Introduction to Control Charts

**Highlights**

Control charts can help you prevent defects before they happen.

- The control chart tells you how the process is behaving over time. It's the process talking to you.

- Control charts include the control limits, which represent the amount of variation that can be expected if only natural variation from common causes were present in the process.

- If the process is not under control, a control chart will indicate or signal a process shift or change.
There are certain rules that govern how control charts are used.

- A process may be shifting if a data point falls above the upper control limit or below the lower control limit.
- A process may be shifting if a run of eight consecutive data points in a row falls either all above or all below the process average line.
- Your team may use or choose a different rule depending on your process. The rules may vary from process to process.

When the process is ready, you will use the SPC Implementation Process.

- The three steps of the SPC Implementation Process are: collect data; control by eliminating special causes; and improve capability by reducing common cause variation.

Once you know that the variation is due to special causes, you can investigate the causes and then take action to bring the process into control.

- The control chart tells you whether the variation that exists in the process is from common causes or special causes.
- You and the SPC team can take action to rid the process of these special causes.
Terms Defined in the Glossary

- Process average
- Control limit
- SPC Implementation Process
- Control chart
- Run
- Stability
What is a Control Chart?

The control chart, or SPC chart, is a simple but powerful tool. Control charts can be used at the workstation on the manufacturing floor by an operator to detect special causes of variation when they occur. They also reflect the extent of common cause variation or the pattern of fluctuations caused by the equipment and the system.

This information forms patterns in the control charts, which helps the operator to understand how the process is behaving. The operator can investigate and then take some appropriate action to correct the process if the chart shows special causes.

Here's what a basic control chart looks like:

![Control Chart Diagram]

**Parts of the control chart**

Although there are many types of control charts, they all consist of the same basic parts, which are drawn on the chart to aid analysis.
As you can see from the example, control charts contain:

- A **process average**, or middle. This is the same as the central tendency on a histogram.

- The **upper and lower control limits** for the process. These control limits are a function of the "spread" of the pattern created by the stable and regular fluctuations in the equipment and system. The data points should fall between these control limits, although if the process is shifting, they may not.

Remember, it is important that you know that *control limits are not the same as specs*.

Let's briefly review the steps in completing a control chart:

1. A control chart starts with the selection of an appropriate parameter to control.

2. Data is then collected over a period of time.

3. This data is given to the SPC expert, who uses it to calculate control limits.

4. The process averages and control limits are drawn onto a chart. The chart is then regularly used by operators to plot data.

5. Operators then analyze the control chart to determine if there are special causes operating in the process.
**Control limits**

Control limits are related to the spread we saw in a histogram. They are calculated *from the data points*. They give us a picture of where the process would be if it were running in control -- affected only by its own variation.

Control limits represent the amount of variation that could be expected if only natural variation from common causes were present in the process. Said another way, the control limits reflect the stable pattern the data would make if only common causes were affecting the fluctuations of data.

**Control limits vs Spec limits**

The upper and lower control limits are *not* the same as spec limits, which usually come from Engineering. Inspection makes sure that the product meets specs -- which are the minimum requirements for the product if the product is to be accepted by the customer or the next process.

Again, control limits show us the normal ups and downs of a process. Specs come from *outside the process*, while control limits come from *the process data itself*.

**How are control charts used?**

Once you know how to read control charts, they can become a very powerful tool for you because they can tell you if your process is under control. *If the process is not in control, a control chart can help you control it.*

Unlike a histogram, control charts help an operator record data *throughout the process*. As the process runs, data for an operation or parameter is plotted on the chart. These data points can be such things as the dimensions of a machined piece, the number of defects on a circuit board, or the percentage of boxes failing an electrical test.
The data point is compared to the control limits. If the variation moves up and down between the control limits, we say that the process is **stable**, or in control. It would look something like this:

![Control Chart Diagram]

The up-and-down fluctuations are coming from common causes -- an ordinary part of a stable process. Remember that common causes tend to produce regular variations.

If we plot the data and it starts going *outside* the control limits, then the process is no longer stable. It is shifting because of some special cause. Remember that special causes tend to produce unusual or irregular variations.
When a control chart looks like this, we say the process is **shifting**, or **out of control**:

![Control Chart Diagram]

In this way, control charts are the process talking to you, telling you whether special or common causes are making an impact on the process. *This helps you fight variation.*
What Are Control Charts Used For?

**Control**

A control chart can tell you if a process is or is not stable or "in control."

**In control / stable**

If data falls regularly between the upper and lower control limits, the source of that variation is due to common causes.

If a process is **stable** or **in control**, its behavior in the near future is predictable. A stable process is consistent over time: consistent with respect to the process average and consistent with respect to dispersion. Here is an example of a chart with a process that is in control:
When a point on a control chart goes outside the control limits, it tells us that the process may be shifting. In addition, the same is true when there is a run of eight consecutive points in a row, either all on one side or all on the other of the process average.

Again, the process average is the central tendency of the process. As with any central tendency, it has to have data on both sides of it. Too much data on one side means it's no longer a true central tendency. The process has shifted. Consider this control chart:

As a rule of thumb, we say that a run of eight consecutive points in a row either all above or below the process average is evidence of a shift in the process. The SPC expert on your SPC team may use a different number, but for our purposes we'll use eight.
Data outside the control limits, or violations of the rule of eight, means there is more variation in the process than expected, or that shifts in the process have happened. This is due to some special cause. Operators can often take action at their workstations to reduce or eliminate these special causes when they occur. For example, they look at such things as the raw materials and production methods the process is using.
Control Chart Rules

*Shifting process*

A process may be shifting if:
- A data point falls above the upper control limit.
- A data point falls below the lower control limit.
• A run of eight consecutive data points in a row falls above the process average line.

Although these are not universal rules, and there may be exceptions, they will be our standard for this course.
How Are Control Charts Used?

When your process or tool is ready for SPC, you and your SPC team will choose what parameters to monitor. (You may decide to look at either variables or attribute data.) When you record this data on control charts, you will be using a three-step procedure called the SPC Implementation Process.

SPC Implementation Process

The SPC Implementation Process has three steps. The steps are:

1. Collect data from the process (because the SPC expert will need to calculate the control limits).

2. Control the special causes of variation through investigation and action.

3. Improve capability by reducing common cause variation.
First, you'll collect data from the process and record it at regular intervals. Soon, you will have enough data to tell you something about the process.

Then, you'll control the process by identifying and eliminating special cause variation.

- The SPC expert on your SPC team will calculate the mean or process average, and the upper and lower control limits -- which come from the data itself. These limits will be put onto a chart.

- You'll use the SPC chart at your workstation to monitor your process and detect special causes of variation. If you cannot identify the special causes, consult with the SPC team. If you can identify the special causes, take appropriate action to bring the process into control.

Eliminating special causes of variation may take some time. In fact, some special causes may never be totally eliminated; they'll continue to occur, so the control phase of SPC implementation will be an ongoing effort. However, when the process is under control during periods of relative stability, your SPC team and others can begin to examine how to improve process capability.
Reducing common cause variation requires an extensive examination of the process, the machines used, measurement systems, raw materials, and the like. To reduce common cause, all these parts of the process must work together better and more efficiently -- and with less variation. Changing these may mean, for example, costly new equipment and supplies or new work patterns or tools. Consequently, reducing common cause variation is a major undertaking, involving management, SPC experts, statistically designed experiments, and significant investments of time and effort.
What You Can and Can't Do with Control Charts

Control charts tell you when to take action and when not to. If a chart indicates a special cause of variation, you need to investigate the cause and, if you know what is wrong, do something about it. But, if all you see are common causes, you should leave the process alone until the SPC team and others have agreed how to improve it.

What not to do

While control charts are capable of tracking stable and shifting processes, there are some functions for which they are not intended.

Unnecessary adjustments

An up-and-down movement of data points between control limits is expected. You don't want to take action on a point in control. Attempting to eliminate these by adjusting the process each time a data point appears near the control limit will actually lead to increased variation. It is an unnecessary adjustment.
Here is what an unnecessary adjustment on a control chart might look like:

While variation between control limits is expected, data points outside control limits or in runs of eight are not. These represent special causes and should be acted upon. Ignoring these may lead to later difficulties in getting the process centered.

*Missed opportunity for adjustments*
Here is what a missed opportunity for adjustment on a control chart might look like:

The up-and-down movements of the points on a chart are to be disregarded unless the point falls outside a control limit. A point outside the control limit is a signal of a special cause of variability. So is a run of eight consecutive points in a row either all above or all below the process average.
What to do

When a point falls outside the control limits, there are some specific actions that can be taken.

Special causes, local actions

If you think there may be special causes, make an immediate check of the following. This check may lead to correcting obvious errors in adjustment or operation:

- The machine: Is it operating normally?
- The raw materials: Are they consistent with other batches?
- Your own actions: Have you forgotten to do something along the way?
- The methods being used: Are they correctly implemented?
- The environment: Are there any recent changes in temperature, humidity, lighting? Was there a shift change when the special cause occurred?
- The process itself: Is it operating normally? What has changed since the last operation?

After you investigate, if you are able to figure out the cause of the problem and are confident that you can correct it, then do so. If you can't correct it, talk to the SPC team. Don't forget to make a note of what action you've taken. The information may be helpful later on.
After you investigate, if you still don't know the cause, you should immediately do the following:

- Notify the SPC team (or follow the rules the SPC team has set down).
- When an action is taken, record the required information on a control chart.
- Make a list of possible causes that your investigation has eliminated. Share that list with your SPC team.

Let's look a little closer at the SPC team you will be working with. It typically may consist of these people working together to eliminate special causes:

*The SPC Team*

- Managers and supervisors
- Operators
- SPC expert
- SPC driver
- Manufacturing engineer
- Quality engineer
- Quality control
- Equipment engineer or maintenance personnel
- SPC program manager
Your SPC team will be formed after you complete this Starter Kit. You will play a role in implementing SPC into your process. You and your SPC team will meet soon to get organized and you'll be involved with deciding what parameters to measure, collecting data, and using control charts to correct special causes of variations.

After your first SPC meeting, you'll take the course "Selecting Parameters," in which you'll learn how to select which parameter to collect data from in your process.
Purpose
This activity will give you practice in analyzing data on a control chart.

Instructions
You have kept track of your miles per gallon for the past three months. At the top of the next page are the average miles per gallon for each week over these three months. In the space provided on the blank control chart, enter these numbers in the appropriate places. When you are done, answer the questions at the bottom of that page. Check your answers with those that follow.

The point
Although we cannot predict the "next single instance" in a process, we can look at a collection of data, plot it on a control chart, and predict what the next collection of data might look like.
### Control Chart for Average MPG

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#### Process Chart

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#### Control Chart Rules

1. Is the process shifting over time? (Check one)
   - ___ Yes ___ No

2. Control chart rules violated: (Check as appropriate)
   - ____ Point outside upper control limits
   - ____ Point outside lower control limits
   - ____ Run of eight consecutive points all in a row above the process average
   - ____ Run of eight consecutive points all in a row below the process average
1. Is the process shifting over time? (Check one)
   ___ Yes          √ No

2. Control chart rules violated: (Check as appropriate)
   ___ Point outside upper control limits
   ___ Point outside lower control limits
   ___ Run of eight consecutive points all in a row above the process average
   ___ Run of eight consecutive points all in a row below the process average
Attribute data
Data that can be counted, or recorded simply as yes/no, pass/fail, or go/no-go. Attribute data is often gathered as the number of defects, defects per unit, percentage defective, or number defective.

Average
The sum of a group of numbers divided by how many numbers there are. The symbol used for the average is a bar ( - ) placed over the letter, as in X bar or $\bar{x}$.

Capable/capability
The extent to which a stable process is able to meet specification.

Central tendency
The center or middle of a distribution, often described as an average or mean.

Common cause
A natural kind of variation that comes from the normal ups and downs of a process. When analyzing control charts it is seen as data points, all within control limits. (See also Special cause.)

Control chart
A graph of a process that has:
- Plotted data
- A process average line
- One or two control limits
It is used to help determine whether a process is stable as well as to aid in maintaining control.
Control limit

A line (or lines) on a control chart used to tell if a process is stable or shifting. A point beyond a control limit shows that special causes are probably affecting the process. Control limits are calculated from data collected from the process and are not to be confused with engineering specifications.

Data

A number or piece of information from a process. SPC data in this course can be attribute or variables data.

Detection method

A method of quality control in which products are checked for meeting specs after they are made. The defective items are then rejected. If the defect rate gets too high, the process is adjusted. In this method, parameters that help make the product are not monitored. This is an old-style method of quality control that tries to find a bad product after it has been made. (See Prevention method.)

Dispersion

The amount of spread in a distribution. Dispersion can be narrow and tightly clustered around the center. Or it can be wide, going out far on each side from the center.

Distribution

A way of describing the variation in a process or the pattern in a group of data. This distribution pattern can be described in terms of its:

- Location
- Spread
- Shape

Location is usually described by the central tendency (mean or average, or median). The spread is usually described by the standard deviation or the range. Shape involves things such as the number of peaks.
**Histogram**

A type of graph showing data values on one axis and frequency on the other. When plotted, the data forms a shape with a central tendency and a certain amount of dispersion.

**In spec**

Meets spec limits.

**Location**

Where the central tendency of the data is; often described by the average.

**Mean**

Average; often used as the label for the process average line on a control chart.

**Not capable**

The spread of a process that is too wide when compared to the spec limits.

**Out of spec**

Defective; nonconforming; does not meet spec limits.

**Prevention method**

A method of quality control that means using SPC to monitor and control many process parameters that go into making a product.

**Process**

A system of elements that work together to produce something.

**Process average**

The overall average of a set of values: the centerline on a control chart.

**Process spread**

How far data points go out on each side from the middle of a process.
**Range**

The highest value minus the lowest value in a sample. It is a way to describe spread, or dispersion.

**Run**

A consecutive number of points all above or all below the process average. It can be evidence that special causes of variation are at work if the run is eight or greater.

**Sample**

A small group of data taken at about the same time. In this course, it means the same as subgroup.

**Shape**

What a distribution looks like.

**SPC Implementation Process**

The series of activities including self-study learning and implementation meetings with SPC team members. Involves choosing parameters to control, collecting data, calculating control limits, and perhaps even improving process capability.

**Special cause**

A type of variation that is shown by a point beyond the control limits or a run of eight points within the control limits. It means something special has happened to the process to make it shift or change.

**Spec/specification**

The engineering requirement for judging if a part is good or bad. Specifications and spec limits should never be confused with control limits.

**Spread**

How far out from the middle the data points go on each side in a distribution.
Stability

A process is stable, or in control, when no special causes of variation are found on the control chart. (See also Statistical control.)

Statistical control

When all special causes of variation are gone and only common causes are left.

Statistical Process Control (SPC)

Using control charts to help keep a process stable and improve its capability. It eliminates special cause variation by finding the root cause of the problem.

Variables data

Data obtained from measurements. Examples include the diameter of a bearing in millimeters, the weight of a door in kilograms, or the length of a line in microns.

Variation

The difference between individual values in a process.