Six Sigma

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Module No. # 01
Lecture No. # 23
Control Charts by Excel

Good afternoon, we continue with our series of lectures on Control Charts, we looked at the x bar chart and the r chart, these are the charts are they utilized for variables control. When the quality characteristic can be measured on a scale and it is a variable quantity, you would like to have accuracy and precision in place and therefore, you would like to utilize the x bar chart and the r chart.

Now, there are obviously, other quality characteristics, for example, the goodness of, the fit of the cap and the body as an example and I never allow the things for example this bottle of water may be, may not be transparent, may have you know beyond the permitted degree of pesticides or bio material stuff and that which would like to avoid.

So, you would then probably call this product, either acceptable or not acceptable, you do it on a go, no-go basis, you do your quality assurance on a go, no-go bases, how do you monitor, how do you monitor the production of such things, how do you assure quality there? The same thing could apply your service situations also, when we have many instances that cannot be measured, many instances of attributes that cannot be measured, but they are attributes, they are like either good or bad.

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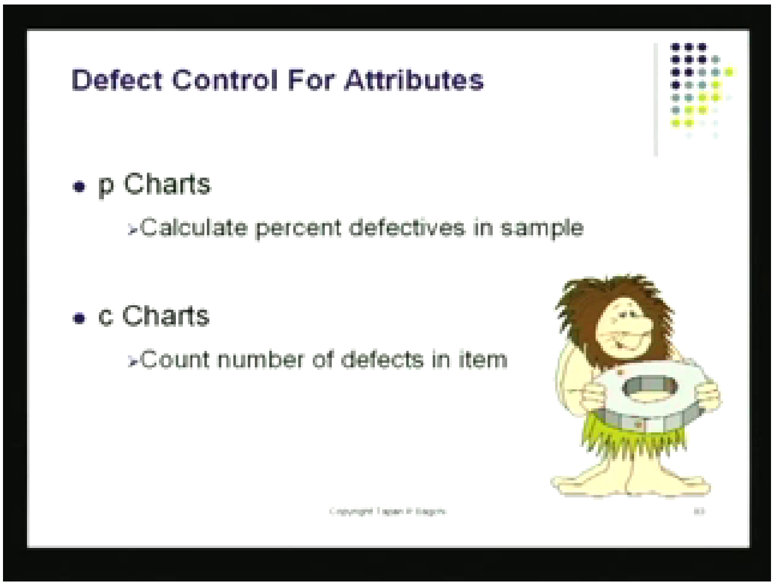

For such thing, there are other charts and I am going to be giving a couple examples, one is the p chart, the p chart calculates percent defectives in a sample. So, if I collect a sample of let us say, a 100 items, how many defective items are there? I can start monitoring just that, I would do that, I will calculate the quantity p which is the fraction defective in that sample and then start producing a chart on that and find out, if that variation is within the acceptable range or is it, has it gone beyond that. I could do the same thing for the number of defective items in the sample.

So, either one I could do fraction defective monitoring or I could do number of defectives so on, both of those could be done on the charts are different, the first is the p chart and the c chart.

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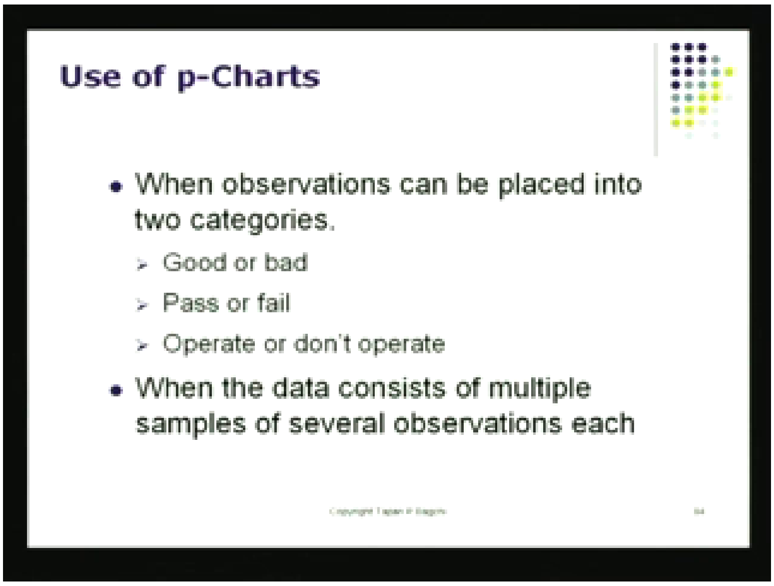

And I will show you the limits for these also. So, in fact what are we talking about, we are talking about quality characteristics that could be measured, not that cannot be measured, but can be just on a good or bad basis, pass or fail basis when data consists of characteristic like this, we would utilize the p chart.

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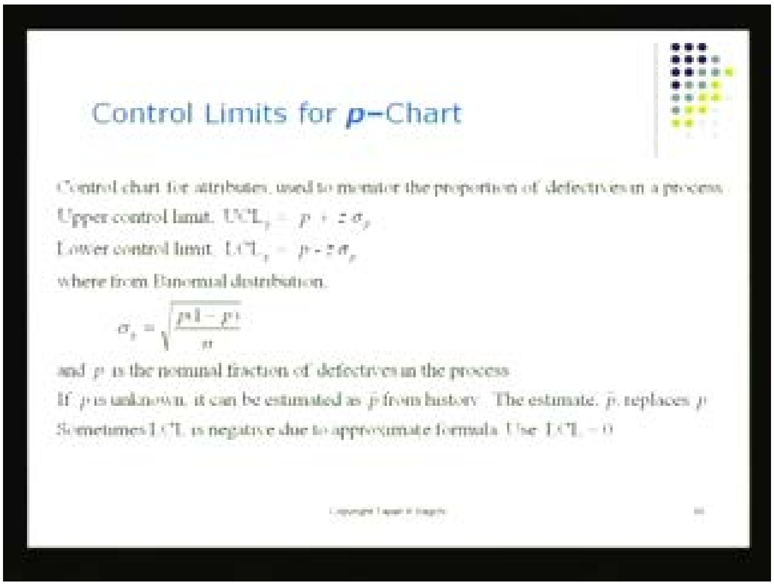

And then, now you are familiar with the control limit calculations and control limits are those you know extreme values that are reached very rarely and one such thing is, for the p chart, for example, the upper control limit is going to be p which is the historical average plus z times sigma p, the z value here is found in such a way that the probability of exceeding this quantity, this upper control limit is going to be very very small, is going to be like gone going beyond the three sigma limit on the x bar chart and the same thing we do on the we do on the lower side also. So, we have got a lower control limit on the p chart and that will be done as p minus z times sigma p, how do I find this z again, this z value is from the standard normal table and it gives you the cut off point, the value of z beyond which only a small tail of the normal distribution lies.

And these of course, have the assumption that the normal distribution is applicable, in this particular case which is like the the distribution of defectives, for example, fraction defectives. It is very easy to to figure out the standard deviation of this and the, because these standard deviation of defectives, that thing is controlled by the binomial distribution, binomial distributions are pretty good model for it. And if that is so, then we can find the sigma as sigma p is equal to p times, square root p times 1 minus p divided by n, this is the sigma limit for p and this same sigma limit I can plug in there, the same sigma value I can plug in there, I can find the exceptional limits on the p chart, I can find the upper control limit on p chart and the lower control limit on p chart; or in some cases, when the load control limit, because there is a negative the value there, it is possible this quantity may turn out to be negative and of course, defects can be negative. So, we make this equal to 0; if this quantity in negative, the convention is make it equal to 0.

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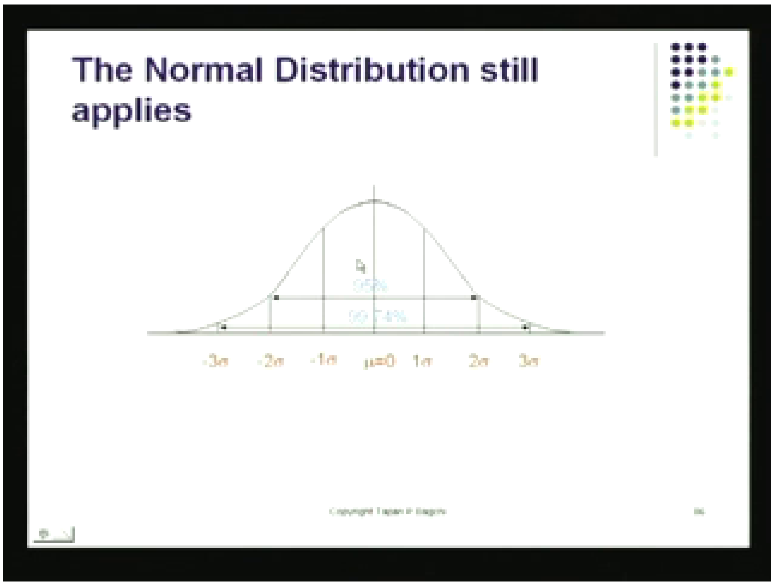

So, in fact we are still using the normal distribution as our, to try to locate the points that are like the extreme situations, when the process is under under normal control, under statistical control and that we do just by again plotting the plotting the chart in such a way that, we got these upper and lower control limits at three sigma p this times, on the high side and also on the low side, around the average.

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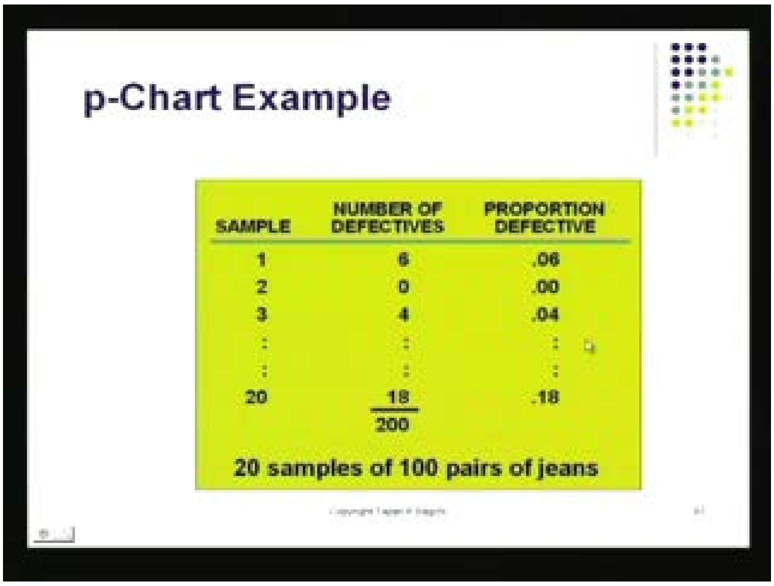

Here is an example, sample number 1, there were 20 samples collected each had 100 pairs and these will, these were jeans, they were inspected, these jeans were produced, they have fabricated and they are inspected to see stitching the effects or button holes not being ride and so on, so forth, or some bluish on the cloth or you know some some seeing not been proper and so on, so forth.

So, they were looked at that and the number of defective jeans in the lots of 100 each they were found and those numbers are shown in the middle column here. So, 6 defectives in the first sample of 100 jeans, none in the second, 4 in the third and so on and there are 18 defective items on the in the 20 th. So, that is like this and proportion defective would then be of course, 6 divided by 100 that is, the size of the lot. So, I have got that thing, there these are my p values, I will have to put control limits on all these.

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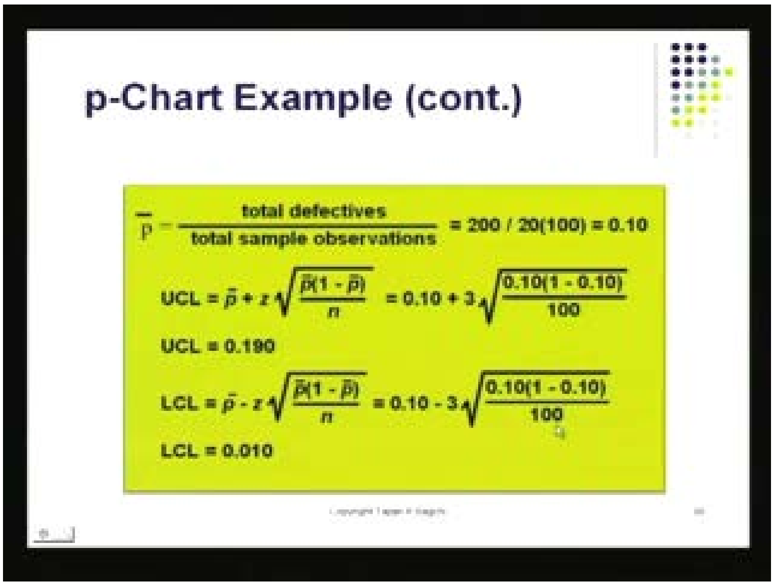

So, for that I just go to the control limit formula and the value of z this time I am going to be taking three sigma limits. So, I put down 3 there and these the value of sigma p and I have got that quantity put down there and if you do the calculation, you will find that the upper limit turns out to be 0.190 and lower limit turns out to the 0.010 which really says, if the value of p if the value of p, p is the fraction defective in any of those lots of size a 100.

If it is above the control limit, or if it is below the control limit, it is an exception situation. I have to stop the process, investigate the causes for it, just like we use the reaction plan in the x bar r case and they did that.

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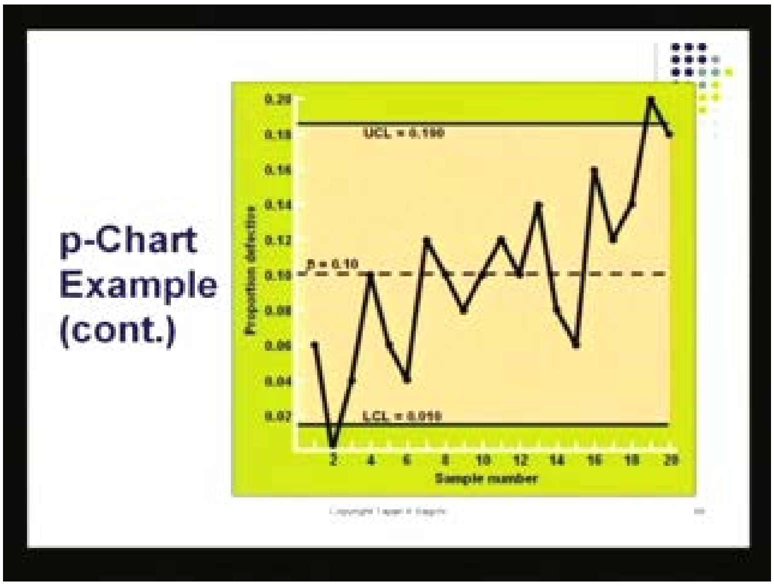

When this was done, you know you had a suspicion that perhaps eighteen defects were too many, right when you look that the 20 th sample and see what they found, they plotted the p chart with the upper and lower control limits shown as calculated and the after plotting the chart, they did find that in this zone, the chart when beyond the control limits. So, this is like an opportunity for finding the finding the defect there, finding the the show there, the problems there.

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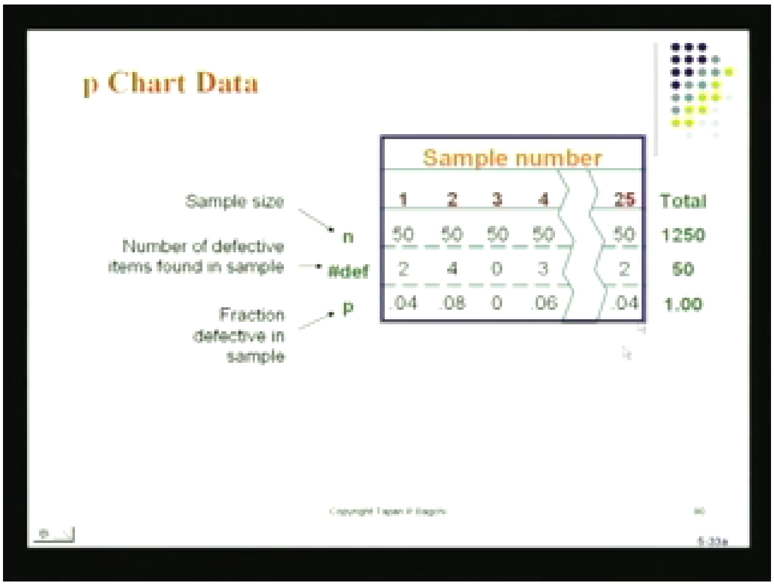

When this is done when this is done, every time the you know like in the x bar chart or the r chart, the movement the chart goes beyond control limits, stop the process, take a look at it and come back and see if indeed everything is ok or yes something did fall out, go beyond the set limit for example, and then you would restore the process to its normal state of phase. And another example, there again there is n, n is the sample size, which is like how many items are there, we had 100 jeans and here we have got something else and they are 50 of those, how many defectives were found, then I find my p value, how is this p found is, 2 divided by 50 or 4 divided by 50, that will give you 0.08 and so on, so forth.

So, these quantities are found by, look at the number of defect dividing by the sample size that is, what gives when this, I do an over all and I find from this, the over all like a we had the x double bar. In this case, we will have p bar and this p bar would be utilize them in calculate the the control limits.

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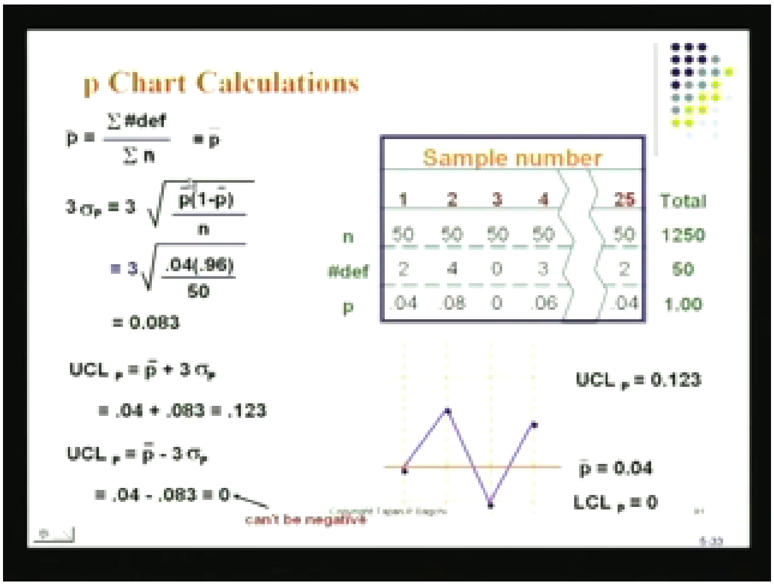

And those are done here, look here, the p bar turns out to be this and I use my control limit calculation, I find my sigma p, three sigma p then and I find my upper control limit which is 0.123 and lower control limit turns out to be 0, because it turn out to be negative, so I made it 0. And then, I low and behold, I got the neural control chart there, everything is in control, because the upper control limit is way out there so on.

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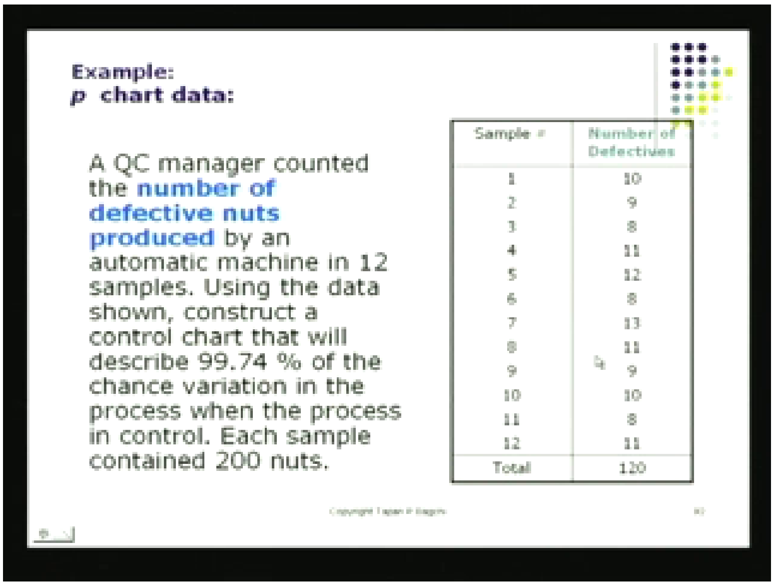

And again another set of data there, I could do the same calculations, absolutely no problems there, and I checkout the sample size, divide that by the number of defectives found there.

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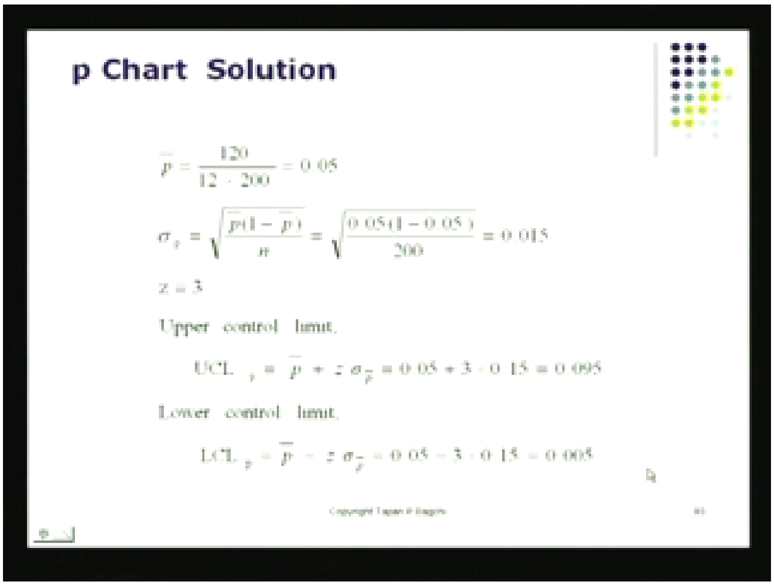

And I draw my control chart there, so they show the calculations there.

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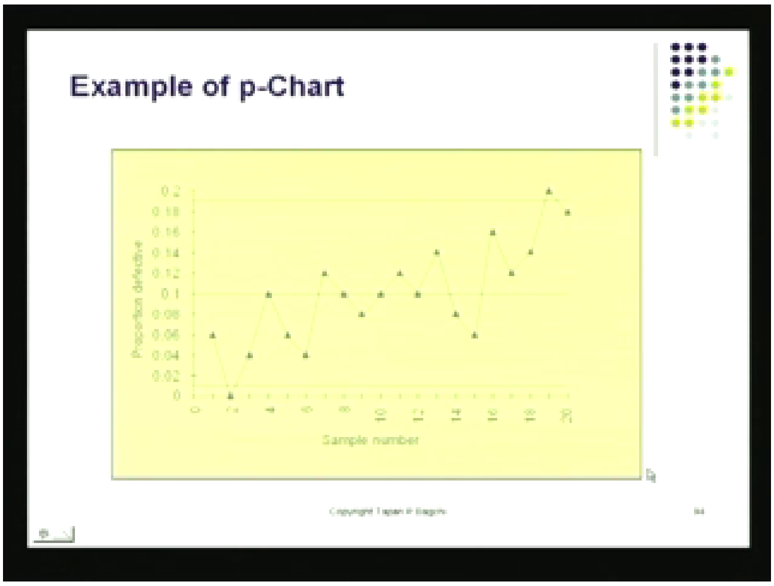

And they show the example of the control chart, these are quite easy.

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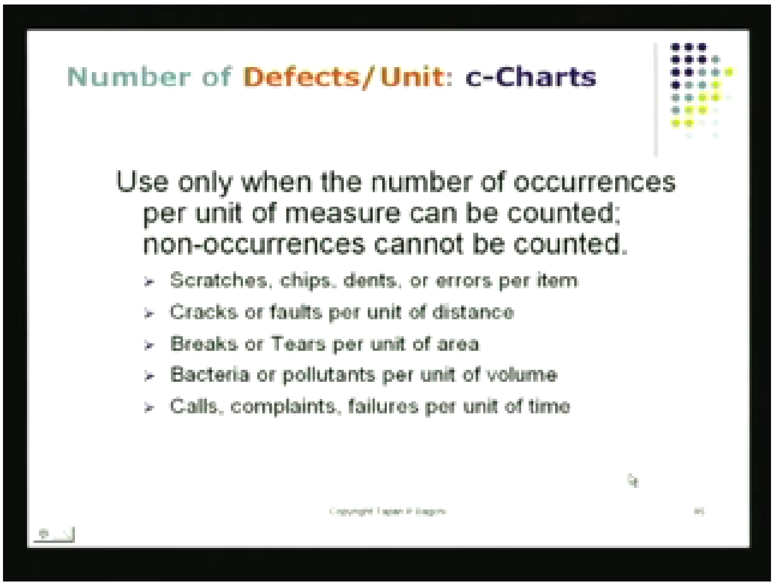

Another way, characteristic quality characteristic, this could be measured is the c chart; the c chart actually is actually, it is looking at the number of occurrences of defects per unit. So, it could like for example, if it is I do not want to have a defective calculator, but see if I had sticky keys or if I had the protected were things here with some scratch on it or the the you know the case the cover did not fit very well the case was there, but when I try to put it back together again, it did not fit very well, that would be a defect.

So, there could be multiple defects on one item there on one item there, if there are multiple possibilities of an item there, what I do is, I construct this c chart and the c chart is found, it is also a count, it again held its own control limits, and I will show you the formulas for it, and some examples are scratches, chips, dents, or errors per item, or cracks, or faults per unit of distance, this could be true. For example, for cables and stuff like that, or breaks, or tears per unit of area, like for example, if I am looking at a piece of cloth, for example, a curtain or something like that, I might take a look at number and defects found per unit area, or pollutants per unit volume of liquid that you that you find in a in a in a in a (()) or a or in a lake or somewhere there, or in a well, while well for example, or calls complaints and failures for unit of time, per hour how many calls are not being answered properly, for example, or they are dropping off, because the queue is too long and stuff like that, those things can be monitored as defects per unit.

So, the unit you set in a manner that make sense to you, find the number defects you produce.

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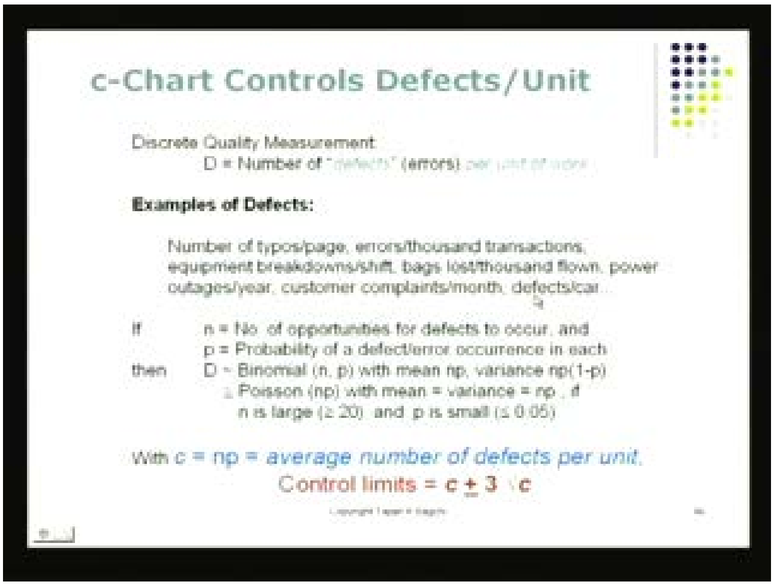

And the rest of it is very similar, I will just remind you up one thing there, we are using the three sigma elevate. In the case of x bar, we were able to comfortably use the normal distribution, because the central limits, therefore (()), if you use the average the average, approximates (()) and the standard normal variable and normal variable. And therefore, there is no real issue there, we could use this six sigma limit there, we kind of did the same approximation we did, when we did the p chart; for a defect, when you counting defects, for example, with the c chart when you counting defects, defects actually have distribution that is Poisson.

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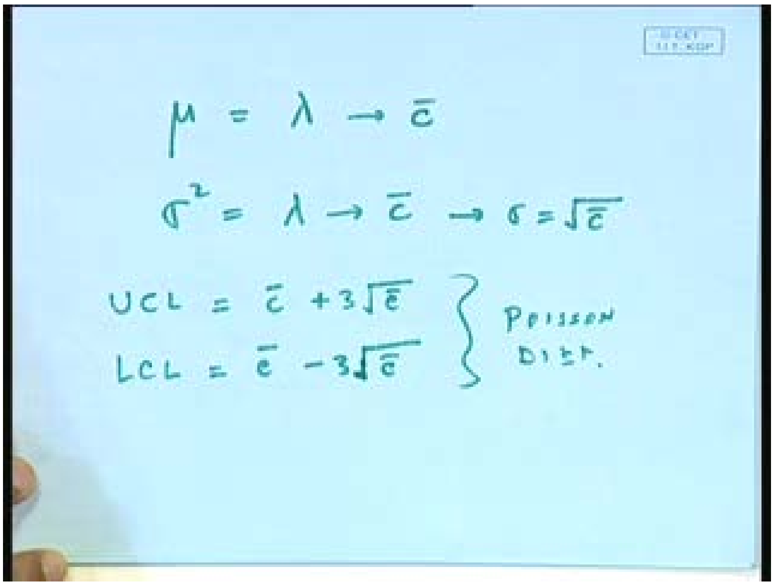

And the Poisson distribution is such that the mean is lambda and the variance is also lambda. So, imagine that I used c to take care of this, c is the c bar, for example, they are which, and c bar would also be the estimate of this. So, therefore, when I am trying to draw my three sigma limits, the upper control limit will be, I will have obviously, c hat c bar plus three sigma x, then what is sigma? Sigma is square root of this. In fact, this leads to sigma equal to square root of c bar. So, I use here square root c bar, a lower control limit is going to be c hat minus three sigma and that is going to be this way, c bar.

So, these are dependent on the Poisson distribution, but these are still the extreme ranges they are still the extreme ranges, I estimated my sigma using the Poisson assumption. So, I was able to do this as, but in actual fact, these still turn out to be limits. In fact, they are probability limits, they are exceptional limits; to exceed them, you you will be you will be the chance of exceeding that, exceeding these limits is very very small, it is you know one or two or three parts per thousand and something like that, it is a rather rare occasion. If it is a rare occasion, this is the very high chance that an assignable causes has cause has disturbed your process, therefore the movement the occurred the the c chart goes beyond your control limits.

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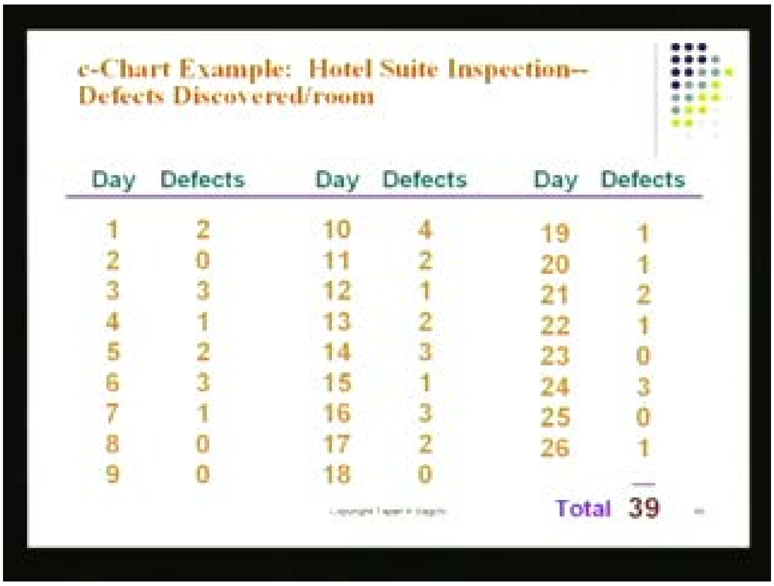

For example

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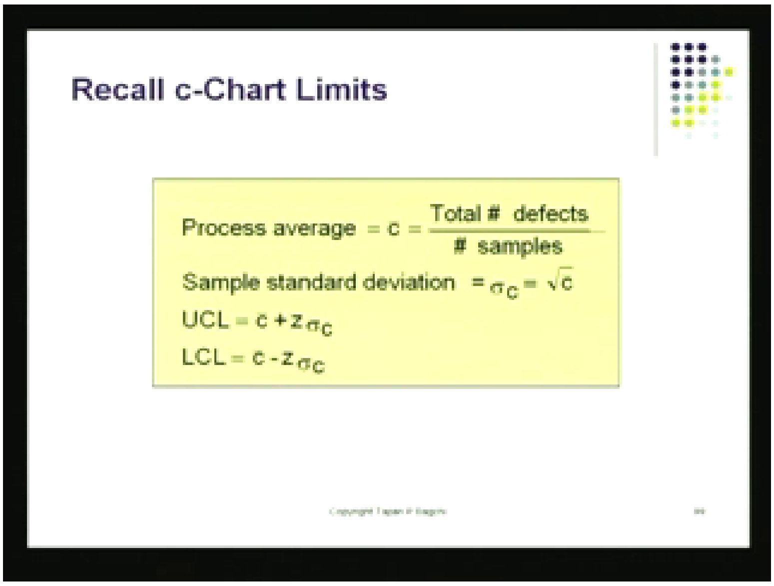

We will take a look at one example there.

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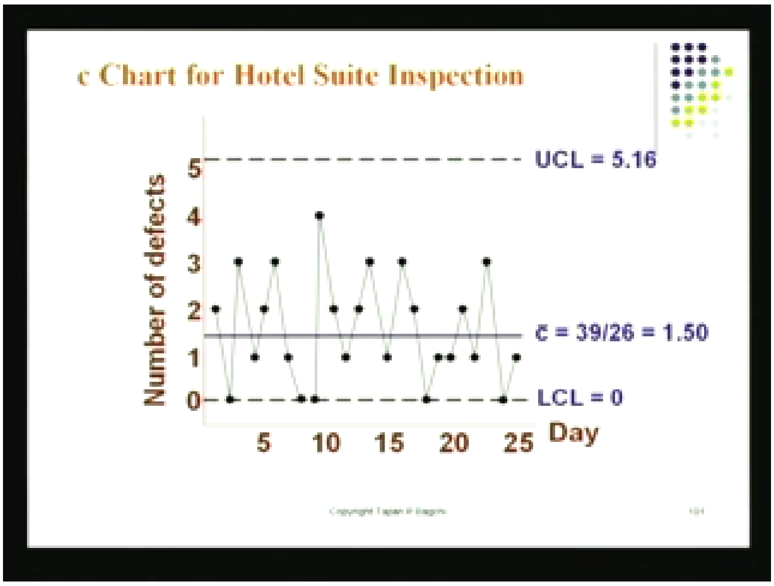

There is a c chart, everything is staying within control limits, no problem there no problem there and to get there, of course we did all those calculations, we looked at the formulas, we looked the raw data, we found the over all grand average which is like, I will be 39 divided by the total number of items there.

Here in this case, for example, it is telling to stay application of the c chart, hotels suit inspection, this is service application, defects you found per room, stationary he was missing, curtain was not pulled to complete close for example, the bed sheet were, sheet was slightly ruffled and the ash tray was slightly nursed to one side and so on, for these of things that the the the the guest may not like. So, these are all marked as defects, I did that and I constructed my, sum of c and I divide that guy by the number of items there, I end up with my quantity there, and I use my control limit calculations and I end up with 39 divided by 26 26 height and so use.

So, c bar is there, upper and lower control limits has been set, lower control limit had to be trimmed at 0, like our p chart, when it became negative, we made it 0, but I have got now my control limit there, and this chart as I shown here shows, everything is ok and I did not really worry too much about this.

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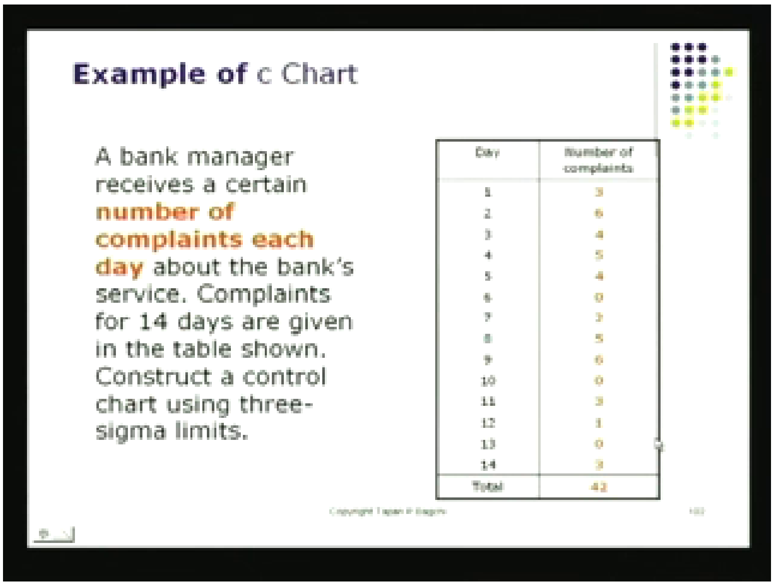

I could have another example, there are two, three examples there, there is one about bank complaints, complaints are a filled up our four 14 days and then of course, I have got a 42 as the total number of complaints there and I could do the same thing there.

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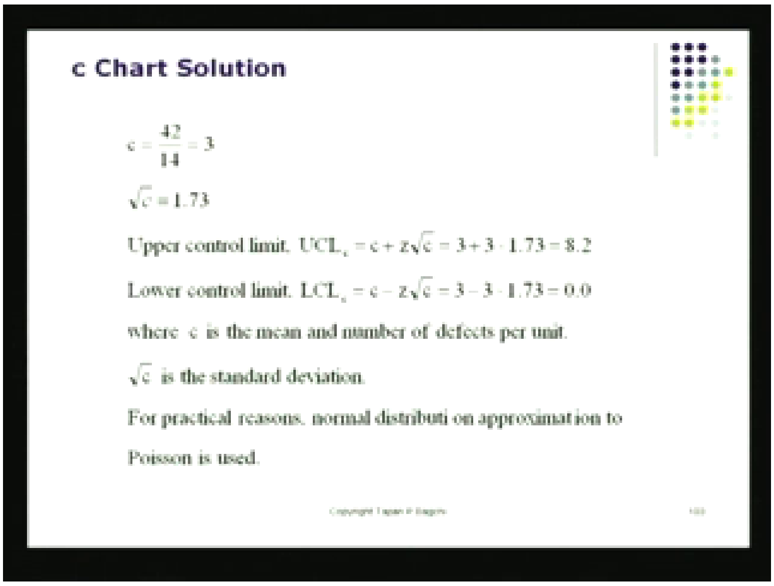

It is not very difficult to do.

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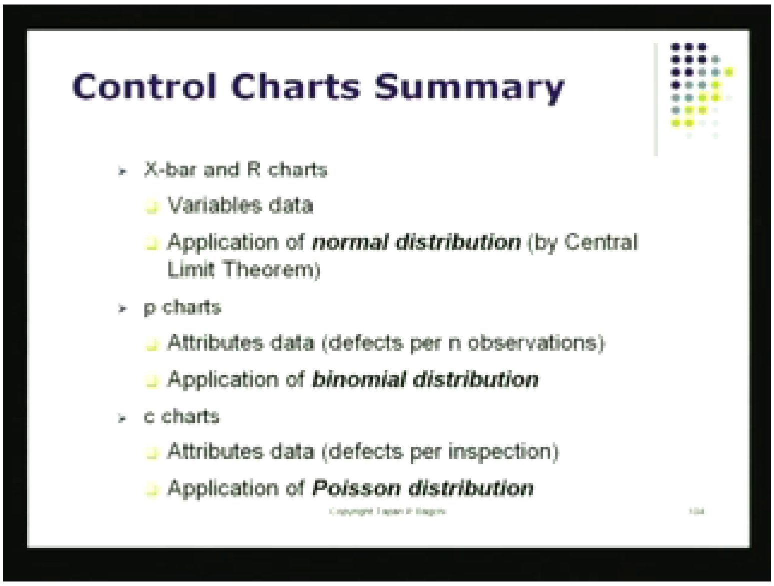

So, again I could construct the c chart there. Now, let us take a look at what sort of things we have been using, for the x bar and r chart, we use the normal distribution to find the control limit, for the p chart we use the binomial distribution as an approximation to normal distribution, it became a approximate into a normal distribution and then, for the c chart, these were counts out defects, we use the Poisson distribution.

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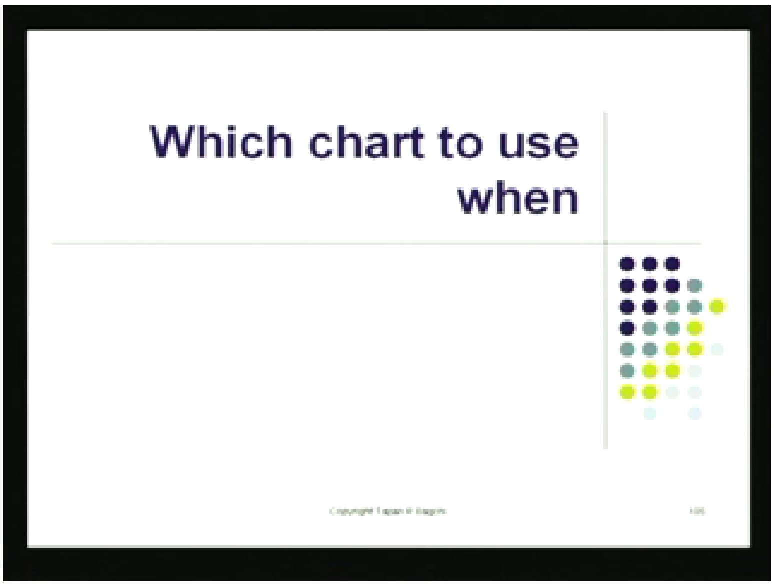

Which chart to use, when? That is also a question.

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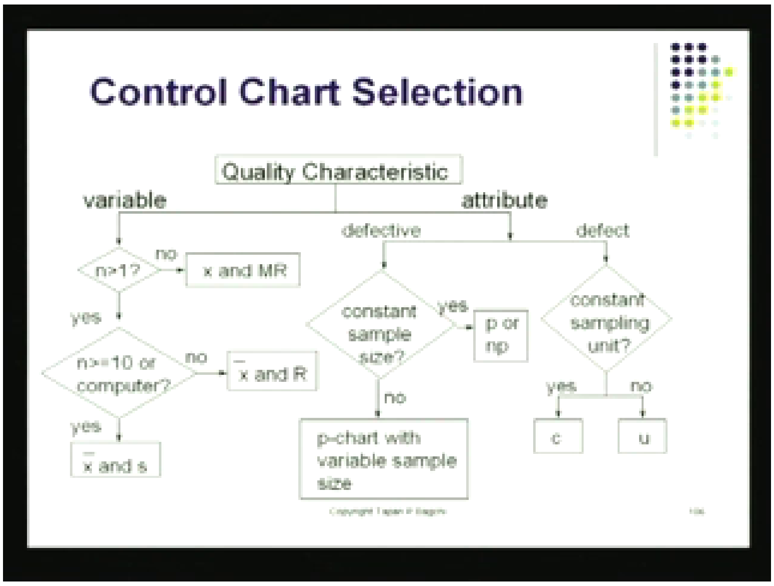

How do I do that, I start with the quality characteristic, what is it, that I am concern about, is it a variable characteristic, like dimension, for example, dimension of these things, either I can measure on a scale, that will be like one class of quality, the other is good or bad.

So, the caps fit or they do not fit, good or bad, the assembly is ok or the assembly is not ok. So, that will be an attribute, variables chart I ask the question, is my sample size greater than 1? If my sample size is not greater than 1, I just use a plain x chart, the raw chart and a moving range chart, and I use the same principles that are used for my x bar r chart, but the chart I will be using here is x bar, which will x x chart which will give me an indication of the accuracy of the process, and the moving range chart will give me an idea of the variation of the process.

If n is greater than 1, that means the samples that I collect, they have a size that is greater than 1, like that 3, 4, 5, 6, what I would do is, I would construct the x bar chart and r chart. If my sample size stays the same if my sample size stays the same, it is very easy for me to do calculation and if they do not stay the same, I might use a computer, I might be able to do it, either either this either this. So, i i could be using the x bar chart and the s chart together or I could be using the x bar chart and the range chart together, this is the story told, story for your variables quality assured, online quality assurance using variables approach, variables measurement approach, for attributes if it is defectives if it is defectives it is you go to the p chart, or the n p chart, n is your sample size.

And in that case, I could probably, I do this without much trouble at all, something that is important for the p chart is, your sample size need not be the same, because the control limit itself has in built in their, so in fact, we go back to the formula that has the p chart there, the p chart will show you that sample to sample there will be a change in sample size and you have no problem at all, use them as if the charts are like the old three sigma up and down it have a control chart, no issues there, if it counting defects like you do in a hotel room, for example, if the sampling unit is constant, that means no real issue there, you could just be doing you know the defect defects per unit. So, if I am just looking at one room each, there is no problem there at all, so I will do that.

But suppose, I am inspecting these calculators and I have got sometimes I get 3, sometime I get 5, sometimes I get 1 and so on, so forth. I should be using what is called the u chart, which is like in that sample, how many defects did I find, in that sample of size 3 or 5 or 2 or 0, not 0, of course 1, how many defectives did I find, how many defects did I find, once I know that, I would I would be able to use the u chart.

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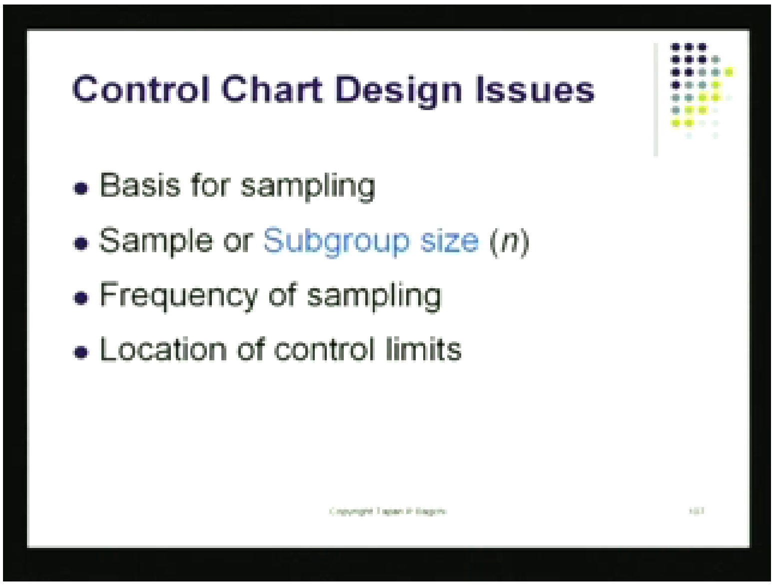

And the u chart runs very very similarly to the c chart there, designing issues, what I saw on the designing issue, this sub group size is the big big issue, sub group size your sample size, it turns out that.

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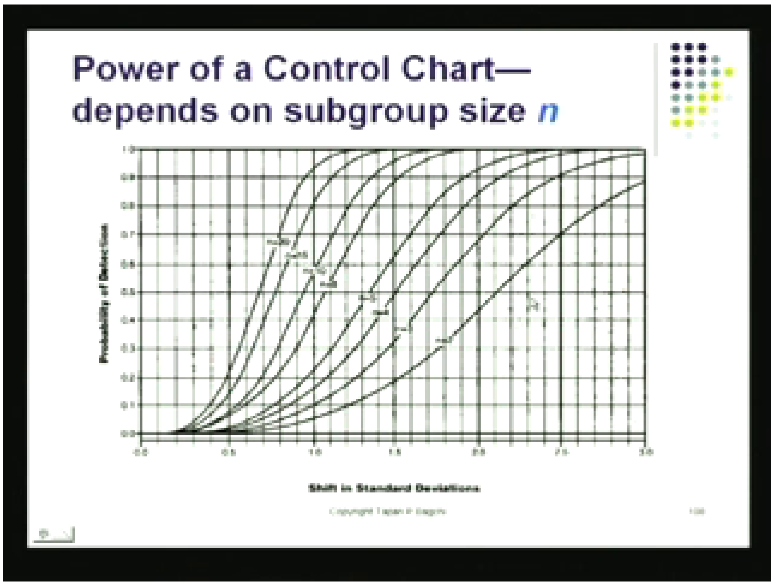

This is what determines, this estimating of the chart or the power of the chart, then larger is your sample size, and the quicker you are to detect a shift in the process. See, if your average is let us see, you are drawing the x bar r chart and when doing that, suppose it turned out that you are, you had a choice of sample sizes, something you got to remember is, when you collect a sample, they give sampling you know these bottles, bottles of water, how many should you collect and when should you collect them, how many should you collect would depend on the power that you want in the chart, what is this power? The power will tell you, if the fill quantity if the fill quantity varies even a little bit, I should have large n, I should have large n. If I have large n, the the chart will have a more power, it will be able to talk for slight variations, even the slight variations in fill quantity, that is one consideration.

The other consideration is if I do expand my sample size, it is very possible that the different bottles that I pick up, those might be produce under different condition. If I collect, for example, 20 bottle, the first five or six might be produced with one speed of filling, the later was might be with some slightly different the speed of filling, because hydraulic pressure changes, something else changes, some controls change and so on, so forth.

So, in fact it turns out that one of the requirements, we have in statistical process control is when I draw a sample when I draw a sample from production, these should reflect one condition of production, that means they should be alike alike statistical variation, but it is not that these collected when voltage, which is an input to the machine fluctuated from 110 volts to 120 volts to again came back to 97 and so on.

If that happened within the collection of this sample there, I will be looking at a mixture of the influence the assignable causes and random causes, both. In fact, within the sample, the variation should be mostly chance (()) there and sample to sample variation which is like, one sample here another sample here, if I am comparing the difference between the measurements there, the average measurements there, and the average measurement there in this one, these two these two should reflect the impact of assignable causes.

So, let me repeat this again, the variation that I would like to see within a sample should be of the homogeneous kind, these each item each of these item should have should have been produced under comparable condition, this is called variability within the sample and when I collect a sample at some other point in time after may be one hour, the difference between the measurements for this one or the statistic for this one, and this one, that should reflect the impact of the assignable causes, and those may or may not have change from going from here to there from here to there, if this does not happen, I will not be able to really catch the presence or the disappearance of an assignable causes.

So, samples size should be determined with these consideration, within the sample, I should be able to see the natural variation of the process between the samples, I should be able to see the impact of the assignable cause. Now, this might seem a little complicated to you, but if you pull up a book on statistical process control, they explain these things, there may be some economic consideration also. For example, can you live with an aspect you know a process that is not running very well; for that you need to have the consideration of power and for that, this power curve that I show there, these basically tell us the probability of detection of a of a problem, it is going to be hire with a it is going to be hire for a small change in the process when my sample size is large, this by for what I am discussing is probably most complex part of control chart theory.

So, if you do not understand this completely, do not worry about it, but keep your n near 4, 5, 6, I let at least assignable production take place, which could be like after an hour or after may be a shift or something like that, to collect the next sample. If you do that, you will maximize the visibility of the assignable causes and you will make sure that, the base variation which is due to the the chance cause is only, that also is apparent and that is pure; within a sample, you only see what we call chance variation.

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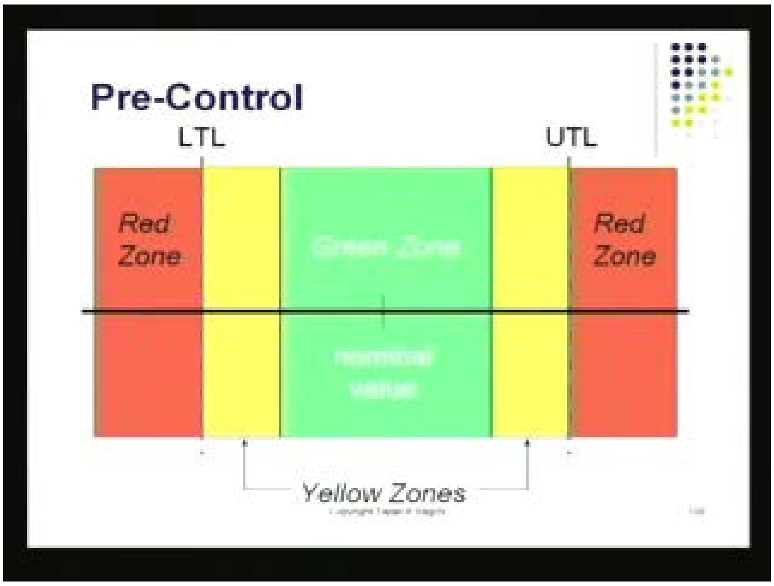

So, just go into this a little bit with your statistics, with your s p c book and you will be able to probably pick up the thing. Now, there is a there is a way to also get warnings out of the process and those are done by pre-control, pre-controls are done, they are also control chart just like the other ones and pre-control charts have three regions; the green zone, the yellow zone, the warning zone, and the red zone and the tolerance limits are used here in place of control limit. When I am doing pre-control, I normally use tolerance limit, tolerance being a specification limit, those are used here.

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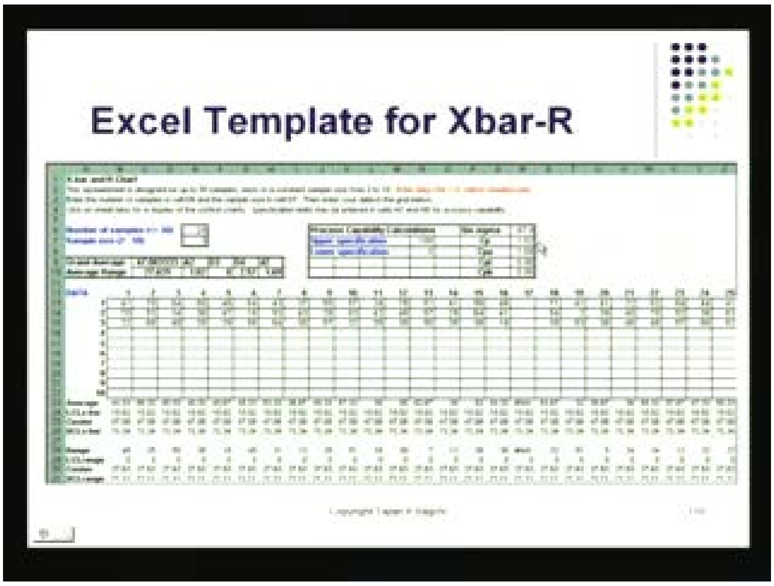

Again, purely decent book on statistics, statistical process control, it should be able to explain to you what the use is, what the utility is of doing your control chart. Now, let us get into using excel to prepare your control chart, now I have a personal bias. In fact, I am up strong supporter I am a strong supporter of using excel and also I get very disturbed when control charts are prepared after seven days of data collection. I get very disturbed. If it is done all most immediately, you do not need to a lot of calculations, you can get your chart done very quickly. I was in a factory and this factory had a built in s p c system, it was like excel, but it is built into that automatic machine that was there. It produced items and it measured the items instantly all most instantly, they had some gauges there, that produce the really really good quality measurement there, there you find that good procedure and everything else, that was exceptionally good, we got the data, we got the data within a minute of production.

So, samples could be collected also, you could press some buttons, have the samples taken out and it would do the x bar, it will be r, we will come back and display the x bar and all. And of course, the control limits were already there, those had been done earlier and with that, you could figure out right away, oh is the process in control, it is not in control, it is it drifting, it is not drifting, it is cycling, any of those things could be found very easily by looking on the chart online pretty well, it was all being done instantly, that

I favor a lot, if at all if you could reduce this time of production and time of looking at the chart, if you could reduce this time, if you could make it all most co inside if you could do that you doing the ideal thing, because then they will not be lot of production done in a in a situation, when these things might have really you know process might have gone out of control and you are continuing to do production.

The other extreme, which is what upsets me a lot is, engineers will go out to the plant and they will collect a lot of data, they will carry their laptops and they will start keying in this data, so they cannot really do this when production is going on. So, they will say guys, please send me last week's data and I will do it in my office. So, they take this last week's data and da da da da da they doing all this, so they produce this little thing.

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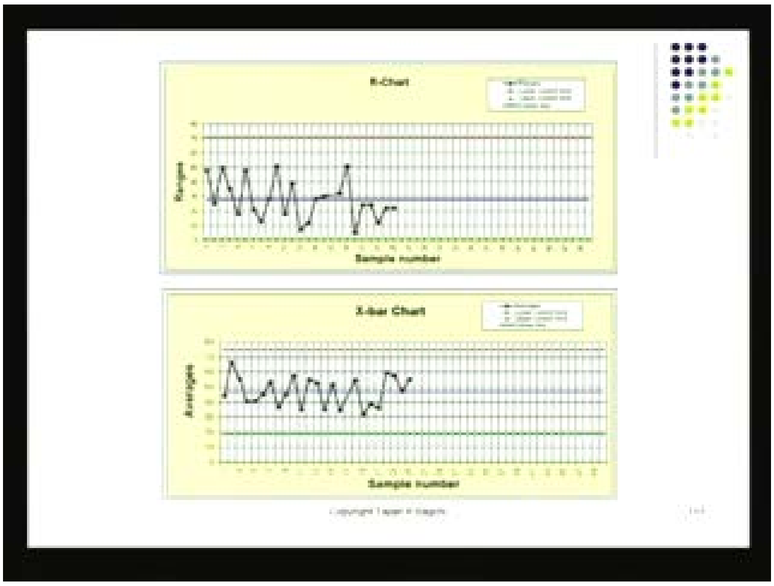

And they produce very nice to be chart, a very impressive chart, they they produce this chart and chart comes out and it is then printed out, early they print and everything as mounted on the wall, but what is this about, it is about last week's production and doing that last week, if there are certain things that went out of control, for example, my god the, when will be the opportunity fix them, because that data is old and that situation is gone, the production is already over, may be the goods already pack, may be that been shift also. I am trying to do online control, but in actual fact what I am doing is, I am delaying this whole chart preparation business just, because I want to use excel conveniently. I am producing my chart one week later or two weeks later and in some places, once in a quarter, what use is that, it is certainly not online control. If you want to do online control, find the way, find some way by which you could really go out there, collect the data and produce the chart quickly, what do the Japanese do? Well, the Japanese first of all do not have this kind of variation in their processes, but in processes that it, they need to measure, they have people trained so well that, they can produce these charts on a online basis, pretty close to online bases.

So, they will produce fabricate something there, they will make some measurements and produce the chart. Let me give you one example, that I saw in this country, in your country, what I found was, I visited this company called BHEL, Bharat Heavy Electricals Limited, these all people who will produce huge, I mean world class power plants. And most of their power plants are turbines and their generator, those are produced by doing this, they are the people who cost huge huge covers for these generators and those are as big as this room for example, huge they want to, they go into 2 to 500 mega watt, that is the size of the you know the power production capacity they have, capability they have.

Now, inside these turbines, of course they are those turbine blades and those those plates are amazing, they are like they are like jet engine blades, that is what they are like and no no words tell them, it is just like jet engine blade they used, because they are expose to high temperatures, steam you know, what pressure lot of stress bla bla all those things are there. So, they must have exceptional performance. I happen to a visiting. one of these BHEL factories, and the city is Haridwar which is in the Himalayas, when you go into the mountains is just the beginning where the mountain begins to rides. I was there in that plant, then I gave a talk on quality assurance, then I went out to the shop floor, I just wanted to see the action there and then heard a lot about BHEL, then their exceptional quality assurance programs and everything else and their level of training and all.

So, I went out there, I went out to the floor and I stood behind, I found a machine is there, he was grinding these these turbine blade and the turbine blades were the this long and they were kind of and they could be held in one's hand and he was doing the machine, a fair amount of it was turn automatic, they needed some others and so on, so forth. And he was doing this one after the other, but after every time he completed, you know fabricating one turbine blade. If you take that turbine blade and you bring it is gauge and you apply the gauge right there and make a lot of measurements make a lot of measurements or certain specific spots on that turbine blade, you would make the measurement and they would write it down, he had a table just like here, see the table there, see the table with the data there, you just fill the water, those he filled by hand.

So, each blade would have some measurements, he was doing pre-control, I looked at that and I found he was doing this totally religiously and also I looked at his work, top notch, only did look like here, real good training in a machine shop, my must have many years of experience also. But he has not very old, he was like in his 30's, mid 30's ambitious, you know you know top performance person there. I found him spending quite a bit of time filling all this data sheet, then he would pick up the next blade and that blade, but have the same feet machining machining machining, measurement measurement machining measurement machining, he did all that, then he put the blade aside, again made the measurement data and entered the data there.

Then he went down, did his x bar calculation, then he did his range calculation and then would you believe? He plotted a few points on control chart, he was right there. So, the top half was the data, other half was the thing and he was doing this, every time he took a blade out, he did this. I walked up to him and I said, sir what do you do, what is it you are doing? Well, I am a you know pushing these turbine blades, that is my job that is what I am good at, and I have been assigned to do these things, here is the design, here is the drawing and so on and so forth. here the machines, and I operate these all machines and I self producing turbine blades. I said, great, that is good piece of work, I mean by looking at your grinding, I would think this has come out of a machine and you are doing by hand, you know really hats off to you, great.

But tell me one thing, why are you wasting your time in this measurement, that measurement, all these things you are doing, my god, what is the point in doing all these things? You are making this measurement, that measurement also, it is really good, you are wasting so much time you are wasting so much time in making these measurements and it is just going on and on and on, you are doing measurements here, entering the data and this really a waste of time I think, I think it is just a waste of time, that is a you know waste of lot of time, why would you rather not focus on your machining, forget about this data collection, charts and all these things, you are good at your machine man, you know why are you he kind of a gave me a stunned look, I am always a stranger, I was somewhat you know I was also myself really shaken up looking at the piercing eyes.

Sir, who are you by the way, and what are you doing here? And before that, I have told him I am a teacher, I am sort of, I came here from I again repeated that, I am well I am a teacher and I was kind of entreat, because you are making a lot of measurements and then putting them on a piece of paper here and trying to do these charts and all you are doing this right here. Then he said, let me tell you something, if this one blade, guess made badly wrapping there are some problems with it and that will show up only on that control chart there. I will either reject it or I would send to a special place where they would be reworking on it. I will not probably do it, because it is some other department that is in charge of looking at all the all the large large problems there and they are supposed to be taken care of it.

My job is, basically to do the first grinding and then produce this chart there, and every blade has an ID. So, I know which blade I have probably what kind of data, I said. But why why is it important, you are producing so many blades any how, I you probably grind 20 blades a day. So, why are you doing all this this, writing and so on.

He said, sir let me explain this to you, if this blade turns out to be faulty, it is going to do, create some real havoc inside the, it will probably vibrate inside the turbine with a lot of pressure fluctuations and so on. And alignment is something else, if it if it is wrong, then perhaps the turbine is going to shutdown and there are control systems that will shutdown the turbine. That means, the generator is going to shutdown, that means, the grid is not going to have supply from that particular this particular system there, and that grid is connected to Delhi. So, you might be from Delhi, you will have no power and how did this happen, because of that one single blade that was not machine right and I did not catch it when I was producing it. I said, my god you know what kind of training does this person have, what level of understanding he has, that is really exceptional; I mean to me, I had not met many machine shop people like that.

So, to me it was just amazing, that this man knew the value of producing data and using that as feedback right, then and there, and that is the beauty of these control charts. If you use them right, they will tell you right away that the signal is there. So, what charts are we looking at, the first chart is of course, the x bar chart, the r chart, it is like the first chart, you can construct very using excel using excel, you could also very easily construct the x bar chart and the s chart.

The reason is, all the calculations are happening in the background and you are able to focus on whatever you want to focus on, which is your analysis, which is pulling out your check list, pulling your your your studies and so on, doing the investigation and so on, that is what you should be doing really, you enter the data, you make the measurements and all, that is all fine, but you should really be doing, thinking instead of doing this bull work there. So, this is where excel is great and excel produces some very neat graphs, very accurate graphs, that is something it is able to do and when you plot these charts, if you do it by hand, if some mistake is there, you will have to erase them all, which is not a problem with the excel at all, so that is there.

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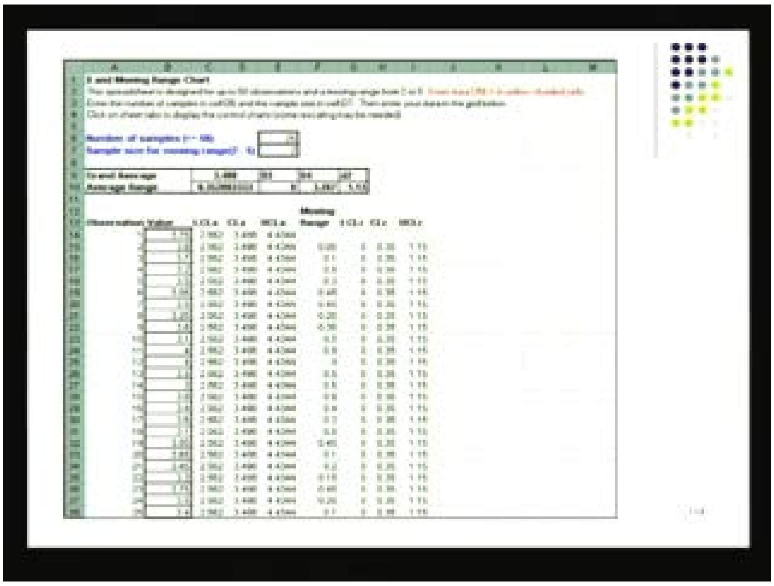

I can do the same thing using my x chart, individual chart or the moving range chart, I will have the same effect here, I will have whatever I do with my x bar chart, and the range chart, I have the same thing done here, no problems, no issues there at all. So, I have my individual chart, then also the moving moving range chart and the moving range chart will give me the signal just like, I get my signal from my range chart there, no real problem there.

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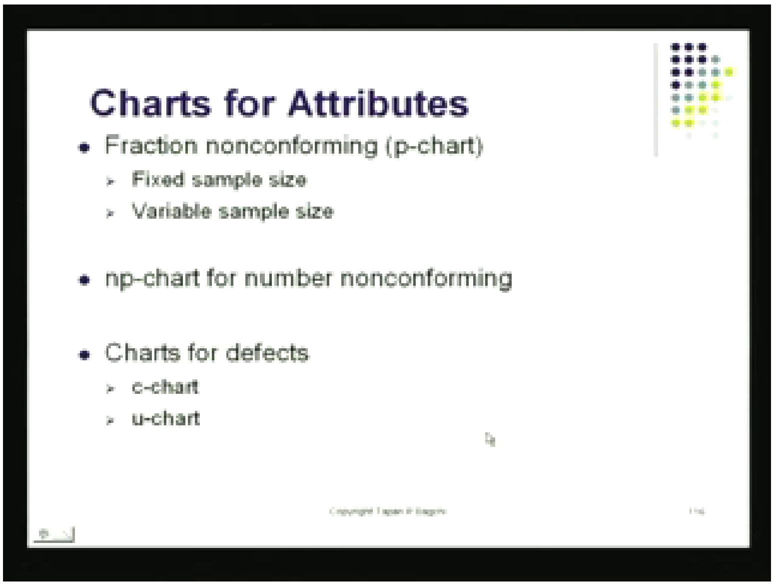

Then, I have got these attribute charts and again I can set up an excel sheet to be able to do this. When I do that, I clean all my data, I rig out you know rig out some of the cells there with the appropriate formulation formulas and I got these formulas there, because I know where where they come from, I you know open the book, I plug in the right quantities there, I refer to some some cells where I have got the references, the pivots and I was, I am able to get my control limits there. Once I have my control limits, I have my regular reading there, I can do my comparison quiet easily.

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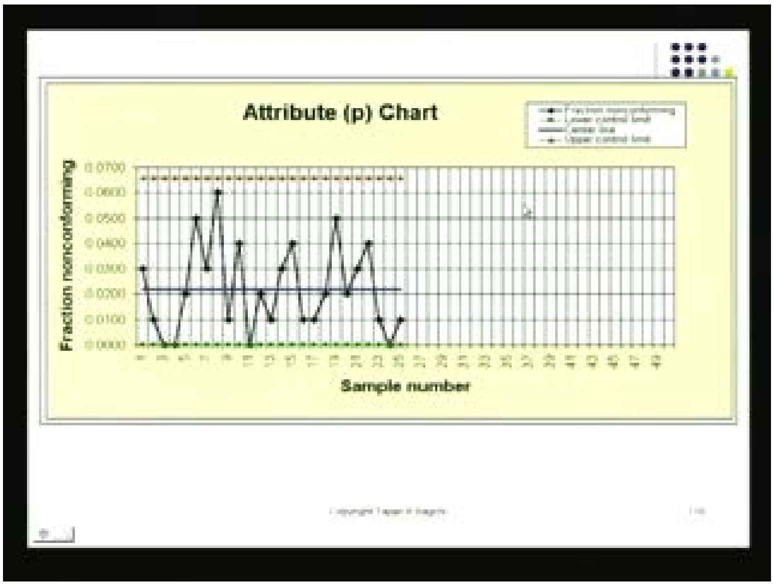

One I do that, I can construct my p chart without any trouble at all, p chart also can come out of the excel, I can again focus on troubleshooting, that I am able to do. So, p chart would really be no sweat at all, if you did in this way and this is also not not very difficult at all. And notice here, something that I did not show you earlier, notice the varying, the variable width of the control limits and can you guess why it is this way? Because the p chart, the control limits of the p chart, has this n in the denominator. I will see, if I could find that formula for you, some place I have got to find that formula for you, that is there with me a little bit, I am just going to take you there.

It is not that far, and you will see that the limits look here, right there, this is sigma p and it is got that sample size right there, which means if sample size is large, for this sample sigma is going to be small. If n is small, sigma is going to be large and that means, in one case, three sigma limit is going to be narrow and the other case, it is going to be a wider and that is exactly what you see when you come out to the p chart that has been built using our friendly, very very friendly excel, you see the control limits there and they are varying. They are varying in a width, because each has a different end, how they all know that, I go back to the sheet there, and I see the sample size and look at the sample sizes, 137, 158, 92 and so on.

How come these are varying, or these could be our only production, and nobody really knows, I do not know, nobody really can guarantee that all the productions going to be exactly that same number of units every time. So, those are those are different, so sample size is varying, n is varying and if n is varying, my you know the control limits are going to change.

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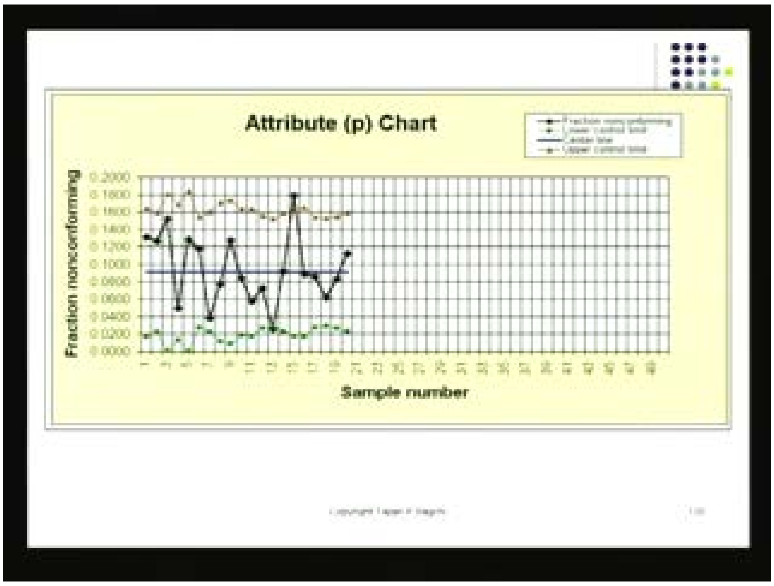

Then I have got this, variable control limit there, they behave still the same way, the same theory applies, you forget about the history, you just took at the latest, you will get the last p point that you want to plot; relative to that, you look at, you compare the position of that p value you just found to the location of the, its own appropriate control limit. Just see, if it has exceeded its own control limit. So, that would be like a very easy thing to do.

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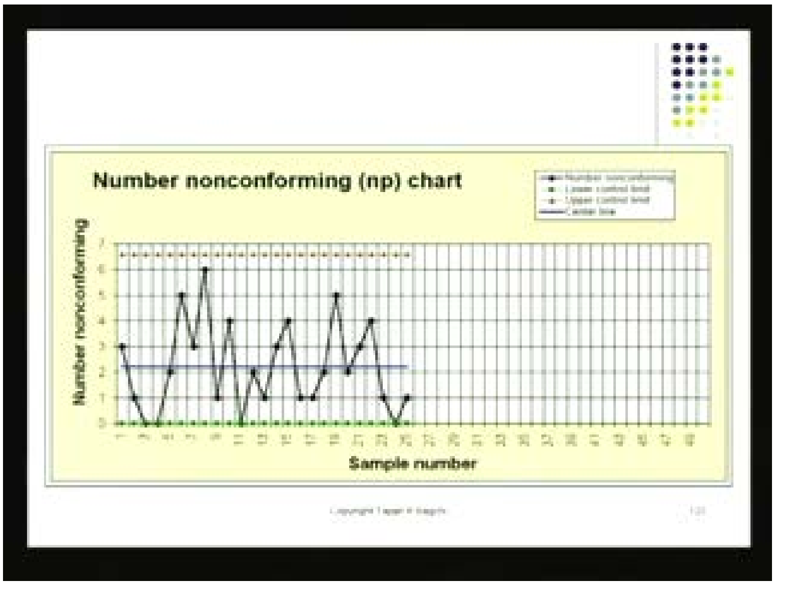

This is something, that again can be done quite easily. Similarly, we got the n p chart done the same way, and then we got the c chart which also can be done quite easily.

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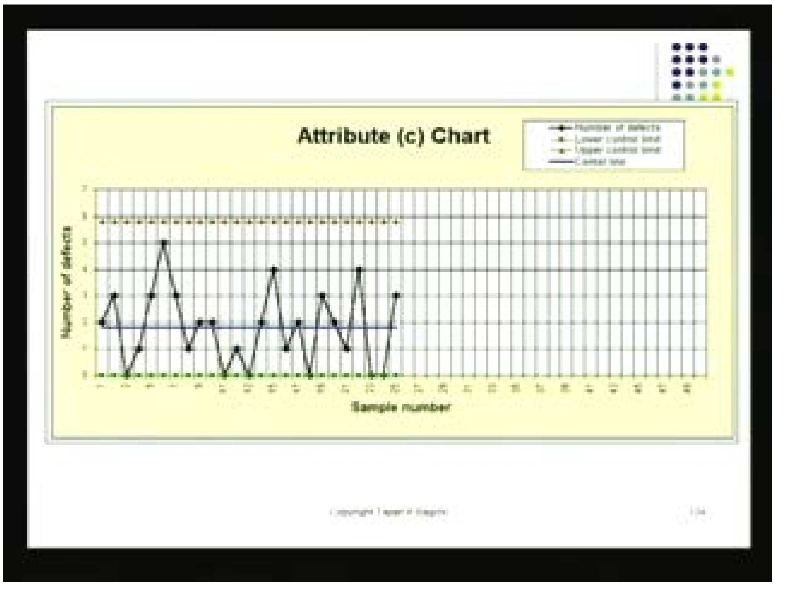

Once you got the data there, excel take just like a fraction of a second; to be able to do that, so I am I am able to construct this c chart also.

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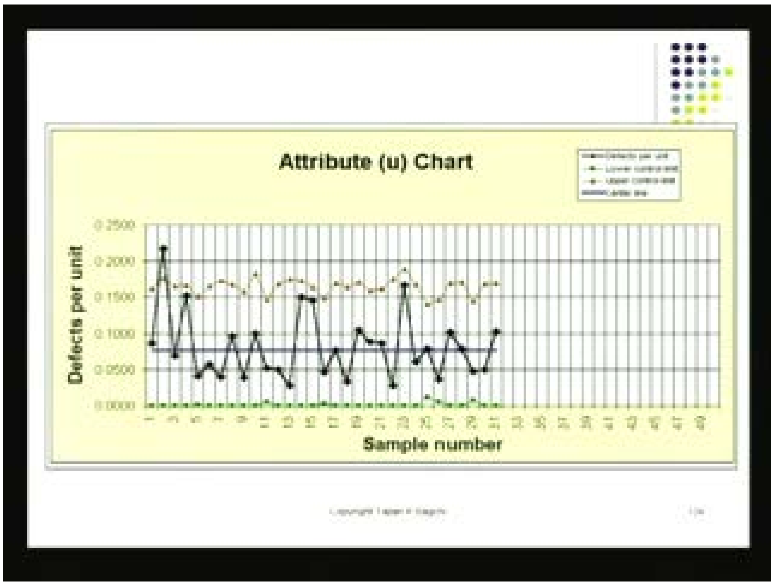

c chart is there, u chart can be done in the same way and notice here, the variable control limits there, that is also there.

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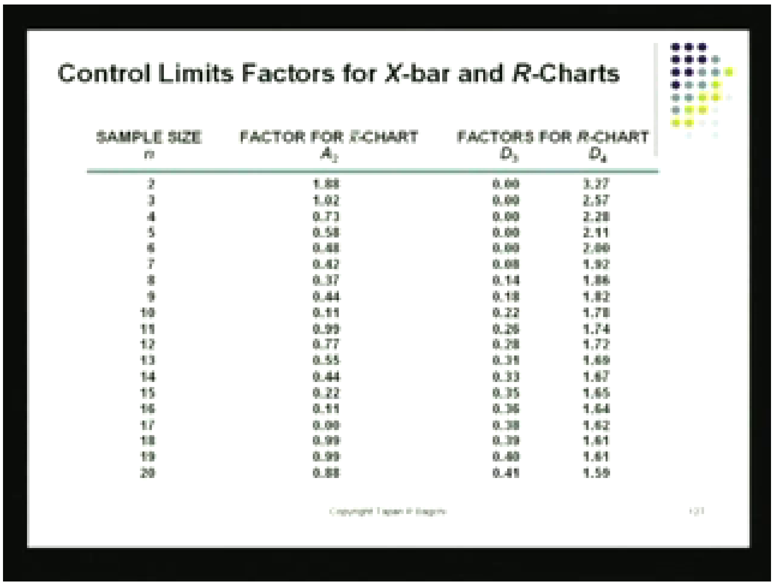
Control Limits Factors for X-bar and R-Charts

SAMPLE SIZE n	FACTOR FOR $\bar{X}$-CHART A_2	FACTORS FOR R-CHART D_3	D_4
2	1.88	0.00	3.27
3	1.02	0.00	2.57
4	0.73	0.00	2.28
5	0.58	0.00	2.11
6	0.48	0.00	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.44	0.18	1.82
10	0.11	0.22	1.78
11	0.99	0.26	1.74
12	0.77	0.28	1.72
13	0.55	0.31	1.69
14	0.44	0.33	1.67
15	0.22	0.35	1.65
16	0.11	0.36	1.64
17	0.00	0.38	1.62
18	0.99	0.39	1.61
19	0.99	0.40	1.61
20	0.88	0.41	1.59

Something we got to remember when we talk about control charts, something we got to remember when we cannot really throw this away. We are constructing the control charts to be able to get signals out of them, and signals are basically indications of major process disruptions and this is being done online, that means as close this actual time of production as possible so that you can take corrective steps, very very quickly.

So, if you look at the old x bar chart, you should not wait for one week or two weeks before you go out and plot your chart, because then the production, later production would be a history, it might have been packaged up, packed up and sold to people, you do not what to do that, you want to catch it as quickly as possible. If there is an exception, catch it as quickly as you can with the help of the control charts.

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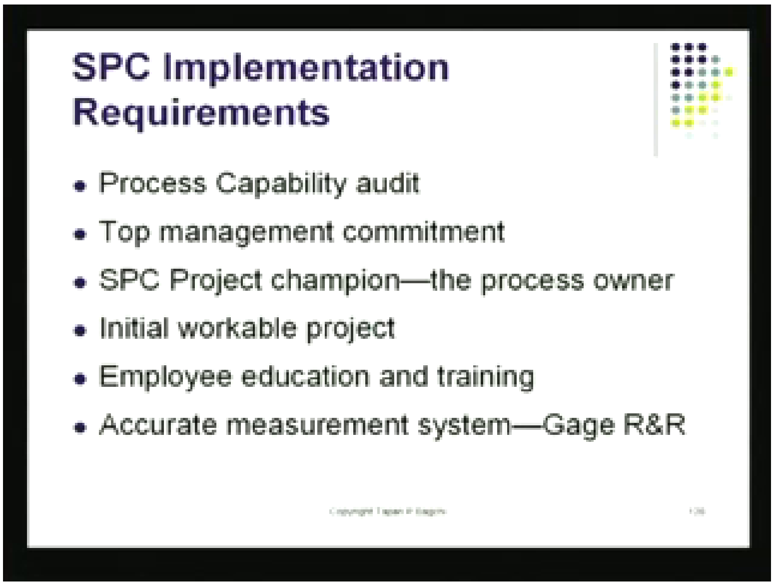

There are certain requirements for implementation of control charts. First of all, something that is very important, that I am going to be discussing in the next session is have an audit done of process capability. And process capability is a is a is a really really cute indication of whether your process, or your machines, or your factory is capable of supplying good quality product, acceptable products to customers.

In fact, do you have the capability of satisfying your customer with any randomly produced part any randomly produced part, or product that you produce, is it capable of meeting specs, that is what is done, that is what that is what is determined by doing process capability analysis. So, this process capability audit is for a the very first things that you must do. In fact, if you are going toward ISO 9000 you cannot escape this today with ISO 9000 2008 you just cannot accept you know go around this process capability measurement.

If you are doing a six sigma project, if you want to launch into DMAC, you should know where you are, if you C p your C p k, these are the process capability induces. If these are near 1 or 1.2 or 1.3, my god you have got a long way to go, because six sigma requires as equivalent to these C p k of 2, that is a exceptional level of you know high quality, you got parts per million defectives.

In fact, only two, or three, or four parts in a million, in a six sigma process are going to beyond the control limits, are going to be defective, are going to be the ones that we call defective; top management commitment, this goes with any kind of quality program, any kind of program in a company. If it is to succeed, it must be driven by the man of top, I do not mean god, I mean somebody who gets paid a little bit more than you and he is the one who has got to be the champion for this.

Many times process SPC, the SPC project champions, these are process owners, they have some interest, they want to make sure their shop gets in ship shape, and this is something that is required by many managers, they want their process to kind of rise up. So, they sometimes become champions of these things and this could also be a six sigma project. It could be easily cast as a six sigma project, you install SPC, you install the monitoring system, SPC is a monitoring system by itself, it does not control anything, because it requires that control loop to come back and control the causes, the production system has causes and it is got the output. Unless I control, unless I look at the output, find the reason to change or adjust the process, unless I do that, there will be no change in the process; in under SPC, we do that by looking at statistical signals out of the output, which will be done by comparing x bar value, or the r value to its control limits, its respective control limits.

Once we do that, we know whether I should leave the process alone as it is, or should I take some steps, try to make sure that the process is in fact, in need of some adjustment or some some exceptional treatment there. Initial workable project, this is something you should start with, do not get too ambitious, start something small, I started a petro chemical process in Singapore, in the late 70's. At that time, the first struggle was to try to tell people that you know people knew a plotting of data, but we were doing that with a specific purpose, we wanted to get signals as exceptional situations.

Whenever there were exceptional situations, we wanted to get a signal and for that, we had to make sure, we train people, we let people know what we were doing, and what would have broad approach was going to be, and we took a simple process, we started monitoring its output, this was actually a pump which was misbehaving and people did not quite know what was happening, what the pump itself that was the cause of the problem or the input that was coming to this. And we found, that the slurry that was coming in that slurry was not homogeneous, that was causing the the pump to struggle at time and that we did that by monitoring the output of this thing and we found that the, we could easily find that, there were occasions when there will be almost no output coming, because this sludge was too thick to go through the pump.

Something as simple as that, this pump was a small unit in that large, huge chemical plant and we had to do that with most of the equipment that was out there and we had to make sure the controllers were doing their job. Only then, it took us two years to get to the point when we had a controlled process and our production was comparable to the benchmark process which came out out of the r and d shop. So, now, our production after two years of study and SPC became more or less what our r and d chief was producing in his special pilot plant, we could do that, employee education and training, this is very very important. Otherwise, people will just think you are counting beans and you know kind of twirling your thumb, that is what you are doing there, you are there, but you really are not adding to production or something. Now, what are you doing, they are probably ask your people to stop this, stop that.

So, they need to be trained, they need to be educated, the Japanese do this to the point when any worker can actually look at a chart, again interpret the chart, you know plotting the chart is trivial, and the bottom of it all is you must have exceptional quality measurement systems, that is that comes under gauge r n r.

If your measurement systems are no good, the data that you would be using to produce these charts, they are also going to be no good. So, therefore, please make sure you start with some sort of gauge r n r assessments and the industry norm is, that the errors, the sigma that is with the gauge and the r n r component of it, it is a one tenth of the sigma that you expect to see in the process under natural condition. Under natural conditions, the process will have some variation and your gauge r n r sigma is got to be one tenth of that. If you do that, you got a decent measurement system there, all most no measurement system will lead to zero repeatability, zero error repeatability and zero error repeatability, almost never you find that, but you got to control the technology, the training and all those things in such a way, that you end up with a measurement system that produces sigma, it shown it might contributes your own sigma, no more than 10 percent of the variation that you see in the final process there. That means, what you are concerned about is that going to be 90 percent or more due to the process itself, that is going to be very very important.

So, let us summarize what we have done so far, in these last three lectures, that is plant various control charts, we looked at, we we appreciated, we ended up seeing various examples and so on.

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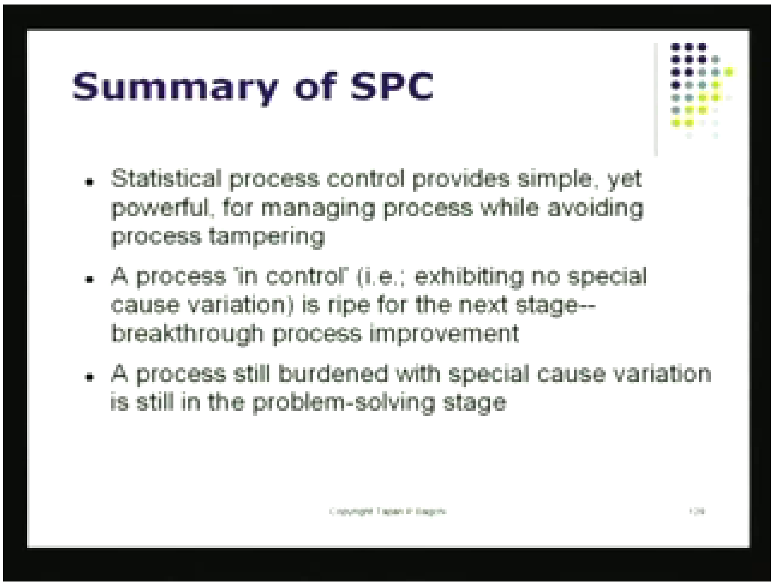

And we understood that statistical process control provides a simple yet powerful method for managing processes, while avoiding process tampering that means, adjusting every little thing every two minutes. If you find a new driver on the road, that fellow will try to adjust the steering wheel every two seconds, every you know two meters, he is going to be adjust his steering wheel, that is not an experienced person. The experienced person has the SPC built in his head, he has also got control limits in there, he may not be able to spell out exactly what it is, but he will be able to tell you, it is only under these conditions that, I will touch, or I will give it to the steering wheel, otherwise I will just hold it steady, your process should run like that, like an experienced driver.

Your process in control is right for the next stage, which is like break through improvement which is what you will be doing when you go to six sigma, you need to have these break through improvements, and for that the tool is obviously, SPC is not enough, SPC will do the monitoring for you, it will setup the candidates, sort of setup the occasions for you to come in and intervene and do your you know troubleshooting and so on, remove the assignable causes. But what you need there is, more powerful method which is design of experiments. I will be studying some of these things, we will looking at some of these things, and of course, a process will always have some chance variation, it is not true that we do all these things and you remove every kind of variation from the process, that is not true.

In fact, if it turns out that the variation that we have left, after removing all the assignable causes, all the vibrations all the tool breakage, all the you know poor training and so on. Even after you remove all those things, they are still are going to be some sources of variations, those are going to be too expensive, to kind of controlling the plant itself; for that, you need like a technological jump, which is like finding justification for going towards six sigma as an example.

If you are trying to reduce the natural variation of the process, you got to go up on technology, that is very important, and that must be justified economically, it probably should you know consider getting into. For example, if you are producing bearings as an example, bearings are used in our roller skates, bearings are used in you know various types of appliances, bearing bearings are also in automotive, bearings are used in for example, you know access of a two wheelers for example, and bearings are also used in aerospace applications and these are all different types of bearings. The ones in roller skating can tolerate a lot of variation, the parts do not really have to fit in exactly, the the the clearance within a bearing does not really have to be that precise with the applications only applications only rolling around town for example, roller skating around town, when it come when it comes to two wheelers, motor cycles for example, it is got to be a little better and these are rated by the bearing industry bearings industry. And then of course, if you are trying to reach even higher, you are going to machine tools, your bearings have to be even better and the ultimate is the same, the bearing that will look about the same, it may cost 50 cents for a roller skate, it may cost 2000 dollars for a aerospace application and they would look just about the same, but the difference is in the capability of the machines that have done it, the precision which the process was controlled to deliver the final product and of course, the durability and the rest of it.

Because parts that are defective, they are not good for a last long time either, because they do not fit very well, they kind of rub on to each other and they create trouble for each other to coexist. I really appreciate this chance to be able to talk to you about control charts. we have many other tools. that I will be bringing out one after the other. And of course, one of the big one is going to be our design of experiments which I will be doing in some short time with you, thank you very much.