Problem Solving Tools
Instructor Guide

Note to Instructor

This primary knowledge (PK) unit introduces several of the tools that can be used to help solve problems in a manufacturing environment. Some of these tools are used by problem solving teams to collect and organize their data, while others are tools from which teams can extract data. This PK provides a brief description of each tool and at least one example. Many of these tools are used or could be used in the Problem Solving Activity that requires the participants to solve a MEMS Process Problem.

The control charts introduced here are explained in detail in the *Statistical Process Control Learning Module*. For the purpose of this learning module, participants only need to know how to interpret a control chart, not construct one, nor to plot the data.

The *Systematic Problem Solving Learning Module* consists of the following:

- Activity: Thinking Creatively
- A Systematic Approach to Problem Solving PK
- Brainstorming Activity
- Problem Solving Activity – The Lawn
- **Problem Solving Tools PK**
- Problem Solving Activity – A MEMS Process Problem

This Instructor Guide (IG) contains all of the information in the Participant Guide (PG) as well as answers to the coaching and review questions at the end of the unit. A PowerPoint presentation is provided for a classroom presentation. The PowerPoint is a summary of the PG.

Description and Estimated Time to Complete

There are many tools that are used to solve problems in a manufacturing environment. Some of these tools are constructed by the problem solving team to help gather and organize data. The Cause & Effect diagram is such an example. Other tools are used by the team to provide information or data that is needed to identify the root cause of a problem. This unit briefly discusses both types of tools. In both cases it is important that you understand the purpose of the tool and how to interpret.

<u>Time to Complete</u>
Approximately 30 - 45 minutes

Objective

- Given several types of charts, explain what information each chart provides.

Introduction

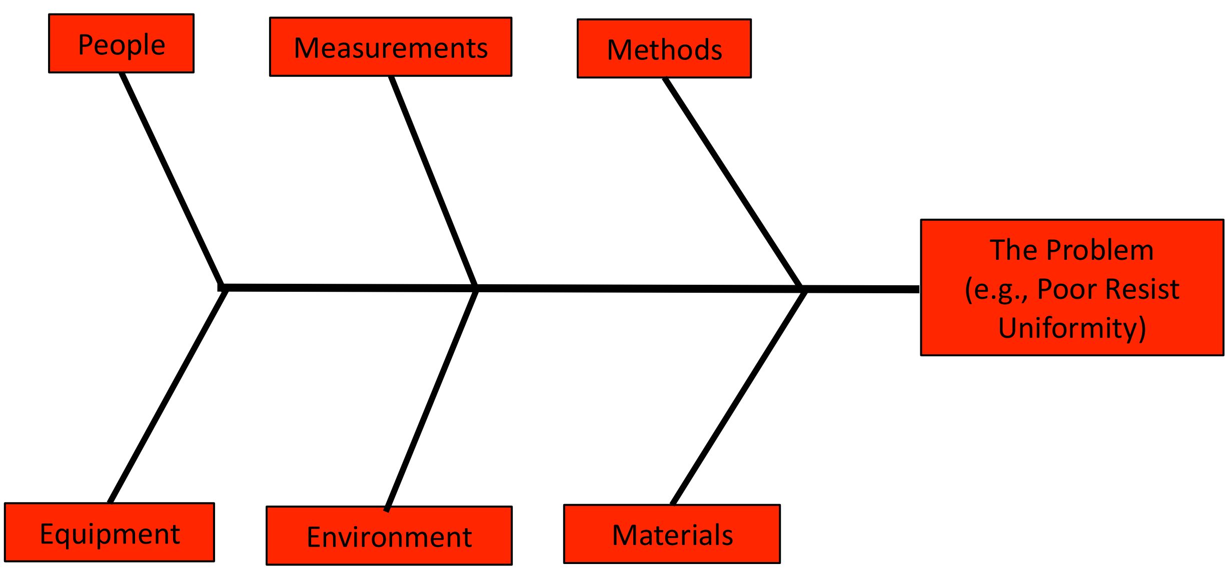
"A picture is worth a thousand words" so why not use pictures to help analyze a process. Many of these tools are pictorial representations of the problem or data that may be associated with the problem. Such tools include checklists, flowcharts, scatter diagrams, cause and effect diagrams, Pareto charts, histograms and control charts. Following are explanations and examples of each of these tools.

Cause and Effect Diagrams

In the 1960's Kaoru Ishikawa of Japan developed several problem-solving tools to be used by quality improvement teams. The cause and effect diagram was one of those tools. Other tools included checksheets, histograms, Pareto diagrams, control charts and scatter diagrams.

The purpose of a C&E diagram is to illustrate various sources or possible causes of a problem relative to specific areas (such as equipment and people) and identify relationships between different areas relative to the problem. It is a tool that helps the problem-solvers structure their ideas in specific categories and generate new ideas through brainstorming.

A C&E (also called an Ishikawa diagram or fishbone diagram) usually has five to six major stems or *fish bones*. In manufacturing, these fish bones are normally labeled *materials, methods, measurements, machine, personnel, and environments*, the six major areas that affect most manufacturing problems. The head of the "fish" is the Problem.

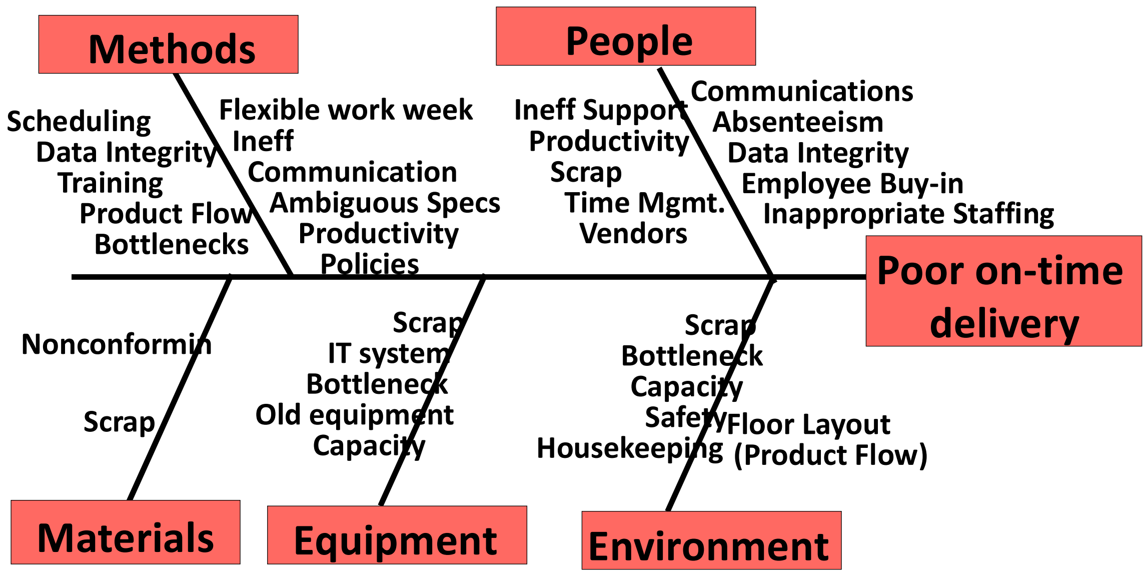


During the brainstorming session, team members generate possible "causes" under each heading that could have an "effect" on the problem. For example, if the problem is "poor resist uniformity" a possible cause could be "uncalibrated equipment" under "Measurements". As with any brainstorming session, the team continues to add "causes" to the diagram until no more can be generated. Once the diagram is complete, the data collected in Problem Solving Step 2 (Analyze the

Problem) is used to eliminate many of the possible causes. For example, maintenance records may show that the measuring equipment had just been calibrated, allowing the team to assume that this is not the cause of the problem.

The team continues to evaluate the C&E data until no more causes can be eliminated. The remaining causes are then prioritized from to the easiest to eliminate to the hardest to eliminate. More questions are asked and more data is collected until the root cause of the problem is identified.

The diagram below is an example of a C&E diagram that was generated by a team at an injection molding company to identify factors affecting "on-time delivery of customer orders".



NOTE: Measurements was eliminated for this particular problem because the team did not see a cause and effect relationship between measurements and poor on-time delivery.

Once the C&E diagram was completed, the team applied the information from its initial problem analysis and identified the causes by the *degree of effect* on the problem. The *degree* ranged from negligible to major effect. The final analysis identified the areas of *scheduling, product flow, and factory layout* as having the "most" effect on late deliveries. At this point, the problem-solving team began to develop solutions followed by action plans. (As an FYI – the team, working with management determined that changing the factory layout was impractical and costly. Therefore, the team tackled scheduling and product flow that was closely tied together. A new product flow chart was designed and implemented. After six months, on-time-delivery data was re-evaluated and was shown to have improved to accepted values.)

Checklist

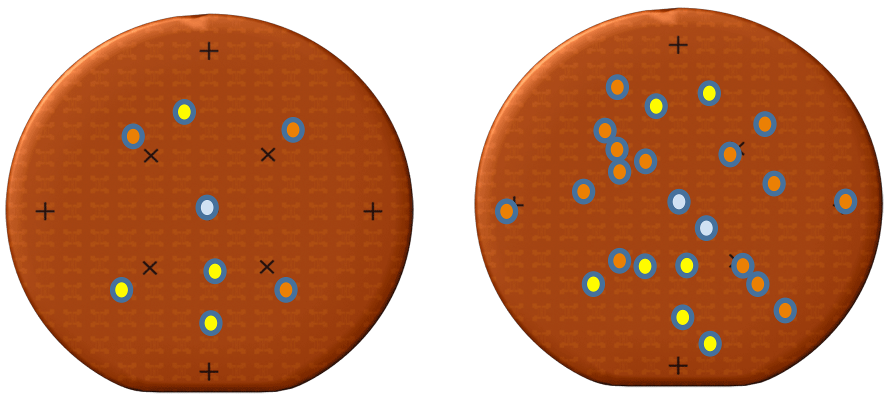
Checklists can also be used to get an accounting of a list of items or track activities. The checklist below provides information on the "poor on-time delivery" problem that was presented in the C&E diagram. This checklist was developed after Step 3 of problem solving when the team brainstormed for possible causes. Under the "People" bone of the diagram, the team listed these items. In order to see if any of these items was indeed a problem, an "item checklist" was made to show the number of occurrences for each item over a four (4) month period. Looking at this data, which items would you eliminate as being probable causes to the "poor on-time delivery" problem?

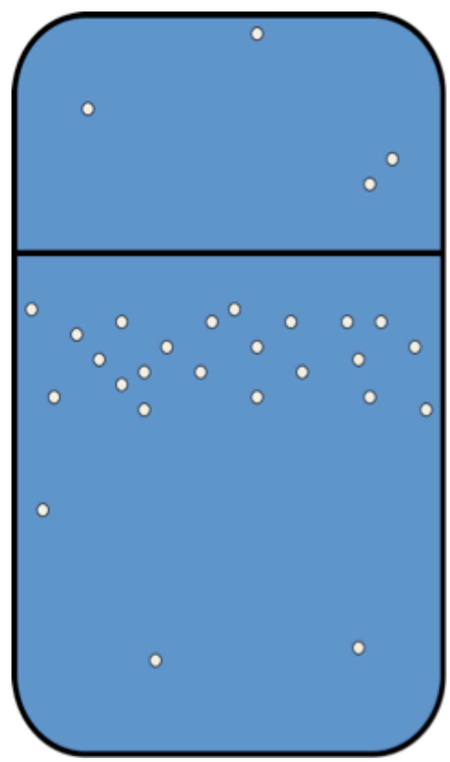
People	# of occurrences (last 4 months)
Retraining	14 people
Follow procedures	4 (failure to follow)
Absenteeism	18 hours / person (average)
New vendors	1
Data Integrity	3 (entry errors)
Promotions	4
New Hires	1

If you eliminated all but "retraining" and "absenteeism", then you are thinking logically. Obviously, one new hire, one new vendor, or only 4 promotions or failures to follow procedures in a 4 month period would probably not contribute to a reoccurring on-time delivery problem. However, having to retrain 14 people during that time period and having an average of 18 hours of absenteeism per person might be contributing factors. Further investigation is probably warranted. (See Pareto Charts)

Location Checklist

Another type of checklist is the "location checklist". The images below illustrate the location of particles on two processing wafers and their size (different colors represent different sizes of particles). The wafer on the left is from post-deposition and the wafer on the right is from post photolithography coat. The particle count on the left is acceptable but the particle count on the right is not. These location checklists make it quite obvious that there is a particle problem in the photolithography aisle and that the particles of the "pink" size are especially a problem. Knowing where the problem exists (photolithography), where it does NOT exists (deposition), and the size of the particles in abundance (pink), we have valuable information that can contribute to solving the problem.





Here is another location checklist. The diagram on the right was used to identify the location of paint scratches on refrigerators that were delivered to the customers and then returned due to surface scratches. Can you identify the cause of the problem by looking at this diagram?

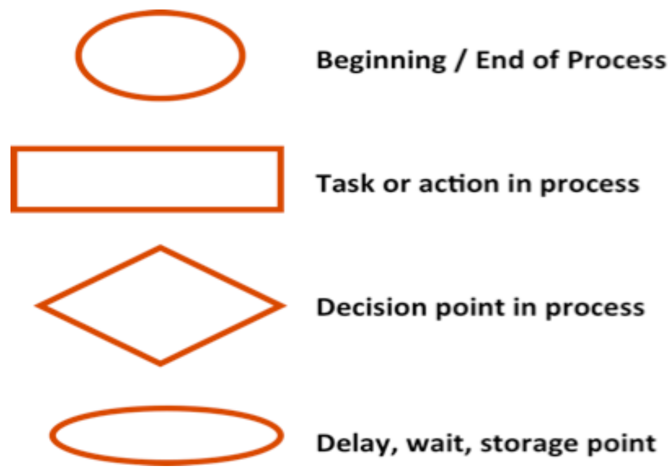
Note to the Instructor: Notice that most of the scratches are below the freezer and in the location of the belt when the refrigerator is secured on a dolly. It looks like the dolly belt is scratching the refrigerators.

Flowcharts

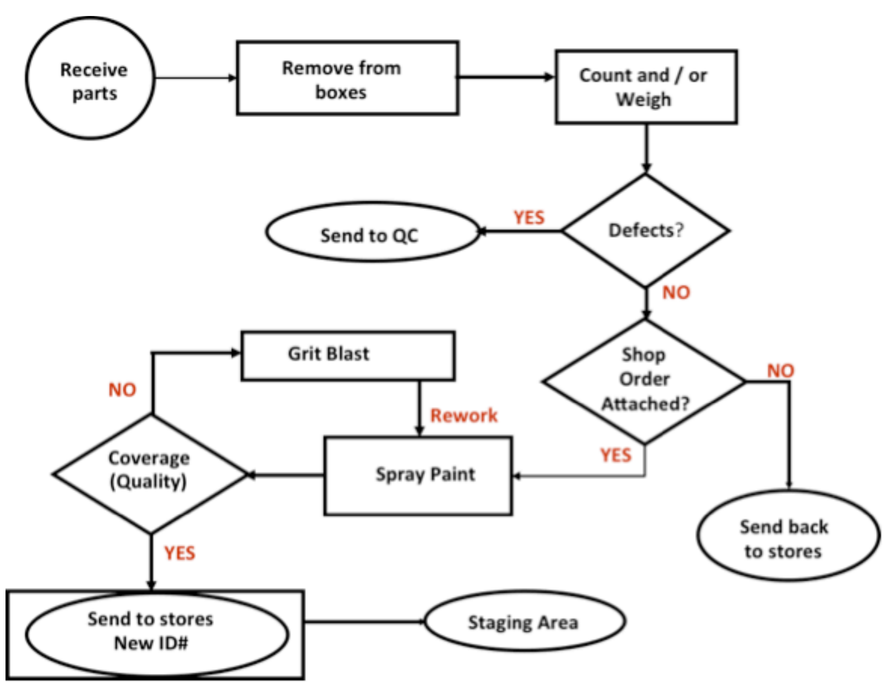
A flowchart is a pictorial representation of a process flow or procedure. It is basically a "roadmap". The objective of creating a process flowchart is to identify and layout the sequential steps of a process or procedure. Flowcharts are used throughout industries for a variety of purposes.

- Outline a standardized procedure for everyone to follow.
- Identify specific skills and knowledge necessary to perform each task listed in the flowchart.
- Identify steps that can be eliminated or rearranged for more efficient operation.

Let's look at an example. First of all, below are the standard symbols that are used in flowcharts and what each symbol represents.



Applying these symbols to a process flowchart (PFC) for a "Painting Process"…



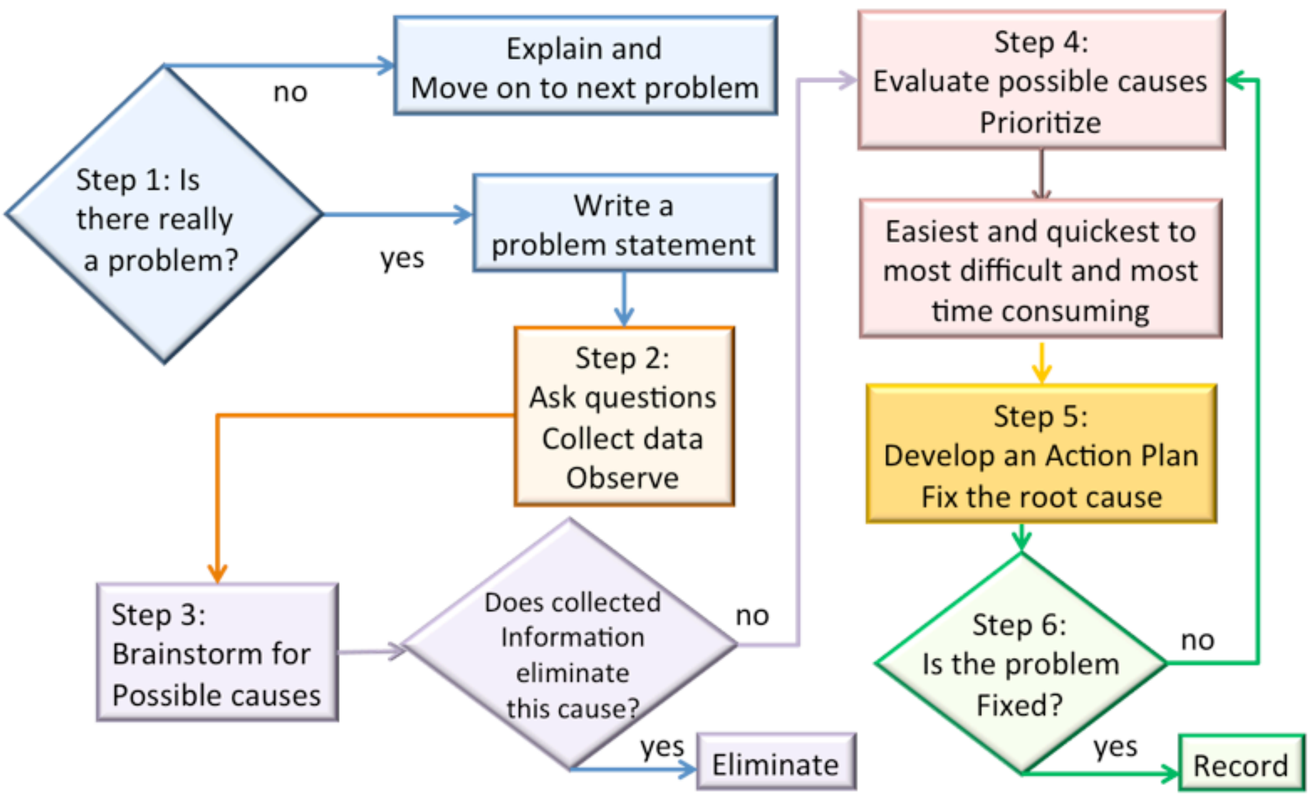
Referring to the "Painting Process PFC", do you see how a company could use this flowchart to identify areas of the process that require specific skills or knowledge? Identify a skill that would probably need training for a person to perform correctly.

Do you see how it could be used as the "standard" for the painting process and a process that EVERYONE should follow?

Do you also see, that when a process is outlined like this, that it makes it easier for the problem solving team to identify areas that could be eliminated, consolidated, or redirected?

Hopefully, you said "yes" to each of these questions. If not, then discuss this PFC with other participants or your instructors.

Here is another example of a process flowchart (PFC) that illustrates the Six Step Problem Solving Process.

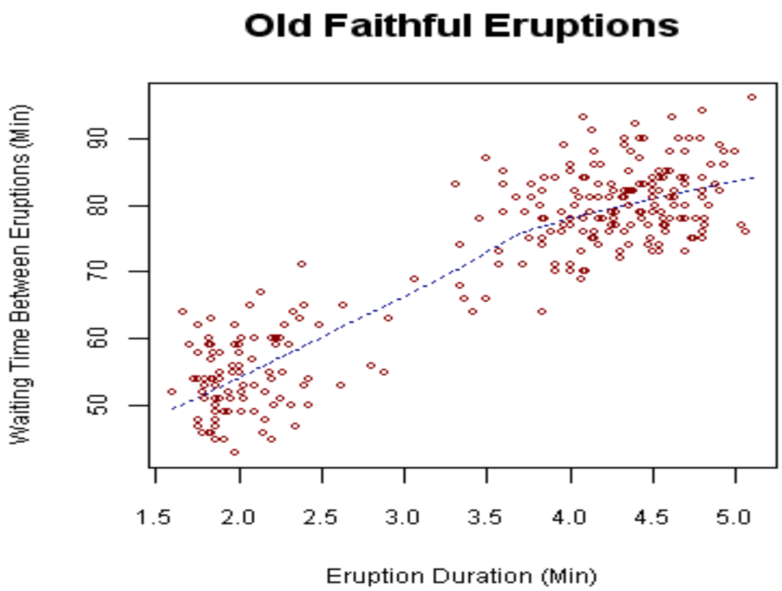


In this "Systematic Problem Solving Learning Module", you are following this exact process. This PFC identifies each of the six steps, what each step is, and points at which decisions need to be made.

Scatter Plots or Scatter Diagrams or Scatter Graphs

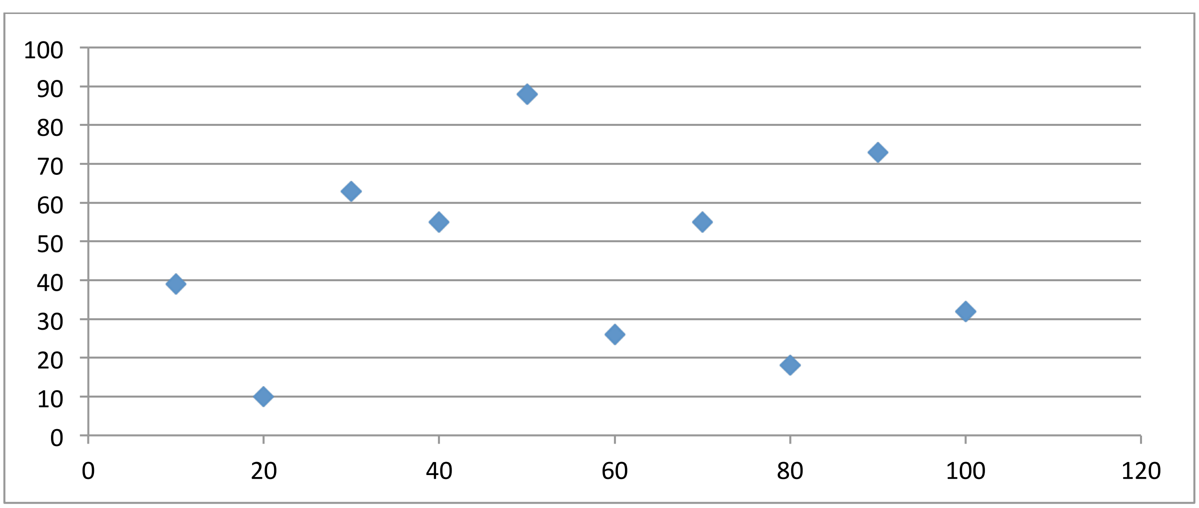
A scatter plot compares the relationship between two variables, usually on an x-y graph. Such a graph helps us to see the relationship between to variables (if one exists).

The scatter graph below is a comparison of the time between Old Faithful Eruptions (y-axis) and the duration of the eruptions (x-axis). What can you say about this comparison? *(This graph is in the public domain.)*



Note to the Instructor: This graph shows that the duration of an eruption is directly related to the time between eruptions. Notice that the shorter the time between eruptions (bottom left), the shorter the eruption time, and the longer the waiting time, the longer the eruption (upper right).

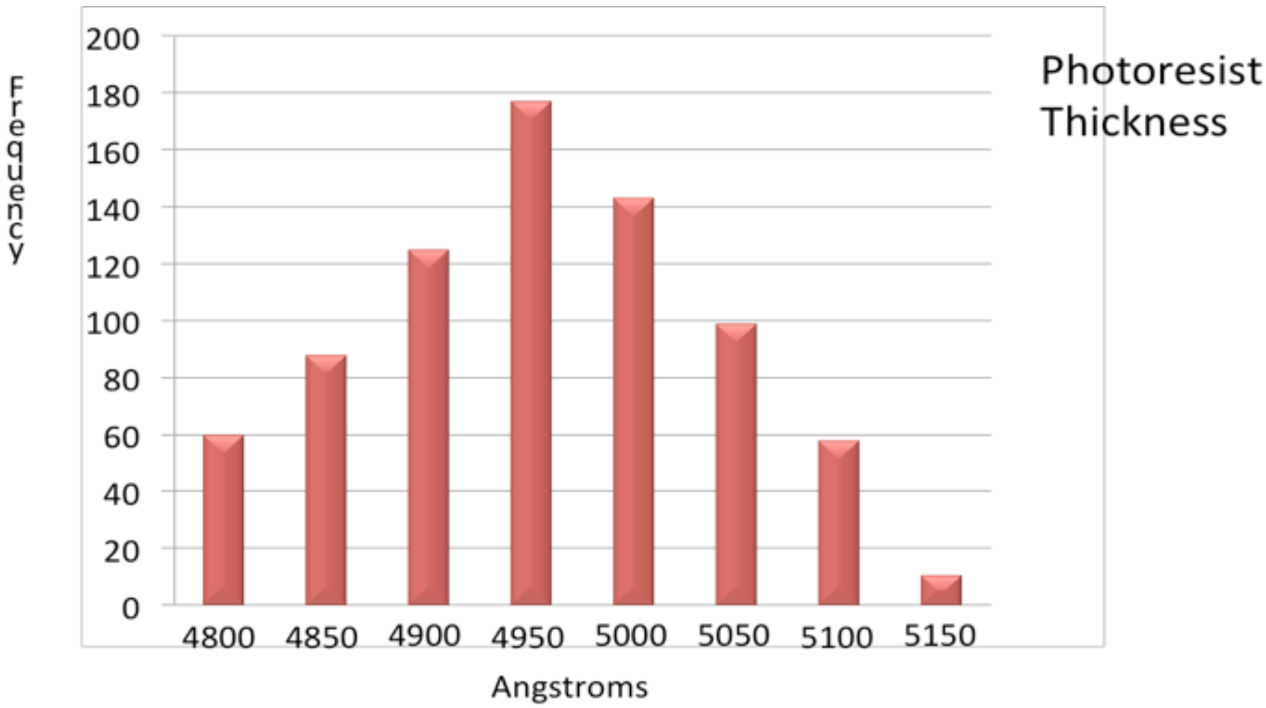
What type of relationship is show by the following scatter plot?



***Note to the Instructor** – This scatter plot shows that there is no relationship between the two variables. In other words, an increase in the y-axis variable does not result in a predictable change in the x-axis variable.*

Histograms

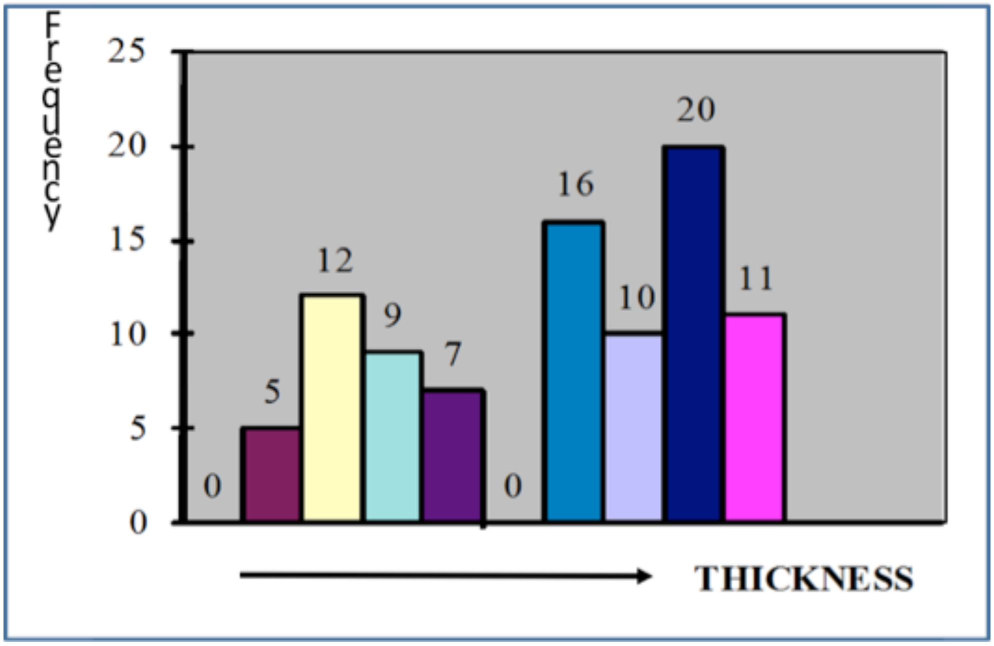
A Histogram is a graphical representation of the distribution the data. It shows the frequency of occurrences, and how the data is distributed. Below is a histogram that shows the photoresist thickness of 700 measurements. The x-axis is the photoresist thickness which is anywhere between approximately 4800 angstroms and 5150 angstroms (Å). The y-axis is the number of occurrences of each measurement. Approximately how many measurements were around 5050 Å? As an estimate, what would you say is the "mean photoresist thickness"?

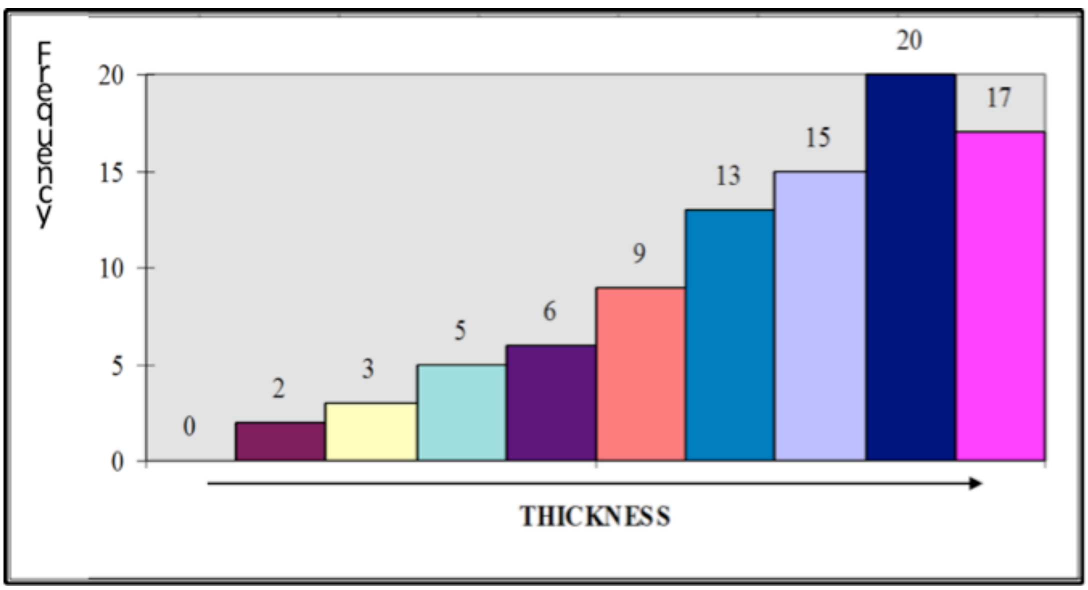


Note to the Instructor: *There are "almost 100" measurements around 5050 Å. The "mean photoresist thickness" can be estimated to be around 4950 Å.*

This particular distribution (above) is called the "normal distribution" or a "bell-curve" because it has the bell curve shape. Many manufacturing processes exhibit a normal distribution where there is a mean and the measurements outside of that mean are somewhat evenly distributed both above and below it (as shown). The mean of such a distribution is called the "target". This concept becomes very important in the understanding of control charts that we'll talk about later on in this unit.

Take a look at these histograms. What can you say about them?





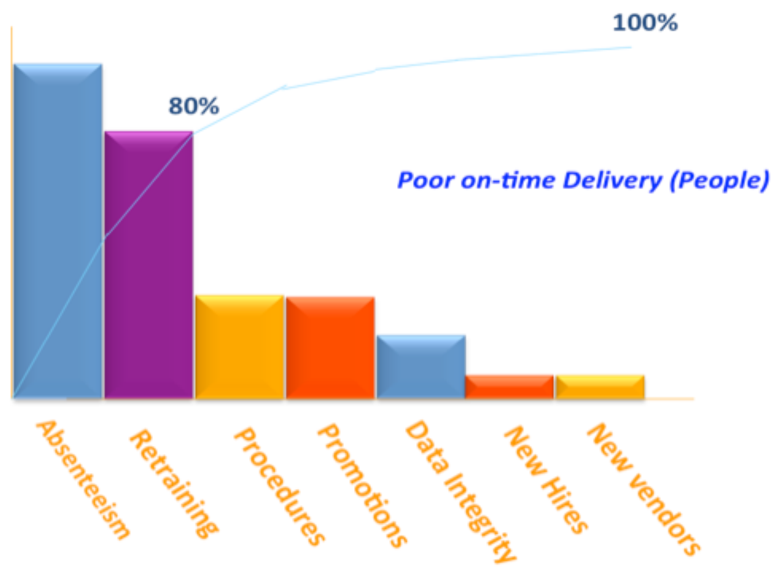
The first histogram is "bimodal", meaning that there appears to be two "mean" thicknesses in this process. In most cases, this is not desired. Can you think of a case in which such a distribution is expected or acceptable?

The second histogram shows a process that is "skewed", meaning that the mean is no longer centered as in a normal distribution. The mean is now skewed to the right (in this case) or "negatively skewed". When a distribution is "negatively skewed" the "tail" is longer on the left side of the chart as shown here. When a distribution is "positively skewed" the "tail" is longer on the right side.

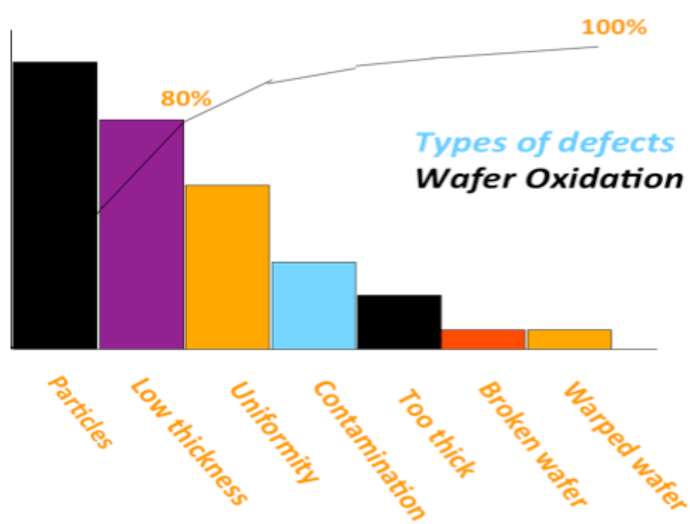
Pareto Charts

A Pareto Chart is a type of chart that uses both bars and a line graph, where the values of each item on the x-axis, are shown in descending order in bar form, and then the cumulative total is represented by the line. Many times a Pareto chart is comparing "frequency of occurrence" (y-axis) with a list of items such as defects, particle size or checklist items (x-axis). The Pareto chart often shows the highest occurring cause(s). The charts below illustrate how the two most reoccurring incidents make up 80% of ALL incidents.

Returning to our previous problem of "poor on-time delivery", here is a Pareto chart of the checklist items. You can quickly see that absenteeism and retraining (in reference to "people") encompasses 80% of the checklist items.



Here is another Pareto that compares the types of defects found in an oxidation process vs. the number of occurrences. When you look at this chart, what do you see as the major cause(s) of the defects?



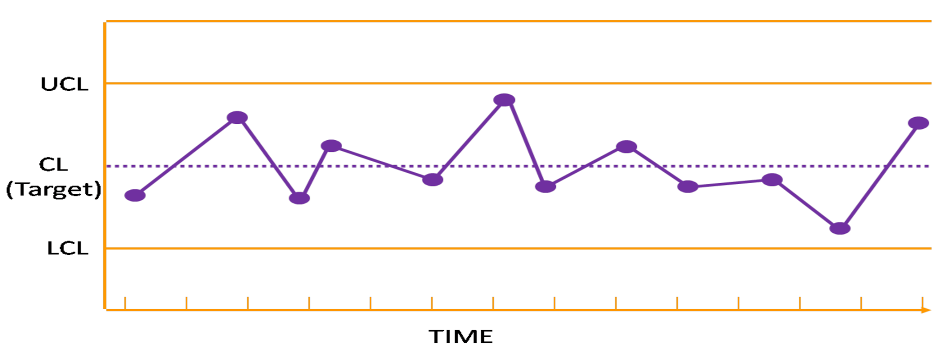
Control Charts

Control Charts are the basic tools used in Statistical Process Control (SPC), a system that allows everyone involved in production to see what is happening at each step of the process right when it happens. Control charts track real time events to look at the process, ensure that it is working, and stop it when it's not. Control charts are found all of the way down the line throughout the process. These are the tools that technicians use on a daily and sometimes hourly basis to make sure that the process is doing what it's supposed to do.

There is a lot of information that technicians and engineers need to know about control charts – how to read them, how to construct them, how to use them to identify both acute and chronic problems, and how to use them to control, as well as improve the process. In this unit we are going to cover control charts very briefly. We'll talk about what they show and how to read them. For more information on control charts, complete the *Statistical Process Control Learning Module*.

The primary purpose of a control chart is to monitor the process, to show "real-time" what the process is doing. For example, looking at the following control chart, the x-axis is "time". The y-axis is a process variable (e.g., oxide thickness, resist thickness, number of defects, oven temperature). The UCL and LCL lines are called the upper and lower control limits, respectively. The middle line is the "mean" or "target", the value that has been found historically to be the mean value for that process. Very simply, when a control chart is initially set up, hundreds of values are collected over a period of time that encompasses all variables that may affect the process (e.g., personal shifts, ambient temperatures, materials). The "mean" and the standard deviation (σ) of those values are calculated. The "mean" is the "target" or centerline, and UCL and LCL are ± 3σ above and below the target (respectively).

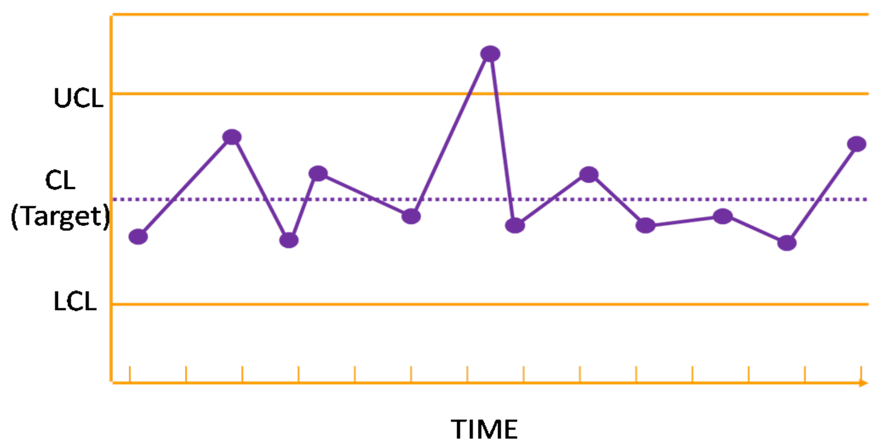
For example, let's say that the following control chart is tracking oven temperatures for a diffusion process. The process setpoint is 1200° C, but after collecting hundreds oven measurements, the mathematical mean of those temperatures is 1207° C. Therefore, the target or CL is 1207° C. One standard deviation or 1σ is calculated to be 2.5° which puts our UCL at 7.5° (3σ) above 1207° or at 1214.5° C. The LCL is 1207° - 3σ or 1195° C. The data collection and calculations are used to setup the control chart. The technician can now use the control chart to track the process to ensure that it is doing what it is "expected" to do. Therefore, the technician that is monitoring the process wants the process to stay within the UCL and the LCL and pretty close to the predictable target. Looking at this process below, would you say we have a problem or are the oven temperature "in-control"?



The oven temperature control chart does not show a problem with the process. This process is stable; the oven temperatures are "in-control". Here are some of the factors that indicate that this process is stable.

- Pattern appears random
- Constant process mean (target) (no mean shift up or down)
- Uniform variability over time
- No treads, runs, shifts, erratic ups and downs
- No points outside of the control limits
- A few points a little more off the target than the other points

Let's look at another chart. What about the process below? Describe what is happening and has happened in this process.



Note to the Instructor: *The sixth point shows the process (e.g., oven temperature) above the UCL. Therefore, this process was "out-of-control (OOC)" at this point. A technician would immediately see this, stop the process, evaluate what is going on, identify the cause of the increase, and correct it in a way that returns the process back to a stable state. Based on the remaining points, it looks like this is exactly what was done. The process was OOC momentarily and is now stable and working properly.*

Summary

This has been a brief summary of some of the tools used by problem solvers to study a problem, determine what is has been doing, what it is doing, and what it is not doing. In the final activity of this learning module, you will use some of these problem solving tools to help your analyze the problem and identify the root cause of the problem. To learn more about these tools, be sure to study the Statistical Process Control Learning Module.

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