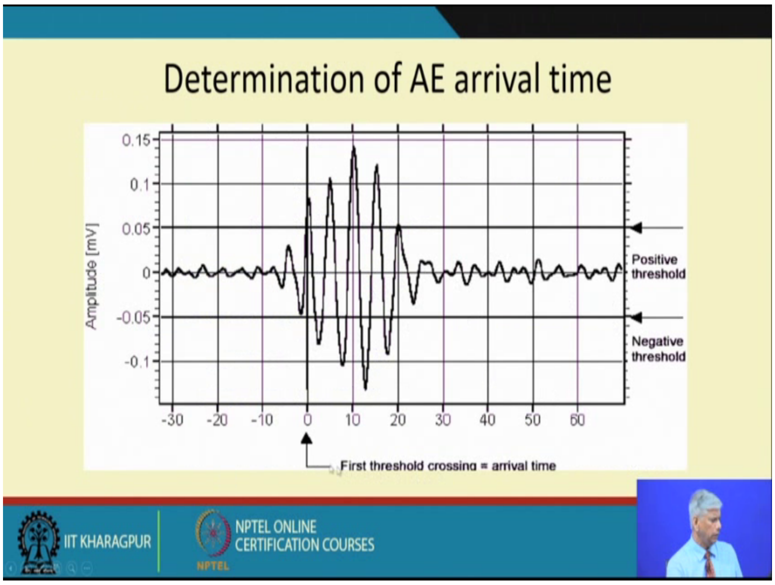

So, typical the arrival time if at a particular sensor location from a sensor and then I can have some limits and then the features of a transgender signals is the rise time.

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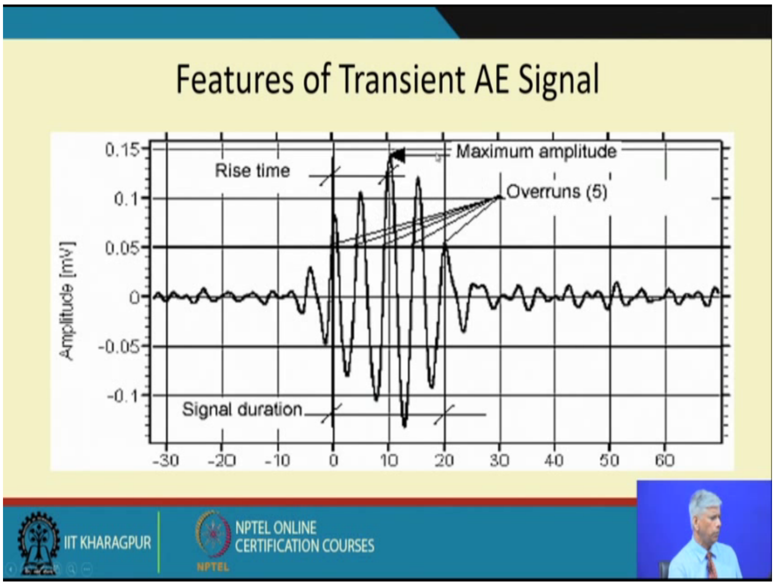

The maximum amplitude number of overshoots and so on and this is how we can quantify the signal because essentially the AE signal has to be captured to give us some clue as to the condition of the machine or the component ok.

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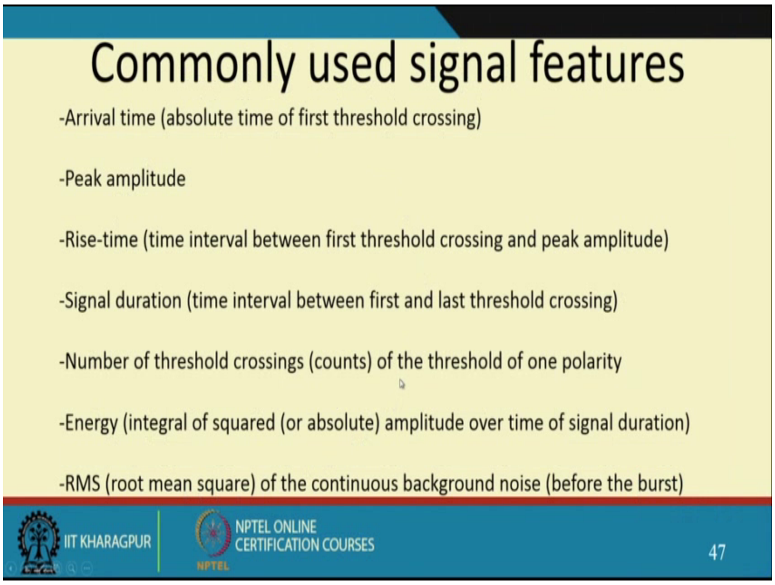

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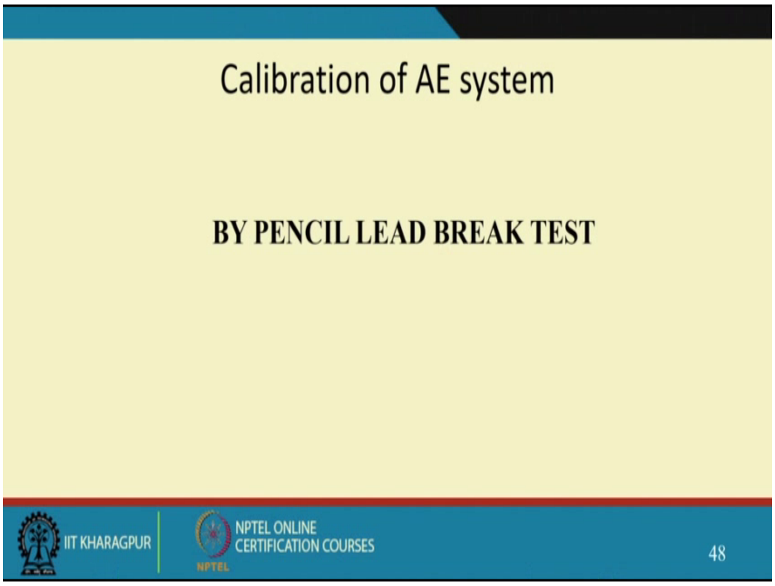

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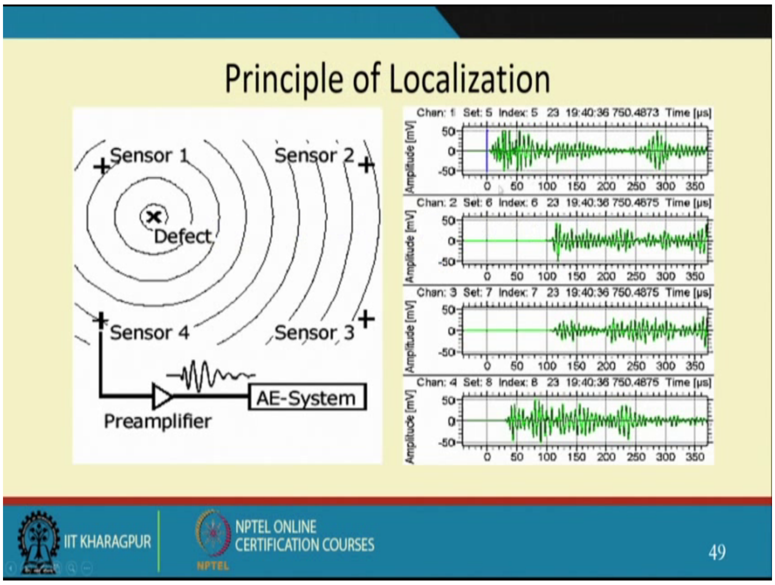

And we can calibrate by this pencil lead break test. So, this is what I meant by the DOA, we can see the, for the different sensors the time difference time of arrival is different and then through a triangles and technique you can find out this source ok.

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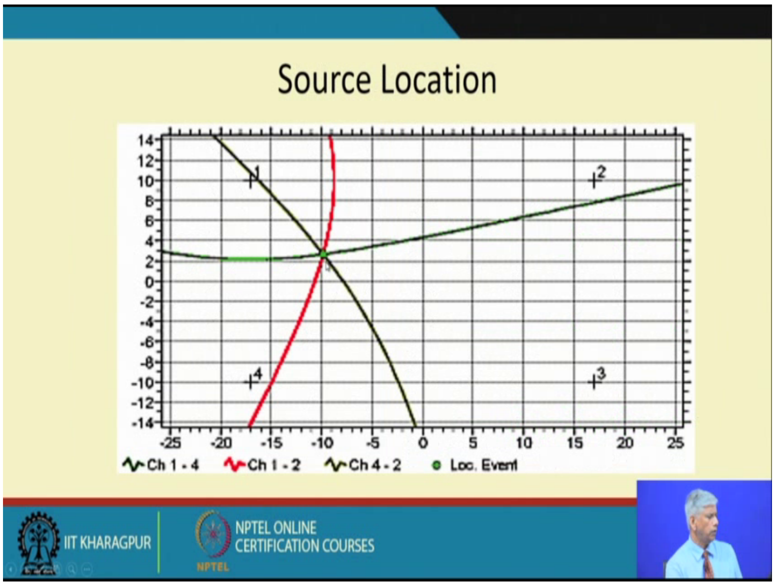

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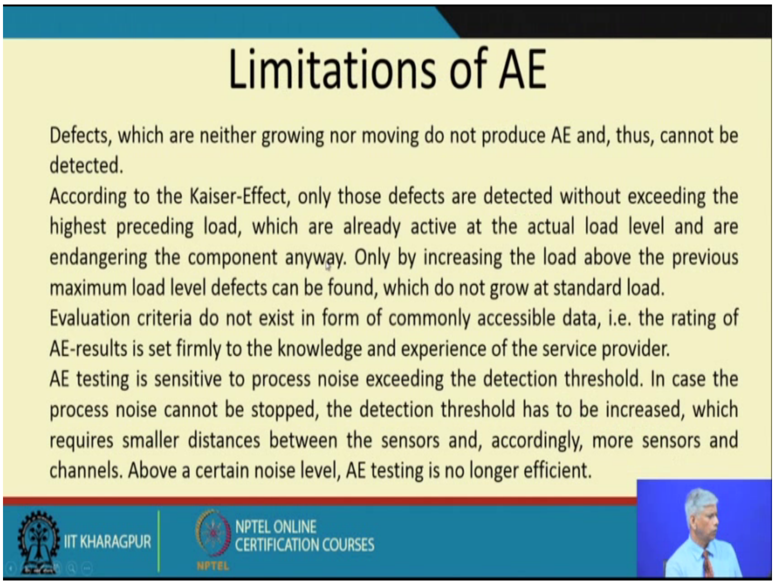

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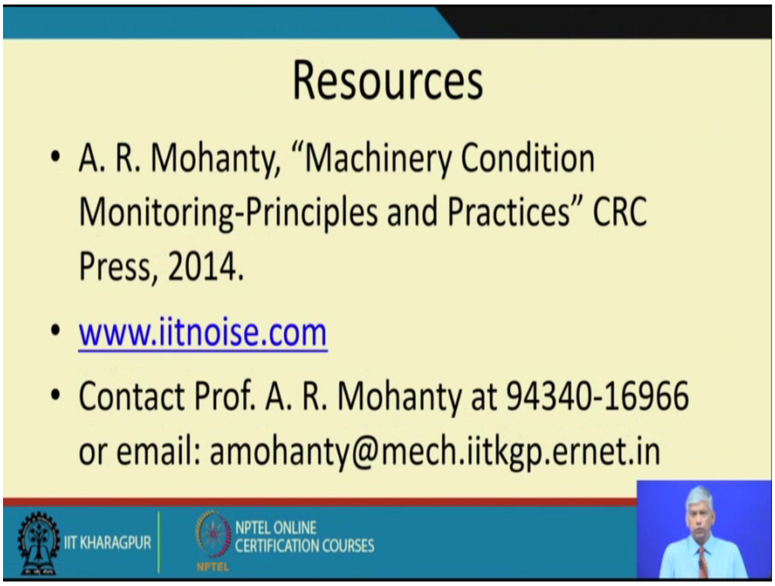

So, more of these you can find and then you can refer to my website IIT noise dot com for the details or you can contact me ok.

Thank you.