Principles of Mechanical Measurements

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Lecture No. # 04

We have seen what is threshold. Now we will see why there is threshold at all? Why there should be threshold? For example consider a piston and a similar type pressure gauge. We have got a piston and cylinder and piston rod, pointer and the scale, this is instrument and why there is the threshold for this instrument? If you analyze you can easily find that there should be some increment in the pressure P say P_i there should be some increment say I will draw it little better piston nearer the cylinder. To make the piston move within the cylinder, the piston has to overcome the friction force say whenever there is a relative motion between two bodies there is friction between any two relatively moving bodies.

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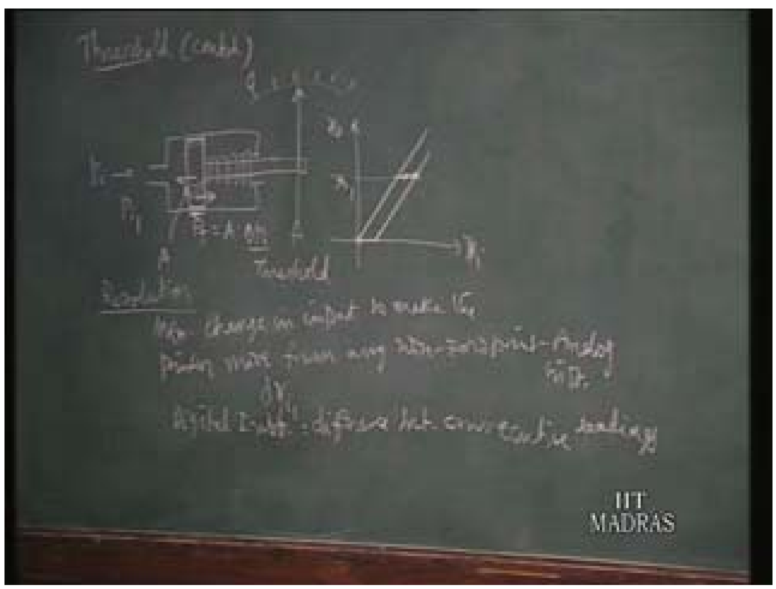

Now the piston has to move within the cylinder with reference to the cylinder. So if you want to make the piston move, the piston has to overcome the friction force between the piston and the cylinder body. So suppose F_f is the friction force then until the F_f is equal to the area A, A into delta p_i. Until this happens, delta P_i is there that is an increment in P_i is there which when multiplied by area is equal to friction force. Until this movement there will not be any motion for the piston. The moment the pressure increase, higher than delta P_i then the friction is over come and the force is acting in this direction and that force compresses the spring and the piston moves as a whole. So there is a need for increase in delta P_i, but in zero to delta P_i there is no movement of the piston hence no movement of the pointer.

So to make the pointer move from zero we have to increase the pressure from zero to delta P_i so we call it this delta p_i as threshold value. So this is a reason why threshold exist in all instruments. Similar reasons are there for other type of instruments, that is threshold. Now the next concept is resolution. This is threshold what we have continued and now it's resolution.

Now the definition for resolution is the minimum requirement in input signal that is minimum requirement or I will call it minimum change in input signal to make the pointer move from any nonzero point that is definition. That is suppose an instrument is functioning somewhere in say P_i and say P_i or okay, I will call it x_i and x_o. Suppose this is the ideal relation and now threshold. Due to threshold that the increment is there only after some delta x_i so somewhere here. Suppose this is the operating point, at certain time this is your x_{o1} and this is a nonzero point, zero is here this is a nonzero point. From any nonzero point to make the pointer move we have to increase input by say another delta x_i and suppose it has to reduce then will you find it comes here.

That is in case of the same instrument, when the pressure drops from certain P_{i1} and to make the piston move further I mean backwards, again the friction for this to move in this direction. So friction will be acting in opposite direction, always piston acts opposite to the motion. So friction will be acting in this direction, to overcome this we find there should be some drop and pressure P_i then only the spring will push it backward. So that much delta x_i is required so delta x_i say 1, we will call it delta x_{i1} that is minimum change in input signal that is delta x_1 to make the pointer move from any nonzero point either from a particular operating point below the point or above the point, there should be some minimum change in input signal. So that the pointer moves from the indicator position from any nonzero position.

So to say you find there is some relation between the threshold and the resolution. What is threshold? Threshold is a minimum change to make the pointer move from zero point whereas resolution is the change required to make the pointer move from any nonzero point that means a commonality is resolution and threshold indicates minimum change input signal, one is from zero point another is from nonzero point. So we can define one concept by another one. That is what is the change required to make the pointer move from any, I mean threshold value any nonzero point is resolution and resolution at zero point is threshold that is using one concept we would define the another concept. Threshold at any nonzero point is resolution and resolution at zero point is our threshold and in digital instruments you will find resolution is the, this is for the analog instrument whereas for digital instrument difference between consecutive readings that is a resolution for the digital instruments.

For example in a digital pressure gauge reading is shifting from 1.1, 1.2, 1.3 and so on. So need to consecutive reading is 0.1 bar, so resolution is 0.1 bar. That means in digital instrument resolution and least count both are same; in digital instruments that is the property. The resolution and least count both same are in digital instruments.

So next concept is precision and accuracy. These two terms are very important in the subject of measurement. Ordinary mechanical engineer or ordinary engineer may not make the difference between these two terms in measurements, they represent I mean, two different quantities in measurements. Though they look alike but they represent two different things. To understand these two terms properly we will take an example before that what the two terms indicate?

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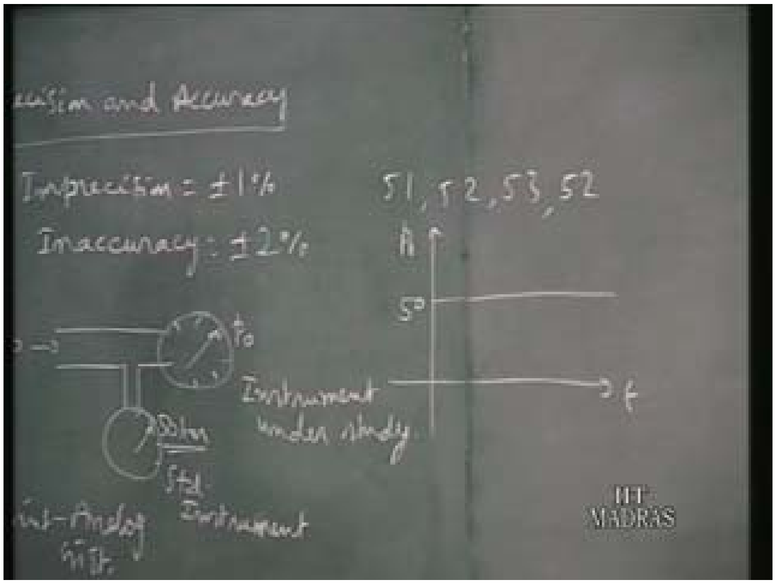

When we say precision of an instrument is plus or minus 1%, actually it's not the precision of 1%. Actually it is imprecision of an instrument is equal to plus or minus 1%. To indicate impression we normally say precision is one plus or 1%, this is a colloquial way of expressing things it's accepted. Similarly when I say accuracy is plus or minus 2% it is not accuracy plus or minus 2%, it is inaccuracy of an instrument is equal to plus or minus 2%. So by using the positive term we indicate the negative things. When I say an instrument has an accuracy of plus or minus 2%, actually we mean the inaccuracy is plus or minus 2%. For an inaccuracy 2%, accuracy should be 98% but we don't say like that. We simply say accuracy is plus minus 2% to indicate inaccuracy is plus or minus 2%.

Now to understand these two terms impression and inaccuracy let us take an example. There is an instrument again we will have the same instrument pressure gauge, it's a very handy to explain many concepts. We are conducting an experiment or a process so to say calibration process in which say I got this pressure source and this I connect it to a standard instrument, call it a standard instrument where I can get the correct reading, standard instrument. Simultaneously it is connected to the instrument under calibration, this is instrument under study and say for example now we have got some 50 bar, as the instrument shows a 50 bar in the standard instrument and we are taking readings in this instrument under study.

So morning and say 10 o'clock, 12 o'clock and 2 o'clock 4, 5 say different timings we take and we keep always the pressure here always 50 bar and what are the reading shown by these instruments, that we are interested. So for example readings are like that 51 bar, 52 bar, 53 bar so 52 like that. The instrument is showing a different timing, these are the readings. So if I plot it may look like this, so this is time at different time and this is our say P_o output of the instrument under study and our standard constant input is 50 bar. This is 50 bar kept constant but the instrument is showing a different times and different readings. So 51, so 52 and 53 and another type 52.

So the readings are spread over in course of a day. Now for this instrument, once you have taken such readings by using the instrument, we have easily compute or find out what is imprecision of the instrument, what is the inaccuracy of instrument for that this experiment is conducted. What is the imprecision or precision? Precision is the capability of the instrument, precision indicates so to say indicates the capability of the instrument to reproduce a reading. This is the definition for precision which indicates the capability of the instrument to reproduce a reading.

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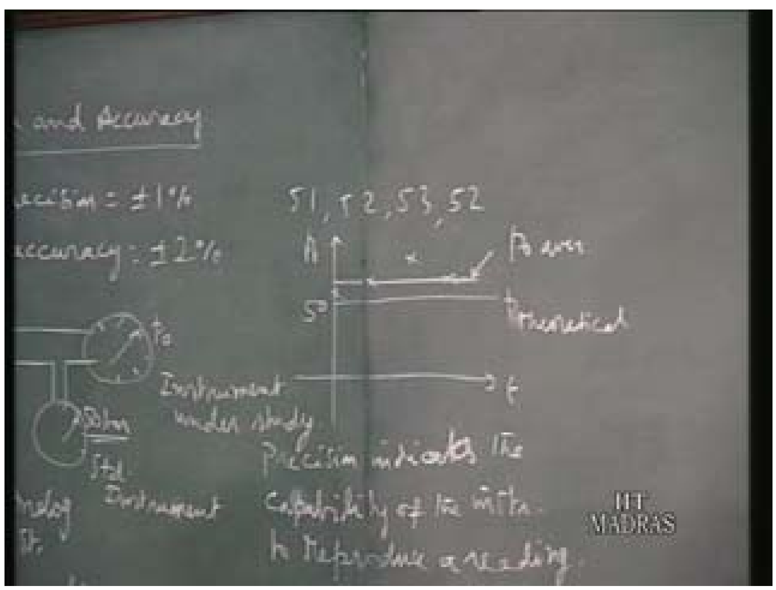

What is reading to reproduce? If suppose reproduce 50 or it's reproduce some say it has shown 51, 52, 53, 54. So different times, two times 52, other times it shows different readings. So to say the precision indicates the scattering of the readings, even though input remains constant, how the readings are scattered? So it's scattering to understand this scattering around which point? So we have to find out the average, 52 is average. This is theoretical so I will say P theoretical, this is theoretical value, p theoretical and this is P_o average. That is our average is 52 because having 52 constant and one less, one time more. So the 52 is the average so scattering of the or I will say the imprecision is given by the equation x measured minus x average divided by x average into 100.

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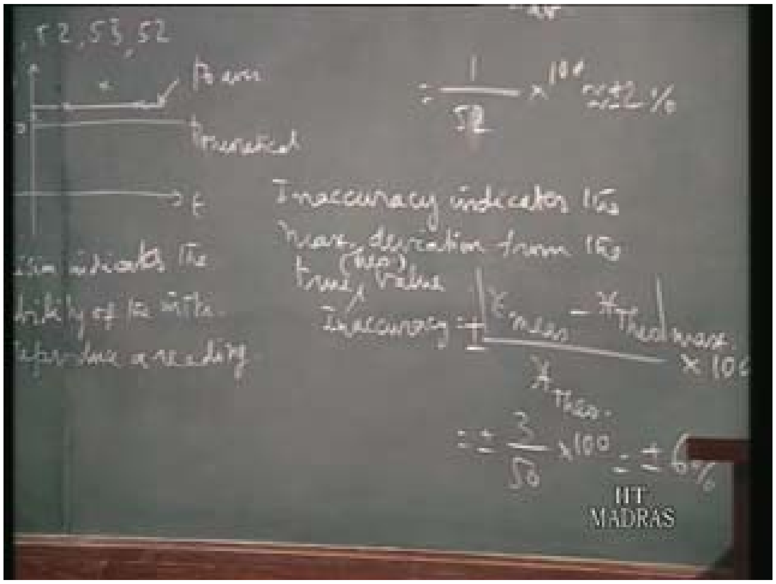

Now it is a set of reading, we have got 4 readings which you have taken. In this reading the maximum deviation we have to find out that is the maximum deviation, magnitude of the maximum deviation x measured minus x average divided x average. If it is single reading then x average doesn't exist at all, if it is so here for a group of readings only it is valid. So we find the maximum deviation from either positive side or higher side or lower side. It does not matter that's why we have put the magnitude of the deviation. So here in this instrument x average 52, the x measured maximum deviation is say 1 bar. So the whole thing comes in as 1 bar, one is the maximum deviation by 50. Now the average is 52 and it is 100, so 100%. So this is equal to approximately 2% approximately 2% and it is customary habit or it is customary in the field of measurements put always plus or minus.

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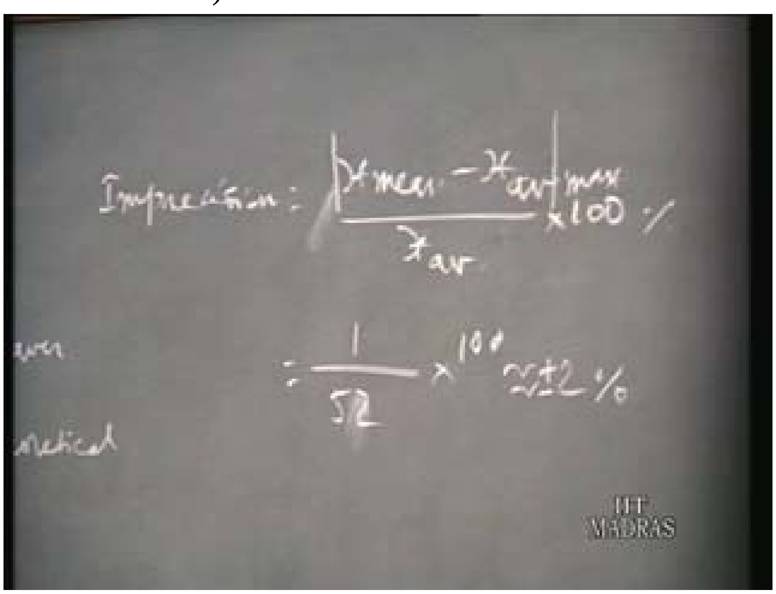

Sometimes the deviation is positive side, sometimes negative side and take the maximum whichever is there and put that limit on both side so to say we are supposed to put plus or minus, after computing put add, it may be positive but it may happens so in some other time it may also happen in the negative side. So always you put minus also, plus or minus. This is the way we are supposed to write the imprecision. So for this instrument, for this behavior imprecision is plus or minus 2%. Now what is the inaccuracy of the instrument? For this the definition says inaccuracy indicates the maximum deviation from the true value.

Now note the difference between the definitions for imprecision and inaccuracy. Imprecision is the deviation from the average value whereas inaccuracy states the deviation from the theoretical value or true value. So the true means theoretical value. So that is the main difference, the inaccuracy always refers to the true value and the imprecision refers to the average value of a set of readings. Now here what is inaccuracy is equal to in terms of equation? Inaccuracy is equal to x measured, x measured here P_o, P_o on the x measured quantities, x measured minus x theoretical or true whatever it is. That is maximum in a set of reading, maximum value.

Maximum deviation from theoretical in a set of reading divided by x theoretical in to 100 in terms of percent we always put as we order for imprecision plus or minus. So for this instrument the maximum deviation x measured minus x theoretical will be. So 53 is the maximum reading because 50 is theoretical value and 53 is the maximum. So deviation is 3, the maximum deviation is the maximum difference is 3. So plus or minus 3 divided by x theoretical 50 because that reading is obtained from the standard instrument, 50 is always the theoretical value, it is maintained constant. So it is theoretical value into 100 so this is equal to plus or minus 5%. Now you note the difference, for the same instrument we have got 2 different quantities from this experiment.

The instrument has got an imprecision of 2% and the instrument has got inaccuracy of plus or minus 6%. Now that's how this example makes very clear that imprecision or inaccuracy are not same they are two different things. Now having seen the difference between the imprecision and inaccuracy we will see how the difference is coming between the inaccuracy and imprecision. Now for imprecision the source is elements within the instrument. What does it mean? The main source for imprecision is the available errors in the elements within the instrument. We know an instrument is made of many units, basic functional units like transducer, transformer and so on. When they were manufactured with certain errors they will contribute towards imprecision and what is source of inaccuracy?

Inaccuracy is obtained from elements within the instruments plus atmospheric conditions and nearby power line mounting conditions and so on etc. So the source for inaccuracy is not only elements within the instrument but also the other conditions outside the instruments give raise to inaccuracy. Now for inaccuracy source are more and imprecision only elements within this, that's why we got 2% smaller value. For imprecision and inaccuracy we have got 6% that is always larger. You will find in an instrument inaccuracy is larger than imprecision but by the process of calibration so called static calibration, if we reduce the error source from other sources then what will remain?

Only elements, the error due to elements within the instrument because we cannot change the elements within the instruments. Once the instrument is manufactured later on changing the elements within is not possible. So by process of static calibration what we normally achieve is the higher value of inaccuracy is brought down to the value of imprecision and reducing below impression is not possible. That is it is decided by the elements we have selected at the time of design and manufacture. So this is the sources and sometime you will find inaccuracy is given in terms of theoretical, what you have got it but another definition for inaccuracy is say inaccuracy is equal to, in terms of full scale reading. Inaccuracy is equal to x measured minus x theoretical.

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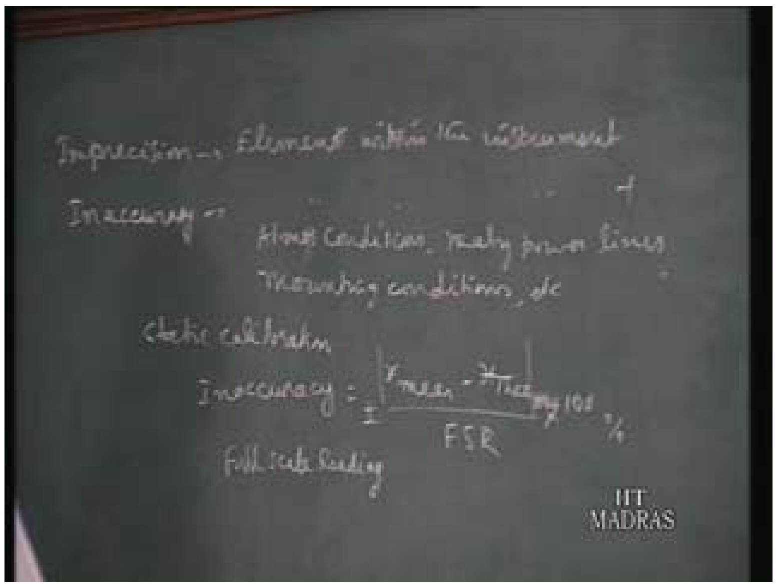

Note the difference is x measured minus x theoretical not x theoretical minus x measured, it is not used for definition inaccuracy, divided by instead of x theoretical we say full scale reading. It is called full scale reading. This also in practice by full scale reading, always the error is referred to full scale reading into 100%, always put plus or minus. This is another definition for inaccuracy was it is referred to not to theoretical value of that particular reading but it is the full scale reading. Inaccuracy it is there for one reading or a group of reading. If it is a group of reading it represents the maximum difference. If it is a single reading, the single reading measured value minus theoretical value divided by the full scale reading into 100. So this will be the error for that reading. So this is all about impression and inaccuracy.

Next is nonlinearity, so to say I will call it linearity. Actually it is called linearity, as we have seen for accuracy and the imprecision the negative term, the accuracy represents inaccuracy and the precision represents imprecision. Similarly here the linearity actually represents nonlinearity, when we say linearity is equal to plus or minus 3% it means nonlinearity of the instrument is 3%, not linearity.

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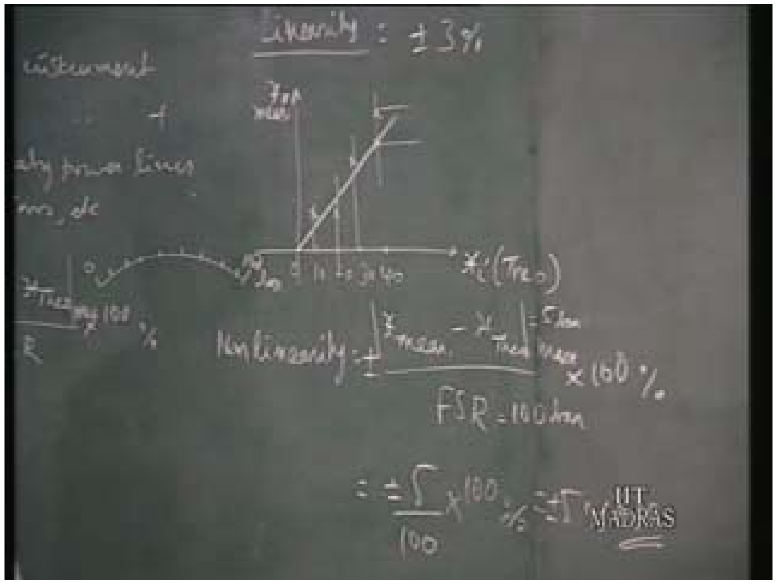

So same way here also colloquially we are using the word linearity to indicate nonlinearity. To understand nonlinearity we have to do a different type of experiment, probably you can assume the same set, where pressure is given to two instruments. One is standard instrument or where we read the actual value, the other one is the instrument under study, such a setup but instead of keeping the input signal same as 50 bar, here what we are going to do, we will change the input signal or pressure from zero onwards. This is the little change in the experiment to understand the phenomenon or concept of the linearity.

The instrument is supposed to be linear, this is the characteristic of the say x_i and x_o and x_i or pressure is varied from zero to maximum value, it can vary. This is the way we are going to conduct the experiment. So at different input level we get readings, so actually this x_o is our indicated reading or measured. This is measured value, x_i is our theoretical one. This is theoretical which is shown by our standard instrument and x_o is measured that is shown by our instrument under study. When we have this say it may be 0 bar, this may be 10 bar, 20 bar, 30 bar, 40 bar it may be like this and 10 bar then reading lies somewhere here, 20 bar reading lies here, 30 bar reading lies there so 40 bar may be lying there.

Suppose readings of the instrument that are residing varies like that then you will find what is maximum deviation for the different inputs and here you will find the last reading has got maximum deviation from the theoretical value. This is supposed to indicate this point but it is say instead of 40 it shows some say 45 something like that. The points are lying not on the line linear that is line means the linear characteristics of the instrument; they are away from the linear characteristics. The nonlinearity represents deviation from the linear characteristic of the instrument and that is for an instrument where is the maximum nonlinearity. So here you will find nonlinearity is equal to maximum there, so we will say the definition is nonlinearity is equal to x measured minus x theoretical.

Actually this is theoretical value should be here, x theoretical divided by full scale reading. Nonlinearity always referred, you will find full scale reading plus or minus. This is maximum deviation into 100%. That is how it is defined nonlinearity. Now here it is this maximum deviation is here, this divided by full scale reading into 100. Suppose full scale reading itself may be 100, full scale reading may be is equal to 100 bar and this maximum deviation may be is equal to 5 bar. So here in this case particular instrument nonlinearity is equal to plus or minus 5 bar.

So here it may be 2 here also 2 here, 1 bar whatever it is. So 5 bar is maximum deviation divided by full scale of the instrument, the instrument scale is here, so 0 bar this is 100 bar. So this is the maximum full scale reading of the instrument 100 bar that is what you are supposed to put into 100 that is a percentage plus or minus. So it is equal to plus or minus 5%, you have to write whenever you are using the full scale reading for the definition always write plus or minus 5% full scale reading. If you don't write that full scale FSR then it means plus or minus 5% of the reading itself, x theoretical value. Otherwise when use FSR as the basis, write here on the specification plus or minus 5% FSR.

That's why you will find many instruments when the manufactures supplies the catalog, he writes nonlinearity is equal to plus or minus 5% FSR, always you have to add the word FSR. We have to be careful whenever the nonlinearity is given in terms FSR, we have to get before that we will see there is some commonality, similarity between the readings between the definitions of inaccuracy and nonlinearity. What is inaccuracy? The x measured minus x theoretical, here also x measured minus theoretical both are same. Both of them indicate the maximum deviation of the measured value from theoretical value. So you will find for an instrument when nonlinearity is given inaccuracy will not be given, when inaccuracy is given nonlinearity will not be given. Any one of them will be indicated. Why it is like that? For linear instruments most of the monitoring type of instruments exhibiting the value, they are monitoring type of instruments nonlinear. They will be linear in characteristics.

The scale will be informally distributed, distance between two consecutive readings will be same that is linear scale and there are instruments for example play ball and speed measuring instrument, using play ball principle you find there will be crowded at the near out the full scale value. (Refer Slide Time: 29:52). I mean at the end of the scale it will not be uniform, they are the nonlinear instruments. For nonlinear instruments the inaccuracy is given, for linear instruments nonlinearity is given. That is so these two things are made use of and now when it is given in terms of full scale reading we have to be careful. We are not supposed to use such an instrument where it is given the nonlinearity in terms of full scale reading near about the say zero point of the instrument you are not supposed to use instruments. Why it is like that? Suppose the full scale reading is equal to say 100 bar, in a given pressure gauge full scale reading is 100 bar. For nonlinearity it is given as nonlinearity for that instrument is equal to plus or minus 2% say 2% full scale reading. This is what manufacturer has written. Can I use this instrument to measure a pressure of say 10 bar.

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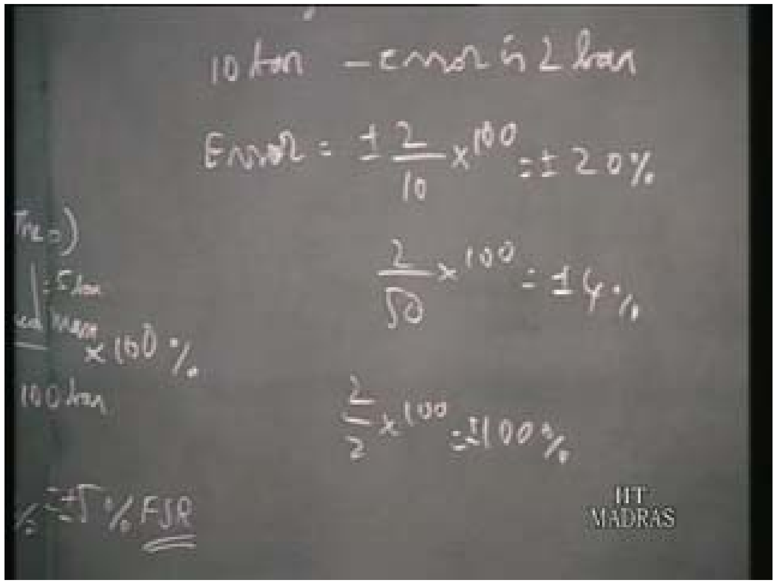

What is the effect, if I use the instrument to measure a 10 bar pressure. The effect is the error in the 10 bar is equal to 2 bar because 2% of full scale reading is 2 bar, full scale reading is 100. So 2 by 100 into 100 so 2 bar will be the error for any reading. Whenever we say error is in terms of full scale reading, the error is constant for any reading within the instrument within the range, within the range of the instrument. It remains constant, 2% of the full scale reading so 2 bar will be the error for any reading. So for 10 bar, inaccuracy we can also call it error in percentage. Error is equal to plus or minus 2 by where 2 bar is the error divided by in terms of relative error. So 10 into100% the error in percentage is equal to this much. So we will find 20% is the error, plus or minus 20%.

If I use the instrument to read a reading of 10 bar, error is already 2 bar so it amounts to 20% error. The 10 bar reading will have an inaccuracy of 20%, such a large error people may not accept. So using that instrument having a 100 bar as maximum reading it’s not correct to use a very low pressure. Then what we should do? We should use such instrument always above the value of half of the full scale reading. So if you use the instrument say 50 and above, so suppose if we use the instrument for 50 bar then what is the error? It becomes 4%, same instrument when we use it for reading a 50 bar then in 50 bar the error is 2 bar. So it becomes plus some 4%. When the input signal is larger and larger actually error of that reading is small and smaller and when we use it for reading 100 bar then it becomes 2% only.

So it reduces like that, suppose we are using to make a reading for 2 bar, when the pressure is 2 bar and we use this instrument to read the 2 bar then error is 2 by 2 into 100. So is equal to 100% error, it means if I use this 2% now a full scale reading instrument to read pressure of 2 bar, the error of that reading is 100% inaccurate. So such way we should not use the instrument, many people do not note this importance.

Whenever the inaccuracy or nonlinearity is given in terms of full scale reading, take care that such an instrument is used to read the pressure or to read the input signal above say half of the full scale of the instrument. Then only the reading of that instrument will be having sufficient accuracy. So this is regarding linearity.

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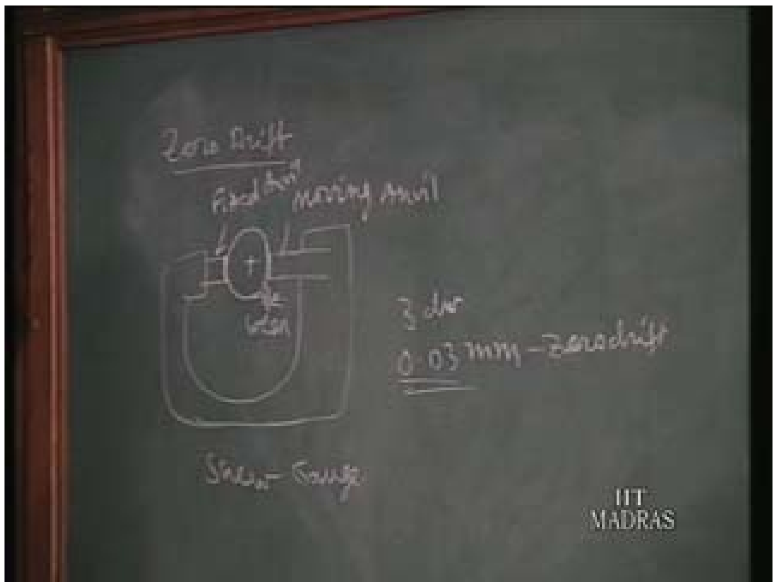

Next concept is zero drift. This means the pointer is shifted from zero and in other words drifted away from zero that's called zero drift. Why it happens during the usage of an instrument for number of years? For example we have seen the screw gauge, we have got fixed anvil and this is the moving anvil and this is an instrument and we are supposed to bring and check whether there is any zero drift in a screw gauge. This is a screw gauge and suppose screw gauge we are using it for number of years and its repeated bringing together you will find there is some wear, wear may take place. Due to wear and tear you find some portion of the anvil it has been worn out. So when you bring it to make it contact with this fixed anvil, this is a moving anvil, this is fixed anvil fixed one. When the move moving anvil is brought to touch this fixed anvil the reading in the instrument should be zero.

This is ideal case but we will find due to wear and tear it rotates some more graduation and then you will find there is zero drift. In the instrument when it is brought to contact, zero is not indicated so it is below zero. So when we use an instrument to read a diameter, to take reading of a diameter of work piece what you are supposed to do? Before bringing the work piece bring this anvil and make it touch the fixed anvil, note down the reading probably it may be 2 or 3 divisions. So 3 divisions represents 0.03 millimeter because one division in such a micrometer is 0.01 mm, so 3 divisions. It is below so that means 0.03 mm you have to add. So you take the reading after putting this piece, whatever the reading add this 0.03mm to get the correct diameter of the piece that is zero drift.

This is actually is your zero drift that taken place this is to be added because it is due to wear and tear. Similarly in some instruments when the input signal is zero, the instrument may be showing some reading and actually input is zero. So what we are supposed to do? Take the reading, add to the reading, later reading or subtract depending upon position of the pointer whether it has come below zero or it is above zero. If it is above zero, when zero input signal the reading is say 2 bar and later on you will find any reading, subtract this 2 bar then you will get the correct reading. So that is called zero drift that is instrument has drifted away from zero position, that is zero drift and that is due to wear and tear and some shift in the elements.

Now next concept is sensitivity drift. We know what is sensitivity. Sensitivity is equal to if it is S, dx_o by dx_i that is our sensitivity, dx_o by dx_i that is our sensitivity is equal to for that piston and cylinder type pressure gauge it is equal to A by C_s into b by a. You have defined what is A C_s b by a and all, remember A represents the area of the piston, C_s is the spring constant of the spring and b by a is the lever ratio of the pointer for that piston and cylinder type pressure gauge.

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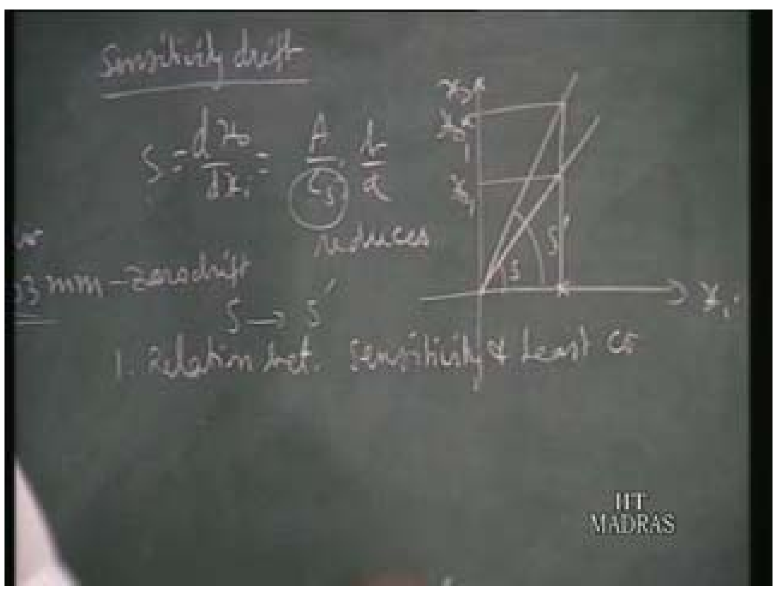

So for that instrument sensitivity, S is equal to A by C_s and b by a and we have seen sensitivity remains constant throughout the working range of the instrument but suppose some adversary changes taken place and it may affect any one of this parameter. Now since sensitivity is dependent on this parameter, when this parameter is changed due to some other reason then sensitivity changes. That is it has drifted from its original value. For example in the same instrument, suppose temperature of the pressure gauge in the working condition, for a temperature of the working atmospheric conditions where the instrument is used as increased from the calibrated condition. So from 30 probably it is gone to 40, due to this higher increase in temperature you find this spring constant reduces.

Spring constant reduces when the operating temperature is higher in atmospheric condition in which the instrument is used, if the temperature increases C_s reduces because the spring material become softer at higher temperature. So when it is softer what will happen and for a given force it will deform more that means for a given pressure since the temperature is higher, since this spring has become softer it is giving more deformation or C_s is affected so sensitivity has drifted from S to S dash. That is what we see in a graph, so this is your say x_i this is your x_o and this is original layer this is your S and now due to temperature change it has drifted to S dash. So now what is the effect of S dash? For given any input instead of a reading being x_{o1} it is being x_o dash or x_o star for example x_{o1} star. So you will find the error will be more and more for higher and higher input values because of sensitive drift.

If the sensitive drift affects the error very much and its magnitude will be depending upon the input value. So lower the input signal smaller will be the error. So this varying error for the input, if there is sensitivity drift it will give raise to varying error in the instrument functioning. We should avoid it that’s why we are supposed to use the instruments in their controlled conditions in which the manufacturer mentioned use the instruments between plus 20 to plus 40. Beyond the range if we use then the error depends upon the value of the input signal. In this particular case or it may vary at different situations that is our sensitivity drift. So we have seen all the important concepts and there is some interrelation between some of the concepts.

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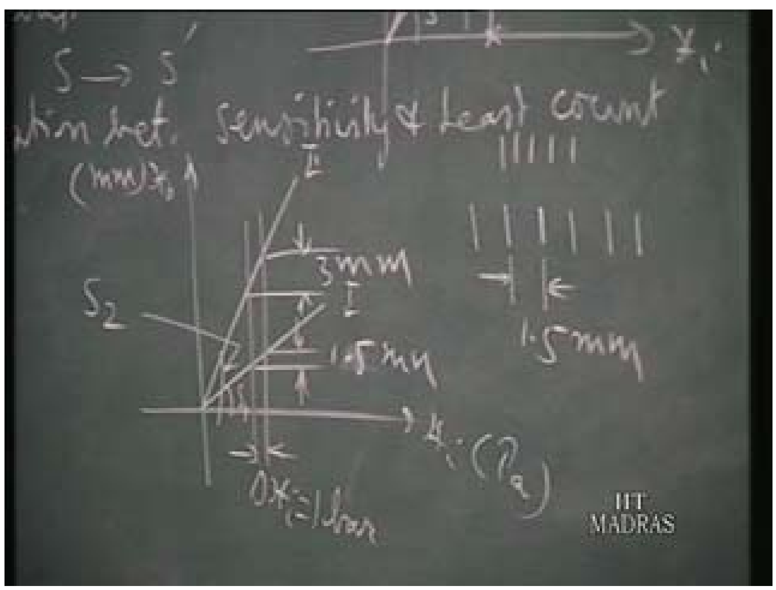

That is first you will take relation between sensitivity and least count. We know individually what is sensitivity, what is the least count but what is the relation between these two things? To understand that let us see these two instruments. One instrument is like this, another instrument is like that so it is our x_i x_o the 2 instrument, instrument 1 and instrument 2. Now one instrument has got, this is S_1 and this is your $S_{2.}$

So sensitivity for second instrument is naturally larger than sensitivity for the first instrument and in this case suppose I give a small change in x_i say delta x_i is the change in the input signal. Simultaneously I am giving input signal for both the instruments and I note down the reaction of the instruments. Now this instrument represents an output of say 1 mm or say 1.5 mm, say 1.5 mm, this x_i output is, this is pressure pascal and output signal is in terms of millimeter. So for first instrument, for a delta x_i may be 1 bar. For 1 bar change the first instrument gives a displacement of the pointer in its scale to an extent of 1.5mm. Second instrument deflects a distance of say 3 mm.

Now there is standard in international practice, the distance between two graduations should not be less than 1.5 mm. So it can be 1.5 mm or more. In a scale the distance between two consecutive graduations should not be less 1.5 mm, that will make the person who takes reading in this scale, his eyes will be less strained the distance of 1.5 or more. If it is smaller you probably can make reading but if you take repeated reading your eye will start aching after sometime. To avoid this all countries are agreed the distance between two graduation in the scale should not be less than 1.5 mm. So in this case what happens since for 1 bar it has given 3 mm, I can have two graduations of 1.5 mm. So least count here it can be 0.5, for 1 bar it has moved 3 mm and it can be divided into two, so 0.5 bar is the least count.

Least count for a second instrument, it can be 0.5 bar because for 0.5 bar itself I have got 1.5 mm less than that means the graduation distance would reduce I cannot do. That means higher the sensitivity lower can be or finer can be the least count. That is the relationship between sensitivity and least count, for higher sensitive instruments we can have finer least count. If the sensitivity is smaller then we cannot have a finer least count because there is an understanding, the distance between the two graduations should not be less than 1.5 mm. The second relationship is the inaccuracy and the least counts.

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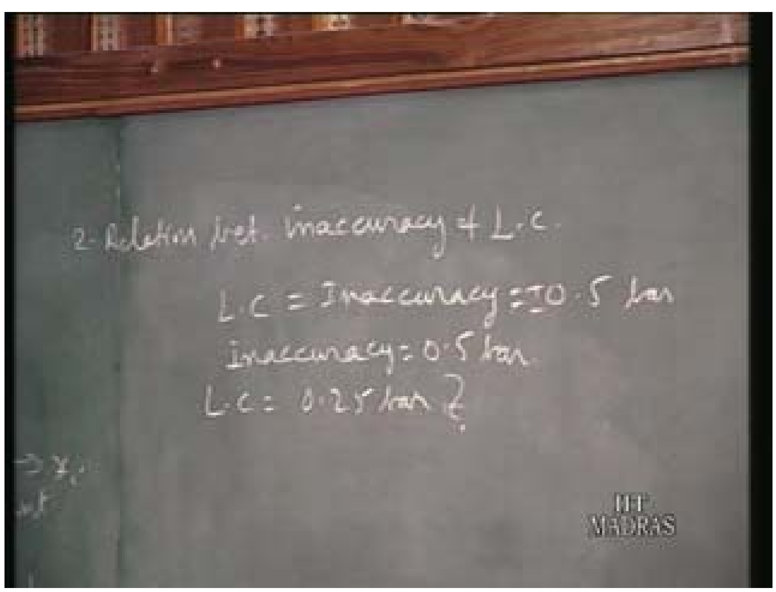

The relation between inaccuracy and least count. What is the relation between inaccuracy and least count? Now the manufacturer is supposed to give us the pamphlet for any instrument we purchase and in course of number of years, we have misplaced the pamphlet. What we should do? We don't have pamphlet where we can refer what is the inaccuracy or in nonlinearity of the instrument we don't have. That book has been lost, in such instances what is recommended is see the least count of the instrument is equal to the make it inaccuracy. That is how the instruments are designed. The least count is made, if we find the sources of inaccuracy, add all the inaccuracies and you will get the certain amount of inaccuracy, say probably here I have got 0.5 bar as a inaccuracy for that particular pressure gauge. Then make that maximum inaccuracy itself as least count. This is the principle normally adopted by all manufactures throughout the world.

So in case you lost the pamphlet don't bother, find out what is the least count of the instrument, make that least count itself as inaccuracy. So for this instrument with a least count of 0.5 bar, inaccuracy also is equal to plus or minus 0.5 bar. This is the norms which we have to adopt in designing of instruments. Suppose inaccuracy is 0.5 bar which the designer has found out, can he have a smaller least count say 0.25 bar. That is inaccuracy is equal to 0.5 bar but least count is equal to 2.0. Is it permitted? Is it all right? Can we have like that? It's not permitted because when the inaccuracy or error is say 0.5 bar, dividing error reading within the error is not permitted doesn't give, there is no no sense if you read below the inaccuracy.

Even though we can have finer and finer least count, simple way of achieving finer least count is increase the pointer length to any length you require and you can have very fine least count but that is not permitted because inaccuracy is much larger. If you can have a larger, finer least count, though it is possible it is not permitted. Hence you cannot increase the length of the pointer alone as you like because inaccuracy is larger after certain increase of the length. So that is a limit for increasing or making the finer least count that puts your limit. Inaccuracy within the instrument puts a limit for the least count. I think with this we can close today.