Critical manufacturing
an ASM PT company

SPC

10.2

March 2024

DOCUMENT ACCESS

Public

SPC

Estimated time to read: 54 minutes

Statistical Process Control (SPC) is the use of statistical techniques to measure and control quality by monitoring a process or production method.

In SPC, quality data is collected in the form of product or process measurements or readings from various machines or equipments. The collected data is then used to evaluate, monitor and control a process. Hence, SPC tools and procedures can help you monitor process behavior, discover issues in internal systems, and find solutions for production obstacles.

Info

SPC is a separately licensed module.

This document will guide you through the setup and usage of SPC functionalities.

Overview

In Critical Manufacturing MES, SPC is a set of statistical methods used to monitor a process. The SPC tools in use help to track the behavior of a process in order to identify trends and out-of-control situations. When SPC violations are identified, protocols and corrective actions can be triggered and tracked.

Concepts

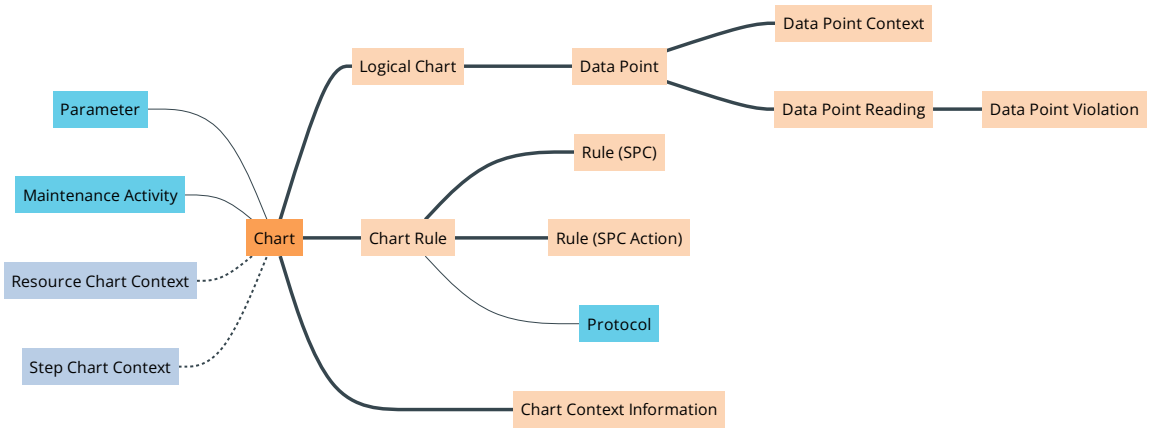
The main concepts related with the SPC module are described in the table below:

Term / Concept	Description
Chart	An SPC Chart configured to control a Parameter for a certain context.
Chart Key	Information that needs to be collected when posting data to the chart and that is used to identify the Logical Chart.
Logical Chart	Each unique combination of chart keys.
Data Point	Represents one complete sample. Different Data Points for the same Chart may have a different number of readings.
Parameter	A numeric value to be monitored in the chart.
Rule	A logic implemented to evaluate if an SPC violation has occurred or not.
Protocol	A protocol is a workflow designed to address a violation.
Sample	A set of collected readings.

Term / Concept	Description
Reading	A measurement of a parameter.

Table: SPC main concepts

The SPC object model revolves around the Chart object as can be seen in the following image:



Chart

A Chart is an object that represents an SPC Chart. Depending on what is intended to be controlled and the sample size, the system currently supports eight different Chart types as listed in the table below. The difference between Variable Charts and Attribute Charts is that Variable Charts monitor continuous variables and typically track two indicators (e.g. Average and Range) while the Attribute Charts monitor discrete variables with a single indicator and are typically related with the number of defects.

Chart Name	Chart Notation	Chart Type	Data Distribution
Average and Range	$\bar{x}$ *R*	Variable	Normal
Average and Standard Deviation	$\bar{x}$ *s*	Variable	Normal
Median and Range	$\tilde{x}$ *R*	Variable	Normal
Individuals and Moving Range	*I-MR*	Variable	Normal
Fraction Defective	*p*	Attribute	Binomial
Number Defective	*np*	Attribute	Binomial
Number of Defects per Unit	*u*	Attribute	Poisson
Number of Defects	*c*	Attribute	Poisson

Table: Critical Manufacturing MES SPC chart types

The next sub-sections describe each chart in more detail.

Average and Range

The Average and Range chart is described in the table below:

Property	Description
Chart	Average and Range *(x̄ R)*
Process Observation Type	Variables
Process Observations Relationships	Independent
Sample Size	< 10, but usually 3 to 5
Distribution type	Normal
Size of Shift to Detect	Large (≥ 1.5σ)
Average (Indicator 1)	$x = \frac{\sum_i x_i}{n}$
Range (Indicator 2)	$r_i = Max(x_1 \cdots x_n) - Min(x_1 \cdots x_n)$
Mean for All Values	$\mu = X = \frac{\sum x_{ij}}{\sum n_i}$
Process Mean	μ
Process Standard Deviation	$\sigma = S_r = \frac{\sum r_i \cdot \frac{[d_2(n_i)]}{[d_3(n_i)]^2}}{\sum \frac{[d_2(n_i)]^2}{[d_3(n_i)]^2}}$ Where r_i is the range for the data point
Average (Indicator 1) Centerline	μ
Average (Indicator 1) Control Limits	$UCL = \mu + \frac{3\sigma}{\sqrt{n_i}}$ $LCL = \mu - \frac{3\sigma}{\sqrt{n_i}}$ Where n_i = number of observations in sample (subgroup)
Range (Indicator 2) Centerline	$R_i = d_2(n_i) \cdot \sigma$
Range (Indicator 2) Control Limits	$UCL = R_i + 3\sigma \cdot d_3(n_i)$ $LCL = max(R_i - 3\sigma \cdot d_3(n_i); 0)$

Table: Average and Range chart properties

Info

The d_2 and d_3 constants are described in *Appendix A - Control Chart Constants*.

Average and Standard Deviation

The Average and Standard Deviation chart is described in the table below:

Property	Description
Chart	Average and Standard Deviation *($\bar{x}$ s)*
Process Observation Type	Variables
Process Observations Relationships	Independent
Sample Size	Usually >=10
Distribution Type	Normal
Size of Shift to Detect	Large (≥ 1.5σ)
Average (Indicator 1)	$x = \frac{\sum_i x_i}{n}$
Standard Deviation (Indicator 2)	$s = \sqrt{\frac{\sum (x_i - x)^2}{n-1}}$
Mean for All Values	$\mu = X = \frac{\sum x_{ij}}{\sum n_i}$
Process Mean	μ
Process Standard Deviation	$\sigma = S = \frac{\sum S_i \cdot \frac{c_4(n_i)}{1-c_4(n_i)^2}}{\sum \frac{c_4(n_i)^2}{1-c_4(n_i)^2}}$ Where S_i is the standard deviation for the data point as given by: $s = \sqrt{\frac{\sum (x_i - x)^2}{n-1}}$
Average (Indicator 1) Centerline	μ
Average (Indicator 1) Control Limits	$UCL = \mu + \frac{3\sigma}{\sqrt{n_i}}$ $LCL = \mu - \frac{3\sigma}{\sqrt{n_i}}$
Standard Deviation (Indicator 2) Centerline	$S_i = c_4(n_i) \cdot \sigma$

Property	Description
Standard Deviation (Indicator 2) Control Limits	$UCL = S_i + 3\sigma \cdot c_5(n_i)$ $LCL = max(S_i - 3\sigma \cdot c_5(n_i); 0)$

Table: Average and Standard Deviation chart properties

Info

The c_4 and c_5 constants are described in **Appendix A - Control Chart Constants** at the end of this page.

Median and Range

The Median and Range chart is described in the table below:

Property	Description
Chart	Median and Range *($\tilde{X}$ R)*
Process Observation Type	Variables
Process Observations Relationships	Independent
Sample Size	< 10, but usually 3 to 5
Distribution Type	Normal
Size of Shift to Detect	Large (≥ 1.5σ)
Median (Indicator 1)	$\tilde{X}$ = The median of a finite list of numbers can be found by arranging all the observations from the lowest to the highest value and picking the middle one. If there is an even number of observations, the median is the average of the two middle values.
Range (Indicator 2)	$r_i = Max(x_1 \cdots x_n) - Min(x_1 \cdots x_n)$
Process Mean	$\mu = \tilde{X} = \frac{\sum \tilde{x}_i}{n}$
Process Standard Deviation	$\sigma = S_r = \frac{\sum r_i \cdot \frac{[d_2(n_i)]}{[d_3(n_i)]^2}}{\sum \frac{[d_2(n_i)]^2}{[d_3(n_i)]^2}}$ Where r_i is the range for the data point

Property	Description
Median (Indicator 1) Centerline	$\tilde{X} = \mu$
Median (Indicator 1) Control Limits	$UCL = \mu + \frac{3\sigma \cdot e1}{\sqrt{n_i}}$ $LCL = \mu - \frac{3\sigma \cdot e1}{\sqrt{n_i}}$
Range (Indicator 2) Centerline	$R_i = d_2(n_i) \cdot \sigma$
Range (Indicator 2) Control Limits	$UCL = R_i + 3\sigma \cdot d_3(n_i)$ $LCL = max(R_i - 3\sigma \cdot d_3(n_i); 0)$

Table: Median and Range chart properties

Info

The d_2, d_3 and e_1 constants are described in **Appendix A - Control Chart Constants** at the end of this page.

Individuals and Moving Range

The Individuals and Moving Range chart is described in the table below:

Property	Description
Chart	Individuals and Moving Range *(I-MR)*
Process Observation Type	Variables
Process Observations Relationships	Independent
Sample Size	1
Distribution Type	Normal
Size of Shift to Detect	Large (≥ 1.5σ)
Individuals (Indicator 1)	x
Moving Range (Indicator 2)	$r_i = Abs(x_i - x_{i-1})$
Mean	$\mu = x = \frac{\sum x_i}{n}$

Property	Description
Mean Range	$MR = \frac{\sum MR_i}{i-1}$
Process Mean	μ
Process Standard Deviation	$\sigma = S_{mr} = \frac{MR}{d_2(w)}$ Because $w = 2$, the $d_2(w)$ can be replaced by the constant `1.1284` Where $MR = \frac{\sum MR_i}{i-1}$ Note that the first data point does not have an MR
Individuals (Indicator 1) Centerline	μ
Individuals (Indicator 1) Control Limits	$UCL = \mu + 3\sigma$ $LCL = \mu - 3\sigma$
Moving Range (Indicator 2) Centerline	$MR_i = \sigma \cdot d_2(w)$
Moving Range (Indicator 2) Control Limits	$UCL = MR_i + 3\sigma \cdot d_3(w)$ $LCL = max(MR_i + 3\sigma \cdot d_3(w); 0)$ Where $w = 2$

Table: Individuals and Moving Range chart properties

Info

The d_2 and d_3 constants are described in **Appendix A - Control Chart Constants** at the end of this page.

Fraction Defective

The Fraction Defective chart is described in the table below:

Property	Description
Chart	Fraction Defective *(p)*
Process Observation Type	Attributes
Process Observations Relationships	Independent
Sample Size	Variable, usually >=50
Distribution Type	Binomial

Property	Description
Size of Shift to Detect	Large (≥ 1.5σ)
Fraction Defective (Indicator 1)	$p = \frac{\text{number of rejects}}{\text{number inspected}}$
Indicator 2	**Not applicable**
Standard Deviation for Sample	$s = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$ Where $\bar{p}$ is the centerline and n is the sample size which can vary by sample
Fraction Defective (Indicator 1) Centerline	$\bar{p} = \frac{\text{total number of rejects}}{\text{total number inspected}}$
Fraction Defective (Indicator 1) Control Limits	$UCL = \min(\bar{p} + 3s; 1)$ $LCL = \max(\bar{p} - 3s; 0)$
Indicator 2 Centerline	**Not applicable**
Indicator 2 Control Limits	**Not applicable**

Table: Fraction Defective chart properties

Number Defective

The Number Defective chart is described in the table below:

Property	Description
Chart	Number Defective *(np)*
Process Observation Type	Attributes
Process Observations Relationships	Independent
Sample Size	Constant, usually >=50
Distribution Type	Binomial
Size of Shift to Detect	Large (≥ 1.5σ)
Number Defective (Indicator 1)	$p = \text{number of rejects}$
Indicator 2	**Not applicable**

Property	Description
Standard Deviation for sample	$s = \sqrt{n\bar{p}(1 - \frac{n\bar{p}}{n})}$ Where $n\bar{p}$ is the centerline and n is the sample size which is constant
Number Defective (Indicator 1) Centerline	$n\bar{p} = \frac{\text{total number of rejects}}{\text{number of samples}}$
Number Defective (Indicator 1) Control Limits	$UCL = n\bar{p} + 3s$ $LCL = \max(n\bar{p} - 3s; 0)$
Indicator 2 Centerline	**Not applicable**
Indicator 2 Control Limits	**Not applicable**

Table: Number Defective chart properties

Number of Defects per Unit

The Number of Defects per Unit chart is described in the table below:

Property	Description
Chart	Number of Defects per Unit *(u)*
Process Observation Type	Attributes
Process Observations Relationships	Independent
Sample Size	Variable
Distribution type	Poisson
Size of Shift to Detect	Large (≥ 1.5σ)
Number of Defects per Unit (Indicator 1)	$u = \frac{\text{number of defects}}{\text{sample size}}$
Indicator 2	**Not applicable**
Standard Deviation	$s = \sqrt{\frac{u}{n}}$ Where u is the centerline and n is the sample size which can vary by sample
Number of Defects per Unit (Indicator 1) Centerline	$u = \frac{c_1 + c_2 + \cdots + c_i}{n_1 + n_2 + \cdots + n_i}$ where *c* is the number of defects per sample and *n* is the sample size

Property	Description
Number of Defects per Unit (Indicator 1) Control Limits	$UCL = u + 3s$ $LCL = \max(u - 3s; 0)$
Indicator 2 Centerline	**Not applicable**
Indicator 2 Control Limits	**Not applicable**

Table: Number of Defects per Unit chart properties

Number of Defects

The Number of Defects chart is described in the table below:

Property	Description
Chart	Number of Defects *(c)*
Process Observation Type	Attributes
Process Observations Relationships	Independent
Sample Size	Constant
Distribution Type	Poisson
Size of Shift to Detect	Large (≥ 1.5σ)
Number of Defects (Indicator 1)	$c = number\ of\ defects$
Indicator 2	**Not applicable**
Standard Deviation	$s = \sqrt{\bar{c}}$ Where $\bar{c}$ is the centerline
Number of Defects (Indicator 1) Centerline	$\bar{c} = \frac{c_1 + c_2 + \cdots + c_i}{i}$ where *c* is the number of defects per sample
Number of Defects (Indicator 1) Control Limits	$UCL = \bar{c} + 3s$ $LCL = \max(\bar{c} - 3s; 0)$
Indicator 2 Centerline	**Not applicable**
Indicator 2 Control Limits	**Not applicable**

Table: Number of Defects chart properties

Logical Charts

A Chart consists of many Logical Charts. A Logical Chart is automatically created by the system for each unique combination of Chart context keys. For example, if there is a parameter to be monitored across ten machines (Resources), it is not necessary to create ten different Charts; it is only necessary to create one Chart and define the Resource as a Chart context key. This mechanism allows the same Chart to be re-used across Steps, Equipment (Resources), Products and so forth. A Chart can have many context keys. In addition to the context keys, a Chart can have defined additional mandatory context information. Non mandatory context can always be supplied.

When a Logical Chart is first created (by posting data to a particular context key combination or by explicitly creating it), the system will automatically create the Logical Chart inheriting all the properties that are defined at the Chart level. However, each Logical Chart will maintain a set of its own properties as listed in the table below:

Property	Description
Lower Specification Limit	Lower Specification Limit
Target Specification Value	Target Specification Value
Upper Specification Limit	Upper Specification Limit
Centerline for Indicator 1	Centerline for Indicator 1 (from which Control Limits are calculated in case the Control Limits are automatic)
Centerline for Indicator 2	Centerline for Indicator 2
Standard Deviation	Standard deviation
Y-Axis Scale	Whether the Y-Axis scale is manual or automatic
Y-Axis Minimum	In the case that the Y-Axis scale is manual, the minimum value
Y-Axis Maximum	In the case that the Y-Axis scale is manual, the maximum value
Y-Axis Major Units	In the case that the Y-Axis scale is manual, the distance between ticks
Data Points Counter	Used internally to count the number of Data Points
Use Automatic Control Limits	Whether to use automatic control limits or not
In Learning Mode	Whether the learning mode is active or not
Disable Auto Calculate Control Limits After Learning	Whether the control limits are no longer recalculated after learning
Auto Calculate Control Limit Indicators	Whether control limits will be automatically recalculated

Property	Description
Auto Calculation Counter	Used internally to count the number of Data Points until the Control Limits must be recalculated (in case the option to recalculate the Centerlines is enabled)

Table: Logical Chart properties

Chart Statistics

The Chart statistics described below, are calculated based on all the data points that are visible in the GUI for the Logical Chart and the calculations exclude **Deleted** and **Excluded** data points. All formulas apply to the indicator one only.

Some Chart statistics use a single value for specification limits and control limits. Because the specification limits (Lower, Target, Upper) as well as Centerlines and Control Limits (Lower Control Limit and Upper Control Limit) may change from data point to data point, changes in these values will be handled based on the value defined in the configuration entry `Cmf/System/Configuration/SPC/MultipleDataPointsStatistics/CalculationMode/` that can have two values:

- **Average** (default and used if no value is present) - uses the average of the values for the considered data points (default). The considered data points are only the ones that contains the required values (Lower Specification Limit, Target Specification Value, Upper Specification, Lower Control Limit, Centerline and Upper Control Limit).
- **Last** - uses the values (Lower Specification Limit, Target Specification Value, Upper Specification, Lower Control Limit, Centerline and Upper Control Limit) from the last data point, if the values are defined for the data point.

Indicator	Formula	Data Points	Readings	Display For	Note
Count	Count	x		All Charts	All dat point
Max	Max	x		All Charts	
Min	Min	x		All Charts	
Mean	$\bar{x} = \frac{x_1 + x_2 + x_3 + \cdots + x_n}{n}$	x		All Charts	
Overall Mean	$\mu = \frac{x_1 + x_2 + x_3 + \cdots + x_n}{n}$		x	Not Displayed	This ir consi indivi readir it excl data p that a aggre
Standard Deviation	$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$	x		All Charts (when Data Points > 1)	

Indicator	Formula	Data Points	Readings	Display For	Note
Overall Standard Deviation	$\delta = \sqrt{\frac{\sum (x_i - x)^2}{n-1}}$		x	Not Displayed	This ir consi indivi readir it excl data p that a aggre
Median	$\tilde{x}$	x		All Charts	The m of a fi of nu can b by arr all the obser from lowes highe and p the m one. I is an numb obser the m the av of the middl value
Range	$Range = Max(x_{1\cdots n}) - Min(x_{1\cdots n})$	x		All Charts	
Within Standard Deviation	For Individuals and Moving Range Charts: $\hat{\delta}_{Within} = \frac{MR}{d2(w)}$ where $d2(w)$ with w=2 is `1.1284`. For the other types of Variable Charts, the Pooled Standard Deviation *(Sp)* is calculated according to the formula: $S_p = \sqrt{\frac{[\sum_i \sum_j (X_{ij} - X_i)^2]}{[\sum_i (n_i - 1]}}$ Then, the degrees of freedom *(d)* is calculated as: $\sum (n_i - 1)$ And finally, the Within Standard Deviation is calculated using the formula: $\hat{\delta}_{Within} = \frac{Sp}{c4(d+1)}$	x	x	Not Displayed	

Indicator	Formula	Data Points	Readings	Display For	Note
Cp - Process Capability	$C_p = \frac{USL - LSL}{6\hat{\sigma}_{Within}}$	x	x	All Variable Charts (when Data Points > 1)	Abou data p to be consi in cas chang missi USL/L pleas to the Calcu Mode descr earlie docu
Cp,upper - Upper Process Capability	$C_{p,upper} = \frac{USL - \mu}{3\hat{\sigma}_{Within}}$ μ to be used is the overall mean for the all the individual readings of the data points considered – same as **Pp**	x	x	Not Displayed	Abou data p to be consi in cas chang missi USL/L pleas to the Calcu Mode descr earlie docu This i consi indivi readi it excl data p that a aggre

Indicator	Formula	Data Points	Readings	Display For	Note
Cp,lower - Lower Process Capability	$C_{p,lower} = \frac{\mu - LSL}{3\hat{\sigma}_{Within}}$ μ to be used is the overall mean for the all the individual readings of the data points considered – same as **Pp**	x	x	Not Displayed	Never displa used calcul later; the da point consi in cas chang missi USL/L pleas to the Calcu Mode descr earlie docu This i consi indivi readi it excl data that a aggre
Cpk - Process Capability Index	$C_{pk} = \min(C_{p,lower}, C_{p,upper})$	x	x	All Variable Charts (when Data Points > 1)	If sing sided, syste consi only t nullab of the equat
Z-Score - Standard Score	$Z = 3C_{pk}$	x	x	All Variable Charts (when Data Points > 1)	**1**

Indicator	Formula	Data Points	Readings	Display For	Note
Pp- Process Performance	$P_p = \frac{USL - LSL}{6\delta}$	x	x	All Variable Charts (when Data Points > 1)	Abou data p to be consi in cas chang missi USL/L pleas to the Calcu Mode descr earlie docu This i exclu the da point are aggre
Pp,upper	$P_{p,upper} = \frac{USL - \mu}{3\delta}$	x	x	Not Displayed	Abou data p to be consi in cas chang missi USL/L pleas to the Calcu Mode descr earlie docu This i exclu the da point are aggre
Pp,lower	$P_{p,lower} = \frac{\mu - LSL}{3\delta}$	x	x	Not Displayed	

Indicator	Formula	Data Points	Readings	Display For	Note
Ppk – Process Performance Index	$P_{pk} = \min(P_{p,lower}, P_{p,upper})$	x	x	All Variable Charts (when Data Points > 1)	Note: sided, syste consi only t nullat of the equat
OOS – Out of Spec	Counts the number of all readings of all data points that are either above the upper spec limit or below the lower spec limit.		x	All Charts	
OOC – Out of Control	Counts the number of data points that are either above the upper control limit or below the lower control limit.	x		All Charts	For th Variat Chart indica only consi Indica
OOC% - Out of Control Rate	$OOC(\%) = 100\% \frac{OOC}{\text{number of data points}}$	x		All Charts	
OTI – On Target Indicator	$OTI = \frac{x - \text{Target Spec Value}}{s}$	x		All Variable Charts (when Data Points > 1)	**2**
OCI – On Center Indicator	$OCI = \frac{x - \text{Centerline}}{s}$	x		All Variable Charts (when Data Points > 1)	**3**
LCLCR – Lower Control Limit Change Ratio	$LCLCR = \frac{LCL - (x - 3s)}{s}$	x		All Variable Charts (when Data Points > 1)	**4**
UCLCR - Upper Control Limit Change Ratio	$UCLCR = \frac{(x + 3s) - UCL}{s}$	x		All Variable Charts (when Data Points > 1)	**5**

Indicator	Formula	Data Points	Readings	Display For	Note
CLCR – Control Limits Change Ratio	if $abs(LCLCR) > abs(UCLCR)$ $CLCR = LCLCR$ else $CLCR = UCLCR$	x		All Variable Charts (when Data Points > 1)	**6**

Table: Chart Statistics

Note

1 Only display if configuration entry `/Cmf/System/Configuration/SPC/ChartStatistics/IncludeZScore` is set to `true`.

Note

2 Only display if configuration entry `/Cmf/System/Configuration/SPC/ChartStatistics/IncludeOTISection` is set to `true`. About the data points to be considered – in case of changing or missing Target Spec Values, please refer to the Calculation Mode described earlier in this document.

Note

3 Only display if configuration entry `/Cmf/System/Configuration/SPC/ChartStatistics/IncludeOTISection` is set to `true`. About the data points to be considered – in case of changing Centerline Values, please refer to the Calculation Mode described earlier in this document.

Note

4 Only display if configuration entry `/Cmf/System/Configuration/SPC/ChartStatistics/IncludeCLRSection` is set to `true`. About the data points to be considered – in case of changing LCLs, please refer to the Calculation Mode described earlier in this document.

Note

5 Only display if configuration entry `/Cmf/System/Configuration/SPC/ChartStatistics/IncludeCLRSection` is set to `true`. About the data points to be considered – in case of changing UCLs, please refer to the Calculation Mode described earlier in this document.

Note

6 Only display if configuration entry `/Cmf/System/Configuration/SPC/ChartStatistics/IncludeCLRSection` is set to `true`.

Data Points

Every time data is posted to SPC a data point is created. A data point stores many properties including the readings that are part of the Data Point. The most important properties are shown in the table below:

Property	Description
State	The state of the Data Point: - Active - Deleted - Edited - Excluded
Number of Readings	The number of readings
Reading Values	The individual reading values
Sample Size	The sample size
Annotation	The annotation if the data point has been annotated
Value 1	The value for Indicator 1 for the data point
Value 2	The value for Indicator 2 for the data point
Upper Specification Limit	The Upper Specification Limit as it applied to the data point
Target Specification Value	The Target Specification Value as it applied to the data point
Lower Specification Limit	The Lower Specification Limit as it applied to the data point
Upper Control Limit 1	The Upper Control Limit for Indicator 1 as it applied to the data point
Centerline 1	The Centerline for Indicator 1 as it applied to the data point
Lower Control Limit 1	The Lower Control Limit for Indicator 1 as it applied to the data point
Upper Control Limit 2	The Upper Control Limit for Indicator 2 as it applied to the data point
Centerline 2	The Centerline for Indicator 2 as it applied to the data point
Lower Control Limit 2	The Lower Control Limit for Indicator 2 as it applied to the data point

Table: Data Point properties

Note

Centerline 2 depends upon the value for **Standard Deviation**. When recalculating control limits, the value for **Standard Deviation** is computed instead of the **Centerline 2**.

The state of a Data Point results in a different graphical representation and it has an effect on how it is considered for statistics and for SPC rules as shown in this table:

State	Active	Edited	Excluded	Deleted
Visible in Chart	x	x	x	
Used for Histograms & Statistics	x	x		
Considered in SPC Rules	x	x		
Used in Centerlines Re-calculation	x	x		

Table: Data Point state effect

Point Statistics

The point statistics that are displayed in the GUI are described in the table below. The statistics are calculated based on a single data point considering the all the data point readings and are applicable only to variable charts.

Indicator	Formula	Display For
Count	Count	All Variable Charts
Max	Max	All Variable Charts
Min	Min	All Variable Charts
Mean	$\bar{x} = \frac{x_1 + x_2 + x_3 + \cdots + x_n}{n}$	All Variable Charts
Standard Deviation	$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$	All Variable Charts when the number of readings is greater than one
Median	$\tilde{x}$ = The median of a finite list of numbers can be found by arranging all the observations from the lowest to the highest value and picking the middle one. If there is an even number of observations, the median is the average of the two middle values.	All Variable Charts
Range	$Range = Max(x_{1\cdots n}) - Min(x_{1\cdots n})$	All Variable Charts
Cp Process Capability	$C_p = \frac{USL - LSL}{6s}$ This value is only calculated when both the USL and the LSL are present for the data point.	All Variable Charts when the number of readings is greater than one
Cpk Process Capability Index	$Min(\frac{USL - \bar{x}}{3s}, \frac{\bar{x} - LSL}{3s})$ This value is only calculated when both the USL and the LSL are present for the data point.	All Variable Charts when the number of readings is greater than one

Indicator	Formula	Display For
Cir	$Cir = \frac{3 \cdot \sqrt{(x - TSV)^2 + s^2}}{Min(USL - TSV, TSV - LSL)}$ where TSV=TargetSpecValue This value is only calculated when the USL, LSL, and the TSV are present for the data point.	All Variable Charts when the number of readings is greater than one

Table: Point Statistics

Step and Resource Chart Contexts

A Chart can be attached to a Step or to a Resource via the Step Chart Context and Resource Chart Context, respectively. The purpose of these contexts is to:

1. Resolve the right of SPC Charts to be used based on the Material or Resource Context;
2. Enable automatic EDC data feed to SPC.

The Step Chart Context can be defined as described in the table below:

Property	Optional	Type	Remark
Step	No	Key	
Product	Yes	Key	
Product Group	Yes	Key	
Flow	Yes	Key	
Material Type	Yes	Key	
Resource	Yes	Key	
Resource Type	Yes	Key	
Model	Yes	Key	
Operation	Yes	Key	Supported operations are: - TrackIn -- for track-in - TrackOut -- for track-out - PerformImmediate -- for perform immediate data collection - MoveNext -- for move next - Rework -- for rework - PerformSetup -- for perform setup
Chart	No	Value	

Property	Optional	Type	Remark
Display Mode	No	Value	Supported modes are: - AcknowledgeAlways -- requires explicit acknowledgment from the user every time - AcknowledgeOnViolationsOnly -- requires explicit acknowledgment from the user only when a violation is detected - DisplayAlways -- displays the chart every time - DisplayOnViolationsOnly -- displays the chart only when there is a violation - None -- never displays the chart

Table: Step Chart Context

The Resource Chart Context defined for a state transition of the resource is as described in the table below:

Property	Optional	Type	Remark
Resource	Yes	Key	
Resource Type	Yes	Key	
Model	Yes	Key	
StateTransition	No	Key	The state transition is defined in the lookup table ResourceChartStateTransitions
Chart	No	Value	
Display Mode	No	Value	Supported modes are the same as described for the Step Chart Context

Table: Resource Chart Context

Info

There can be multiple Charts for the same context combination both for the Step Chart Context and the Resource Chart Context.

SPC Rules

SPC rules are used to detect SPC violations. A Chart can have many SPC rules. An SPC rule tests a particular indicator for a specific pattern. It is also possible to specify for each Chart SPC rule an Exception Protocol to be opened and an action to be executed automatically whenever that SPC rule pattern is detected.

SPC rules can be system rules or user defined rules. The system rules are based on the Specification Limits as well as on the Nelson and Western Electric Rules and are described in the table below:

Rule Name	Description

Rule Name	Description
OutOfSpec	Any reading above the upper specification limit (if defined) or below the lower specification limit (if defined/)
Nelson1	1 of 1 point above +3 sigma or below -3 sigma (same as **WesternElectric1**/)
Nelson2	9 of 9 points on the same side of the centerline (similar to **WesternElectric4** with 9 points instead of 8/)
Nelson3	6 consecutive increasing or decreasing points
Nelson4	14 consecutive alternating points
Nelson5	2 of 3 consecutive points above +2 sigma or below -2 sigma on the same side of the centerline
Nelson6	4 of 5 consecutive points above +1 sigma or below -1 sigma on the same side of the centerline
Nelson7	15 consecutive alternating points on either side of the centerline
Nelson8	8 consecutive points between +1 and -1 sigma on either side of the centerline
WesternElectric1	1 of 1 point above +3 sigma or below -3 sigma
WesternElectric2	2 of 3 consecutive points above +2 sigma or below -2 sigma on the same side of the centerline
WesternElectric3	4 of 5 consecutive points above +1 sigma or below -1 sigma on the same side of the centerline
WesternElectric4	8 of 8 points on the same side of the centerline

Table: System SPC Rules

In addition to the system rules above, the following user defined rules are also available out of the box.

Rule Name	Description
SPCHoldMaterial	1.If there is no Material, the system will not process information. 2. Rule will look for the first Hold Reason in the Material step that is still not assigned to the Material. If no reason is found, the system will not process information. 3. The rule will put the Material on hold for the reason found in 2.
SPCPutEquipmentDown	1. If there is no Resource, the system will not process information. 2. Rule will look for a Resource with State Model set to SEMI E10, and State set to Unscheduled Down. If no State Model exists or if no State Model State matches the Unscheduled Down SEMI E10 attribute, the system will not process information. 3. The rule looks for a transition from the current Resource state to the state found in 2. If it is found, it will perform a Resource State Change to the state found in 2, otherwise it will perform an Adjust State to the state found in 2.

Rule Name	Description
SPCSendMail	1. Rule will send an email to the distribution list defined in `/Cmf/System/Configuration/Mail/LocalSupport/` with the following information: a) Subject b) Body 2. If a distribution list is not defined, the system will not process information.

Table: User Defined SPC Rules

The applicability of an SPC rule to an Indicator as well as to a particular Chart or Chart Type is given by the generic table ChartRuleScope. By default the system ships with the configuration shown below:

Rule	Indicator Scope	Scope Type	Chart Type	Chart
OutOfSpec	Indicator1	All		
Nelson 1	Indicator1And2	All		
Nelson 2	Indicator1And2	All		
Nelson 3	Indicator1And2	All		
Nelson 4	Indicator1And2	All		
Nelson 5	Indicator1	ChartType	Variable	
Nelson 6	Indicator1	ChartType	Variable	
Nelson 7	Indicator1	ChartType	Variable	
Nelson 8	Indicator1	ChartType	Variable	
Western Electric 1	Indicator1And2	All		
Western Electric 2	Indicator1	ChartType	Variable	
Western Electric 3	Indicator1	ChartType	Variable	
Western Electric 4	Indicator1And2	All		

Table: Default generic table ChartRuleScope configuration used for scope resolution

⚠ The Indicator1And2 scope can't be selected for new **SPC Rules**.

Point Selection

Only the points that have not been deleted or excluded should be taken into account for the calculation of the SPC rules. Also, if the configuration value for `/Cmf/System/Configuration/SPC/ChartRules/FilterByControlLimits` is set to `true`, the selection of the points that can be counted for the rule calculation must take the following caveats into account:

For all charts:

- Consider only the points that have the same value for Centerline 1 as the last point.

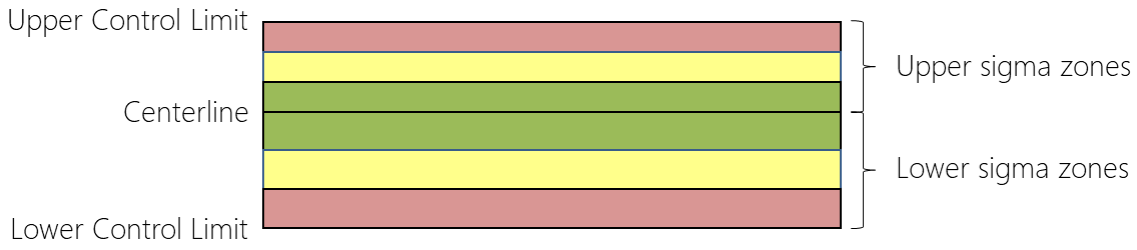
For Variable charts:

- If the value for Standard Deviation in the last point is not null, consider only the points that have the same value for Standard Deviation as the last point;
- If the value for Standard Deviation in the last point is not null, consider only the points that have the same value for Centerline 2 as the last point.

> **Note**
>
> Value can be null if calculation is manual.

Zones

The sigma regions mentioned in the SPC rules are always based on the centerline and the control limits, regardless of whether the limits are defined manually or automatically as shown in the figure below. The upper sigma zones are calculated by dividing the difference between the upper control limit and the centerline by three. Conversely, the lower sigma zones are calculated by dividing the difference between the centerline and the lower control limit by three.



> **Info**
>
> It is possible to extend the list of SPC rules by customization by creating a new DEE Action and linking it to a Rule object of scope SPC. For more information on how to develop custom SPC rules, please refer to the Developer Guide.

SPC Actions

It is possible to define an SPC action to be triggered when an SPC rule is violated. For example, it is possible to put the Material on hold, put the Equipment down, request Maintenance, send an Alarm or send an Email. The system comes with three SPC Actions as shown in the table below, but it is possible to create any desired SPC Action. For information on how to create an SPC Action, please refer to the Developer Guide.

Rule Name	Description
SPCHoldMaterial	If a Material is part of the Data Point context information, this action will look for the first Hold (sorted alphabetically) reason in the current Material Step that is not yet assigned to the Material and will put the Material on hold for that particular reason.

Rule Name	Description
SPCPutEquipmentDown	If a Resource is part of the Data Point context information and that Resource has a State Model associated with it, this action will look for the first State Model State (sorted alphabetically) for which the attribute SEMI-E10 is Unscheduled Down and it will adjust the state of the Resource to that particular state.
SPCSendMail	This action will send an email with information about the Chart and violation to the distribution list defined in the configuration entry: `/Cmf/System/Configuration/Mail/LocalSupport/`

Table: System SPC Actions

Info

SPC Actions must be rule objects of scope SPCAction.

Control Limits

The Control Limits - Upper Control Limits (UCL) and Lower Control Limits (LCL) - are the Voice of the Process (VOP) and often referred in SPC terminology as UAL (Upper Action Limit) and LAL (Lower Action Limit). The control limits vary from chart type to chart type. In some cases, they are fixed over time, and for other cases they are variable (to account for differences in the sample size).

Automatic and Manual Control Limits

Ideally, the Control Limits are defined based on historical data. In Critical Manufacturing MES, when using automatic control limits, it is necessary to define the centerline and in the case of variable charts also the standard deviation. Using the Chart specific statistical formulas, the system calculates automatically the upper and lower control limits based on the chart type, sample size and using the control chart constants tables described in **Appendix A - Control Chart Constants** at the end of this page.

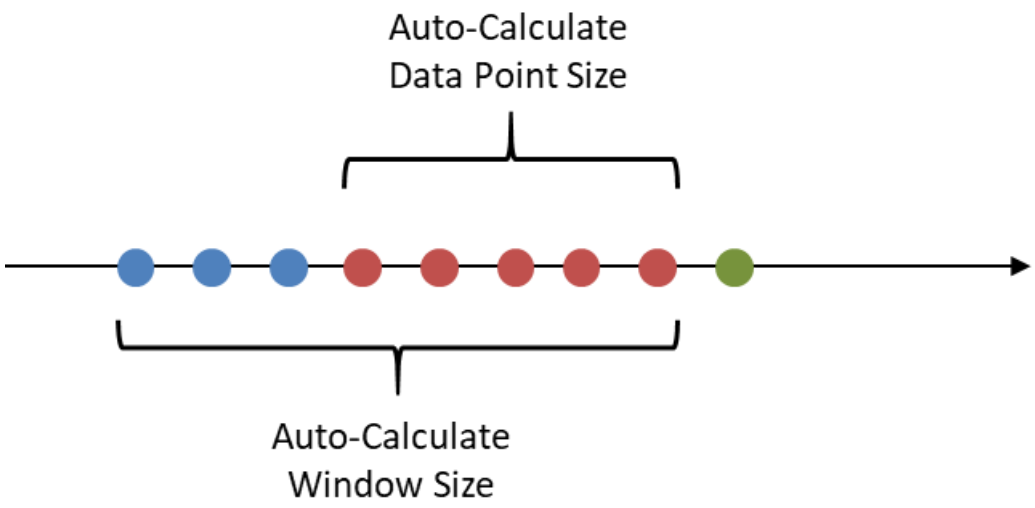
It is also possible, but not recommended, to configure a Chart to use manual control limits in which case the user must define them manually. When defining the control limits manually, it is possible to define the upper control limit, the centerline and the lower control limit for Indicator 1 and Indicator 2 (for variable charts).

Info

Each Logical Chart has its own control limits even though they are copied from the original Chart when the Logical Chart is first created.

Automatic Control Limit Recalculation

When using automatic control limits, at the Chart level it is possible to configure that the control limits (centerlines) must be recalculated every time after a certain number of data points by enabling the Auto-Calculate option in the Chart. There are two parameters that affect this recalculation: the Auto-Calculate Window Size (when to recalculate), and the Auto-Calculate Data Point Size (how many data points to consider in the recalculation) as shown in the figure below:



The system can also be configured to simply collect data points and then, after a certain number of configured data points, calculate and set calculate the centerline (and also the standard deviations in case of variable charts). This is achieved by activating the Learning Mode either in the Chart or in the Logical Chart. When activating the Learning Mode it is also possible to configure the system to stop recalculating the centerline (and standard deviation for variable charts) after a certain number of data points.

Info

When using automatic control limits, it is possible to recalculate the control limits at any time by using the Recalculate and Set transaction.

Specification Limits

The Specification Limits -- Upper Specification Limit (USL), Target Specification Value (TSV) and Lower Specification Limit (LSL) are the Voice of the Customer (VOC). The Specification Limits are optional and can be defined for the Chart and for each Logical Chart.

Using Product or Product Group Specification Limits

It is common for the specification limits to be defined by Product or Product Group. This has the advantage of maintaining the specification limits where it belongs as well as it provides the benefits associated with versioning and change control. To enable Product or Product Group Specification Limits, it is necessary that the Chart has either the Product or the Product Group as context key. If that requirement is met, it is necessary to set the Specification Limits mode to Product. Once the Specification Limits mode is set to Product when creating a logical chart, the system will look for the Product (or Product Group) parameters of type Specification that match the Chart parameter as well as the Chart Product (or Product Group) values to set the specification limits automatically. In addition, if the Chart defines the Step as key, the Product Parameter Step must match the Chart Step key value as well.

Setting Up an SPC Chart

In order to setup an SPC Chart it is necessary to follow the steps as described in this short table:

Step	Title	Description

Step	Title	Description
1	**Create the Necessary Parameter**	Create the Parameter to be controlled.
2	**Create the Chart**	Create the SPC Chart.
3	**Associate the Chart with the Desired Steps and Resources (Optional)**	Using the Step Chart Context or Resource Chart Context smart tables, associate the created Charts. Please refer to the section Step and Resource Chart Contexts for more information.

Table: SPC Setup steps

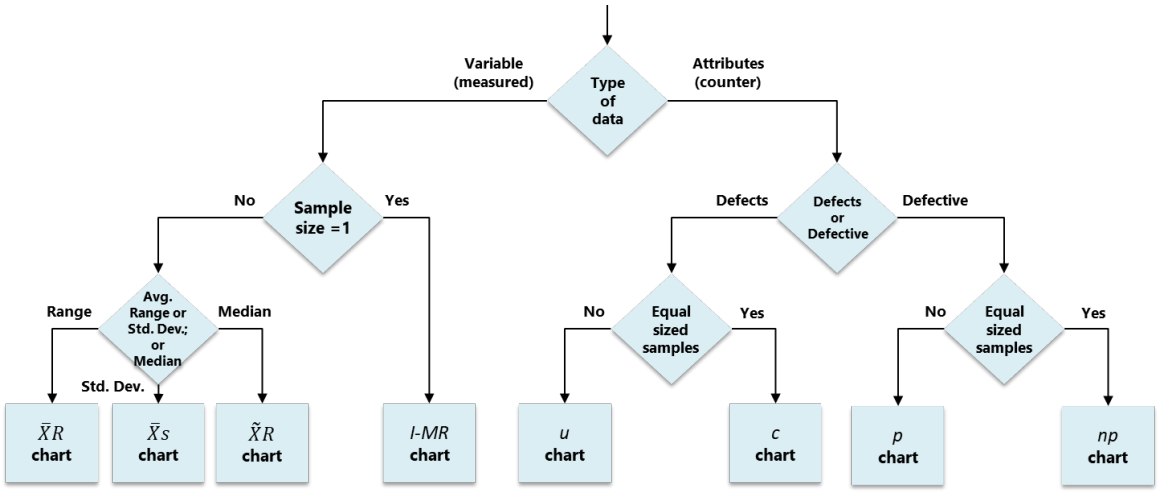
Note

The scope of the Parameter must have the Data Type Decimal, Duration or Long and must be either EDC_SPC or EDC_SPC_Recipe.

The second step, Create the Chart, is specific to SPC and is described below in more detail.

Create a Chart

To create a Chart, it is necessary to select the appropriate control chart, the image that follows provides guidance on the selection. Nevertheless, the final decision is up to the process specialist based on the specific scenario that is intended to apply SPC control.



- It is better to use $\bar{X}$ R charts than $\bar{X}$ s charts when sample sizes are less than 4 [Stapenhurst 2005].
- Although $\bar{X}$ R charts can be used when the subgroup size is not constant, it is not a good practice. In these cases, $\bar{X}$ s charts should be used instead [Montgomery 2009].
- For *c* charts, if the average is large (>5), *I-MR* charts can be used [Stapenhurst 2005].
- For *p* charts, if *p* is near 0.5 and n>10, variable charts can be used [Stapenhurst 2005].

The table that follows describes the most important properties from the different Chart creation step General Data:

Property	Description
Parameter	The parameter to be controlled by the Chart
Chart Type	The type of Chart - the system supports four variable charts and four attribute charts
Minimum Sample Readings	The minimum number of readings
Maximum Sample Readings	The maximum number of readings
Sample Readings Source	Optionally a lookup table from which the reading names are taken to be presented to the user
Sample Size	For attribute Charts with fixed sample size
Minimum Sample Size	For attribute Charts with a variable sample size, what is the minimum sample size
Maximum Sample Size	For attribute Charts with a variable sample size, what is the maximum sample size
Terminate Logical Charts On Zero Data Points	Specifies whether the Logical Charts must be automatically terminated if they have no Data Points
Auto Calculate Centerline(s)	Whether to automatically recalculate the centerlines (on which the control limits are based). This option is only enabled if the Control Limits mode is Automatic.
Auto Calculate Window Size	Defines the recalculation frequency in terms of number of posted data points.
Auto Calculate Window Data Point Size	Defines the number of data points to be considered when recalculating the centerline (and standard deviation).
Learning Mode	Whether the Chart begins without control limits and the limits are calculated and set automatically after a certain number of data points.
Disable Calculation After Learning	Whether the Chart stops recalculating the centerline (and standard deviation) after learning.
Retention Time	Defines how many hours the data points are kept in the online database.

Property	Description
Retention Data Points	Defines how many data points are kept in the online database. If either the retention time (in hours) or retention data points are exceeded, the point is removed from the online database. Note that the data is still available in the operation data store (ODS).

Table: SPC creation wizard General Data step important properties

Below you can see a description of the most important properties from the different Chart creation step Display:

Property	Description
Default Filter Mode	Whether by default, the Chart displays a certain number of points or a certain time frame.
Show Histogram by Default	Whether the histogram must be shown by default or not.
Default Graphs to Show	For Variable Charts, whether to show by default the Graph for Indicator 1, for Indicator 2 or for both.
Default Panel to Show	The default information panel to be displayed.
Y-Axis Scale Mode	Whether the Y-Axis scale is manual or automatic.
Y-Axis Major Units	When the Y-Axis scale is manual, what are the major units.
Y-Axis Minimum Value	When the Y-Axis scale is manual, what is the minimum value.
Y-Axis Maximum Value	When the Y-Axis scale is manual, what is the maximum value.
General Annotation Source	A lookup table from which the user will have to select a value when annotating a data point that has no violations.
Violation Annotation Source	A lookup table from which the user will have to select a value when annotating a data point that has violations.

Table: SPC creation wizard Display step important properties

Next follows a description of the most important properties from the different Chart creation step Limits:

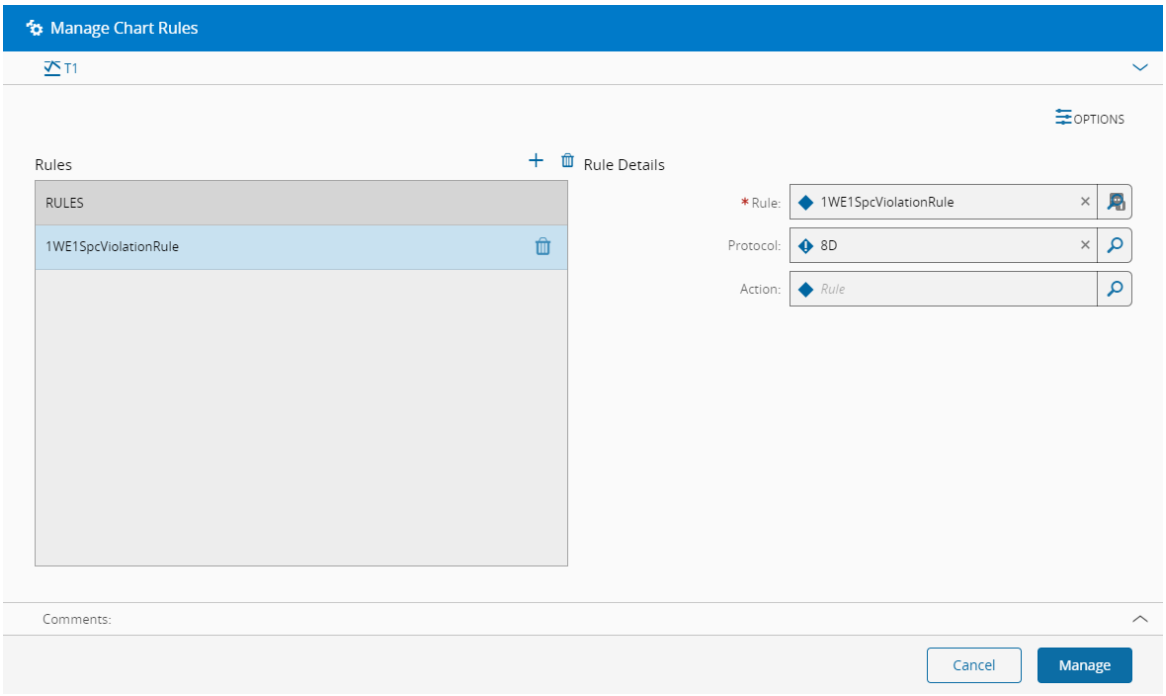
Property	Description
Specification Limits Mode	In the case that context includes the Product or the Product Group as a key, it is possible to define the Specification Limits mode as Product -- please refer to the section Using Product or Product Group Specification Limits for more information.

Property	Description
Upper Specification Limit	Upper Specification Limit (optional)
Target Specification Value	Target Specification Value (optional)
Lower Specification Limit	Lower Specification Limit (optional)
Control Limits Mode	Whether the control limits are manually or automatically managed.
Upper Control Limit 1	The upper control limit for Indicator 1. It can only be specified if the control limits mode is not automatic.
Centerline 1	The centerline for Indicator 1. This value is mandatory if the control limits mode is automatic.
Lower Control Limit 1	The lower control limit for Indicator 1. It can only be specified if the control limits mode is not automatic.
Upper Control Limit 2	The upper control limit for Indicator 2. It can only be specified if the control limits mode is manual. This property is only available for variable Charts.
Centerline 2	The centerline for Indicator 2. This value can only be set if the control limits mode is not automatic. This property is only available for variable Charts.
Lower Control Limit 2	The lower control limit for Indicator 2. It can only be specified if the control limits mode is not automatic. This property is only available for variable Charts.
Standard Deviation	The value for the Standard Deviation. This property is only available for variable charts and must be set if the control limits mode is automatic

Table: SPC creation wizard Limits step important properties

In the Context step of the SPC creation wizard, it is necessary to specify the context keys that define each Logical Chart. It is important to bear in mind that each unique combination of the context key values generates a new Logical Chart. In addition to the context keys, any context that is defined for the Chart and that is not marked as key will be treated as required context values (in addition to the context keys) that need to be supplied when posting data to the Chart.

Once the Chart is created, it is possible to manage the Rules using the Manage Rules transaction available in the Rules section. In the Manage Rules transaction, as shown in the figure below, it is possible to add many SPC Rules and for each rule it is possible to define an Exception Protocol to be opened automatically as well as to define a SPC Action to be executed automatically whenever the SPC rule detects a violation.

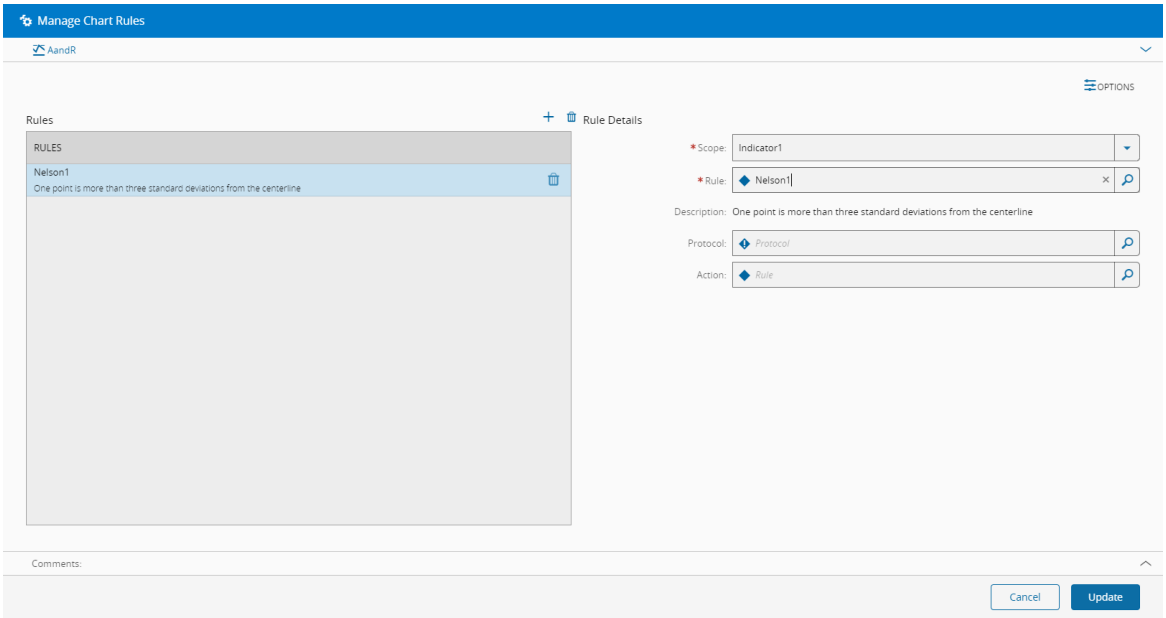


The option **Allow user triggered protocols** specifies whether the user can manually open or not a Protocol which is associated with the Chart.

Creating Logical Charts

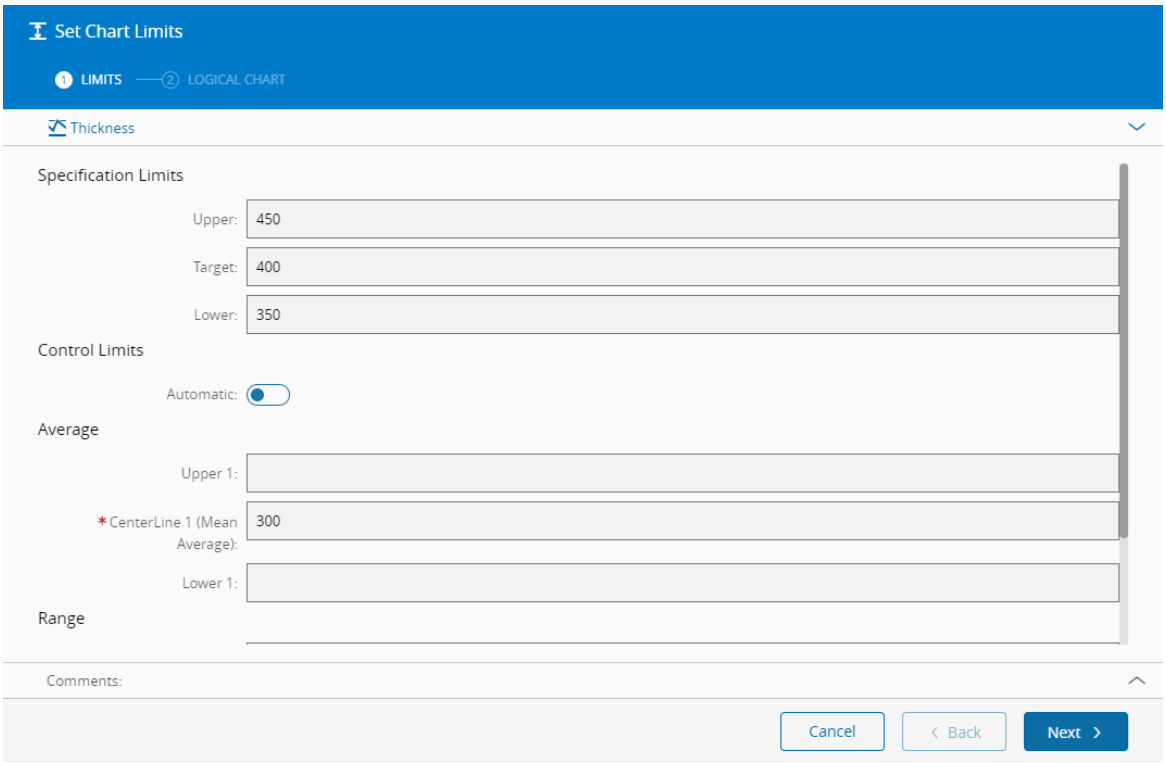
As stated earlier, a Logical Chart is created automatically every time a data point is posted to a unique Chart context key combination. Data can be posted manually using the Post Chart Data Point or Post Chart Data Point Aggregated transactions (see Posting Data Points to a Logical Chart) or automatically by configuring a Data Collection to send data automatically to SPC (see the section Integrating Data Collection with SPC).

A Logical Chart can also be created explicitly by using the transaction Manage Logical Charts.



Setting Chart Limits

With the Set Chart Limits transaction it is possible to modify the specification and control limits for the chart and for the respective logical charts. The Set Chart Limits transaction also allows the modification of the Control limits mode and in case that the Chart Context Keys include the Product or the Product Group, it is also possible to change the Specification Limits mode.



- The Upper, Target and Lower Specification Limits can only be modified if the Specification Limits mode is Chart.
- The Upper and Lower Control Limits can only be modified if the Control limits mode is set to Manual.
- Using Learning Mode can also be enabled, allowing the user to decide whether the limits are set and used automatically when the centerlines are recalculated.

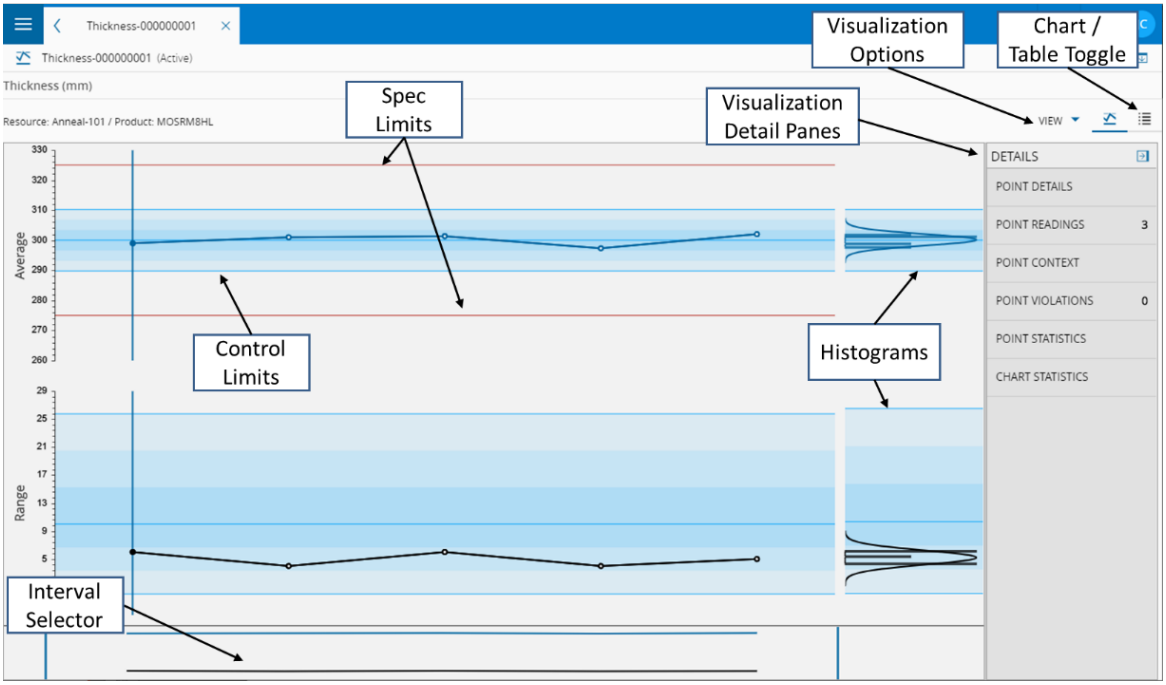
Enabling or Disabling a Chart

A Chart can be enabled or disabled using the Enable Chart and Disable Chart transactions. When a Chart is disabled it is not possible to post data to any of its logical charts.

Using SPC Charts

Chart Visualization

When opening a Logical Chart, the system will display the Chart graphically using the Chart default Display options (refer to the Create a Chart for more information). The next figure shows a standard Chart visualization:



The color and shape of each data point provides meaningful information, as shown below:

Shape and color	Symbol	Comment	Exclusion	Violations
	Blue circle			
	Grey circle		x	
	Red circle			x
	Blue square	x		
	Grey square	x	x	
	Red square	x		x

Table: Data Point shape and color information

On the right side there are different Detail panels that are detailed in the following table:

Panel	Description
Point Details	Shows information and statistics about the selected data point
Point Readings	Shows the individual reading values for the selected data point
Point Context	Displays the selected data point context
Point Violations	Displays the selected data point violations

Panel	Description
Point Statistics	Shows the selected data point statistics
Chart Statistics	Shows the chart statistics considering all the visible data points

Table: SPC Details Panels

- It is possible to revert to the default view by pressing the **Reset View** button.
- It is possible to export the Chart either as an image or as an Excel table by pressing the **Export** button.

The different Chart visualization options can be seen in the table below:

Option	Description
Spec Limits	Displays (or hides) the specification limits
Target Value	Displays (or hides) the specification target value
Timestamp	Displays (or hides) the timestamp of the data points
Histogram	Displays (or hides) the histograms
Zoom	Displays (or hides) the interval selector
Indicator 1	For variable Charts, displays (or hides) Indicator 1
Indicator 2	For variable Charts, displays (or hides) Indicator 2

Table: Chart visualization options

Chart Operations

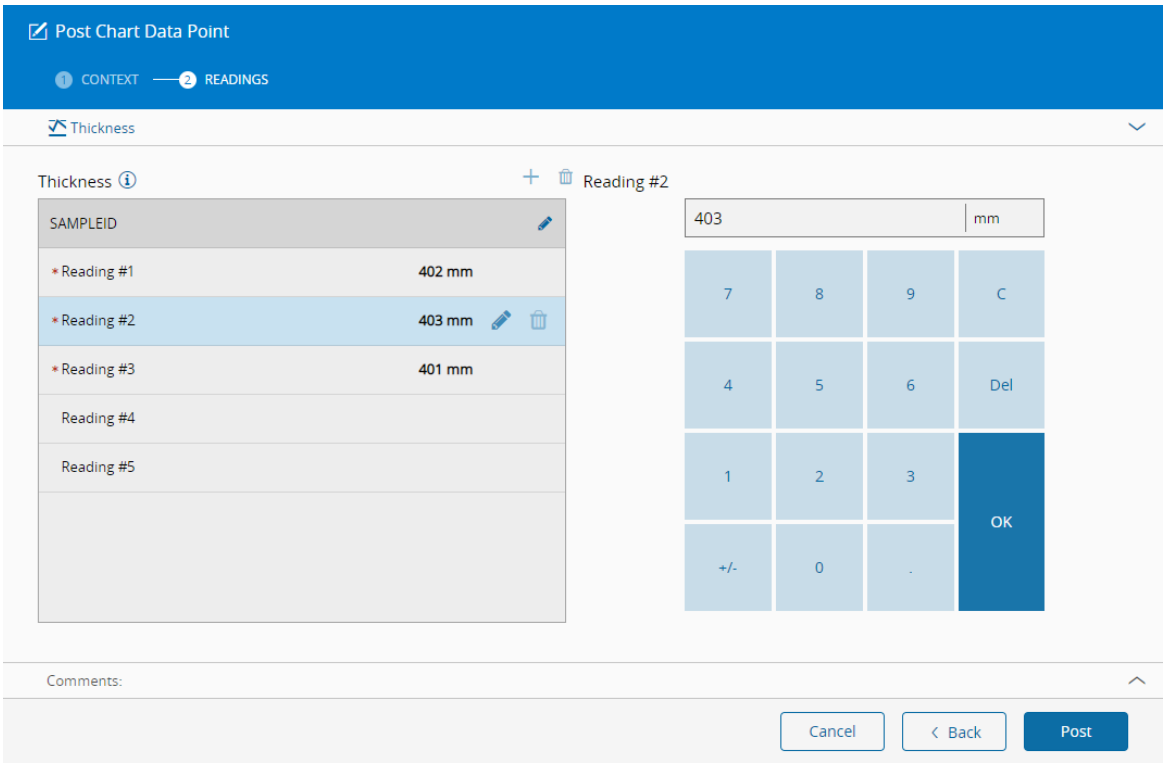
For a Logical Chart, it is possible to perform the operations described in the table below:

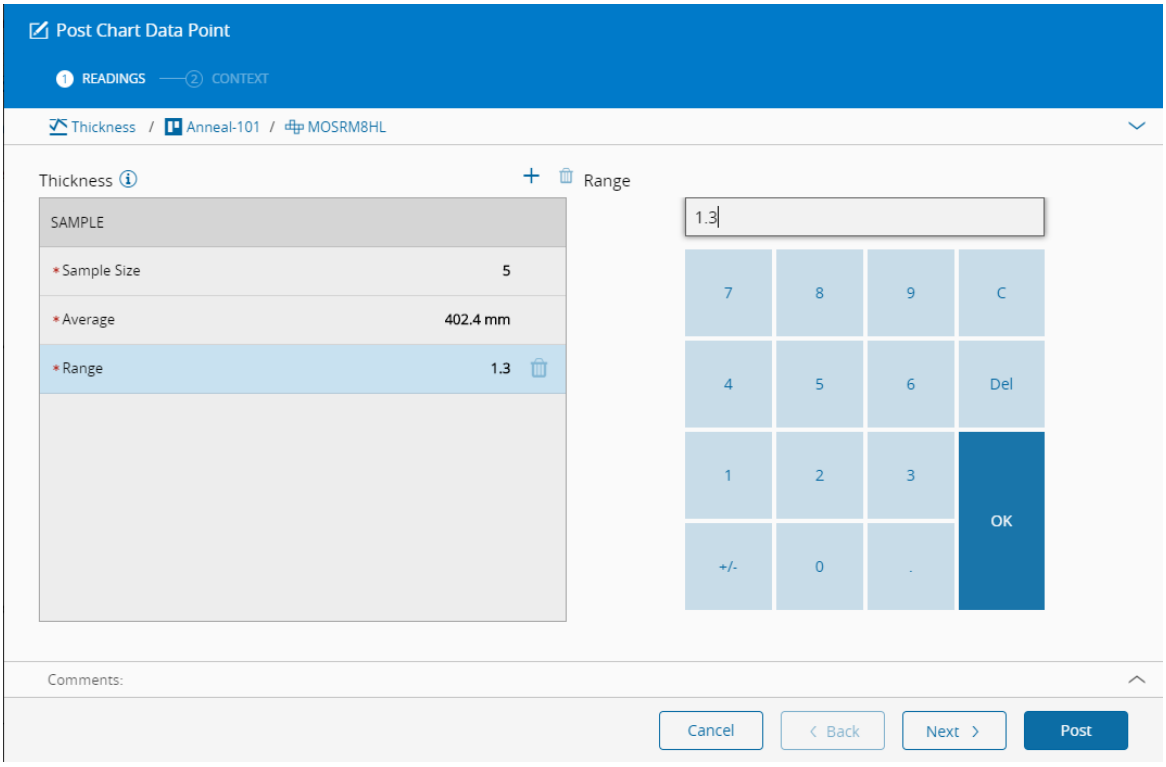
Operation	Description
Post Data Point	Posts a data point to the Logical Chart. Please refer to the section Posting Data Points to a Logical Chart.
Post Data Point Aggregated	Posts a data point by just providing the summary data. Please refer to the section Posting Data Points to a Logical Chart.
Recalculate & Set	Recalculates and sets the Centerline(s) based on historical data.
Go to Chart Definition	Opens the base Chart object.

Table: Chart operations

Posting Data Points to a Logical Chart

To post a data point to a Chart it is necessary to use the Post Chart Data Point transaction as shown below. The Post Chart Data Point Aggregated transaction is available for variable charts and it allows the user to post just the summary of the data (sample size, indicator 1 value, indicator 2 value) and not the individual reading values as shown below:





- When calling the Post Chart Data Point transaction from the Chart, it is necessary to specify the Logical Chart keys. When calling the Post Chart Data Point transaction from the Logical Chart, the context keys are automatically supplied to the transaction.

- The mandatory context must always be filled. Additional supplementary context can also be supplied by pressing the **Add** button in the Context tab.
- When posting data to a Logical Chart for the first time, the Logical Chart is automatically created with the default settings for the Chart.
- If a comment is entered when posting the data, the comment will be automatically associated with the data point.
- Depending on the configured SPC rules for the chart, if an SPC violation is detected, a Protocol may be opened and/or a SPC Action may be executed automatically.
- The value for the readings must be provided and must comply with the minimum and maximum readings sample size definition for the chart. By default, the maximum number of readings are displayed, and the mandatory readings are marked with an (*) at the beginning. The name of the readings can be changed.
- The values for the Standard Deviation are read from the Logical Chart Standard Deviation at the time of the Data Point post. This value may not be the same as the one that is associated to the Chart Data Point Statistics.

Data Point Operations

For a Data Point, it is possible to perform the operations described in the table below:

Operation	Description
Edit	Edit the individual data point reading values (only possible if the data point is not aggregated) - SPC rules are not run when the reading values are modified. - The applicable specification limits and centerlines from the original data point will still apply when editing a data point.
Annotate	Annotates a data point - If there is no violation for the selected data point and there is a General Annotations Source defined, it is necessary to select a value from the defined source lookup table. - If there is a violation for the selected data point and there is a Violation Annotations Source defined, it is necessary to select a value from the defined source lookup table.
Exclude	Excludes a data point - Excluded and deleted data points are not considered in the calculation of control limits.
Include	Includes a data point that has been previously excluded.
Delete	Deletes a data point from the Logical Chart - Once deleted, a data point cannot be undeleted!
Open Protocol	If the option Allow User Triggered Protocols is set, it is possible to manually open a Protocol Instance for a particular data point.

Table: Data Point operations

Integrating Data Collection with SPC

It is possible to configure a Data Collection to feed data automatically to SPC. This is accomplished in the case of Material Tracking and Resource Tracking by matching Parameters in the Data Collection and in the Chart that are resolved for a context. For Material Tracking and Resource Tracking, Data Collection and

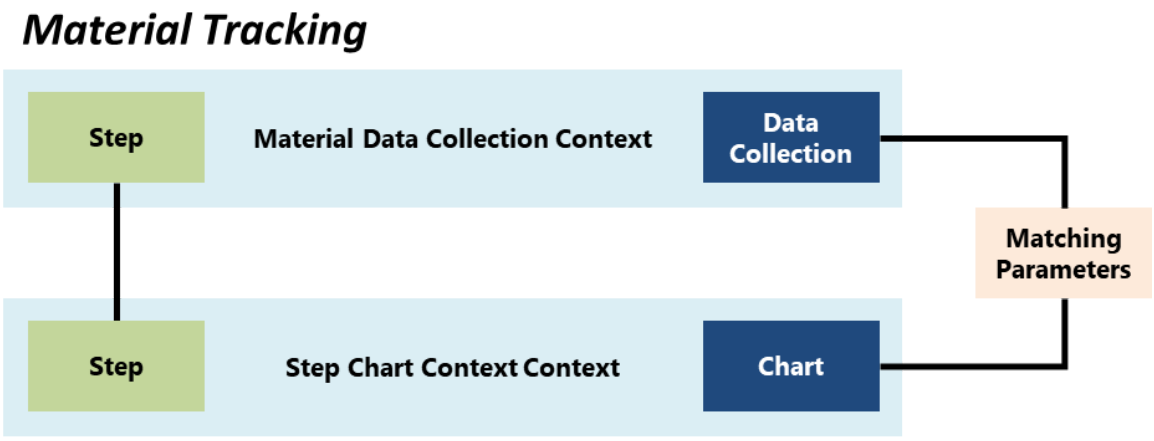
Charts are resolved with the same context information. For all matching parameters from the Data Collection with a Chart parameter, the data will be fed automatically to an SPC. In the case of Maintenance Management, the integration is configured directly per Maintenance Activity. The table below provides a summary on how to integrate Data Collections with SPC and the figure provides an illustration of this integration.

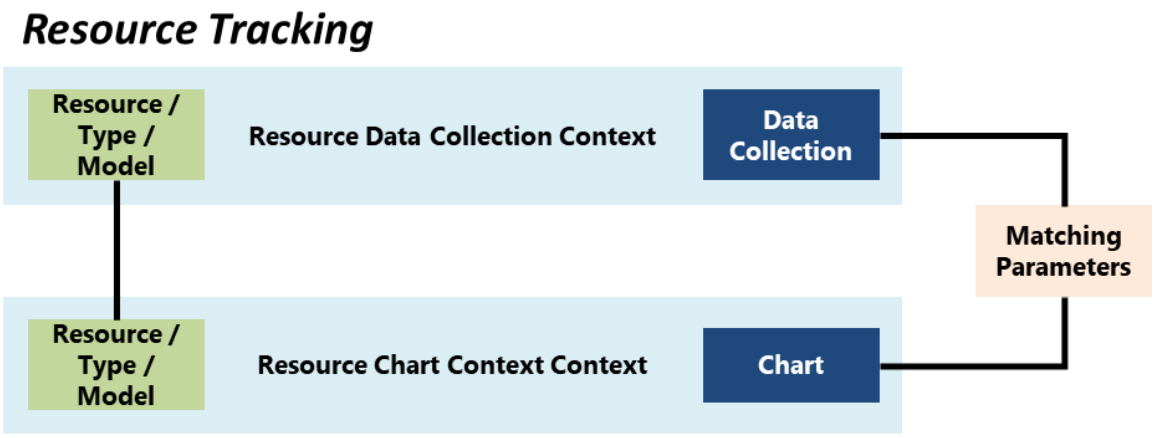
Module	Data Collection and SPC Integration Mechanism
Material Tracking	Matching parameters in: - Material Data Collection Context - Step Chart Context
Resource Tracking	Matching parameters in: - Resource Data Collection Context - Resource Chart Context
Maintenance Management	Per Maintenance Activity, by matching parameters in the Execution Data Collection and associated Execution Charts

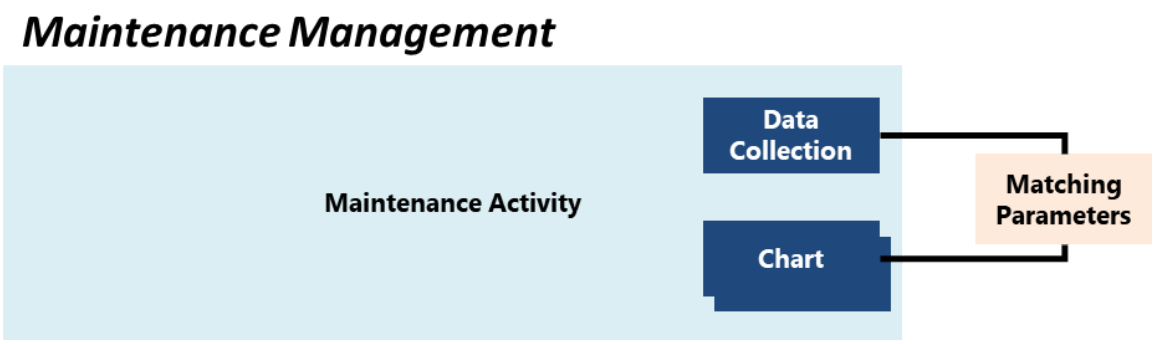
Table: Data Collection and SPC Integration

Note

There may be many Charts for the same context.







When feeding data from EDC to SPC, the system will automatically supply as much context is available both for the Material and for the Resource. The table below lists the context that is supplied automatically by the system when sending data automatically from EDC to SPC. Note that the context matching between the system context and the Chart context is made by *[Name]* only.

Context	Description	Applicable To
Facility	Facility name	Material and Resource
Area	Area name	Material and Resource

Context	Description	Applicable To
Material	Material name	Material only
MaterialType	Material type	Material only
Step	Step name	Material only
Resource	Resource name	Material and Resource
ProcessResource	Material last process step resource name	Material only
Product	Product name	Material only
ProductType	Product type	Material only
ProductGroup	Product group name	Material only
Flow	Flow name	Material only
FlowPath	FlowPath name	Material only
LogicalFlowPath	Logical FlowPath name	Material only
MaterialOperation	Material operation name	Material only
SampleId	Sample Id (if Parameter SampleSource is MaterialId or List)	Material only
ResourceTransition	Resource transition name	Resource only
DataCollection	Data Collection name	Material and Resource
DataCollectionInstance	Data Collection Instance id	Material and Resource

Table: Data Collection system context supplied to SPC

When sending data automatically from a Data Collection to SPC there are three possible modes as shown in the table below. The mode is defined at the Data Collection level and applies to all the Data Collection Parameters.

Mode	Description
OnPostPerSample	Data is posted to SPC every time a Data Collection sample is posted
OnClosePerSample	Data is posted to SPC per sample and only when the Data Collection instance is closed

Mode	Description
OnClosePerParameter	Data is posted to SPC per parameter (readings from all samples are all grouped in one single sample) only when the Data Collection instance is closed

Table: EDC system context supplied to SPC

Info

When feeding Data Collection data to variable charts, it is very important that the number Data Collection parameter readings falls between the SPC Chart minimum and maximum sample sizes.

Info

When feeding Data Collection data to attribute charts, in the Data Collection, the Parameter to be sent to SPC must have the Sample Id defined as Sample Size and the number of readings must be one.

Info

If a Chart is disabled, the data will be saved in the Data Collection Instance, but no data will be posted to the Chart.

Info

If a Chart requires additional mandatory context (as key or just as mandatory information) and this information is not available, an error will be thrown when trying to feed data automatically to the Chart.

Info

If in the Data Collection the Parameter Sample Id is List or Resource, the Data Point Sample Id will be set with the supplied Data Collection Sample Id unless the mode is OnClosePerParameter in which case the Sample Id will be the Material name.

Document References

Here are the document references used in this document:

Reference	Document
[Cano et al. 2015]	"Quality Control with R: An ISO Standards Approach", 2015, Springer, Emilio L. Cano, Javier M. Moguerza, Mariano Prieto Corcoba
[Milivojevich 2015]	"Control Chart Constants -- How to Derive A2 and E2", 2015, Andrew Milivojevich
[Minitab 2019]	"Minitab 18 Support", 2019, Minitab LLC

Reference	Document
[Montgomery 2009]	"Introduction to Statistical Quality Control" 6th Edition, 2009, John Wiley & Sons - Douglas C. Montgomery
[Stapenhurst 2005]	"Mastering Statistical Process Control - A Handbook for Performance Improvement Using Cases", 2005, Elsevier Butterworth-Heinemann, Tim Stapenhurst
[SPC For Excel]	"SPC For Excel Help", 2020, BPI Consulting
[Statsoft 2009]	"Statistica Help Manual", 2019, Statsoft
[Walker et al. 2012]	"The Certified Quality Inspector Handbook", 2012, ASQ Quality Press, H. Fred Walker, Ahmad K. ElshennawY, Bhisham C. Gupta, Mary McShane Vaughn

Table: Document references

Appendix A - Control Chart Constants

List of the c_4, c_5, d_2, d_3 and e_1 control chart constants ([Cano et al. 2015], [Montgomery 2009], [Walker et al. 2012], [Statsoft 2009], [Milivojevich 2015]).

Subgroup size (n)	c_4	c_5	d_2	d_3	e_1
2	0.797885	0.60281	1.1284	0.8525	1
3	0.886227	0.463251	1.6926	0.8884	1.16
4	0.921318	0.38881	2.0588	0.8798	1.093
5	0.939986	0.341213	2.3259	0.8641	1.198
6	0.951533	0.307547	2.5344	0.848	1.134
7	0.959369	0.282154	2.7044	0.8332	1.214
8	0.96503	0.262139	2.8472	0.8198	1.162
9	0.969311	0.245838	2.97	0.8078	1.223
10	0.972659	0.232238	3.0775	0.7971	1.174
11	0.97535	0.220663	3.1729	0.7873	1.228
12	0.977559	0.210662	3.2585	0.7785	1.188
13	0.979406	0.201901	3.336	0.7704	1.233

Subgroup size (n)					
14	0.980971	0.194154	3.4068	0.763	1.2
15	0.982316	0.187231	3.4718	0.7562	1.237
16	0.983484	0.180995	3.532	0.7499	
17	0.984506	0.175351	3.5879	0.7441	
18	0.98541	0.170197	3.6401	0.7386	
19	0.986214	0.165475	3.689	0.7335	
20	0.986934	0.161125	3.7349	0.7287	
21	0.987583	0.157098	3.7783	0.7242	
22	0.98817	0.153362	3.8194	0.7199	
23	0.988705	0.149875	3.8583	0.7159	
24	0.989193	0.146619	3.8953	0.7121	
25	0.98964	0.143571	3.9306	0.7084	
26	0.990052	0.140702	3.965	0.7041	
27	0.990433	0.137994	3.997	0.7012	
28	0.990786	0.135437	4.028	0.6983	
29	0.991113	0.133023	4.058	0.6956	
30	0.991418	0.13073	4.086	0.6929	
31	0.991703	0.12855	4.113	0.6902	
32	0.991969	0.126481	4.139	0.6877	
33	0.992219	0.124505	4.164	0.6852	
34	0.992454	0.122618	4.189	0.6828	
35	0.992675	0.120815	4.213	0.6804	
36	0.992884	0.119086	4.236	0.6781	
37	0.99308	0.11744	4.258	0.6758	

Subgroup size (n)				
38	0.993267	0.115848	4.28	0.6736
39	0.993443	0.114328	4.301	0.6715
40	0.993611	0.112859	4.322	0.6694
41	0.99377	0.11145	4.342	0.6674
42	0.993922	0.110087	4.361	0.6654
43	0.994066	0.108779	4.38	0.6635
44	0.994203	0.107519	4.398	0.6617
45	0.994335	0.106292	4.415	0.6598
46	0.99446	0.105116	4.432	0.6581
47	0.99458	0.103974	4.449	0.6564
48	0.994695	0.102868	4.466	0.6547
49	0.994806	0.101789	4.482	0.6531
50	0.994911	0.100758	4.498	0.6515

Table: Constants for c_4, c_5, d_2, d_3 and e_1

Legal Information

Disclaimer

The information contained in this document represents the current view of Critical Manufacturing on the issues discussed as of the date of publication. Because Critical Manufacturing must respond to changing market conditions, it should not be interpreted to be a commitment on the part of Critical Manufacturing, and Critical Manufacturing cannot guarantee the accuracy of any information presented after the date of publication. This document is for informational purposes only.

Critical Manufacturing makes no warranties, express, implied or statutory, as to the information herein contained.

Confidentiality Notice

All materials and information included herein are being provided by Critical Manufacturing to its Customer solely for Customer internal use for its business purposes. Critical Manufacturing retains all rights, titles, interests in and copyrights to the materials and information herein. The materials and information contained herein constitute confidential information of Critical Manufacturing and the Customer must not disclose or transfer by any means any of these materials or information, whether total or partial, to any third party without the prior explicit consent by Critical Manufacturing.

Copyright Information

All title and copyrights in and to the Software (including but not limited to any source code, binaries, designs, specifications, models, documents, layouts, images, photographs, animations, video, audio, music, text incorporated into the Software), the accompanying printed materials, and any copies of the Software, and any trademarks or service marks of Critical Manufacturing are owned by Critical Manufacturing unless explicitly stated otherwise. All title and intellectual property rights in and to the content that may be accessed through use of the Software is the property of the respective content owner and is protected by applicable copyright or other intellectual property laws and treaties.

Trademark Information

Critical Manufacturing is a registered trademark of Critical Manufacturing.

All other trademarks are property of their respective owners.