

**Machinery Fault Diagnosis and Signal Processing**  
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**Lecture - 59**  
**Overview of CBM facilities**

Well, over the past 11 weeks I have introduced you to many techniques of CBM, be it vibration monitoring, be it where did these analysis, be it motor current signature analysis, NDT techniques. And some of the results which I have discussed were actually from the research being carried out at our acoustics and condition monitoring laboratory at IIT, Kharagpur and we have many state of the art CBM facilities at IIT, Kharagpur in our laboratory. And then sometimes you know I also as a consultant or go as an expert visit many industries wherein we carry lot of equipment to do in situ balancing, in situ measurements troubleshoot things etcetera. So, I thought I must also give you a pictorial guide of the facilities which we have at IIT, Kharagpur.

And also welcome all of you to come down visit our laboratories physically because we also have visitors all over the world visiting us some time in the past and they do that regularly from both the Americas, North America, South America, Europe, Asia people visit us, Australia, spend some time with us do research do collaborative research do experiments. And I also go to other laboratories throughout the world and exchange ideas and collaborate with exchange students and so on.

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Facilities at Acoustics and Condition Monitoring Laboratory, IIT Kharagpur

- Test Setups
  - Acoustical Impedance Tube
  - Material Transmission Loss Setup
  - Muffler Transmission Test Rig
  - Generator Radiated Noise Test Rig
  - Sound Intensity Probe
  - Gearbox NVH Test Rig
  - Material Damping Measurement Setup
  - Data Acquisition & Signal Processing
  - Engine Noise Simulator
  - Rotor Test Rig
  - Machinery Fault Simulator
  - Anechoic Chamber
- Specialized Software
  - NASTRAN, ANSYS, ALGOR, SYSNOISE, ADAMS, AUTOCAD, MATLAB, PRO-E, FEMAP, HYPERMESH, CATIA
- Specialized Equipment
  - 8 Channel DAT Recorder
  - Several Multi Channel FFT Analyzers
  - Wired and Wireless Data Acquisition System
  - Single Point and Rotational Laser Vibrometer
  - Arbitrary Waveform Generator, Oscilloscope
  - Single Channel Acoustic Emission Transducer System
  - Single Filter Set, Transducer Power supplies
  - Various Accelerometers, Microphones and tacho probes
  - Encoders, High Temperature Accelerometers
  - Charge Amplifier, Measuring Amplifiers, Power Supplies
  - Hydrophones and Acoustic Pinger
  - Sound Level Meters and Sound Intensity Probe
  - Omni Sound Source
  - Human Hand Arm Seat Vibration Measuring System
  - Thermal Imaging Camera
  - 3 Axis Vibration Excitation System, Impact Hammer
  - Hall Effect Current Probes
  - Phased Array Ultrasonic Testing System

So, I thought I will I must let you know that what are the facilities available. We have few dedicated test setups, we are specialized equipment and a lot of software either at our laboratory or on campus wide institute wide licensed software these are some of the commercial softwares which you have and we have access to do the modeling has not been required.

While come into this setup we have an acoustical impedance tube where we can measure the materials properties. Initially of course, some of those were actually developed by our own efforts and then has time progress we also have procured some of the equipment of the international standards. We have the material transmission loss setup, we can measure the transmission loss of mufflers, we can measure the generated radiated noise sound intensities, gearbox in which the strikes material damping measurement run of detection and signal processing systems engine noise similar to rotor test rate machinery fall simulator encourage chamber well.

So, some of these facilities are there well coming specifically to some of the specialized equipment some of them which you would have already seen, we have a data recorder which is one of the oldest equipment in our lab and its close to about 15 years old the oem has stopped manufacturing them, but I still have them and it is a very favorite equipment. So, that I can take this recorder to the field and capture records and then

analyze them. So, in fact, I have recordings fifteen years ago I can play them to you they will sound as if and they will behave as if you are sitting next to the machine next to you.

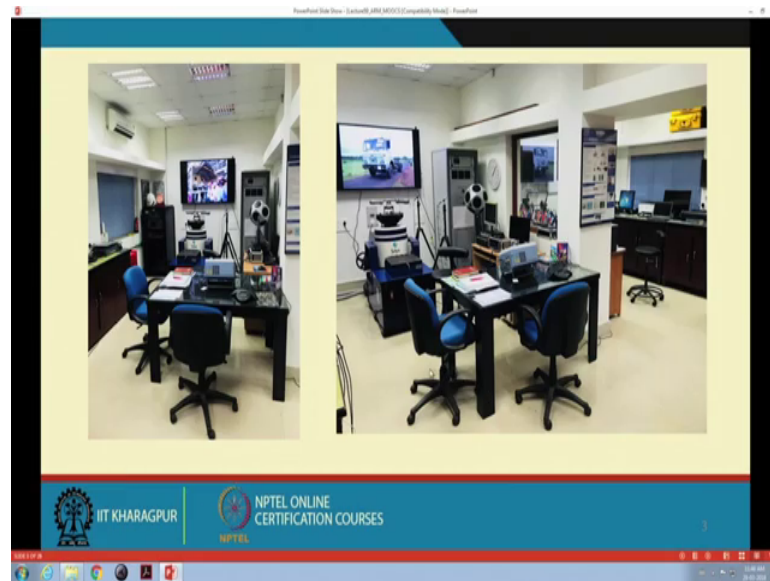
Many multiples your channel analyzers 8 channels, 4 channels, 3 channels, 7 channels, 40 analyzers are there of course, a lot of data acquisition systems cards with high sampling rates even we have wireless systems wherein we can acquire wireless data equation. You must have seen the single point laser vibrometer we also have couple of rotational laser vibrometers. For a lot of signal processing and underwater what are acoustic studies we have arbitrary waveform generator oscilloscopes. We also do studies in acoustic emission we have a single channel acoustic emission transducer system.

Again for analysis we have a lot of filter sets, lot of this transducers bead accelerometers or microphones require power supplies which need to be portable giving you the polarized voltage or the charge to voltage amplifiers ok. Encoders we have high temperature accelerometers these are charge type accelerometers and of course, associated amplifiers power supplies etcetera.

We have the hydrophones for underwater acoustics, acoustic pinger few sound level meters sound intensity probe. We have an Omni sound source. We do lot of human arm hand arm seat vibration measurements we have systems for their thermal imaging camera, 3 axis vibrations excited system modal exciters impact hammers all affect current probes phased array ultrasonic testing systems and lot more ok.

So, it is a full fledged acoustics vibration conditioned mountain lab and I can proudly boast that perhaps this lab is the only lab in India amongst academic institutes which has all the equipment for CBM, for northern viruses measurements, for signal processing and so on.

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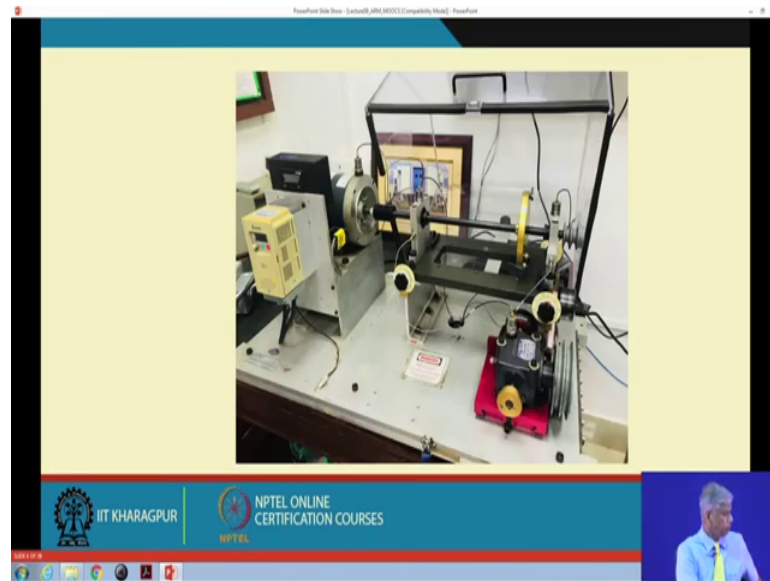


So, this is one view of the office peers of the lab we have about close to about 1000 square feet of space and this is the lab with some of the major equipment here is another view here for.

Of course to this lab you know we have IP enabled so that he cannot cameras where you can access experiments also externally over the internet and so on ok. And you can see these yellow pelican cases these are the cases which we have a lot of them. So, that the equipment which are there whenever I need to carry them to the field I use this yellow boxes and of course, I know I get priority checking and clearance in the airport with the yellow boxes.

And then of course, a lot of sitting areas of course, this is a ground floor and the top floor we have the sitting areas where the student sit and they do all the numerical and the soft computing we have a sound quality room, we have an NVH engine room, we have an underwater acoustic tank as well.

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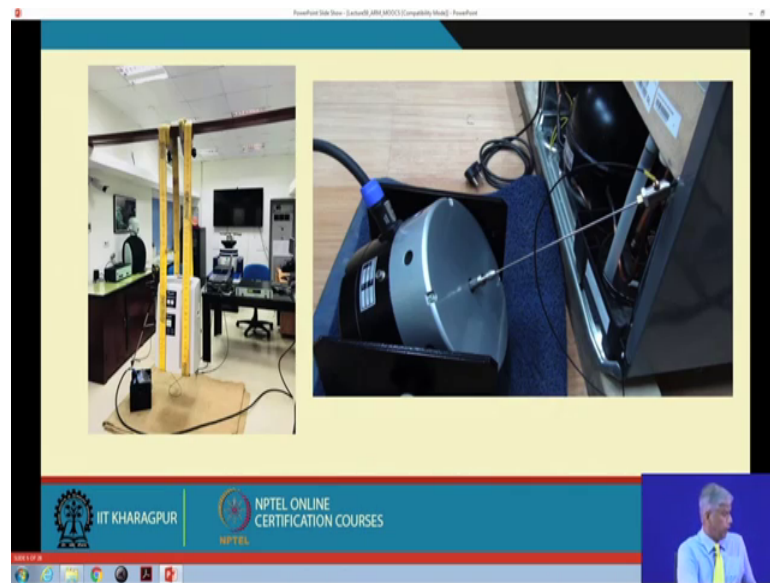


So, this is a machinery fault simulator where in I can do many faults in this theater that the shaft faults in terms of unbalanced, in terms of misalignment, in terms of couplings, in terms of bearing faults, the motor faults there are faults seated in the motor which could be replaced gear faults pulley faults bell faults.

We also have a pump which can be coupled to this and then in a avitation falls impeller faults. So, this is a good setup where in all such fault scenarios can be simulated and then we if you can see here these are accelerometers which have been put. So, we can measure the vibration signature of course, you can also remove the control panel of the motor and get access to the current and measure the current from this machine. So, all sorts of tests can be done using such a system and this very favorite amongst the students to generate signal and so on wherever they need to have nice signals in a controlled laboratory environment to develop signal processing algorithms.

Of course we also rely on lot of field data made the railway locomotive data build a paper mill data, be it a underwater piling noise, be it a gearbox you know vibration in a cement plant. So, all this data is there and that is why we carry that data recorder to the field and then the capture the data.

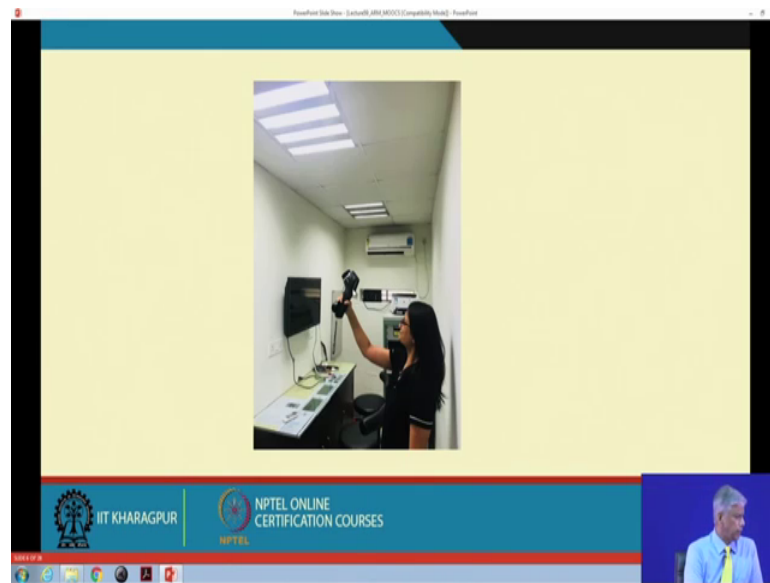
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This you must have seen in some of the earlier lectures that this is a view of the model testing being done on a portable air conditioning system of an Italian manufacturer where they have identified us to do some noise reductions and this. So, we are doing a modal testing here to find out the resonant frequencies.

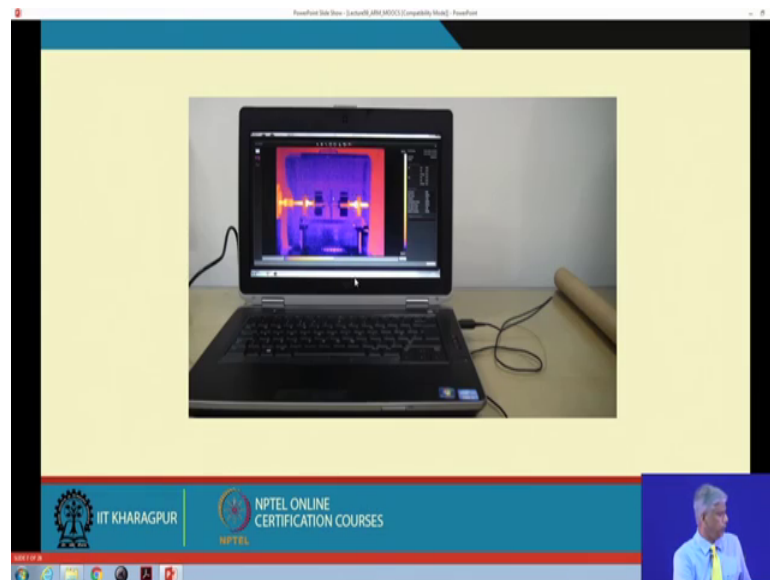
You can see this lab thought, (Refer Time: 09:34) for sound quality analysis you can get a view of the electromagnetic exciters you know with a slip table. So, I can excite it in three directions of course, we have a large panel TV where all the signals, we can see this is a modal testing which is being done on a refrigerator and you can see this is the electromagnetic slider and this and this is the impedance head, wherein I can simultaneously measure the driving point of RF by measuring the acceleration and the force input to the system. And this is the incline because then I can give in vibration at 2 or 3 different directions.

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We have an infrared camera this is a student using the infrared camera to measure the temperature ok. It is a handheld infrared camera with about now it can measure up to 700 degree Celsius all you have to be careful is how you set the emissivity and the resolution is about 0.1 degree Celsius.

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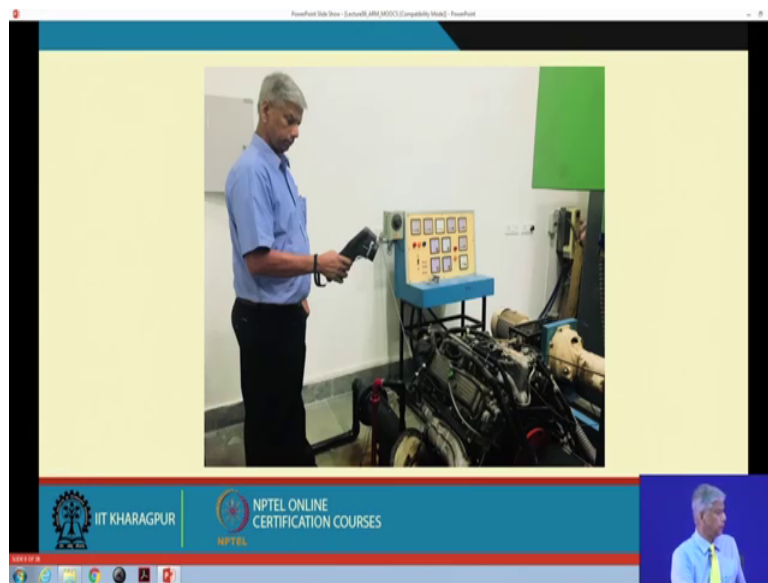


And this is a view of the thermal image of the rotor rig with an misalignment know if you can see this black to disk these are the heavy discs which are creating a load on the

bearing and you can see how the temperature of the bearings have increased because of the misalignment between the motor shaft and the shaft across the coupling.

This is a video which was captured. So, I thought I could share with you and this video was captured by this infrared camera where if we can also fill in such temperature profiles.

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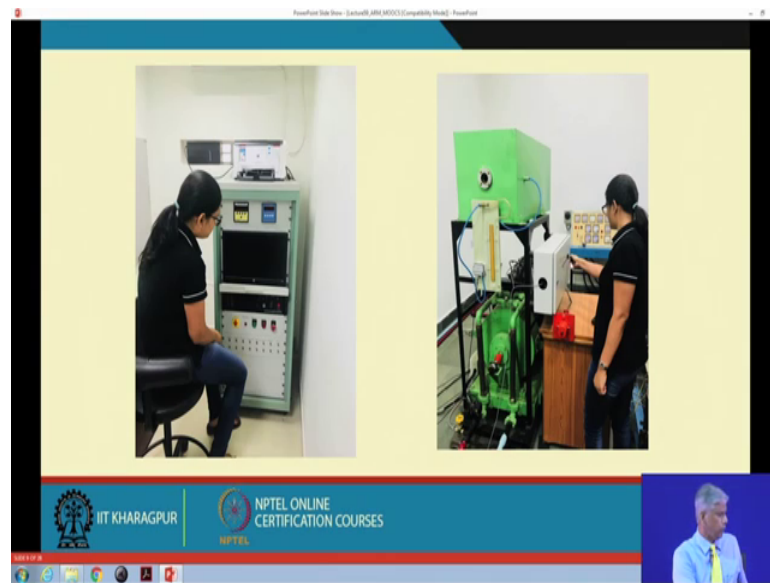


This is myself, holding this IR camera to measure the temperature of this engine. This is another 4 cylinder petrol engine which we have in the laboratory which is instrumented with sensors inside the cylinder to measure the cylinder pressure high temperature accelerometers to measure the cylinder vibrations.

We have instrumented manifolds to measure the intake pressures, exhaust pressures, we have lambda sensor. So, you can do whole lot a lot of diagnostics on this engine both from a vibration point of view, from a sound quality point of view, we can see defects in this engine and do lot of studies from the signals that is generated.

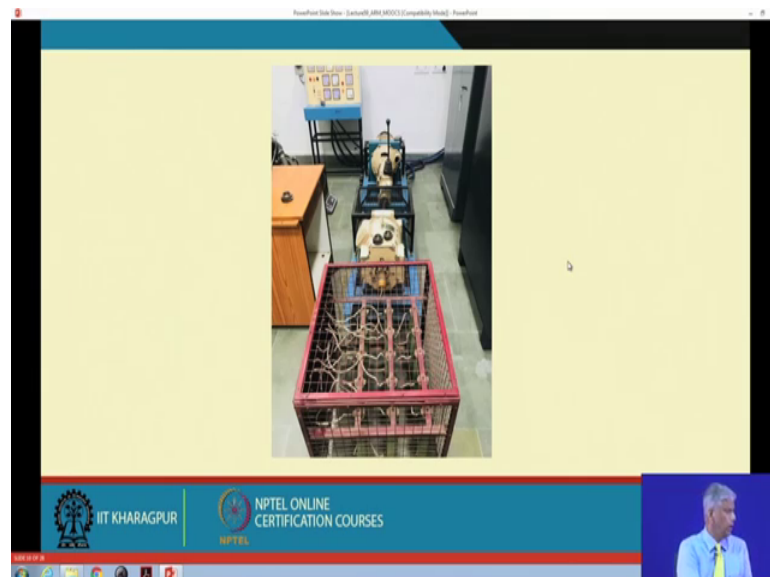


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This is the control panel of that same engine where the student and of course, this engine is connected to an eddy current dynamometer where all the load tests can be done, the efficiency calculations going to be done and then you can see this motion test where one of the engine cylinders is being misfired.

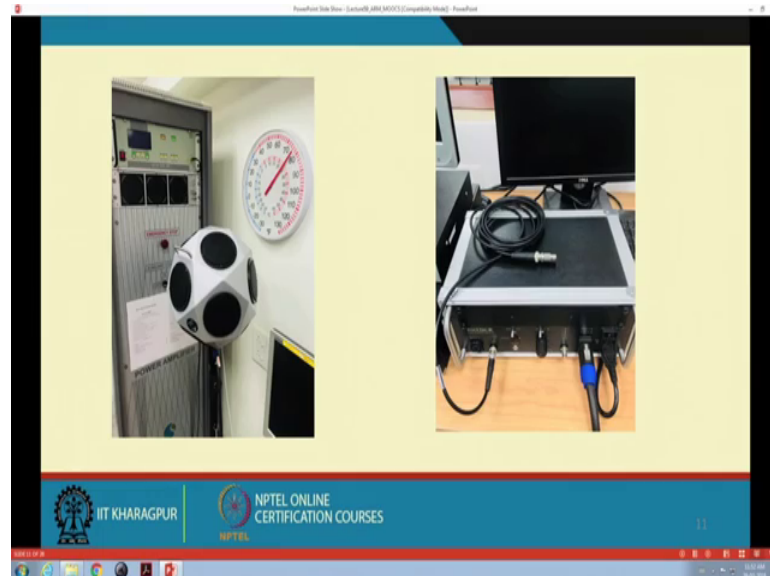
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This is the gearbox just like I had mentioned when I was talking about the motor current signature analysis. This is the gearbox which you can see driven by a motor and this is the control panel and this gearbox is driving a generator and then we have the resistance

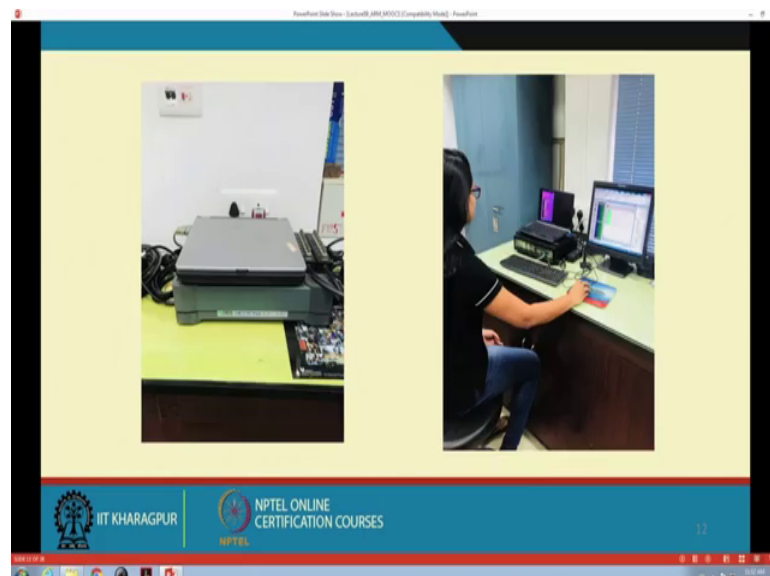
bank which is loading the motor the gearbox and then of course, with the hall effect sensors we can measure the current.

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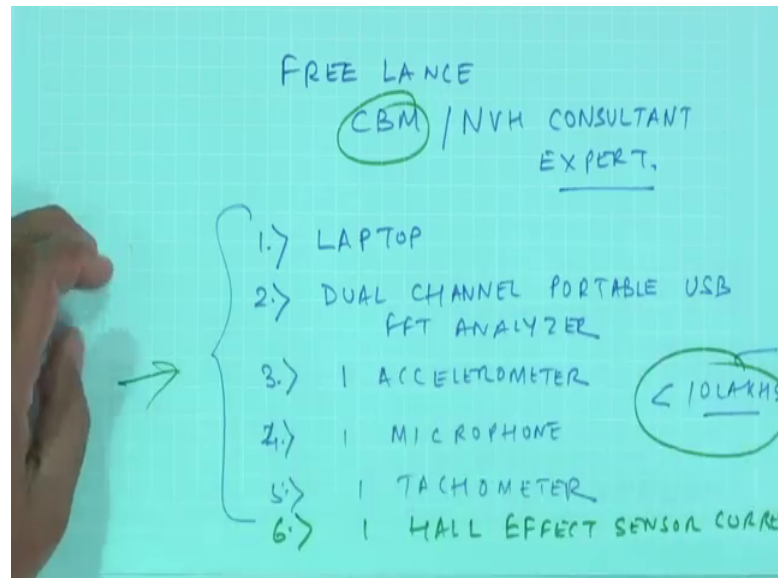
This is the only sound source you know there where it can we can generate a lot of sound and we can this is a signal generator amplifier we where we can generate pink noise white noise we can play recorded noise to simulate a lot of noises, because you know this helps to understand the building of cost of the we can measure reverberation time through such system.

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These are some of the FFT analyzers, this is another one FFT analyzer, this is another FFT analyzer, where we are doing signal analysis ok. And we have few more you know which are dual channel FFT analyzers and let me tell you know many people in many of the short courses I conduct if somebody wants to be a free lance CBM or NVH consultant or an expert what is the minimum equipment watch one should carry.

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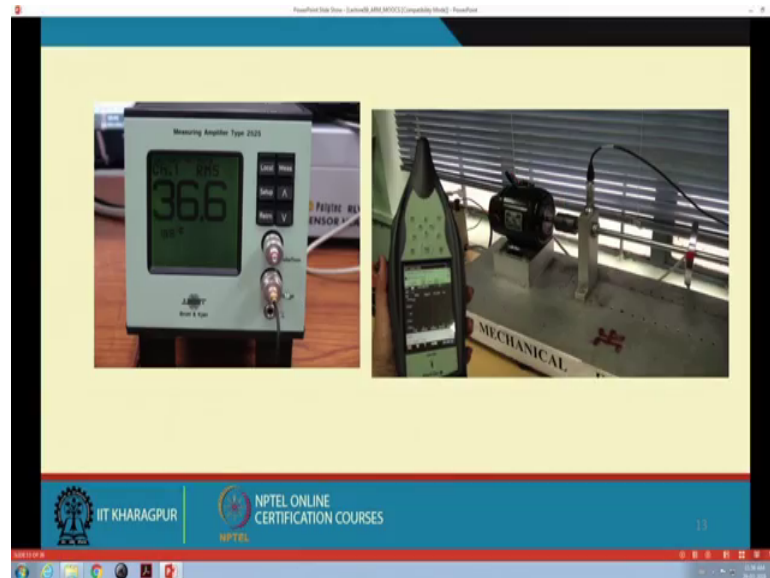
I would first say of course, a laptop connected with a at least a dual channel portable USB based FFT analyzer.

If you are low on budget at least 1 accelerometer and 1 microphone maybe this is this as input maybe 1 tachometer ok. In this maybe you know less than 10 lakhs. Many of my colleagues who are watching this in from the universities students researchers you know who want to go into this field and I am just this is from my experience within 10 lakhs of rupees you can invest on this.

And whatever you have gained or learned from me you can become an independent engineer being CBM, doing balancing doing fault identification and then of course, with time you can add maybe one hall effect sensor to whether current etcetera ok. So, I am sure know with the advancement in electronics miniaturization of transducers the costs have come down and the technology is well understood today and I do not see any reason why any engineer who has a little bend in becoming an entrepreneur cannot do this it is quite possible.

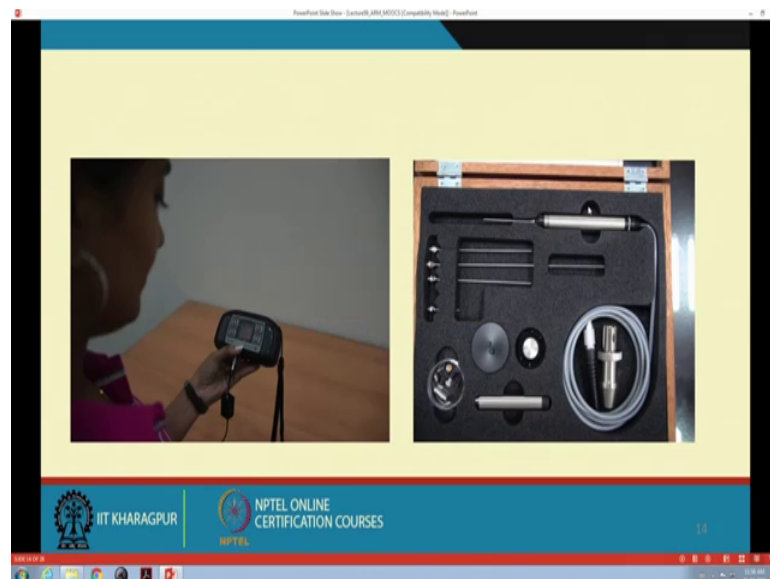
And I would be happy to see many such young engineers come up in our country who can do this and help the Indian industries. This is a measuring amplifier which can take in either the charge type of the autotrol type accelerometer.

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This is an industrial vibration meter and you can see the industrial accelerometer which is used. So, these are which are there.

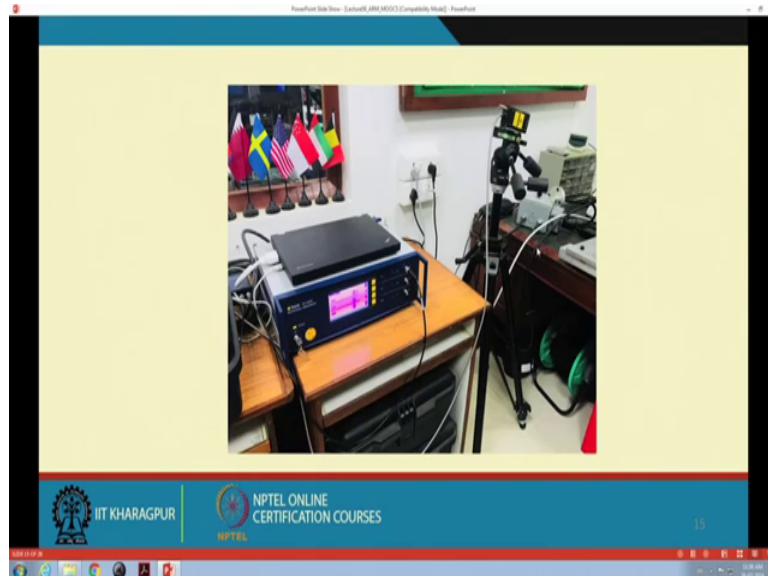
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This is hand arm vibration meter because we have the seat accelerometers. This is a probe microphones it is a very expensive microphone this diameter is about one-eighth

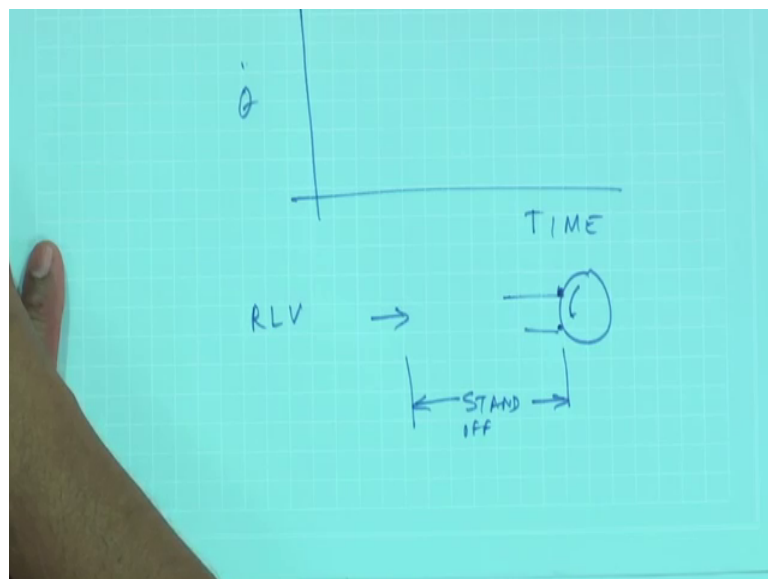
of an inch, but this is used to measure the noise out of an engine exhaust such systems are there in place.

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I was mentioning about the rotational laser vibrometer this requires signal a conditioner this is the head of the rotational a survivor (Refer Time: 17:14) meter and then it can interface it to a laptop where you could calculate.

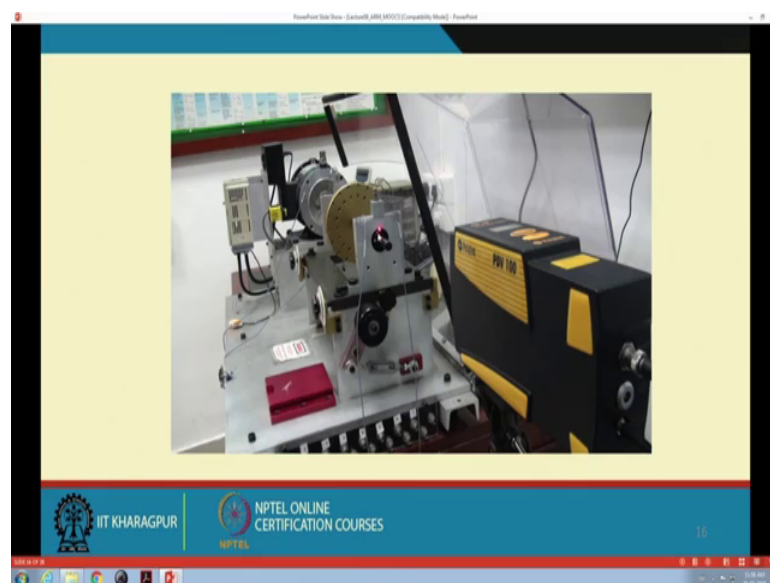
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And so theta dot versus time, but the problem this rotational laser vibrometer is for a fixed RLV to focus on a shaft which is rotating because of this separation distance there is what is known as the standoff distance.

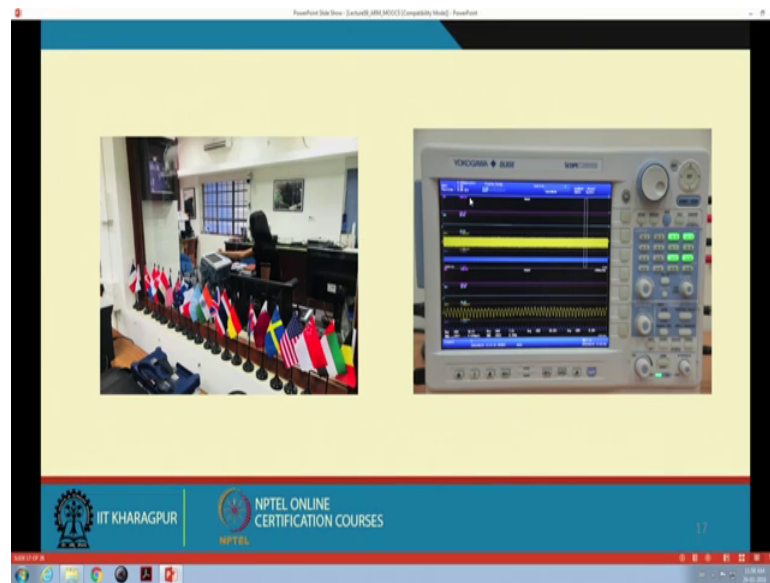
So, one has to be careful about this standoff distance ok. Unlike the linear vibrometer where laser vibrometer where you can be measuring from over a large distance and in fact, this is a linear laser parameter in the laboratory wherein we are shooting the laser beam onto the outer race of the bearing.

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Imagine in traditional vibration monitoring I put an accelerometer along the housing. But if I have a laser beam I can focus it on a very small point and measure the vibration and this is what is being done in the present setup.

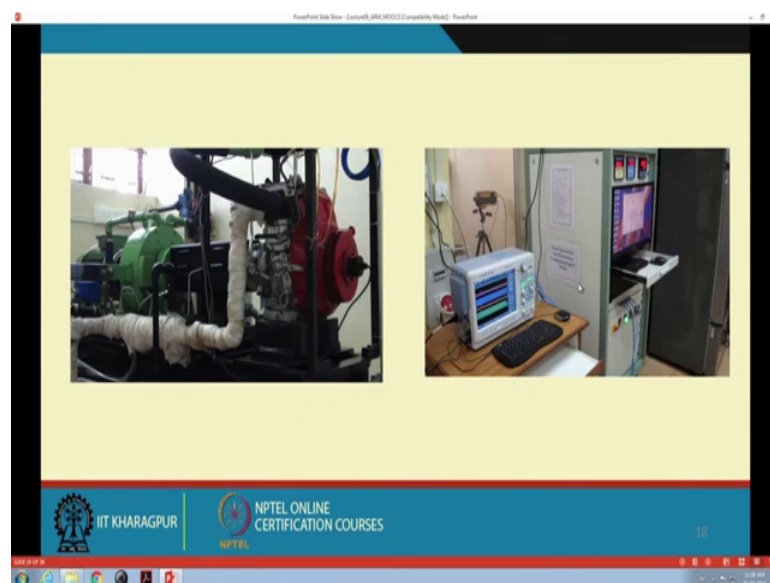
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Of course you know we have a data recorder ok, this is a 16 channel data recorder and this my students working on the data analysis of course, you can see this colorful flags in my lab these are the flags of the country I have visited and I keep on trying to at least add one new country every year and let us see how what happens ok.

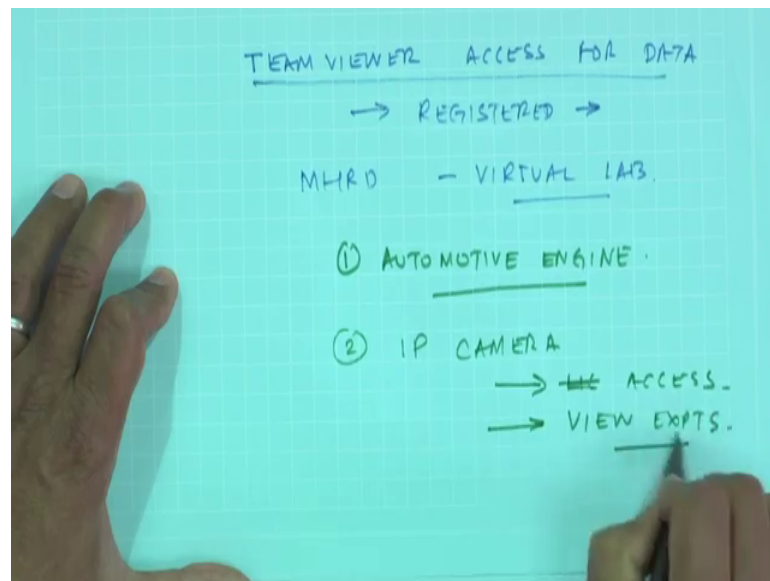
And this is the signal which has been recorded and in such data recorder this is another lab another engine which you have in the single cylinder engine.

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Of course, this engine you can see a motor here this could be fired off from the internet you know provided you have prior permission you can request me to give you prior permission of the allotted time slot for some registration fees, I think you will be allowed to see the signals and on this we are measuring the vibrations and all the parameters from this engine and dumped on the computer. And through team viewer you have access to the data on measured from this engine and then you can do all your experiments.

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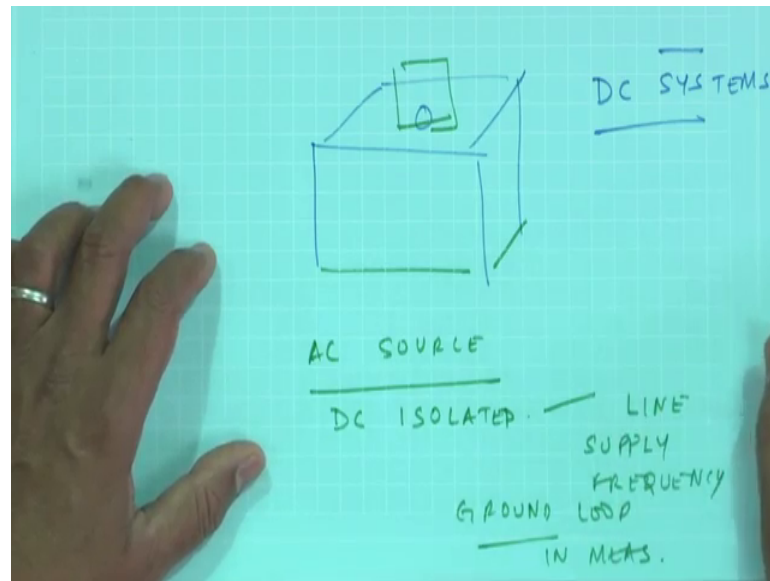


So, even in the laboratory we have you know team viewer access for data , but this because of safety issues it is only to registered a register. Not students as far in this class, so specials were registered for this to access the data ok. We had an MHRD sponsored virtual lab experiment. So, this is a part of that virtual lab.

So, we have such systems running and then you can access to do any tests on automotive engine ok. So, this is also available in the internet and of course, we have an IP camera where I can give you license or access. So, that you can view some of the experiments while it is being conducted the experiments I believe whatever we teach or we study it is nothing like doing it yourselves you know even holding an accelerometer or mounting an accelerometer on a machine is a very rewarding I mean it sounds very easy that you know just go make a tap and put an accelerometer.

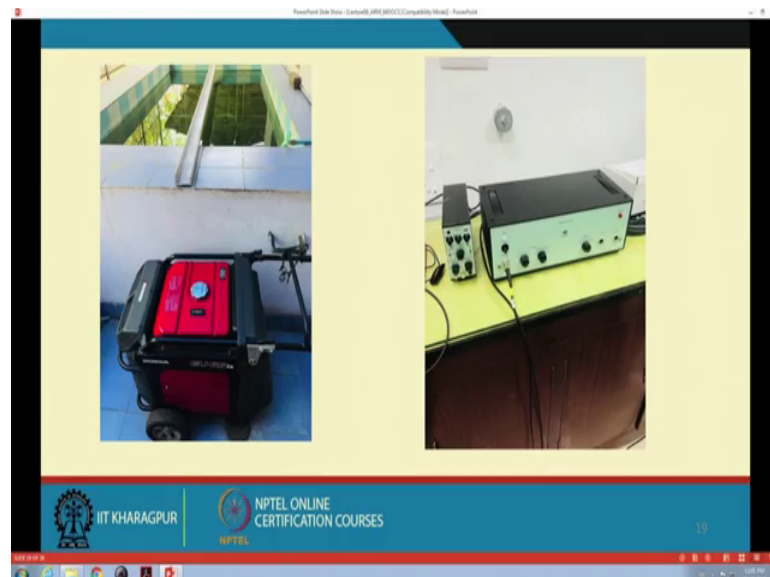


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But if you go to the real field you know you may not have even access to this location you may not have an access to it tap there could a lot of grease a lot of sludge ok. So, there are real issues. So, I would recommend that you know whenever you get a chance try out doing this experiments yourselves, trying to analyze signals and then a become more versatile engineer.

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We do a lot of work for the Indian navy ok. And this is an underwater tank where and we put in hydrophones and so the and of course, the acoustic pinger and then this is the

amplifier for the driving the acoustic pinger or the hydrophones and hydrophones are easily charged type equipment. So, a lot of underwater machinery monitoring we have transducers for underwater vibration measurements for round or water noise measurements because people would like to know the condition of underwater machineries.

So, how do you measure the noise and vibration of them? So, by hydrophone around accelerometers and we have a portable gen sets and I when I go to the field some many a times when we do experiments in the field where we do not have an AC source, sometimes I use this to power our equipment etcetera. Of course, you know I would not recommend an ac source to power or a field equipment because there should be proper AC isolated DC source is much better otherwise you can have the line supply frequency problem as a ground loop in all your measurements.

So, wherever possible try to use DC systems ok, for a measurement for transducers and it is a good practice to switch of your laptop and run it on the battery mode when you are taking signals.

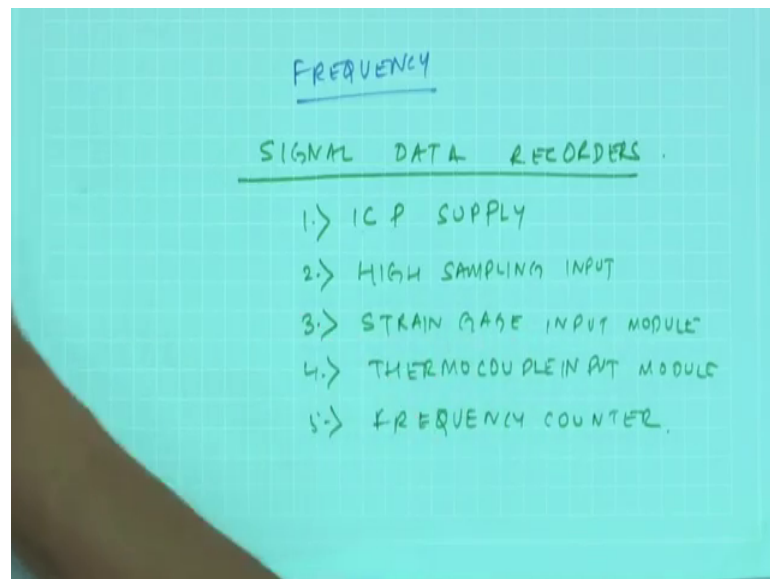
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My students do a lot of signal processing algorithm development with this an industrial PC. The signal analyzer for the laser parameters, this is an amplifier for the electromagnetic exciter, this is a filter wherein you can have a low pass high pass or a bandpass setting.

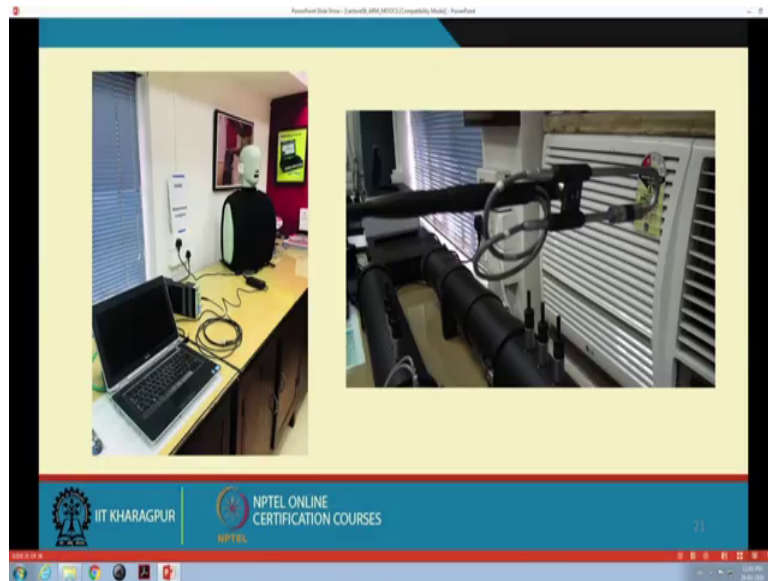
This is another amplifier for a sound source this is an oscilloscope this is a dual channel arbitrary waveform generator. So, you can generate your own waveform and generate signals to drive in a signal conditioning we have a power source and then of course, a multimeter a digital counter. So, a lot of these encoders we need to read also to measure the frequency. So, some of these signal data recorders which we have can take a multiple of inputs.

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For example they will give you an ICP supply, they have a high sampling input they have a strain gauge input module they have a thermocouple input module and then they have an frequency counter. So, you can have all of these as plug in models to this signal data acquisition systems.

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And this is the view of the torso and this is a sound intensity probe and you can see the material testing tube here ok.

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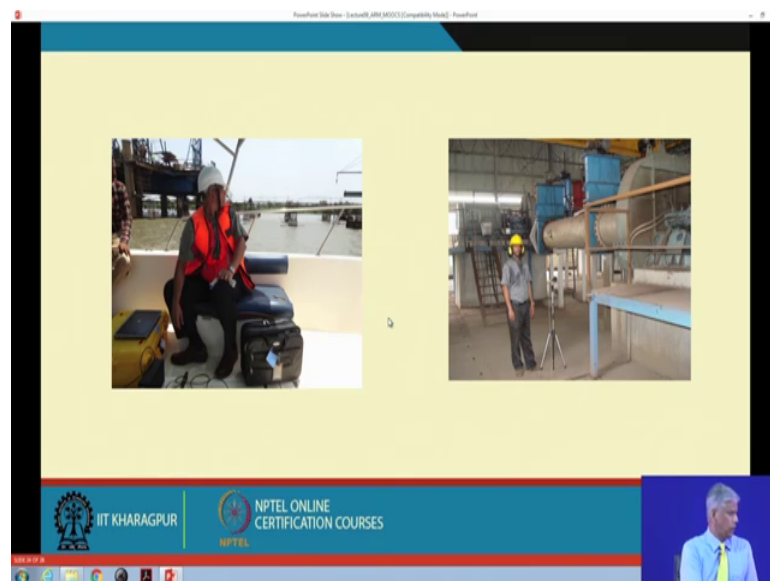
We of course, have the ultrasonic only phase know the phase area system to here we created a plate with artificial weld effect. So, an ultrasonic scanning is being done.

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This is the slip table for the electromagnetic shaker.

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Of course as I was telling you I do lot of external noise and virus monitoring this is somewhere in the Bombay high, where we are measuring an underwater piling noise and you can see my favorite yellow suitcase and this is you know in a plant which we are measuring the blower noise.

So, CPM is very interesting and wonderful experience you get to do signal processing on your own you understand the theory you become field doctors ok, you go to the field

pick up data troubleshoot do a failure analysis you need some extra money as well ok, so that keeps you going.

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Of course, you know I must introduce you to our research group. We have postdocs PhD scholars, and M.Tech students, B.Tech students and then the students and I change every year and we have a very vibrant young group who help in different active.

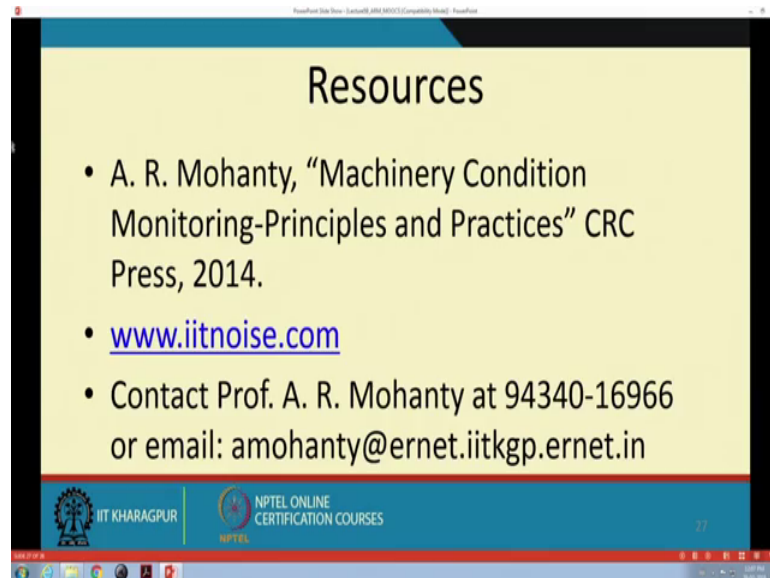
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And of course, I must thank our sponsors over the years who have a sponsored many of our projects through which we are able to buy all this equipment, I do research do

consulting and help them. So, help the industry help the classroom help the students and life is fun ok. Thank you.

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**Resources**

- A. R. Mohanty, "Machinery Condition Monitoring-Principles and Practices" CRC Press, 2014.
- [www.iitnoise.com](http://www.iitnoise.com)
- Contact Prof. A. R. Mohanty at 94340-16966 or email: amohanty@ernet.iitkgp.ernet.in

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Of course details you can see in our website and of course, you can get all of my book to learn the rest of the story.

Thank you.