TUTORIALS FOR
Quality Control Analyses

STATGRAPHICS *PLUS*® for WINDOWS

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Introduction

This manual contains tutorials for the Quality Control analyses in STATGRAPHICS *Plus*.

For information about quality control in general, see the section, *Overview of Quality Control*, in the online help system.

Tutorials in This Manual

The quality control tutorials in this manual are:

- *Assessing the Statistical Control of a Manufacturing Process*
- *Determining Statistical Control of a Chemical Process*
- *Evaluating the Effectiveness of Measurement Tools*

TUTORIAL 1

Assessing the Statistical Control of a Manufacturing Process

This example, adapted from Montgomery and Runger (1994), demonstrates how you assess statistical control of a manufacturing process. In this example, a large aircraft manufacturer purchased two components from two different vendors. The company found that the components frequently showed excessive variability, which made it impossible to assemble the final product, and caused expensive rework costs and delay.

A group in the company inspected the parts to try to improve the situation. They maintained X-bar and R charts on the suspected dimension for both vendors and found the fraction of nonconforming units to be about the same, but for different reasons. Vendor A produced parts with a mean dimension equal to the required specification, but the process was out of statistical control. The other vendor maintained good statistical control, but the process was so far off the nominal required dimension that many of the components did not meet specifications.

To perform the analysis, you will use the X-bar and R Charts and Process Capability analyses from the Quality and Design product. In the first part of the tutorial, you will determine initial limits for the control charts, save the results in a StatFolio (**Example1.sgp**), and use them in the last part of the tutorial to re-evaluate the process.

Using control charts for the measurements, you will use the vane opening on a casting as the parameter that will determine if the process is in statistical control. Then you will use process capability to measure the ability of the vane openings to meet engineering specifications.

In preparation, measurements for 20 subgroups of five castings each were collected and entered into a file named **Vanes**; the variable that contains the measurements is **Vane**.

To begin, open STATGRAPHICS *Plus* and the **Vanes** data file.

Determining Initial Limits for Control Charts

1. Choose SPECIAL... QUALITY CONTROL... VARIABLES CONTROL CHARTS... X-BAR AND R... from the Menu bar to display the Analysis dialog box.

2. Enter **Vane** into the Observations text box.

3. Place the mouse pointer in the Subgroup Numbers or Size text box, then type, ***5*** (see Figure 1-1).

   You entered 5 because each subgroup contains five measurements.

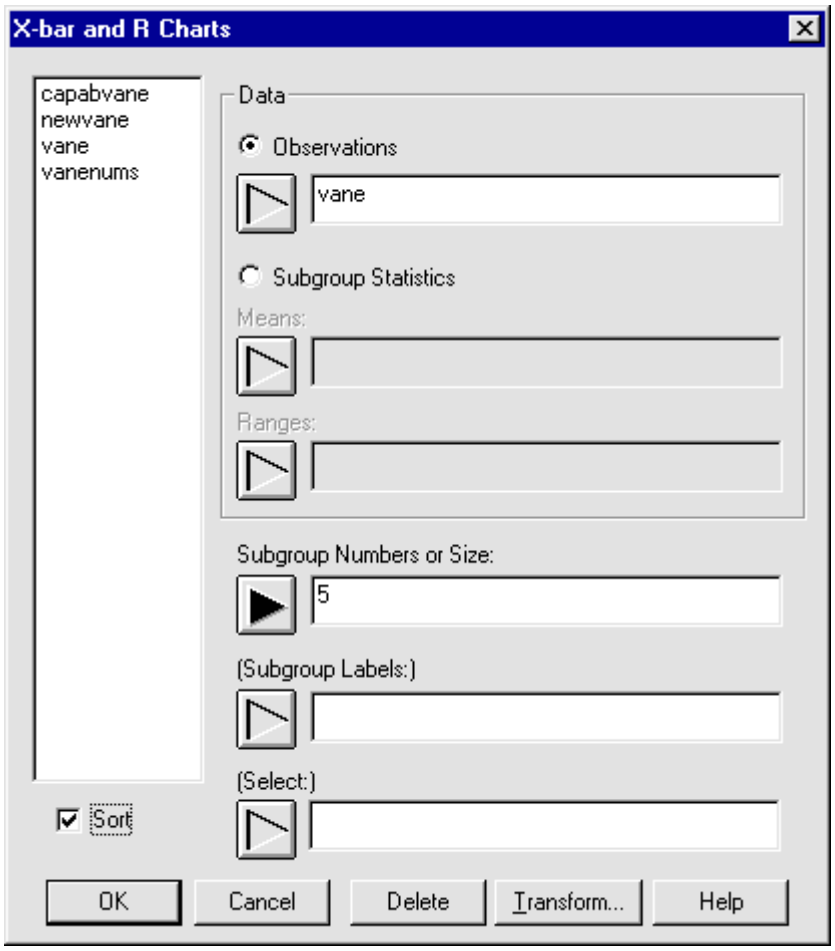

Figure 1-1. Completed Analysis Dialog Box

4. Click OK to display the Analysis Summary and X-bar Chart in the Analysis window. Maximize the Analysis Summary (see Figure 1-2).

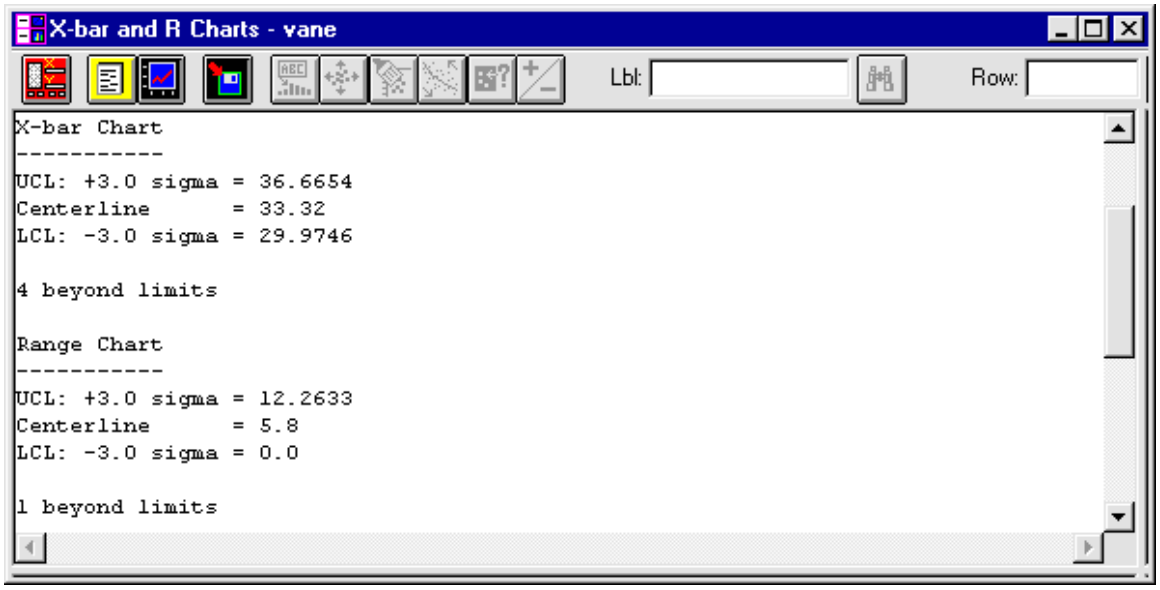

Figure 1-2. Analysis Summary

The Analysis Summary displays the values for the Upper Control Limit (UCL), the Centerline, and the Lower Control Limit (LCL). It shows that four subgroups are beyond the control limits for the X-bar Chart and one subgroup is beyond the limits for the Range Chart. Estimates for the process mean, process sigma, and mean range are shown at the bottom of the table.

To identify subgroups that are out of control, you will create a Subgroups Report.

5. Click the Tabular Options button to display the dialog box, then click Subgroup Reports, and click OK to display the report shown in Figure 1-3.

Use the Vertical Scroll Bar on the right side of the report to view the entire table. Notice that asterisks denote values that are beyond the limits.

Now look at the results in graphical form.

6. Minimize the Subgroup Reports pane and maximize the X-bar Chart.

7. Click the Graphical Options button to display the dialog box, then click the Range Chart check box, and OK to display the X-bar and Range charts in the graphics panes (see Figure 1-4).

Note: Most of the graphs and plots in these tutorials have been modified to make them easier to read. Therefore, when they display on your computer screen they may not look the same. You can make the modifications yourself using the Graphics Options dialog box, which you access by clicking the right mouse button on a plot pane.

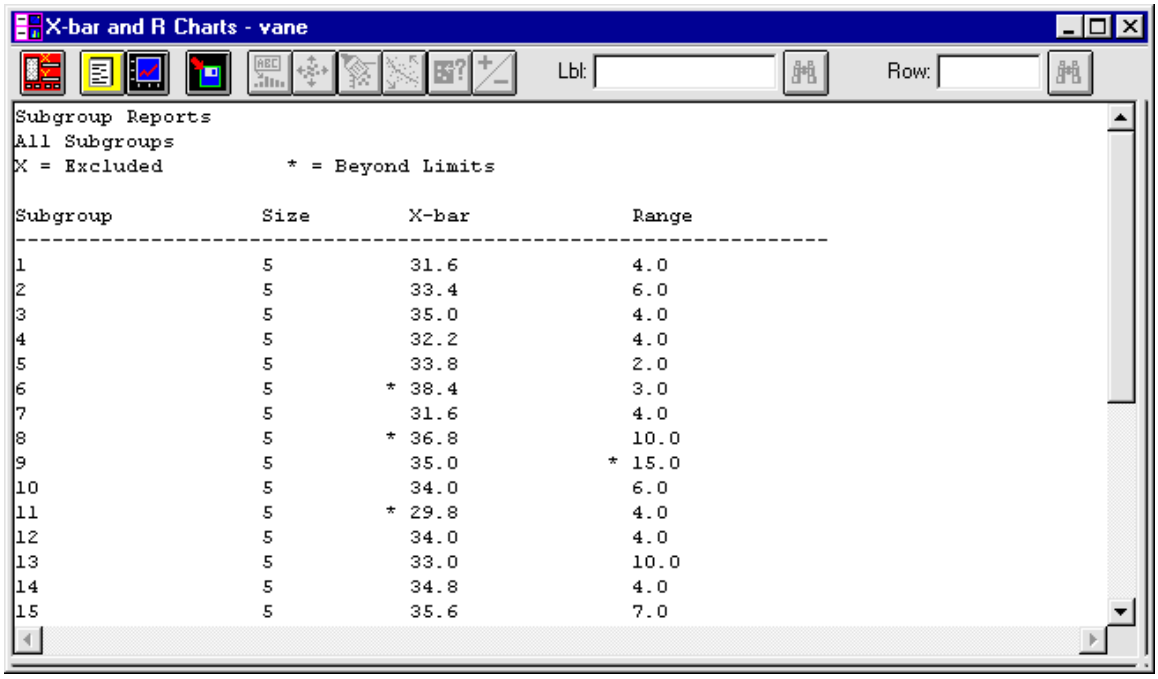

Figure 1-3. Subgroup Reports

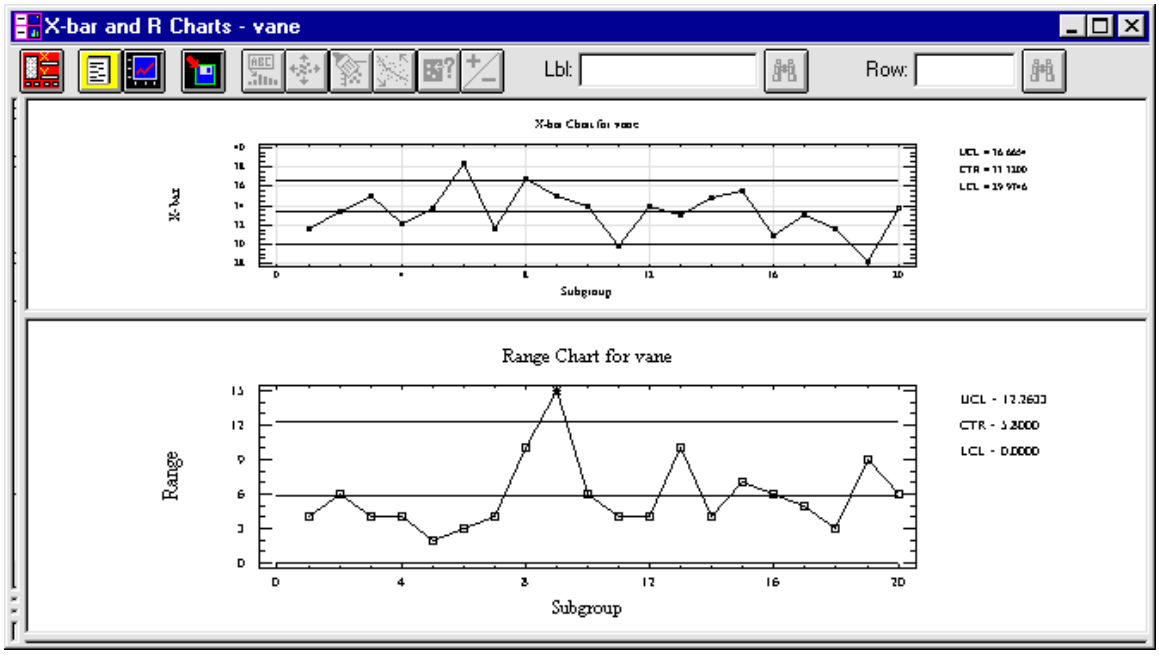

Figure 1-4. X-bar and R Charts Showing Out-of-Control Limits

The two plots confirm that some subgroups are beyond the control limits. After you have identified the cause for the variation, you can exclude the out-of-control subgroups from the analysis.

Excluding Out-of-Control Subgroups

1. Minimize the plots and maximize the Analysis Summary.

2. Place the mouse pointer on the Analysis Summary, click the right button then the left on Analysis Options to display the X-bar and R Charts Options dialog box.

3. Click the Exclude command to display the Exclude/Include Options dialog box.

4. Click the Automatic option; your screen should look like the one shown in Figure 1-5.

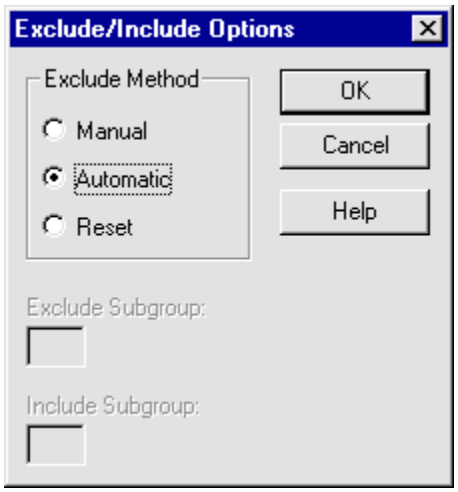

Figure 1-5. Completed Options Dialog Box

5. Click OK on both dialog boxes to exclude the out-of-control subgroups and recalculate the analysis.

   Note: Use caution when choosing the Automatic option. The program can remove more out-of-control subgroups than it initially finds because it recalculates the limits after it excludes the subgroups. Consequently, subgroups that were previously within the limits may fall beyond the recalculated limits.

   So far in this tutorial, you have established control limits for the process by removing subgroups that were affected. Subsequent subgroups will be plotted against this standard to determine if the process remains in control.

Saving the Analysis in a StatFolio

1. Choose FILE... SAVE AS... SAVE STATFOLIO AS... from the Menu bar to display the Save StatFolio As... dialog box.

2. Type ***Example1.sgp*** in the File Name text box, then click Save to save and name the StatFolio.

Ensuring that a Process Stays in Control

To ensure that a process stays in control, you collected current measurement data for the vane opening and stored them in a new variable called **Newvane**.

Now you will analyze the new data in a Control-to-Standard Study using the parameters that were determined in the Initial Study. These parameters are the values for the Mean and Sigma **or** the values for the control limits for the X-bar and Range charts that were shown in the Analysis Summary for the Initial Study.

1. Choose FILE... OPEN... OPEN DATA FILE... from the Menu bar to display the Open Data File dialog box.

2. Enter ***Vanes.sf*** in the File Name text box and click OK.

3. Choose SPECIAL... QUALITY CONTROL... VARIABLES CONTROL CHARTS... X-BAR AND R... from the Menu bar to display the Analysis dialog box.

4. Enter **Newvane** into the Observations text box.

5. Place the mouse pointer in the Subgroup Numbers or Size text box, then type ***5***, and click OK to display the Analysis Summary and X-bar Chart in the Analysis window (see Figure 1-6).

   Again, you are entering 5 because each subgroup has five measurements.

6. Click the right mouse button on the Analysis Summary, then the left on Analysis Options to display the X-bar and R Charts Options dialog box.

7. Click the Control to Standard option under the Type of Study portion of the dialog box to activate the Specify Parameters text boxes under the Control to Standard options.

8. Place the mouse pointer in the Mean text box, and type ***33.32***, which is the average from the Initial Study.

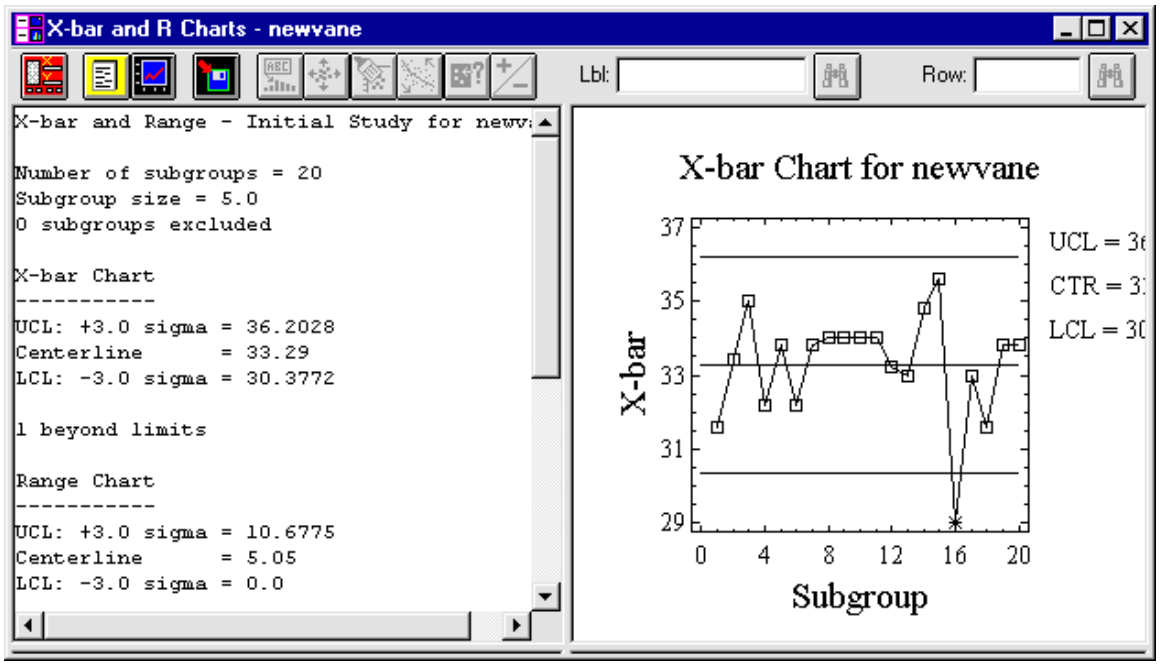

Figure 1-6. Analysis Summary and X-bar Chart in the Analysis Window

9. Place the mouse pointer in the Sigma text box, and type ***2.493555***, which is the estimated sigma from the Initial Study.

Figure 1-7 is an example of the completed X-bar and R Charts Options dialog box.

10. Click OK to redisplay the Analysis Summary and X-bar Chart in the Analysis window.

11. Click the Graphical Options button to display the dialog box, then click the Range Chart check box, and OK to display the two charts in graphics panes.

Look at each chart separately (see Figures 1-8 and 1-9).

Notice that in Figure 1-8, the X-bar Chart, one value is beyond the limits. The Range Chart in Figure 1-9, shows that all the data points fall within the control limits. Again, the cause for the variation has been determined, and you can now exclude the out-of-control subgroup(s) from the analysis.

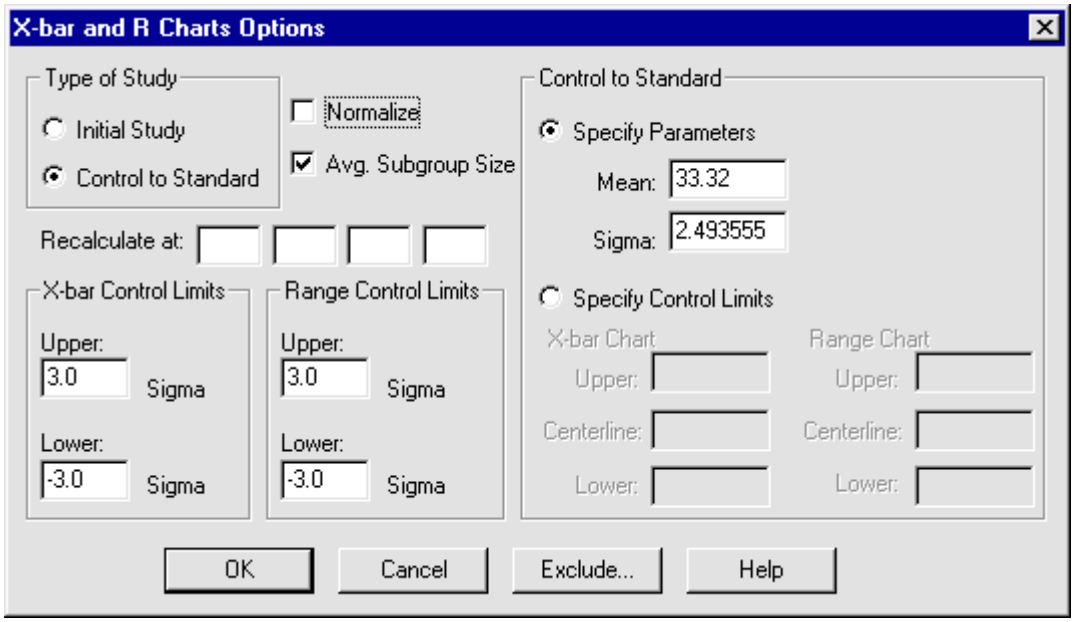

Figure 1-7. Completed X-Bar and R Chart Options Dialog Box for a Control-to-Standard Study

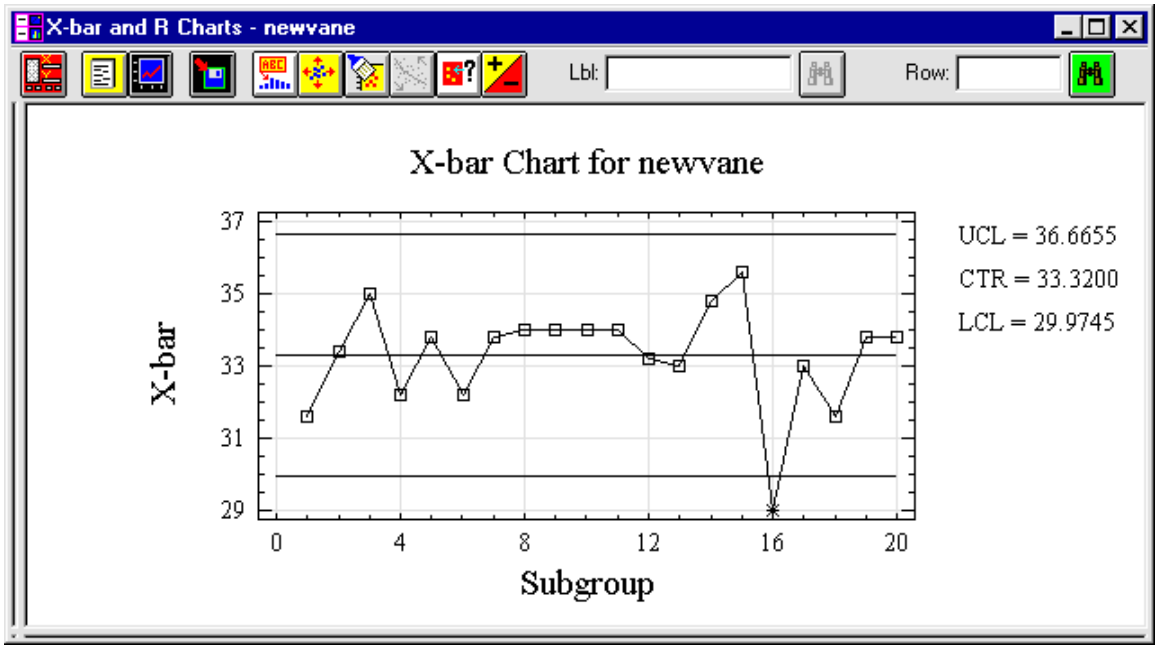

Figure 1-8. X-bar Chart for a Control-to-Standard Study

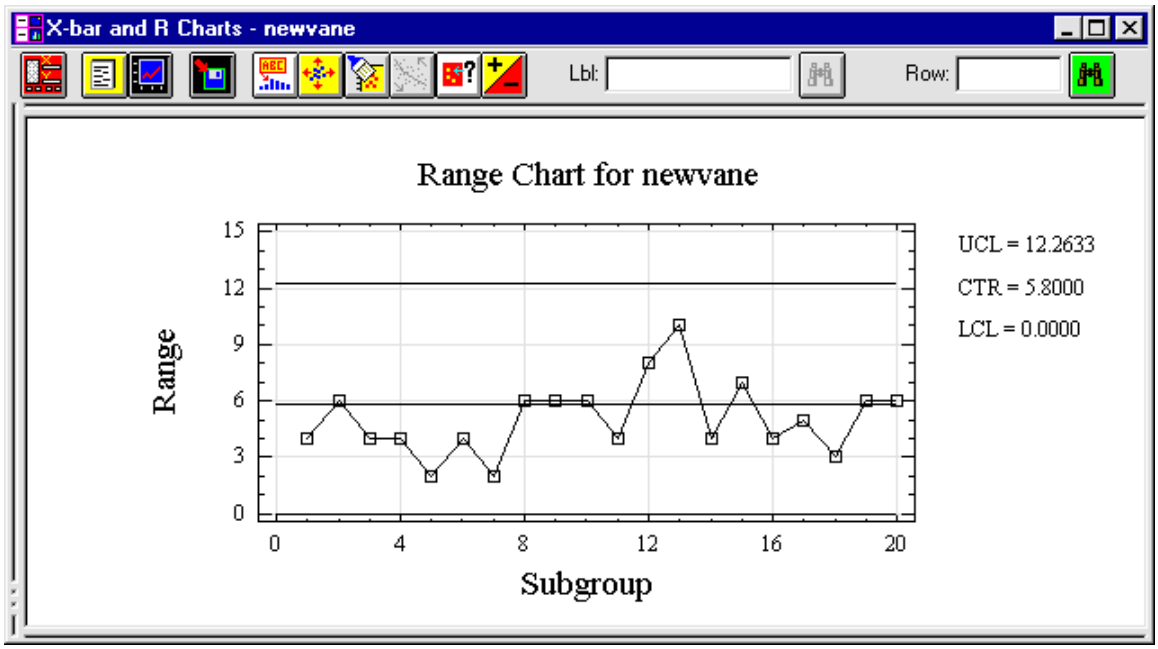

Figure 1-9. Range Chart for a Control-to-Standard Study

Exclude Out-of-Control Points

1. Maximize the X-bar Chart.

2. Click on the point that is below the LCL (Subgroup 16), then click the Exclude/Include button (see Figure 1-10) on the Analysis toolbar to delete the point.

Figure 1-10. Exclude/Include Button

With the out-of-control subgroup excluded, the remaining subgroups are within the new control limits. Before you re-evaluate the process, save the StatFolio following the steps you used previously.

Re-Evaluating the Process

To ensure that a process remains in control, you periodically need to re-evaluate it. You should also re-evaluate a process any time you make improvements to it; for example, when you add a new piece of equipment.

Your next step is to use the Process Capability Analysis to determine the capability of the process; for example, does the process meet the specifications?

The assumed target or nominal value of the process is 30, so the vane openings should have a measurement of 30. Due to random variation, you can accept any measurement between 20 and 40, therefore, the upper specification limit is 40, and the lower is 20. You will randomly choose 100 components, then measure the vane openings.

Before you begin, open the **Example1.sgp** StatFolio that you saved earlier in this tutorial.

1. Choose SPECIAL... QUALITY CONTROL... PROCESS CAPABILITY ANALYSIS... from the Menu bar to display the Process Capability Analysis dialog box.

2. Enter the following information into the text boxes:

Data: ***Capabvane***
USL: ***40***
Nominal: ***30***
LSL: ***20***

Leave the Select text box empty. Your screen should look like the dialog box shown in Figure 1-11.

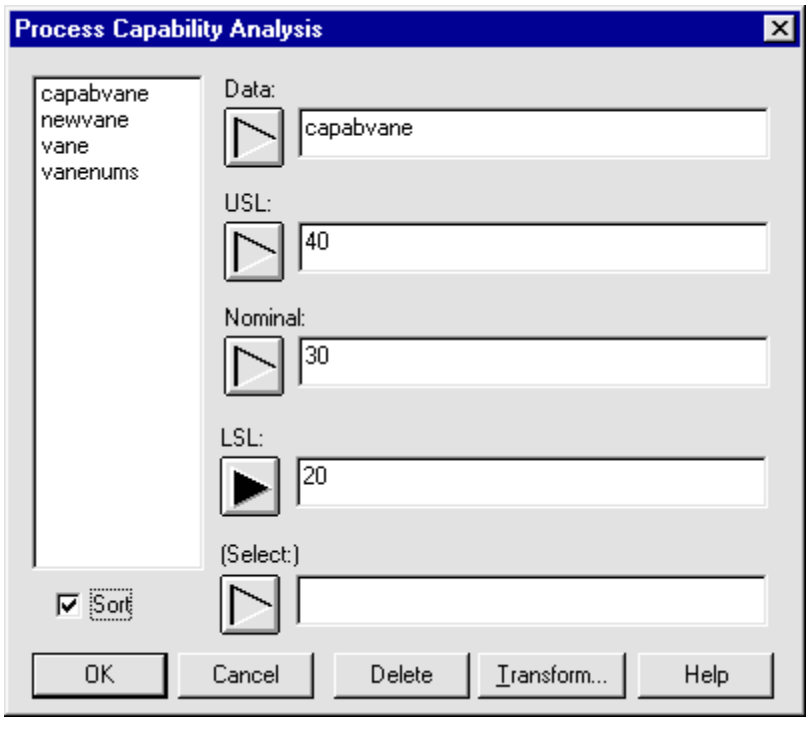

Figure 1-11. Completed Process Capability Analysis Dialog Box

3. Click OK to display the Analysis Summary and Capability Plot in the Analysis window.

4. Click the Tabular Options button to display the dialog box, then click the Capability Indices option, and OK to display the indices.

5. Maximize the Capability Indices (the second text pane) (see Figure 1-12).

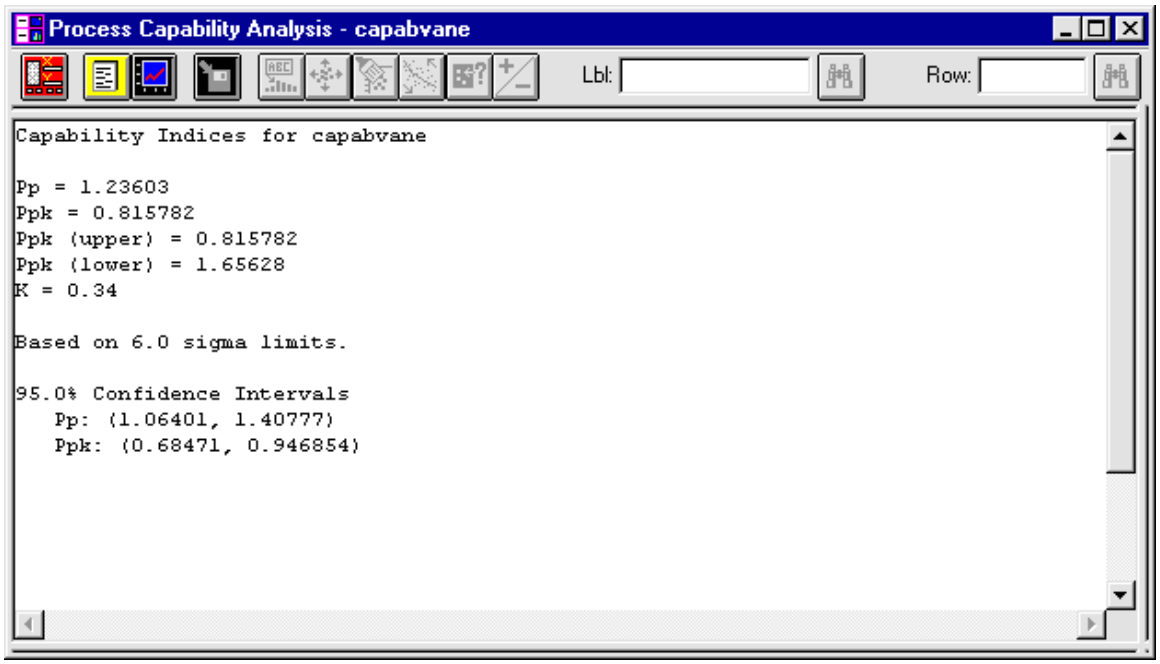

Figure 1-12. Capability Indices

The P_p value represents the capability of the process. The summary shows the P_p value to be 1.236. In general, if the mean is located close to the midpoint of the tolerances, a P_p less than 1.00 indicates the process is not capable. A P_p value between 1.00 and 1.33 indicates that the process is capable but should be monitored as P_p approaches 1.00.

Note: The Capability Indices Options dialog box allows you to choose whether you want to use P_p, P_{pk}, etc., or C_p, C_{pk}, etc. (see Figure 1-13).

Verifying the Data

1. Click the Graphical Options button to display the dialog box, then click the Capability Plot option, and OK to display the plot shown in Figure 1-14. Maximize the plot.

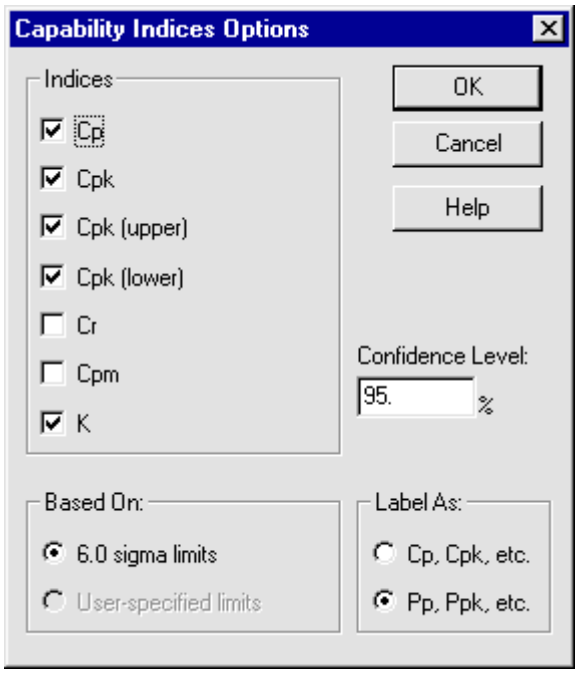

Figure 1-13. The Capability Indices Options Dialog Box

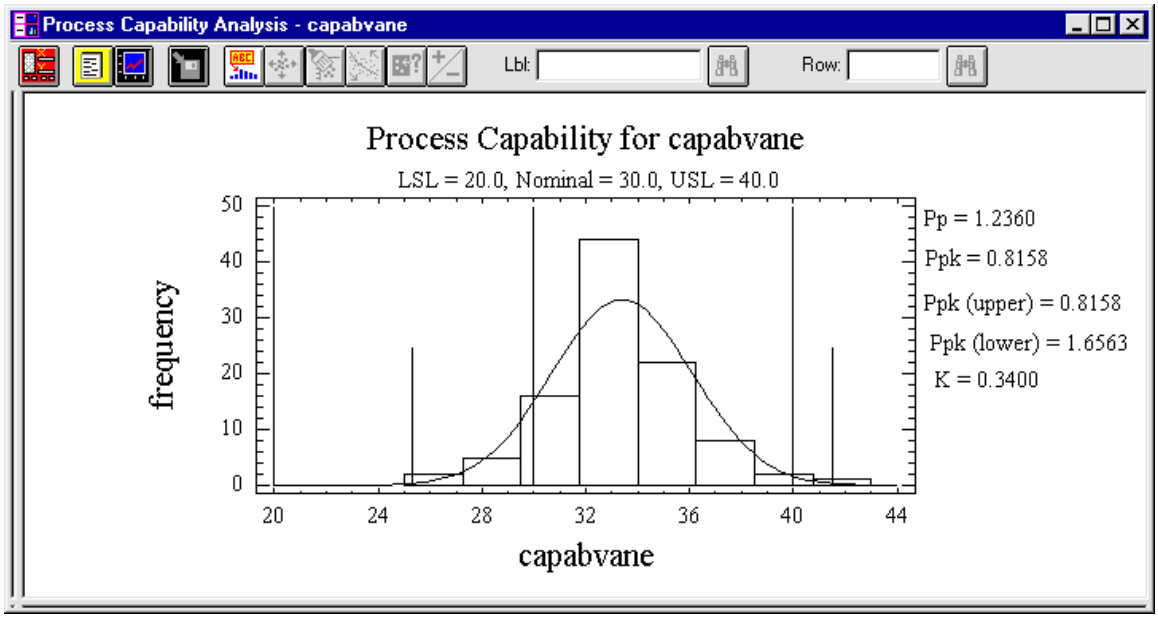

Figure 1-14. Capability Plot for Verifying Data

The Capability Plot shows that the process falls nearly within the specifications, but is off-center in relation to the nominal. The actual

capability is less than indicated by the P_p value. When the process is off-center, use the P_{pk} statistic rather than P_p to measure the process capability.

A P_{pk} value less than 1.00 indicates that at least one of the sigma limits is outside of a specification limit and that the process may not be capable of performing to specification. The P_{pk} value for the data is 0.816; therefore, you can conclude that the process may not be capable of performing to specification and you need to investigate possible causes.

References

Montgomery, D. C. and Runger, G. C. 1994. *Applied Statistics and Probability for Engineers.* New York: Wiley & Sons.

TUTORIAL 2

Determining Statistical Control of a Chemical Process

This tutorial is also adapted from Montgomery and Runger (1994). In it you will use the Individuals charts and Cumulative Sum Individuals charts analyses to determine statistical control of a chemical process.

A chemical engineer investigated the concentration levels of the output from a chemical process. You will follow up by using the X-bar and R Charts Analysis to maintain control. When a process does not allow collection of subgroup data, individual observations can be collected and used with Individuals charts, which are control charts especially designed for this type of data.

In the data, one observation per hour for 20 hours was recorded. The variable name is **Concent.** You will first examine an MR(2) Chart.

To begin, open STATGRAPHICS *Plus* and the **Individ.sf** data file.

Analyzing the Data

1. Choose SPECIAL... QUALITY CONTROL... VARIABLES CONTROL CHARTS... INDIVIDUALS... from the Menu bar to display the Analysis dialog box.

2. Enter **Concent** into the Observations text box and click OK to display the Analysis Summary and X-Chart in the Analysis window.

3. Click the Graphical Options button to display the dialog box, then click the MR(2) Chart option, and OK to display the chart. Maximize the chart (see Figure 2-1).

The MR(2) Chart shows the moving ranges for successive observations. The process is out of control if points are shown above the upper control limit. Currently, all of the data points are within the control limits. To see the individual data points, switch to the X Chart.

4. Minimize the MR(2) Chart, then maximize the X Chart in the first graphics pane (see Figure 2-2).

Like the MR(2) Chart, this chart shows that the points are all within the control limits; therefore, the concentration levels are in control.

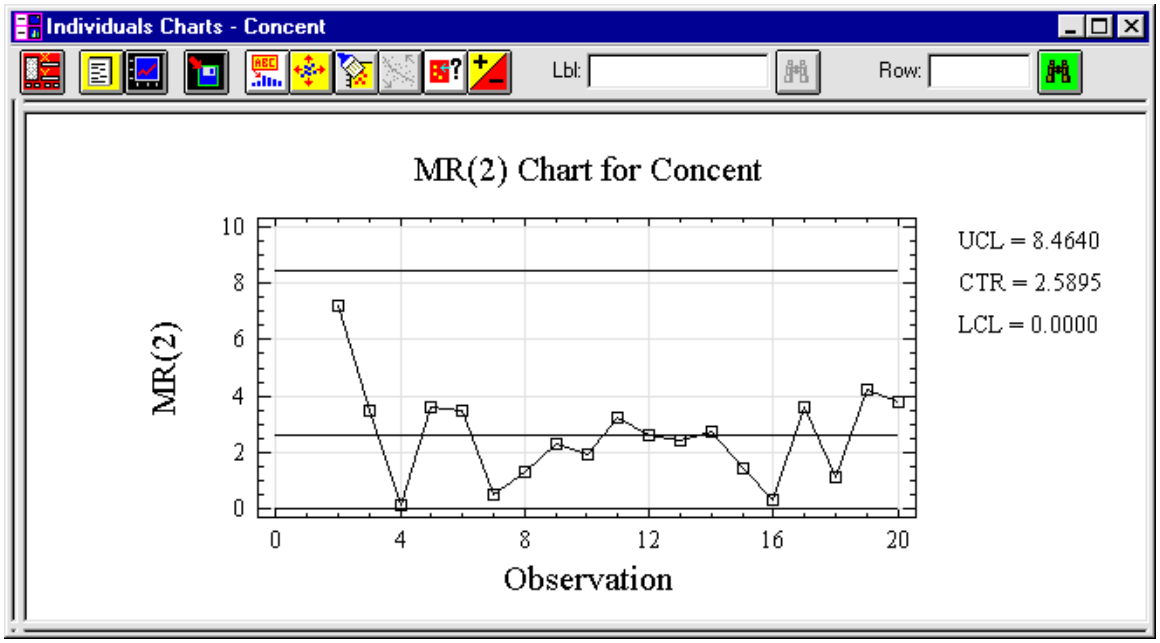

Figure 2-1. MR(2) Chart

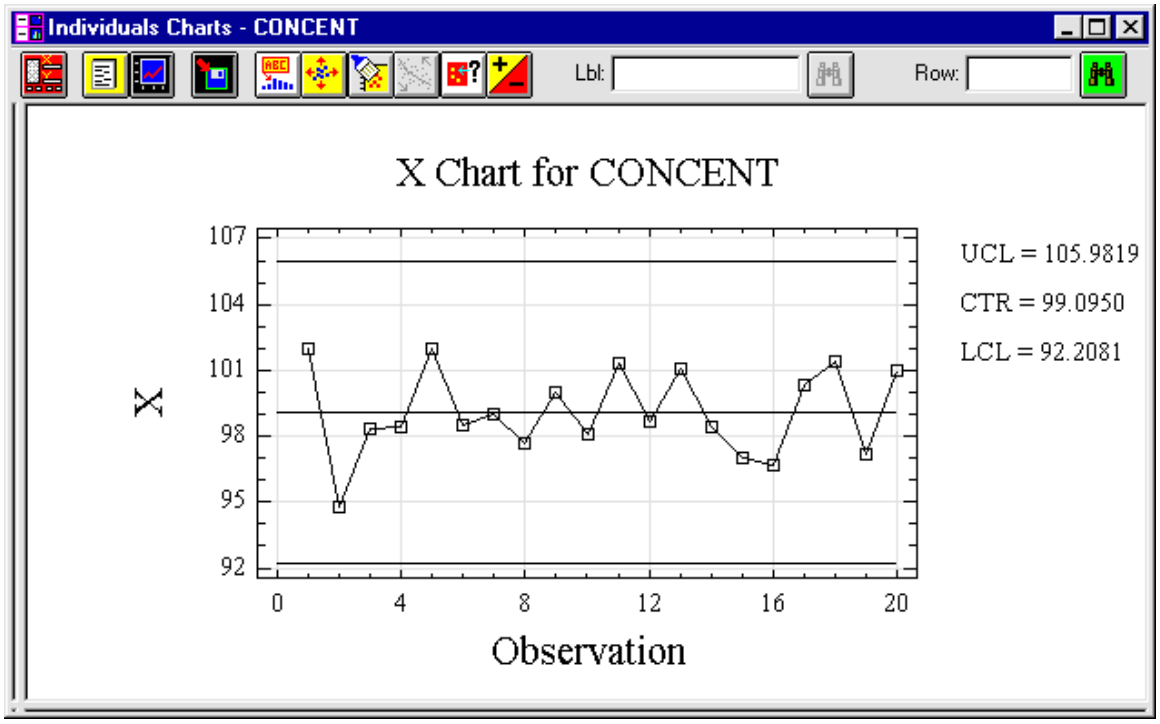

Figure 2-2. X Chart

Because the Individuals Charts Analysis cannot be used to detect small shifts in the mean concentration levels, and even small shifts can disrupt a

chemical process, you need to use another analysis that will detect them. The CuSum Individuals Chart Analysis is effective in detecting small shifts in the process mean.

Detecting Shifts in a Process Mean

1. Choose SPECIAL... QUALITY CONTROL... TIME-WEIGHTED CHARTS... CUSUM INDIVIDUALS (V-MASK) CHART... from the Menu bar to display the Cumulative Sum Individuals Chart (V-Mask) Analysis dialog box.

2. Enter **Concent** into the Observations text box.

3. Click the Tabular Options button to display the dialog box, then click the CuSum Individuals Chart option, and OK to display the report. Maximize the report (see Figure 2-3).

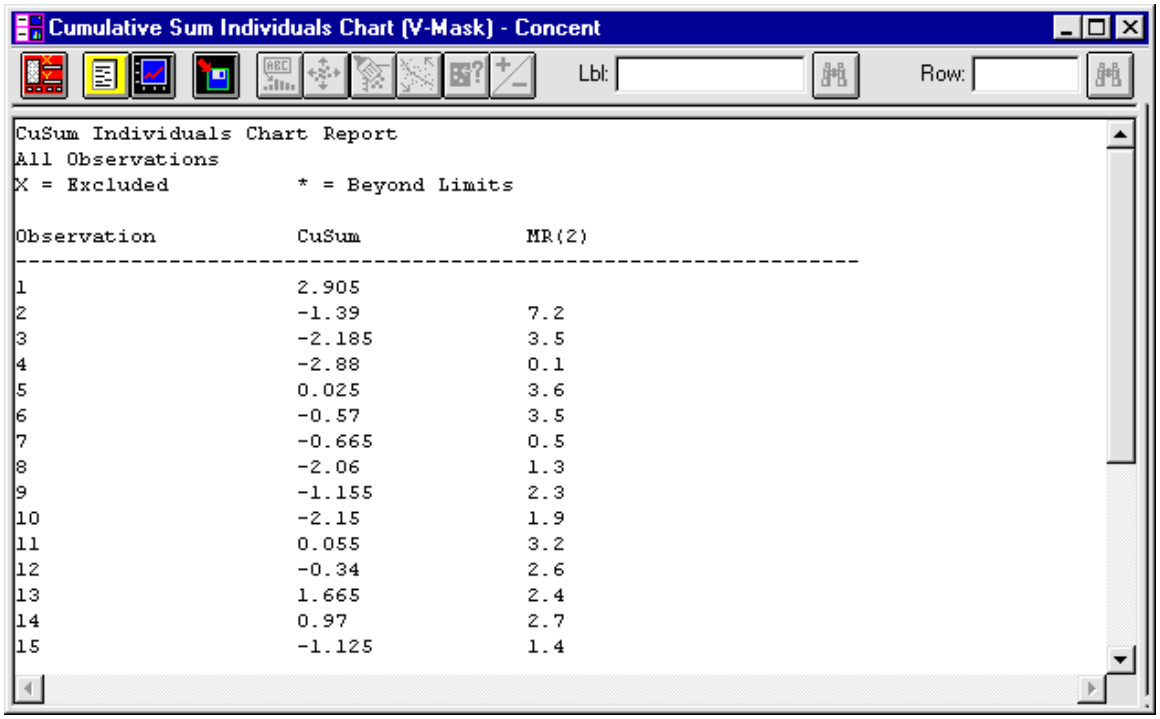

Figure 2-3. Cumulative Sum Individuals Chart (V-Mask) Report

According to the report, all the data points are within the control limits.

Now you will create a Cumulative Sum Chart so you can see the results graphically.

4. Minimize the CuSum Individuals Chart and maximize the Cumulative Sum Chart (see Figure 2-4).

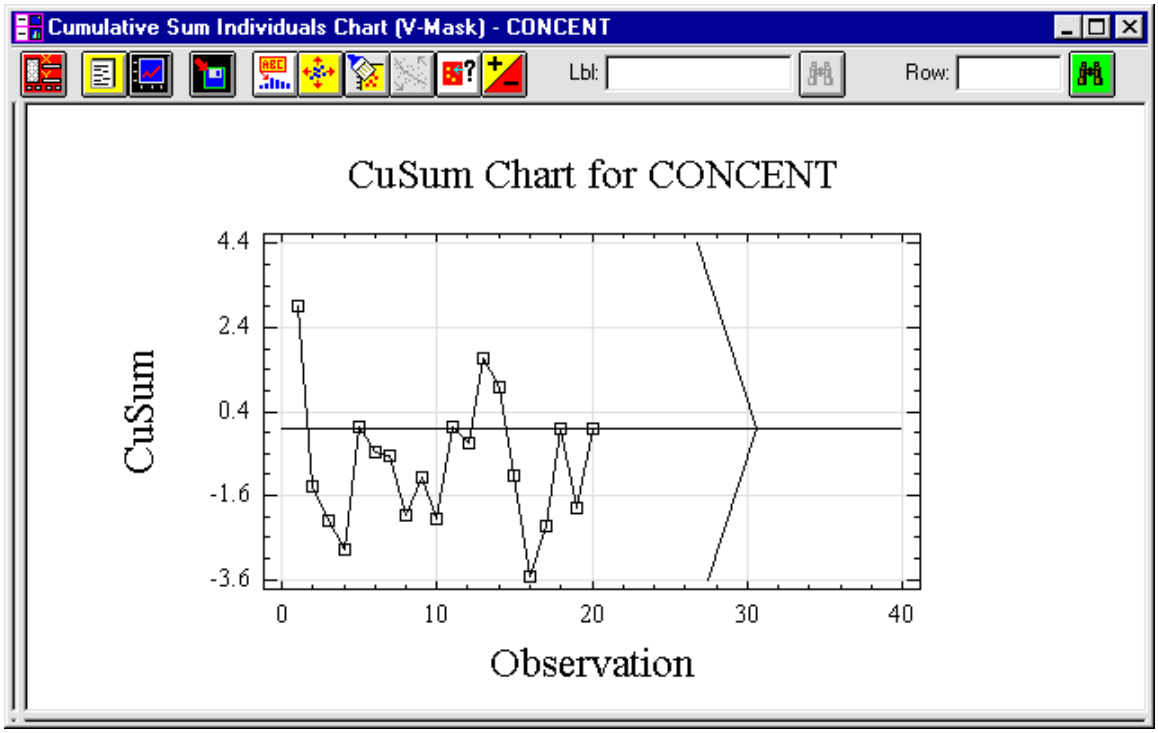

Figure 2-4. Cumulative Sum Chart

The Cumulative Sum Chart indicates that all the points fall within the control limits. The V-mask is drawn on the chart at observation 20 (see Montgomery [1991] for additional information on V-masks). If a shift occurs in the process mean, the CuSum data values fall outside the arms of the V. In this example, all the data points fall within the V-mask so you can be certain that the chemical process is under statistical control.

References

Montgomery, D. C. and Runger, G. C. 1994. *Applied Statistics and Probability for Engineers.* New York: Wiley & Sons.

TUTORIAL 3

Evaluating the Effectiveness of Measurement Tools

Gage Repeatability and Reproducibility (Gage R&R) is an important part of assessing quality control. The Gage R&R Analysis in STATGRAPHICS *Plus* is a tool to help you evaluate the effectiveness of the measurement tools you use in a quality-control analysis.

This example, adapted from AIAG (1990), demonstrates how you use the Average and Range Method in a Gage R&R analysis. In the example, the quality engineer must evaluate the company's measurement systems. The evaluation began with the gage that measures the thickness of gaskets the company produces.

Three operators were randomly chosen to each measure 10 parts. Because time is a constraint, the operators performed two trials; that is, each operator measured each part twice. The measurement data were entered into the ***Thickness*** variable.

To begin, open STATGRAPHICS *Plus* and the **Gage.sf** data file.

Setting Up Data Variables

1. Choose SPECIAL... QUALITY CONTROL... GAGE R&R... DATA SETUP... from the Menu bar to display the Analysis Setup dialog box.

2. Type ***10*** in the Number of Parts text box; leave the Randomize Trials check box blank; click the Default Operator Names text box to deselect that check box (see Figure 3-1).

3. Click OK to display the Operator Names Options dialog box.

4. Complete the dialog box so it looks like the one shown in Figure 3-2.

5. Click OK to display the Analysis Summary in the Analysis window. Maximize the Analysis Summary (see Figure 3-3).

   The Analysis summary shows the setup for the analysis. It displays the operator, part number, and trial number in tabular format.

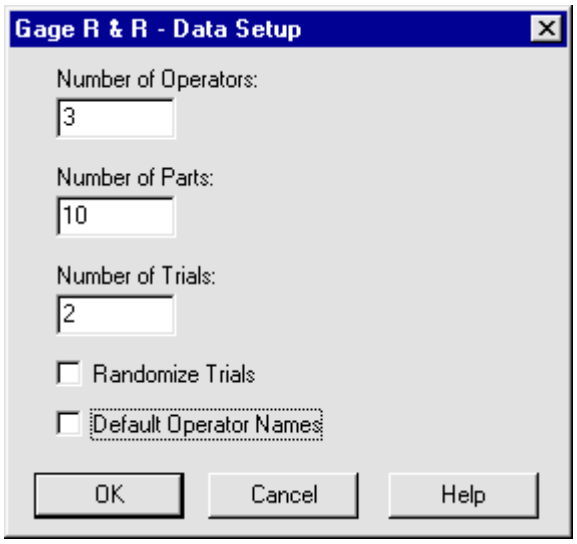

Figure 3-1. Completed Gage R&R Data Setup Dialog Box

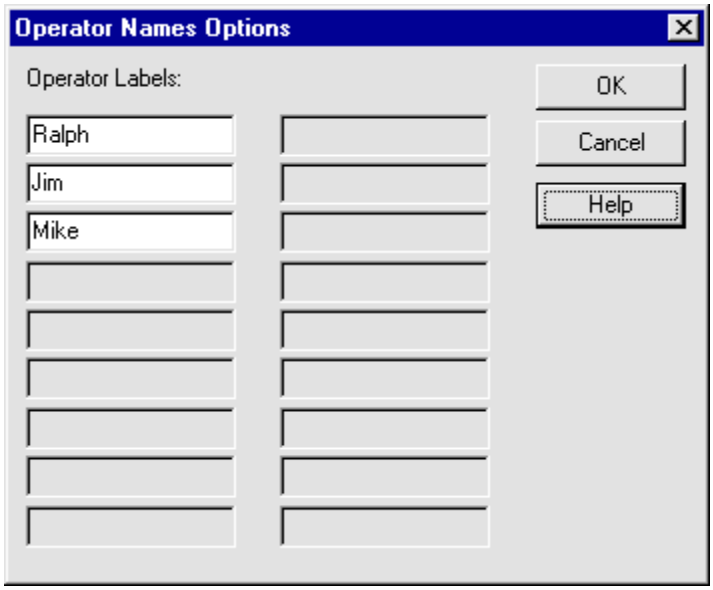

Figure 3-2. Completed Operator Names Options Dialog Box

Saving the Setup

1. Click the Save Results button on the Analysis toolbar (the fourth button from the left) to display the Save Results Options dialog box.

2. Click the following check boxes: Operators, Parts, and Trials. Your dialog box should look like the one shown in Figure 3-4.

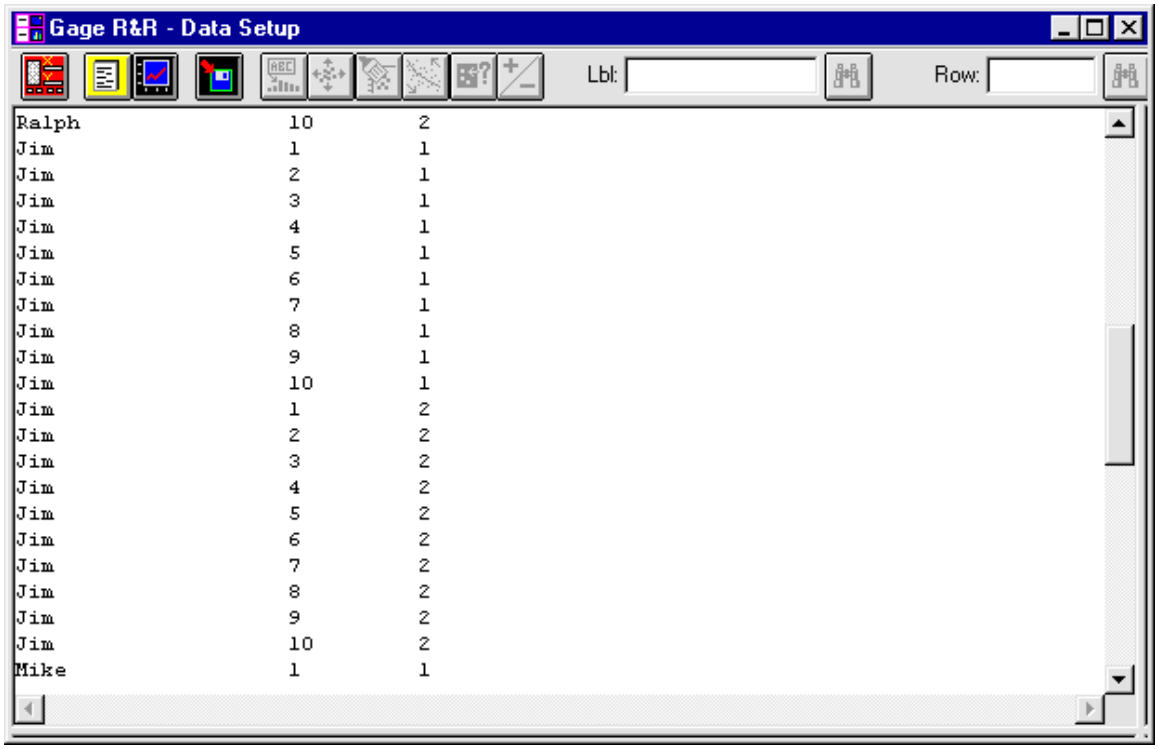

Figure 3-3. Data Setup Report

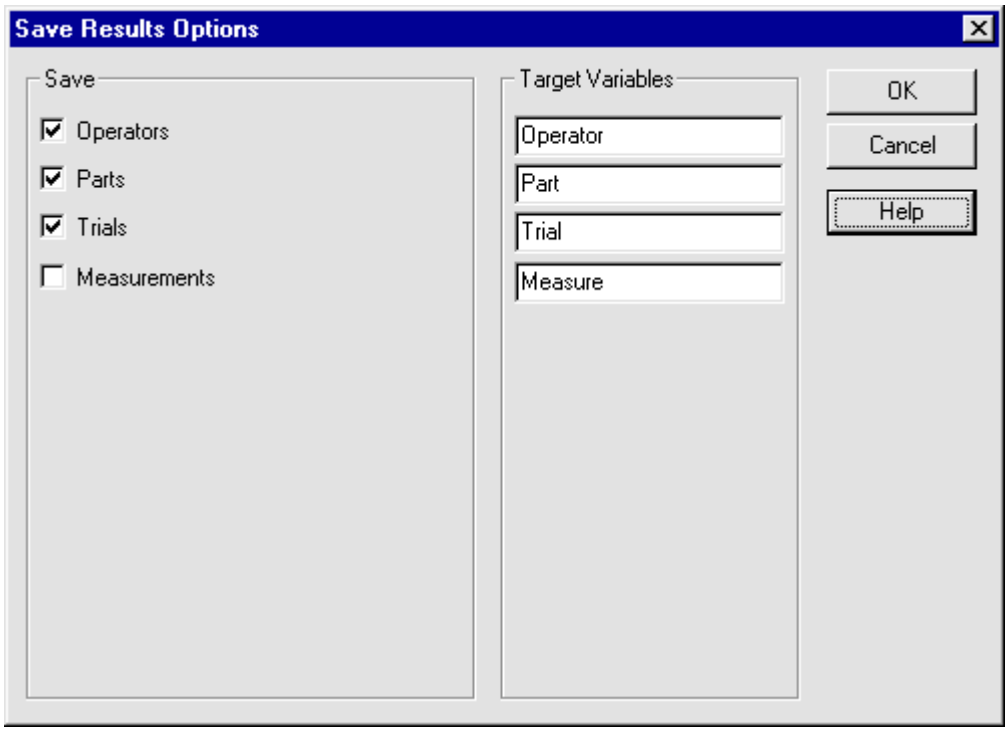

Figure 3-4. Save Results Options Dialog Box with Options for Data Setup

3. Click OK to save the data setup and redisplay the Analysis Summary.

   You are now ready to perform the analysis.

   There are three types of methods you can use to perform a Gage R&R analysis: the Average and Range Method, Range Method, and ANOVA Method. You will use the Average and Range Method

Performing an Average and Range Method Analysis

1. Choose SPECIAL... QUALITY CONTROL... GAGE R&R... AVERAGE AND RANGE METHOD... from the Menu bar to display the Average and Range Method dialog box.

2. Enter **Operator** into the Operators text box.

3. Enter **Part** into the Parts text box.

4. Enter **Trial** into the Trials text box.

5. Enter **Thickness** into the Measurements text box. The dialog box should look like the one shown in Figure 3-5.

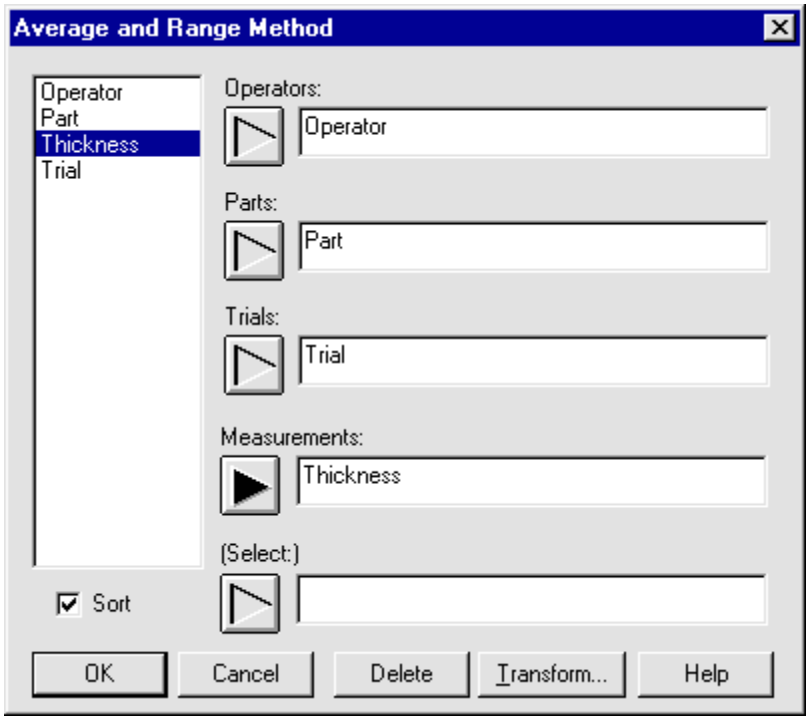

Figure 3-5. Completed Dialog Box for the Average and Range Method

6. Click OK to display the Analysis Summary and Operator and Part Plot in the Analysis window. Maximize the Analysis Summary.

   The Analysis Summary displays the names of the variables and the following statistics: Estimated Sigma, Estimated Variance, and Percent of Total. The Percent of Total shows how much of the total estimated variance can be attributed to repeatability versus reproducibility.

7. Click the Tabular Options button to display the dialog box, then click the Gage Report option, and OK to display the Gage Report (see Figure 3-6).

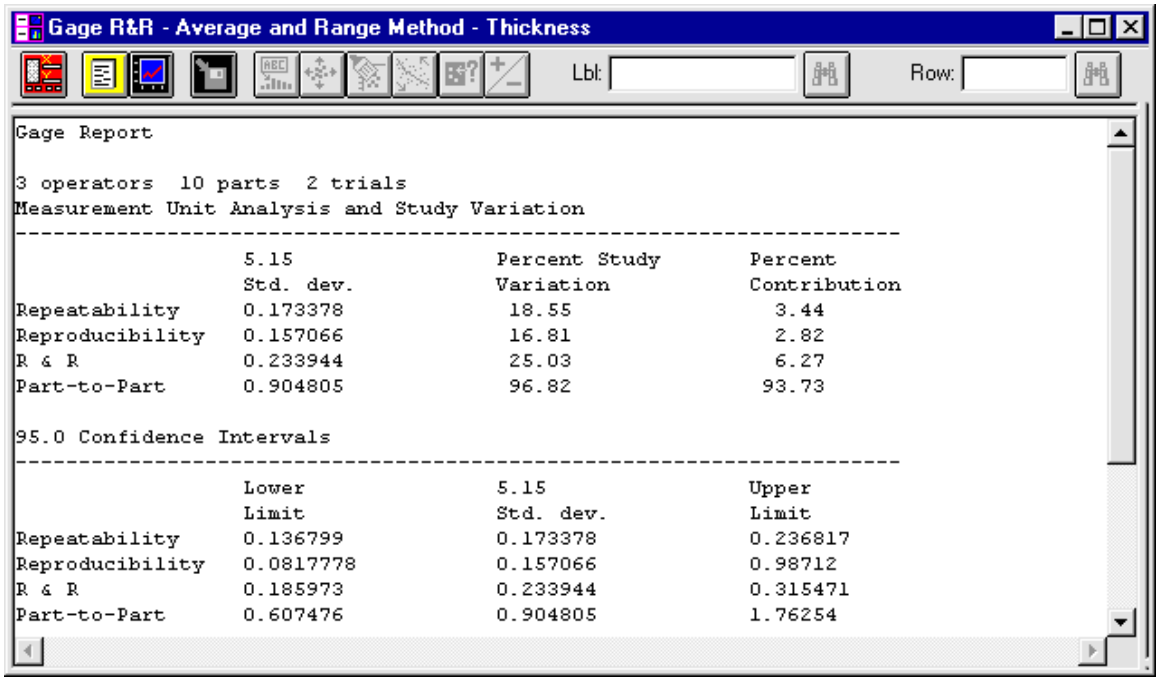

Figure 3-6. The Gage Report

The Gage Report shows that the R&R Percent of Tolerance and Percent of Process Sigma are larger than 30 percent, which indicates that the gage measurement process needs considerable improvement. You will use the Average and Range Method Options to change these statistics.

8. Click the left mouse button on the report pane, then the right on Analysis Options to display the Average and Range Method Options dialog box.

9. Type ***.04*** in the Tolerance text box.

   This is the tolerance for the thickness of the gasket and is calculated by subtracting the lower specification from the upper specification.

10. Accept the default in the Sigma Intervals text box.

11. Type ***.05*** in the Process Sigma text box.

This value represents the estimated process sigma required to produce the gaskets.

12. Accept the default in the Confidence Levels text box.

The dialog box should now look like the one shown in Figure 3-7.

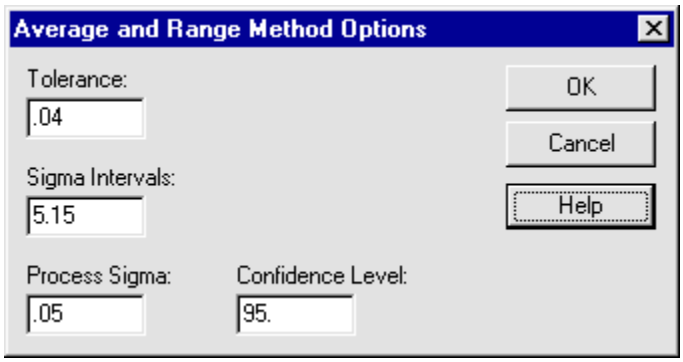

Figure 3-7. Completed Average and Range Method Options Dialog Box

13. Click OK to process the changes and redisplay the report.

Use the vertical scroll bar on the right side of the report to see it in its entirety. A plot of the data illustrates the results.

14. Click the Graphical Options button to display the dialog box, then click these options: Range Chart by Part and R&R Plot. The Operator and Part Plot option should already be checked.

15. Click OK to display the three plots in the Analysis window. Look at each one separately by maximizing it (see Figures 3-8, 3-9, 3-10).

The Operator and Part Plot in Figure 3-8, shows the difference in the measurements taken by each operator on the same part. The differences are the reasons for reproducibility taking up such a large percentage of the tolerance and process sigma.

The Range Chart by Part in Figure 3-9, plots the ranges for each part, grouped by each operator.

The R&R Plot in Figure 3-10, illustrates repeatability and reprodicibility, with one box for each operator.

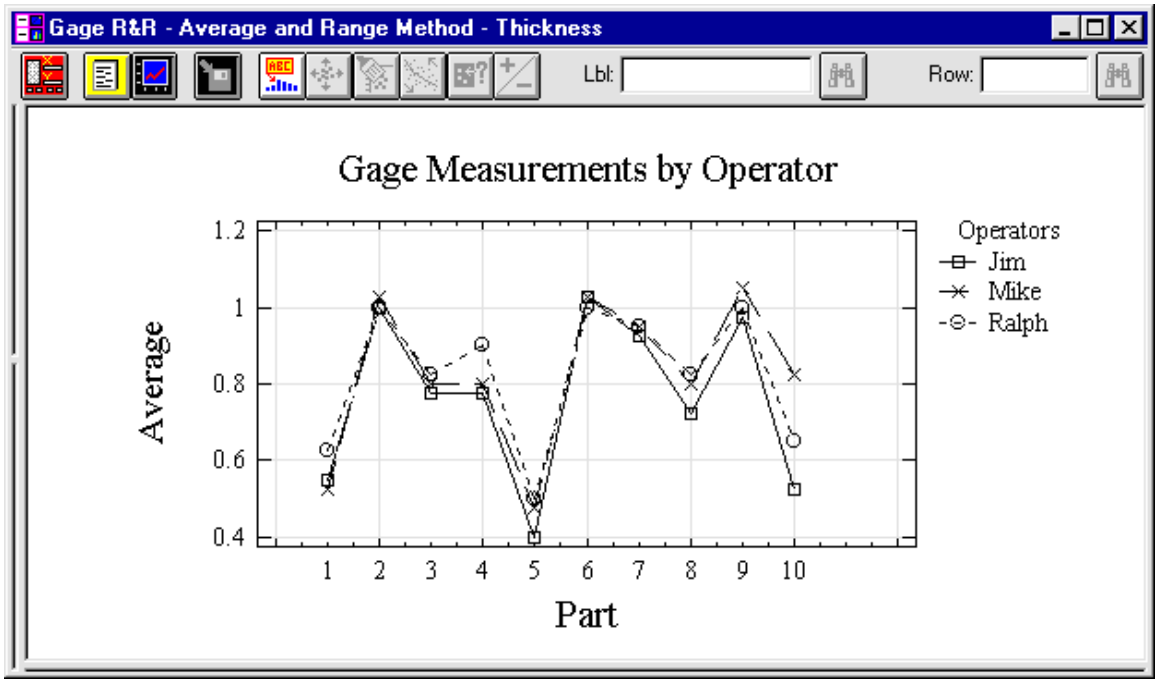

Figure 3-8. Operator and Part Plot

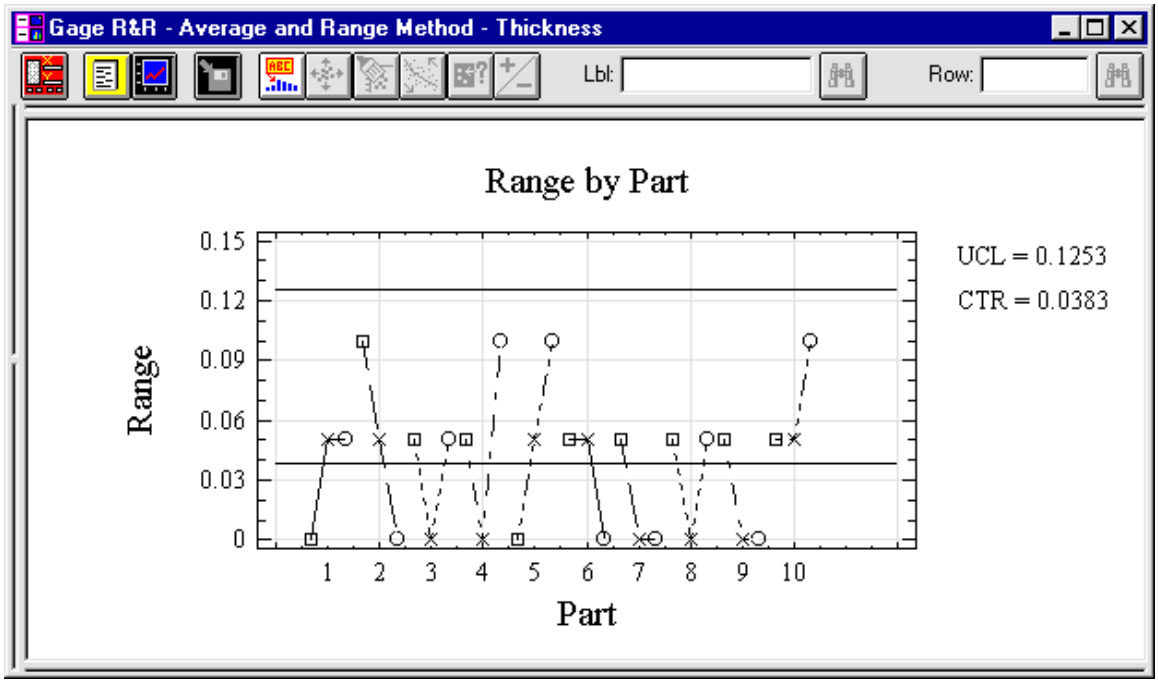

Figure 3-9. Range Chart by Part

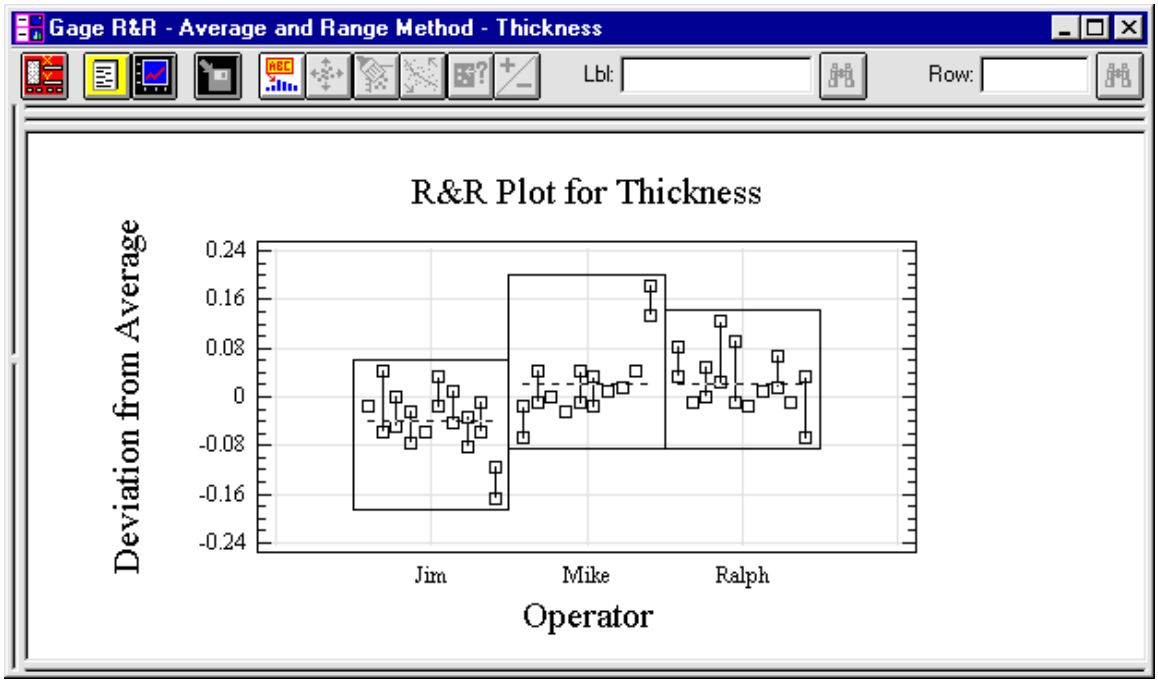

Figure 3-10. R&R Plot

The plots show that operator skill and the quality of the gage (part) each contribute to the variation. Additional training for the three operators and an investigation to locate better gages might be undertaken to improve accuracy.

References

AIAG. 1990. *Measurement System Analysis Reference Manual*. AIAG: Troy, Michigan.