CHAPTER 3

Process Capability versus Process Control

This first part of chapter is talking about the process performance and process capability, short term and long term data and the conclusion between control and capability charts. The second part shows the current problem and its analysis.

3.1 Causes of variation

In the production process, some amount of natural variability will always exist. This natural variability is cumulative effect of unavoidable causes. In statistical quality control, this natural variability is called a random cause of variation. A process with only random cause of variation is said to be in statistical control. Another kind of variability may be presented in the output of the process. This variability is usually arises from three sources, machines, operator, and raw material. This variability is generally large when compared to the background noise. The causes of those variables are called assignable cause. A process that is operating in the presence of assignable causes is said to be out of control.

3.2 Process capability and process performance.

Process capability and process performance are to assess a process relative to specification. A customer might set a process capability targets and ask the suppliers for the level of conformance to the targets.

Process Capability is the 6σ range of a process's inherent variation, for statistically stable process only when σ is usually estimated by $\frac{\overline{R}}{d_2}$

Process Performance is the 6σ range of a process's total variation, where σ is usually estimated by s, the sample standard deviation.

The index below shows the description of each symbol used in this chapter.

C_p is the capability index which is defined as the tolerance width divided by the process capability, irrespective of process centering. This described the allowable tolerance spread to the actual spread of the data when the data follow a normal distribution. This relationship is

$$C_p = \frac{USL - LSL}{6\sigma}$$

Where USL and LSL are upper specification limit and lower specification limit and 6σ represent the range or spread of the process. The standard deviation, σ_{ST}, in this equation calculates from short term data which will be described later in section 3.3.

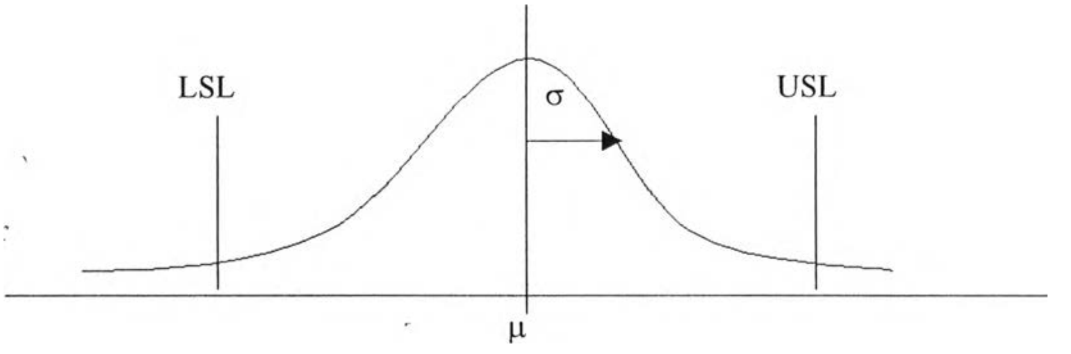

Figure 3-1 Normal distribution curve.

C_{pk} is the capability index which accounts for process centering. It relates the scaled distance between the process mean and the closest specification limit to half the total process spread which can be calculated by the minimum value of 2 quantities.

$$C_{pk} = \min\left[\frac{USL - \mu}{3\sigma_{ST}}, \frac{\mu - LSL}{3\sigma_{ST}}\right]$$

P_p is the performance index which defined as the tolerance width divided by the process performance, irrespective of process centering. Typically, this is expressed as the tolerance width divided by six times the sample standard deviation. It should be used only to compare to or with C_p and C_{pk} and to measure and prioritize improvement over time, sometimes called long term capability or performance index. The calculation formula was shown below.

$$P_p = \frac{USL - LSL}{\sigma_{LT}}$$

Where other values are the same as C_p except σ_{LT}. This σ is calculated using long term data (see section 3.3).

P_{pk} is the performance index which accounts for process centering by the same sense as C_{pk} and to measure and prioritize improvement over time. The calculation formula was shown below.

$$P_{pk} = \min\left[\frac{USL - \mu}{3\sigma_{LT}}, \frac{\mu - LSL}{3\sigma_{LT}}\right]$$

The intent of process capability is not to address directly how well a process is executing relative to the needs of the customer. Process capability considers short term variability. A long term variability assessment attempts to address directly how well the process is performing relative to the needs of the customer.

Process capability indices C_p and C_{pk} typically assess the potential short term capability by using a short term standard deviation estimate. On the other hand, P_p and P_{pk} typically are long term capability by using a long term standard deviation estimate while sometimes P_p and P_{pk} are referred to process performance.

Z- Distribution The capability can be described using the distance of the process average from specification limits in standard deviation units or Z from the standardized normal curve. The calculation formula for this Z value was shown below.

$$Z_{USL} = \frac{USL - \mu}{\sigma}$$

$$Z_{LSL} = \frac{\mu - LSL}{\sigma}$$

When a process is in statistical control and is normally distributed, calculated Z values can be used to estimate the proportion of output beyond any specification. When talking about Z score, we are normally talk about minimum Z score. There is a relationship between C_{pk} and P_{pk} with Z score was shown below

$$C_{pk} = \frac{Z_{\min}}{3} \text{ for short term data}$$

$$P_{pk} = \frac{Z_{\min}}{3} \text{ for long term data}$$

3.3 Long term and Short term data.

The chart that shows the quality of the products was simulated and shown below to make the concept of σ in each calculation clearer.

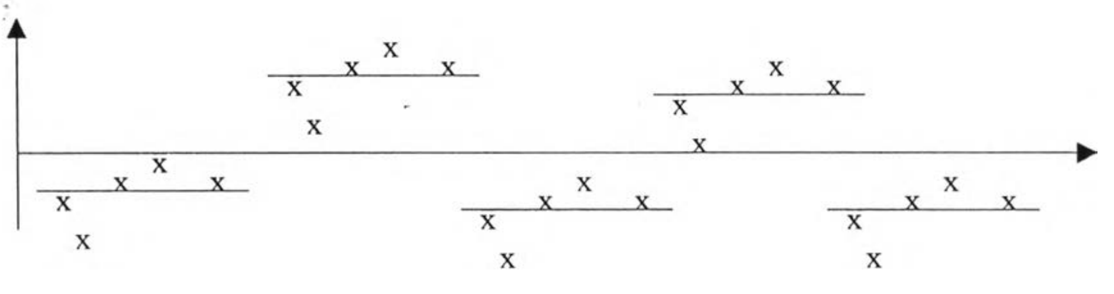

Figure 3-2 The plotted of raw data

The variance of the overall process can be calculated by the formula below

$$\sigma^2 = \sigma^2_{within} + \sigma^2_{between}$$

When $\sigma^2_{between}$ is the variance between subgroup and σ^2_{within} is the variance within subgroup. For simplicity, let's assume that every subgroup has the same size. The calculation formula of σ^2_{within} was shown below.

$$\sigma^2_{within} = \frac{\sigma_1^2 + \sigma_2^2 + \ldots\ldots \sigma_n^2}{n}$$

As stated above about the calculation of σ that the total σ have to consist of both within and between subgroup. The point that is the different point between short term and long term calculation was shown below.

For short term data, the $\sigma_{between}$ was considered to be equal to 0, so the value of total σ is only based on σ_{within}.

For long term data, the σ is concern in both $\sigma_{between}$ and σ_{within}.

3.3.1 Type of process that considered as has short term data.

The process that is considered to have short term data may have the situation as listed below.

- Free of assignable cause.
- Represent the effect of random cause only.
- Collected across a narrow inference space.
- Across one shift of production.
- Using only one machine.
- Using only one operator.
- Using raw component from only one lot of material.

From the criteria above, it can be seen that very few process have ability to provide true short term sample.

3.3.2 Type of process that considered as has long term data.

The process that is considered to have long term data may have the situation as listed below.

- Reflects the influence of random causes as well as assignable cause.
- Taken across a broad inference space.
- Across many shifts of production.

- Using many machines
- With many operators
- Using many lots of raw material.

In most process, the data that is collected is close to long term data.

3.3.3 Process capability of the collected data

From appendix, the process capability of this manufacturing process can be calculated from the estimated Z value. As seen in section 3.2 that the process capability and Z value has relationship to each other. The data came from many sifts of operation, many machines and many operators. Thus, from the criteria that explained in section 3.3, we can conclude that data used in this research is long term data.

The calculation process is shown as listed below.

1. Calculate average process mean. From the data in appendix, the average of the overall data is equal to 0.196.
2. Find the Z level of this value by looking at the Z table. Thus, Z is equal to 0.804. It means the USL or LSL of the process is 0.804 σ away from process mean by assuming that process are on target that is mean is at center of specification limit.
3. Therefore,

$$Z = \frac{USL - \bar{x}}{\sigma} = \frac{\bar{x} - LSL}{\sigma} = 0.804$$

When compare with the definition of P_{pk} in section 3.2,

$$P_{pk} = \min\left[\frac{USL - \mu}{3\sigma_{LT}}, \frac{\mu - LSL}{3\sigma_{LT}}\right]$$

Then we can conclude that P_{pk} can be approximated from Z level by

$$P_{pk} = \frac{Z_{\min}}{3} \text{ for long term data}$$

From the data that is calculated above, the P_{pk} is equal to 0.804/3 = 0.268

3.4 Capability and Control Process.

From section 3.2, the definition of process capability (C_p and/or P_p) and process performance (C_{pk} and/or P_{pk}) require specifications (USL and LSL). In creating control chart, 3 lines are defined, i.e., Upper control limit, lower control limit , and center line. All of these lines are calculated from process (collected data), not the specification. Since control limits has nothing related to specification. Therefore, no relationship exists between control and capability chart. In fact, one can show that the following conclusions between control and capability charts, i.e.

1. Process in control and capable. This chart shows the process that all data align in control limits and does not have any point out of specification limits shown in figure 3-3.

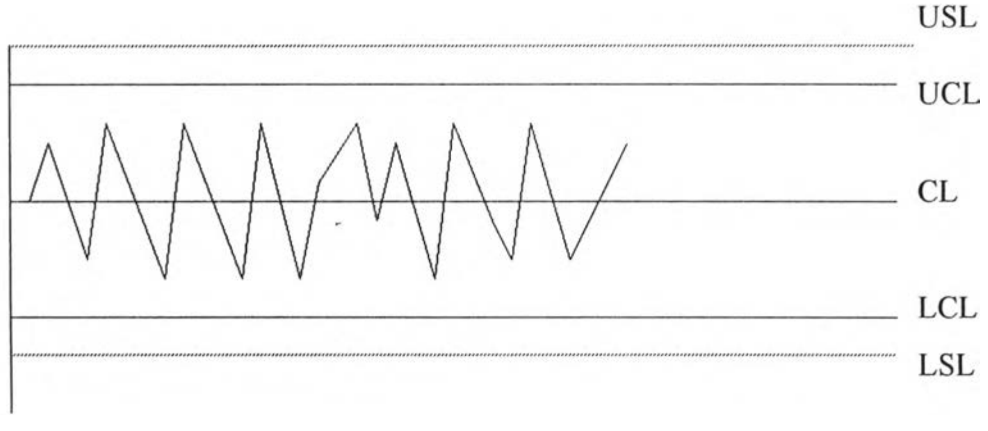

Figure 3-3 Control chart that shows the in control and capable process.

2. Process in control but not capable. Figure 3-4 shows the process that all the variables are in control but have some points out of specification.

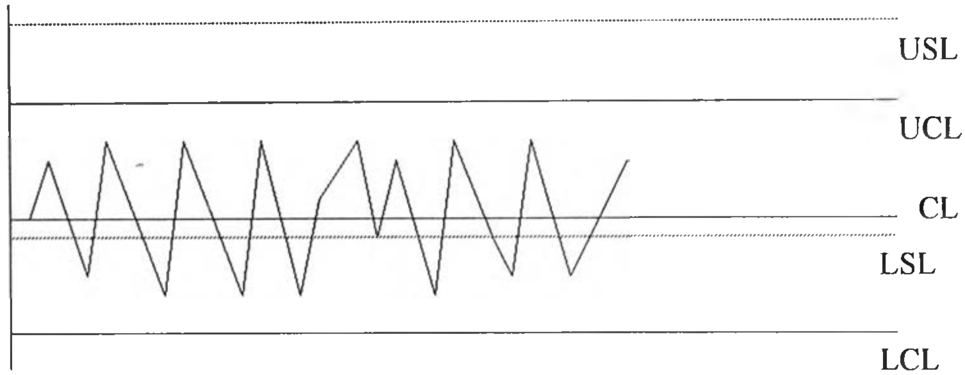

Figure 3-4 Control chart that shows process that in control but not capable.

3. Process out of control but capable. The chart shows the alignment of data that has some points out of control but still in specification limits in figure 3-5

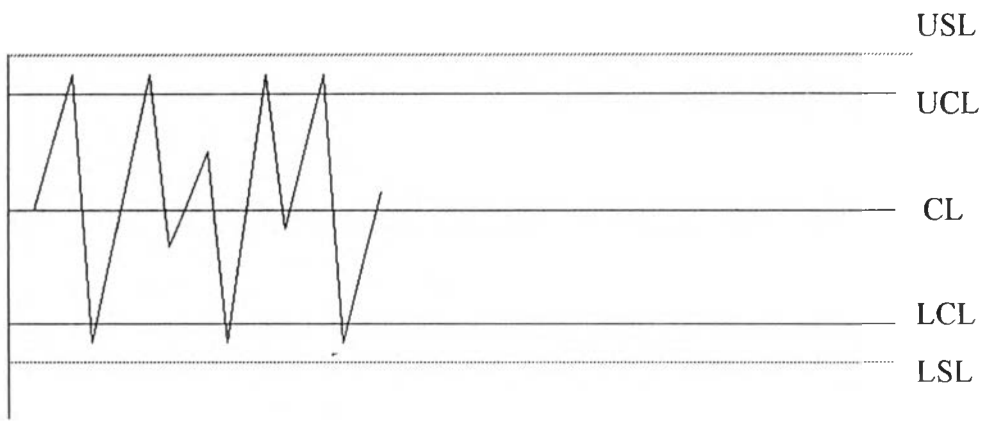

Figure 3-5 The process is out of control but still capable.

4. Process is not capable and out of control. The chart that shows process that is out of control and align beyond the specification limits shown in figure 3-6.

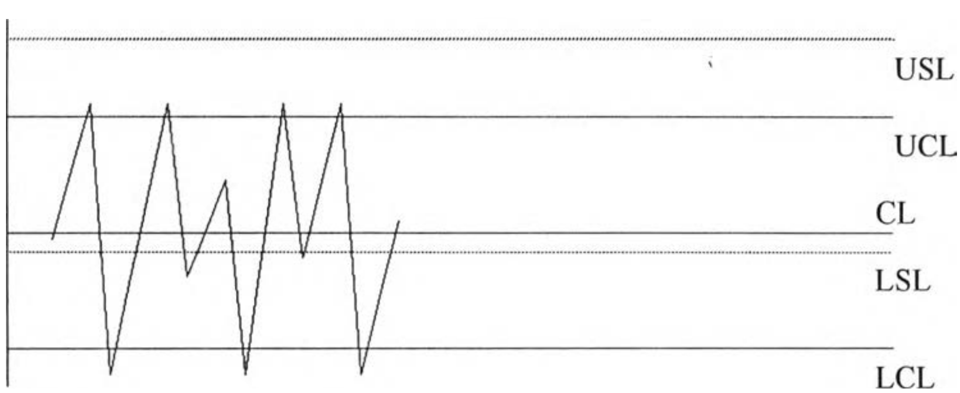

Figure 3-6 the process that out of control and not capable.

3.5 Existing problem.

The case factory is a harddrive manufacturer. The problem is about the test performance of the electrical tester in test department.

3.5.1 Current method.

Head Gimbal Assembly manufacturing process

The HGA manufacturing process chart is shown in the flowchart below. From the flowchart, we can see that the electrical testing process is one of the important in the process.

Electrical Tester

Head Gimbal Assembly or HGA is one of the very important component of hard drive which consists of 3 main components which are slider, flexture, and wire. The testing on HGA is first done by testing on wafer which will be transformed to be a slider. At this process, the wafer is tested by static test.

The next process is to test whether the flexture can fly on the disc or not. At this stage, there are 2 testing processes, the fly height test and electrical head response test.

Fly height test is done by the fly tester used to test the ability of flying when composed on flexture.

The electrical tester is the tester used to test the response of HGA on the media when the signal is sent to the HGA to write on the disc and when send signal back from HGA.

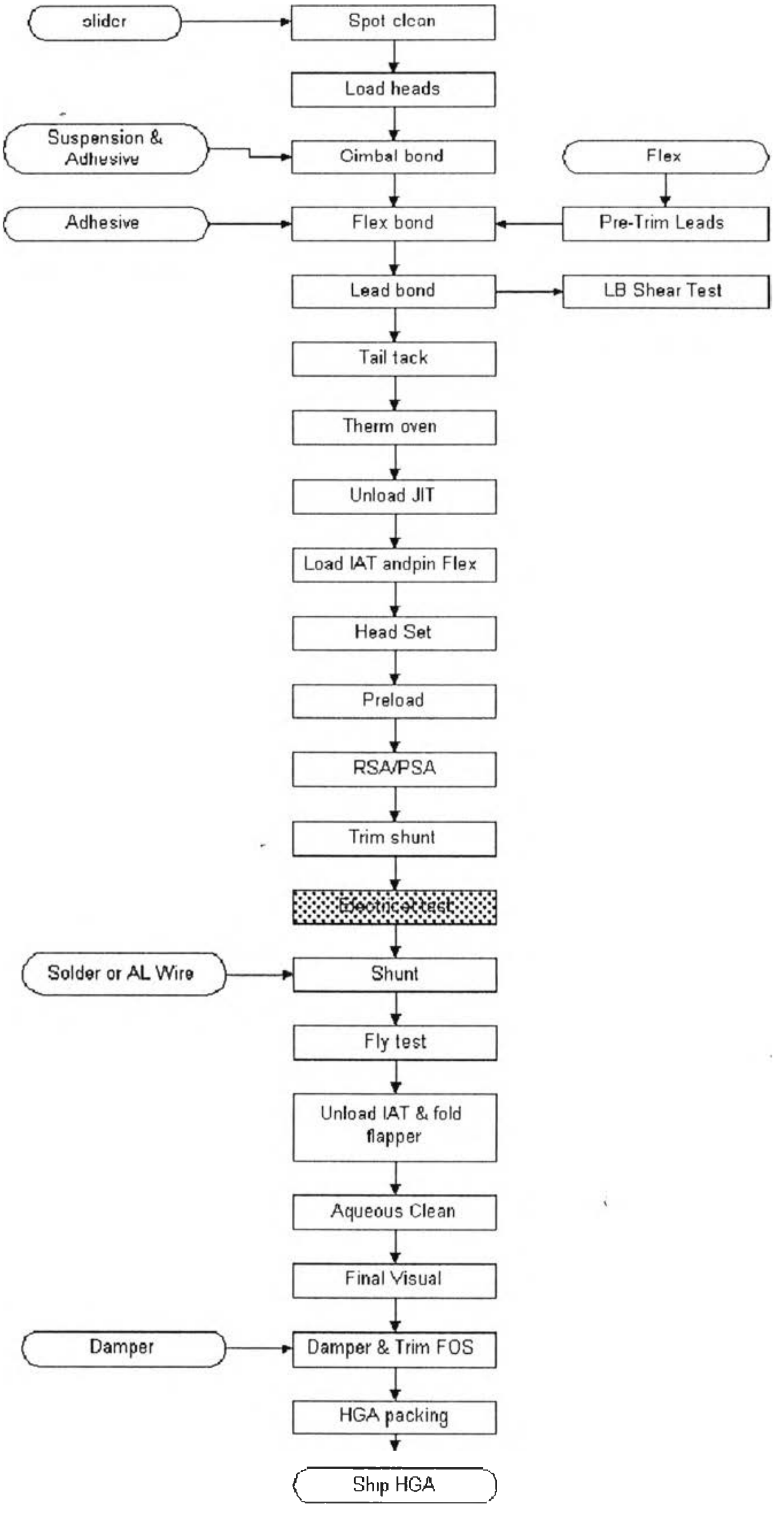

Figure 3-7 Operation flow chart

3.5.2 Current test procedure.

- The current method is to test 50 HGA every hour.
- Find the mean value of the pass percentage of this 50 HGA.
- Plot in p-chart.

The important point in this current situation is the data used to calculate the control limits of this chart. They didn't use the current data to calculate control limits. They use data of last 2 shifts to calculate control limit and detect the point that beyond the control limits in real time process. The control limits will be changed every shift. This will help engineers to visual the process by looking at the point that beyond the control limits and take action at that time. The problem at this point is the recalculate of control limits at the current situation may not be the most efficient way to do. So, this research is to find the most suitable point of time to recalculate control limits with supported theory which will give the most efficient result.

There are a lot of factors in the Electrical testing process and also the test is done with many testers in the same time, also the fraction nonconforming is not low. That's why SPC will be useful in this stage.

3.6 Problem analysis.

In the existing system of electric tester for the HGA manufacturing line, the company use a software to calculate it.

This software is current used to automatically calculate the control limit of p-chart and will recalculate the control limits continuously.

3.6.1 The calculating procedure of the existing system.

1) Set up control chart for nonconforming by using the data from the last 2 shifts to calculate center line, Upper Control Limit, and Lower Control

Limit. The calculation of control limits is using the range of 0.7σ from the center line. The calculation is using the formula shown below.

$$UCL = \bar{p} + 0.7\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$
$$CL = \bar{p}$$
$$LCL = \bar{p} - 0.7\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$\bar{p}$ in this calculation represents the fraction of nonconforming items

2) Transform the nonconforming center line, Upper Control Limit, and Lower Control Limit to the conforming value by using the formula below.

Fraction for conforming Fraction for nonconforming

$$\text{Fraction for conforming} = 1 - \text{Fraction for nonconforming}$$

3) Collects data for every hours from 50 Electrical Tester.

4) Calculate the percent of conforming parts which is calculated by the parts passed the test divided by all tested parts multiply by 100. The formula for calculate the percent of conforming parts is shown below.

$$\frac{\text{parts the pass the test} \times 100}{\text{all tested parts}}$$

5) Plot the percent of conforming parts in the chart.

6) The points that have lower yield than the control limits will be indicated in the computer screen of the engineer for them to go into the production line to take action immediately. This is due to there must be anything wrong in the production line or the testing equipment.

7) If there is nothing wrong in the testing process, the computer screen will indicate the percentage of conforming parts as a normal colour. The engineer does not have to do anything with the process.

8) After the end of the shift, the control limits will be calculated again by using the data of the last 2 shifts. So, the control limits and centerline of the charts will be set as a new control chart. This means the control charts will be changed in every shift.

3.6.2 Advantages of the existing system.

- It can detect the point that beyond the control limit to let the engineer goes into the production line to take action immediately. This is because the detection system of the program will indicate and warn the engineers on the computer screen about the points that has low yield immediately.

- It can simultaneously calculate the control limits. Due to the description above, the calculation of the control limits and centerline will be done in every shift by using the data of last 2 shifts, the control chart will be set up every shift of the manufacturing system. This will ensure the system that the control limits will be set up due to the data of the latest manufacturing components.

3.6.3 Disadvantages of the existing system.

- Due to the logic of the system shown above, this system will recalculate the control limits and centerline in every shift, no matter anything or any change has occurred in the system or not. If there is any change in the process such as the machine changing or newly trained operator that will make the points lower than normal points, the calculating of the next 2 shifts control limits will be difference from the normal control limits. This is not a good control system in the SPC way.

- This system will only detects the low percentage points of the conforming parts, not the high percentage points. This is not a good way of control the process because not all the high fraction conforming points are attributable to improved quality. It may represent the errors in testers.

- The logic of computing control limits, centerline, and also the data that used to calculate them are not the way that has any statistical theory support the way of calculating. The reconstruct of control chart in every shift by assume that its mean has shifted in every shift of operation may not be correct. This has not been proven by any statistical hypothesis.