

The software described in this white paper forms the basis of the Quinn-Curtis software product **SPC Control Chart Tools for .Net**. You can find details, a demo, documentation and a trial version of that product on our web site at:

<http://www.quinn-curtis.com/QCSPCChartProdPage.htm>.

The Quinn-Curtis, Inc. home page is:

<http://www.quinn-curtis.com/>

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Quinn-Curtis SPC (Statistical Process Control) Software

Usually the SPC engineer tasked with automating an existing SPC charting application has to make a decision about the amount of programming he wants to do. Does he purchase an application package that implements standard SPC charts and then go about defining the charts using some sort of menu driven interface or wizard. This is probably the most expensive in terms of up front costs, and the least flexible, but the cheapest in development costs since a programmer does not have to get involved creating the displays. Another choice is to use a general purpose spreadsheet package with charting capability to record, calculate, and display the charts. This is probably a good choice if your charting needs are simple, and you are prepared to write complicated formulas as spreadsheet entries, and your data input is not automated. Another choice is writing the software from scratch, using a charting toolkit like our **QCChart2D** software as the base, and creating custom SPC charts using the primitives in the toolkit. This is cheaper up front, but may be expensive in terms of development costs. Often times the third option is the only one available because the end-user has some unique requirement that the pre-packaged software can't handle, hence everything needs to be programmed from scratch.

We have created a library of SPC routines that represents an intermediate solution that still requires an intermediate level programmer, but it does not require advanced knowledge of SPC or of charting. Built on top of our **QCChart2D** software (much like our **QCRTGraph** Real-Time Graphics software), it implements templates

and support classes for the following SPC charts and control limit calculations.

Variable Control Charts Templates

- X-Bar R – (Mean and Range Chart)
- X-Bar Sigma (Mean and Sigma Chart)
- Median and Range (Median and Range Chart)
- X-R (Individual Range Chart)

Attribute Control Charts Templates

- p Chart (Fraction or Percent of Defective Parts)
- np Chart (Number of Defective Parts)
- c-Chart (Number of Defects)
- u-Chart (Number of Defects per Unit)

Analysis Chart Templates

- Frequency Histograms
- Probability Charts
- Pareto Charts

SPC Support Calculations

- Array statistics (sum, mean, median, range, standard deviation, variance, sorting)

SPC Control Limit Calculations

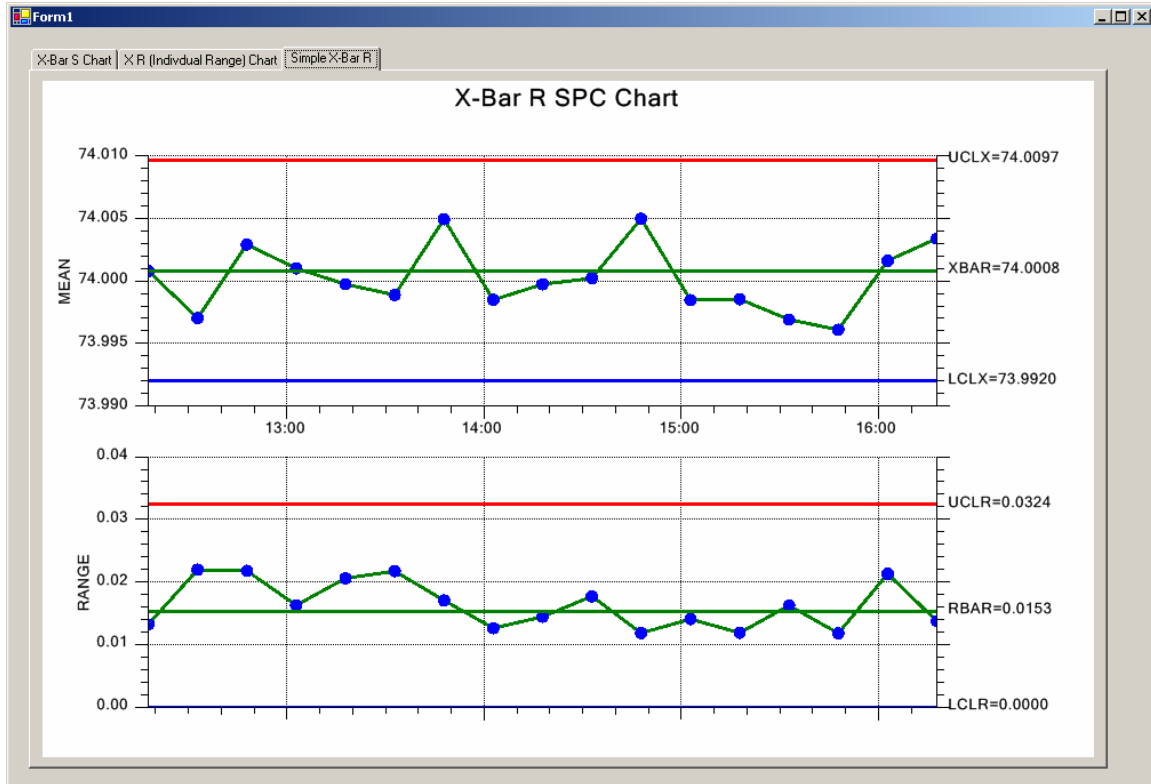
- High and low limit control calculations for X-Bar R, X-Bar Sigma, Median and Range, X-R, p, np, c and u charts

Standard SPC Control Charts

There are many variations of the SPC control chart, divided into two major classifications: *Variable Control Charts*, and *Attribute Control Charts*. Within each classification there are many sub variants.

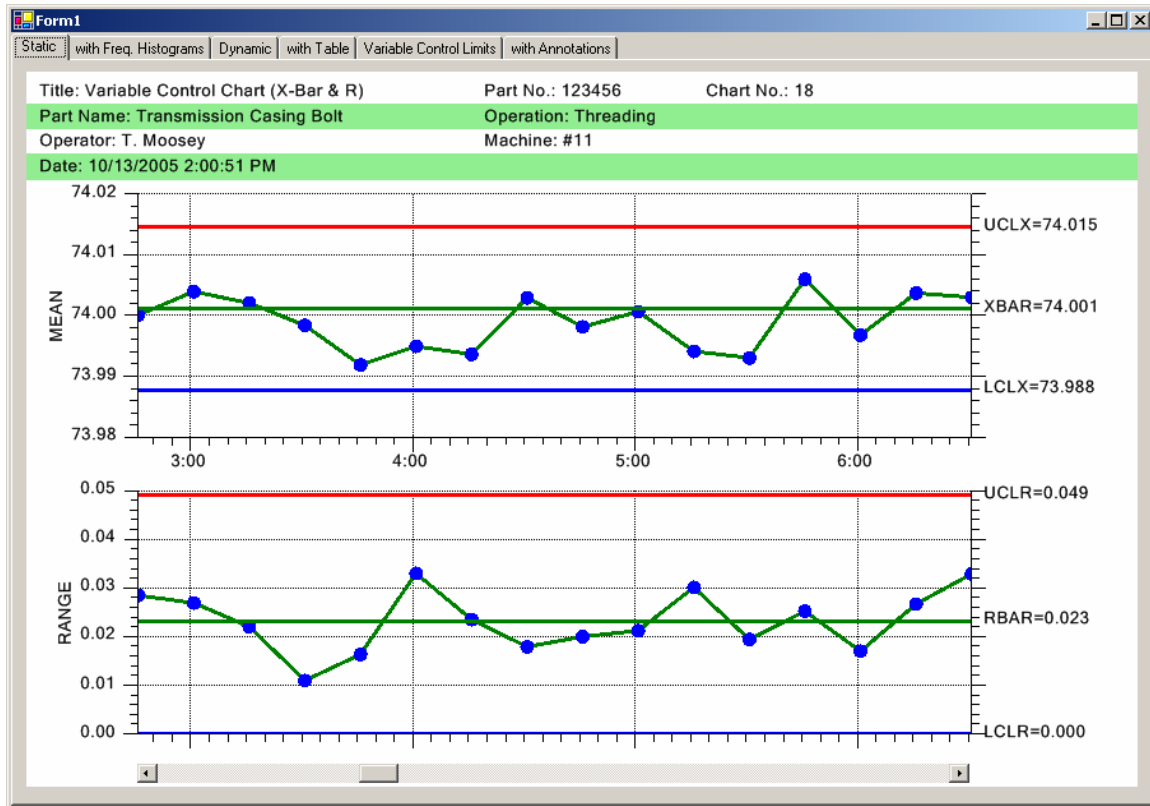
Variable Control Charts

Simple Variable Control (X-Bar R) Chart



Variable Control Charts are for use with sampled quality data that can be assigned a specific numeric value, other than just 0 or 1. This might include, but is not limited to, the measurement of a critical dimension (height, length, width, radius, etc.), the weight a specific component, or the measurement of an important voltage. Common types of *Variable Control Charts* include X-Bar R, X-Bar Sigma, Median Range and Individual Range charts.

Typical Variable Control Chart (X-Bar R)



X-Bar R Chart – Also known as the Mean (or Average) and Range Chart

The X-Bar R chart monitors the trend of a critical process variable over time using a statistical sampling method that results in subgroup of values at each time interval. The X-Bar part of the chart plots the mean of each sample subgroup and the Range part of the chart monitors the difference between the minimum and maximum value in the subgroup.

X-Bar Sigma – Also known as the X-Bar S Chart

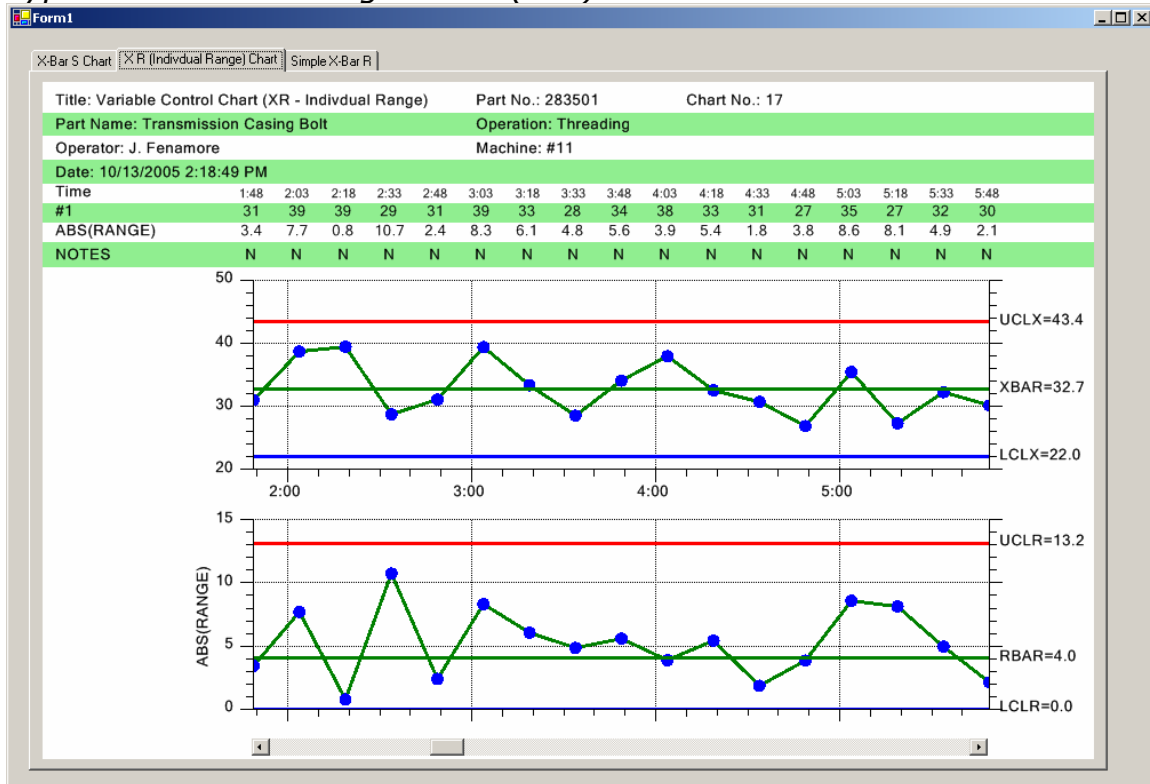
Very similar to the X-Bar R Chart, the X-Bar Sigma chart replaces the Range plot with a Sigma plot based on the standard deviation of the measured values within each subgroup. This is a more accurate way of establishing control limits if the sample size of the subgroup is moderately large (> 10). Though computationally more complicated, the use of a computer makes this a non-issue.

Median Range – Also known as the Median and Range Chart

Very similar to the X-Bar R Chart, Median Range chart replaces the Mean plot with a Median plot representing the median of the measured values within each subgroup. In order for a Median Range chart to be

used, the process should be well behaved, where the variation in measured variables are (1) known to be distributed normally, (2) are not very often disturbed by assignable causes, and (3) are easily adjusted.

Typical Individual Range Chart (X-R) with data table



Individual Range Chart – Also known as the X-R Chart

The Individual Range Chart is used when the sample size for a subgroup is 1. This happens frequently when the inspection and collection of data for quality control purposes is automated and 100% of the units manufactured are analyzed. It also happens when the production rate is low and it is inconvenient to have sample sizes other than 1. The X part of the control chart plots the actual sampled value (not a mean or median) for each unit and the R part of the control chart plots a moving range that is calculated using the current value of sampled value minus the previous value.

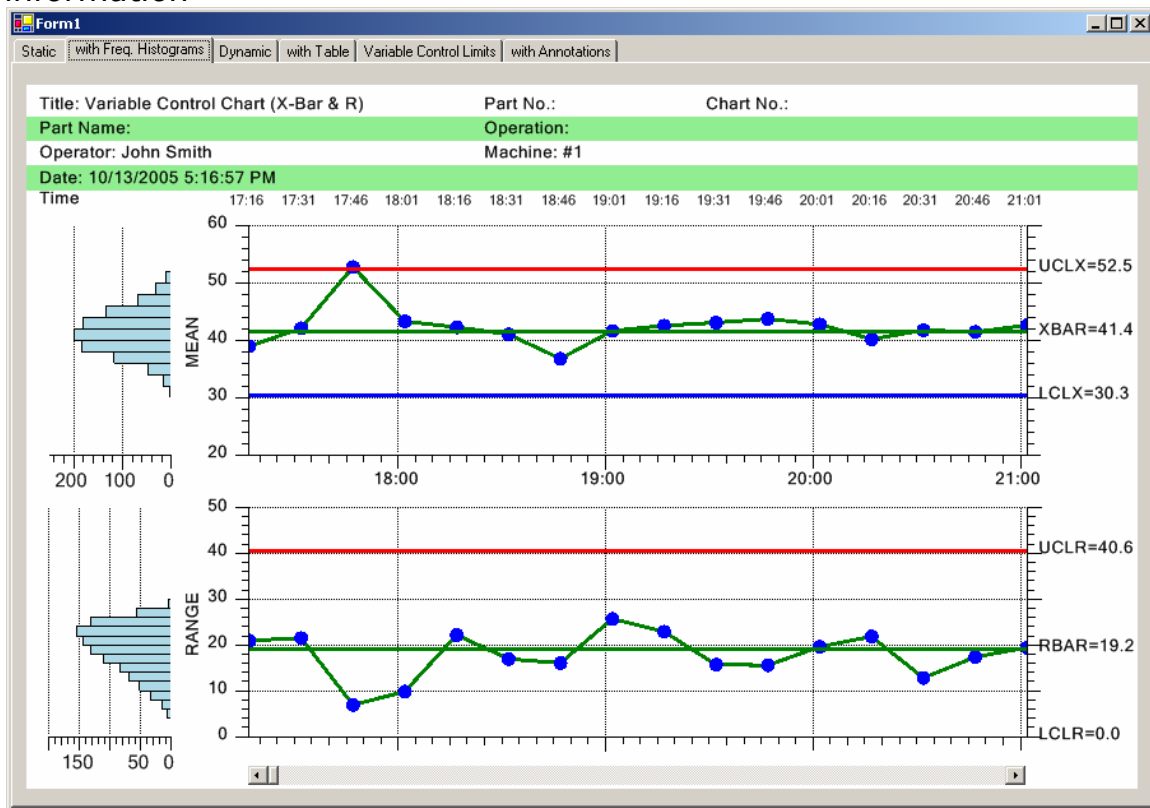
Measured Data and Calculated Value Tables

Standard worksheets used to gather and plot SPC data consist of three main parts. The first part is the header section, identifying the title of the chart, the process being monitored, the machine operator, part number and other important information specific to the chart. The second part is the measurement data recording and calculation

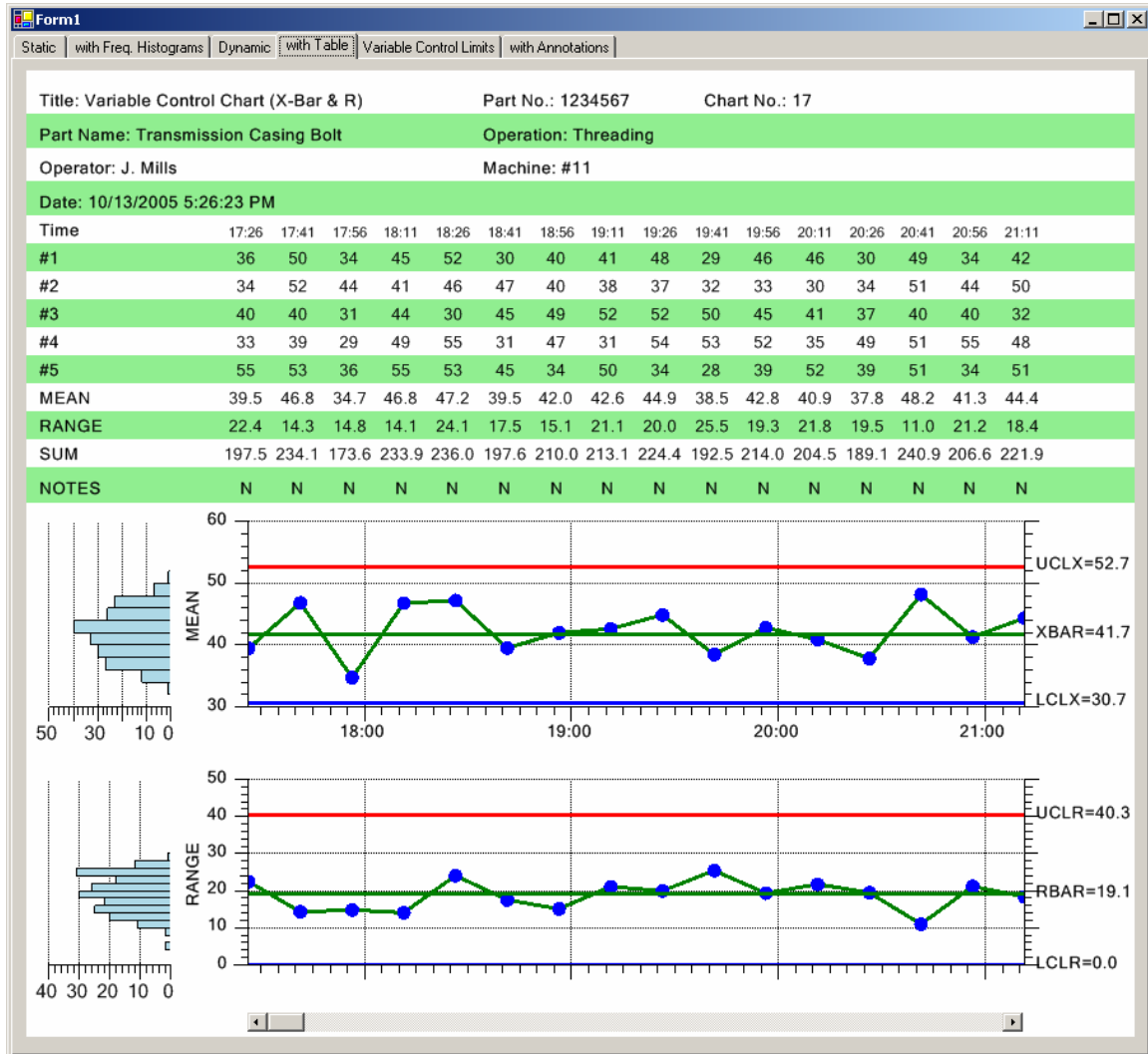
section, organized as a table so that sample data is recorded in a neat, readable fashion, and where the SPC calculations are made. The calculated SPC values for the sample group variables are plotted in the third part, the SPC chart section.

The *Variable Control Chart* and templates that we have created have options that enable the programmer to customize and automatically include header information along with a table of the measurement and calculated data, in the SPC chart. If the scrollbar option is enabled, you can display the tabular measurement data and SPC plots for a window of 8-20 subgroups, from a much larger collection of measurement data represented hundreds or even thousands of subgroups, and use the scrollbar to move through the data, similar to paging through a spreadsheet.

Scrollable XBar-R Chart with frequency histograms and basic header information



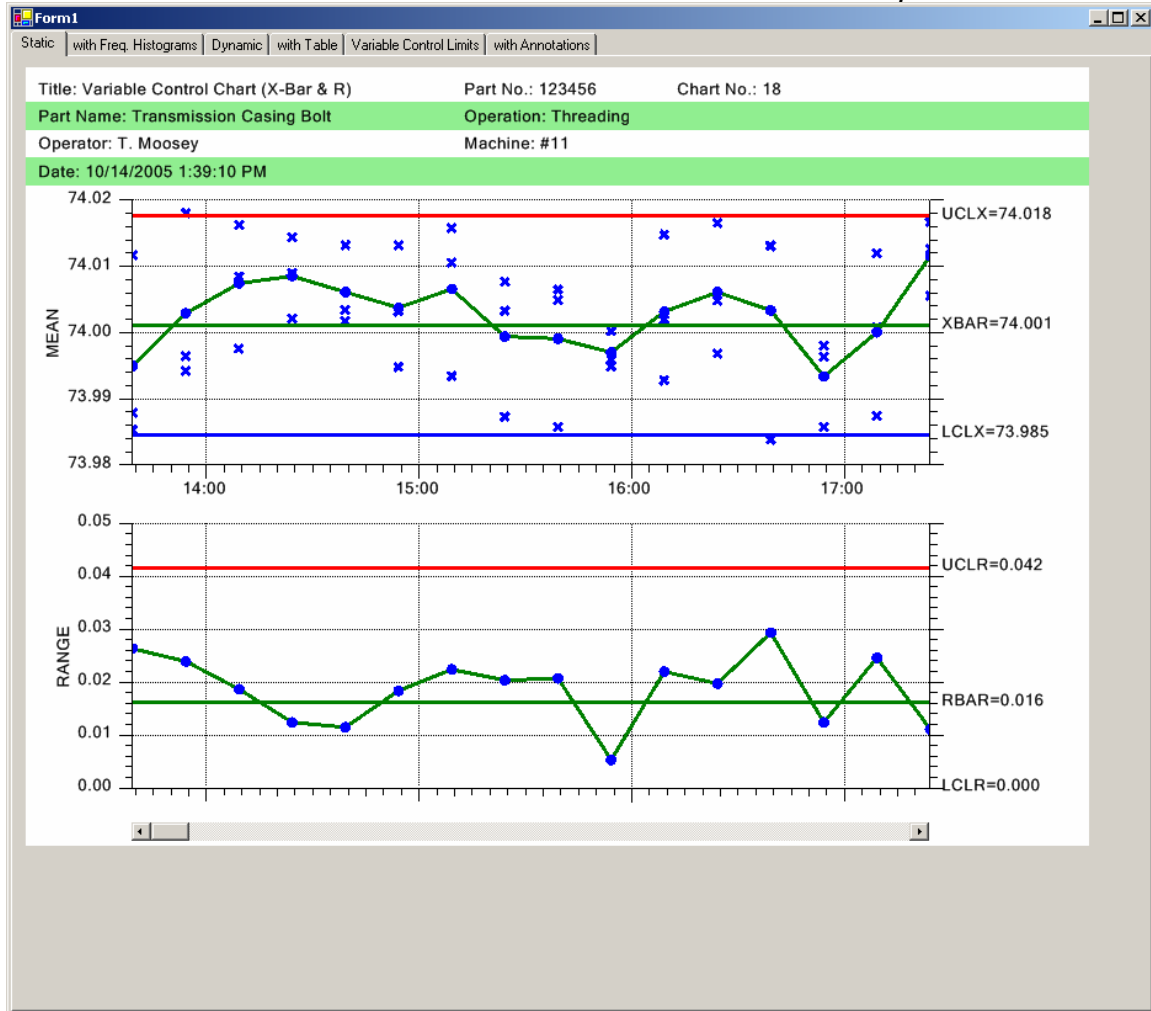
Scrollable XBar-R Chart with frequency histograms, header, measurement and calculated value information



Scatter Plots of the Actual Sampled Data

In some cases it useful to plot the actual values of a sample subgroup along with the sample subgroup mean or median. These samples can be plotted in the SPC chart using additional scatter plots.

Scrollable XBar-R Chart with Scatter Plot of Actual Sampled Data

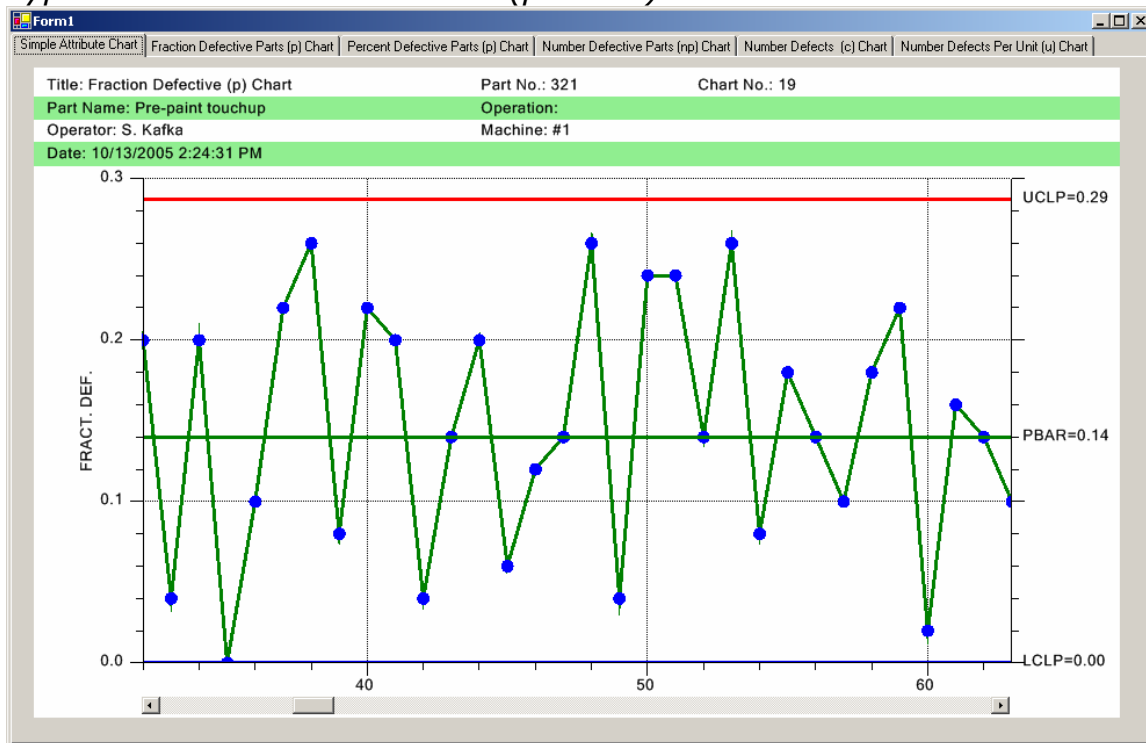


Attribute Control Charts

Attribute Control Charts are a set of control charts specifically designed for tracking defects (also called non-conformities). These types of defects are binary in nature (yes/no), where a part has one or more defects, or it doesn't. Examples of defects are paint scratches, discolorations, breaks in the weave of a textile, dents, cuts, etc. Think of the last car that you bought. The defects in each sample group are counted and run through some statistical calculations. Depending on the type of *Attribute Control Chart*, the number of defective parts are tracked (p-chart and np-chart), or alternatively, the number of defects are tracked (u-chart, c-chart). The difference in terminology "number of defective parts" and "number of defects" is highly

significant, since a single part can not only have multiple defect categories (scratch, color, dent, etc), it can also have multiple defects per category. A single part may have 0 – N defects. So keeping track of the number of defective parts is statistically different from keeping track of the number of defects. This affects the way the control limits for each chart are calculated.

Typical Attribute Control Chart (p-Chart)



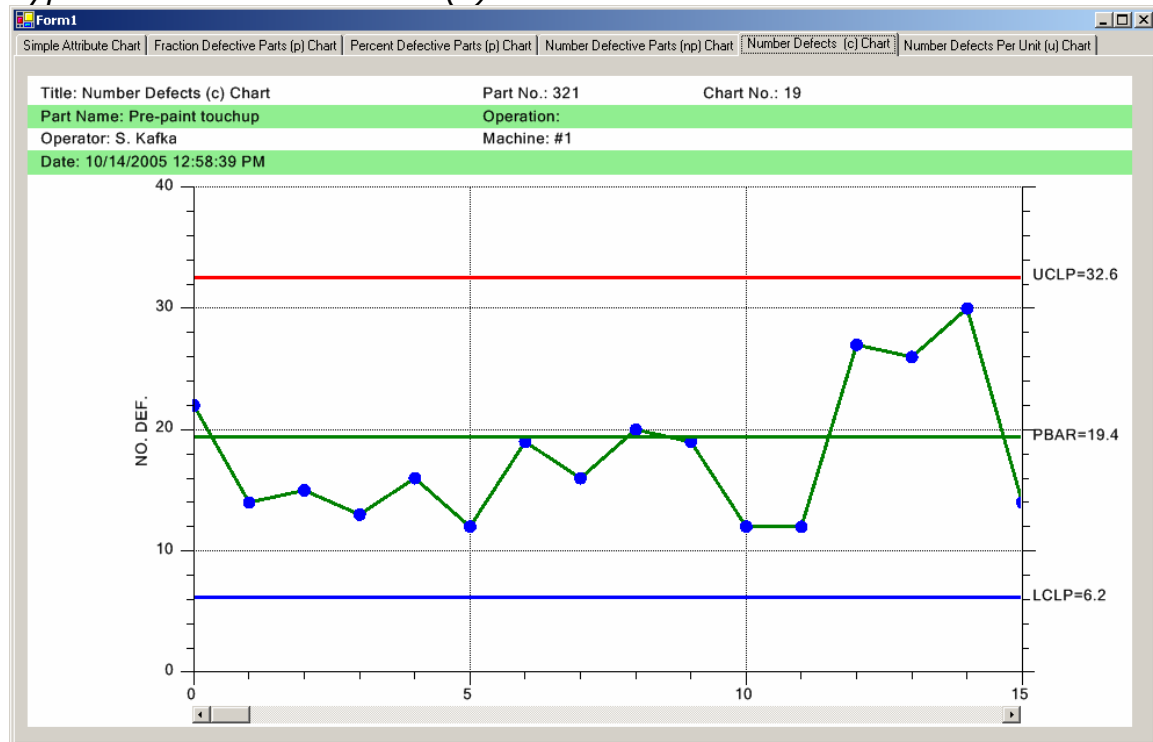
p-Chart - Also known as the Percent or Fraction Defective Parts Chart

For a sample subgroup, the number of defective parts is measured and plotted as either a percentage of the total subgroup sample size, or a fraction of the total subgroup sample size. Since the plotted value is a fraction or percent of the sample subgroup size, the size of the sample group can vary without rendering the chart useless.

np-Chart – Also known as the Number Defective Parts Chart

For a sample subgroup, the number of defective parts is measured and plotted as a simple count. Statistically, in order to compare number of defective parts for one subgroup with the other subgroups, this type of chart requires that the subgroup sample size is fixed across all subgroups.

Typical Number of Defects (c)



c-Chart - Also known as the Number of Defects or Number of Non-Conformities Chart

For a sample subgroup, the number of times a defect occurs is measured and plotted as a simple count. Statistically, in order to compare number of defects for one subgroup with the other subgroups, this type of chart requires that the subgroup sample size is fixed across all subgroups.

u-Chart – Also known as the Number of Defects per Unit or Number of Non-Conformities per Unit Chart

For a sample subgroup, the number of times a defect occurs is measured and plotted as either a percentage of the total subgroup sample size, or a fraction of the total subgroup sample size. Since the plotted value is a fraction or percent of the sample subgroup size, the size of the sample group can vary without rendering the chart useless.

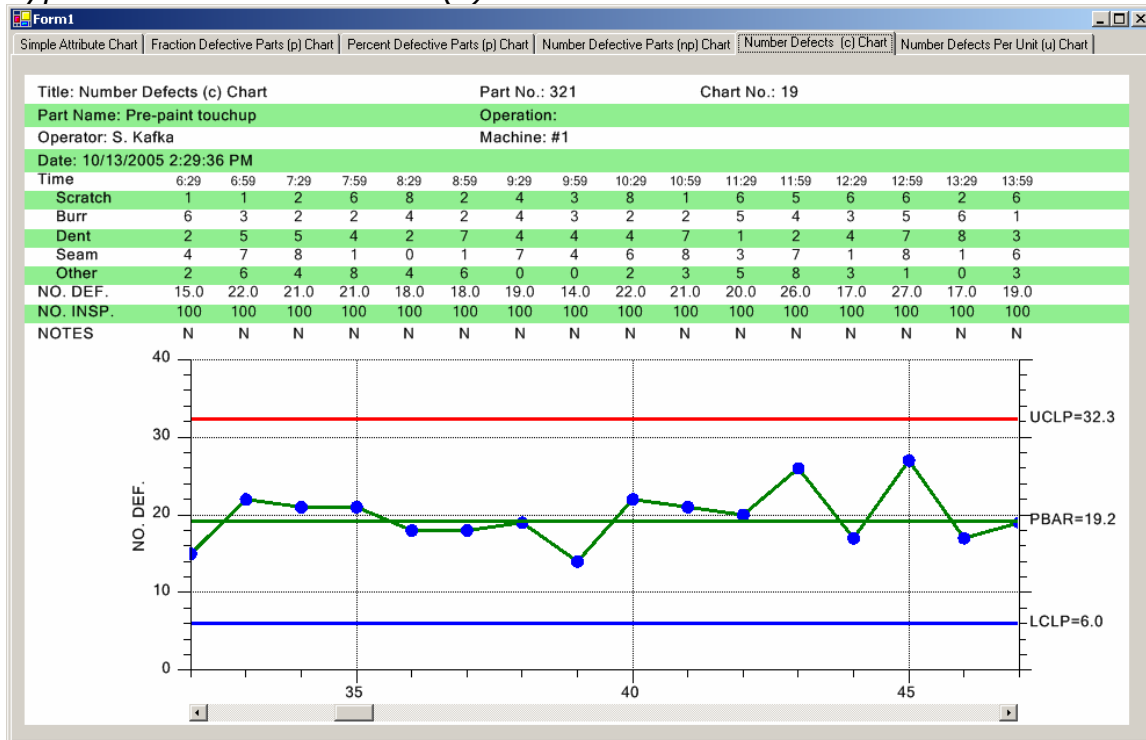
Defect and Defect Category Data Tables

As discussed under the *Variable Control Chart* section, standard worksheets used to gather and plot SPC data consist of three main parts. The first part is the header section, identifying the title of the chart, the process being monitored, the machine operator, part number and other important information specific to the chart. The

second part is used to record the defect data, organized as a table so that defect data is recorded in a neat, readable fashion, and where the SPC calculations are made. The calculated SPC values for the defect group variables are plotted in the third part, the SPC chart section.

The *Attribute Control Chart* templates that we have created have options that enable the programmer to customize and automatically include header information along with a table of the defect data, organized by defect category, number of defective parts, or total number of defects. If the scrollbar option is enabled, you can display the tabular defect data and SPC plots for a window of 8-20 subgroups, from a much larger collection of measurement data representing hundreds or even thousands of subgroups, and use the scrollbar to move through the data, similar to paging through a spreadsheet.

Typical Number of Defects (c) Chart with data table

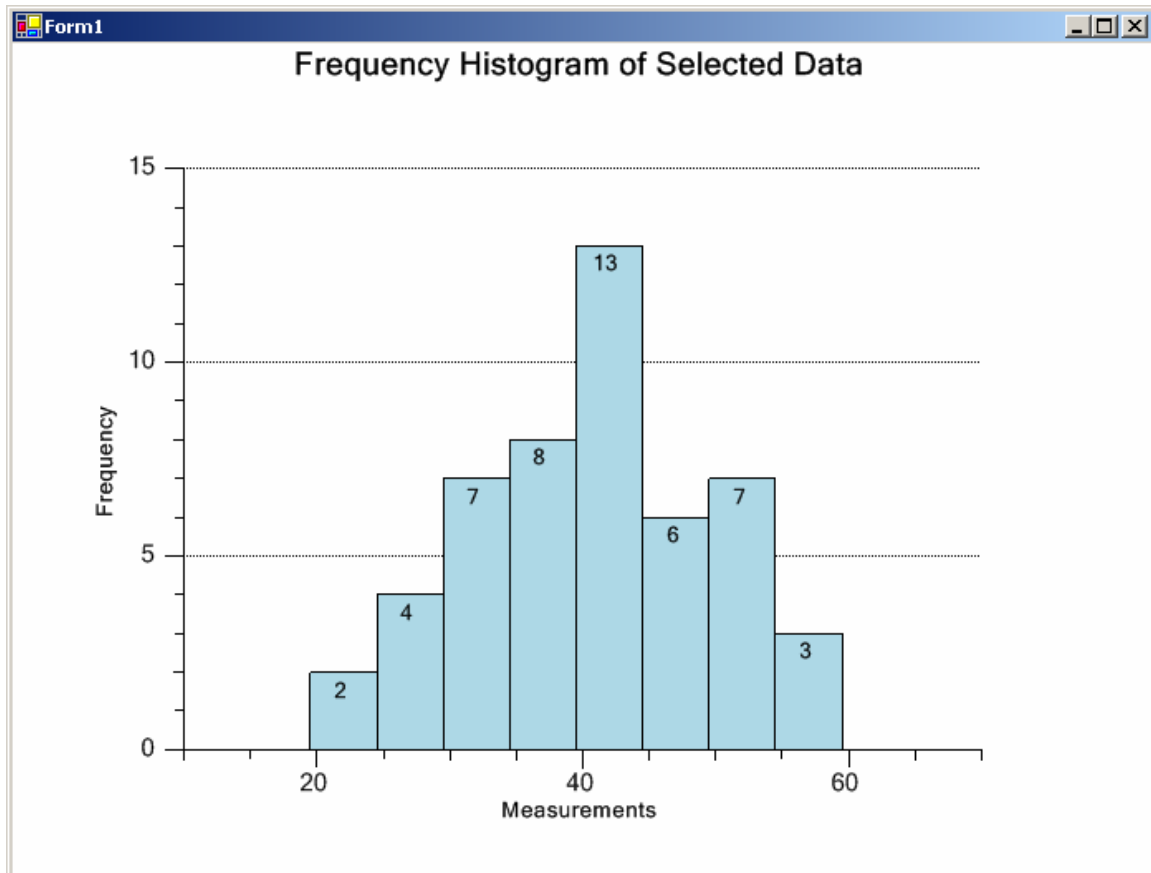


Other Important SPC Charts

Frequency Distribution Chart

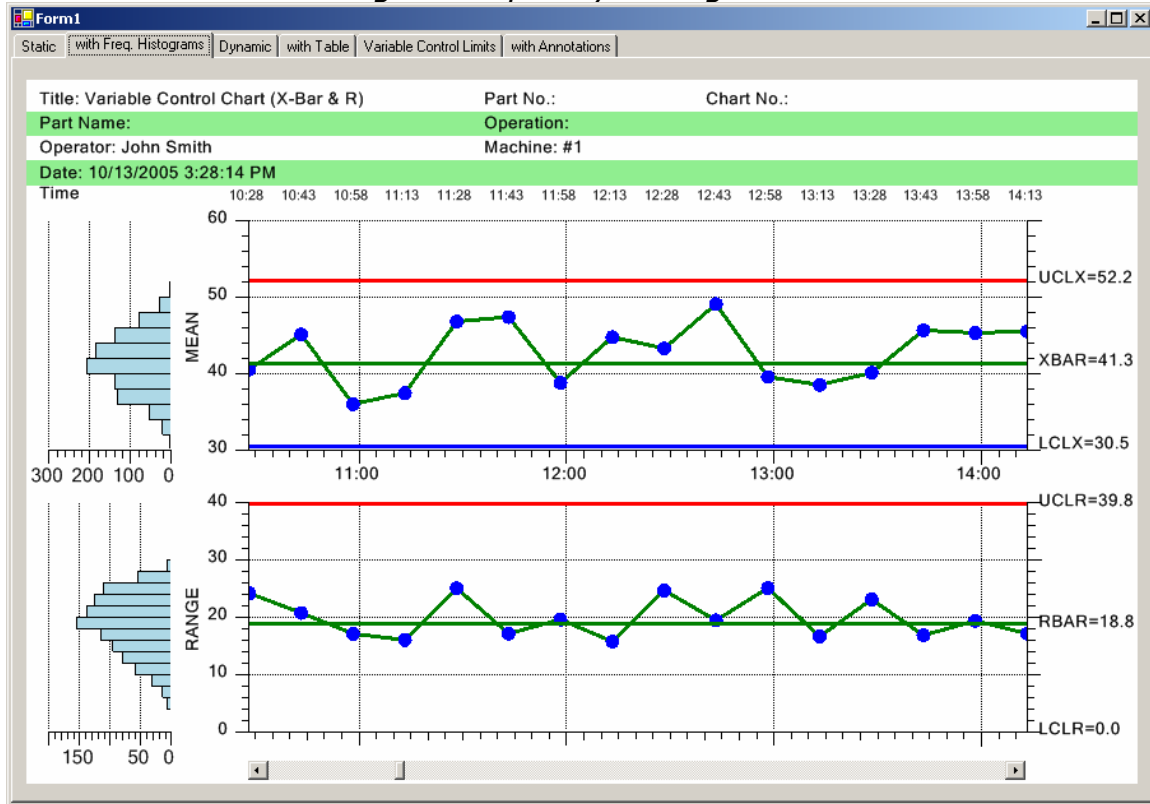
An SPC control chart will allow you to track the trend of critical variables in a production environment. It is important that the production engineer understand whether or not changes or variation in the critical variables are natural variations due to the tolerances

inherent to the production machinery, or whether or not the variations are due to some systemic, assignable cause that needs to be addressed. If the changes in critical variables are due to the natural variations, then a frequency histogram of the variations will usually follow one of the common continuous (normal, exponential, gamma, Weibull) or discrete (binomial, Poisson, hypergeometric) distributions. It is the job of the SPC engineer to know what distribution best models his process. Periodically plotting of the variation of critical variables will give SPC engineer important information about the current state of the process. A typical frequency histogram looks like:



Viewing frequency histograms of both the variation in the primary variable (Mean, Median, count, or actual value), and the secondary variable (Range, Sigma or Moving Range) side-by-side with the SPC control chart makes it even easier to find out whether the variations are the result of natural variations or the result of some systemic change in the process.

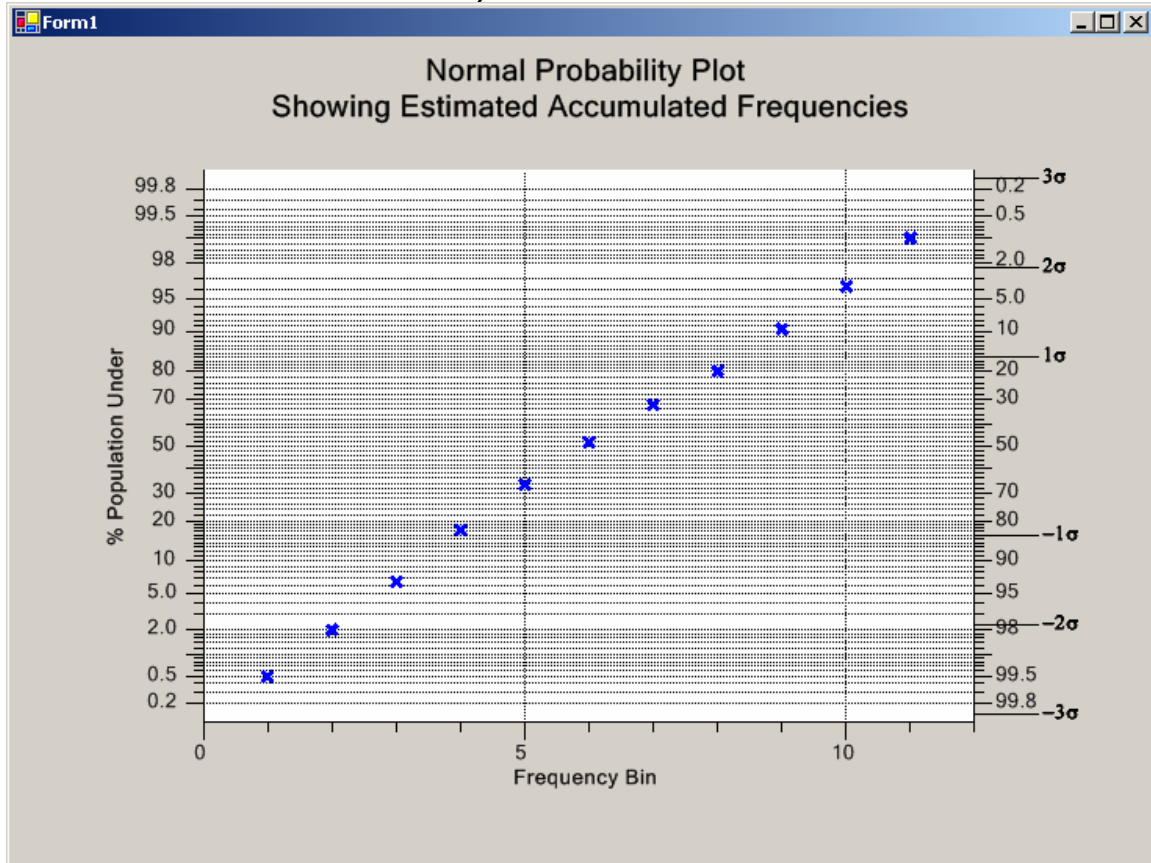
XBar-R Chart with Integral Frequency Histograms



Probability Plots

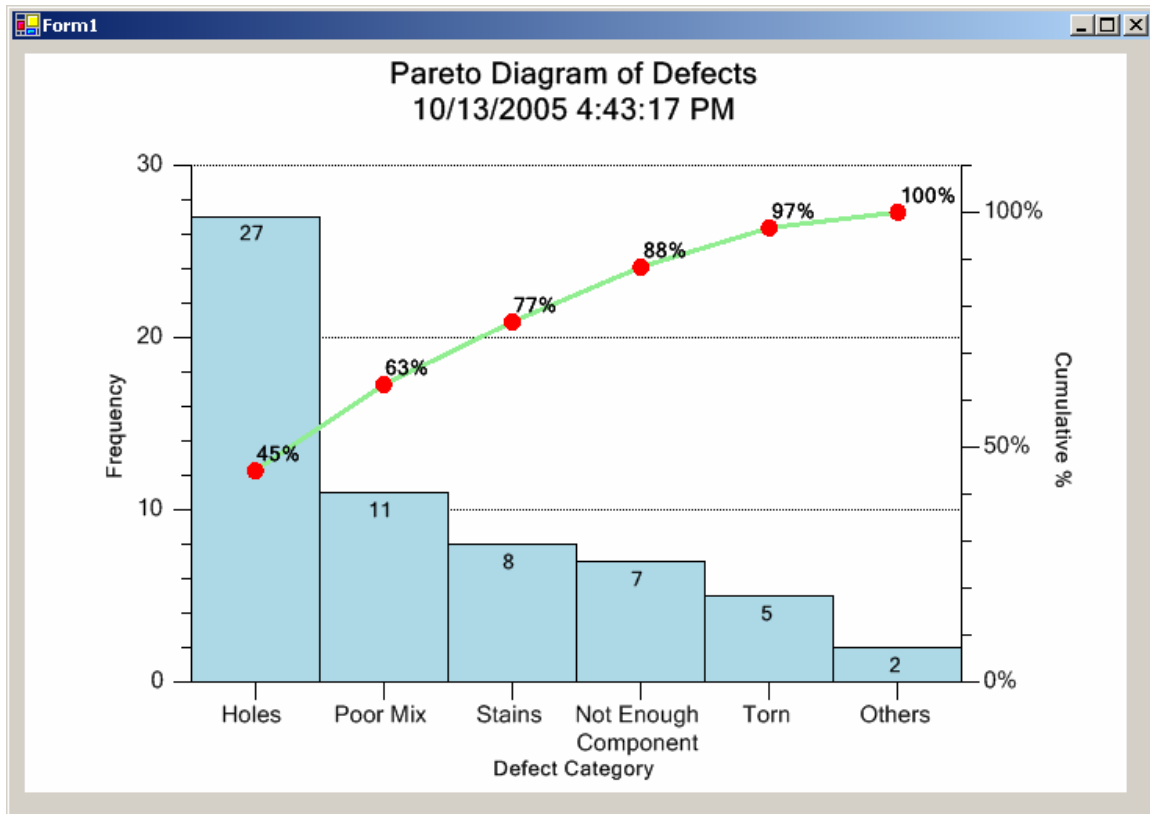
Another important tool the SPC engineer uses to model the process variation is the probability plot. The probability plot is a simple way to test whether control chart measurements fit a normal distribution. Usually probability plot graphs are plotted by hand using special probability plot graph paper. We have added probability scale and axis classes that enable you to plot probability plots directly on the computer. Control chart measurements that follow a normal distribution curve will plot as a straight line when plotted in a normal probability plot.

Cumulative Normal Probability Chart



Pareto Diagrams

The Pareto diagram is a special type of bar graph combined with a line plot, plotted in a chart that uses two different y-axis scales. The bar graph scale is a frequency scale that measures the number of times a specific problem has occurred. The line plot scale is a cumulative percentage scale.

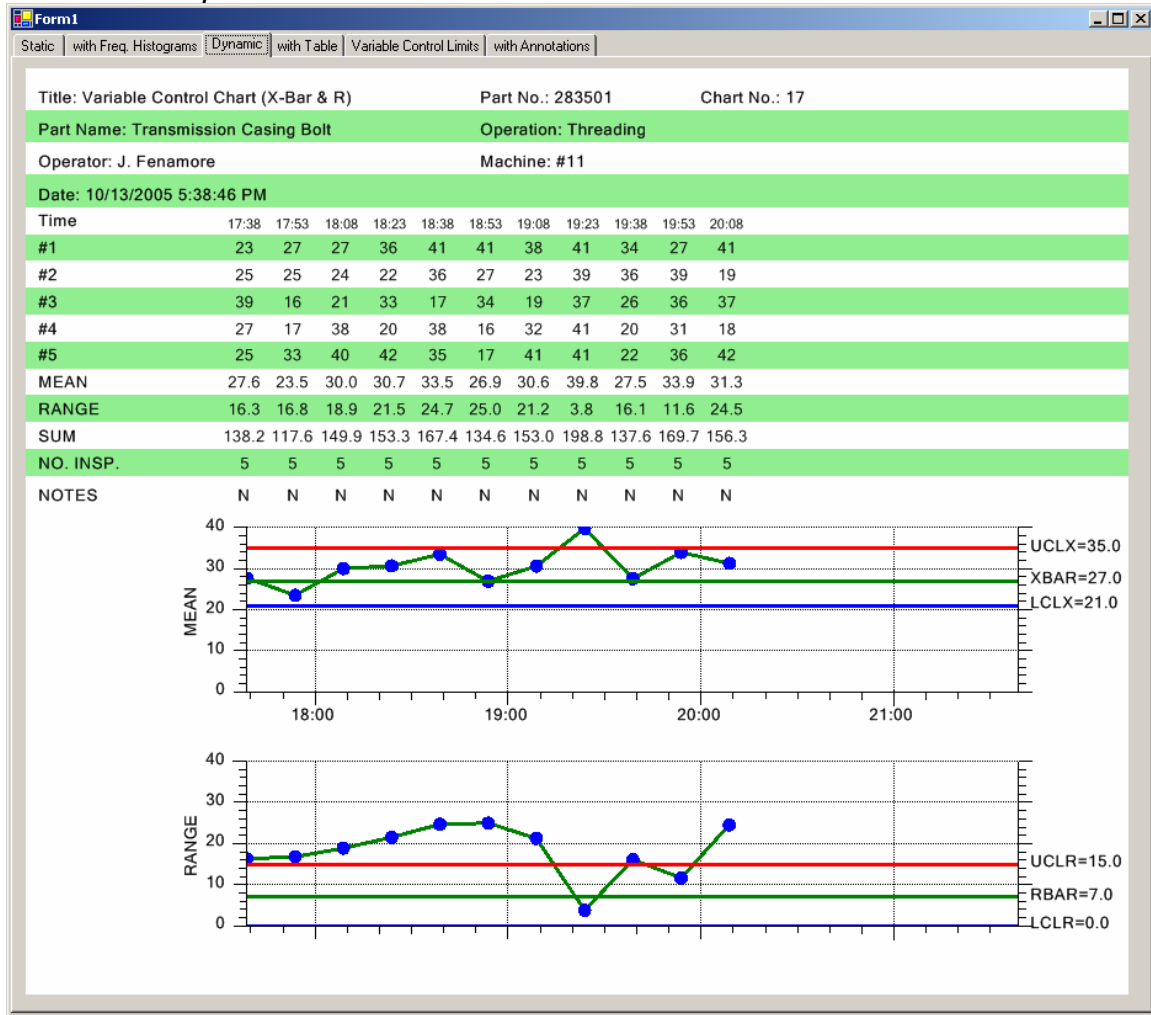


The chart is easy to interpret. The tallest bar, the left-most one in a Pareto diagram, is the problem that has the most frequent occurrence. The shortest bar, the right-most one, is the problem that has the least frequent occurrence. Time spend on fixing the biggest problem will have the greatest affect on the overall problem rate. This is a simplistic view of actual Pareto analysis, which would usually take into account the cost effectiveness of fixing a specific problem. Never less, it is powerful communication tool that the SPC engineer can use in trying to identify and solve production problems.

Real-Time Updates

The SPC chart templates are not just for the static display of previous collected data. They are designed to be updated in real-time, if that is what you want to do. As the SPC chart is updated with new measurement data in real-time, not only will the chart scroll as new data is added, but the table of the measurement and calculated data will also scroll.

Real-Time Update of X-Bar R Chart



Alarm Conditions

A real-time SPC chart will monitor the production process constantly, comparing current critical process values to SPC high and low control limits calculated using previously collected data. Should a critical process variable fall outside of these limits, some sort of action will need to be taken in order to prevent the process from deteriorating further.

The big advantage to automating an existing SPC charting application using an modern programming language is that you can trap an alarm event the second it is detected and execute code that you write to output a warning messages to the machine operator, foreman, QC

Engineer, whomever is responsible for further checks and/or corrections to the process.

We have added the code necessary to check for the current process variable falling outside of the SPC high and low control limits that you specified for that process. The alarm condition will trigger a software event to which you can attach a delegate. In that delegate you can add your own customized code for handling the alarm condition.

Related Documentation

QCChart2D Charting Tools for .Net Manual

American Society for Quality Control. *American National Standard. Definitions, Symbols, Formulas, and Tables for Control Charts*, 1987. Publication number: ANSI/ASQC A1-1987.

Amesden, Ropert T., *SPC Simplified – Practical Steps to Quality*, Productivity Inc., 2nd edition, 1998.

Montgomery, Douglas C., *Introduction to Statistical Quality Control*, John Wiley and Sons, 5th edition, 2004.

Wise, Stephen A., *Innovative Control Charting*, ASQ Quality Press, 1998.

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