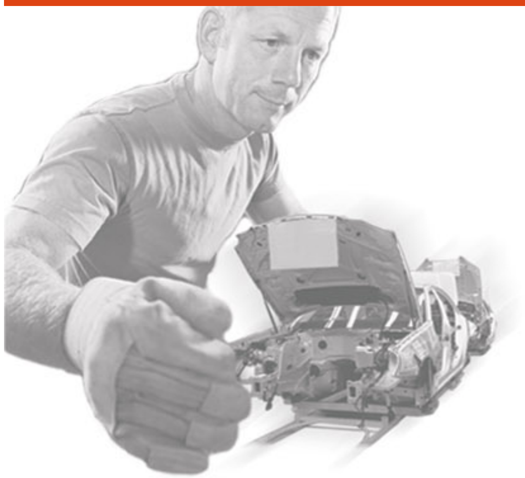
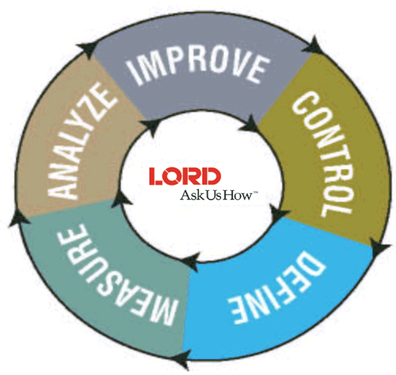


The Basic Tools of Improvement



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Objectives

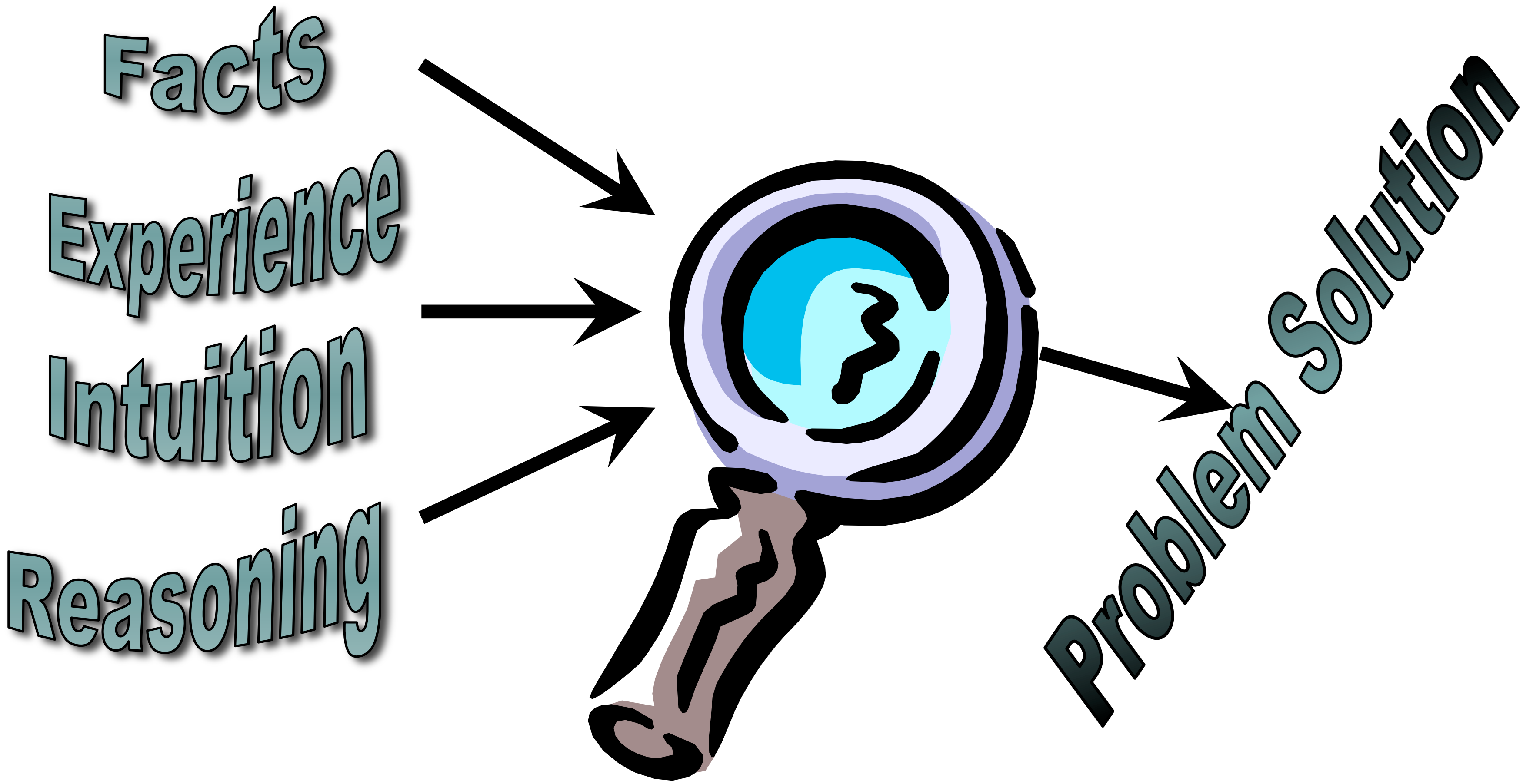
Upon completion of this session you will

- ♦Be able to define problems and apply a structured approach to problem.
- ♦Identify work as a process with inputs and outputs.
- ♦Know when and how to apply the basic tools of improvement to various problems and analyses
- ♦Be able to make more informed decisions based on facts and data
- ♦Understand how to determine if a process is in control and capable

The Basic Tools and Concepts of Improvement

- Developing a Problem Statement and Problem Solving
- Brainstorming
- Cause and Effect Analysis
- Flow Charts
- Data Collection
- Pareto Diagrams
- Scatter Diagrams
- Histograms
- Process Capability
- Control Charts

What do We Use to Solve Problems?



What is Problem Solving?

- The systematic investigation of a process to identify the most likely **ROOT CAUSE** of the gap
- Taking corrective action to eliminate the gap
- Keeping the problem from occurring in the future

A Good Problem Solver:

- Fixes the problem quickly
- Corrects the cause of the problem
- Fixes the problem so it stays fixed
- Doesn't create new problems
- Extends the fix into preventive action

Some Characteristics of Effective/Ineffective Problem Solvers

Effective Problem Solvers	*Ineffective Problem Solvers*
Draw sketches, write equations	Jump to conclusions.
Don't jump to conclusions.	Do not check.
Check and recheck.	Don't break the problem apart
Break the problem into sub-problems	Don't know where to start
Start at a point they first understand	

Benefits of Good Problem Solving:

- Quickly arrive at an answer
- Avoid redundant actions
- Get to optimum answers
- Reduce frustration and stress
- Eliminate trial and error
- Gain consensus among group
- Uncover ideas applied to other problems
- Personal satisfaction

It Begins with the Problem Statement:

A Problem Statement:

- Significantly clarifies the current situation
- Specifically identifies what needs improved
- Identifies the level of the problem and where it is occurring

A problem well stated is a problem well on its way to being solved!

A Problem Statement Should Answer These Questions:

- What is wrong?
- Where is the problem appearing?
- How big is the problem?
- What's the impact of the problem on the business?

A Problem Statement Should Not:

- State an opinion about what is wrong
- Describe the cause of the problem
- Assign blame or responsibility for the problem
- Prescribe a solution
- Combine several problems into one Problem Statement

Problem Statement Example

Problem Statement:
Inventory levels are too high and must be reduced!

Good or Bad? Why?

This Problem statement is bad!

- Too little information is given
- Does not give you the ability to take specific action, enlist support, and obtain information
- It includes speculation about the cause and action that will be taken

Improved Problem Statement

The Old Problem Statement:

Inventory levels are too high and must be reduced!

The Improved Problem Statement:

Inventory levels at the West Metro inventory storage process in Scottsdale are consuming space, taking up asset management time, and creating clash flow issues. Inventory levels are averaging 31.2 days, with a high of 45 days. These levels have exceeded the target of 25 days 95 percent of the time since January 2005. We would save $250,000 per year if we were at the targeted level.

Benefit of a Good Problem Statement

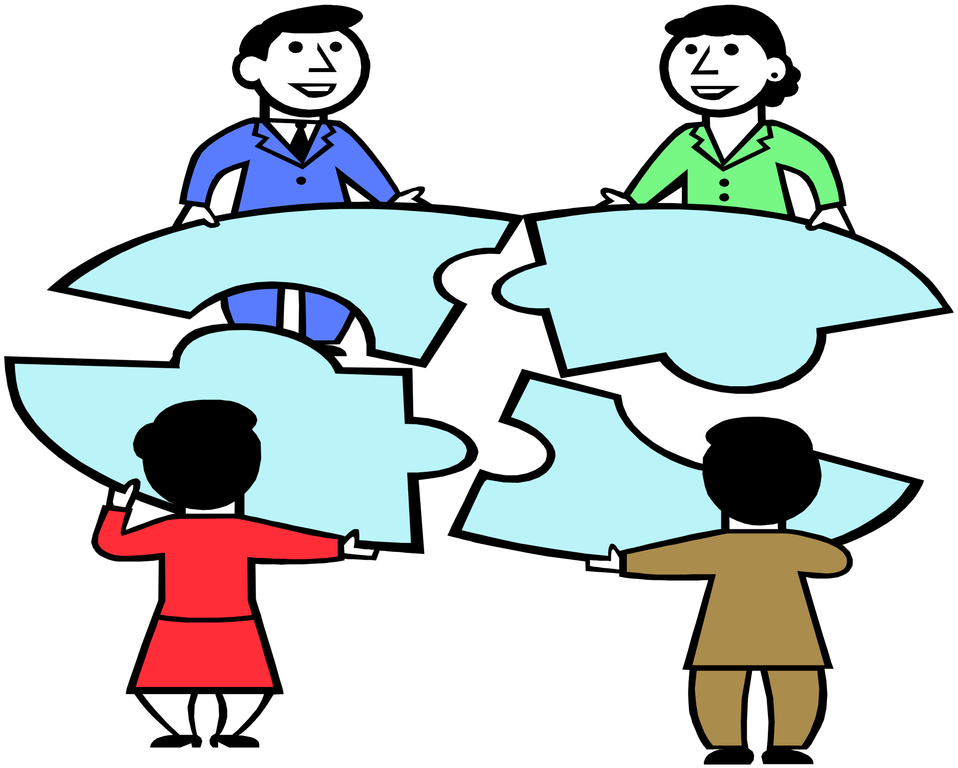
Problem Statement:
Inventory levels at the West Metro inventory storage process in Scottsdale are consuming space, taking up asset management time, and creating clash flow issues. Inventory levels are averaging 31.2 days, with a high of 45 days. These levels have exceeded the target of 25 days 95 percent of the time since January 2005. We would save $250,000 per year if we were at the targeted level.

We get more information from the improved problem statement such as:

- Where the problem is occurring
- How long it has occurred
- The magnitude of the problem
- How much it is costing

Some Problem Solving Models

- **Kepner-Tregoe Method**
- **Global 8D**
- **PDCA**
- **7-Step Method**
- **Others?**



KT Problem Solving Steps

1. Problem Statement
2. List Observed & Comparative Facts
3. Identify Differences
4. List Relevant Changes
5. Generate Likely Causes
6. Test Likely Causes
7. Verify Most Likely Cause

A Good Problem Statement:

- Significantly clarifies the current situation
- Specifically identifies what needs improved
- Identifies the level of the problem and where it is occurring
- Describes it in clear **measurable** terms

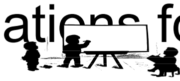
A Problem Statement Should Not:

- State an opinion about what is wrong
- Describe the cause of the problem
- Assign blame or responsibility for the problem
- Prescribe a solution
- Combine several problems into one Problem Statement

Brainstorming

What is Brainstorming?

- An excellent way identify problems that you see on your job
- A group problem solving method that helps people identify and solve problems by bringing out a lot of ideas in a short time
- A good way to gather many possible explanations for a specific problem



What Do You Need for Brainstorming?

A Group Willing to Work Together

- Include everyone who is concerned with the problem
- Include those people who can take an active part in solving the problem

A Leader

- Anyone can lead – can be the manager, one of the regular team members, or an outsider
- Leader is to provide guidance and keep the group on track
- Leader must walk the line between control and participation

A Meeting Place and Equipment

- A place to meet where there are no distractions
- The group will need flipcharts, markers, and masking tape to put the charts up on the wall

How Brainstorming Works

General Rules for a Good Brainstorming Session

1. Choose the subject for brainstorm.
2. Make sure everyone understands what the problem or topic is.
3. Make sure everyone takes a turn and expresses one idea. If somebody can't think of anything, he or she says "Pass."
4. Have a recorder who will write down each idea as it is expressed.
5. Write down *all* the ideas.
6. Encourage wild ideas.
7. Hold criticism until after the session – the aim of brainstorming is quantity and creativity.
8. Laughter is fun and healthy – laugh with someone and not at them.
9. Allow a few hours (or days) for further thought – an incubation period allows the mind to release more creative ideas.

Troubleshooting a Brainstorming Session

The ideas slow down or dry up

- "Piggyback" or build on others ideas

The silent member

- Be patient – they may open up later
- Encourage the silent member to at least say "Pass" if they do not have an idea
- Ask for suggestions but do not put the person on the spot

Criticism

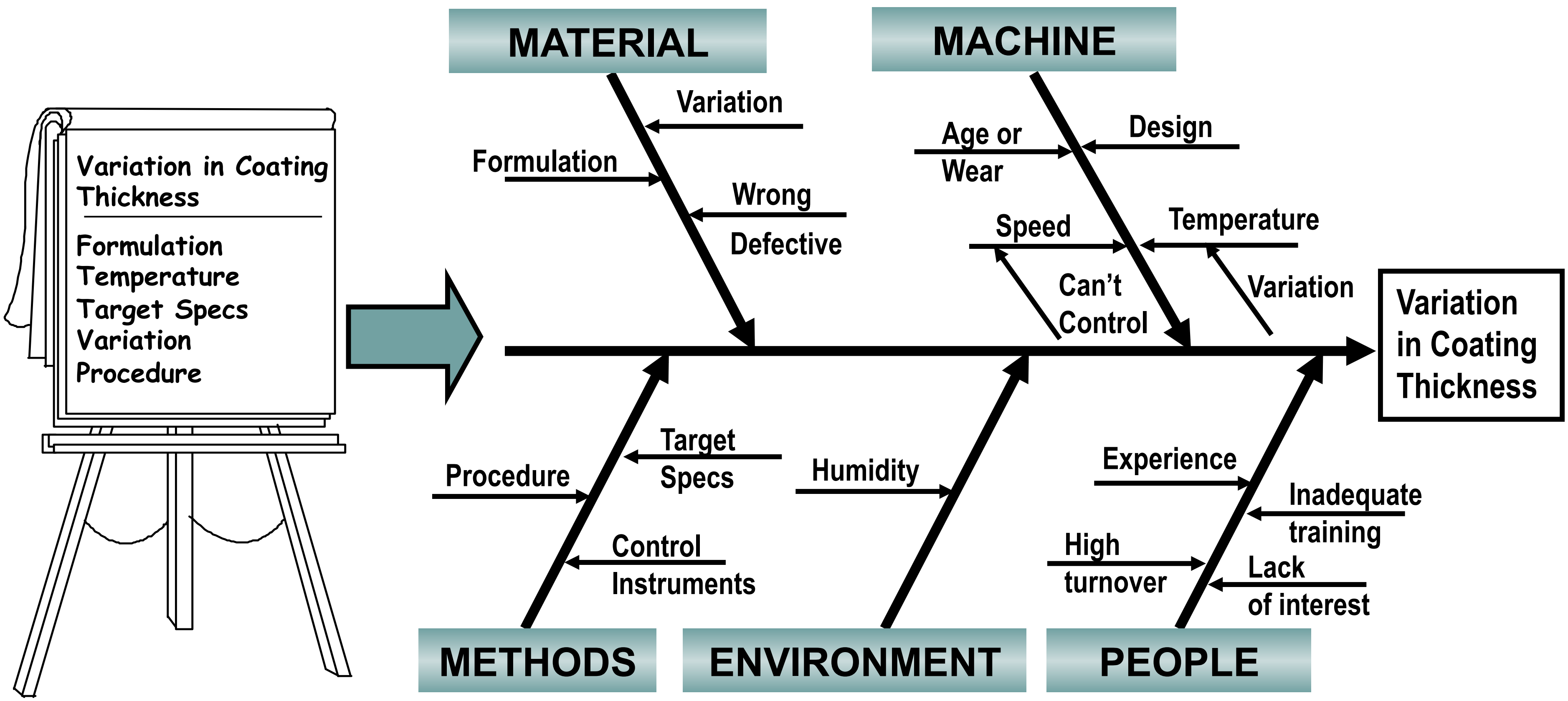
- Criticize problems, not people
- Do not publicize mistakes

The difficult member

- Be firm but friendly – discuss the issue in private
- When disruption occurs gently direct the conversation back to the topic

Cause and Effect Diagram

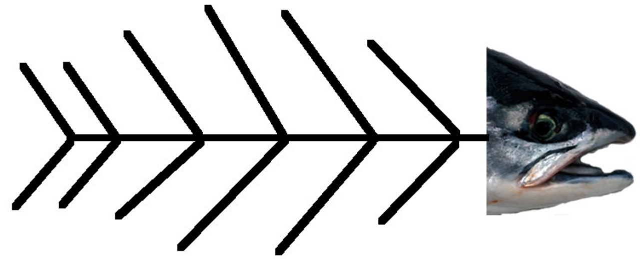
Organize a Brainstorm List of Causes



Cause and Effect Diagram

Also called a "Fishbone" or "Ishikawa" Diagram

Why Use the C and E Diagram?



- ♦Organize the ideas of a brainstorming session
- ♦Sort ideas into basic categories
- ♦Show the relationship between ideas
- ♦Helps complete the brainstorming session
- ♦Helps the team to keep track of where they are in the problem solving process

How to Construct the Cause and Effect Diagram

Step 1. Gather the Material

- Use big flipchart or large sheets of paper, masking tape, flipchart markers with fairly broad points, and the brainstorm idea list.

Step 2. Call together everyone involved with the problem

- The leader and members of the brainstorm group and any outside experts such as engineers or people from sales or quality.

- One person is to volunteer to act as a recorder and draw the diagram

How to Construct the Cause and Effect Diagram

Step 3. Begin to construct the diagram

- On the right hand side of the paper, write the problem or effect. Be sure to stat it clearly so that everyone understands what they will be discussing.

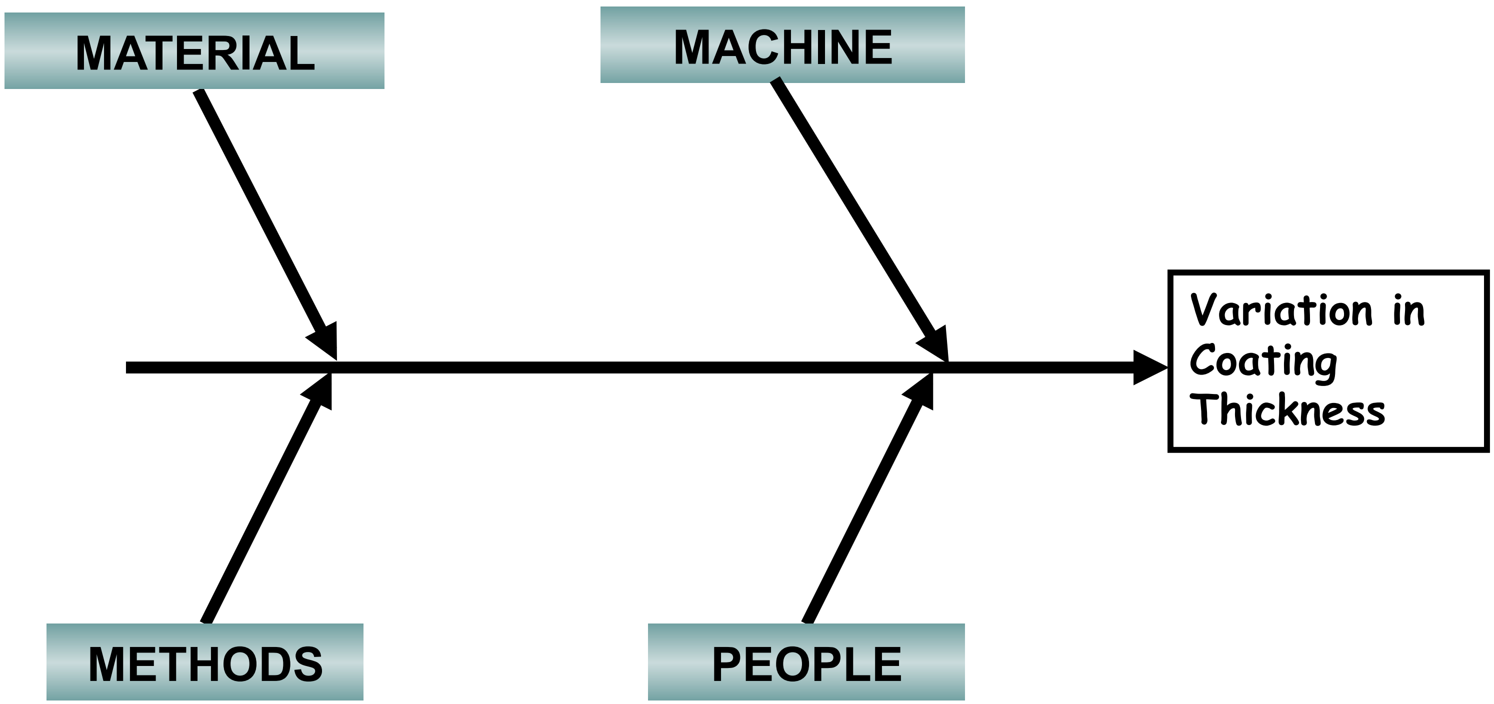
Step 4. Draw the spine of the "fishbone"

- Begin at the left-hand side of the paper and draw an arrow to the box

How to Construct the Cause and Effect Diagram

Step 5. Add the main causes

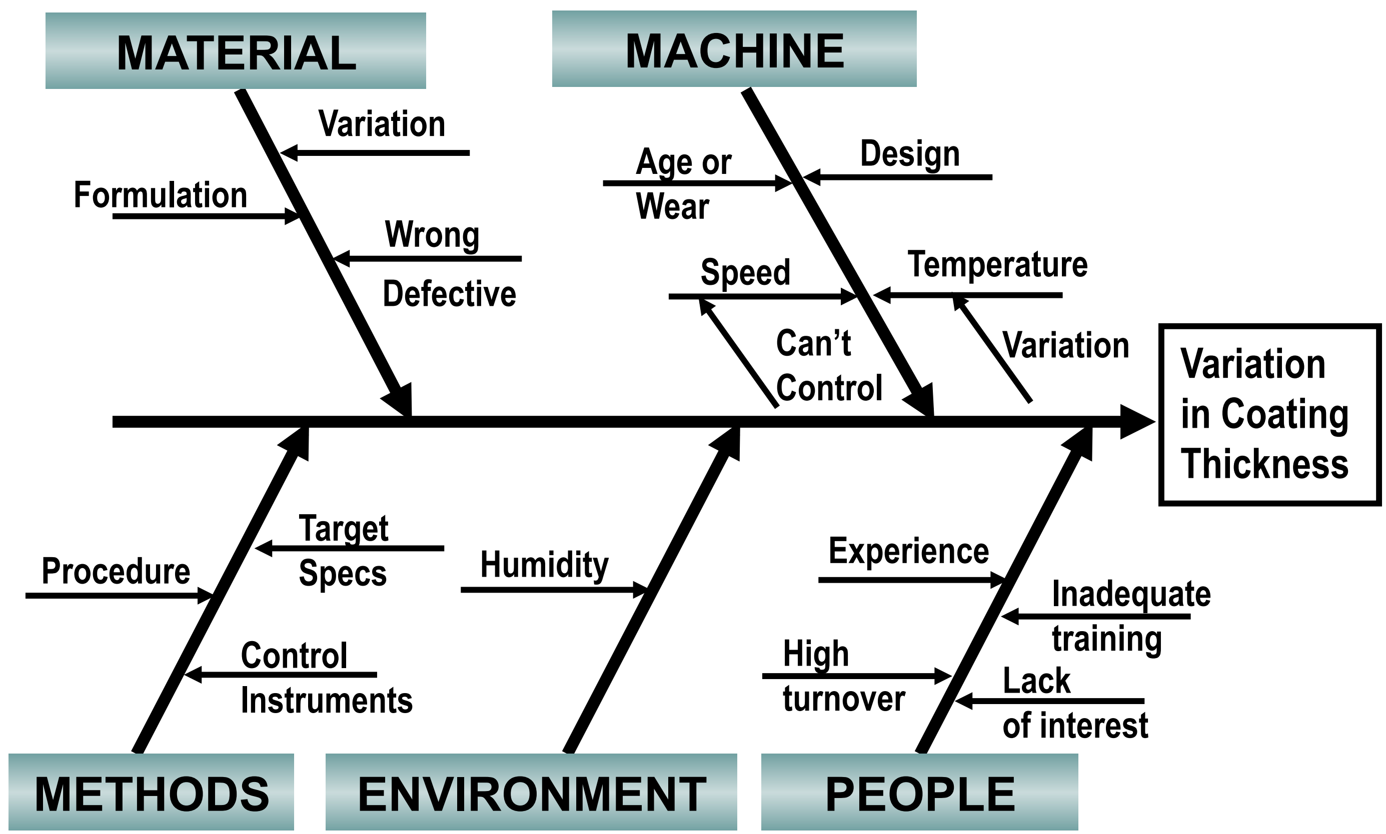
- Material, machine, methods, and people are the four main headings most often used
- Your team may decide other categories are appropriate such as money, management, gauges, environment, etc.



How to Construct the Cause and Effect Diagram

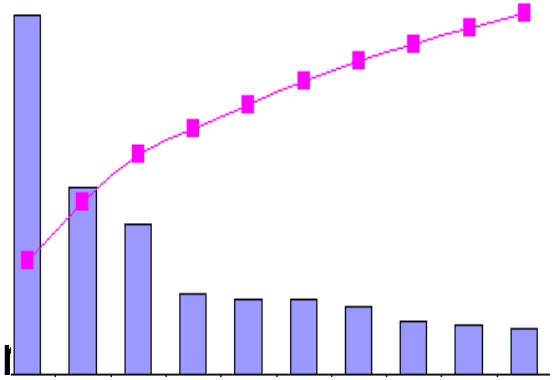
Step 6. Add the brainstorm ideas

♦Ideas come from a previous brainstorm sessions or you can suggest ideas as you build the diagram.



Pareto Analysis

20% of the sources cause 80% of any problem



Why do a Pareto Analysis?

♦To help you decide which of several chronic pr
to attack

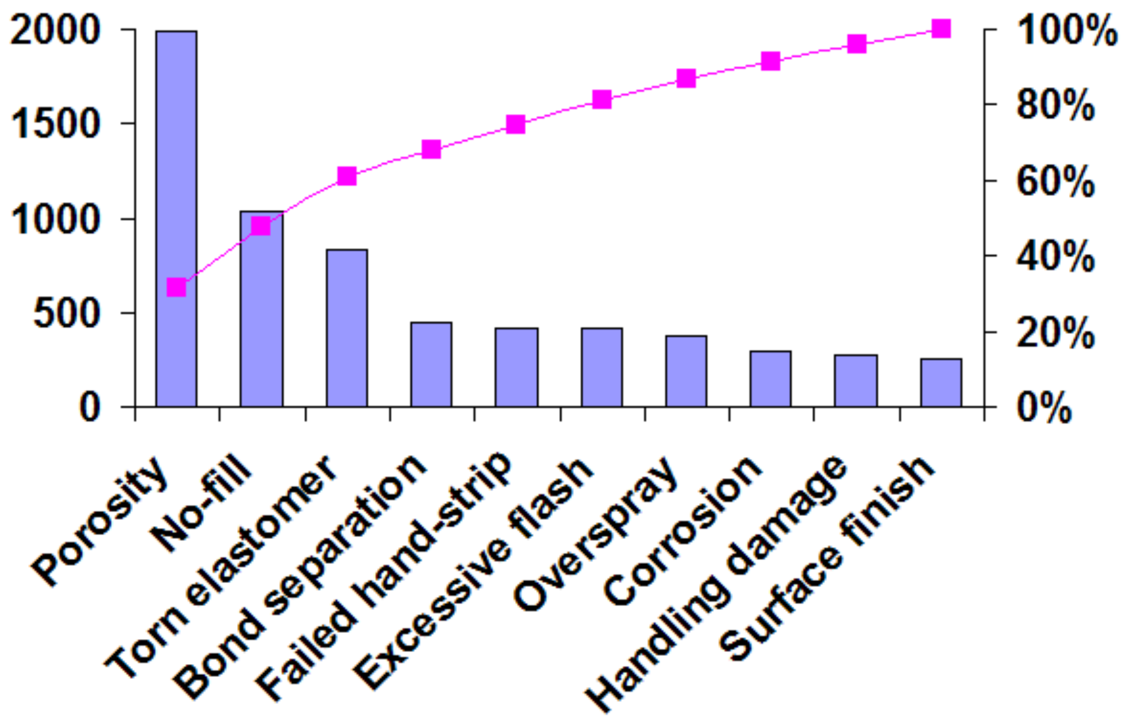
♦To sort out the few really important problems from the more numerous but less important problems

♦To create a highly visible format that provides the incentive to push for more improvements

Pareto Diagram

What is a Pareto Diagram

- A special type of bar graph that displays problems in order of frequency
- Frequency may mean cost in dollars, number of defects, or how often a failure occurs.



How to Construct a Pareto Diagram

Step 1. Specify your goal clearly

- Such as reduce the rate of defects

Step 2. Collect data

- Determine if data is already available
- There may be many existing reports where you can get the data you need

	A	B
2	**Defect**	**Count**
3	Porosity	1987
4	No-fill	1039
5	Torn elastomer	834
6	Bond separation	442
7	Failed hand-strip	413
8	Excessive flash	413
9	Overspray	371
10	Corrosion	292
11	Handling damage	275
12	Surface finish	258
13	**Total**	6324

How to Construct a Pareto Diagram

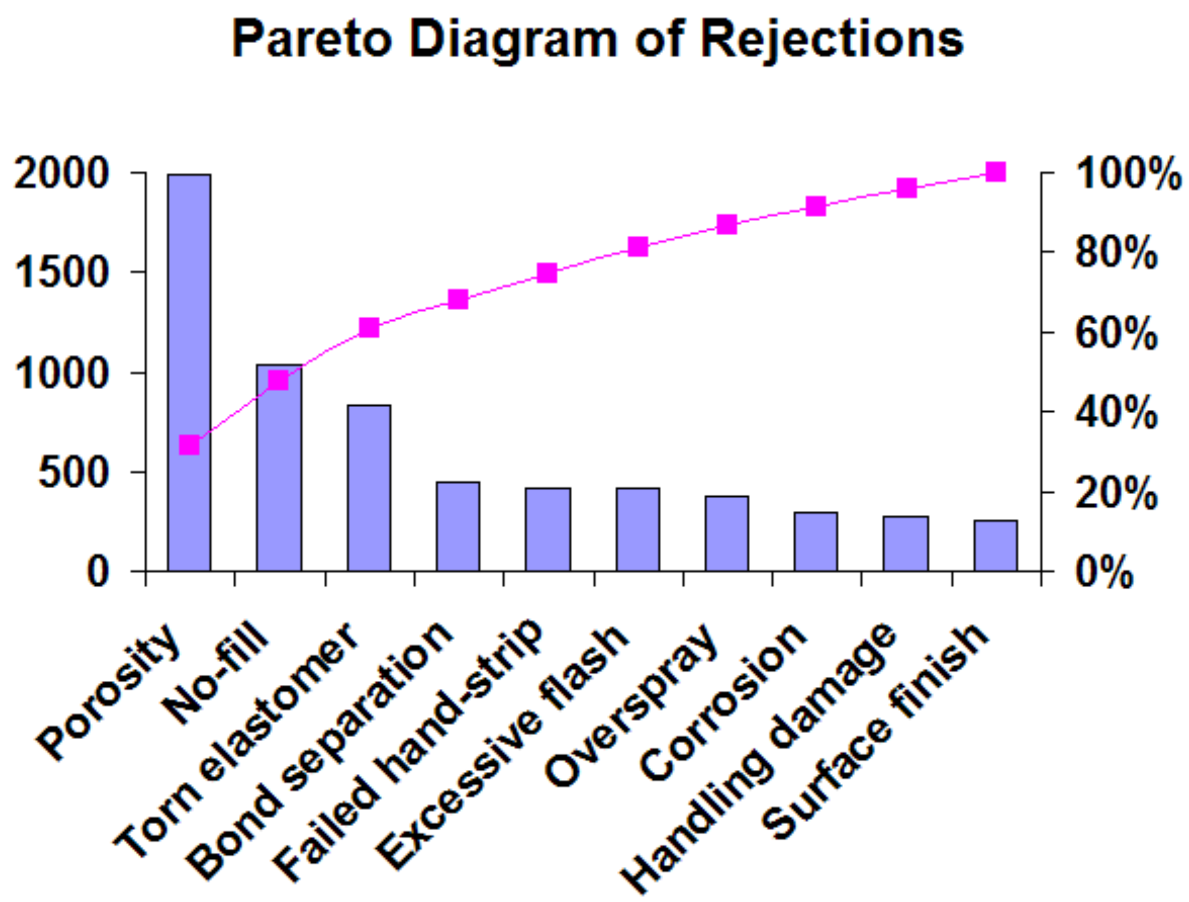
Step 3. Tally the data and rank the categories of defects by frequency

- This is easily done in Excel

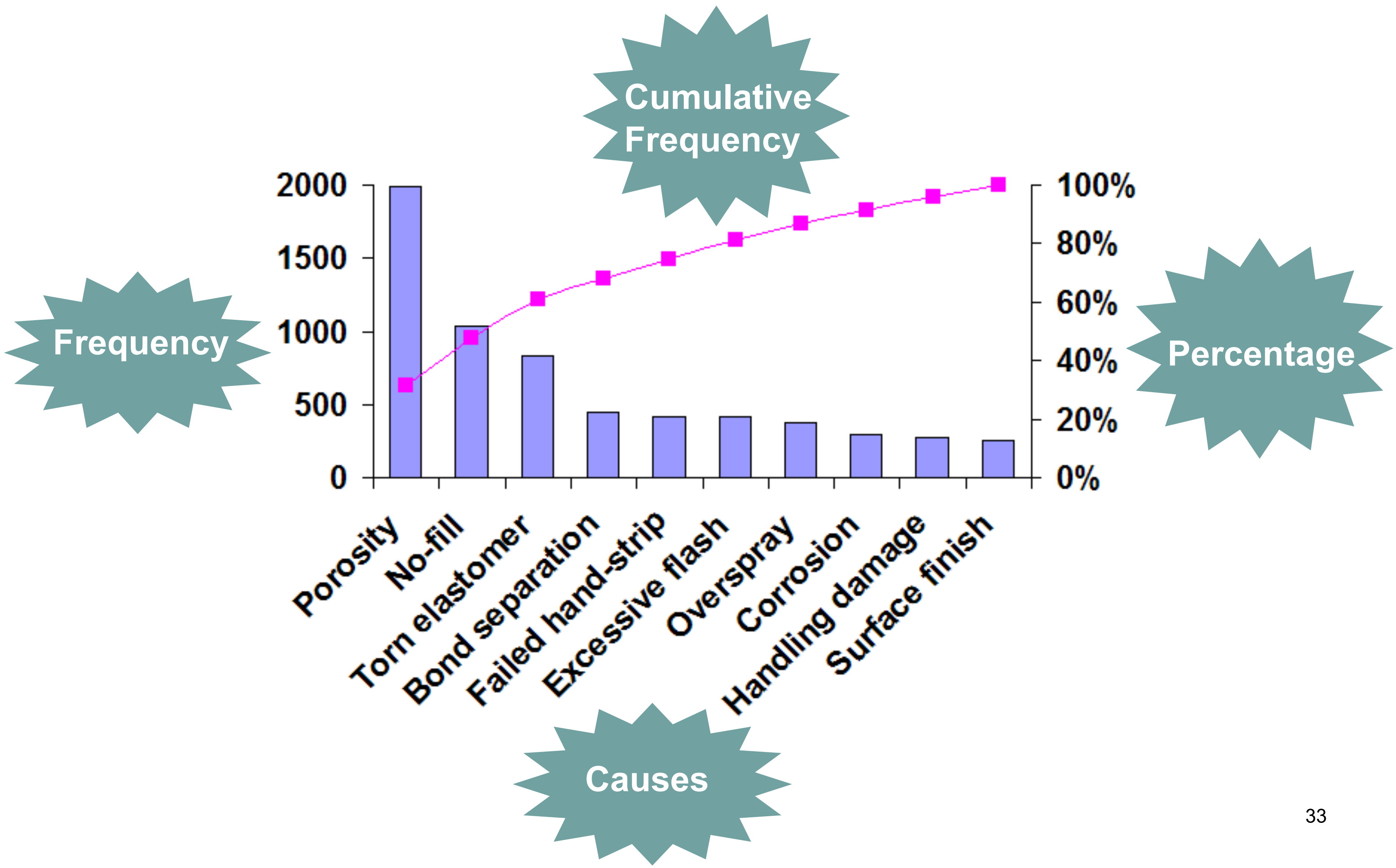
	A	B	C	D
2	**Defect**	**Count**	**Frequency**	**Cumulative Frequency**
3	Porosity	1987	31.42%	31.42%
4	No-fill	1039	16.43%	47.85%
5	Torn elastomer	834	13.19%	61.04%
6	Bond separation	442	6.99%	68.03%
7	Failed hand-strip	413	6.53%	74.56%
8	Excessive flash	413	6.53%	81.09%
9	Overspray	371	5.87%	86.95%
10	Corrosion	292	4.62%	91.57%
11	Handling damage	275	4.35%	95.92%
12	Surface finish	258	4.08%	100.00%
13	**Total**	6324	100.00%	

How to Construct a Pareto Diagram

Step 4. Create the Pareto diagram

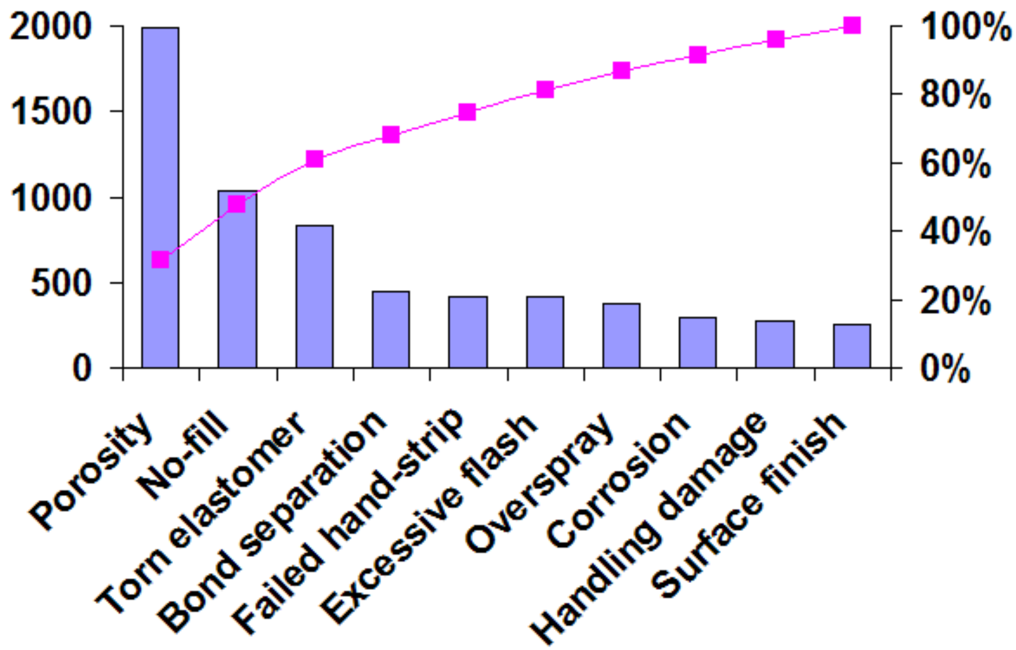


Components of the Pareto Diagram



Interpreting the Pareto Diagram

- ♦Generally the tall bars indicate the biggest contributors to the overall problem
- ♦Be careful – most frequent or expensive is not always the most important
- ♦Always ask: What has the most impact on the goals of our business and customers?



Flowcharts

What is a flowchart?

- A graphic representation of a process
- A necessary step toward improving a process
- A tool that allows a team to identify the ACTUAL flow or sequence of events in a process

Flowcharts

The purpose of using a flow chart is to:

- Show unexpected complexity, problem areas, redundancy, unnecessary loops
- Show where simplification and standardization may be possible
- Allow everyone to come to agreement on the steps of the process
- Identify locations where additional data can be collected and investigated
- Serve as a training tool to understand the complete process

How to Construct a Flowchart

1. Determine the frame or boundaries of the process

- Clearly define where the process begins and ends
  Agree on the level of detail for the flowchart
- Allow everyone to come to agreement on the steps of the process

2. Determine the steps in the process

- Brainstorm a list of all major activities, inputs, outputs, and decisions
- Document brainstorming on a flipchart or whiteboard

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How to Construct a Flowchart

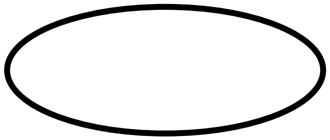
3. Sequence the steps

- Arrange the steps in the order they are carried out
- Use Post-It notes so you can move them around

Unless you are flowcharting a new process it is important to first chart how the process actually works.

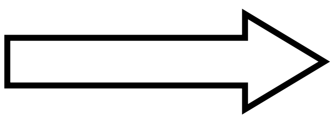
How to Construct a Flowchart

3. Draw the appropriate symbols

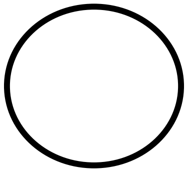


Used to show the materials, information, or action (inputs) to start the process or to show the results at the end (output) of a process

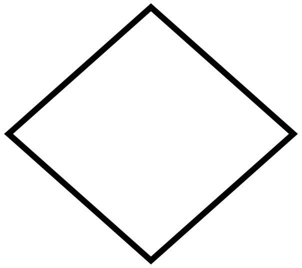
Used to show an activity or task in the process



Arrows show the direction or flow of the process



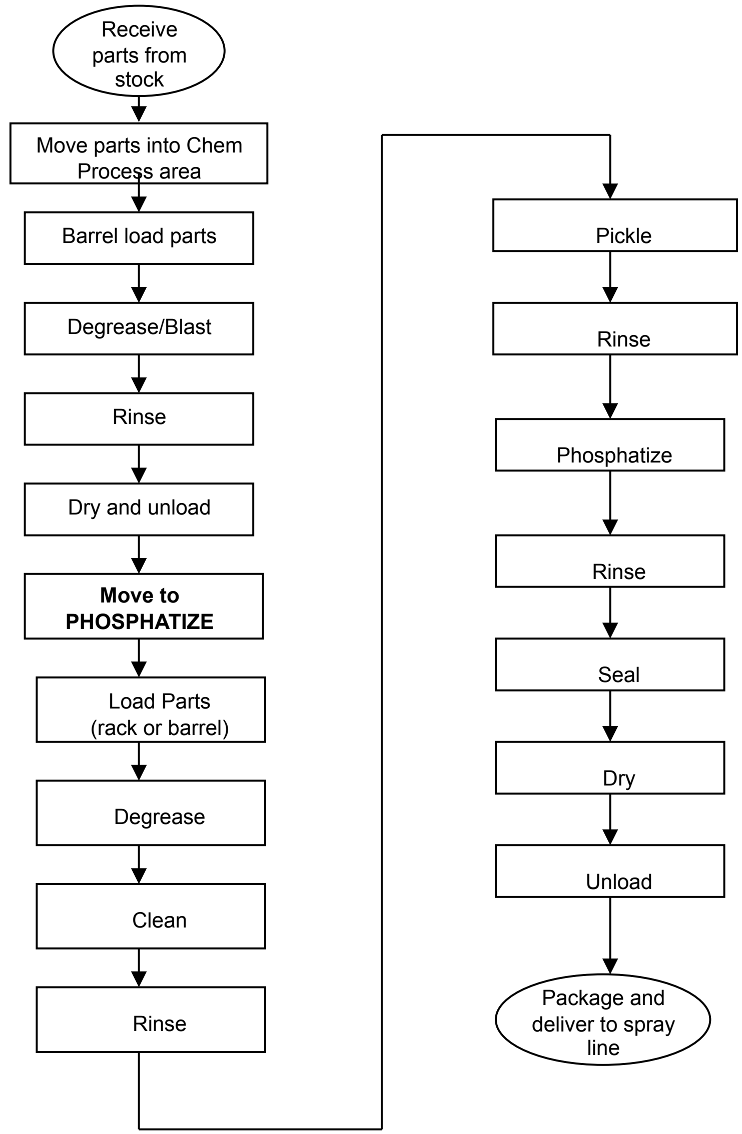
A circle with either a letter or number identifies a break in the flowchart and is continued elsewhere on the same page or another page



Shows those points in the process where a yes/no question is being asked or a decision is required

A Basic Flowchart

A Phoshpatizing Process



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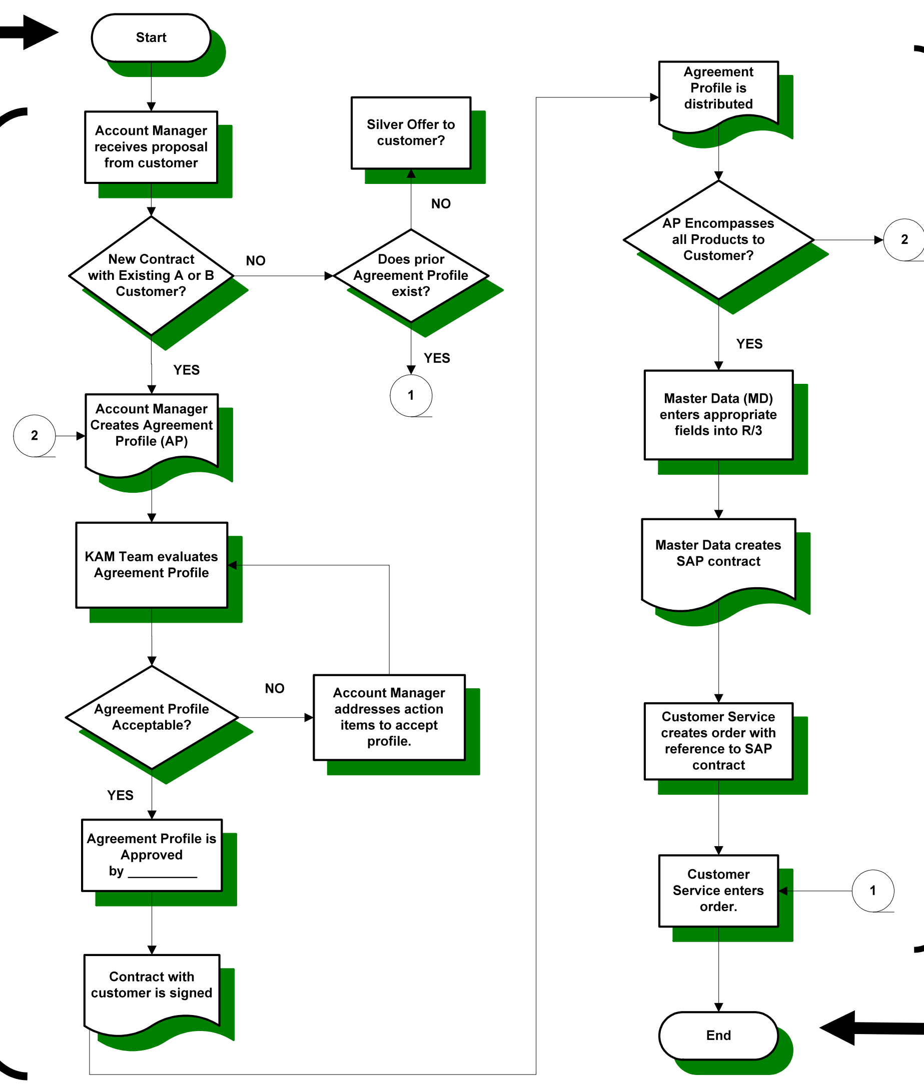
A More Detailed Flowchart

Agreement Profile Process for New Customer Orders

Start of the process

Connectors



Process Steps and Decision Points

Process Steps and Decision Points

End of the process

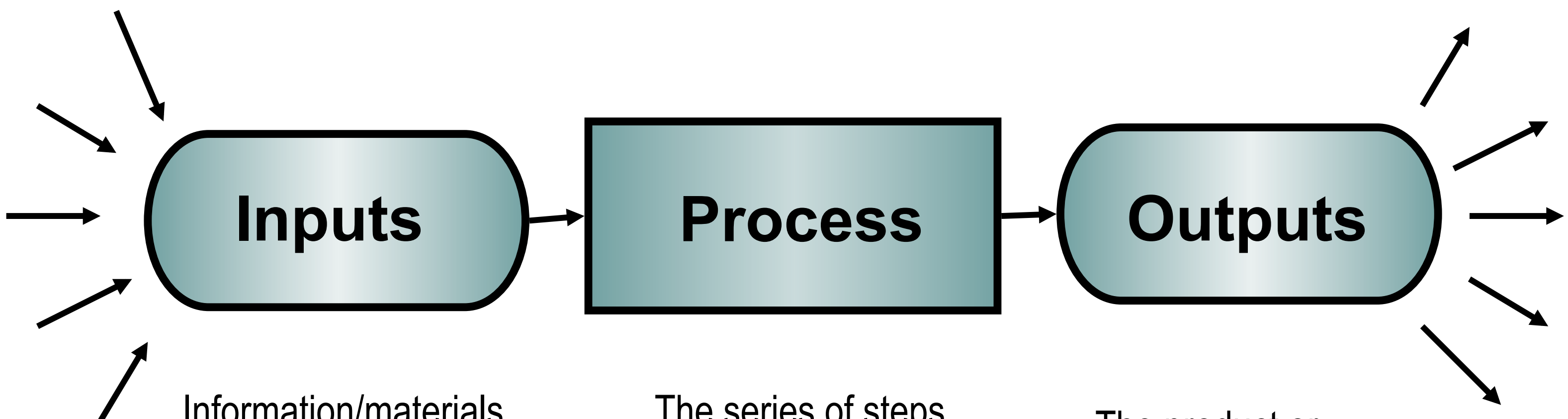
Flowcharting Tips

- ♦Always flow chart with a team. Rarely does one person have all process knowledge.
- ♦Investigate the process by watching it in many different conditions. Watch the process as it happens to see the detail you need.
- ♦Walk through the actual process
- ♦Brainstorm and list the steps on paper before attempting to use software to construct the chart
- ♦Maintain your charts and maps with dates and update them as necessary. Use them as a reference and training tool.

All Work Is a Process - SIPOC Analysis

We analyze processes relative to these parameters in order to understand their impact

SUPPLIERS



CUSTOMERS

Inputs: Information/materials provided by suppliers that are consumed or transformed by the process.

Process: The series of steps that transform and add value to the inputs.

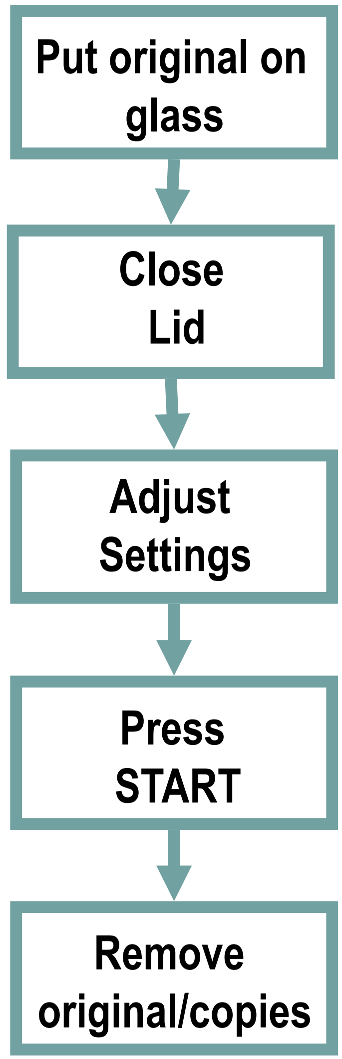
Outputs: The product or service used by the customer

SIPOC Analysis

SUPPLIERS	INPUTS (Xs)	PROCESSES (Xs)	OUTPUTS (CTQs)	CUSTOMERS
Manufacturer	Copier		Copies	You
Office Supply Company	Paper	Making a Photocopy		File
	Toner			
Yourself	Original			
Power Company	Electricity			

SIPOC Analysis Example

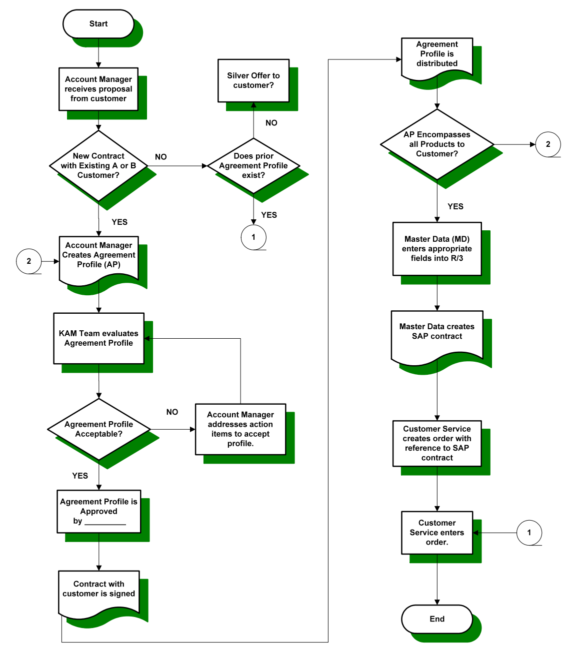
PROCESS STEPS



Workshop – Process Flow

Select anyone of these simple processes (or use one of our own. As a group develop a basic process flow diagram using any of the models we have discussed.

- ♦Changing a tire on a passenger car
- ♦Recording a television program using a VCR or DVD recorder
- ♦Making a fresh pot of coffee
- ♦Taking a photograph with a digital camera
- ♦Others?



Data Collection

Why collect data?

- To obtain clear, useful, information about problems and their causes in order to make improvements
- To describe the extent of a problem
- To measure and understand the variation in our processes
- To determine if our processes are consistently able to meet specifications
- Others reasons?

Data and Information

Data = Facts

Information = Answers to Questions

"Information" Includes "Data"

"Data" does Not Necessarily Include Information

Simply collecting data does not always mean that your team will have useful information.

Generating Information

To generate information we need to:

- ♦Formulate precisely the question we are trying to answer
- ♦Collect the data and facts relating to that question
- ♦Analyze the data to determine the factual answer to the question
- ♦Present the data in a way that clearly communicates the answer to the question

Accurate, precise data, is useless if it does not clearly address a question that someone cares about

Planning for Data Collection

In order to plan for good data collection, ask these questions:

- What question do we need to answer?
- How will we recognize and communicate the answers to the question?
- What data analysis tools (Pareto, histogram, etc.) do we envision using, and how will we communicate the results?
- What type of data do we need in order to construct this tool an answer this question?
- Where in the process can we get this data?
- Who in the process can give us this data?
- How can we collect this data from these people with minimum effort and chance of error
- What additional information do we need to capture for future analysis?

Basic Types of Data

Discrete Attribute Data

- Places data into “discrete” classes
- Sometimes simply called “discrete: or “attribute”
- Examples include: conforming and nonconforming, on-time and late; excellent, good, fair, and poor; types of defects

Continuous Variable Data

- Actual measurement values
- Often simply referred to as continuous data
- Examples include tensile, load deflection, length, weight
- Have many more uses than simple discrete data
- Examples include tensile, load deflection, length, weight

Data Collection Forms

Almost any format can be used but follow these basic rules:

- Keep the form simple and easy to use
- Minimize the opportunities for errors
- Capture data for analysis, reference, and traceability
- The form should be self explanatory
- The form must look professional

Data Collection Checklist

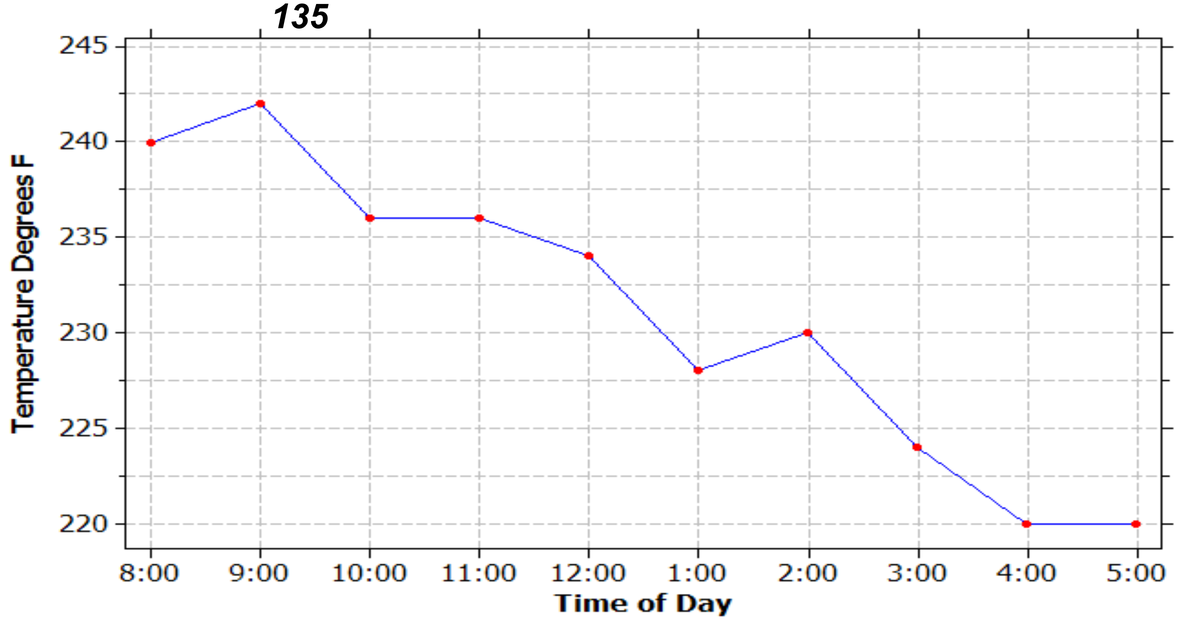
- ♦Read the temperature to the nearest degree in the area designated.
- ♦Plot the temperature and time on the grid using a dot.
- ♦Reading should be taken on the hour (+/- 5 minutes).
- ♦Use the "Notes" section to record anything unusual.

Date:_____________

Line# _____________

Inspector:__________________

Questions? Contact Mark Wang at ext. 135



Data Recording Checklist

DEFECT	Shift 1	Shift 2	Shift 3
Porosity	//	///	////
No-fill	~~////~~ //	////	~~////~~
Overspray	///	~~////~~ ////	//
Torn elastomer	///	//	//
Excessive Flash	~~////~~	///	//

There are many different types of checklists – design and use the format that is appropriate for your situation.

Data Collection – Samples

Random Sample

- ♦Each and every observation or data measure has an equal and likely chance of being chosen
- ♦Use a random number generator or table to select the samples

Sequential Sample

- ♦Every nth sample is selected

Stratified Sample

- ♦A sample is taken from stratified data groups

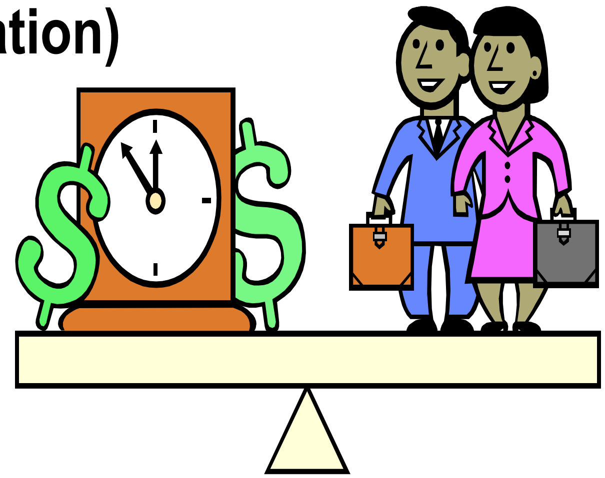
Collect data over a sufficient period to be sure the data represents typical results during a typical cycle.

Data Collection – Summary

1. Formulate a good question
2. Consider the appropriate data analysis tool
3. Define the sampling method and data collection points
4. Select an unbiased person to collect the data
5. Design a data collection form
6. Prepare the instructions for data collection
7. Train the data collectors
8. Audit the collection process and validate the results

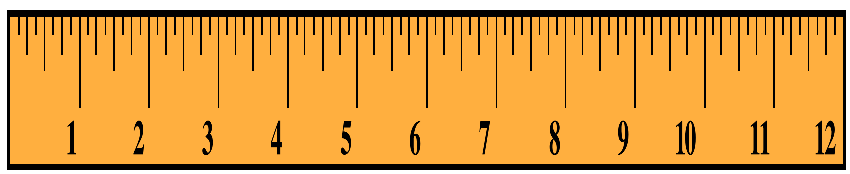
Basic Numerical Descriptions of Data

Measures of **Central Tendency (or Location)**



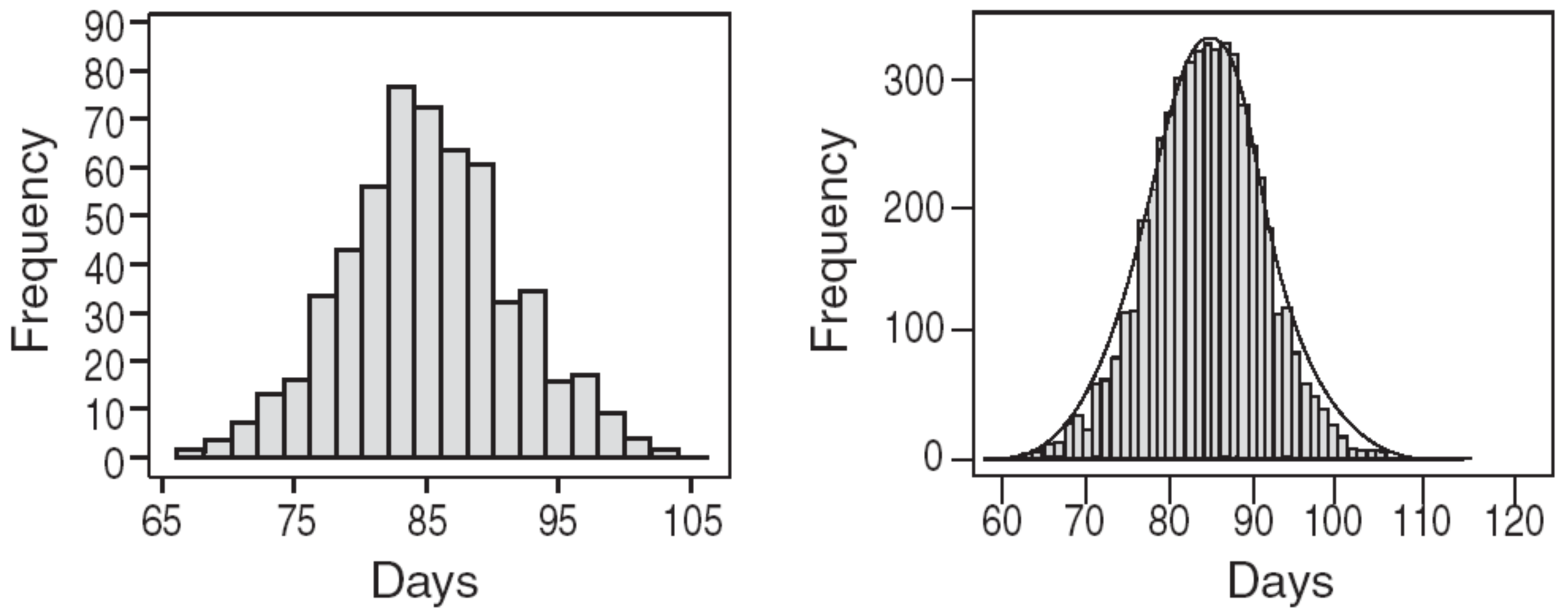
The **Mean**
The **Median**
The **Mode**

Measures of **Variation (or Spread)**



The **Range**
The **Variance**
The **Standard Deviation**

Sample Statistics Approximate Population Parameters



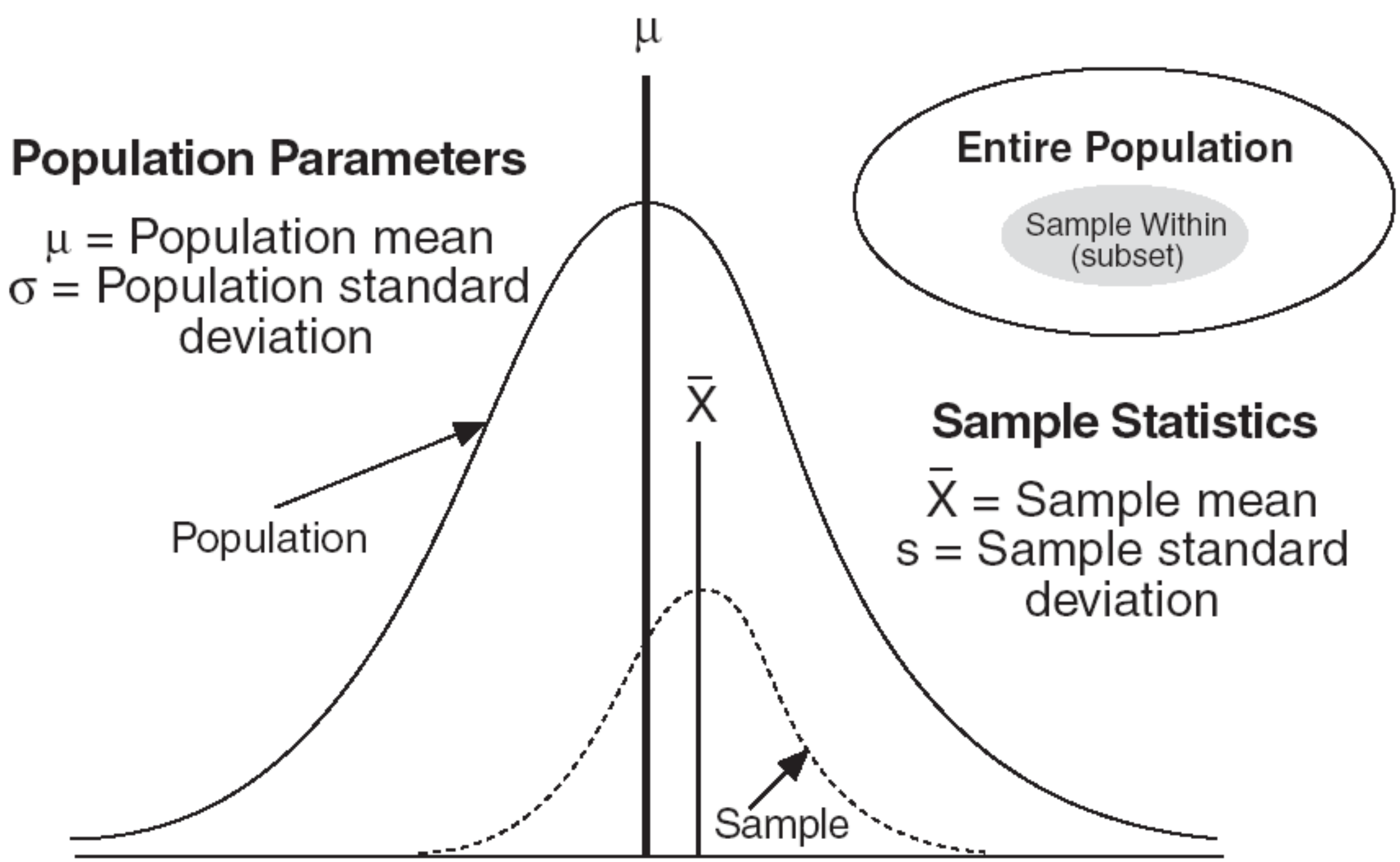
Sample Statistics

$\bar{X}$ = 84.99
s^2 = 34.57
s = 5.88
n = 600

Population Parameters

μ = 85.06
σ^2 = 36.53
σ = 6.04
N = 5,000

Populations and Samples



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Population and Sample Equations

Sample mean

n = A subset of the population

$$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n} = \frac{x_1 + x_2 + x_3 + \ldots + x_n}{n}$$

Sample standard deviation

$$s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{(n-1)}}$$

Population mean

N = Every member of the population

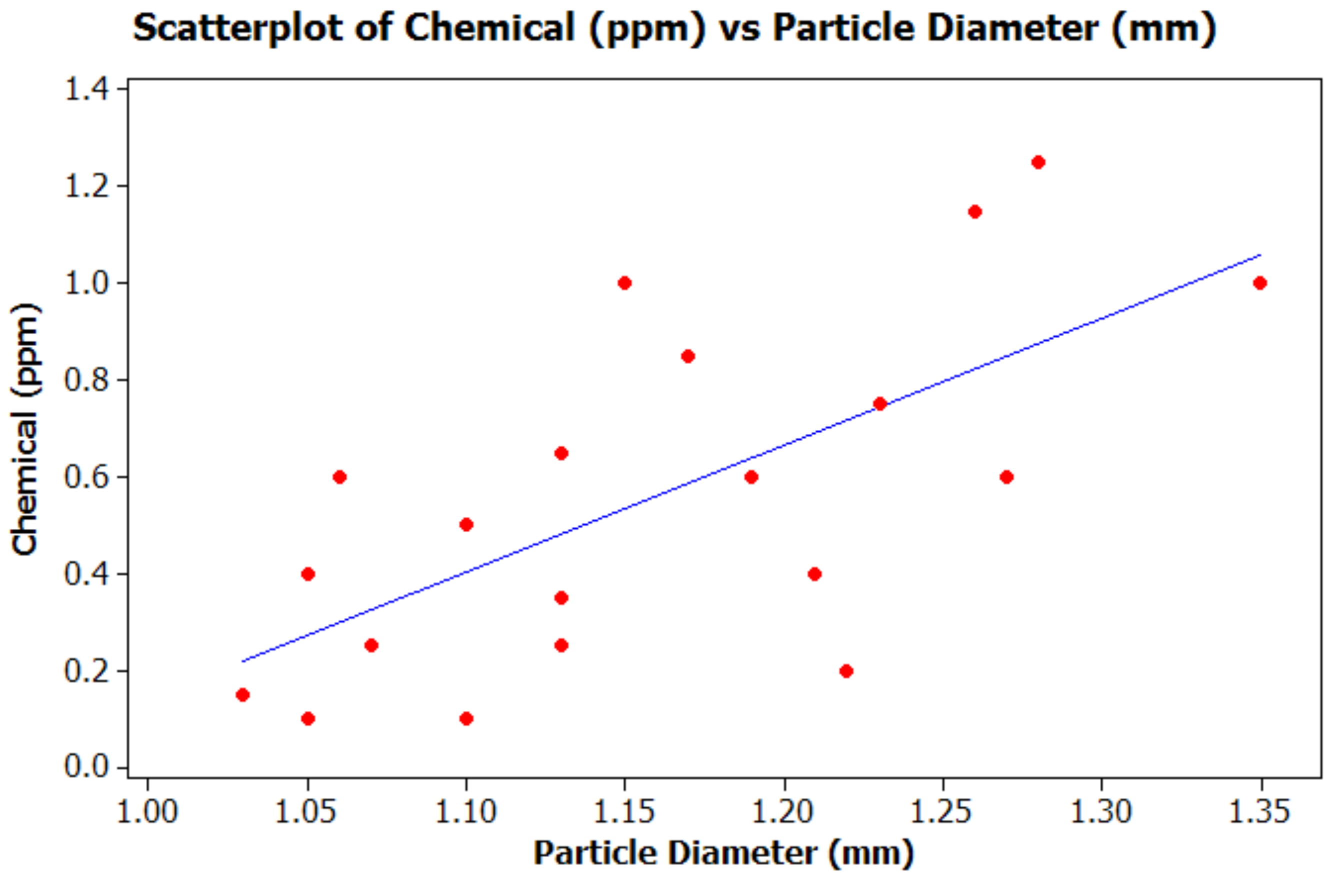
$$\mu = \frac{\sum_{i=1}^{N} x_i}{N} = \frac{x_1 + x_2 + x_3 + \ldots + x_N}{N}$$

Population standard deviation

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N} (x_i - \mu)^2}{N}}$$

Scatter Diagram

Indicates how two variables may be related



Scatter Diagram

Why use it?

- To study and identify the possible relationship between the changes observed in two different sets of variables.

What does it do?

- Supplies the data to confirm that two variables are related.
- Provides a visual and statistical means to test the strength of a potential relationship.
- Provides a good follow-up to a Cause & Effect Diagram to find out if there is more than just a consensus connection between the cause and effect

How to Construct a Scatter Diagram

1. Determine if the problem is suitable for a scatter diagram

- Are the points you are going to plot from variable (measurable) data?
- Are there two things you can measure (two variables?
- Are you trying to see if the two variables affect each other?

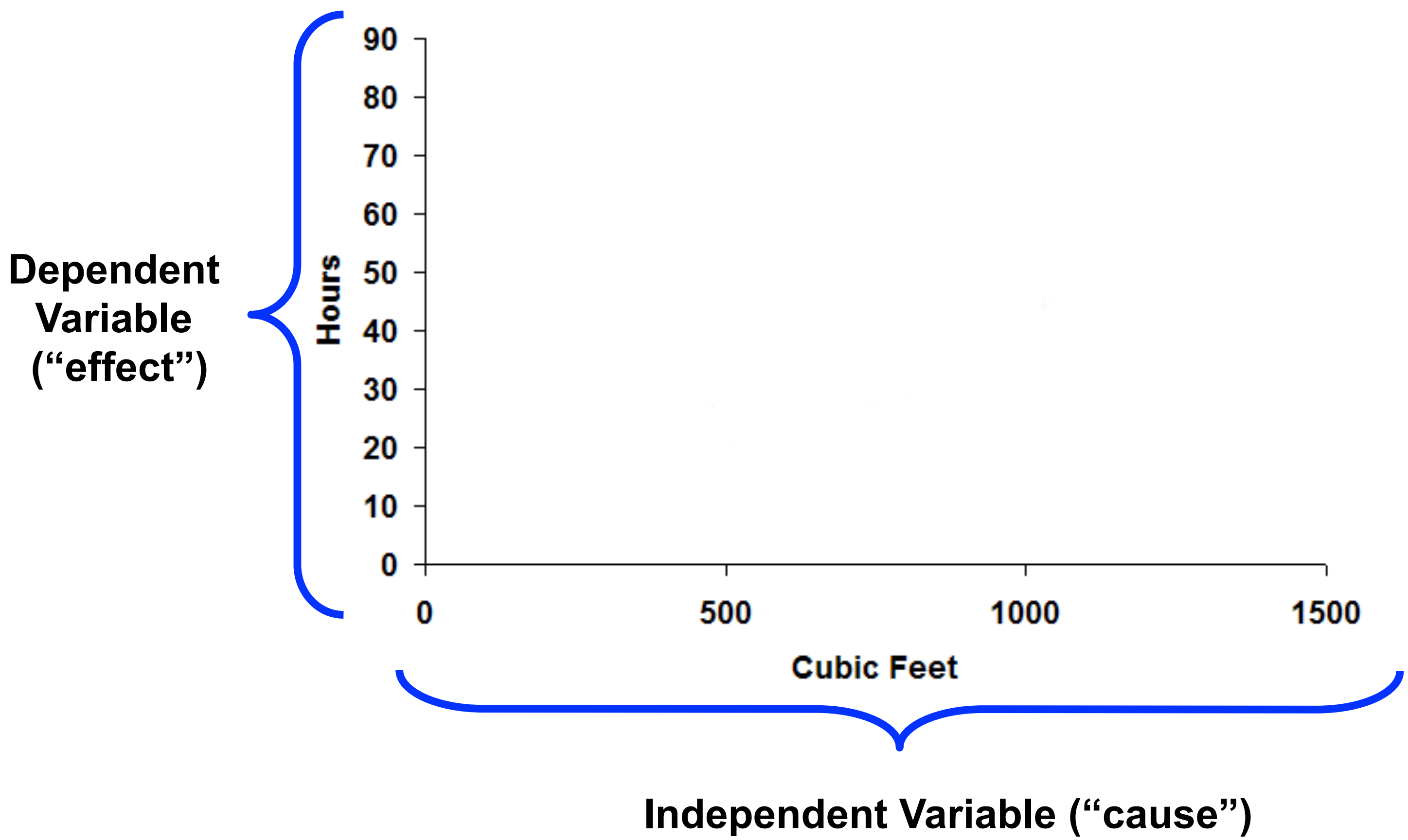
2. Collect the data

- 50-100 paired samples of data are normally required, however in some circumstances less data will still work
- Record any interesting or peculiar things that happen

How to Construct a Scatter Diagram

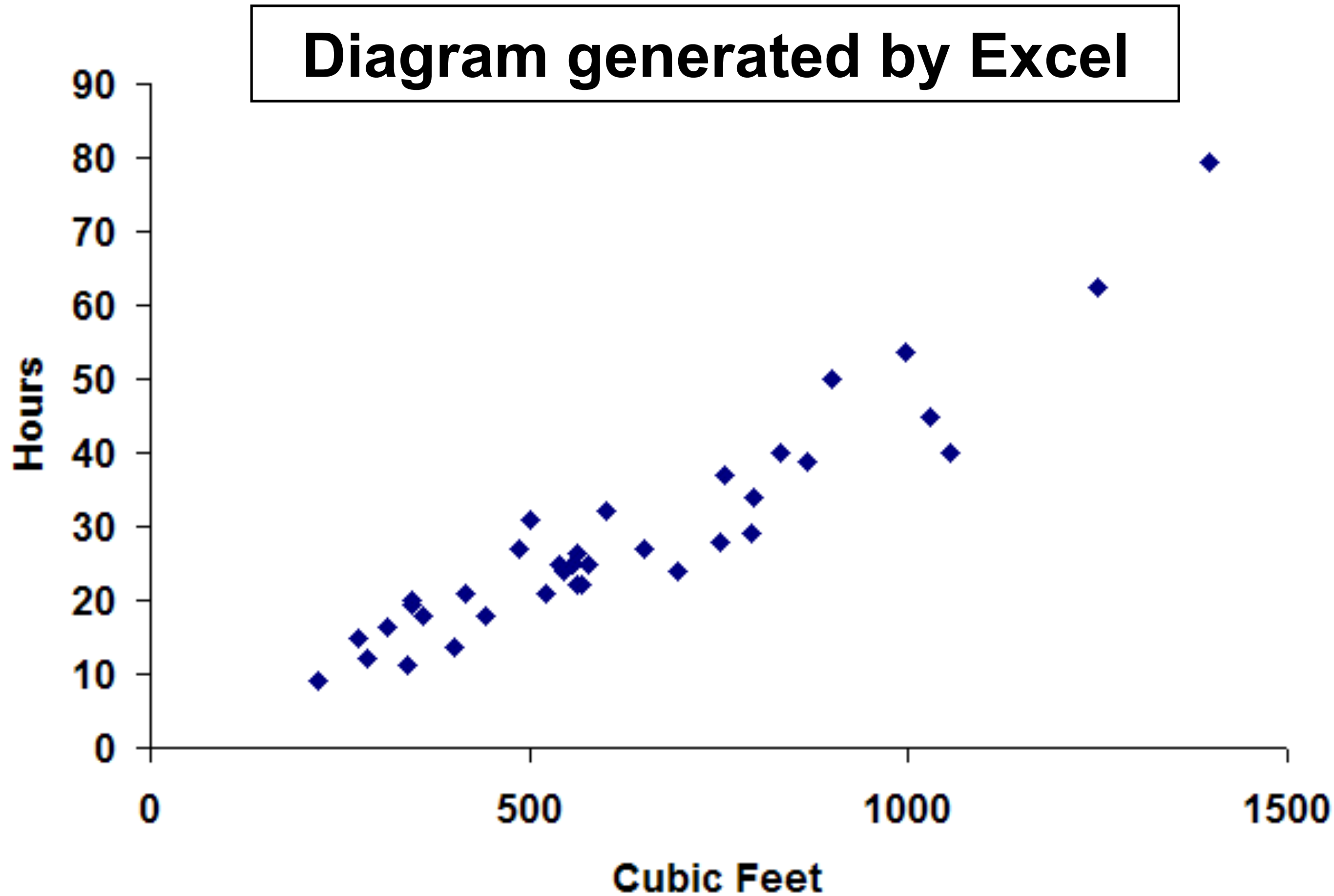
3. Draw the horizontal (x axis) and vertical (y axis)

- This is normally done with your software (Excel, Minitab, etc.)



How to Construct a Scatter Diagram

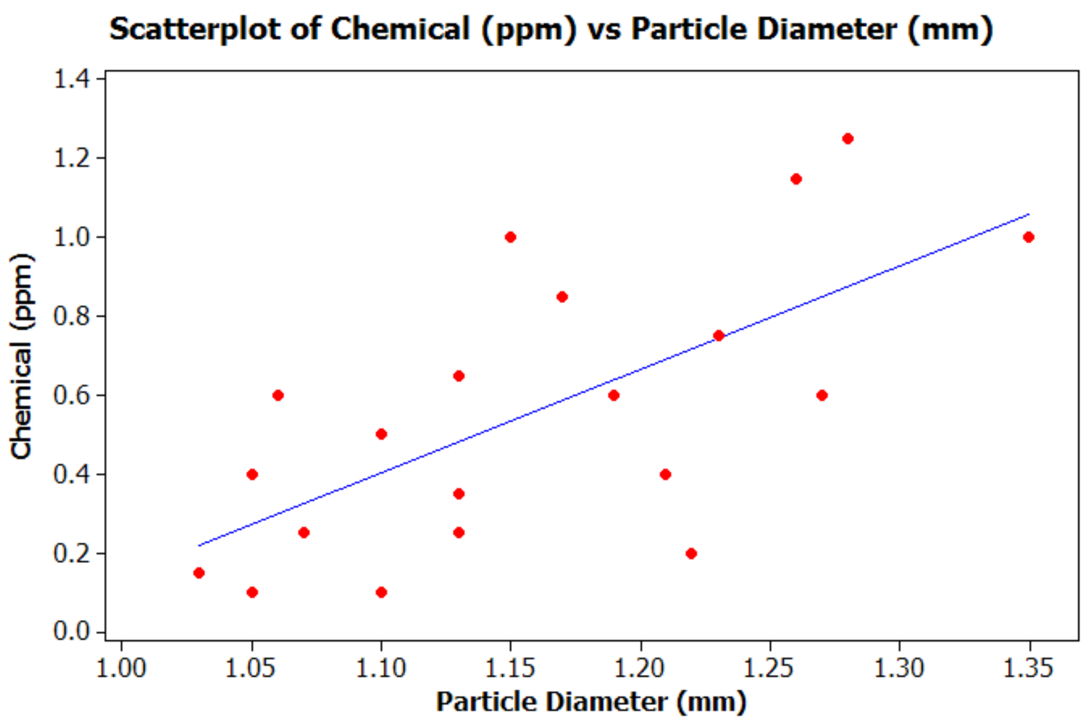
4. Plot the data on the diagram



How to Construct a Scatter Diagram

4. Interpret the diagram

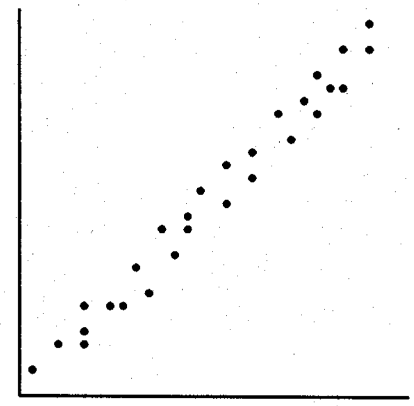
- ♦Many different ways to analyze a scatter diagram
- ♦In this training we will focus only on the visual interpretation of scatter diagrams



Interpreting a Scatter Diagram

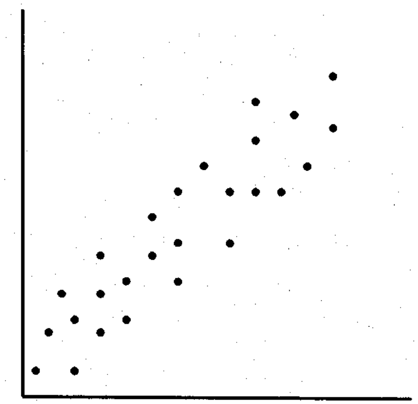
Positive Correlation

An increase in y may depend on an increase in x.



Possible Positive Correlation

If x is increased, y may increase somewhat



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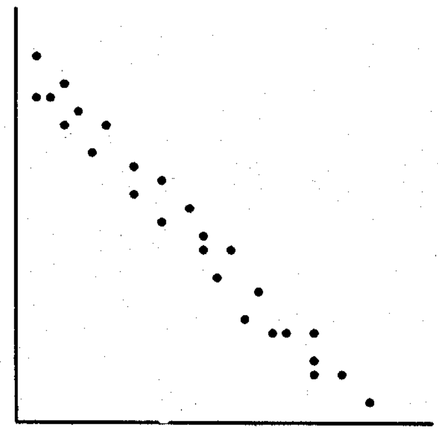
Interpreting a Scatter Diagram

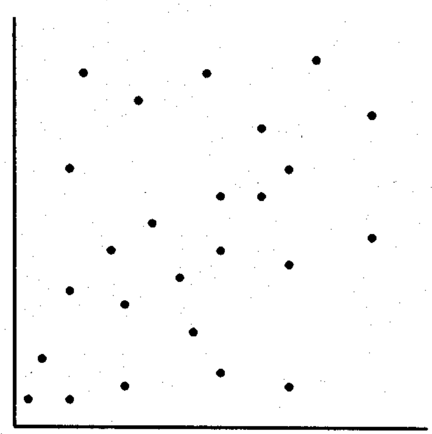
Negative Correlation

An increase in y may depend on an increase in x.



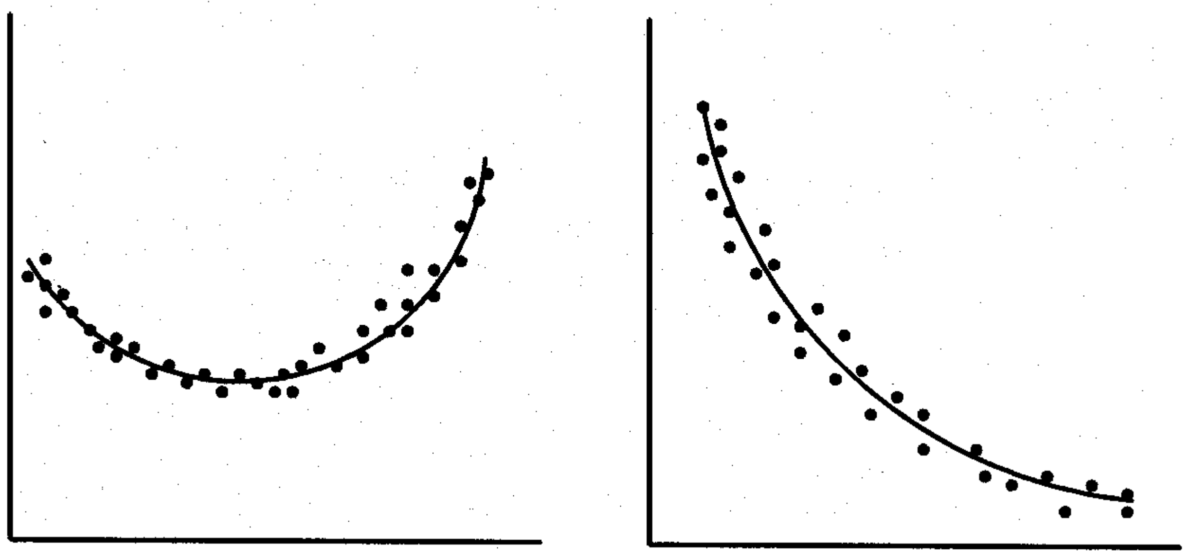
No Correlation

There is no demonstrated connection between y and x



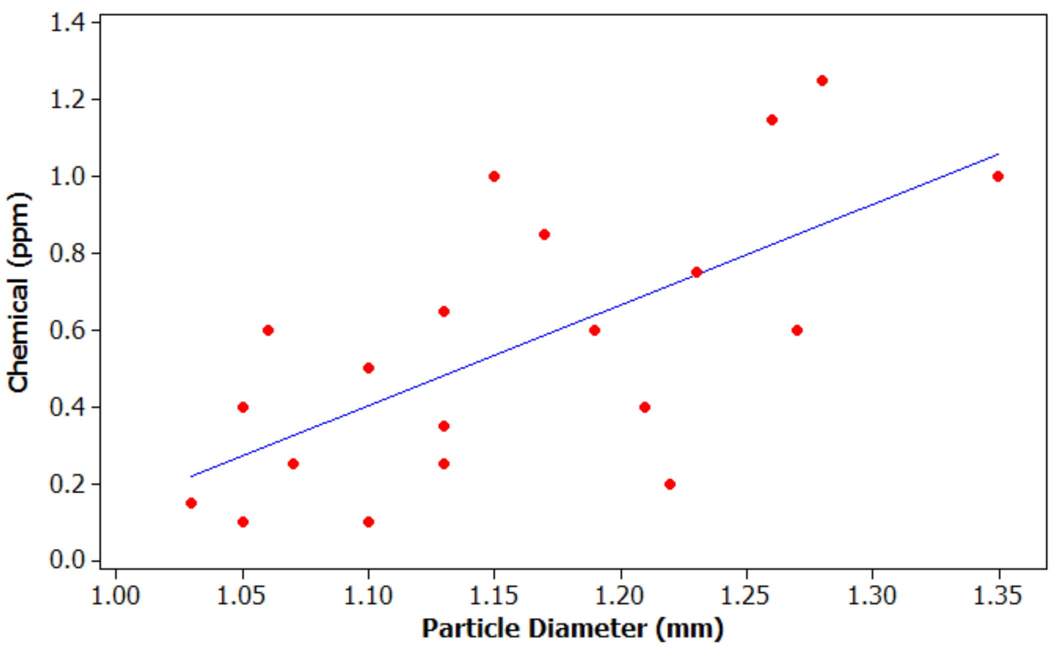
Interpreting a Scatter Diagram

Non-linear Relationships



Scatter Diagram Summary

- ♦The scatter diagram does not predict cause and effect relationships
- ♦The scatter diagram shows the strength of the relationship between two variables
- ♦The stronger the relationship, the greater the likelihood that change in one variable will affect change in the other



Variation

- Variation is the difference in the measured output of a process
- Everything has some amount of variation
- Over time, variation in the measured output from a process will follow a pattern.
- A histogram is one tool that helps us keep track of variation

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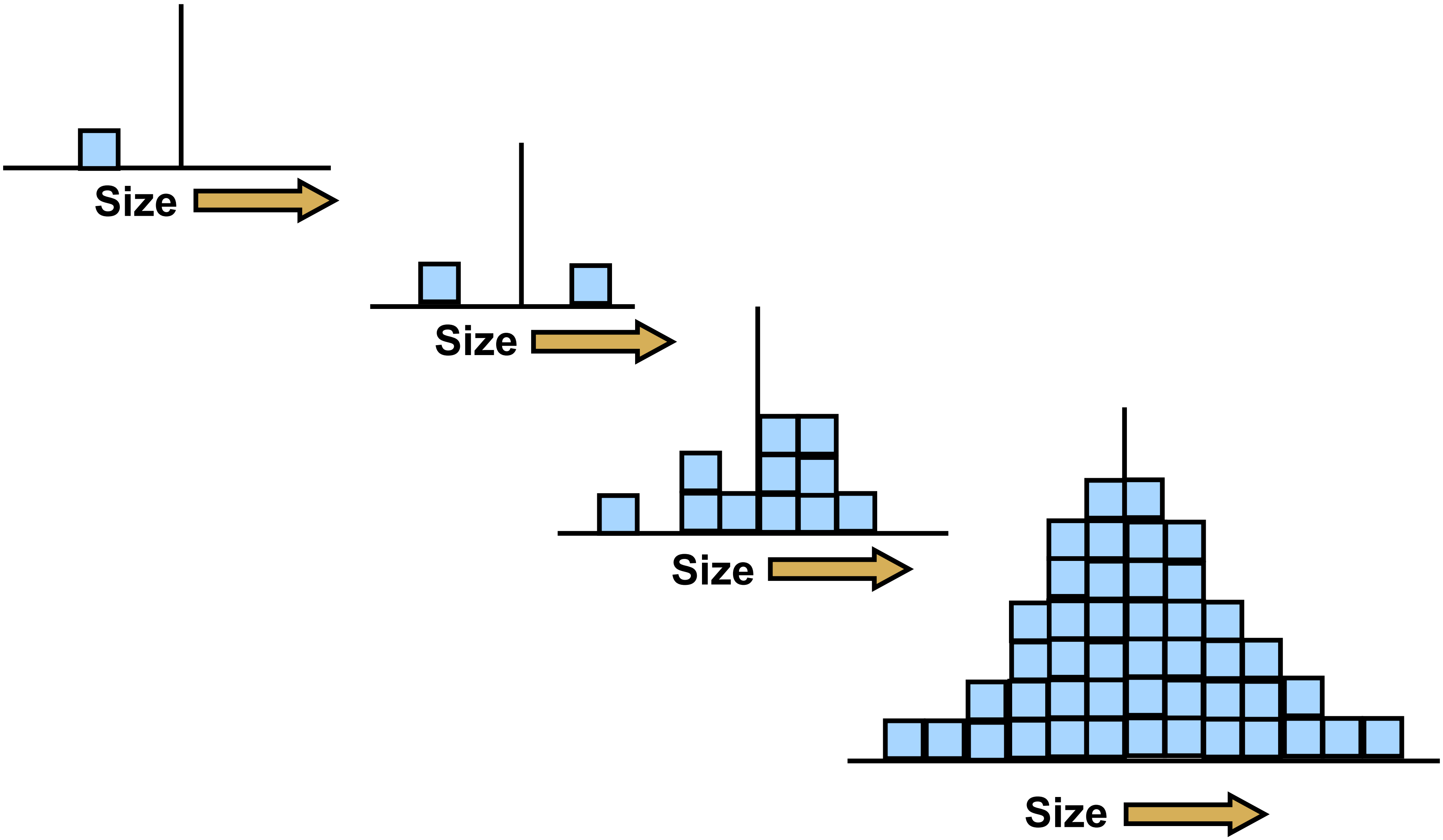
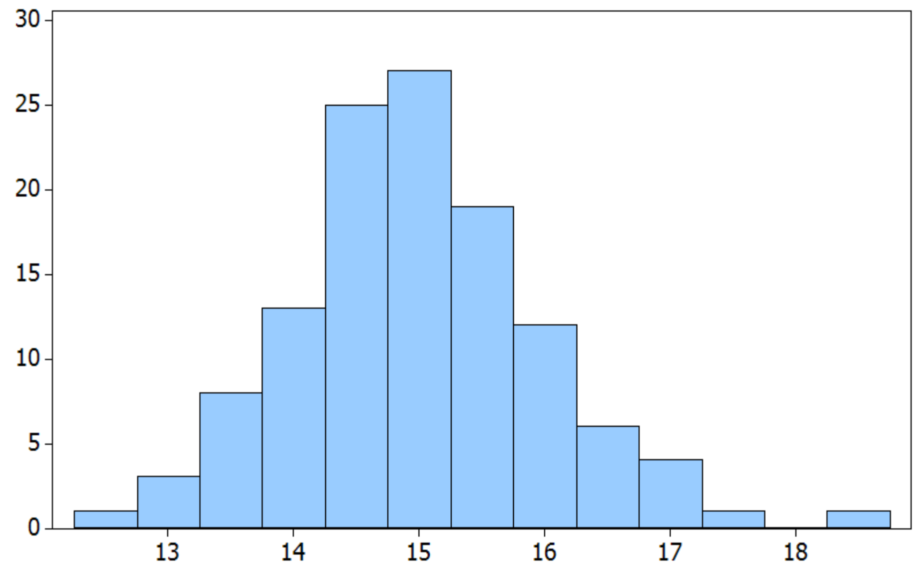
Variation in Data Forms a Pattern



Histogram

A Histogram is used to:



- Display large amounts of data that would be difficult to interpret in a table or other format
- Show the frequency of occurrence of various values
- Illustrate the underlying distribution of the data
- Provide useful information for predicting future performance
- Assist in assessing process capability

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Viscosity Measurements from 120 Batches

12.6	15	16.3	13.3	14.4	15.1
13.7	15.2	17.6	13.9	14.6	15.3
14.1	15.4	13.7	14.3	14.9	15.5
14.3	15.6	14.1	14.4	15.1	15.8
14.5	16	14.3	14.6	15.2	16.2
14.8	16.5	14.5	14.9	15.5	17
14.9	13.1	14.7	15.1	15.8	13.6
15.2	13.8	14.9	15.2	16.1	14
15.3	14.2	15.2	15.4	16.9	14.3
15.6	14.4	15.3	15.7	13.5	14.4
16	14.5	15.6	16.1	14	14.7
16.4	14.8	15.9	16.9	14.3	14.9
12.8	15	16.4	13.4	14.4	15.1
13.7	15.2	18.6	14	14.6	15.3
14.1	15.4	16	14.3	14.9	15.6
14.4	15.7	16.5	14.9	15.2	15.9
14.5	16	13	15	15.3	13.9
14.8	16.6	13.8	15.2	15.6	14.2
15	13.3	14.2	15.4	16.1	14.4
14.8	14.5	14.4	15.7	16.8	14.5

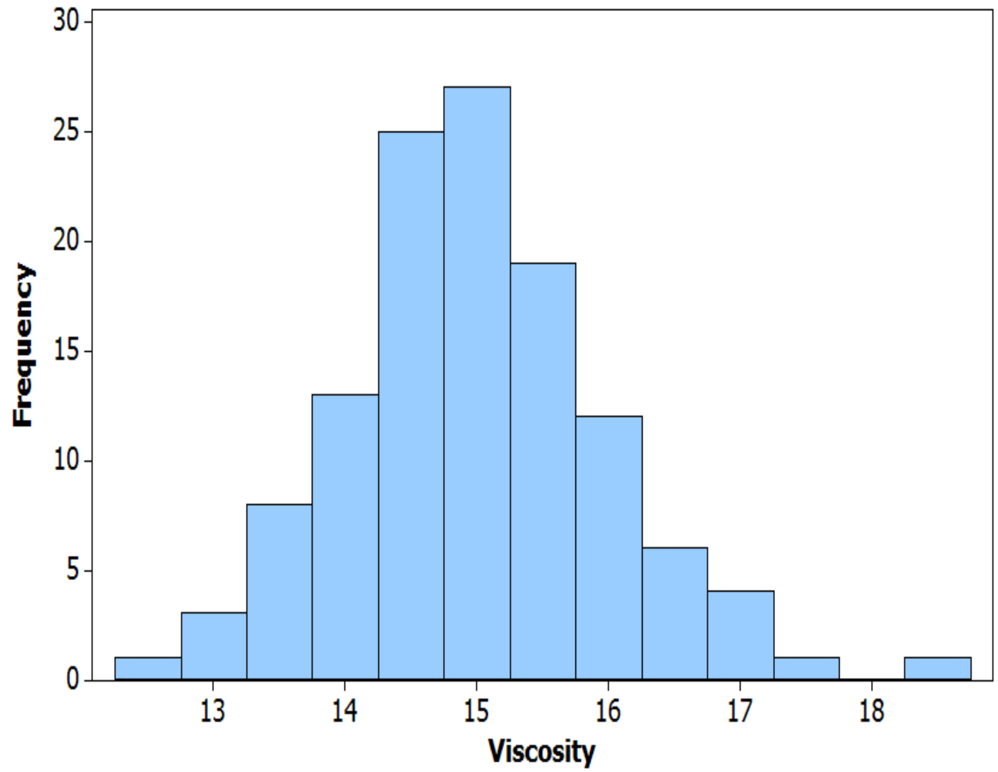
How would you interpret this data?

What can you say about the amount of variation?

What about the pattern of variation?

Histogram of Viscosity Measurements

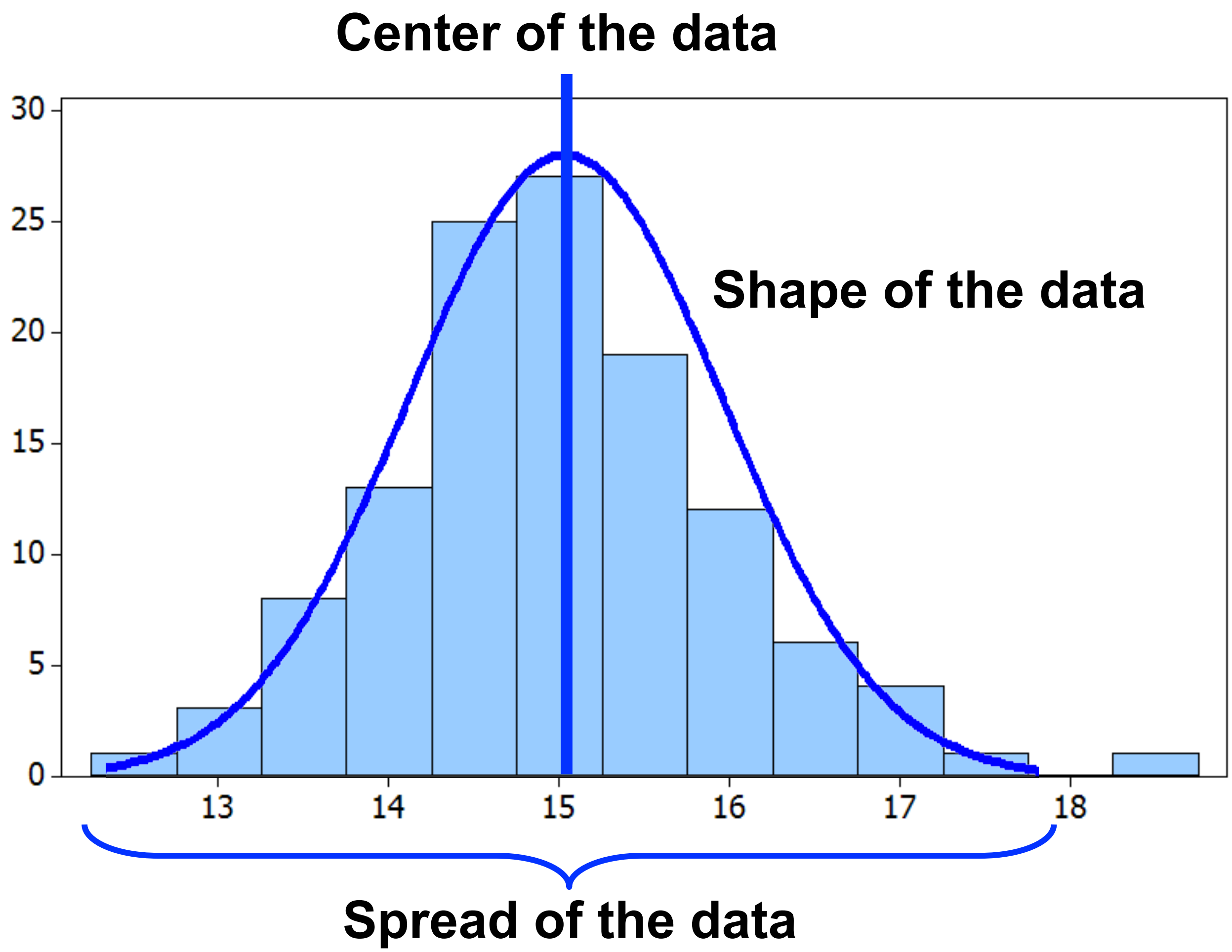
12.6	15	16.3	13.3	14.4	15.1
13.7	15.2	17.6	13.9	14.6	15.3
14.1	15.4	13.7	14.3	14.9	15.5
14.3	15.6	14.1	14.4	15.1	15.8
14.5	16	14.3	14.6	15.2	16.2
14.8	16.5	14.5	14.9	15.5	17
14.9	13.1	14.7	15.1	15.8	13.6
15.2	13.8	14.9	15.2	16.1	14
15.3	14.2	15.2	15.4	16.9	14.3
15.6	14.4	15.3	15.7	13.5	14.4
16	14.5	15.6	16.1	14	14.7
16.4	14.8	15.9	16.9	14.3	14.9
12.8	15	16.4	13.4	14.4	15.1
13.7	15.2	18.6	14	14.6	15.3
14.1	15.4	16	14.3	14.9	15.6
14.4	15.7	16.5	14.9	15.2	15.9
14.5	16	13	15	15.3	13.9
14.8	16.6	13.8	15.2	15.6	14.2
15	13.3	14.2	15.4	16.1	14.4
14.8	14.5	14.4	15.7	16.8	14.5



The histogram gives us a visual summary of the data.

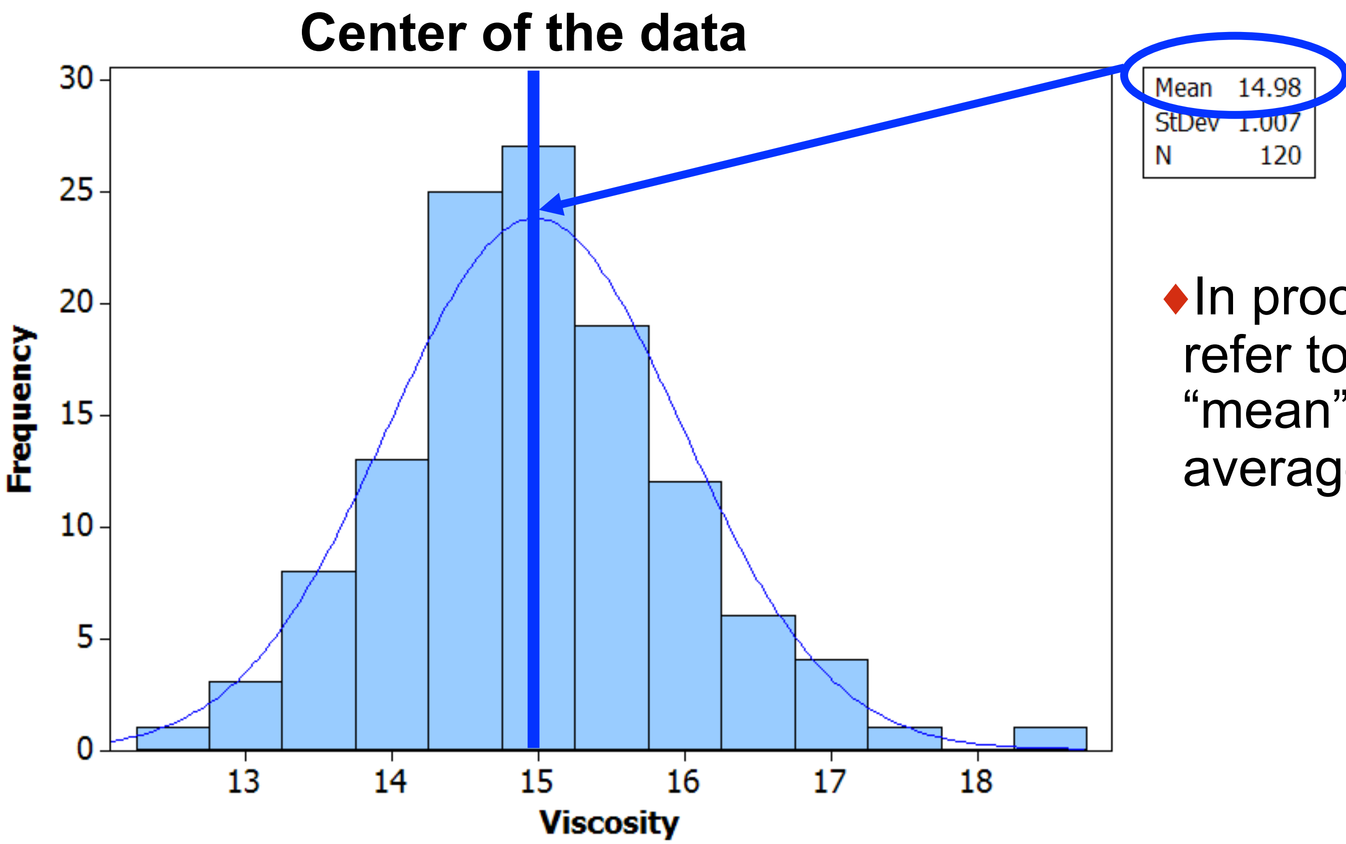
Histogram of Viscosity Measurements

What does the histogram show us?



What is Meant by the Center?

The Center of a Process

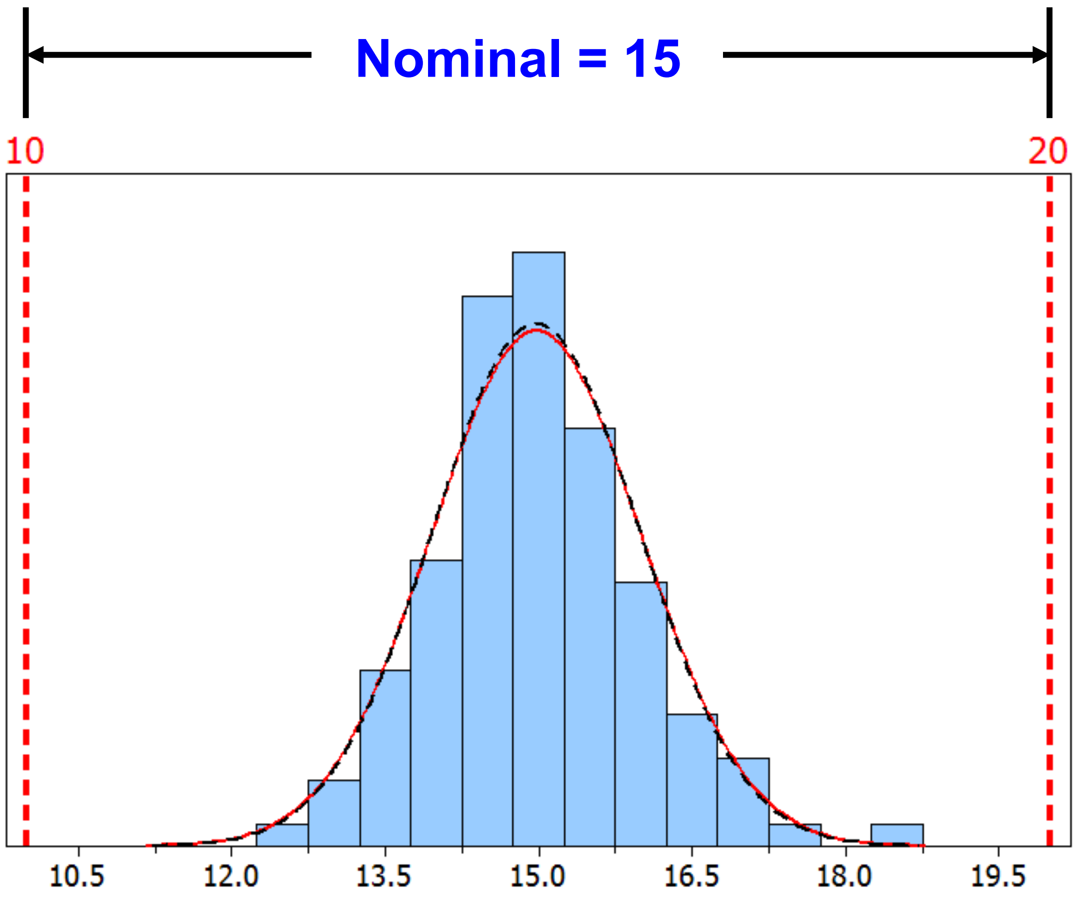


- In process control we refer to the center as the "mean" or "arithmetic average" or "X-bar"

What is Meant by the Center?

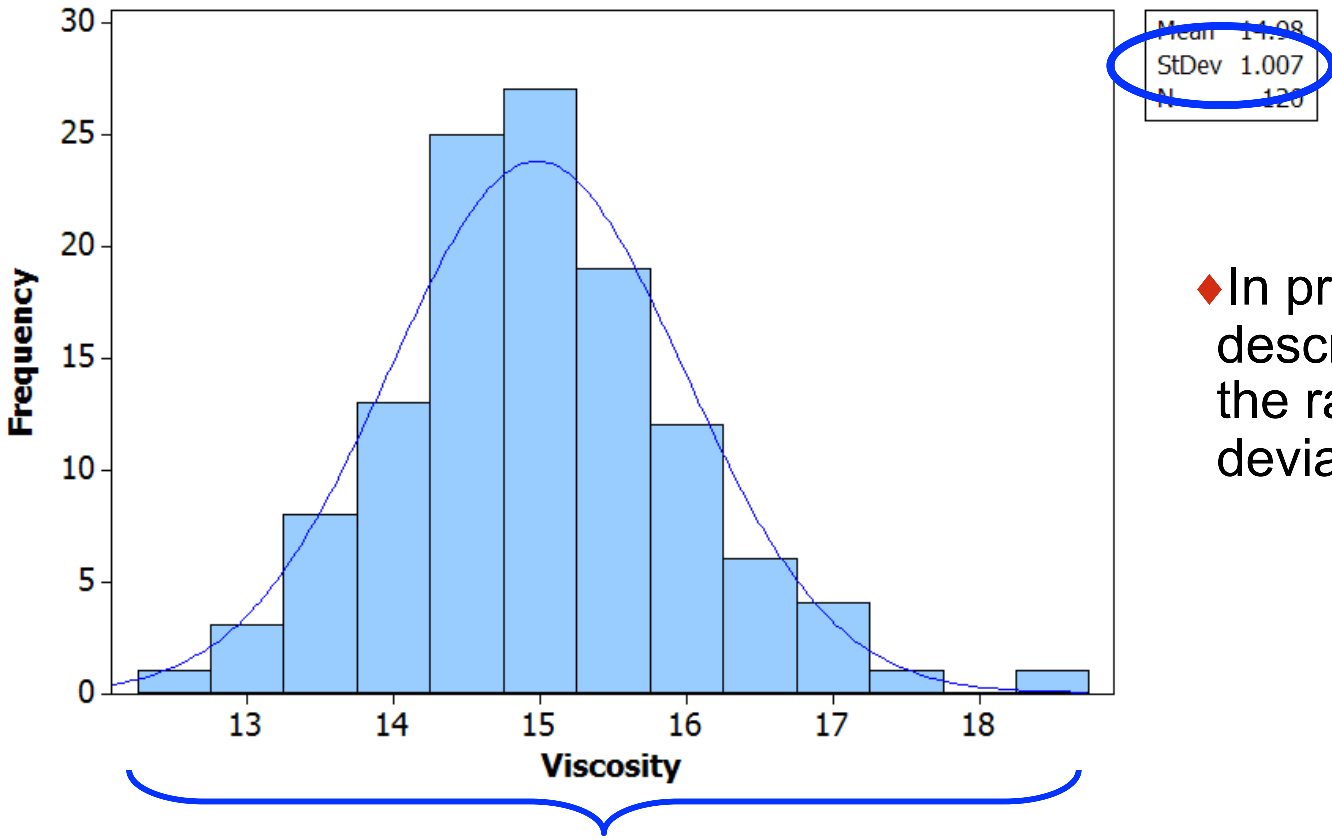
The Center of Specifications

- The mid-point between the upper and lower specification limit
- Often referred to as specification “nominal”



What is Meant by the Spread?

The Spread of a Process

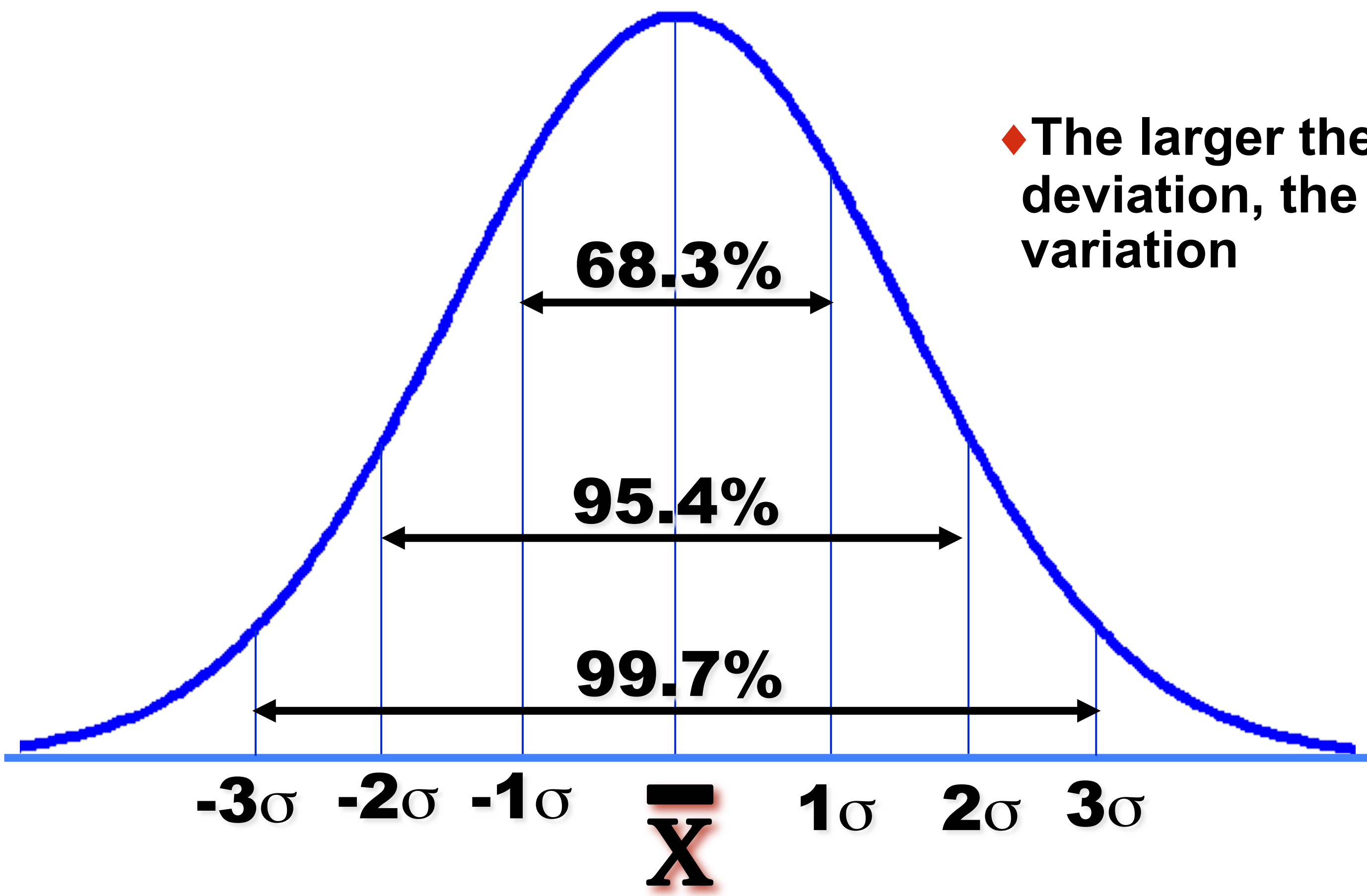


Spread of the data

- In process control we describe the spread by the range or the standard deviation

What is Meant by the Spread?

The Standard Deviation describes the Spread



- **The larger the standard deviation, the greater the variation**

What is Meant by the Spread?

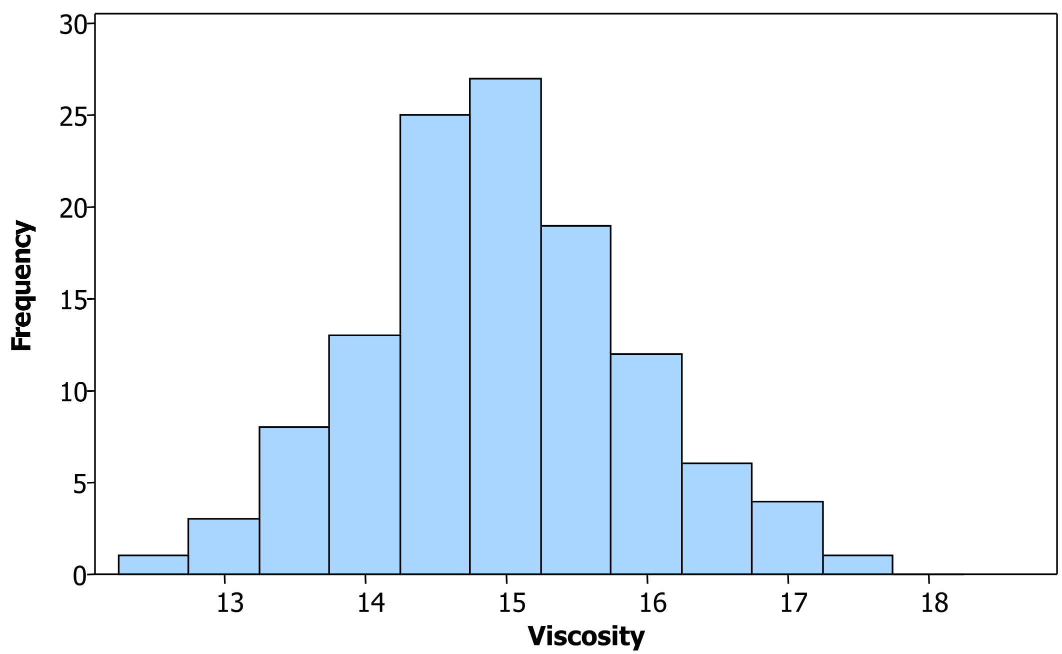
The range is the difference between the largest and smallest values.

$$R = \text{Largest Value} - \text{Smallest Value}$$

Interpreting the Shape of the Histogram

Normal Distribution

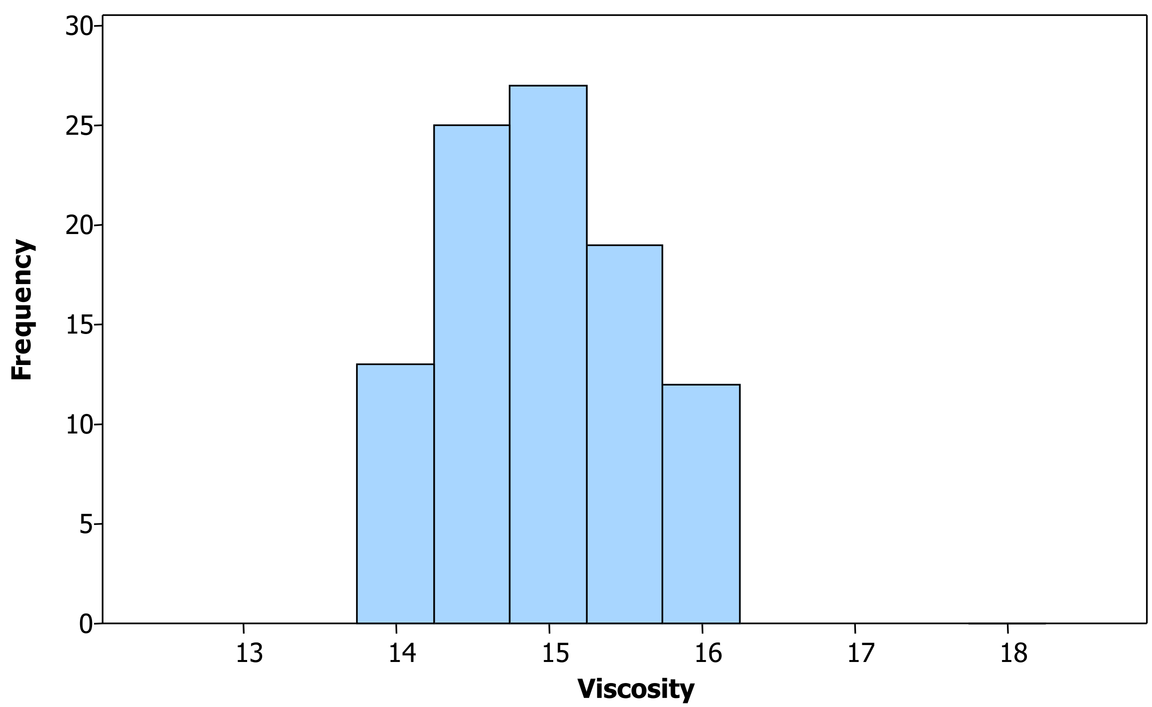
- Bell shaped
- Tapers off evenly on both ends



Interpreting the Shape of the Histogram

Truncated Distribution

- Not normal as there are no tapered ends
- Parts may have been sorted from both ends
- Too few classes (or intervals) may have been chosen

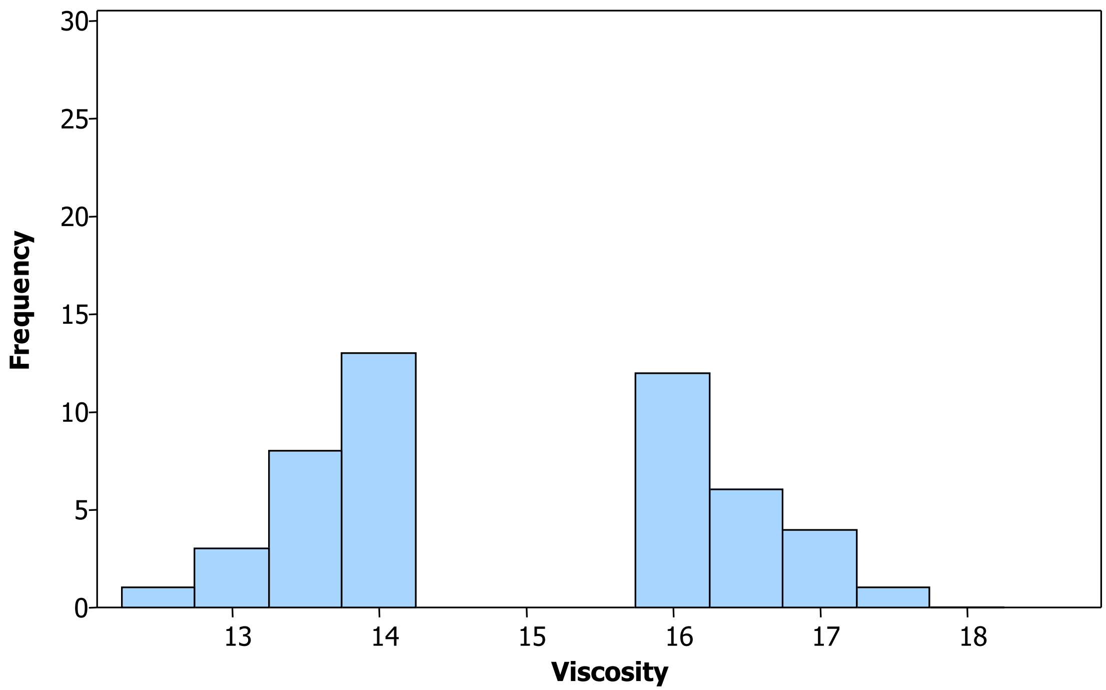


Interpreting the Shape of the Histogram

Missing Center

- The center has been sorted from the rest

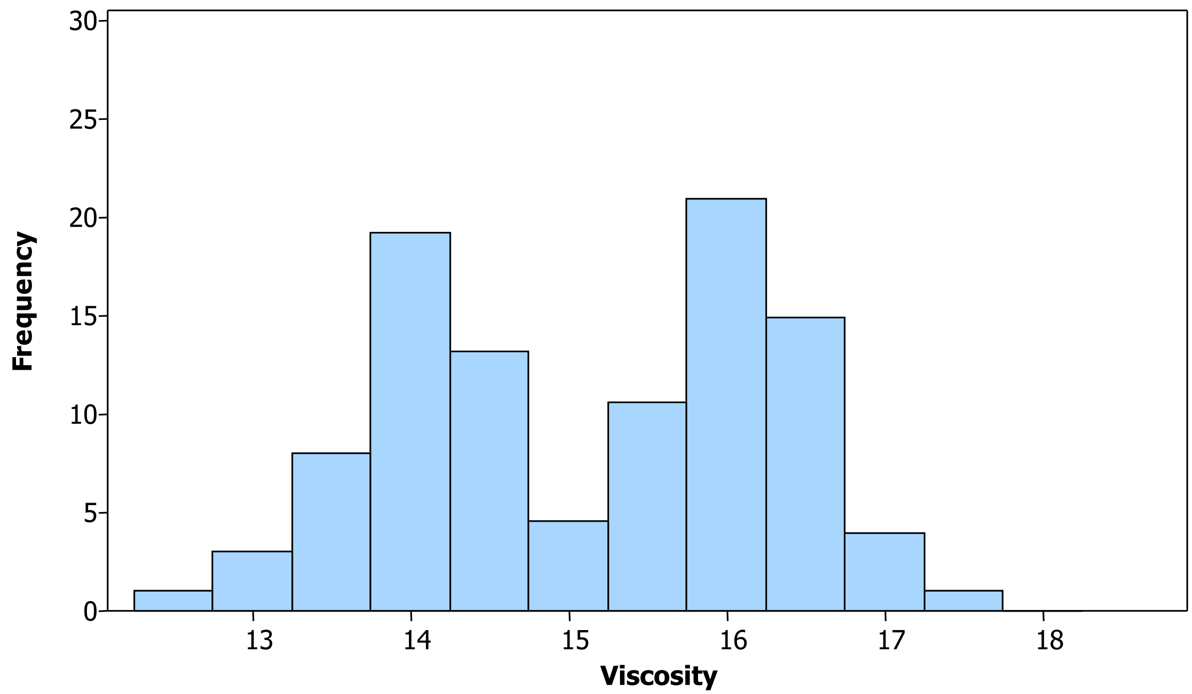
- This portion may have been delivered to a customer with tighter specifications



Interpreting the Shape of the Histogram

Bimodal Distribution

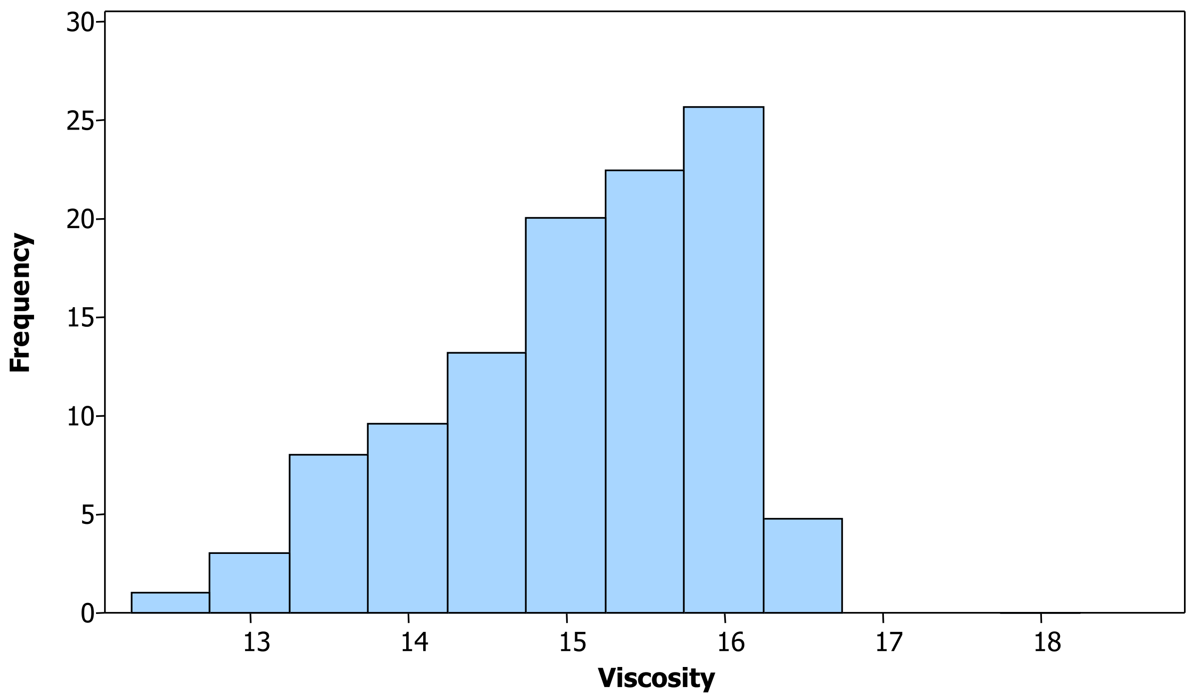
- Two combined populations
- Two shifts, operators, gages, tools, settings, etc.



Interpreting the Shape of the Histogram

Negatively Skewed

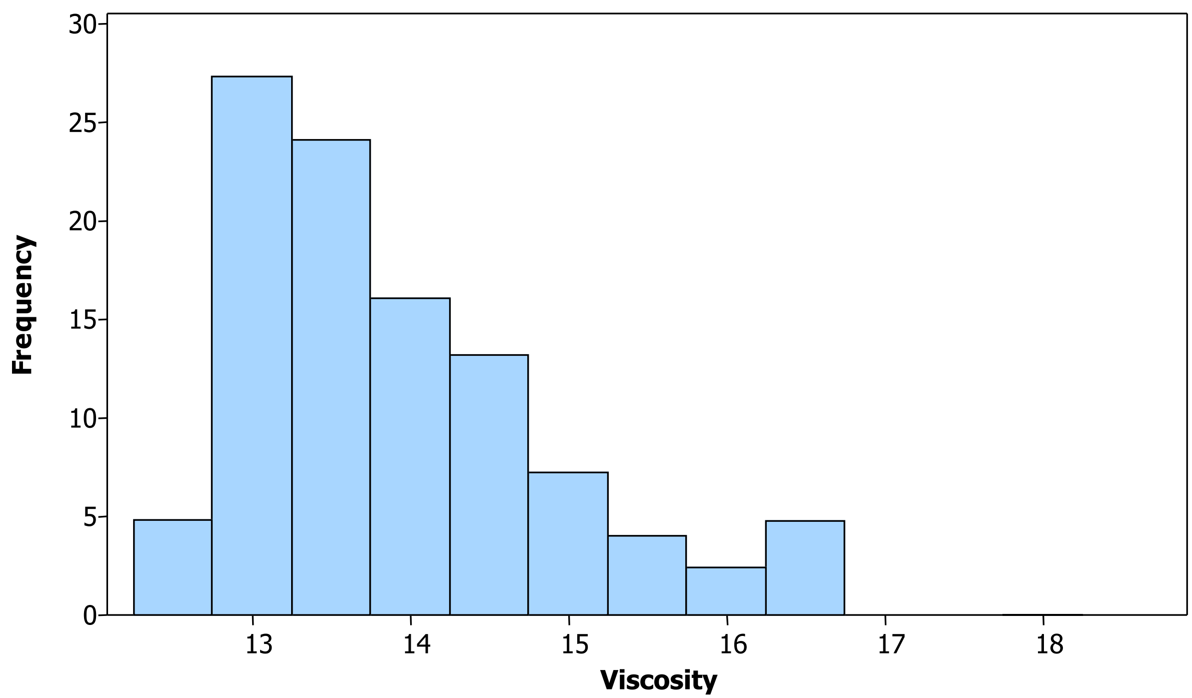
- Process centered toward the low end of the tolerance
- Parts that fall out on the low side are sorted
- The nature of the process prohibits any measurement past a minimum value



Interpreting the Shape of the Histogram

Positively Skewed

- Process centered toward the high end of the tolerance
- Parts that fall out on the high side are sorted
- The nature of the process prohibits any measurement past a minimum value

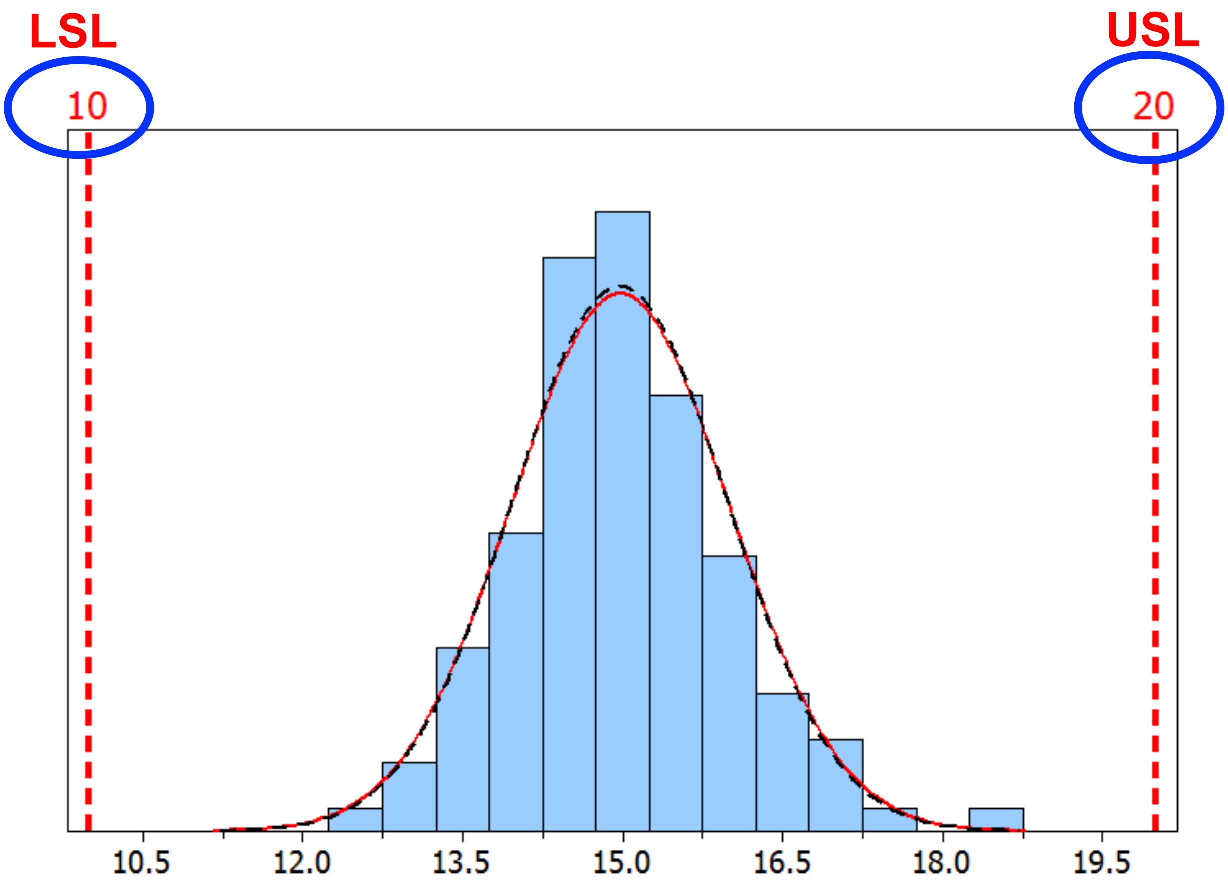


Histograms in Production Situations

Histogram for the viscosity data where:

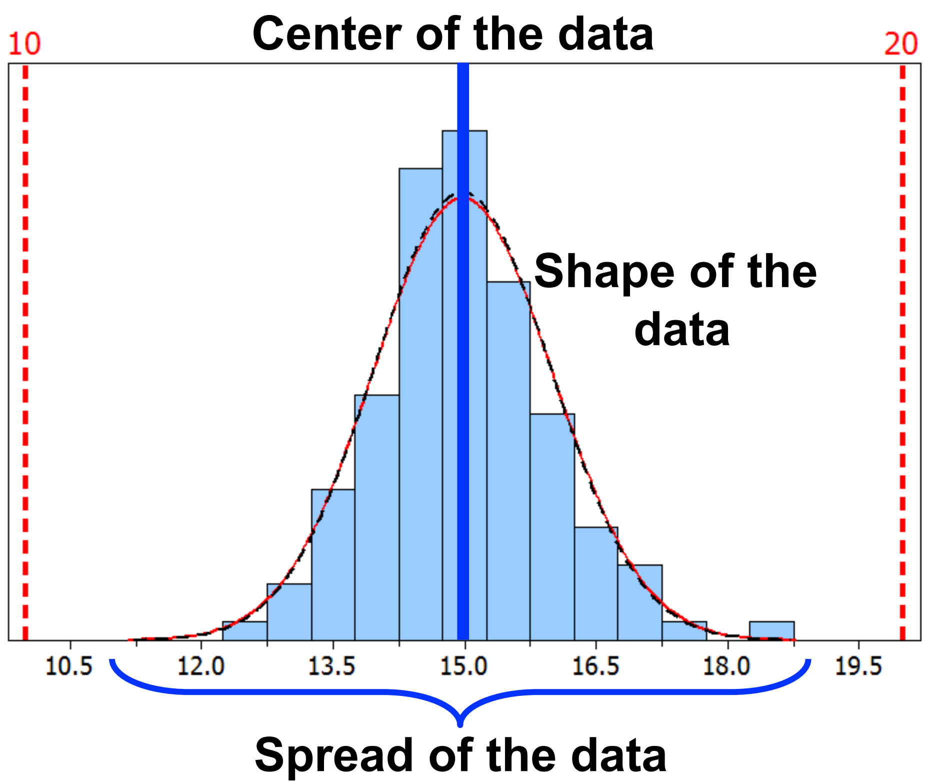
Lower Specification Limit (LSL) = 10

Upper Specification Limit (USL) = 20



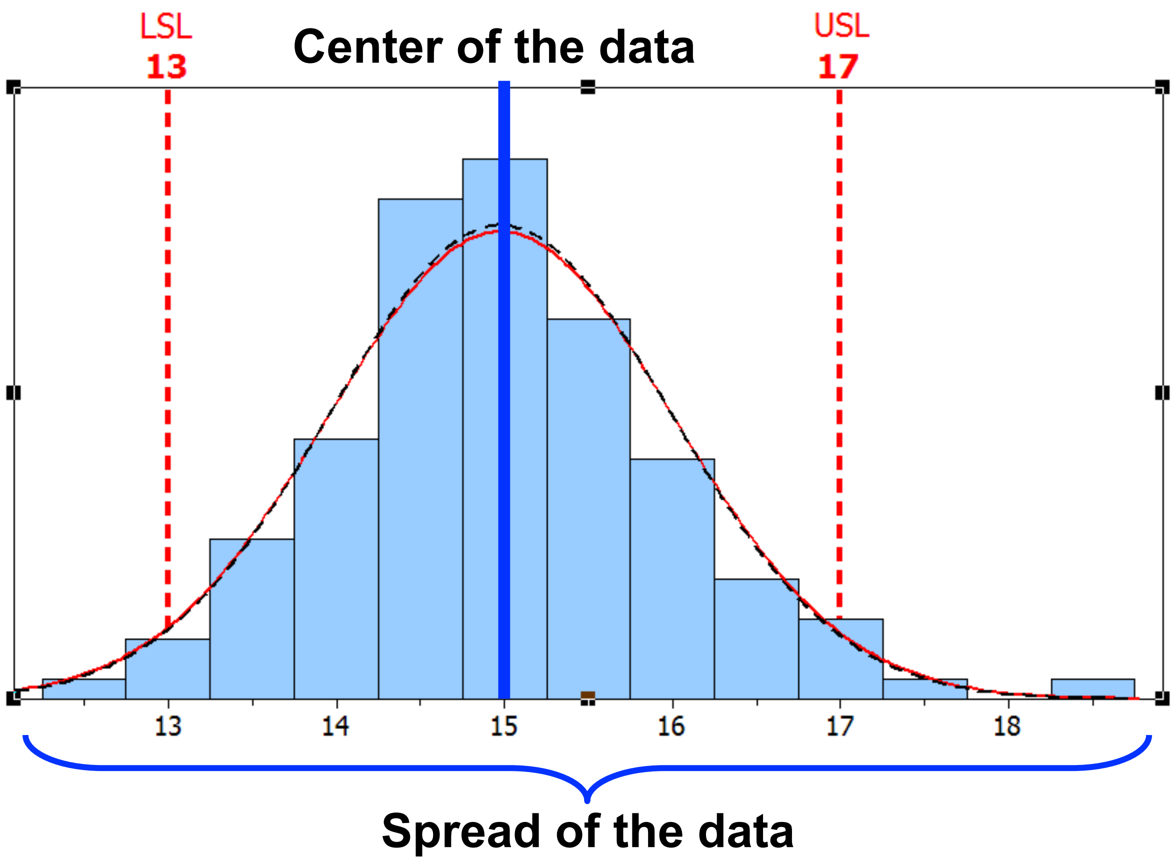
Interpreting the Histogram

- The amount of variation is so small that all units have been produced inside the specifications
- The distribution is symmetrical
- The process is centered at midpoint between the specifications



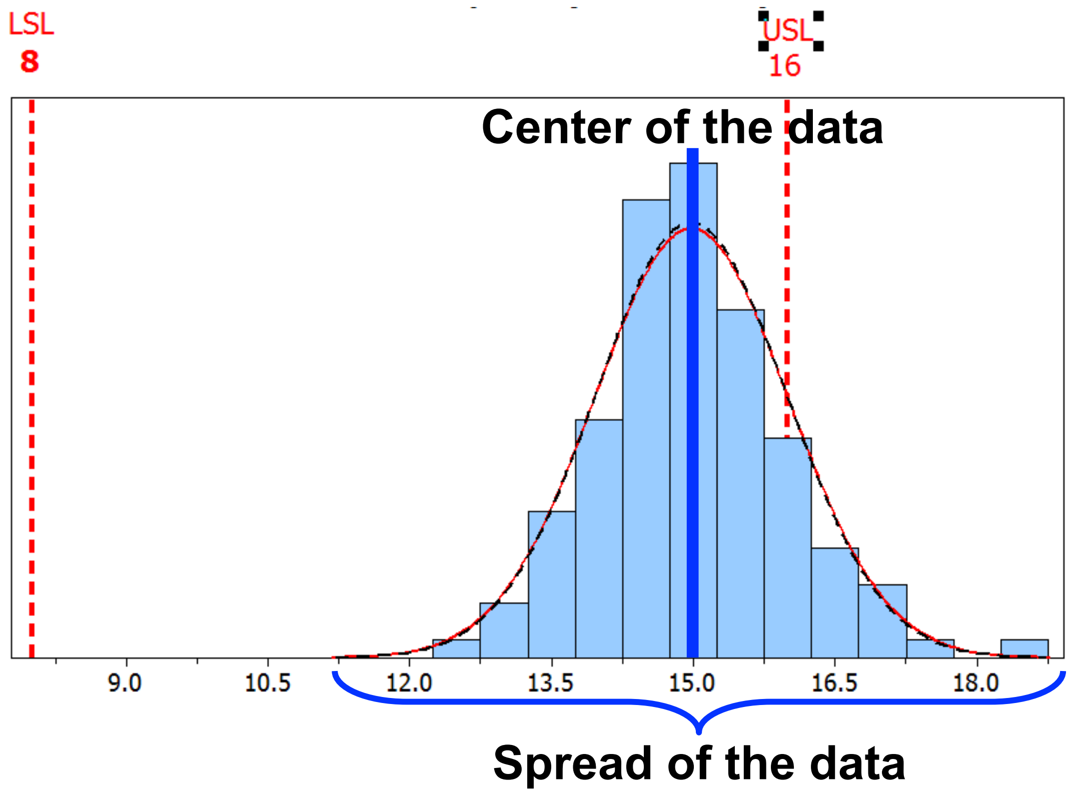
Too Much Variation – Spread is the Problem

- The viscosity measurements of some batches are too low, and others too high
- It is already centered within the specification limits
- The process is still centered at the mid-point of the specifications



Centering is the Problem

- The process center has shifted toward the Upper Specification Limit
- Moving the process center to the middle of the specification limits will improve the process



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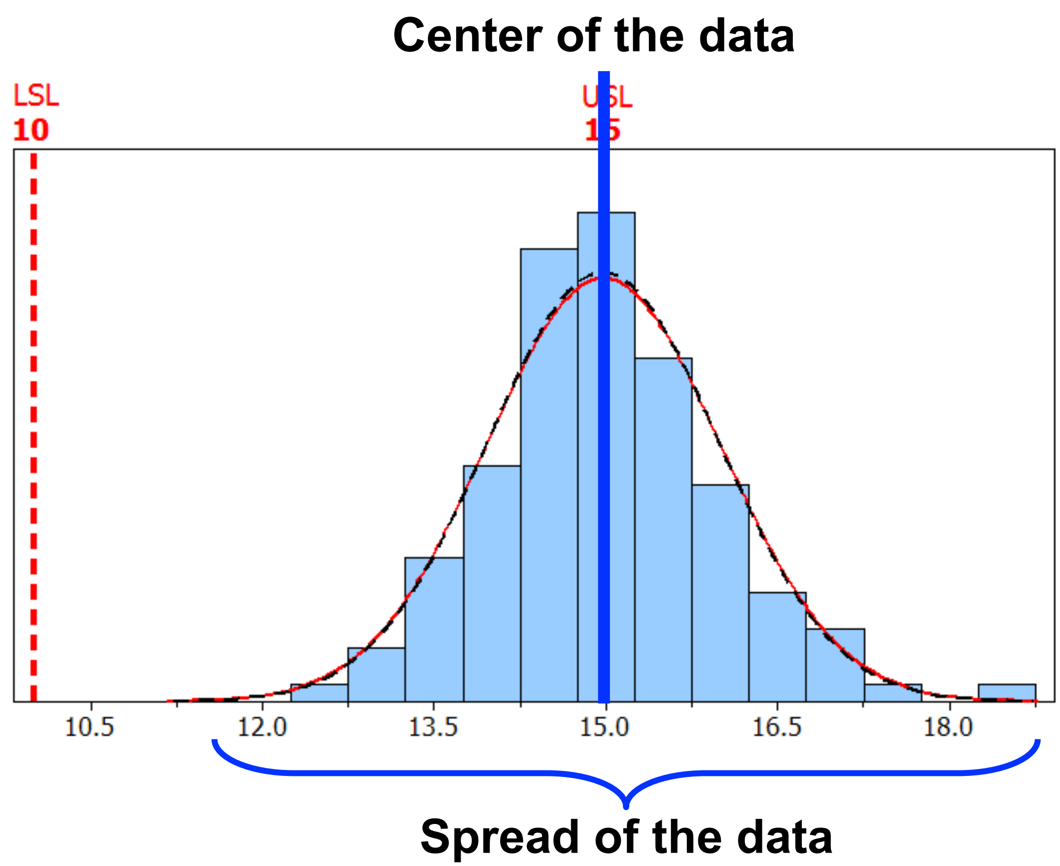
Centering and Spread is the Problem

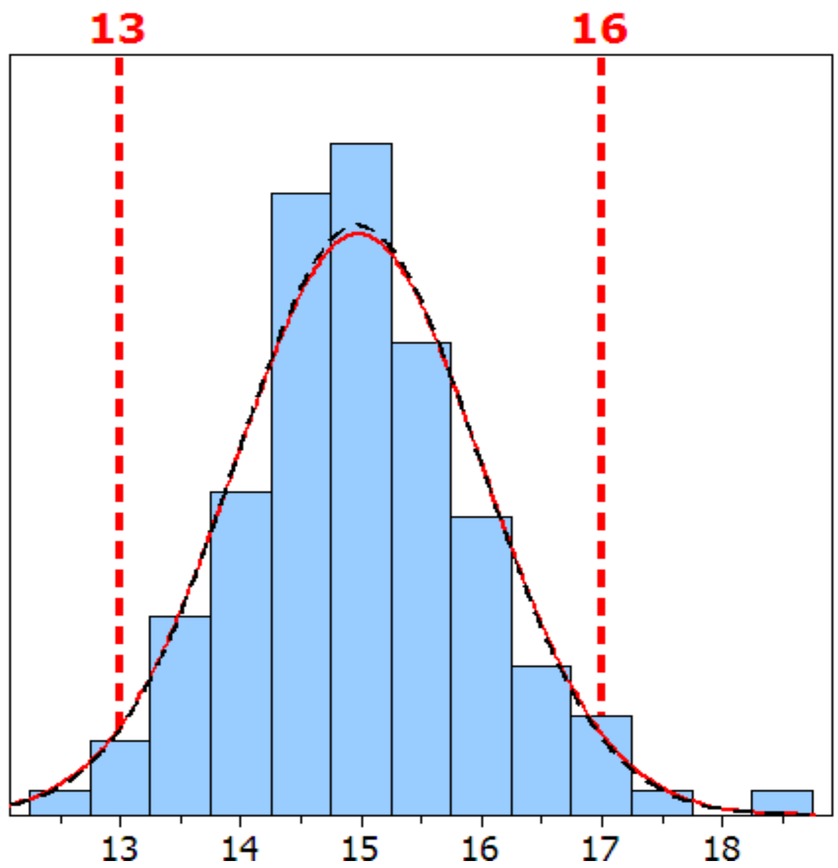
- The process center has shifted toward the Upper Specification Limit
- The spread, or the total amount of variation is wider than the specification limits – centering will not help



Process Capability Analysis

What is Process Capability Analysis?

A procedure that involves bringing the process in statistical control for a period of time and comparing the long term process performance to management or engineering specifications.



A comparison of process spread vs. specification width

Process Capability Indices

What are the indices used for?

- To provide a single number to assess the performance of a process
- To provides a scale for comparing processes
- To show over time if a process is able to meet specifications

Potential (Within) Capability	
Cp	1.63
CPL	1.62
CPU	1.64
Cpk	1.62
Overall Capability	
Pp	1.65
PPL	1.64
PPU	1.66
Ppk	1.64
Cpm	*

The indices are calculated by software however, you need to know how to interpret them.

Short Term Capability Index

$$C_p = \frac{USL - LSL}{6\sigma_{ST}}$$

- **Compares the width of the specification to the short-term width of the process**
- **Only looks at variation and ignores the extent to which the process is on target.**

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Adjusted Short Term Capability Index

$$C_{pk} = \text{minimum}\left(C_{pl}\,,\,C_{pu}\right)$$

- Looks at variation and takes into account the location of the process average relative to specification nominal
- Used when the process is not "centered" on specification nominal

Adjusted Short Term Capability Index

$$C_{pl} = \frac{\bar{X} - LSL}{3\sigma_{ST}}$$

$$C_{pu} = \frac{USL - \bar{X}}{3\sigma_{ST}}$$

Long Term Capability Index

$$P_p = \frac{USL - LSL}{6\sigma_{LT}}$$

- Compares the width of the specification to the long - term width of the process
- Only looks at variation and ignores the extent to which the process is on target.

Adjusted Long Term Capability Index

$$P_{pk} = \text{minimum}\left(P_{pl}\,,\,P_{pu}\right)$$

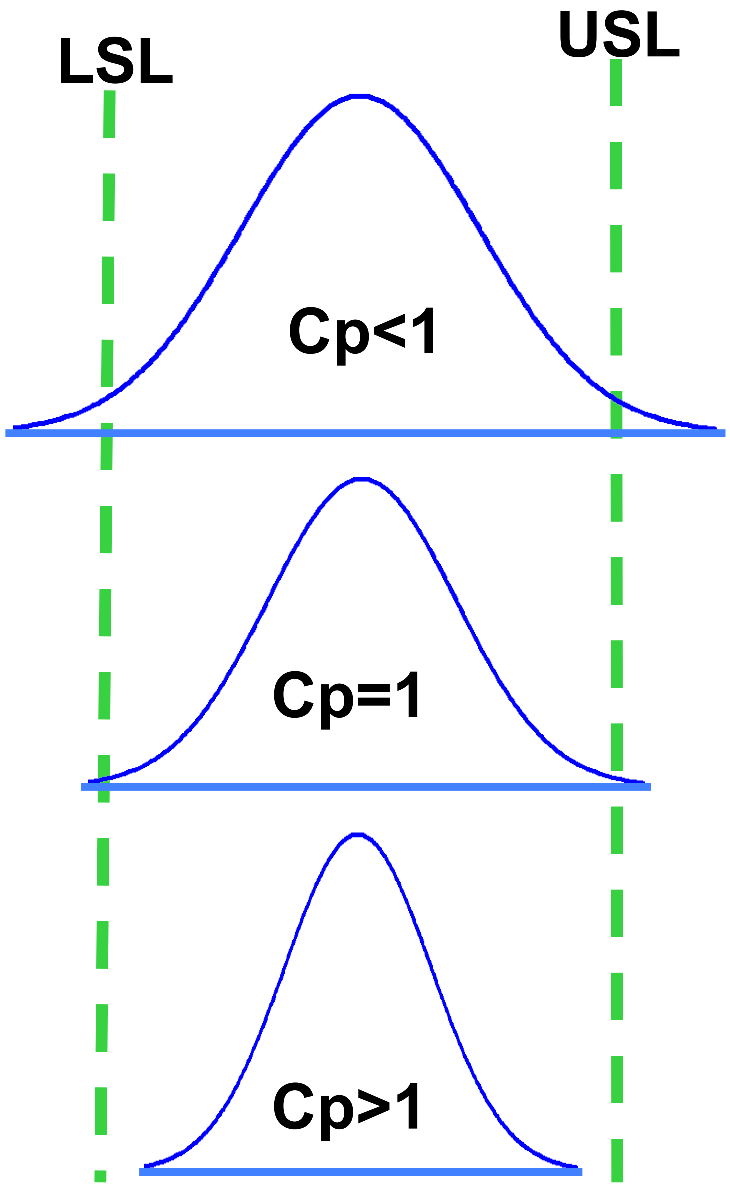
- Looks at variation and takes into account the location of the process average relative to specification nominal
- Used when the process is not “centered” on specification nominal

Adjusted Long Term Capability Index

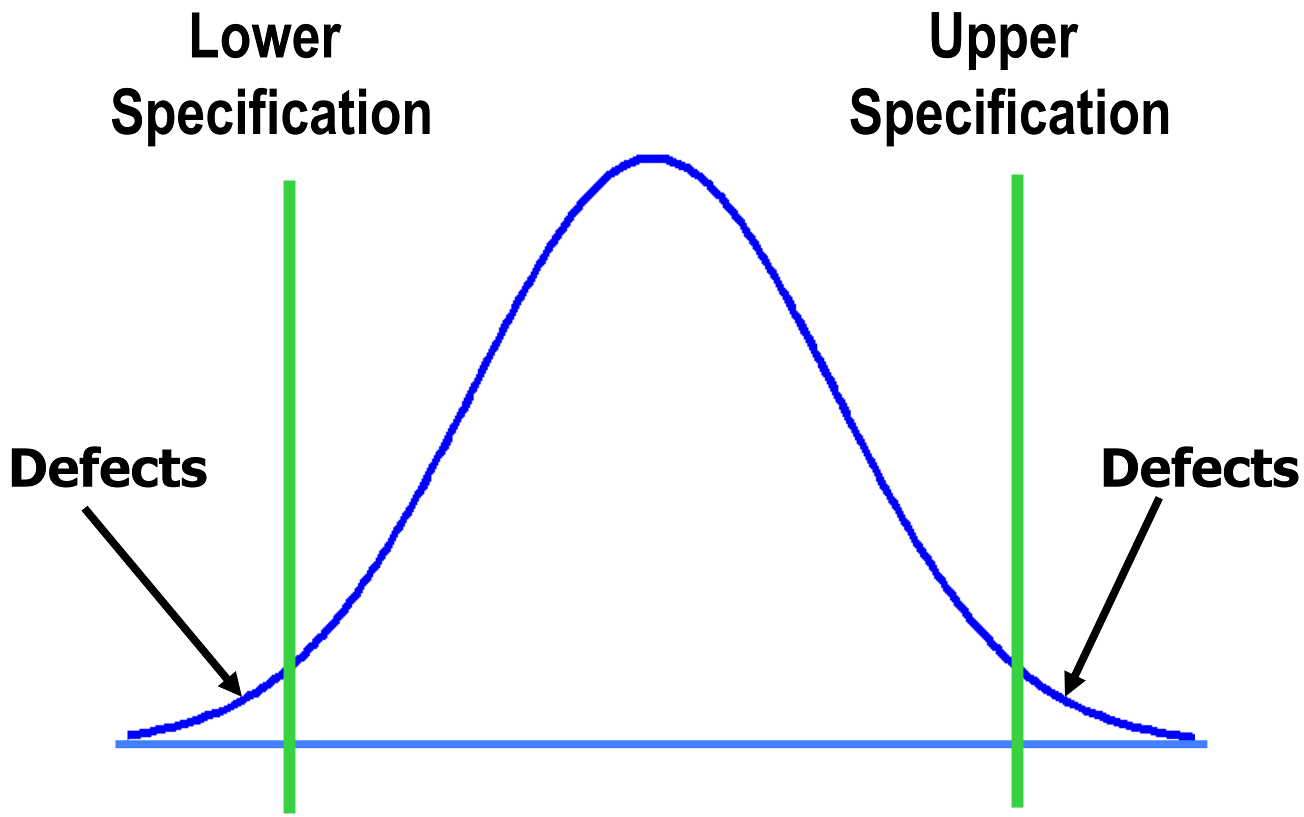
$$P_{pl} = \frac{\bar{X} - LSL}{3\sigma_{LT}}$$

$$P_{pu} = \frac{USL - \bar{X}}{3\sigma_{LT}}$$

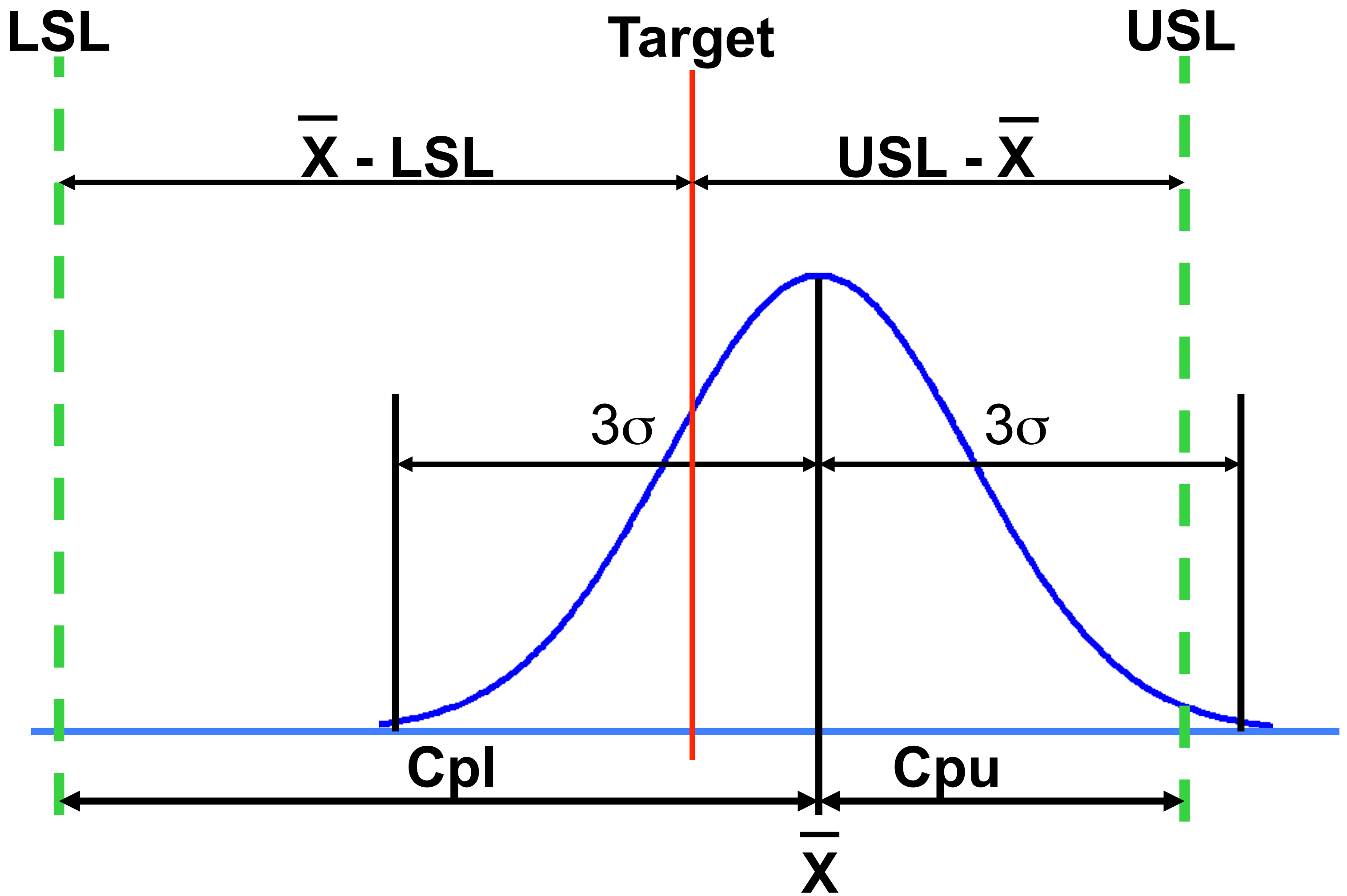
Short Term Capability Index



Spread is Too Wide

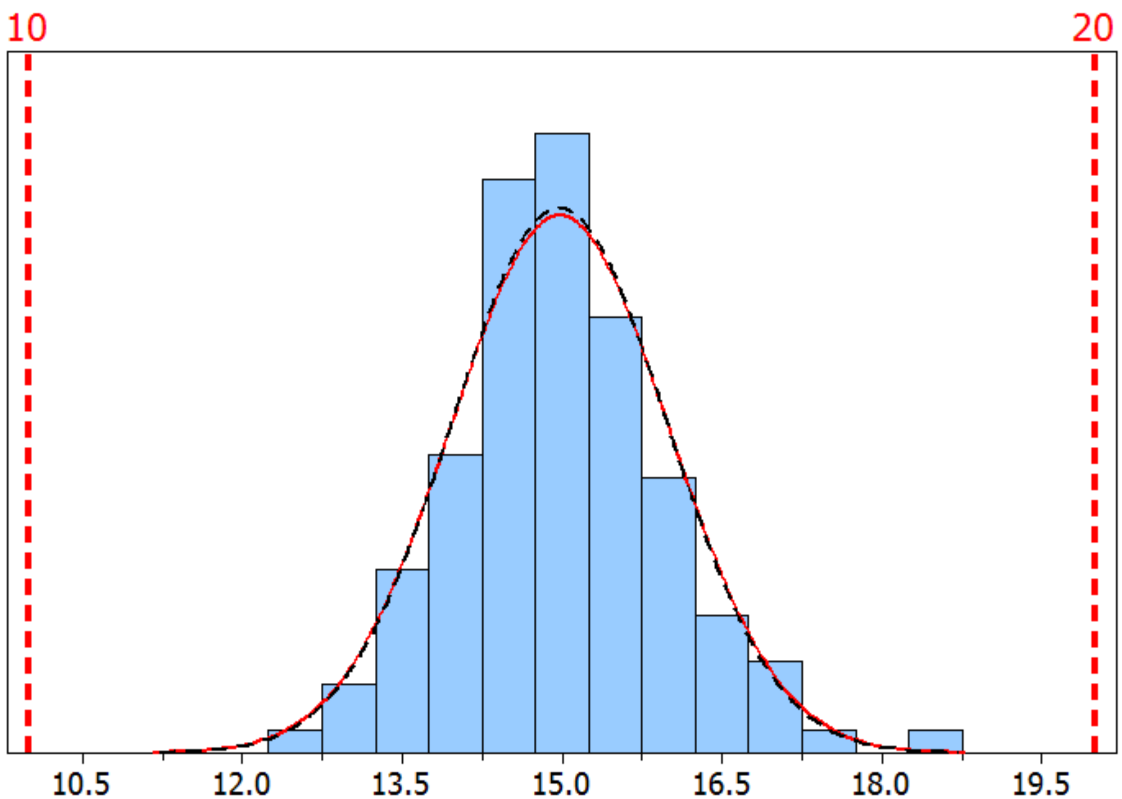


Adjusted Short Term Capability Index



A Centered and Capable Process

Capability indices where:
Lower Specification Limit (LSL) = 10
Upper Specification Limit (USL) = 20



Process Data	
LSL	10
Target	*
USL	20
Sample Mean	14.9775
Sample N	120
StDev(Within)	1.02286
StDev(Overall)	1.00911

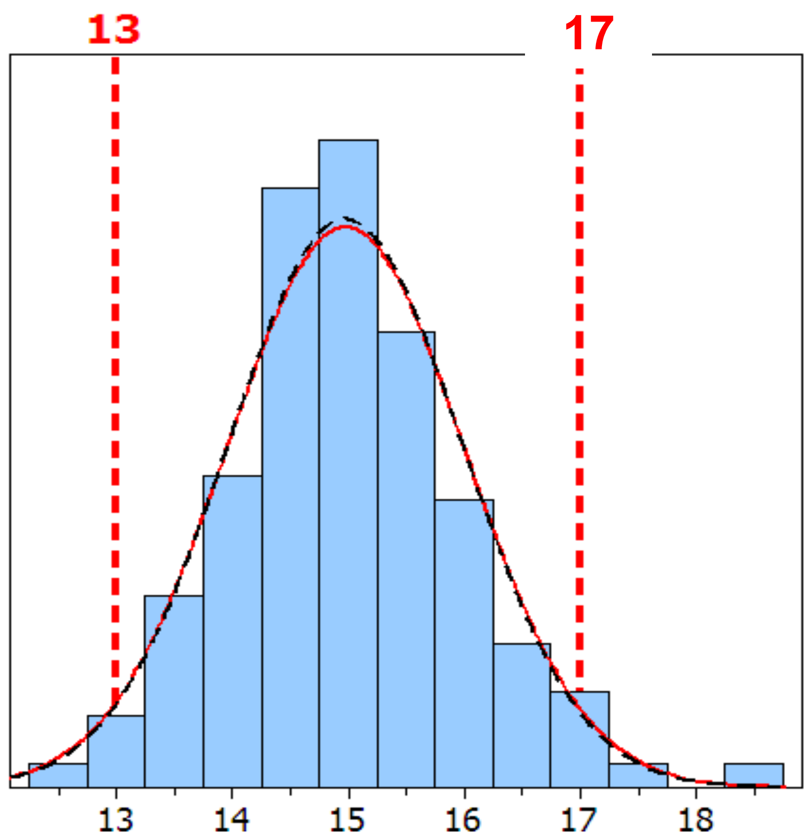
Potential (Within) Capability	
Cp	1.63
CPL	1.62
CPU	1.64
Cpk	1.62
Overall Capability	
Pp	1.65
PPL	1.64
PPU	1.66
Ppk	1.64
Cpm	*

A Process Centered and Not Capable

Capability indices where:

Lower Specification Limit (LSL) = 13

Upper Specification Limit (USL) = 17



Process Data	
LSL	13
Target	*
USL	17
Sample Mean	14.9775
Sample N	120
StDev(Within)	1.02286
StDev(Overall)	1.00911

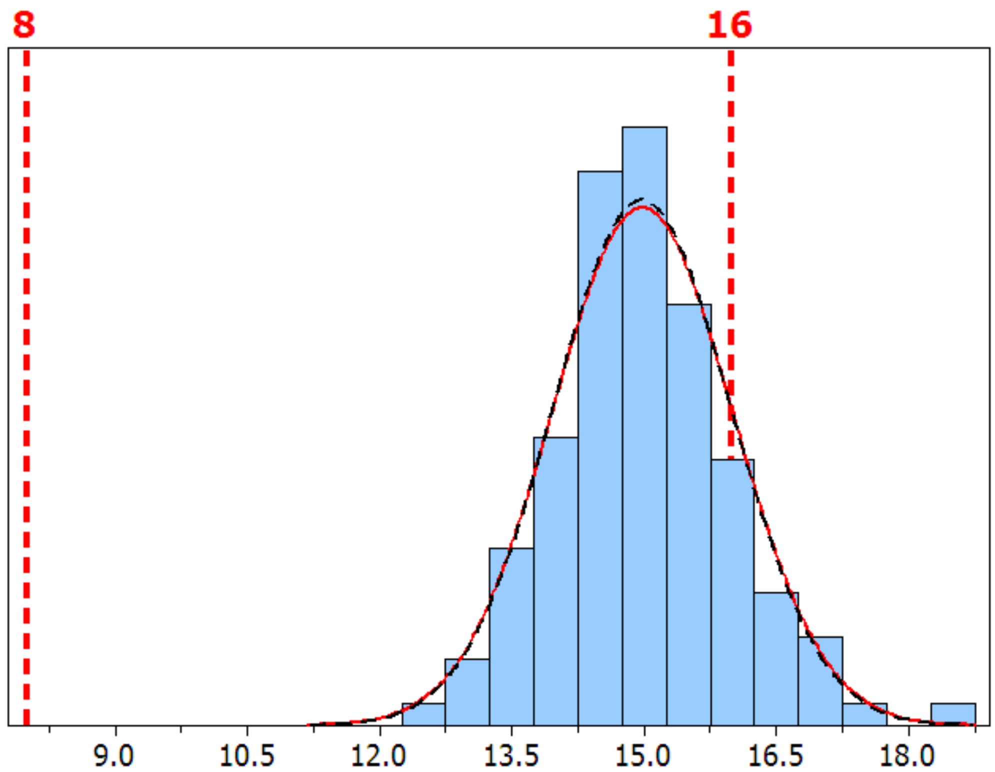
Potential (Within) Capability	
Cp	0.65
CPL	0.64
CPU	0.66
Cpk	0.64
Overall Capability	
Pp	0.66
PPL	0.65
PPU	0.67
Ppk	0.65
Cpm	*

Potentially Capable and Not Centered

Capability indices where:

Lower Specification Limit (LSL) = 8

Upper Specification Limit (USL) = 16



Process Data	
LSL	8
Target	*
USL	16
Sample Mean	14.9775
Sample N	120
StDev(Within)	1.02286
StDev(Overall)	1.00911

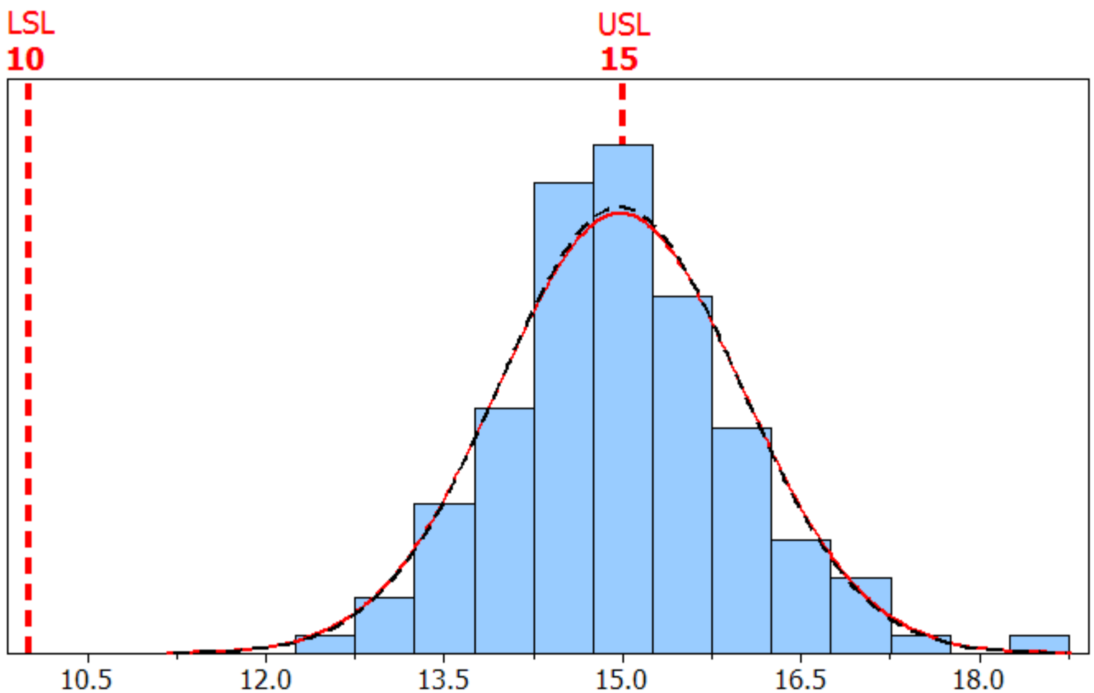
Potential (Within) Capability	
Cp	1.30
CPL	2.27
CPU	0.33
Cpk	0.33
Overall Capability	
Pp	1.32
PPL	2.30
PPU	0.34
Ppk	0.34
Cpm	*

Not Centered and Not Capable

Capability indices where:

Lower Specification Limit (LSL) = 10

Upper Specification Limit (USL) = 15

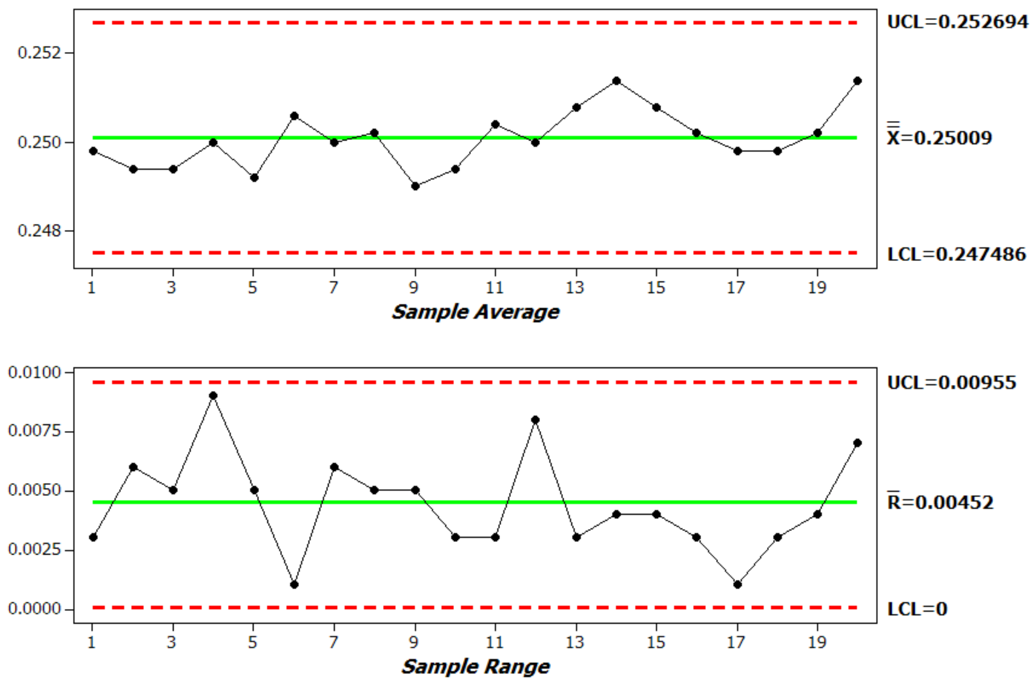


Process Data	
LSL	10
Target	*
USL	15
Sample Mean	14.9775
Sample N	120
StDev(Within)	1.02286
StDev(Overall)	1.00911

Potential (Within) Capability	
Cp	0.81
CPL	1.62
CPU	0.01
Cpk	0.01
Overall Capability	
Pp	0.83
PPL	1.64
PPU	0.01
Ppk	0.01
Cpm	*

Control Charts

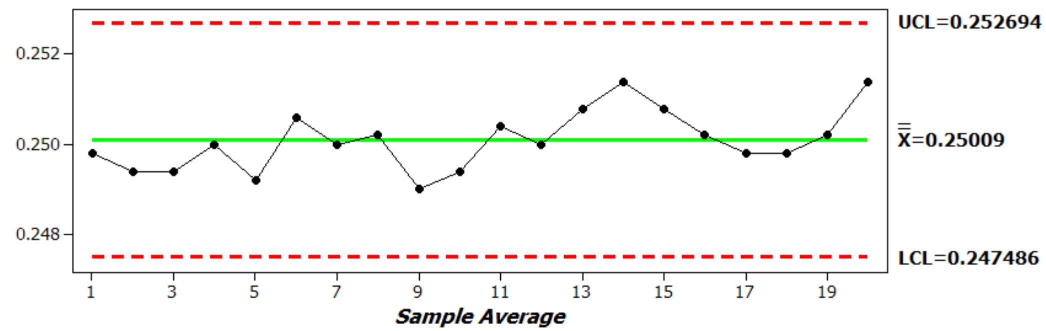
- ♦Tools used to analyze the variation in any process – administrative or manufacturing.
- ♦A line graph that displays a dynamic picture of process behavior

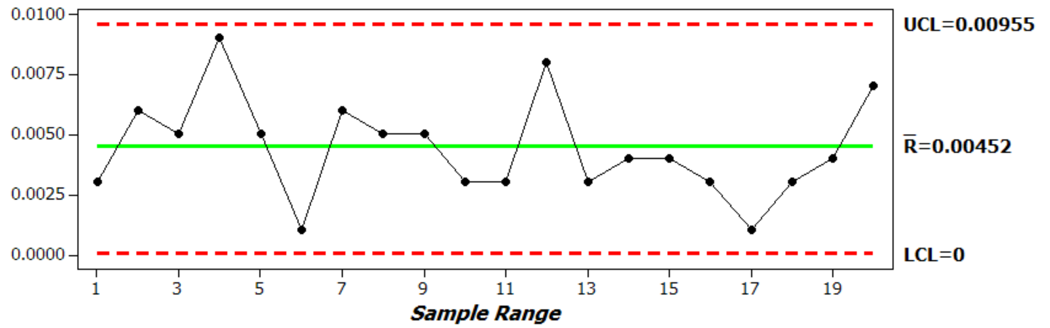


Control Charts

A Control Chart is:

- ♦A line graph of a sample statistic
- ♦In Time ordered fashion
- ♦With Centerline and statistically determined control limits

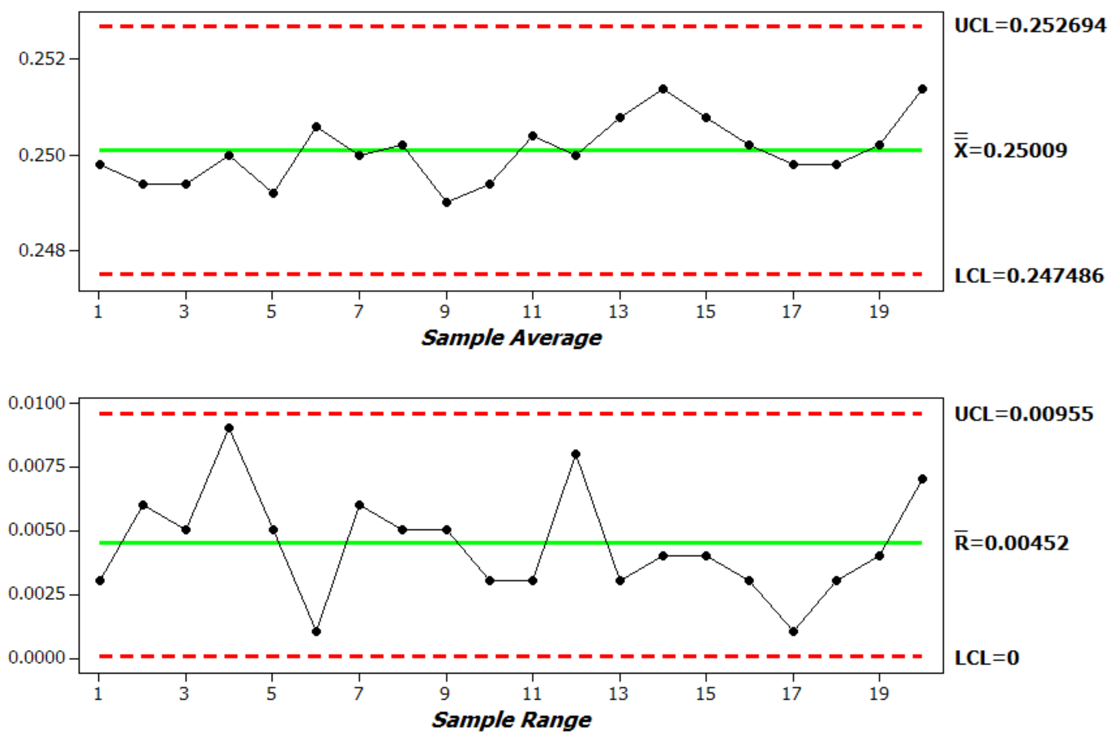




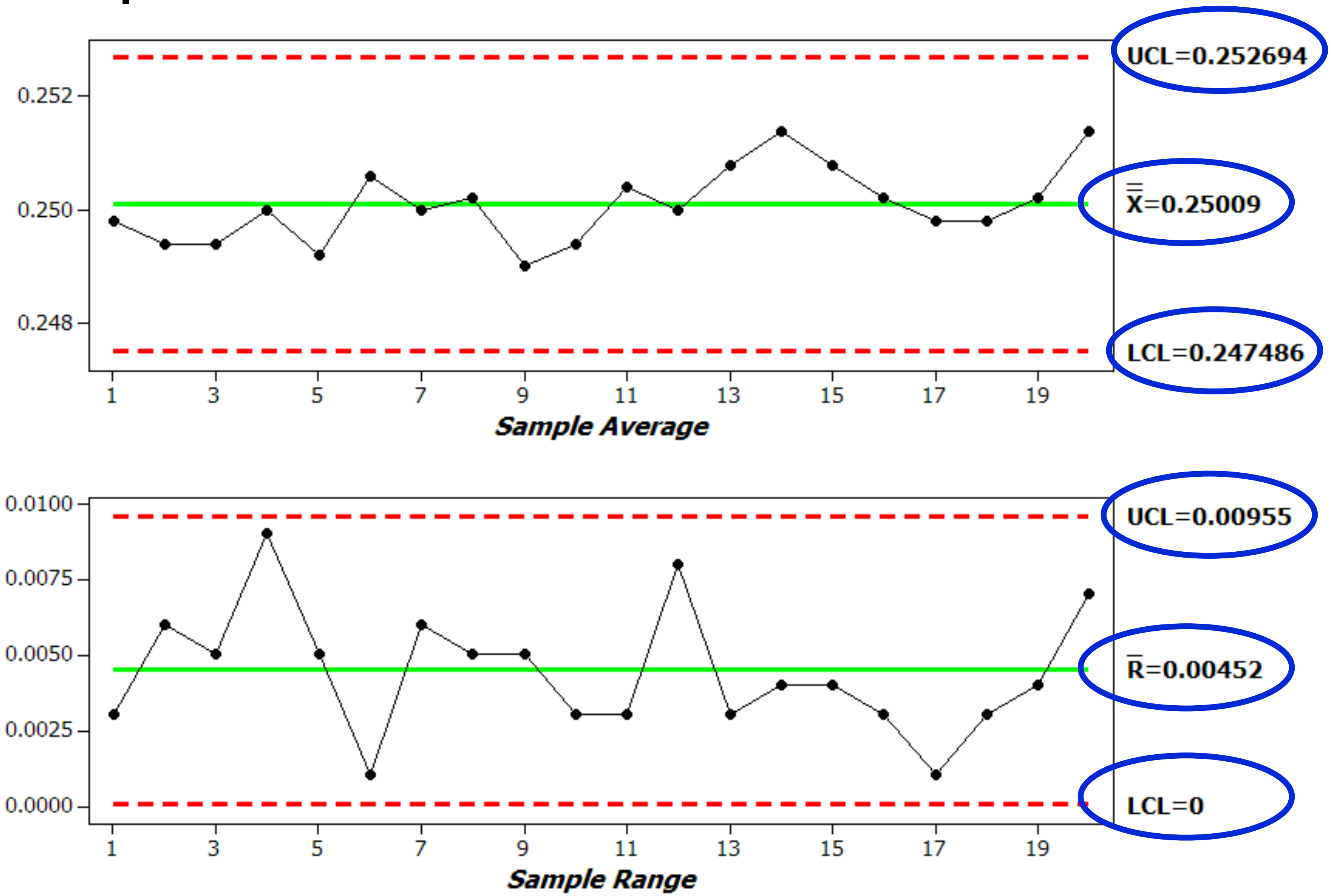
What are Control Charts Used for?

- To Distinguish between random and assignable causes of variation

- To assist in determining the capability of the process

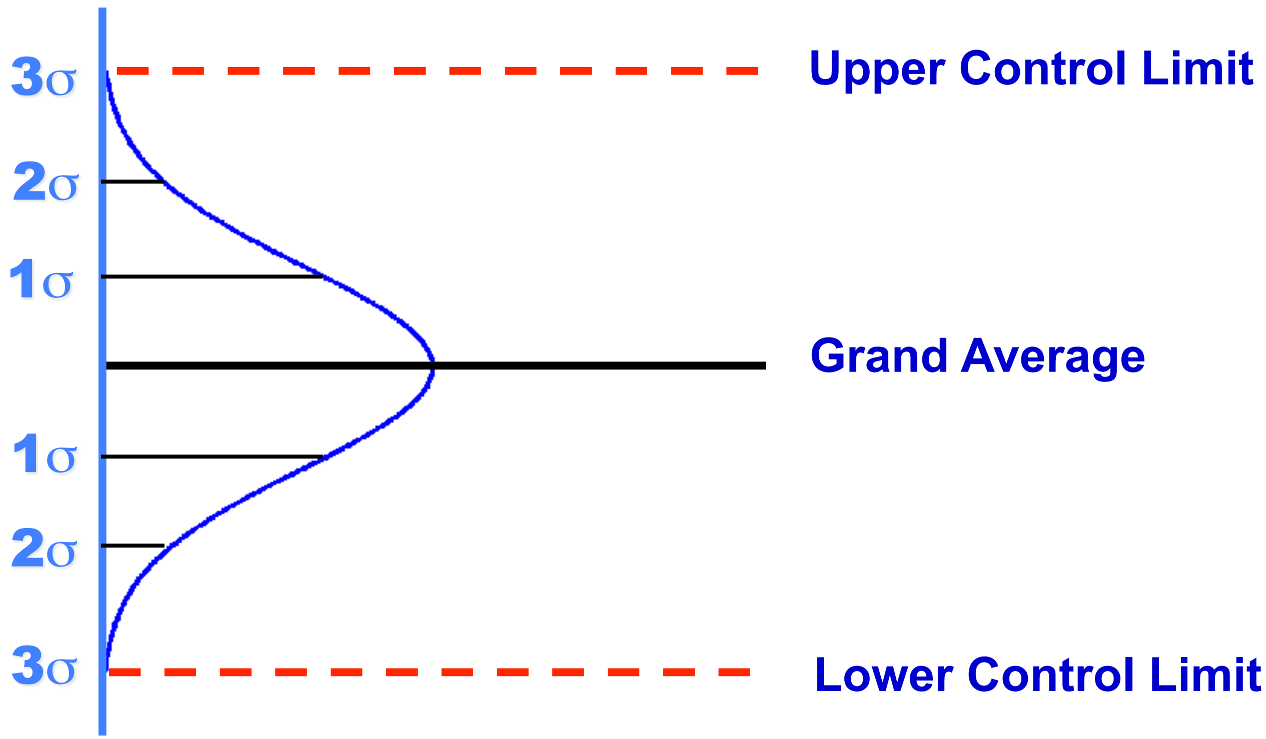


Components of a Control Chart



Control Limits

Boundaries **set by the process** that alert us to process stability and variability



Common Types of Control Charts

Variables Control Charts

- Averages and Range
- Individuals and Moving Average
- Moving Average and Moving Range
- Averages and Standard Deviation

Attribute Control Charts

- p chart
- np chart
- n chart
- c chart

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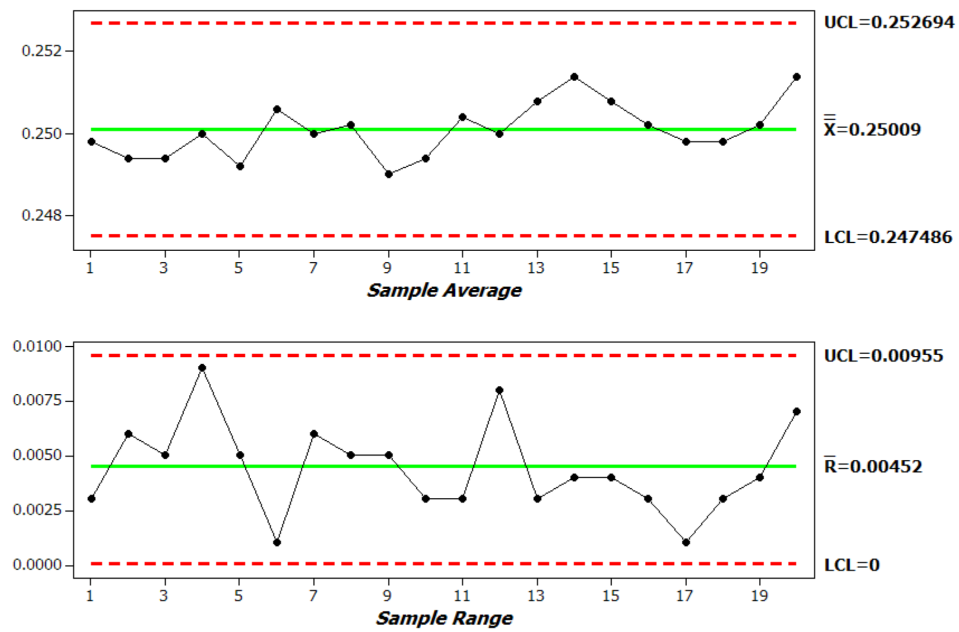
Control Charts for Variables

Plot specific measurements of a process characteristic such as:

- ♦ **Temperature**
- ♦ **Size**
- ♦ **Weight**
- ♦ **Sales Volume**
- ♦ **Shipments**



Control Charts for Attributes

Plots general measurement of the total process such as:

- ♦**Number of complaints per order**
- ♦**Number of orders on time**
- ♦**Absenteeism frequency**
- ♦**Number of errors per document**

Interpretation of Control Charts

A process is in statistical control when:

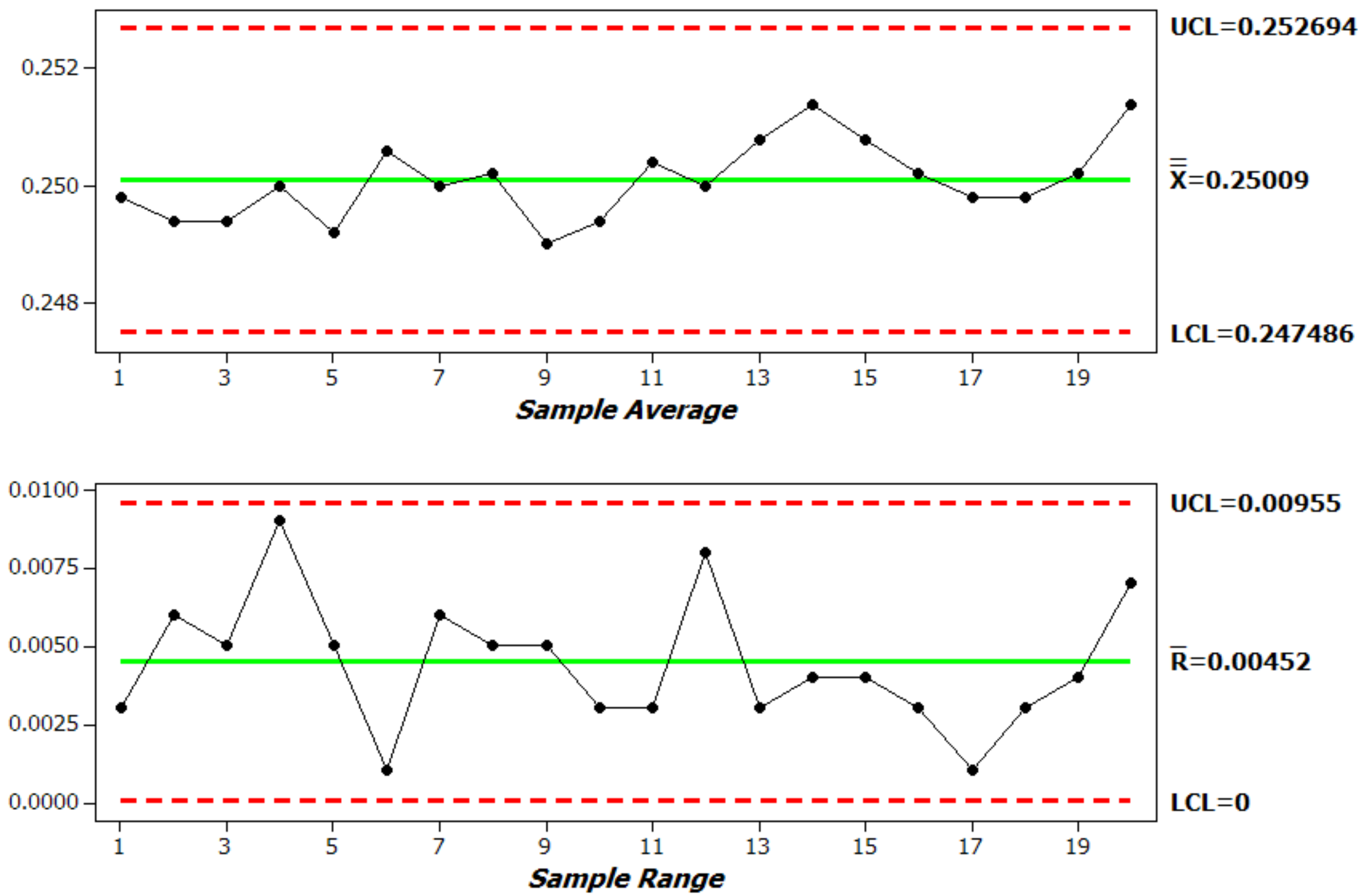
- Only common causes of variation are present
- The points fall within the control limits
- There are not unnatural patterns

Process Data – Molded Diameter

Measurements were obtained from a molded diameter using a micrometer. The specification for the diameter is .250 inch plus or minus .008 (.242/.258). Five pieces in a row were measured every 15 minutes at the times noted in the table.

Time					
7:15	.249	.251	.251	.248	.250
7:30	.251	.246	.252	.248	.250
7:45	.250	.250	.246	.250	.251
8:00	.249	.253	.245	.254	.249
8:15	.250	.246	.251	.249	.250
8:30	.250	.250	.251	.251	.251
8:45	.247	.251	.253	.250	.249
9:00	.250	.251	.253	.249	.248
9:15	.246	.250	.248	.250	.251
9:30	.251	.248	.249	.249	.250
9:45	.251	.249	.249	.251	.252
10:00	.251	.255	.248	.247	.249
10:15	.250	.252	.252	.249	.251
10:30	.250	.251	.254	.251	.251
10:45	.252	.251	.248	.252	.251
11:00	.249	.250	.249	.251	.252
11:15	.250	.249	.250	.250	.250
11:30	.248	.250	.249	.251	.251
11:45	.251	.248	.250	.250	.252
12:00	.254	.251	.254	.247	.251

Average/Range Control Chart – Molded Diameter



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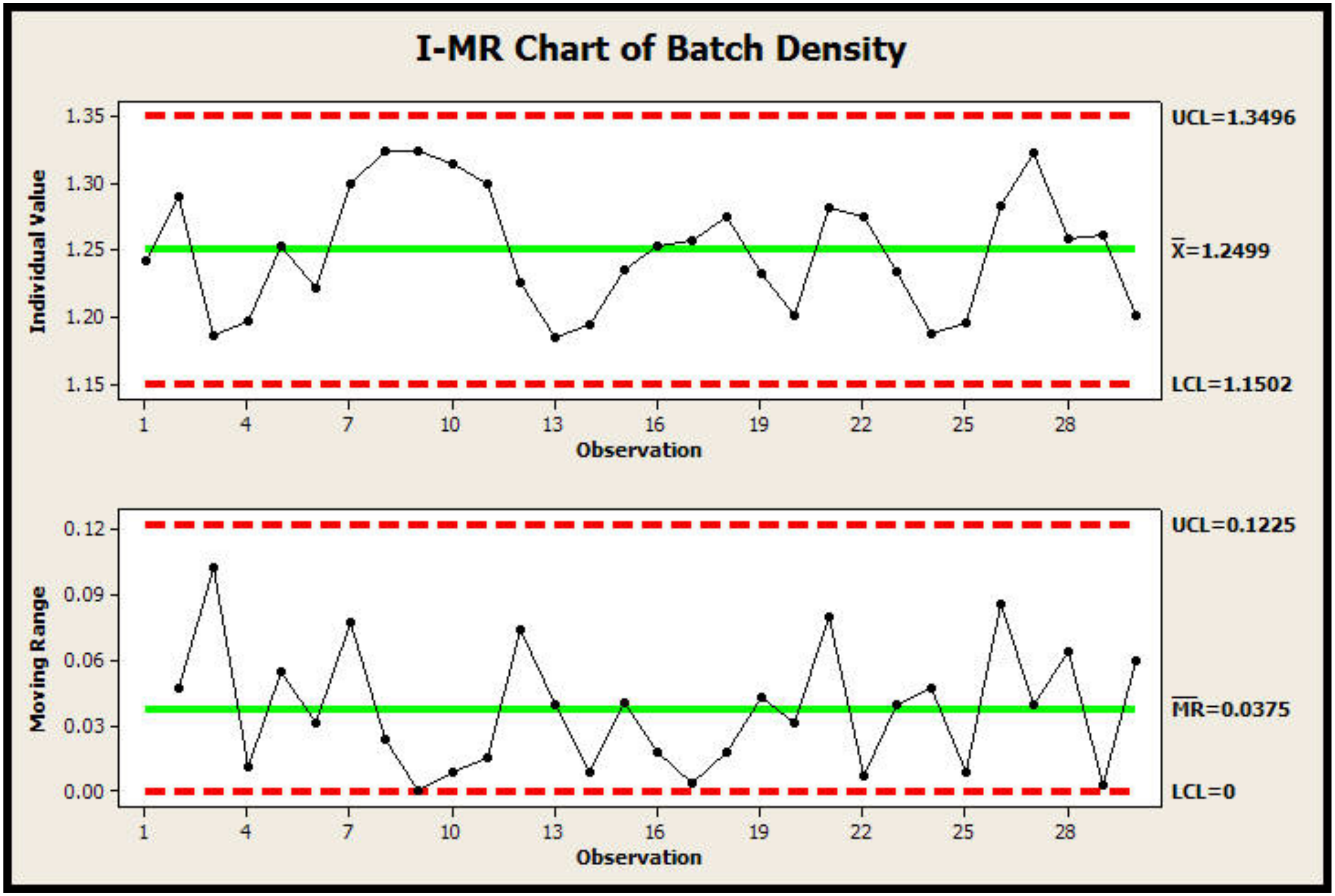
Process Data – Batch Density

2,000-gallon batches of a liquid chemical product, A-744, is produced once every two days. Production takes place in a single tank, agitated as the ingredients are added and for several hours thereafter. The density of the finished product is measured in grams per cubic centimeter and is measured by only one reading per batch. During a 60-day period, 25 batches of A-744 are produced.

Date	Density	Date	Density
5/6	1.242	6/10	1.253
5/8	1.289	6/12	1.257
5/10	1.186	6/14	1.275
5/13	1.197	6/17	1.232
5/15	1.252	6/19	1.201
5/17	1.221	6/21	1.281
5/20	1.299	6/24	1.274
5/22	1.323	6/26	1.234
5/24	1.323	6/28	1.187
5/27	1.314	7/1	1.196
5/29	1.299	7/3	1.282
5/31	1.225	7/5	1.322
6/3	1.185	7/8	1.258
6/5	1.194	7/9	1.261
6/7	1.235	7/11	1.201

IX-MR Control Chart for Batch Density



Interpretation of Control Charts

A process is out of control when:

- Special causes of variation are present
  in either the average chart or range chart or both

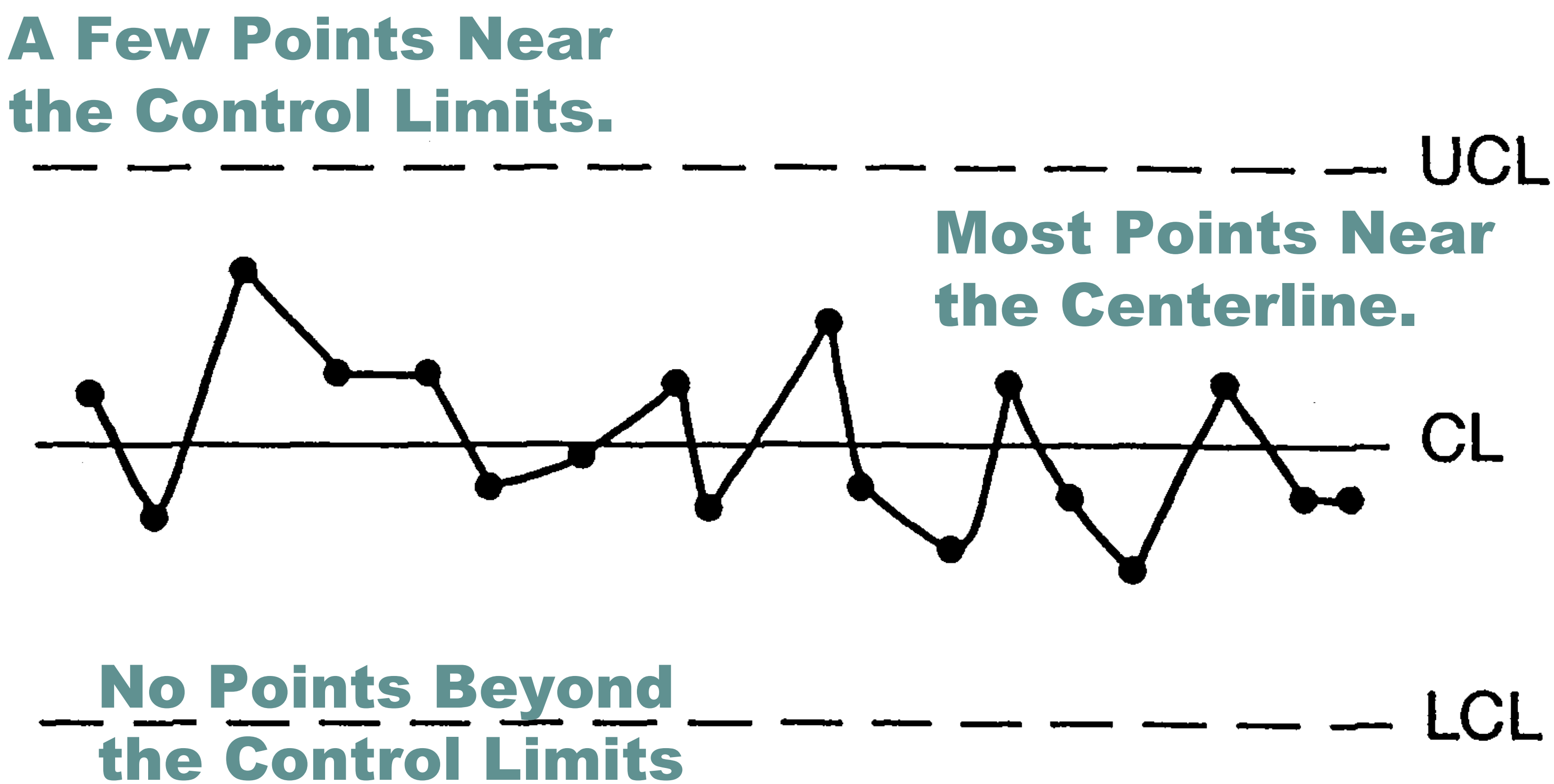
- Points are outside the control limits

- There are unnatural patterns

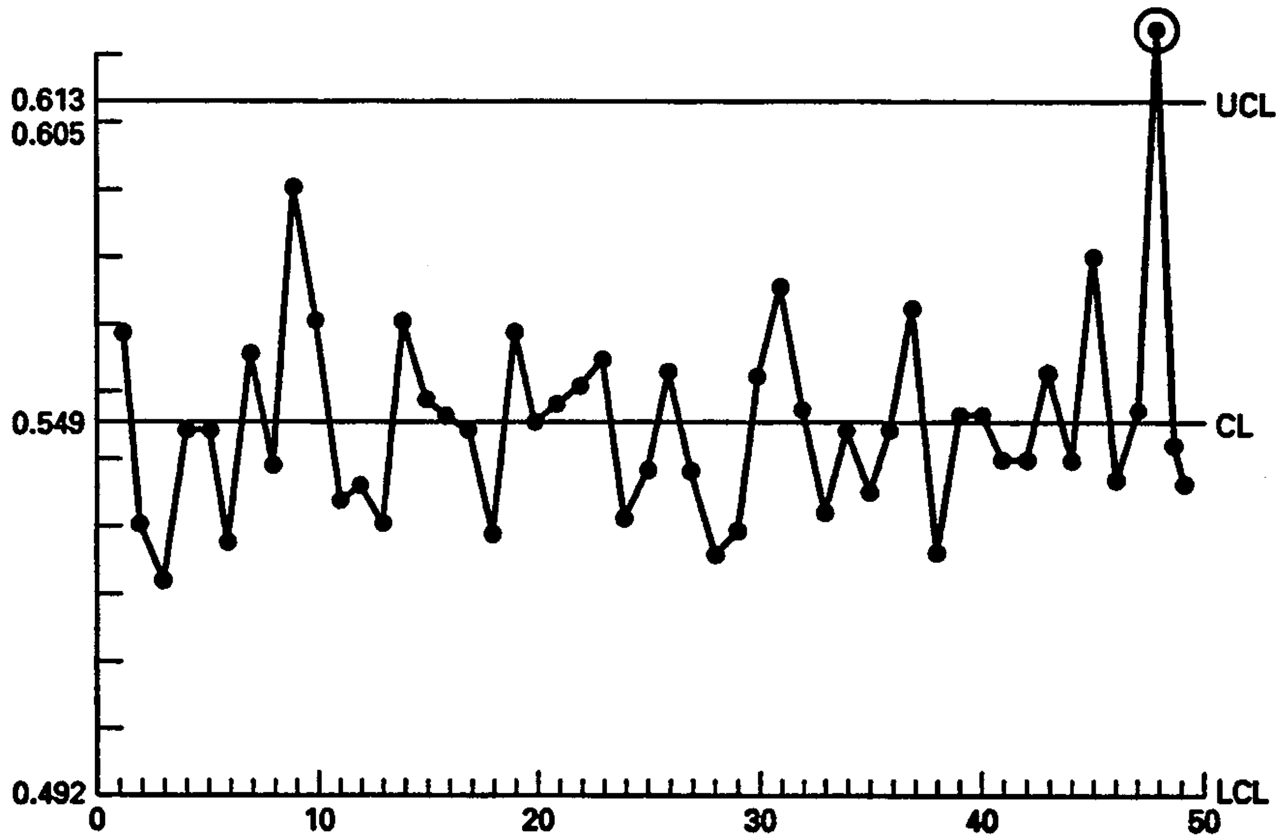
Basic Control Chart Interpretation Rules

- Specials are any points above the UCL or below the LCL
- A run violation is seven or more consecutive points above or below the centerline
- A 1-in-20 violation is more than one point in twenty consecutive points close to the control limits
- A trend violation is any upward or downward movement of 5 or more consecutive points or drifts of 7 or more points

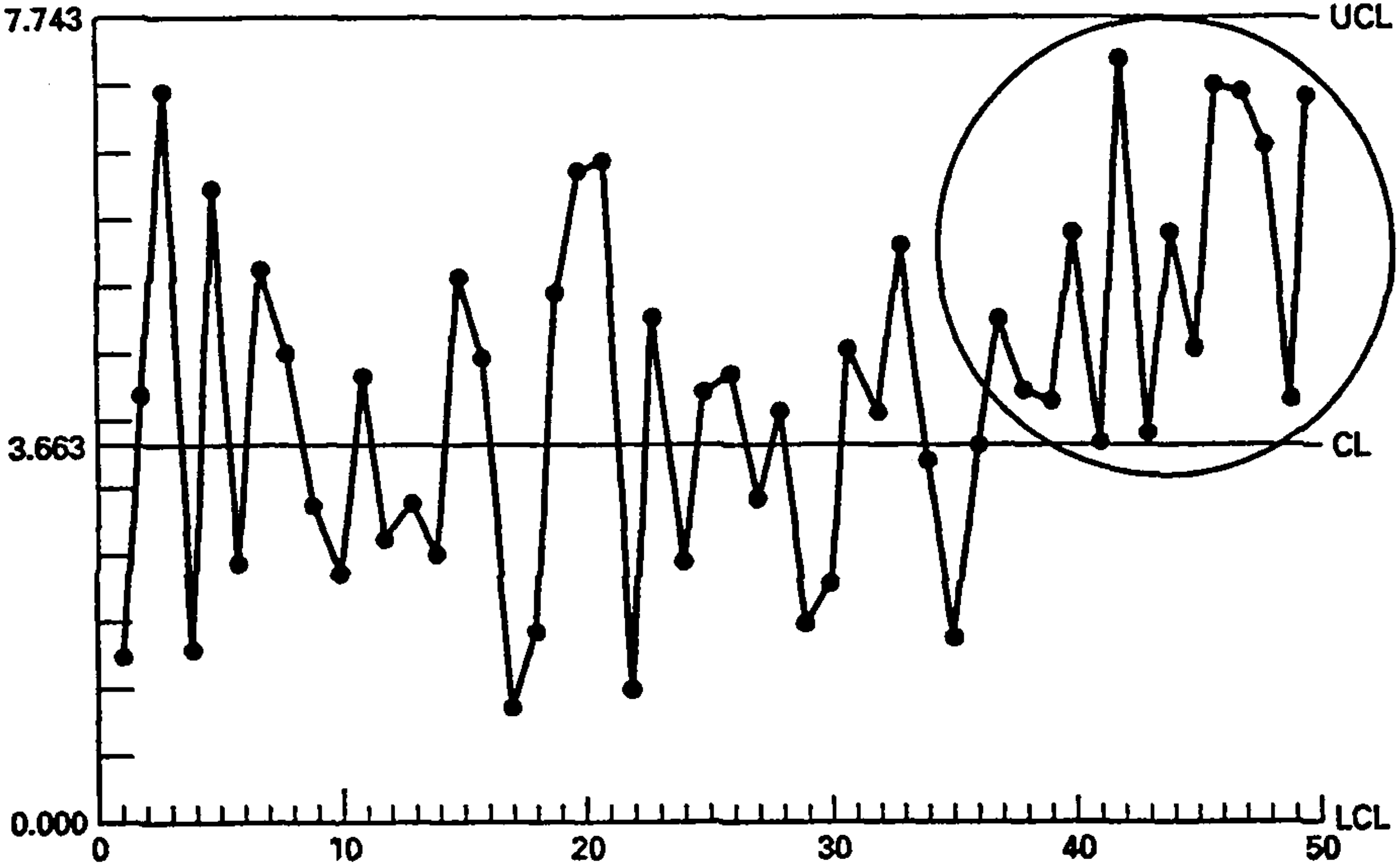
Interpretation of Control Charts



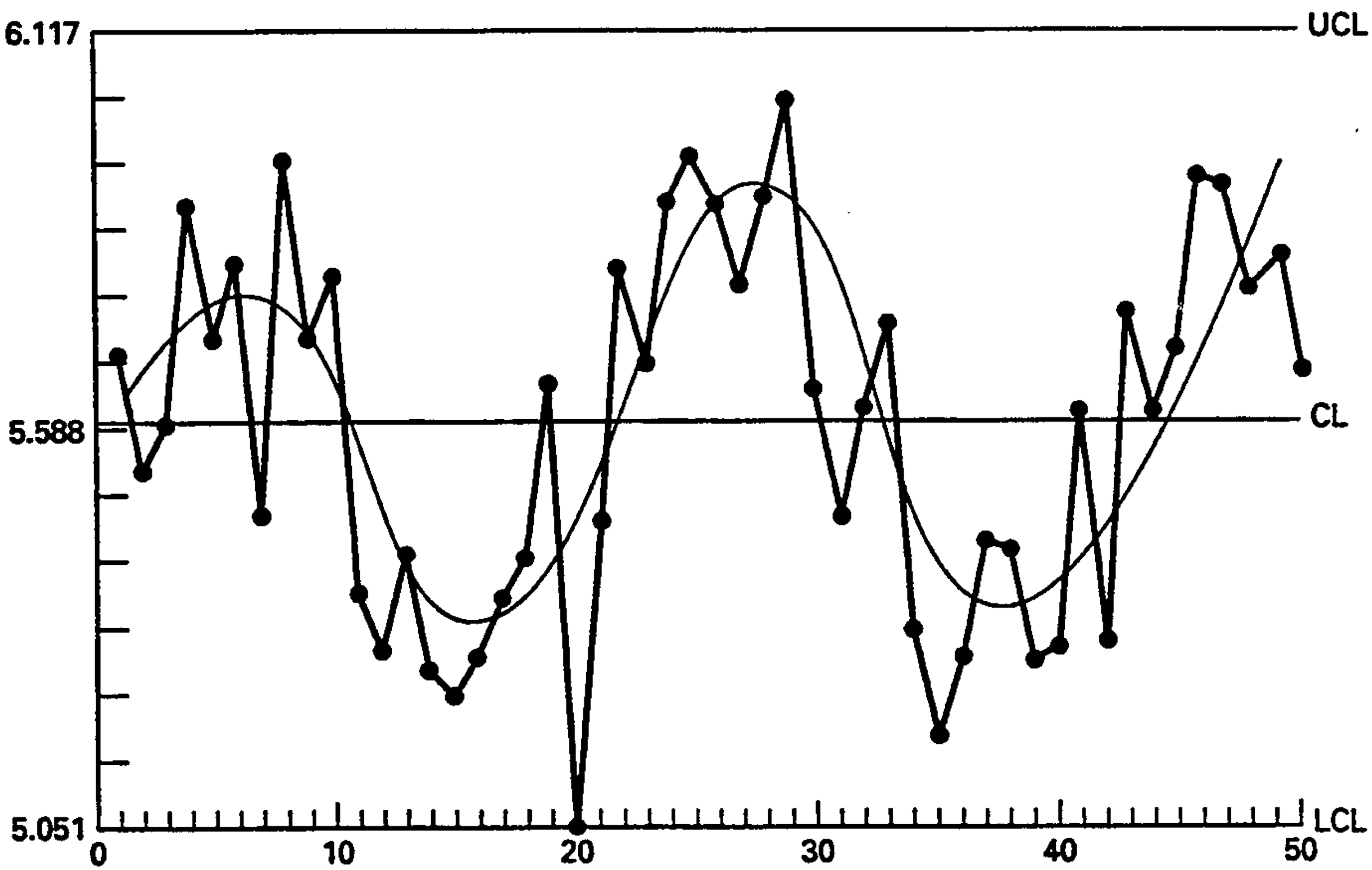
One Point Outside Control Limits



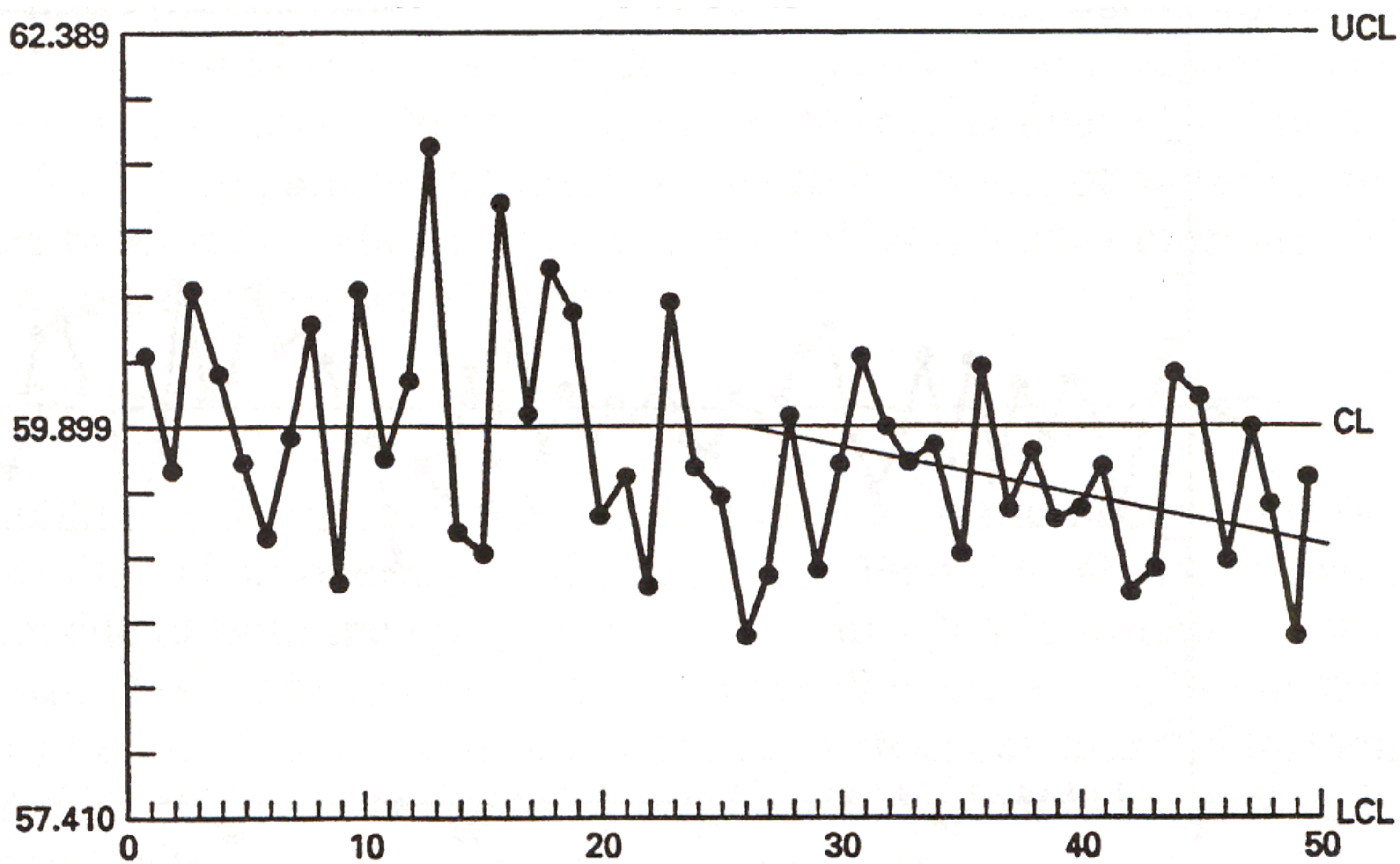
Shift in the Process Average



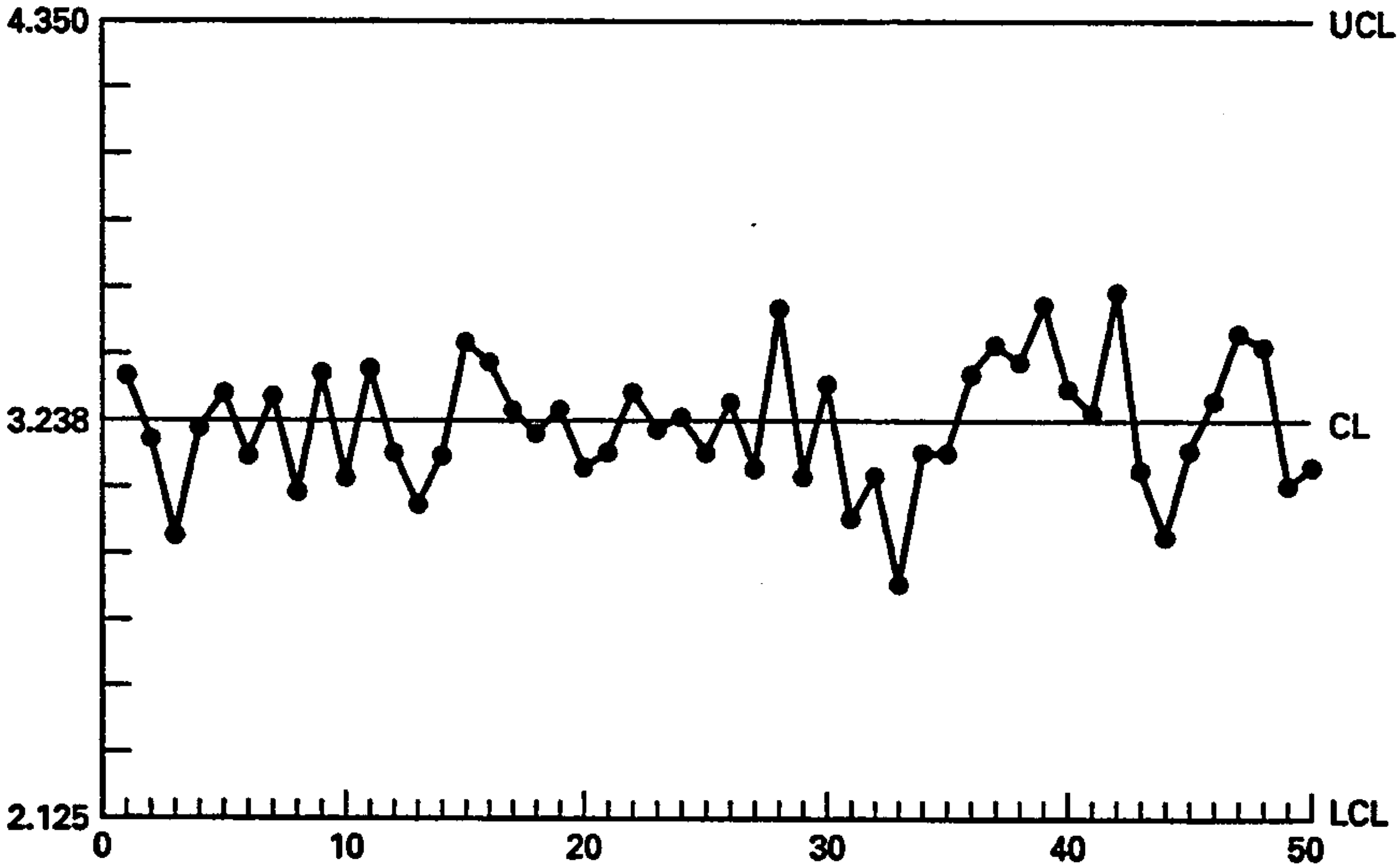
Cycles



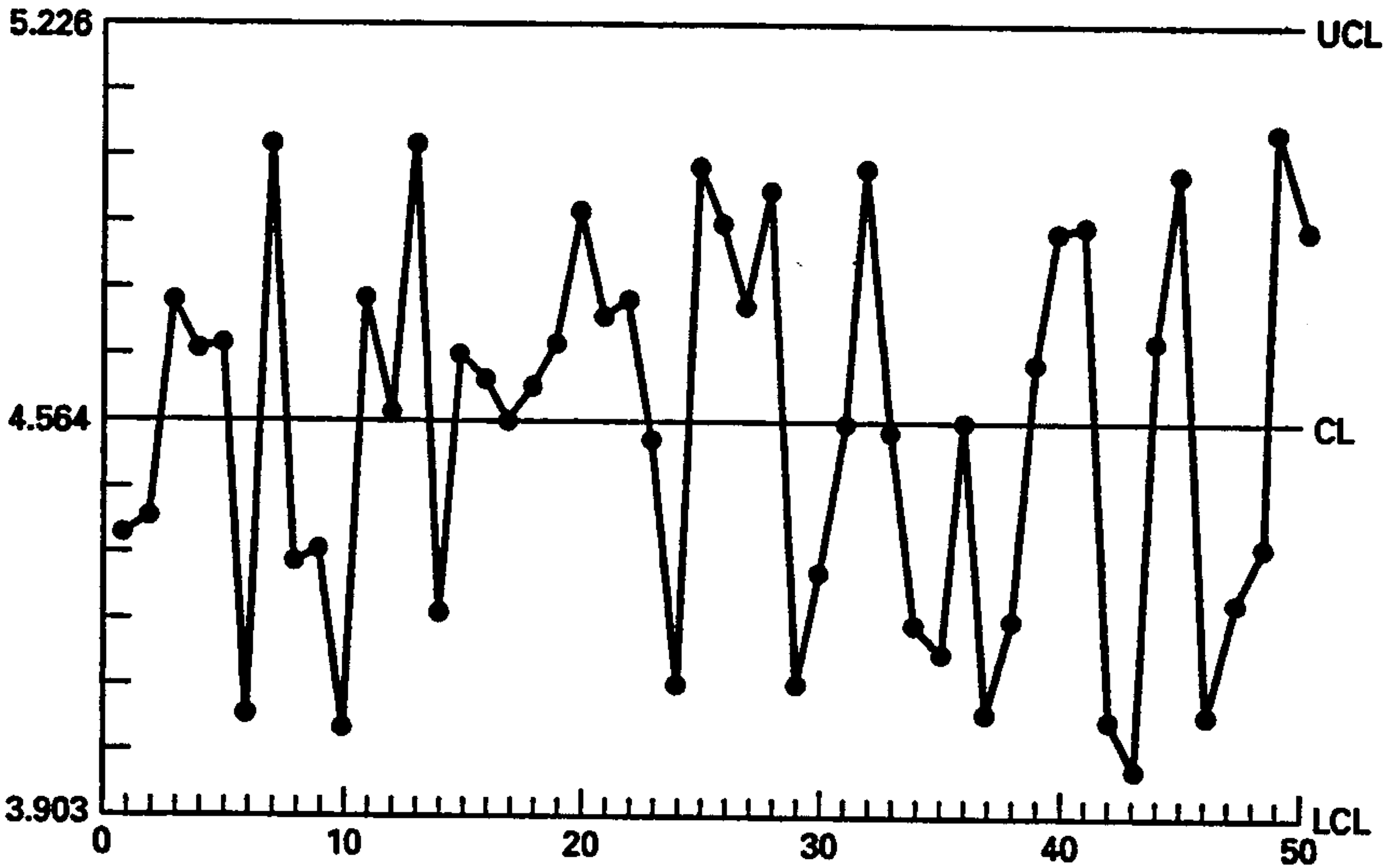
Gradual Trend



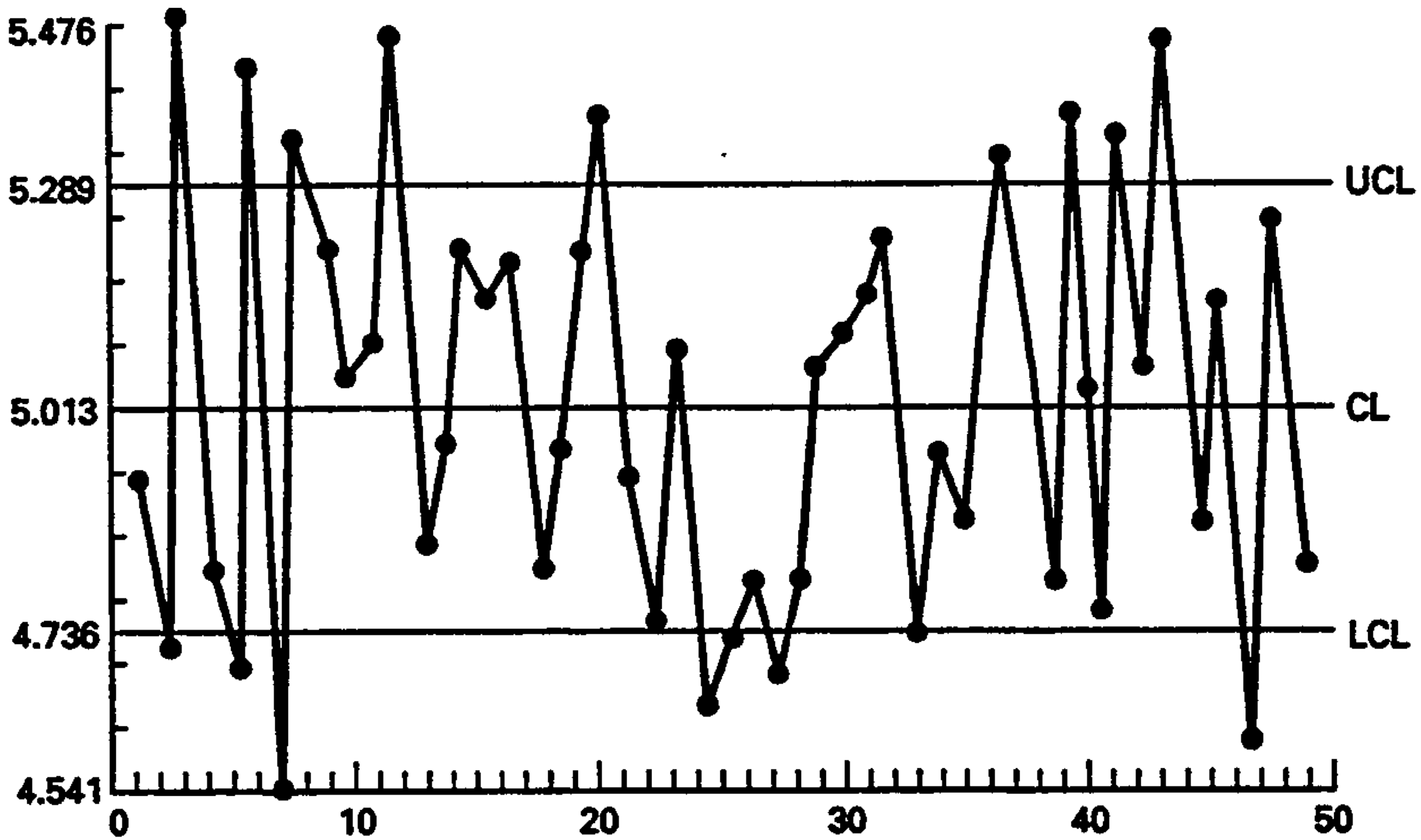
Hugging the Centerline



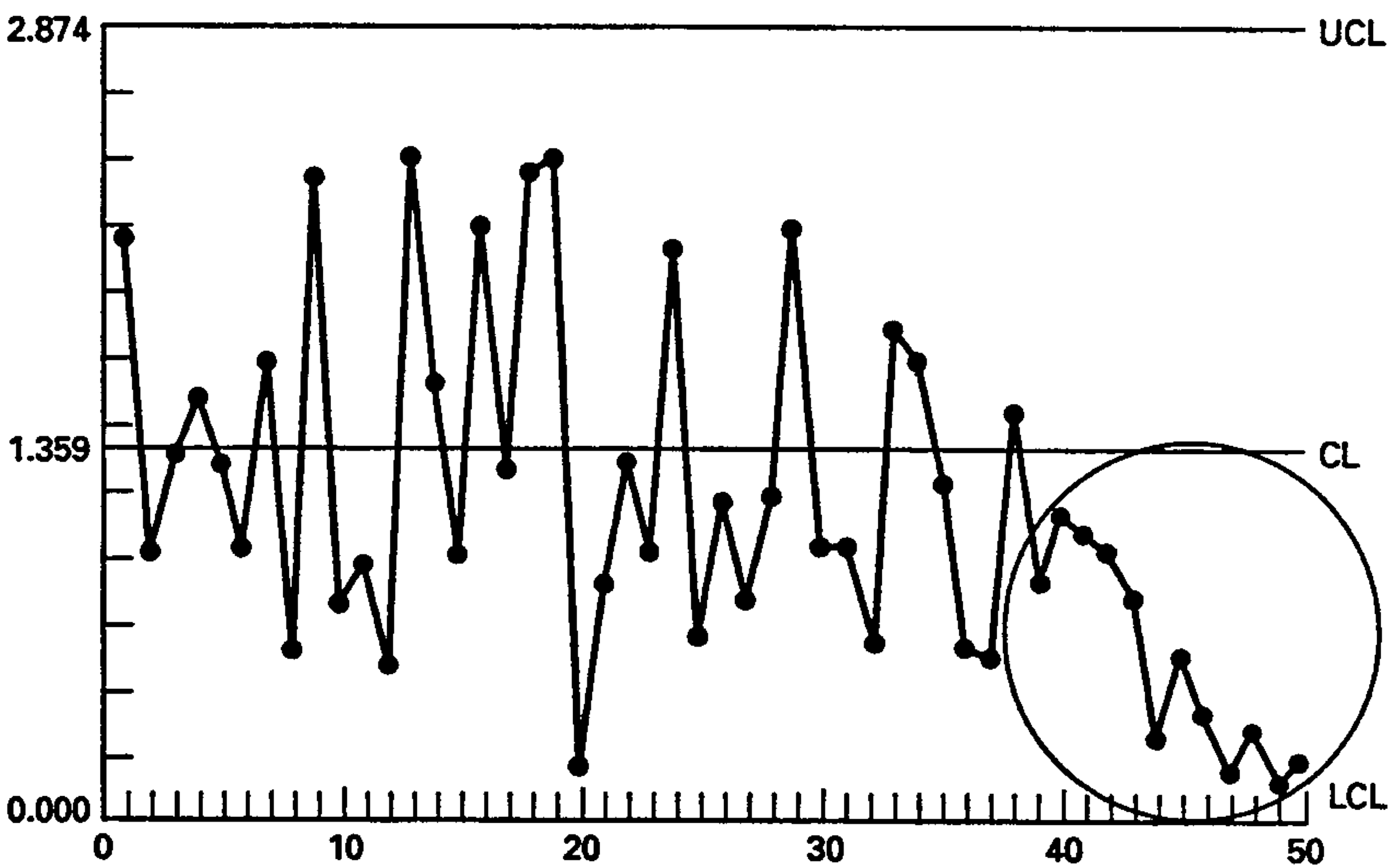
Hugging the Control Limits



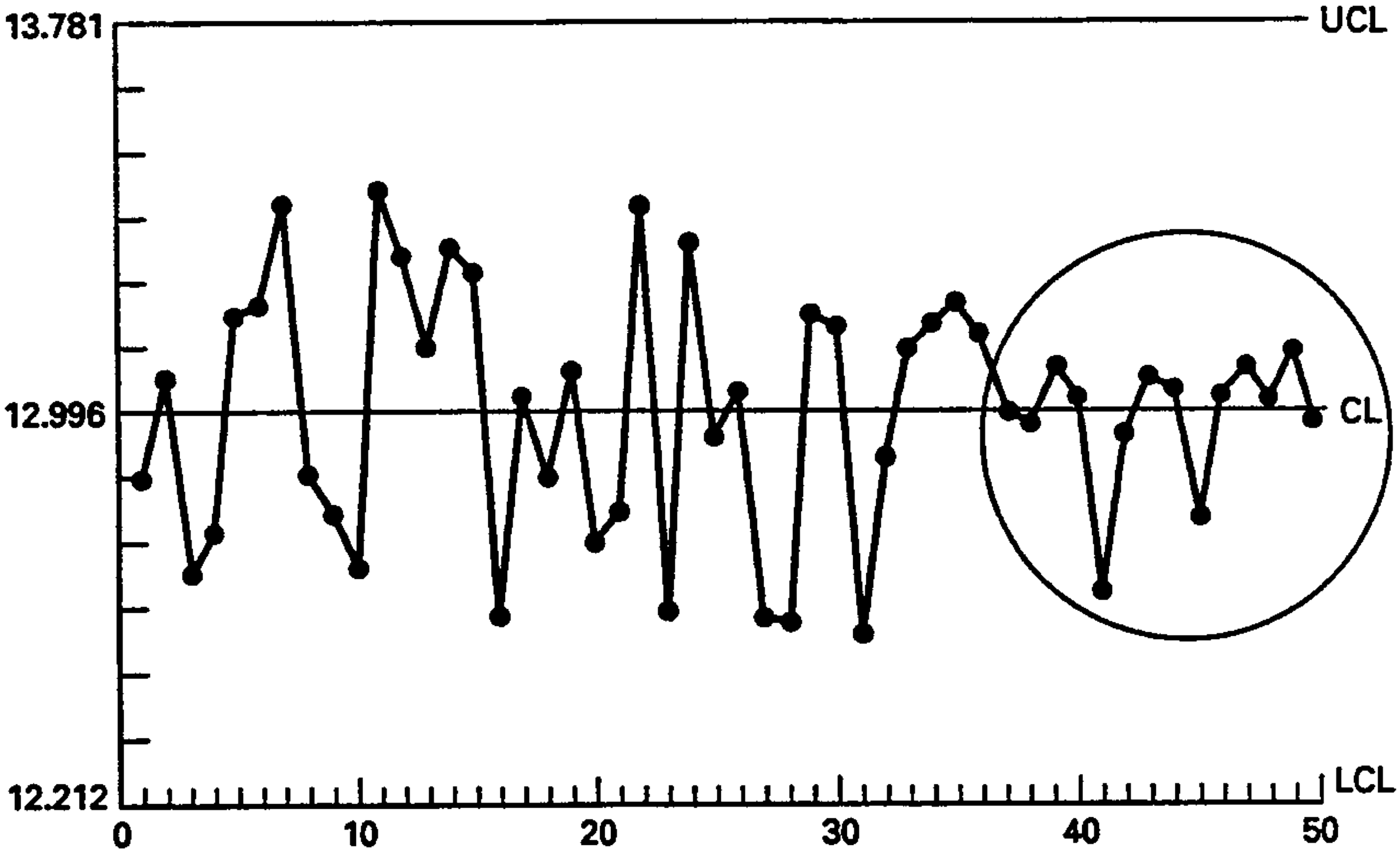
Instability



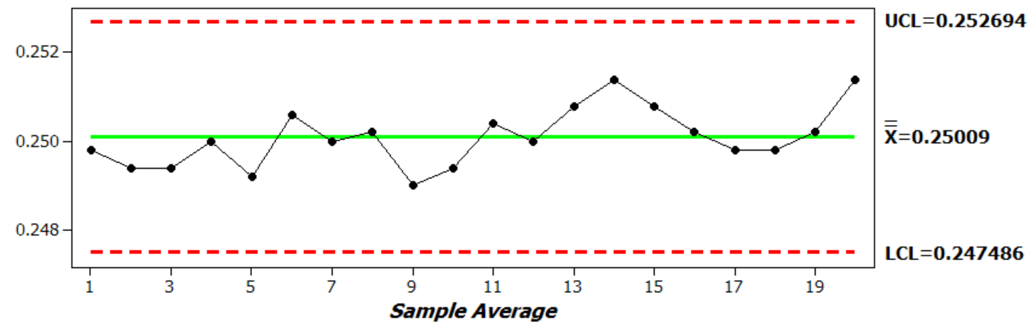
Downward Trend in the Range

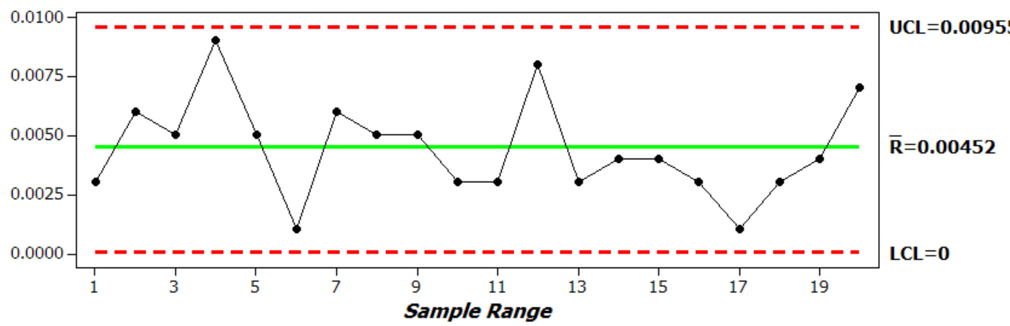


Smaller Variation in the Average



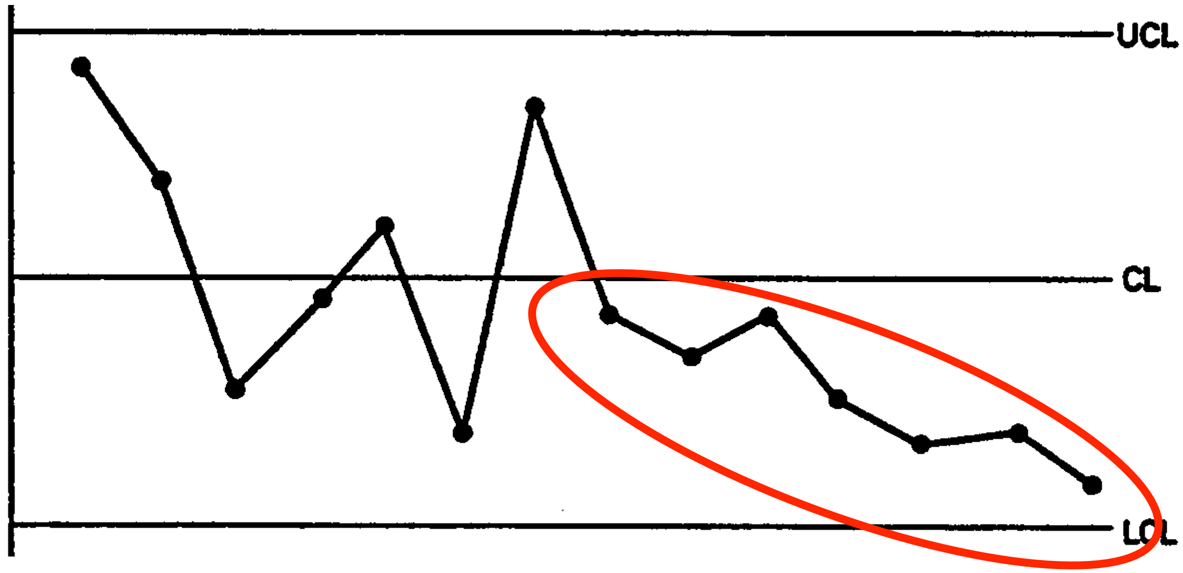
Workshop





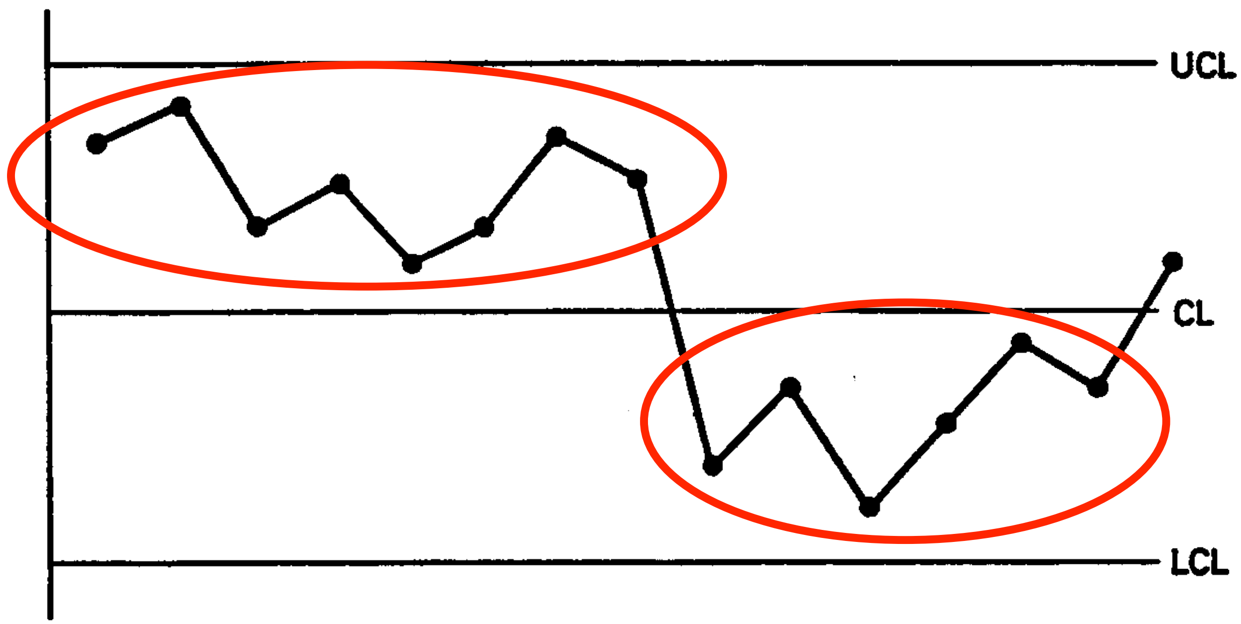
Interpretation of Control Charts

In or Out of Control?



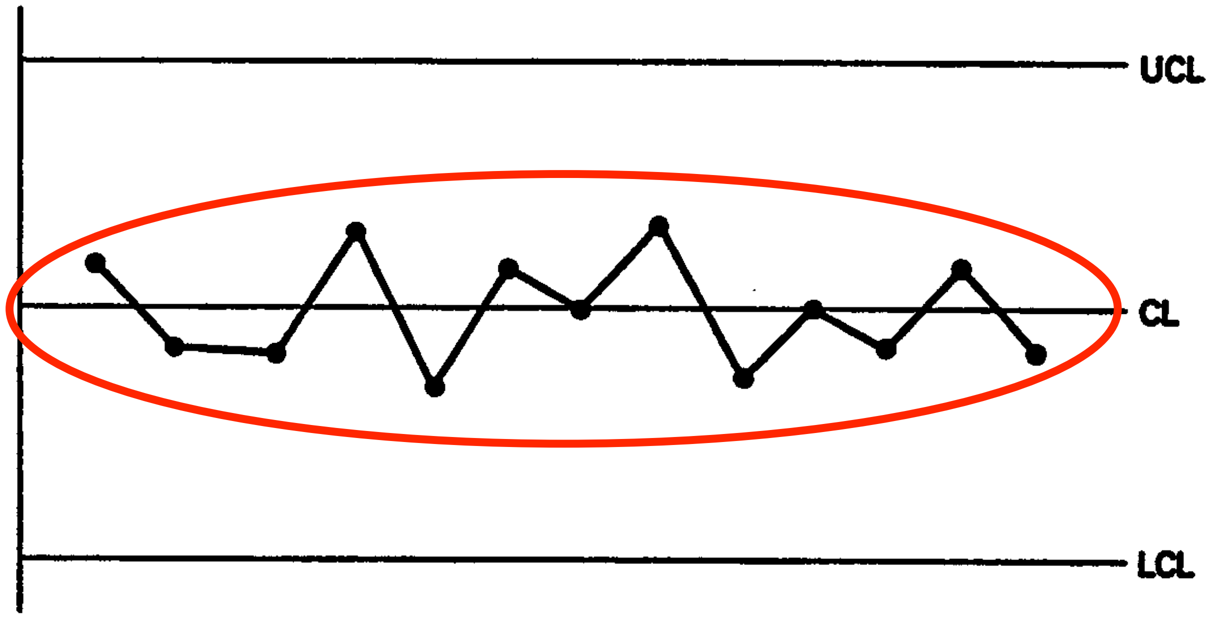
- ♦Out of Control
- ♦Steady trend moving toward control limit
- ♦Measured value seems to be getting gradually smaller

In or Out of Control?



- ♦Out of Control
- ♦Points do not fall randomly above and below the centerline
- ♦Measured value seems to have shifted abruptly

In or Out of Control?



♦Out of Control

♦All points are close to the centerline

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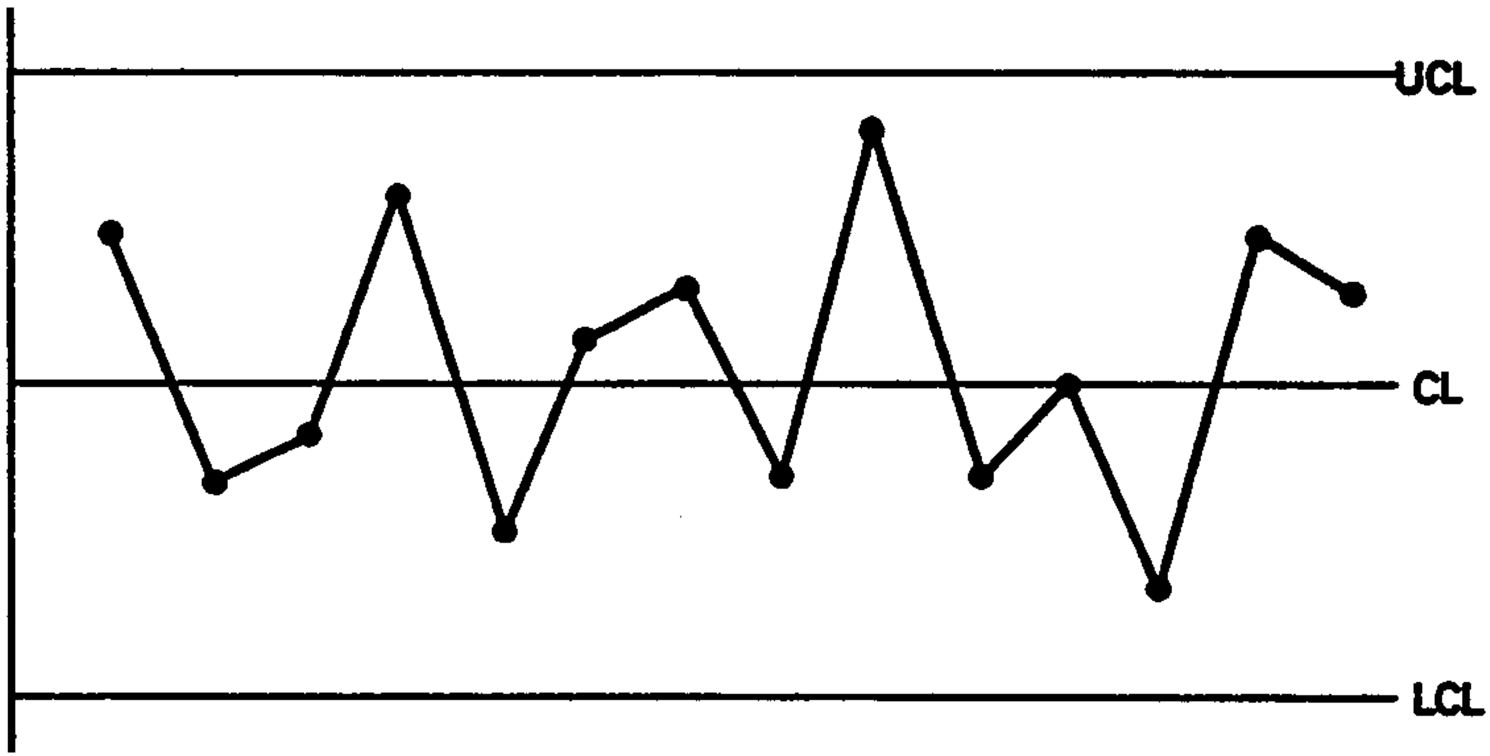
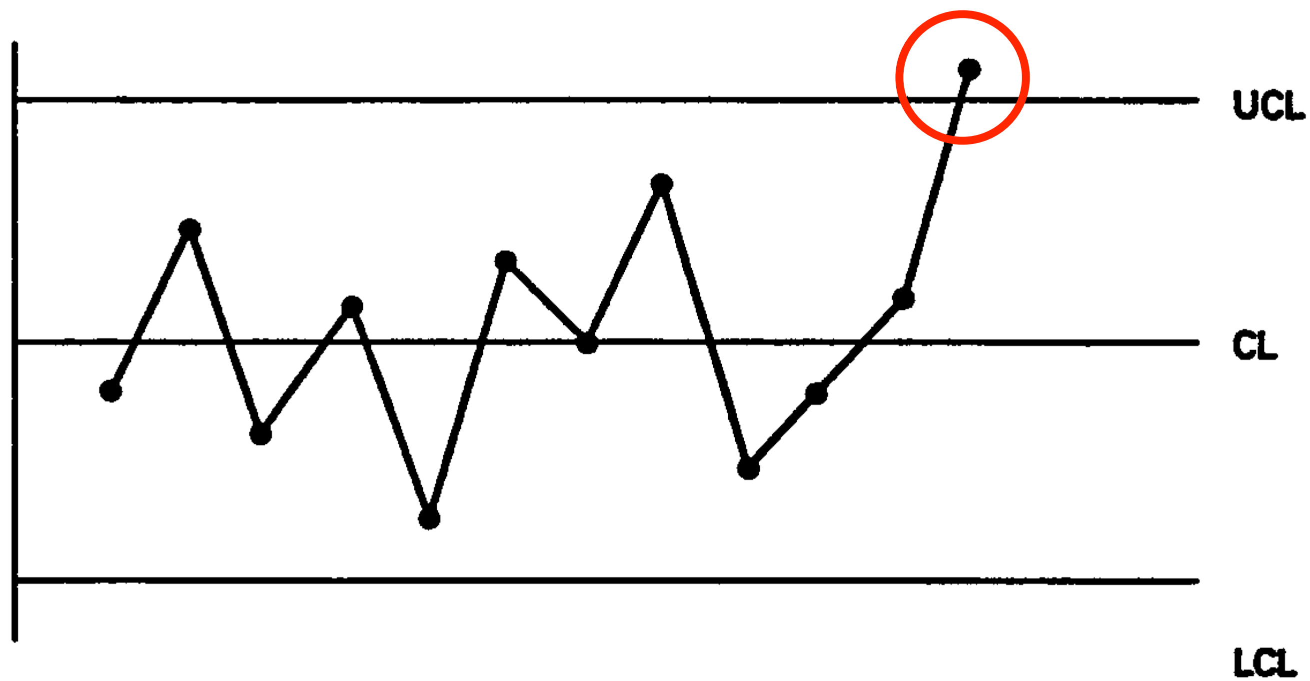
In or Out of Control?



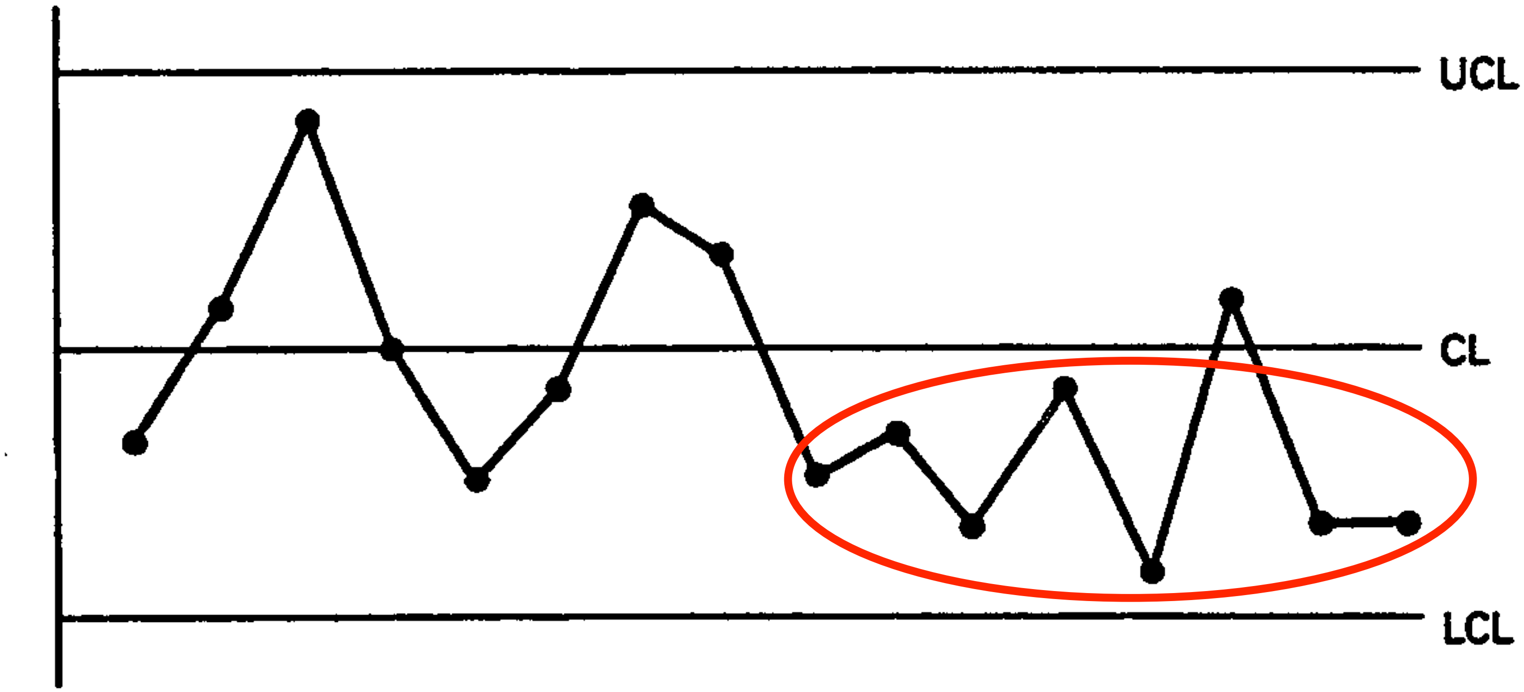
In Control

In or Out of Control?



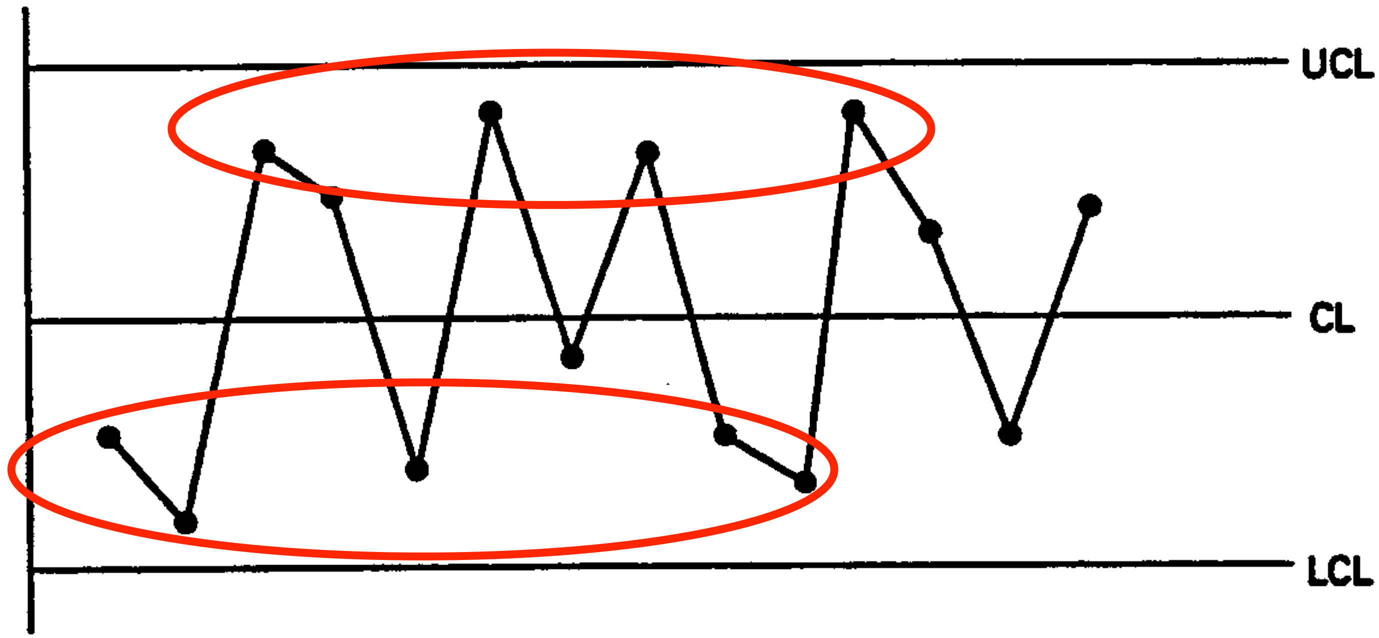
- Out of Control
- Point beyond the control limit

In or Out of Control?



- Out of Control
- Seven of the last eight points below the centerline

In or Out of Control?



- Out of Control
- Too many points close to the control limits

In or Out of Control?