



Welcome to the Highway Materials Engineering Course Module A, Lesson 9: Quality Control. This lesson explains various ways in which a quality control plan can be developed and used, including types of control charts and their applications.

A printer-friendly version of the lesson materials can be downloaded by selecting the paperclip icon. A copy of the slides and narration are provided for download.

If you need technical assistance during the training, please select the Help link in the upper right-hand corner of the screen.

Learning Outcomes



By the end of this lesson, you will be able to:

- Explain various ways in which a quality control plan can be developed and used to maintain the quality of a product or service
- Describe a typical quality control plan
- Relate variability to quality control
- Describe different types of control charts and their applications
- Establish and calculate control chart limits

During this lesson, knowledge checks are provided to test your understanding of the material presented.



This lesson will take approximately 100 minutes to complete.



MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



By the end of this lesson, you will be able to:

- Explain various ways in which a quality control plan can be developed and used to maintain the quality of a product or service;
- Describe a typical quality control plan;
- Relate variability to quality control;
- Describe different types of control charts and their applications; and
- Establish and calculate control chart limits.

During this lesson, knowledge checks are provided to test your understanding of the material presented.

This lesson will take approximately 100 minutes to complete.

Document Needed For This Lesson



Take a moment to download and print the Module A, Lesson 9 Exercise PDF document by selecting the paperclip icon.

For this lesson, you will need the following exercises:

- Module A, Lesson 9: Exercise 1



• To open the exercise document, select the paperclip icon.



MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



During this lesson, you will be prompted to reference the lesson exercise document. The document referenced during this lesson is attached to the lesson in the paperclip icon. Please take a moment to open and print the document.

Definition of Quality



- Quality:
 - [Quality Control Plan](#)
 - [Quality Control](#)
 - [Process Control](#)
 - [Control Charts](#)



Select each term to learn more.

U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



Let's look at some terms used throughout the module. You are probably familiar with them, but their definitions are discussed to make sure we share a common language when discussing quality control. They are:

- Quality control plan;
- Quality control (QC);
- Process control; and
- Control charts.

Select each term to learn more.

Image description: Stack of books.

The screenshot shows a web interface with a title "Definition of Quality" and an HME logo. A list of terms under "Quality:" includes "Quality Control Plan", "Quality Control", "Process Control", and "Control Charts". A blue tooltip box is open over "Quality Control Plan", containing a definition and a "CLOSE" button. The footer includes the U.S. Department of Transportation Federal Highway Administration logo and the text "MODULE A LESSON 9".

Definition of Quality

Quality

- [Quality Control Plan](#)
- [Quality Control](#)
- [Process Control](#)
- [Control Charts](#)

Select each term to learn more.

Quality Control Plan


A project-specific document prepared by the contractor that identifies all QC personnel and procedures that will be used to maintain all production and placement processes "in control" and meet the agency specification requirements. The document also addresses actions to be taken in the event that a process goes "out of control."

U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

A project-specific document prepared by the contractor that identifies all QC personnel and procedures that will be used to maintain all production and placement processes "in control" and meet the agency specification requirements. The document also addresses actions to be taken in the event that a process goes "out of control." The quality control plan is the sum total of activities performed by the seller (producer, manufacturer, and/or contractor) to make sure that a product meets contract specification requirements.

Definition of Quality




- **Quality:**
 - [Quality Control Plan](#)
 - [Quality Control](#) ←
 - [Process Control](#)
 - [Control Charts](#)

Select each term to learn more.

Quality Control (QC) X CLOSE

The system used by a contractor to monitor, assess, and adjust their production or placement processes to ensure that the final product will meet the specified level of quality. QC includes sampling, testing, inspection, and corrective action (where required) to maintain continuous control of a production or placement process.

 **MODULE A**
LESSON 9

Quality control (QC) is the system used by a contractor to monitor, assess, and adjust their production or placement processes to ensure that the final product will meet the specified level of quality. QC includes sampling, testing, inspection, and corrective action (where required) to maintain continuous control of a production or placement process.

Definition of Quality

HME

- **Quality:**
 - [Quality Control Plan](#)
 - [Quality Control](#)
 - [Process Control](#)
 - [Control Charts](#)

Select each term to learn more.

Process Control [X] CLOSE


A method for keeping a process within boundaries and/or the act of minimizing the variation of a process. Process control activities may include sampling, testing, inspection, and corrective action performed by a contractor in addition to QC requirements to improve the likelihood that the final product will meet the specified level of quality.

U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9


Process control is a method for keeping a process within boundaries and/or the act of minimizing the variation of a process. Process control activities may include sampling, testing, inspection, and corrective action performed by a contractor in addition to QC requirements to improve the likelihood that the final product will meet the specified level of quality.


Definition of Quality



- **Quality:**
 - [Quality Control Plan](#)
 - [Quality Control](#)
 - [Process Control](#)
 - [Control Charts](#) ←

Select each term to learn more.

 **MODULE A**
LESSON 9

Control Charts 

Graphical plots of quality control that detect when assignable causes are acting on a process and when a systematic variation from the expected results is occurring in a continuous production line process.

Control charts are graphical plots of quality control that detect when assignable causes are acting on a process and when a systematic variation from the expected results is occurring in a continuous production line process.

The diagram illustrates the components of Quality Assurance. It features a large dark red rectangle with the text "Quality Assurance" at the top. Inside this rectangle are three horizontal bars: a yellow bar labeled "Quality Control", a white bar labeled "Acceptance", and another white bar labeled "Independent Assurance". The slide also includes a title "Quality Assurance" at the top left, an HMEC logo at the top right, and a footer with the U.S. Department of Transportation Federal Highway Administration logo, "MODULE A LESSON 9", "QUALITY CONTROL", "Resources Glossary Help", and navigation arrows.

We learned earlier that there are three components of quality assurance (QA):

1. Quality control;
2. Acceptance; and
3. Independent assurance.

In this lesson, we will concentrate on quality control.

Parts of a Quality Control Plan



- QC procedures and requirements
 - Quality control requirements
 - Properties to measure



The QC procedures and requirements in a quality control plan are made up of two parts: quality control requirements and the properties to be measured. These are the main ingredients that constitute the quality control plan.

Image description: Photo of man measuring a brick.

Quality Control Plan Goal



- Measure properties
- Inspect activities when corrective action can be taken



It is important to know that the purpose of the quality control plan is to measure properties and inspect activities that impact the production early.



It is important to know that the purpose of the quality control plan is to measure those properties and inspect those activities that impact the production at a time when corrective action can be taken to prevent the appreciable “non-conforming” product from being incorporated into the project. In this case, if non-conforming product is made, it will be quickly identified. This purpose should be the guide to the decisions used in establishing the requirements and determining the properties to measure. It is less expensive and easier to fix problems early on.

Image description: Image of man holding a giant magnifying glass.

Image description: Image of a ruler.

Quality Control Plan



Who establishes the quality control plan?

ANSWER



The determination as to who establishes the quality control plan is an important one.

Select the box to answer the question, who establishes the quality control plan?

Image description: Photo of men looking at documents on a construction site.

Quality Control Plan



CLOSE

The quality control plan should be the contractor's plan, not the agency's. The contractor should know what activities are necessary to test and inspect to produce acceptable product. But this doesn't always work. Generally, two approaches have been used by agencies to specify the quality control plan that is required.



Who establishes the quality control plan?

ANSWER



Ideally, the quality control plan should be the contractor's plan, not the agency's. The contractor should know what activities are necessary to test and inspect to produce acceptable product. But this doesn't always work. Generally, two approaches have been used by agencies to specify the quality control plan that is required. The next screen will discuss the two approaches.

Image description: Photo of men looking at documents on a construction site.

Agency May Specify



- Minimum QC requirements and properties
 - Lets contractor know the least that is required
- Specify all QC requirements and properties that must be performed
 - Likely to be all inclusive



When the agency specifies the QC plan, the first approach is to require the minimum QC requirements and properties that the QC plan must contain. By stating the minimum requirements and properties, the agency lets the contractor know the least that is required. The disadvantage is that the contractor may view this as all that is necessary for adequate QC rather than the minimum. If a minimum type QC plan is decided upon, the agency may want to require their approval of the plan prior to construction.

The other approach is to specify all of the requirements and properties that must be performed. By stating all the requirements and properties required, the plan is likely to be all inclusive, but the contractor may view the QC plan as the agency's plan rather than the contractor's plan and therefore it may contain procedures that some contractors need and others don't need.

Image description: Image of scales.

Typical QC Requirements

- Quality control plan
- Qualified technicians
- Qualified laboratory
- Properties to measure and inspect
- Control charts
- Action criteria
- Corrective actions



U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



Addressing the typical QC requirements provides the contractor with the necessary information needed for staffing, procuring laboratory equipment, etc. Some of the QC requirements that the contractor may need to include are:

- Submit the quality control plan for review and agency approval;
- Employ qualified technicians;
- Use a qualified laboratory;
- State the properties to be measured and inspected;
- Maintain effective control charts and state the properties that will be plotted and how often the data will be plotted;
- State the action criteria that will be used to identify “out-of-control” productions by the control charts; and
- List the corrective actions to follow when “out-of-control” product is identified including procedures to use for quality control and state who is in charge of these actions.

Image description: Approved Stamp.

Qualified Versus Certified Technicians



- Qualified
 - Must undergo certification procedure established by State



All sampling and testing data must be executed by qualified sampling and testing personnel.



The use of the terms, qualified versus certified has arisen due to some States' legal definitions. In order to be a qualified technician, sampling and testing personnel must undergo a certification procedure, which is usually established by the State.

AASHTO R 25 Standard Practice for Technician Training and Qualification Programs indicates the terms “qualification” and “technician” are meant to be generic descriptions. It is generally understood that the technicians must be qualified, and one way to assure this is to require them to have undergone some certification procedure.

According to the requirement contained in FHWA 23 CFR Part 637b, all sampling and testing data to be used in the acceptance decision or the independent assurance program will be executed by qualified sampling and testing personnel.

Image description: Photo of a man using testing equipment.

Quality Control: Legal Issues



What constitutes acceptance or rejection of the plan and what are the consequences to the contractor?

If approval is required, does this mean that once approval is obtained the contractor has no further restrictions?

- **Plan should not be too complicated or involved to be viewed as unworkable**

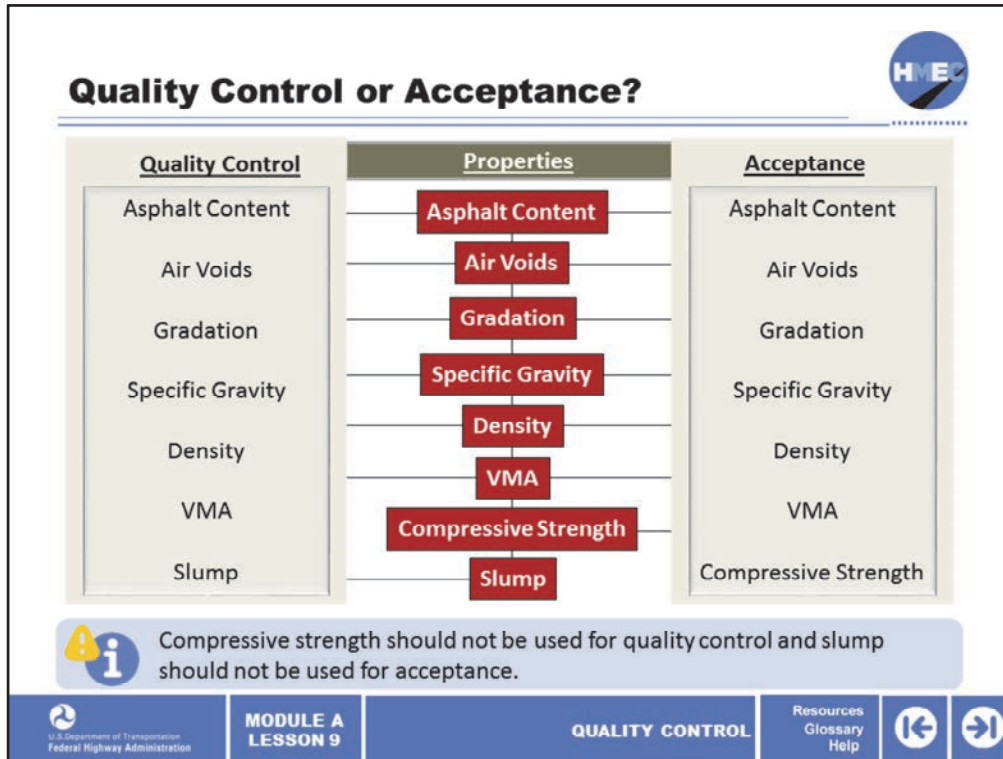


Legal issues can arise if the quality control plan requires agency review and/or approval that should be considered when making the decision concerning agency approval. For instance, if the agency only reviews the plan, what constitutes acceptance or rejection of the plan and what are the consequences to the contractor?

If approval is required, does this mean that once approval is obtained the contractor has no further restrictions? If the quality control plan is stipulated by the agency, care should be taken to assure that the plan is not so complicated or involved as to be viewed as being unworkable. This is not likely to be a concern if the contractor determines the QC plan.

Here is how one State handles the QC plan: it is reviewed. The agency should not "approve" because then it becomes the agency's QC plan. The agency should "accept" because it meets the minimum requirements. By accepting, the agency avoids the legal ramifications implied with approval.

Image description: Photo of a gavel laying on a document.



Will the property be used for quality control or acceptance? Listed here are several material properties. The measurement of certain properties may be more ideally suited for the quality control function, while others are better suited for acceptance. However, for some properties, the decision whether to make the property part of the quality control function or the acceptance function may be more arbitrary. Ideally, the properties used for quality control do just that as they are intended to control the quality of the material while it is being produced.

For instance, concrete compressive strength is a poor property to use for quality control. How many days to wait to break the cylinders; 4, 7, 28? For any of those dates, the material has already been in place for too long to influence production. Slump is a good QC property as it can provide information in a timely manner to affect production. On the other hand, properties for acceptance are intended to affect the performance of the end product and thus, compressive strength is a good property for this purpose.

And there are properties that can be used for both, such as in-place air voids in an asphalt pavement. It can be measured by a nuclear density gauge to provide data that can alter the rolling pattern if necessary while the pavement is still hot for quality control and then tested after paving for acceptance.

Determine For Each Property



- Requirements for sampling and testing procedures
- Test frequency




Two determinations must be made for each property: the requirements for sampling and test procedures and those for test frequency. There are several ways that have been successfully used to implement a quality control plan. The plan may be stipulated by the agency, chosen by the contractor, or it may be a combination of the two in which the agency chooses some ingredients and leaves others up to the choice of the contractor. Regardless of who develops the plan, the method chosen will impact the way the quality control plan is implemented and the decisions that must be made during the implementation of the plan. Random sampling should be observed.

Image description: Photo of a hand adjusting a scale with a bucket of gravel on it.

Establish Procedures

- Sampling
- Testing
- Inspection
- Testing frequency



The image shows a balance scale with two pans. The left pan is labeled 'Control' and the right pan is labeled 'Resources'. The scale is balanced, indicating that these two factors should be in equilibrium. The scale is set against a light blue background.

U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help

◀ ▶

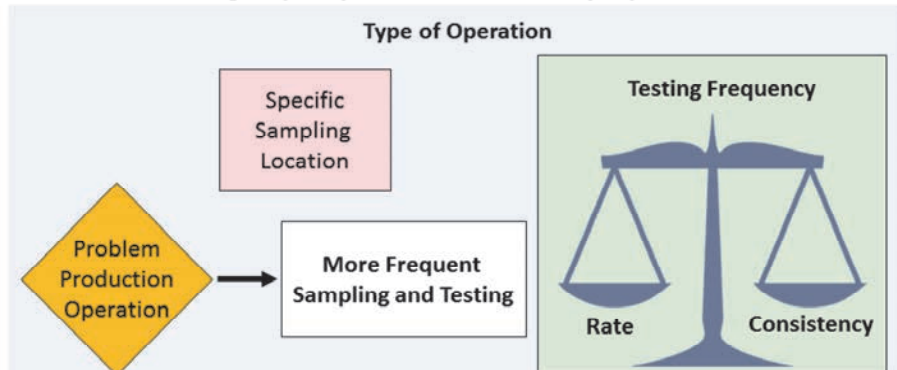
There are several procedures that should be established in the quality control plan. The sampling procedures for control, including the point of sampling, must be established. The test procedures and inspection activities that are best related to early indications of quality control should be determined. These decisions will depend on the type of operation for which the quality control plan is being developed. Also, the testing frequency should be established to create a balance between enough tests to determine if the product is in control, but not so many tests as to be impractical. So the frequency should balance control with the resources.

Image description: Scale.

Operation-Specific Procedures



- QC procedures are different for each operation
 - May require sampling from a specific location
 - Problem production operations require more frequent sampling and testing
 - Relate testing frequency to rate and consistency of production



U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



In reality, quality control procedures are different for each operation and, ideally, the decisions should be operation-specific. Operation-specific quality control procedures may require sampling from a specific location for some production plants. Likewise, production operations with a history of quality control problems will require more frequent sampling and testing than operations that typically have few problems.

One of the keys to achieving a balance in testing frequency is to relate the testing frequency to the rate and consistency of production. If the production tends to be continuous and consistent, less frequent testing may be permissible than if there are a lot of interruptions. The contractor should be in the best position to know what are the best indications of control and what frequency is necessary for control.

Image description: Image of a scale with rate and consistency.

Generic QC Procedures



- Creates a “level playing field” for all contractors
- Not operation-specific
- A specific operation may require more or less testing than the generic minimums



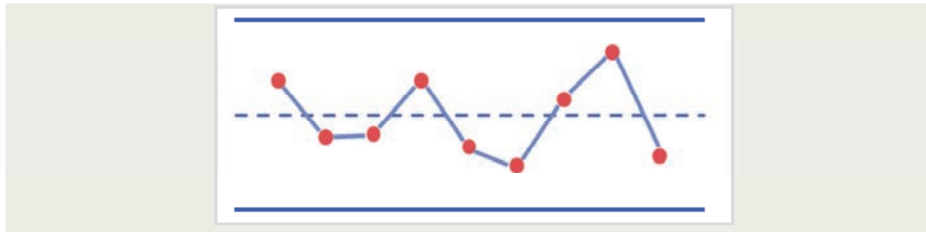
There are several reasons why agencies choose to make QC procedures generic, although the ideal is operation-specific procedures. One reason an agency might establish generic quality control procedures is because the contractor may not be familiar with what is necessary to control the operation or may be inhibited by an inadequate staff to perform the level of testing that should be done. Another reason is that the contractor may not want to test more properties or test more often than the competition because of the impact on staffing and cost.

These are some of the reasons that many agencies stipulate at least minimum QC plan procedures. A generic quality control plan has potential disadvantages to the contractor and to the agency. The sampling and test procedures and the test frequency are stipulated and will not be operation-specific. This is a disadvantage for the contractor that has few occasions of an out-of-control product. It is also a disadvantage to the agency when they encounter a contractor that needs more frequent sampling and testing than the generic minimums to maintain control.

Using Control Charts to Identify QC Problems



- Statistical control charts
 - Provides a means of verifying that a process is in control
 - Provides a visual warning mechanism



Statistical Control Chart




It is important to understand that control charts do not get or keep a process under control. The contractor must still control the process.



The quality control procedure that we will now concentrate on is the use of control charts, particularly statistical control charts. Control charts provide a means of verifying that a process is in control. It is important to understand that control charts do not get or keep a process under control—the contractor must still control the process. Control charts simply provide a visual warning mechanism to identify when the contractor or material supplier should look for possible problems with the process.

Image description: Statistical control chart.

Two Types of Variability




- **Inherent or chance causes**
 - Part of every process
 - Can be reduced
 - Can't be eliminated
- **Assignable causes**
 - Factors that can be eliminated
 - Reduce variability when identified
 - Examples:
 - Gradation for an aggregate blend goes out of specification due to a hole in one of the screens
 - Cold feed conveyor setting is incorrectly adjusted
 - Asphalt pump malfunctions

U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



We should recognize by now that variation of construction materials is inevitable. The purpose of control charts, then, is not to eliminate variability, but to distinguish between the two types of variability:

1. Inherent or chance causes of variability; and
2. A system of assignable causes.

Chance causes (sometimes known as common causes) are a part of every process, and can be reduced but generally cannot be eliminated. Chance causes are something contractors and material suppliers must learn to live with. While they cannot be eliminated, it may be possible to reduce their effects.

The second cause of variation, assignable causes (sometimes known as special causes), are factors that we can eliminate, thereby reducing variability, if we can identify them. They can create major problems. Examples of assignable causes might be when the gradation for an aggregate blend goes out of specification due to a hole in one of the screens, or because the cold feed conveyor setting is incorrectly adjusted, or an asphalt pump malfunctions.

Chance Causes



- Everything varies
- Duplicate measurements will not always be identical
- Every process has inherent variability that can't be eliminated
- Individual results are unpredictable
- Groups from a constant system tend to be predictable



Chance causes are normal because everything varies. Duplicate measurements will not always be identical. Every process has some inherent variability that cannot be eliminated, but can possibly be reduced by changing the process. Due to this variability, individual results cannot be accurately predicted. However, groups from a constant process or system tend to be predictable.

Image description: Image of sleight of hand trick.

Example: Chance Causes



- People live to be different ages
 - Insurance companies use actuarial tables to predict life span variability
 - Tables are the basis for establishing insurance premiums



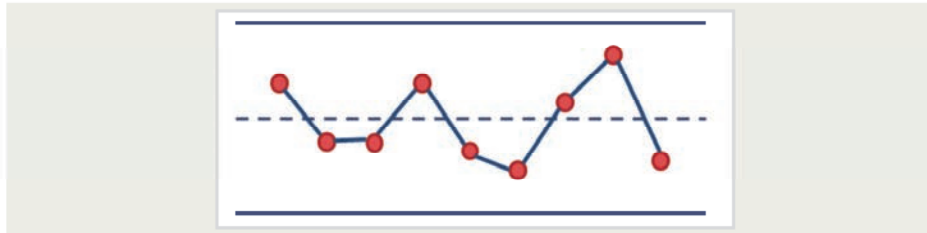
An example of chance cause is that it is not possible to predict how long an individual will live. However, insurance companies have actuarial tables that predict with relatively high accuracy what percentage of the population will live to various ages. These tables are the basis for establishing insurance premiums. We can do the same thing with a construction materials process, provided the process is in control.

Image description: Image of people and children.

Benefits of Control Charts



- Early detection of trouble
- Decrease variability
- Establish process capability
- Reduce price adjustment costs
- Establish permanent record of quality
- Instill quality awareness



Control charts have been used for years in the manufacturing industry and have been successfully employed in construction materials applications. There are many benefits for using control charts. Some are:

- They provide early detection of trouble, before much out of spec material is produced;
- They decrease variability by monitoring the control charts in real time;
- They establish process capability;
- They reduce price adjustment costs by eliminating or minimizing out of spec material;
- They establish a permanent record of quality; and
- They instill quality awareness within the company.

Image description: Statistical control chart.

Control Chart Measures



- Measures of Center
 - Average, \bar{X}
 - Moving Average, \bar{X}_m
- Measures of Variability
 - Standard Deviation, s
 - Range, R
 - Moving Range, R_m



Many different forms of statistical control charts are available. But in whatever form, a measure of the center and a measure of the variability must be obtained to be most effective. After all, we're trying to estimate the population being produced and we know we have to have a measure of the two population parameters to do that. Two measures of the center are discussed: the average X -bar and the moving average X -bar sub m . But only one of the two is chosen to be used.

Similarly, three measures of variability will be discussed: the standard deviation, s , the range, R , and the moving range, R sub m . And again only one will be chosen to be used. The range is useful as a quick way of determining a measure of variability, but since it only uses the maximum and minimum values in a data set, it is often not the best estimate of variability. Nonetheless, because of its simplicity, it is often used for control charts.

Quality Control Limits



- Are not tolerance or specification limits
- Established by process capabilities





Control limits are not tolerance or specification limits. They are established by the process capabilities (that is by the variability of the process).


 U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



Quality control limits are different from specification limits. Control limits are not tolerance or specification limits. The control limits are established by the process capabilities (that is by the variability of the process). This has been a common mistake made by some agencies and contractors that have not understood the correct purpose of control charts.

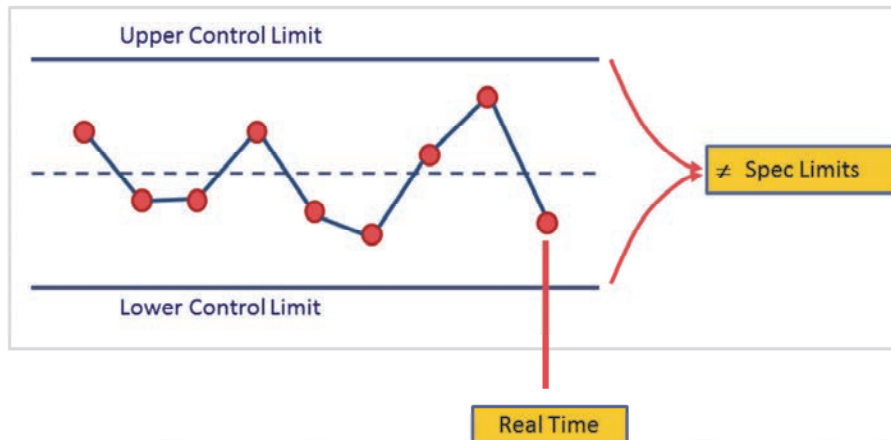
If the control limits are not within the allowable specification tolerance limits, then the contractor will have to modify the process to reduce variability to bring the control limits within the specification limits. If this is not done, the contractor will have a serious problem trying to meet the specs.

Image description: Statistical control chart showing spec limits.

Control Chart Considerations



Control Chart Usage



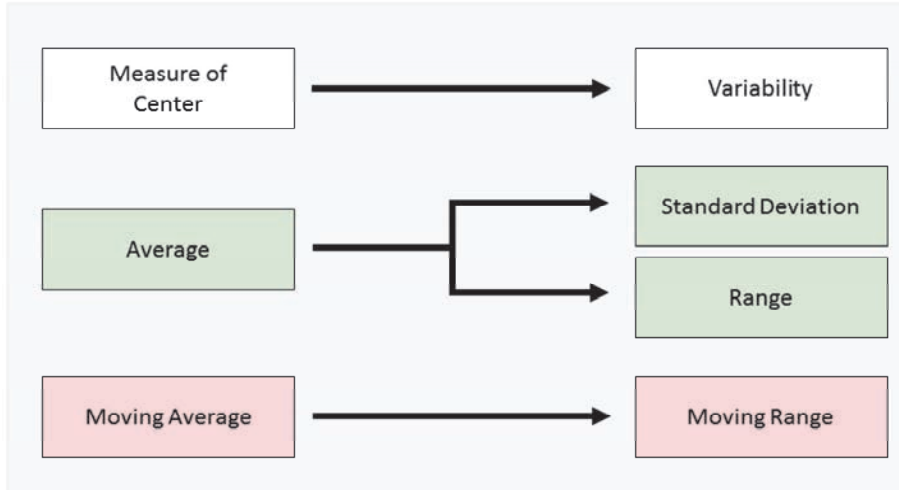
In order for control charts to be used as intended—that is, to indicate process control problems—they must be kept in real time. It does no good to plot control charts days after production. Have you ever visited a contractor’s lab on a rainy day and seen the technician catching up the control charts? This does absolutely no good as far as producing meaningful results.

Image description: Statistical control chart showing spec limits and real time.

Control Chart Usage



- Control charts are used in pairs



As mentioned earlier, control charts are used in pairs; that is, a measure of the center is coupled with a measure of variability. So a control chart for the average would be paired with a control chart for either the standard deviation or the range. Likewise, if the control chart used the moving average, it would be paired with one for the moving range.

Independent Values



- \bar{X} , R, and s Control Charts
 - Independent points
 - Plotted per lot
- \bar{X}_R and R_m Control Charts
 - Points are not independent
 - Plotted per test



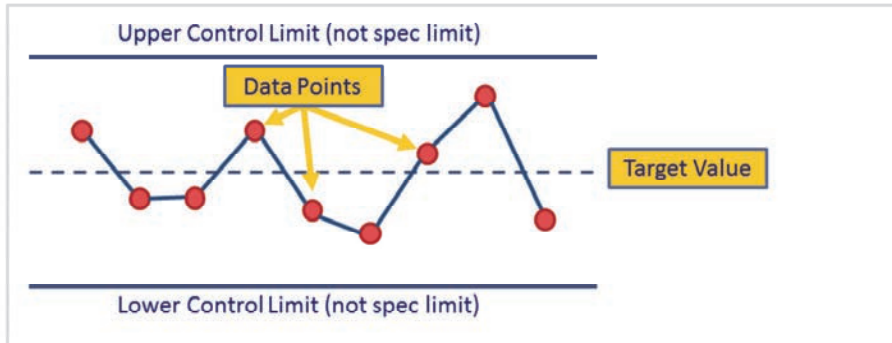
Control charts using the average and standard deviation, or range, are more correct from a theoretical statistical standpoint than the moving average and moving range because the data set in the former for each lot is independent of the next. For moving averages and moving ranges, each value is combined with a given number of previous values to provide the sample statistics and, thus, the data set is not independent.

However, the advantage of the moving average and moving range is that decisions can be made continuously without having to wait for a lot to be complete. Some contractors are reluctant to use control charts, although their benefits have been proven. So often if a contractor chooses to use moving average and moving range charts, this should be allowed.

Statistical Control Charts



- Target based on population average or average variability
- Control limits are established from measure of variability



A statistical control chart includes a target value, upper and lower control limits, and a series of data points that are plotted, usually by subgroup, in real time. The target is based on either the population average or average variability and the control limits are established from a measure of variability.

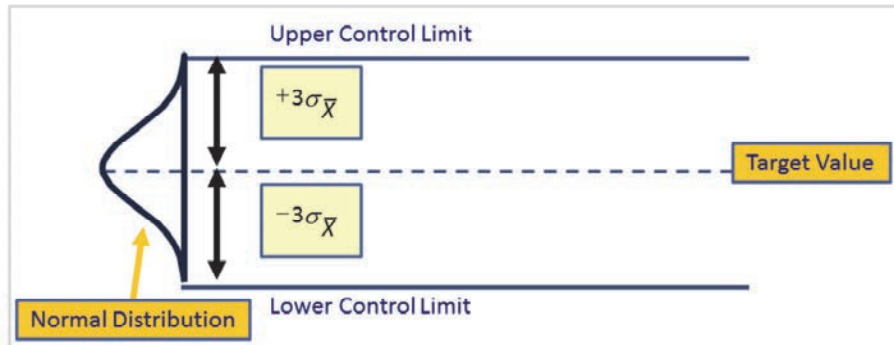
If a job mix formula (JMF) is being used, it should be compared to the target value but not used as the target value. If these two values are not close, the contractor will likely have trouble meeting the spec.

Image description: Statistical control chart showing data points and target value.

Control Limits – \bar{X} Charts



- Statistical control chart for averages or means
 - 99.7% of average or mean values fall within plus or minus three standard deviations of the mean



A statistical control chart for averages, or means, can be viewed as a normal distribution on its side and relies on the fact that, for a normal distribution, essentially all, that is 99.7% of the average or mean values will fall within plus or minus three standard deviations of the mean ($\sigma_{\bar{X}}$).

$\sigma_{\bar{X}}$ is used because we're dealing with average or mean values. And the normal distribution can be used because the distribution of sample means is normally distributed; remember the "central limits theory."

Image description: Statistical control chart for average or means showing a normal distribution curve and target value.

Control Charts for Variability



- Range Chart

- Considers variability of material
- Prevents extremely large positive and negative results from canceling out and not being detectable on control chart for means

Range, R → $n \leq 10$, but usually 3 to 5

- Standard Deviation Chart

- Better measure of variability than the range but not as easy to use

Standard Deviation, s → usually $n \geq 10$



U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



Control charts for variability use either the range, R , or the standard deviation, s . The range chart considers the variability of the material and prevents extremely large positive and negative results from canceling out and not being detectable on the control chart for means.

While the standard deviation is a better measure of variability than the range, for the small sample sizes typically used in construction, say n less than or equal to 5, the range is nearly as good an estimator as the standard deviation, s . Since the range is the easiest measure of variability to use in the field, contractors and producers often prefer it to the standard deviation.

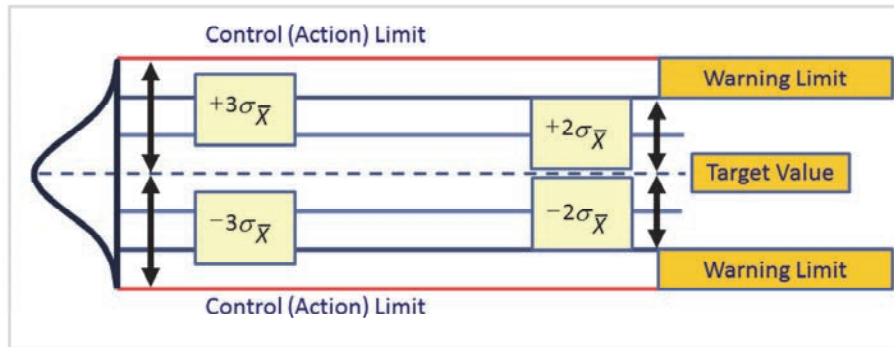
Image description: Range R example.

Image description: Standard deviation example.

Control Limits for \bar{X} Charts



- To provide a quick response to potential problems, warning limits are established at 2 sigma X -bar from target value
 - 95% of population should be within 2 sigma X -bar from the mean



Control limits for the mean or X -bar charts are based on plus or minus 3 sigma X -bar and are called control or action limits. Sometimes, to provide a quick response to potential problems, warning limits are established at 2 sigma X -bar from the target value. We know from the 68-95-99.7 rule that 95% of the population should be within 2 sigma X -bar from the mean, so there's only 1 chance in 20 that a value will be outside the warning limits if the process is in control.

Image description: Statistical control chart for control limits showing a normal distribution curve, warning limits and Target value.

Estimate Population Parameters



- Estimate population parameters for control charts
 - Base estimates on early production that is “in control”
 - Use 25 or more data points (lots)
- Usually estimated from early production
- Prefer at least 25 data points (lots)
- May not be practical for certain construction situations



It is necessary to estimate the population parameters for the control charts. The control charts we will use assume that the population parameters will be estimated based on early production and that the production is “in control.” Statistical texts suggest that 25 or more data points (lots) be used to assume a state-of-control exists and, thus, provide an estimate of the process capability. Permanent plants provide the ideal opportunity to develop these parameters.

In many highway applications that is unrealistic because of movable plants and other processes that change frequently. However, the consequences of establishing estimates of the population parameters based on relatively few data must be kept in mind. If you do not have enough data to measure the typical variability in a process, when a data point is outside our limited data, we will assume it is out-of-control whereas it may be part of the normal variability. However, practicality must prevail and we may be limited by the amount of data that is available when establishing the limits. We should keep in mind that the engineering decision should overrule the statistical decision when there is a conflict between the two.

Example of Estimating the Mean and Variability



- Sample size $n = 4$

	X_i	\bar{X}	s	R
Lot 1	5.6, 5.8, 5.4, 5.4	5.55	0.19	0.4
Lot 2	5.7, 5.6, 5.5, 5.8	5.65	0.13	0.3
Lot 3	5.2, 5.4, 5.2, 5.4	5.30	0.12	0.2
Lot 4	5.4, 5.6, 5.7, 5.7	5.60	0.14	0.3
Lot 5	5.4, 5.5, 5.3, 5.4	5.40	0.08	0.2
		27.50	0.66	1.4
		$\bar{\bar{X}} = 27.5/5$ $\bar{\bar{X}} = 5.5$	$\bar{s} = 0.66/5$ $\bar{s} = 0.13$	$\bar{R} = 1.4/5$ $\bar{R} = 0.28$
		Grand Mean	Standard Deviation	Control Limits



Let's walk through an example of estimating the mean and variability using both the range, R , and the standard deviation, s .

Consider five lots of sample size $n = 4$ of asphalt content. For each lot, the mean and range are calculated. The values in Lot 1 are 5.6, 5.8, 5.4, and 5.4. The average of Lot 1 is 5.55, the standard deviation, s , is 0.19, and the range is 0.4. The value for each average is summed (27.50) and divided by the number of lots (5) to obtain the grand mean, $\bar{\bar{X}}$, of 5.5.

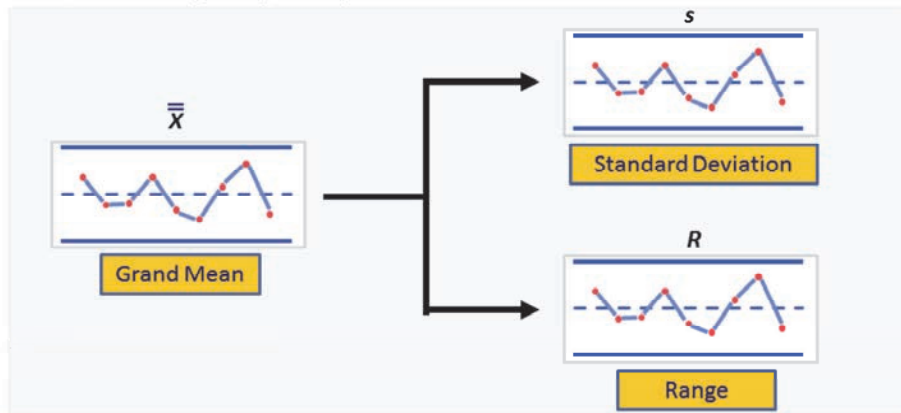
The same procedure is used to obtain the average standard deviation, \bar{s} , that is s summed is 0.66 divided by 5 equals 0.13. Then \bar{R} is obtained by summing the individual ranges, R is 1.4 dividing by 5 produces the average range \bar{R} 0.28. These values will be used to establish the control limits.


Image description: Example of estimating the mean and variability.

Control Limits for Mean and Variability



- After estimating the grand mean, \bar{X} -double bar, and average standard deviation, s -bar or average range R -bar, the control limits can be calculated for each



 Remember that the average charts are used with either the standard deviation or range chart to provide the most effective process control tool.



After estimating the grand mean, \bar{X} -double bar, and average standard deviation, s -bar, or average range R -bar, the control limits can be calculated for each. These will be discussed separately for each sample statistic, but we should remember that the average charts are used together with either the standard deviation or range chart to provide the most effective process control tool. There are some contractors that use only the mean, \bar{X} -bar, chart but this is not an adequate QC tool because there is no measure of variability, which is necessary to estimate the population being produced.

Image description: Statistical control chart for grand mean pointing to Statistical control charts for standard deviation and range.

Control Limits for Mean Charts



- Mean, $X\text{-bar}$ (\bar{X}) chart

Using \bar{R}

Target Value = $\bar{\bar{X}}$

$$\text{UCL} = \bar{\bar{X}} + (A_2 \times \bar{R})$$

$$\text{LCL} = \bar{\bar{X}} - (A_2 \times \bar{R})$$

Using \bar{s}

Target Value = $\bar{\bar{X}}$

$$\text{UCL} = \bar{\bar{X}} + (A_3 \times \bar{s})$$

$$\text{LCL} = \bar{\bar{X}} - (A_3 \times \bar{s})$$



U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



The first control chart we'll discuss in detail is the mean, $X\text{-bar}$, chart. For this chart, the grand mean, $X\text{-double bar}$, becomes the target value and the control limits which are action limits are calculated for the upper control limit, UCL and lower control limit, LCL. There are two different factors to use depending on whether the range, R , is used or the standard deviation, s , is used.

The control limits are found by determining a function of the average range, $R\text{-bar}$, or average standard deviation, $s\text{-bar}$, and adding and subtracting it from the grand mean, $X\text{-double bar}$. If the range, R , is used, the factor is A_2 . If the standard deviation is used, the factor is A_3 . These factors are determined by using the sample size, number of standard deviations and, in the case of range, a factor that converts standard deviation to range. (The factors A_2 and A_3 are shown on the next slide). This factor is multiplied by the average range, $R\text{-bar}$, or average standard deviation, $s\text{-bar}$, as appropriate, to determine the function to be added to the grand average, $X\text{-double bar}$, for the UCL, or subtracted to the grand average for the LCL. The calculations of control limits using either the range or standard deviation are similar, so the examples that follow will use only the range for simplicity.

Image description: Example of determining a function of the average range, \bar{R} .

Image description: Example of determining a function of the average standard deviation, \bar{s} .

Factors for Mean Chart When Using Range



- This table includes sample sizes of $n = 2$ to $n = 7$

n	A_2
2	1.880
3	1.023
4	0.729
5	0.577
6	0.483
7	0.419



To determine the control limits for the mean chart when using the range as the estimate for variability, the factor A_2 is used. The values for the factor A_2 depend on the sample size. This table includes sample sizes of $n = 2$ to $n = 7$.

- For a sample size of $n = 2$, the A_2 factor is 1.880;
- for $n = 3$, the A_2 factor is 1.023;
- for $n = 4$, the A_2 factor is 0.729;
- for $n = 5$, the A_2 factor is 0.577;
- for $n = 6$, the A_2 factor is 0.483; and
- for $n = 7$, the factor is 0.419.

Setting Target and Control Limits for the Mean Chart using the Range



- Control chart using the range, R , are shown here for percent passing the 0.075mm (#200) sieve for HMAC

- Sample size $n = 4$

Lot	X_1	X_2	X_3	X_4	\bar{X}	R
1	6.4	6.9	5.8	6.0	6.3	1.1
2	5.7	5.2	6.1	6.4	5.8	1.2
3	6.0	5.5	7.0	6.8	6.3	1.5
4	6.2	5.4	4.8	6.4	5.7	1.6
5	5.9	6.5	6.7	6.5	6.4	0.8
6	6.2	7.2	7.5	6.9	7.0	1.3

Average:

$\bar{\bar{X}}$

\bar{R}

Grand Mean

Average Range



An example of establishing the target and control limits for the average control chart using the range, R , are shown here for percent passing the 0.075 mm (#200) sieve for HMAC.

There are 6 lots with each containing a sample size of $n = 4$. The data are used to illustrate the computation for establishing the target and control limit values. From this table, the means of the 6 lots are 6.3, 5.8, 6.3, 5.7, 6.4, and 7.0 respectively.

These are summed and divided by 6 to produce the grand mean, $\bar{\bar{X}}$, of 6.2 and this becomes the target value for the mean.

Likewise, the ranges, R , of the 6 lots are 1.1, 1.2, 1.5, 1.6, 0.8, and 1.3 respectively. These are summed and divided by 6 to produce the average range, \bar{R} , of 1.25. This value, 1.25, will be multiplied by the factor A_2 to determine the control limits.

Image description: Example of establishing the target and control limits for the average control chart using the range, R .

Example – Control Limits for Mean



- Control limits are determined by taking the grand mean, \bar{X} -double bar, and adding and subtracting the function of the range, R

- Sample size $n = 4$

$$\begin{aligned} \text{UCL} &= \bar{\bar{X}} + (A_2 \times \bar{R}) = 6.2 + (0.729 \times 1.25) = 7.1 \\ \text{LCL} &= \bar{\bar{X}} - (A_2 \times \bar{R}) = 6.2 - (0.729 \times 1.25) = 5.3 \end{aligned}$$

(0.9)

(0.9)



The control limits are determined by taking the grand mean, \bar{X} -double bar, which is the target value found to be 6.2 and adding and subtracting the function of the range, R . This function is the factor A_2 , which is 0.729 for a sample size of $n = 4$, multiplied by the average range, R -bar, which was found to be 1.25 and equals 0.9.

Thus, the upper control limit, UCL, is $6.2 + 0.9$, which equals 7.1

The lower control limits, LCL, is $6.2 - 0.9$, which equals 5.3.

Since this is only one part of the two necessary control charts, we must find the limits for the variability. We have chosen to use the range, R , for the measure of variability. First we must introduce the factors to use with the range chart.

Image description: Example of control limits for mean.

Factors for Range Charts



n	Lower Control Limit (LCL) D_3	Upper Control Limit (UCL) D_4
2	0	3.267
3	0	2.574
4	0	2.282
5	0	2.114
6	0	2.004
7	0.076	1.924



Just as we had the factors A_2 for the means chart, we have factors D_3 and D_4 for the range chart. D_3 is used to establish the lower control limit, LCL, and D_4 is used for the upper control limit, UCL. These factors will be multiplied by the average range, $R\text{-bar}$, to establish the limits. Notice that is zero through $n = 6$. We will see how this affects the lower control limit, LCL, when we apply the factors in the example.

Setting Target and Control Limits for the Mean Chart using the Range



- Example is repeated here to facilitate calculating the limits for the range, R , chart

- Sample $n = 4$

Lot	X_1	X_2	X_3	X_4	\bar{X}	R
1	6.4	6.9	5.8	6.0	6.3	1.1
2	5.7	5.2	6.1	6.4	5.8	1.2
3	6.0	5.5	7.0	6.8	6.3	1.5
4	6.2	5.4	4.8	6.4	5.7	1.6
5	5.9	6.5	6.7	6.5	6.4	0.8
6	6.2	7.2	7.5	6.9	7.0	1.3

Average:

$\bar{\bar{X}}$

\bar{R}

Grand Mean

Average Range



The example of results for establishing the target and control limits for percent passing the 0.075 mm (#200) sieve for HMAC for the six lots is repeated here to facilitate calculating the limits for the range, R , chart. The process for establishing control limits for variability follows a similar pattern to those for the mean.

Image description: Example of results for establishing the target and control limits for percent passing the 0.075 mm (#200) sieve for HMAC for the six lots.

Example of Control Limits for the Range Chart



- For the range, R , chart target value becomes the average range

- Sample size $n = 4$

$$UCL = D_4 \times \bar{R} = 2.282 \times 1.25 = 2.85$$

$$LCL = D_3 \times \bar{R} = 0.0 \times 1.25 = 0.0$$



So now that we know how to establish control limits, how many lots are enough?

ANSWER



U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



For the range, R , chart target value becomes the average range. R -bar and the factors D_4 and D_3 are used as multipliers to establish the upper control limit (UCL), and the lower control limit (LCL).

For the upper control limit, the D_4 factor for a sample size of 4 is 2.85 and the D_3 factor is 0. Remember the average range was 1.25, which becomes the target value. The first thing that is obvious is that the limits are not symmetrical. The upper control limit, UCL, minus the target value is $2.85 - 1.25$, which equals 1.60, and the target value minus the lower control limit, LCL, is $1.25 - 0$, which equals 1.25.

This is because the measures of variability, the range, R , and the standard deviation, s , are not normal distributions, which means they are symmetrical. The other thing we notice is that because D_3 is zero, the lower control limit is also zero. The significance of this is the range can be zero, that is all four results can be the same and the process is considered to be in control. That same observation applies through a sample size of $n = 6$.

Select the box to answer the question, so now that we know how to establish control limits, how many lots are enough?

Image description: Example of control limits for the range chart.

Example of Control Limits for the Range Chart



- For the range, R , chart target value becomes the average range

• Sar

Ideally, 25 or so data points, or subgroups, are desired to establish control limits, but this is sometimes unfeasible. Thus, control limits can be established for the mean, \bar{X} , the range, R , and the standard deviation, s , based on a smaller data set. But it must be recognized that the process may not be stable at this point and additional chance causes may occur that have not been captured. If control limits are based on fewer than 20 to 25 lots, it is best to recompute the limits after each new data point is added until the limits begin to stabilize at the proper value for the process.

CLOSE



So now that we know how to establish control limits, how many lots are enough?

ANSWER



U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



Ideally, 25 or so data points, or subgroups, are desired to establish control limits, but this is sometimes unfeasible. Thus, control limits can be established for the mean, \bar{X} , the range, R , and the standard deviation, s , based on a smaller data set. But it must be recognized that the process may not be stable at this point and additional chance causes may occur that have not been captured. If control limits are based on fewer than 20 to 25 lots, it is best to recompute the limits after each new data point is added until the limits begin to stabilize at the proper value for the process.

Image description: Example of control limits for the range chart.

What Does “Out-of-Control” Mean?



- The process (population) has changed in some way
 - Center has changed
 - Variability has changed
 - Center and variability have both changed



The process is out-of-control if it has changed in some way and is no longer operating as it was when we calculated the control limits. A process can change in several ways:

- The center can change;
- The variability can change; and
- Both the center and variability can change.

Control charts help to identify when a process has actually changed, as opposed to just the natural variability of the process. But it takes an investigation as to why it may have changed. Knowing the history of the operation is a valuable tool in seeking the cause of the change. For instance, if the change has occurred previously, what was found to have caused it and how was it corrected?

First Decision Rule

- One point outside control limits

UCL

Target

LCL

U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help

← →

There are many different decision rules that can be used to indicate that a process is out-of-control. We will consider two of the many decision rules that are used for control charts for sample means. The first rule that indicates that the process is out-of-control is if one point is outside the control or action limits.

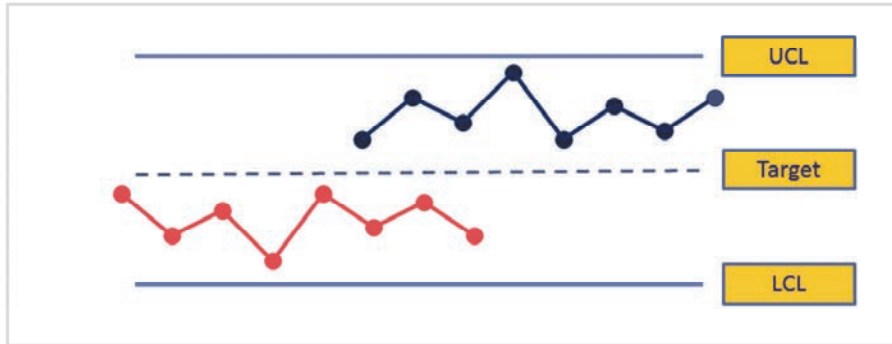
From what we already know, it is very unlikely that a point would fall outside the 3 sigma \bar{X} control limits if the process had not changed in some way. We know from the 68-95-99.7 rule that only 0.3% of the population will be outside plus or minus 3 sigma \bar{X} limits. This decision rule of one point outside the control limits, is also appropriate for control charts for sample ranges and sample standard deviations.

Image description: Statistical control chart showing UCL, LCL and target value.

Second Decision Rule



- Eight points in a row on same side of target



What is 0.5 to the eighth power?

ANSWER



U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



The other decision rule is based on what is called the theory of runs. Probability theory can show that each of these events is about as likely (or unlikely) to occur as one point outside the control limits. This decision rule is that if eight consecutive points are on the same side of the target value, the process is out-of-control. The probability of this occurring is one half (0.5) raised to the eighth power that is 0.5 times 0.5, 8 times.

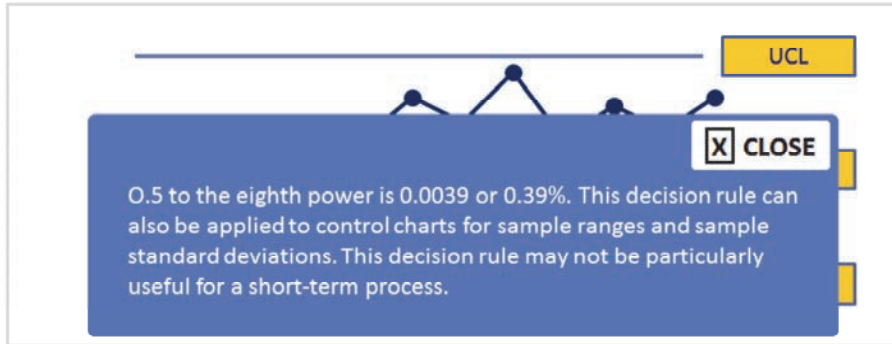
Select the answer box to answer the question, What is 0.5 to the eighth power?

Image description: Statistical control chart showing UCL, LCL and target value.

Second Decision Rule



- Eight points in a row on same side of target



What is 0.5 to the eighth power?

ANSWER



0.5 to the eighth power is 0.0039 or 0.39%. This decision rule can also be applied to control charts for sample ranges and sample standard deviations. This decision rule may not be particularly useful for a short-term process.

Image description: Statistical control chart showing UCL, LCL and target value.

Exercise 1: Calculate



- Calculate the \bar{X} and R for each lot for these Superpave air void data
- Then determine if any lot is out-of-control

Superpave Air Void Data					
Lot	X_1	X_2	X_3	X_4	X_5
1	4.9	4.9	5.8	4.0	3.8
2	5.7	5.2	5.1	4.6	5.1
3	6.0	4.7	4.1	3.8	3.8

UCL for the Mean Chart is = 5.0
LCL for the Mean Chart is = 3.6
UCL for the Range Chart is = 2.41
LCL for the Range Chart is = 0.00

To open the exercise document, select the paperclip icon.



MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



Now let's take a moment for an exercise. Use the exercise document that is provided from the paperclip icon. Please allow 10 minutes to conduct this exercise.

Calculate the \bar{X} and R for each lot for these Superpave air void data. Then determine if any lot is out-of-control. Use the following control limits:

- UCL for the mean chart is = 5.0;
- LCL for the mean chart is = 3.6;
- UCL for the range chart is = 2.41; and
- LCL for the range chart is = 0.00.

Exercise 1: Recap



- Calculate the \bar{X} and R for each lot for these Superpave air void data
- Then determine if any lot is out-of-control

Superpave Air Void Data					
Lot	X_1	X_2	X_3	X_4	X_5
1	4.9	4.9	5.8	4.0	3.8
2	5.7	5.2	5.1	4.6	5.1
3	6.0	4.7	4.1	3.8	3.8

For Lot 1, $\bar{X} = 4.7$, $R = 2.0$

For Lot 2, $\bar{X} = 5.1$, $R = 1.1$

For Lot 3, $\bar{X} = 4.5$, $R = 2.2$

The lot mean for Lot 2, 5.1 is above the UCL of 5.0 so this mean is out-of-control. All other means are in control. All lot ranges are in control.



The correct answers are:

- For Lot 1, $\bar{X} = 4.7$, $R = 2.0$;
- For Lot 2, $\bar{X} = 5.1$, $R = 1.1$; and
- For Lot 3, $\bar{X} = 4.5$, $R = 2.2$.

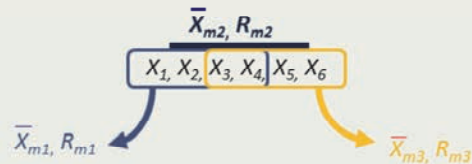
The lot mean for Lot 2, 5.1 is above the UCL of 5.0 so this mean is out-of-control. All other means are in control. All lot ranges are in control.

Moving Average and Moving Range



- Use the same concepts and factors for establishing limits

- Sample size $n = 4$



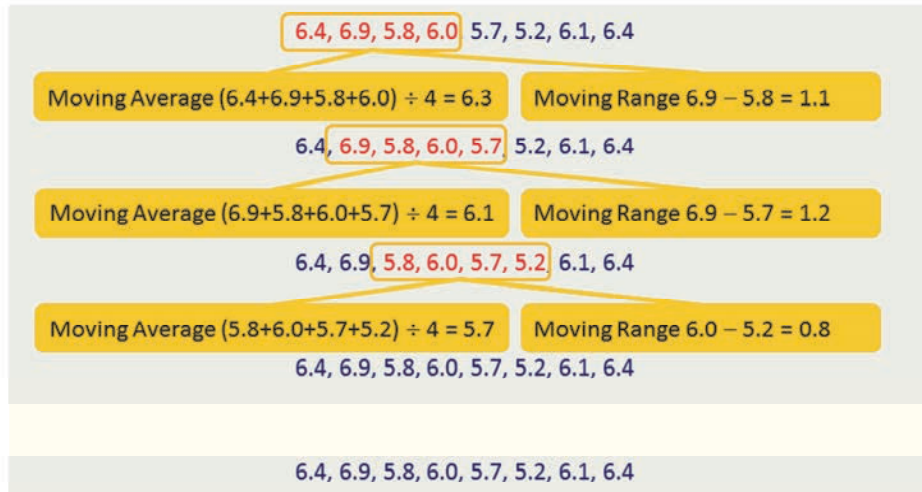
The moving average and moving range were mentioned earlier as substitutes for averages and ranges. They use the same concepts and factors for establishing control limits. For moving averages and moving ranges, a sample size, say $n = 4$, must first be determined. The first average and range are then determined from the first four values. For the second moving average and moving range, the fifth value replaces the first value in the calculations.

Image description: Example of moving average and moving range.

Moving Average and Moving Range




- Calculating moving averages and moving ranges



Using the data on this slide for the percent passing the 0.075 mm (#200) sieve, the first moving average would be calculated from the first four values, that is $(6.4 + 6.9 + 5.8 + 6.0) / 4 = 6.3$. Similarly, the first moving range would be $6.9 - 5.8 = 1.1$. For the next moving average, the first number, 6.4 is dropped and the fifth number, 5.7, is added, providing the second moving average of $(6.9 + 5.8 + 6.0 + 5.7) / 4 = 6.1$ and second moving range of $6.9 - 5.7 = 1.2$.


Likewise, the third moving average would drop the second number, 6.9, and add the sixth number, 5.2, to give the third moving average of $(5.8 + 6.0 + 5.7 + 5.2) / 4 = 5.7$ and the third moving range would be $(6.0 - 5.2) = 0.8$.


Image description: Example of moving average and moving range.



Select all that apply. Which of the following benefits apply to control charts?

- a) A way to educate technicians
- b) An early detection of trouble
- c) A way to keep the process going
- d) A way to decrease variability
- e) A way to establish process capability
- f) A way to reduce the likelihood of disincentives



 Knowledge Check Try again Submit Clear

 U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help

Select all that apply. Which of the following benefits apply to control charts?

- a) A way to educate technicians;
- b) An early detection of trouble;
- c) A way to keep the process going;
- d) A way to decrease variability;
- e) A way to establish process capability; and
- f) A way to reduce the likelihood of disincentives.



Select all that apply. Which of the following benefits apply to control charts?

- a) A way to educate technicians
- b) An early detection of trouble
- c) A way to keep the process going
- d) A way to decrease variability
- e) A way to establish process capability
- f) A way to reduce the likelihood of disincentives



Knowledge Check Debrief




MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help




The correct answers are b) An early detection of trouble; d) A way to decrease variability; e) A way to establish process capability; and f) A way to reduce the likelihood of disincentives.




True or false? Action limits are set at the target value plus or minus 3 sigma \bar{X} and warning limits are set at plus or minus 1 sigma \bar{X} .

a) True

b) False



 Knowledge Check Try again Submit Clear

 U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help

True or False? Action Limits are set at the target value plus or minus 3 sigma \bar{X} and warning Limits are set at plus or minus 1 sigma \bar{X} .



True or false? Action limits are set at the target value plus or minus 3 sigma \bar{X} and warning limits are set at plus or minus 1 sigma \bar{X} .

- a) True
- b) False



Knowledge Check Debrief




MODULE A
LESSON 9

QUALITY CONTROL


Resources
Glossary
Help






The correct answer is b) False. Warning limits are set at plus or minus 2 sigma \bar{X} .

Select all that apply. How does variability relate to quality control? 


- a) While the standard deviation is a better measure of variability than the range, the range is nearly as good an estimator as the standard deviation.
- b) While the range is a better measure of variability than the standard deviation, the standard deviation is nearly as good an estimator as the range.
- c) Control charts for variability use either the range or the standard deviation.

 Knowledge Check Try again Submit Clear


 **MODULE A**
LESSON 9 **QUALITY CONTROL** Resources
Glossary
Help  


Select all that apply. How does variability relate to quality control?

- a) While the standard deviation is a better measure of variability than the range, the range is nearly as good an estimator as the standard deviation;
- b) While the range is a better measure of variability than the standard deviation, the standard deviation is nearly as good an estimator as the range; and
- c) Control charts for variability use either the range or the standard deviation.

Select all that apply. How does variability relate to quality control? 

- a) While the standard deviation is a better measure of variability than the range, the range is nearly as good an estimator as the standard deviation.
- b) While the range is a better measure of variability than the standard deviation, the standard deviation is nearly as good an estimator as the range.
- c) Control charts for variability use either the range or the standard deviation.



 Knowledge Check Debrief

 U.S. Department of Transportation
Federal Highway Administration

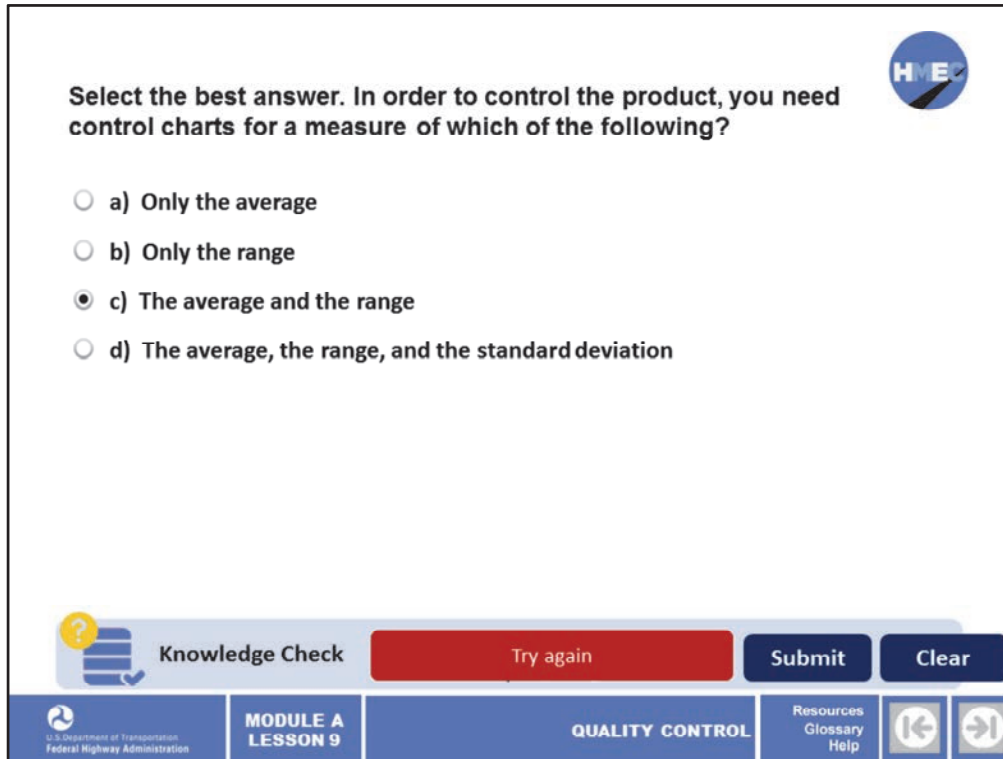
MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help

The correct answers are a) While the standard deviation is a better measure of variability than the range, the range is nearly as good an estimator as the standard deviation; and c) Control charts for variability use either the range or the standard deviation.



The screenshot shows a digital interface for a knowledge check. At the top right is a circular logo with the letters 'HME' and a pencil icon. The main text asks the user to select the best answer for controlling a product using control charts. There are four radio button options: 'a) Only the average', 'b) Only the range', 'c) The average and the range' (which is selected), and 'd) The average, the range, and the standard deviation'. Below the question is a 'Knowledge Check' section with a question mark icon, a red 'Try again' button, a dark blue 'Submit' button, and a dark blue 'Clear' button. The bottom navigation bar includes the U.S. Department of Transportation Federal Highway Administration logo, 'MODULE A LESSON 9', 'QUALITY CONTROL', and links for 'Resources', 'Glossary', and 'Help' with left and right arrow icons.

Select the best answer. In order to control the product, you need control charts for a measure of which of the following?

- a) Only the average
- b) Only the range
- c) The average and the range
- d) The average, the range, and the standard deviation

Knowledge Check Try again Submit Clear

U.S. Department of Transportation Federal Highway Administration MODULE A LESSON 9 QUALITY CONTROL Resources Glossary Help

Select the best answer. In order to control the product, you need control charts for a measure of which of the following?

- a) Only the average;
- b) Only the range;
- c) The average and the range; or
- d) The average, the range, and the standard deviation.



Select the best answer. In order to control the product, you need control charts for a measure of which of the following?

- a) Only the average
- b) Only the range
- c) The average and the range
- d) The average, the range, and the standard deviation



Knowledge Check Debrief



MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



The correct answer is c) The average and the range.

Select all that apply. How does the measure of center relate to measure of variability?

- a) If the control chart used the moving average, it should not be paired with one for the moving range.
- b) Control charts are used in pairs.
- c) A control chart for the average should be paired with a control chart for either the standard deviation or the range.

Knowledge Check Try again Submit Clear

U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help

Select all that apply. How does the measure of center relate to measure of variability?

- a) If the control chart used the moving average, it should not be paired with one for the moving range;
- b) Control charts are used in pairs; and
- c) A control chart for the average should be paired with a control chart for either the standard deviation or the range.



Select all that apply. How does the measure of center relate to measure of variability?

- a) If the control chart used the moving average, it should not be paired with one for the moving range.
- b) Control charts are used in pairs.
- c) A control chart for the average should be paired with a control chart for either the standard deviation or the range.



Knowledge Check Debrief



MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



The correct answers are b) Control charts are used in pairs; and c) A control chart for the average should be paired with a control chart for either the standard deviation or the range.

Learning Outcomes Review



You are now able to:

- Explain various ways in which a quality control plan can be developed and used to maintain the quality of a product or service
- Describe a typical quality control plan
- Relate variability to quality control
- Describe different types of control charts and their applications
- Establish and calculate control chart limits

Return to the module curriculum to select the next lesson. To close this window, select the "X" in the upper right-hand corner of your screen.



U.S. Department of Transportation
Federal Highway Administration

MODULE A
LESSON 9

QUALITY CONTROL

Resources
Glossary
Help



You have completed Module A, Lesson 9: Quality Control. You are now able to:

- Explain various ways in which a quality control plan can be developed and used to maintain the quality of a product or service;
- Describe a typical quality control plan;
- Relate variability to quality control;
- Describe different types of control charts and their applications; and
- Establish and calculate control chart limits.

Close this lesson, and return to the module curriculum to select the next lesson. To close this window, select the "X" in the upper right-hand corner of your screen.