Machinery Fault Diagnosis and Signal Processing
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Lecture - 28
Errors in Measurements

Yeah, well, this week, we will continue our discussions on measurements and in this lecture, particularly, I will be talking about errors in measurements well one very fundamental rule in measurements to be good measurements is wrong measurement or data is not a measurement or data.

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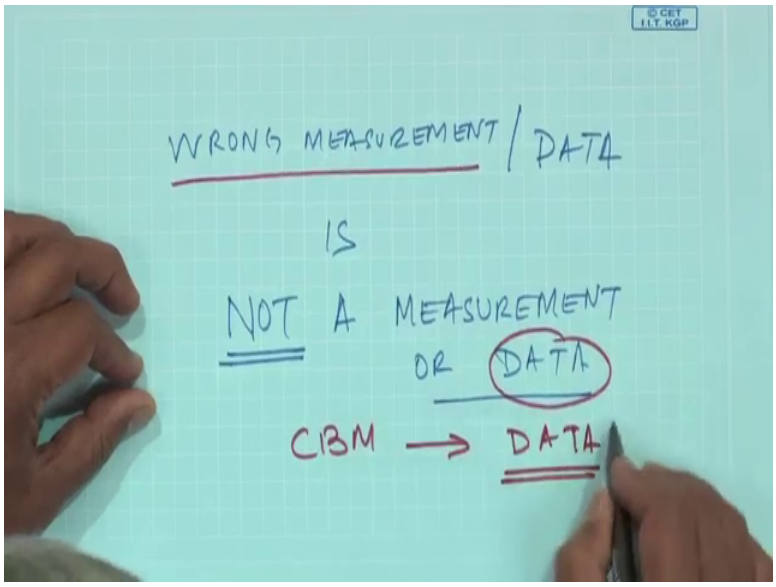

It is very important that you know we need not spend lot of resources on putting up transducers around the machines to collect data with an objective to monitor the condition of the machine, but if the data itself is wrong for reasons known to us because of our ignorance and because as you would know in CBM, all our decision depends on the data and if this data is wrong, my decision on the machines condition would be wrong and that is what one would not do.

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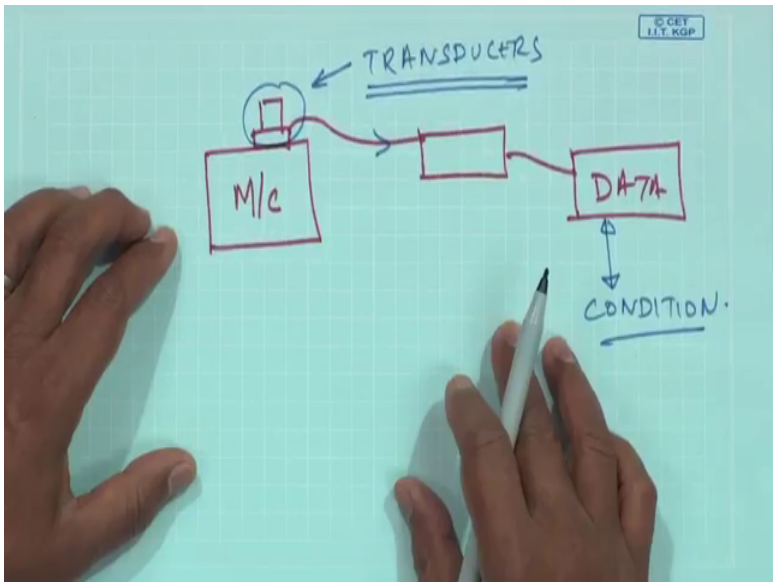

And as you know by now that in CBM, I have a machine on which I put a transducer and I have a signal conditioner and then get some data. So, on analysis of the data, I infer that machines condition. So, when you are talking about transducers we will see that; what is the possible errors while measuring using a transducer and how we can avoid it ok.

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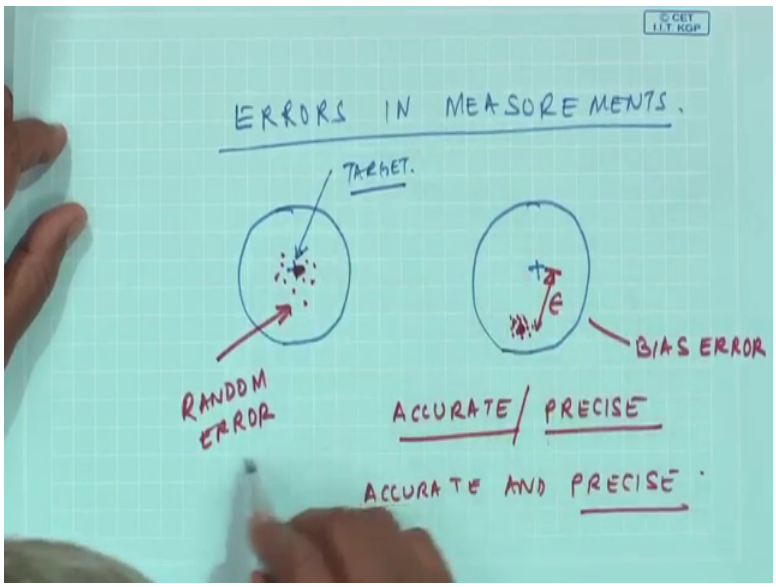

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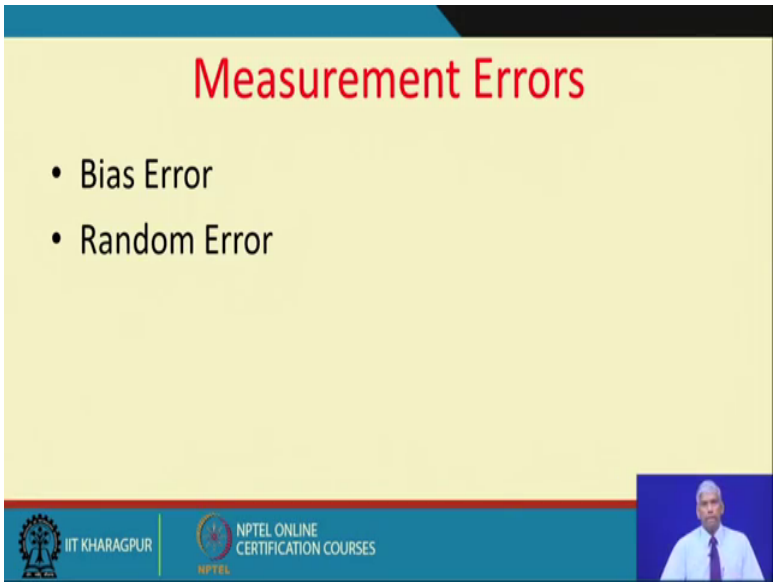

Now, to explain these two important errors in measurements, if I want to classify them one is a bias error and other is an random error. Let me just illustrate; what I mean by a bias error or an random error. Now suppose this center of this circle is my target is my desired data or is my accurate representation of the physical condition of the machine, but while doing a measurement, I am getting things randomly around the target, but not quite equal to the bull side.

In another case, I have data which are very precise and located at one part. So, if you will see here that this could be considered as one large dot offset by an value epsilon and this if you will see, if you average them, this will hit the bull side. So, this kind of an error is the; what is known as the random error and this is known as the bias error. So, I need to be both accurate and precise. So, accuracy and precision; there is a difference in the sense, how accurate I am to the target is this explanation and how precise I am by an I am only offset by an quantity epsilon.

So, a good transducer will be both accurate and precise; that means, if I repeat the number of measurements I am always going to get the same value. So, this is the precision and accurate means I am always close to the target or at the target.

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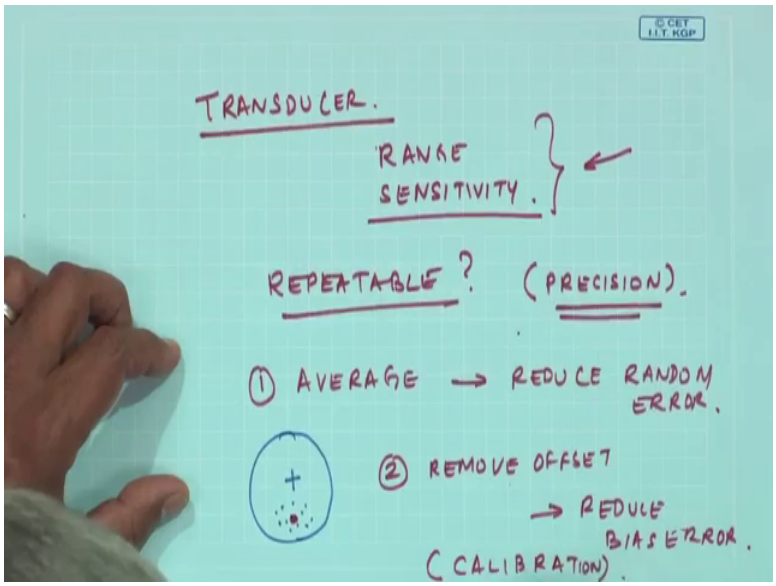

Now, any transducer which we measure; which we buy from the market has some features in it, most important being, it is range sensitivity, we need to know these quantities. So, that the mechanical quantities which we are measuring can be equally or can be represented with an equivalent electrical value or a voltage value.

But question is my measurement repeatable; that means, every time I measure am I able to get the same value or not. So, this should indicate the precision of the instrument and then. So, question is this error which we discussed about random error, how can I reduce random error? Obviously, if I average the measurements averaging, I can reduce random error, if you go back to the diagram here if I average all the measured values here, I would be coming close to my target that is the target value.

So, usually to wherever we see that the measurement is scattered around a point we can always average it for example, mine now my target is here, but I am getting all values around this place. So, even if I average it, I may get a value around here. So, this is both having a bias error and an random error.

So these combinations can happen in the instrumentation or in the measurements and now the next one to bias error can remove the offset remove offset to reduce the bias error and this is actually done by what is known as a calibration, we will talk about calibration just in the little while.

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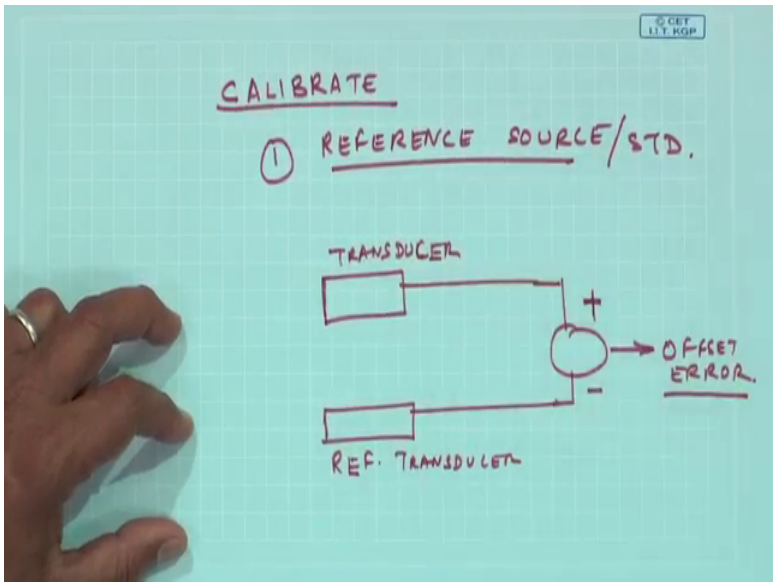

So, by calibration, we can remove the bias error. Now how do I calibrate? So, there are many methods of calibrating one is we have of a reference source or a standard where we will compare the results from the transducer and the reference transducer.

So, we will compare. So, whatever is the difference will be the offset error. So, we can always remove the offset whichever is whether it is positive or negative and then we can remove the offset from the measured values so that we can reduce the bias errors.

But then something regarding this reference source, I will tell you in subsequently, but then.

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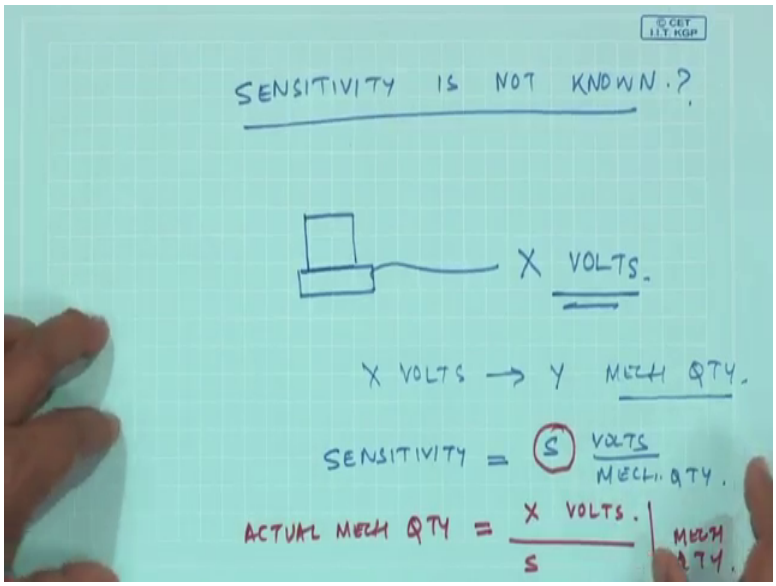

Suppose the sensitivity is not known, how do I do or what do I do? Suppose, I have a transducer, I have put on a machine, I get some X volts. Now this X volts corresponds to some Y mechanical quantity, right. So, unless I know the sensitivity. Sensitivity will be some you know S volts by mechanical quantity.

So, the if I get a actual mechanical quantity will be nothing, but the measured voltage X volts divided by S sensitivity. So, this is the unit some mechanical quantity. So, this sensitivity is something which the transducer manufacturer provides.

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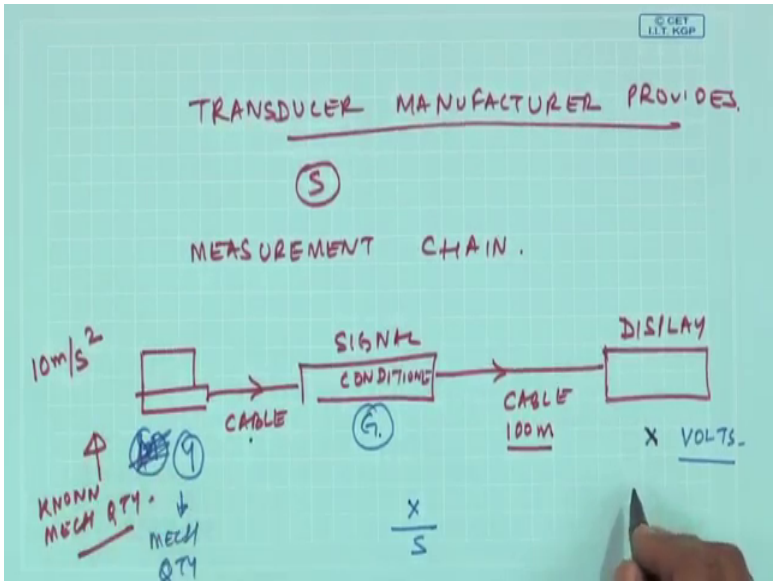

And now question is if I have a measurement chain, wherein I have got a transducer, I have got signal conditioner, I have got some cable and then I have a display. So, this in this cable also, there could be some attenuation. For example, if you are talking about a long cable, now you are measuring the condition of a popular bearing in a large ship where the cable could be about 100 meter long.

So, there could be voltage drop because of the resistance in the cable. So, then we will get some display. So, in this case and then, here I could have given some gain in the amplifier. So, all this factors are not known to me. So, what happens if I measured my actual quantity is some quantity m is the mechanical quantity, I will get some voltage X or we make the previous diagram, if I have the mechanical quantity, I am getting some X volts, if I take the manufacturers sensitivity my actual quantity mechanical quantity is nothing, but X by S.

But I do not know; what is my gain value, what is my drop in the cable. So, usually in such scenario, we always give a known mechanical quantity in the field, particularly while you are measuring vibrations. So, there are calibrators which will give you known mechanical quantity. So, if I get; if I know this is I am giving an actual input of 10 meters per second square, I am getting X volts I know whenever I get Y volts, it will corresponds to 10 by X times Y and so on.

So, this field calibration or field calibration of transducers is important because in such scenario I need not worry about what is the voltage drop in the cable; what is the gain set in the amplifier and so on I have been too many factories where in you know people produce a set of voltage values from a transducer and say and ask me what is wrong in the machine this becomes very difficult for the diagnostic engineer because we do not know what is the actual physical mechanical quantity.

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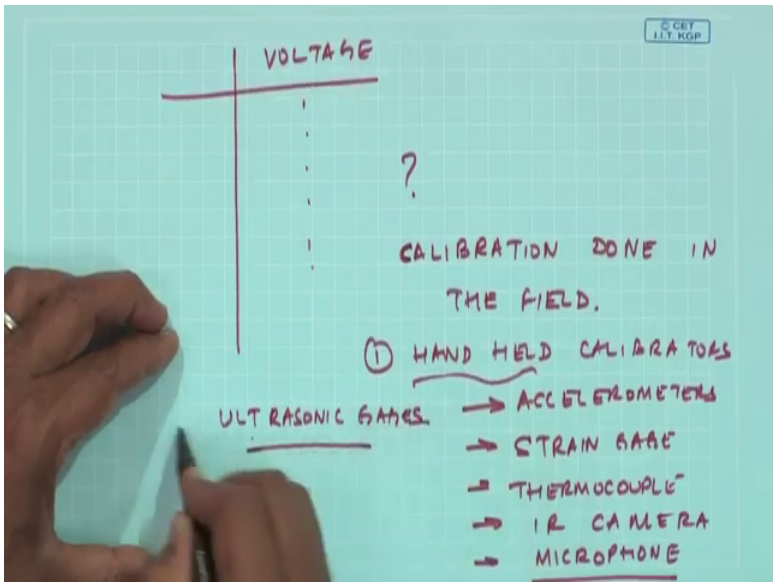

So, always it is good to have a calibration done in the field by there are certain hand held calibrators for accelerometers, even for strain gages, there could be some sand bridge calibrators strain gage, even for I would say hand held or portable caliber for thermocouples we will talk about this later on from I r cameras for microphone.

So, different calibrators are available depending on the type of transducer even for ultrasonic gages, otherwise what happens unless I give a known physical quantity whatever voltage, I get at might display there is no relationship. So, one has to be carrying CBM in the condition monitoring kit such calibrators for that this can be done, but this was regarding the field calibration, but sometimes in the laboratory or in the factory in their tool room, we can have reference standard.

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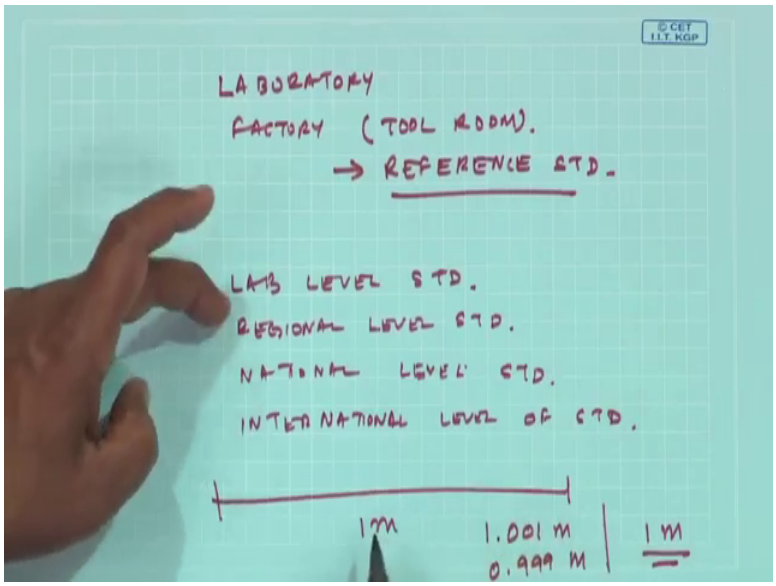

Which need not be used daily, but you know any transducer which goes out of the field can be brought back to the laboratory or to the tool room to check the values against the reference standard kept locally in that place because as you all know.

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There are many national and international standards on measurements and all of these refer. So, because we have a lab level standard, we have a regional level standard, we have a national level standard and of course, the international level standard, I will just give an example somebody says you know such an distance is 1 meter right. How do you

know that this is not 1.001 meter or 0.999 meter, but 1 meter? So, these rulers or meter length sticks, there are international calibration standards, they are checked against the regional standard national standard international standard, I will give you an example.

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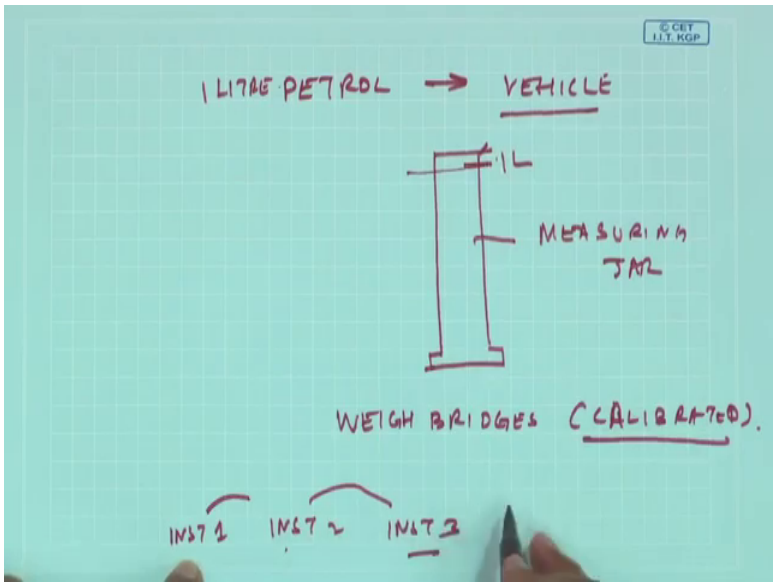

When we fill in petrol say 1 liter petrol in our vehicle and if you have been to a petrol pump, you will see the meter displaying 1 liter and such an such amount, but how do you know it is 1 liter and not 1 point or 0.95 liter, never, it will be more, but it will be say why how do you know it is less. So, if you will see in a nowadays in the petrol filling stations they have measuring jar with a 1 liter mark.

So, when the gas station attendant fills an petrol, it will only to fill up to the standard. So, this jar has been standardized. So, we have the department of weights and measures you know standards and. So, and. So, all the quantities we deal with you know because you know if you are talking about CBM is one aspect, but if you are talking about trade you know when you say so much metric tons of you know coal iron ore crude, how are you sure that it is so much. So, that is why in large scenarios we have you know weigh bridges which are calibrated against whatever they are going to indicate. So, calibration becomes a very very important aspect in having correct measurements being done.

So, when we talk about you know all this standard units of mass length seconds you know and of course, the other six units other three they are all calibrated and there is a reference standard international reference standard stored in the; you know different labs

throughout the world. So, all of us make our standards comparable to those standards. So, everyday it is not possible to check our equipment against that standard.

But if we see all the one instrument is instrument one is checked against instrument two against instrument three. So, one is more accurate than the other and. So, on and then finally, they all will go to the reference standard. So, this unknowingly to the CBM engineer these are all done.

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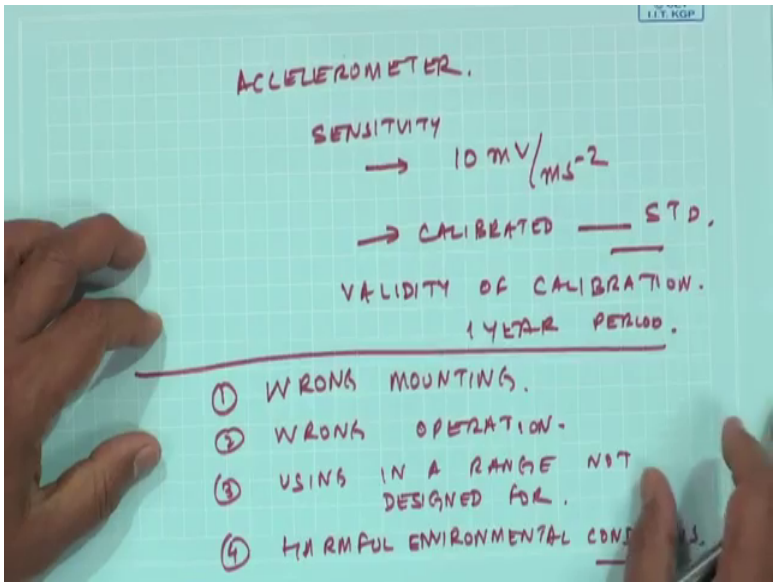

And if you look at the when we will talk about transducers in details later on if you took look at an accelerometer if you buy it, it will come with a sensitivity say may be 10 millivolt per meter per second square and it will say calibrated to such and such standard and it says a validity of the calibration. Calibration usually you know a one year period. So, every measurement which we do in CBM for every transducer with an accelerometer with a microphone with a thermo couple be it in a ultrasonic gage be it in a flow meter all of them are calibrated against some reference standard which is finally, calibrated or is traceable to the international standards.

And as long as we have maintained proper calibration of our transducers we would be doing a correct measurement of course, another reason possible reason why errors can happen is other reasons are these are these are when we talked about random error and bias error, these are errors inherent because of the transducer itself, but as a CBM engineer we can have errors introduced because of wrong mounting wrong operation.

Using in a range not designed for harmful environmental conditions. In fact, you know I will just give you an example with my mechanical watch you know, I was in a factory wherein there is lot of magnetic field.

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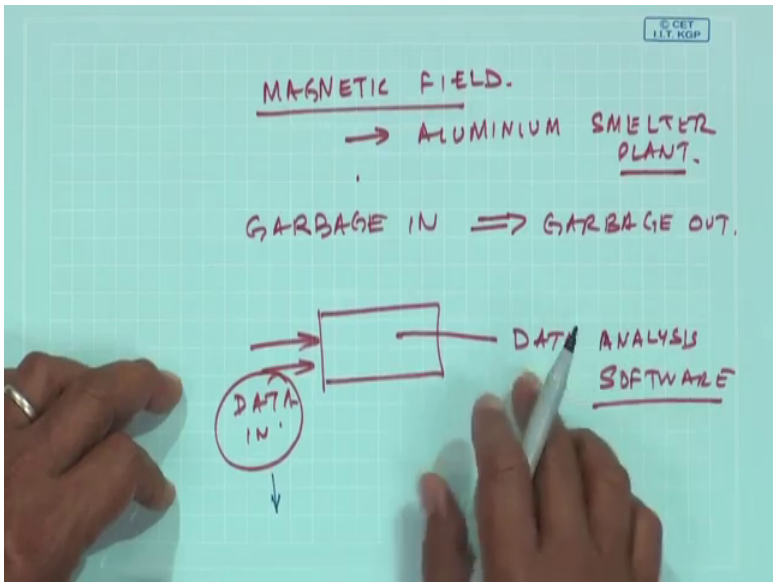

This happened in an aluminum smelter plant because of the electromagnetic process by which this is done the electromagnetic process is a very strong magnetic field. So, the mechanical watch which I wore had an dissipation dissipative force being applied and the watch slowed.

So, this was an environmental condition which could hamper your measurements the clock or the watch which you are measuring will slow down in a strong magnetic field. So, we have to ensure for this scenarios which may happen during measurement and which can give us wrong result.

So, the watch would never show you will show you a wrong timing. So, this kind of scenarios do happen. So, one has to be careful about. Now we will talk about how the range in which the transducer is not designed for, if you use it, what kind of errors will come in the subsequent class, but then this is very important to keep in mind that wrong measurements is no measurements do not measure wrongly if you want to interpret anything out of the machine.

So, as they call garbage in is garbage out because if you look at the software available today or data analysis they will work on the data a data in and they will not of course, nowadays know smart analytics have come up wherein, they can tell you whether the data itself is having some wrong trends or outliers which could be removed, but everything depends on my data.

So, if the data is wrong then our analysis would be wrong. So, to summarize, to reduce the random error, we need to average the measurements and to remove the bias error we can have a calibration done and the transducers every transducers which is used for the CBM has to have been calibrated to a reference standard and so on. So, more on this you can find in my book.

Thank you.