Appendix A
The GAGE Application

Appendix Table of Contents

Appendix A
The GAGE Application

This appendix describes the GAGE application, which is a tool for assessing gage repeatability and reproducibility (R&R). The GAGE application is available with Release 6.10 of the SAS/QC Sample Library.

Introduction

Measurement systems are essential to the quality of a manufacturing process. The gages or instruments that take measurements are subject to variation. Too much variation in the measurement system may mask variation in the process.

One type of measurement variation is caused by conditions inherent in gages. This variation, known as repeatability, is obtained when one person measures the same characteristic several times with the same gage. Another type of measurement variation, known as reproducibility, occurs when different individuals measure the same characteristic with the same gage. Other sources of measurement variation include part-to-part variation, accuracy, stability, and linearity.

Two graphical methods for evaluating the measurement system are range charts and average charts. Range charts assess repeatability by showing whether the gage variability is consistent. Average charts show consistency of operator variability (reproducibility) and part-to-part variation.

Two statistical approaches to determining gage R&R are the average and range method and the variance components method. The variance components method can provide more information, is more accurate, and is more flexible than the average and range method.

The GAGE application makes it easy for you to enter your data, create range and average charts, and determine gage R&R. Whether you use the average and range method or the more powerful variance components method, the GAGE application reports the results in a standard form. It allows you to save the graphs for later reference, and it allows you to save the reports. You can save the data in a SAS data set for subsequent gage analysis or for more extensive analysis using other components of the SAS System. Because gage R&R techniques are open to local interpretation, this application has been designed so that it can be modified to suit the needs of your company.

Terminology

The following definitions describe the terms used in a gage R&R study.

Gage	any device used to obtain measurements, for example, a micrometer or a gasket thickness gage.
Condition	typically an operator, but can be thought of more generically as any condition affecting the measurements. For example, with an automated process, condition might be a set-up procedure or an environmental condition such as temperature. For the remainder of this appendix, condition is referred to as operator.
Trial	a set of measurements on all parts taken by one operator. Multiple trials help separate the gage variability (repeatability) from the variability contributed by operators (reproducibility).
Part	the item that is measured, for example, a gasket. The parts selected should represent the entire operating range (variability) of the process.
Measurement System	the complete process used to obtain measurements. This includes people, gages, operations, and procedures.
Repeatability	the variation resulting from repeated measurements taken on the same part with the same gage by the same operator. Repeatability is the gage or equipment variation.
Reproducibility	the variation in the average of the measurements resulting when different operators using the same gage take measurements on the same part. Reproducibility is the operator-to-operator variability.

Getting Started

Suppose that ABC Company needs to evaluate a gasket thickness gage. Three operators (George, Jane, and Robert) are selected for this study. Using the same gage, each operator measures ten parts (gaskets) in a random order. Each part is measured by each operator twice (two trials). Table A.1 gives the measurements (gasket thicknesses) collected by each operator and is patterned after an example given in *Measurement Systems Analysis Reference Manual* (1990).

Table A.1. Gage Study Data

	George		**Jane**		**Robert**	
Part	Trial1	Trial2	Trial1	Trial2	Trial1	Trial2
1	0.65	0.60	0.55	0.55	0.50	0.55
2	1.00	1.00	1.05	0.95	1.05	1.00
3	0.85	0.80	0.80	0.75	0.80	0.80
4	0.85	0.95	0.80	0.75	0.80	0.80
5	0.55	0.45	0.40	0.40	0.45	0.50
6	1.00	1.00	1.00	1.05	1.00	1.05
7	0.95	0.95	0.95	0.90	0.95	0.95
8	0.85	0.80	0.75	0.70	0.80	0.80
9	1.00	1.00	1.00	0.95	1.05	1.05
10	0.60	0.70	0.55	0.50	0.85	0.80

These data are used to illustrate the GAGE application throughout this appendix.

Invoking the GAGE Application

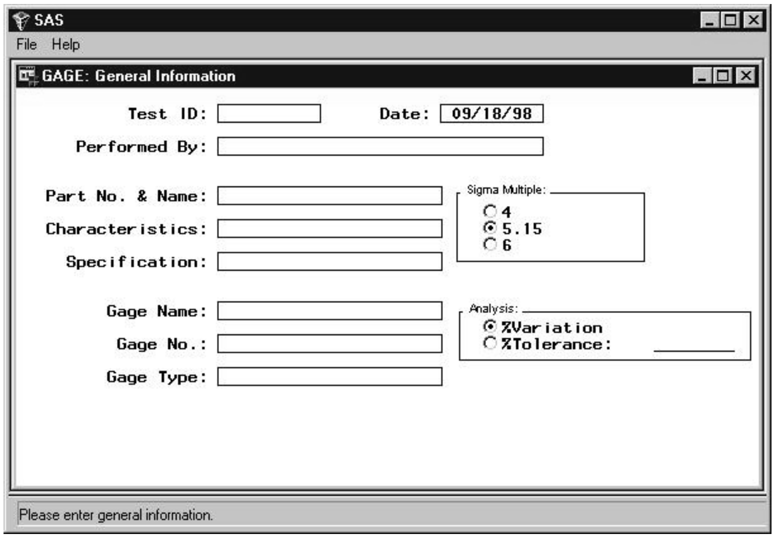
The interface to the GAGE application was implemented using FRAME entries in SAS/AF software. The application is stored in the gage catalog. (File extensions for SAS catalogs differ based on the operating system.)

Assume that you are using the SAS System under Microsoft Windows and that the SAS/QC Sample Library is stored in the c:\sas\qc\sample directory. (Check with your SAS site representative for the location of the Sample Library on your system.) You invoke the application as follows:

1. First you must tell the SAS System where the catalog is stored:
```
libname gage 'c:\sas\qc\sample';
```
2. You then issue the following command from any SAS display manager window:
```
af c=gage.gage.gage.frame
```

The main window in the application appears, as shown in Display A.1.

Display A.1. General Information Window



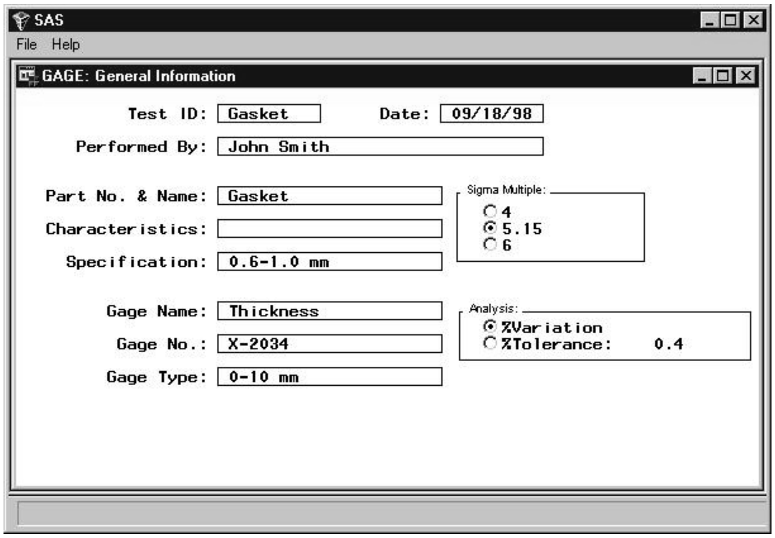
You specify the following general information for your gage study in this window: who performed the study, part number and part name, characteristics, specification, and gage name, number, and type.

The test ID is required for each set of data to be analyzed. It uniquely identifies each gage study. Date is set to the current date and can be changed. You also select either the percent of process variation analysis (%Variation) or the percent of tolerance analysis (%Tolerance). You must specify a tolerance value for the percent of tolerance analysis.

Set the multiple of sigma to whatever level you use for gage studies. This multiple may be a standard level established within your organization. For example, the automotive industry typically uses 5.15σ (ASQC Automotive Division/AIAG 1990), and SEMATECH uses 6σ (SEMATECH, Inc. 1991).

The general information for the gasket thickness gage example is entered, as shown in Display A.2.

Display A.2. General Information for Gage Study

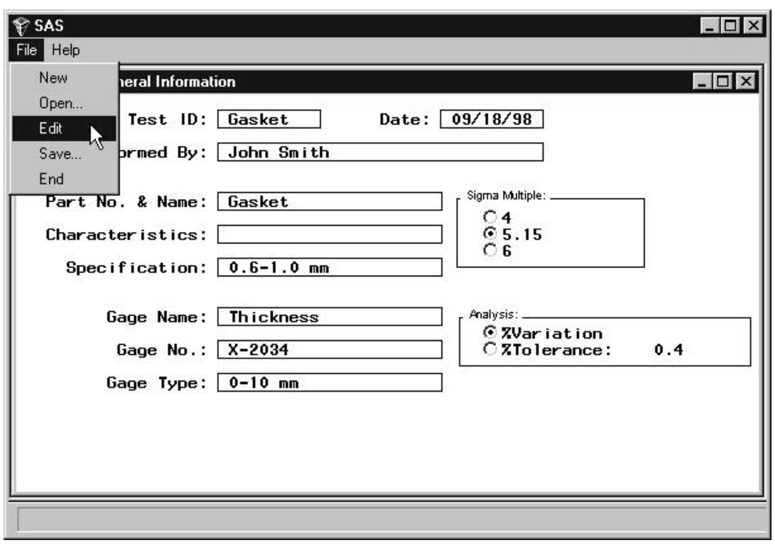


This study is identified with the test ID Gasket. The analysis is based on 5.15σ, and a percent of tolerance analysis based on a tolerance of 0.4mm is requested.

Entering Data

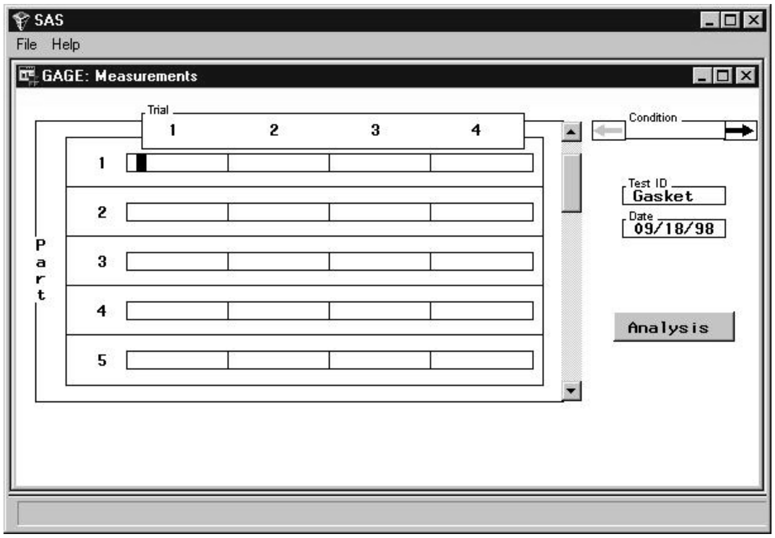
The next step is to enter the data provided in Table A.1. In the General Information window, choose Edit from the File menu, as shown in Display A.3.

Display A.3. Choosing Edit from the File Menu



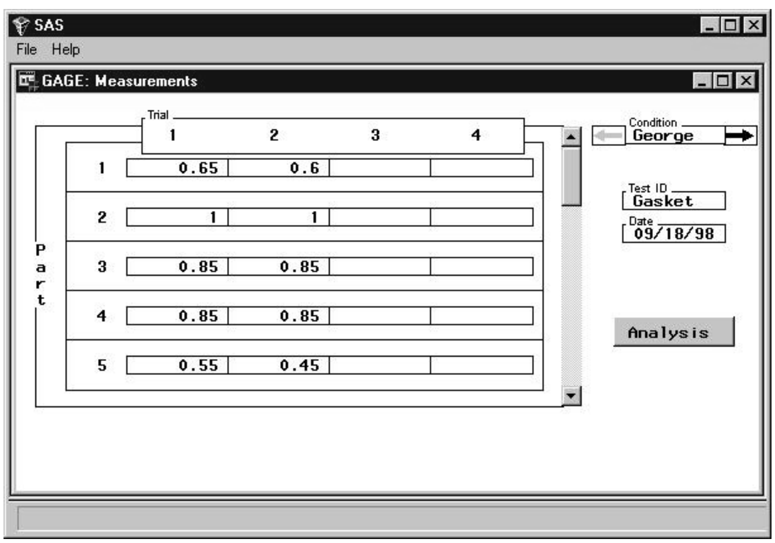
The Measurements window appears, as shown in Display A.4.

Display A.4. Measurements (Data Entry) Window



Enter data for one operator (Condition) in this window only. Only five parts are displayed at one time. Use the scroll bar to move the data region vertically. The first operator is George, whose measurements for parts1-5 are shown in Display A.5.

Display A.5. Measurements for Operator George

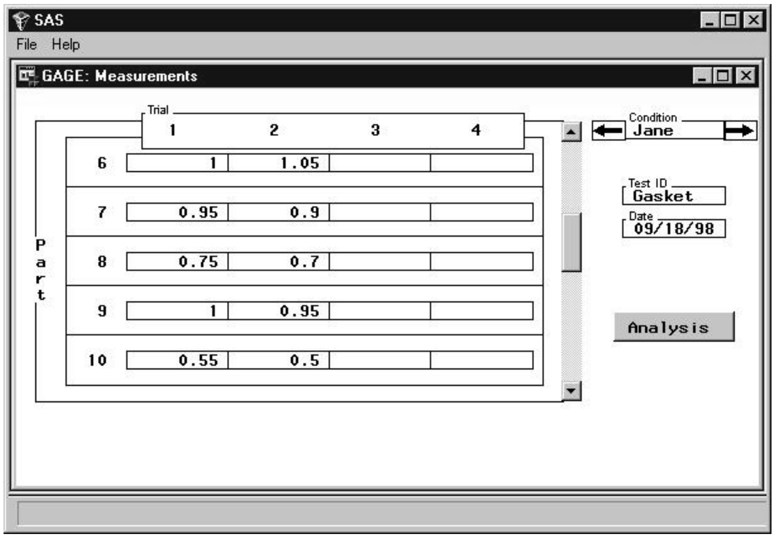


To enter the next operator's measurements, press the arrow ⇒ to the right of Condition. An empty Measurements window similar to Display A.4 appears.

The second operator is Jane. Her measurements for parts 6–10 are shown in Display A.6.

Data for the third operator are entered similarly. Press the arrow ⇐ to the left of Condition to move to the previous operator.

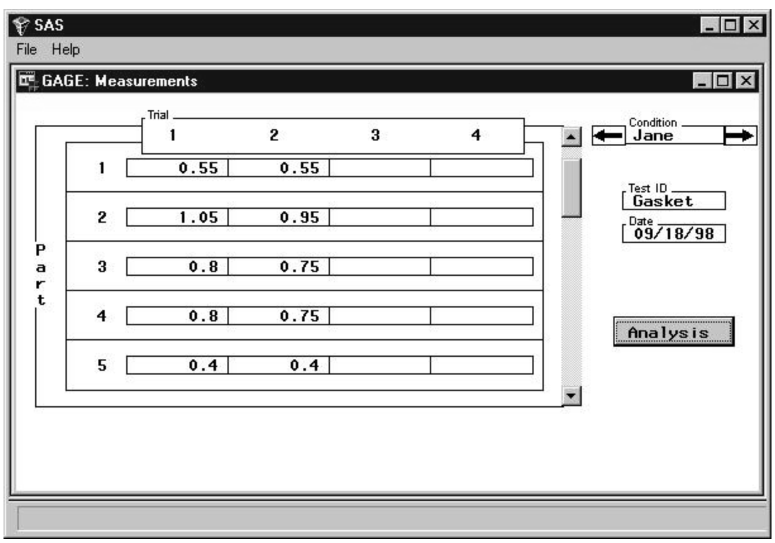
Display A.6. Measurements for Operator Jane



Performing a Range Chart Analysis

Now that the data are entered, the gage variability (repeatability) can be checked for consistency. This is done graphically with a range chart. Press the Analysis button in the Measurements window. A menu of analysis options appears, as shown in Display A.7.

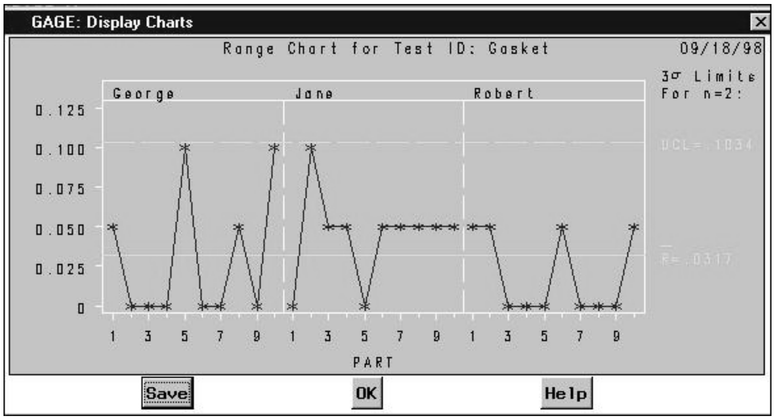
Display A.7. Analysis Button Options



Select Range Chart. The range chart of the data is displayed, as shown in Display A.8.

No points are out-of-control, and the variability across operators is fairly comparable. This indicates that all operators are using the gage in the same way. If there were any out-of-control points, they should be investigated and dealt with before proceeding.

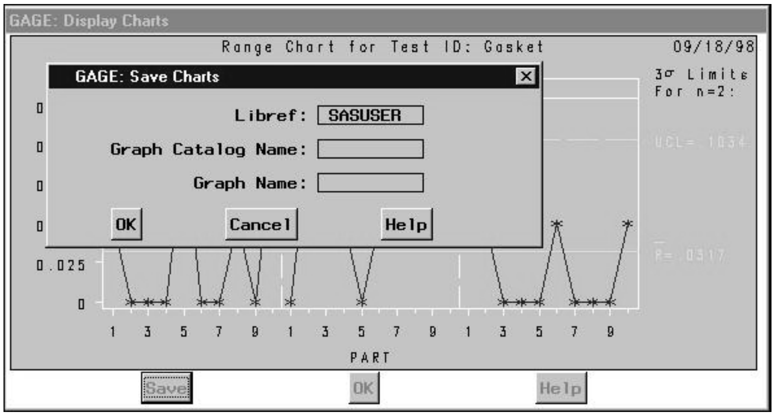
Display A.8. Range Chart for Gage Study Gasket



You can save this chart in a SAS graphics catalog. Then you can use the GRAPH window or the GREPLAY procedure to view charts stored in the catalog. You also can create hard-copy versions of charts stored in the catalog.

Press the Save button to save the range chart. The Save Charts window appears, as shown in Display A.9.

Display A.9. Saving the Range Chart



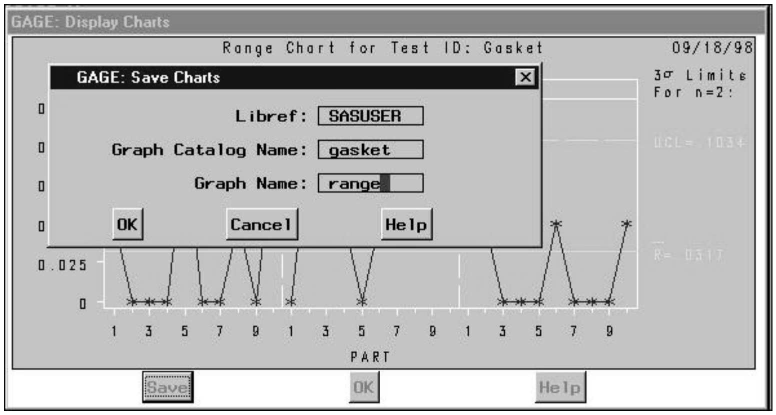
Libref
tells the SAS System where to store the SAS graphics catalog. The libref SASUSER stores the catalog in the SASUSER data library, which is created automatically by the SAS System. You must assign other libref locations with the LIBNAME statement.

Graph Catalog Name
is the name of the SAS graphics catalog in which to store the chart.

Graph Name
is the name of this range chart when stored in the SAS graphics catalog.

Display A.10 shows that the range chart is to be stored in SASUSER.GASKET.RANGE.

Display A.10. Saving the Range Chart



Press the [Cancel] button if you decide not to save the chart. Press the [OK] button to save the chart.

You return to the window displaying the range chart. Press the [OK] button to leave the Display Charts window.

Refer to SAS/GRAPH documentation for more information on SAS graphics catalogs, the GRAPH window, and the GREPLAY procedure.

Performing an Average Chart Analysis

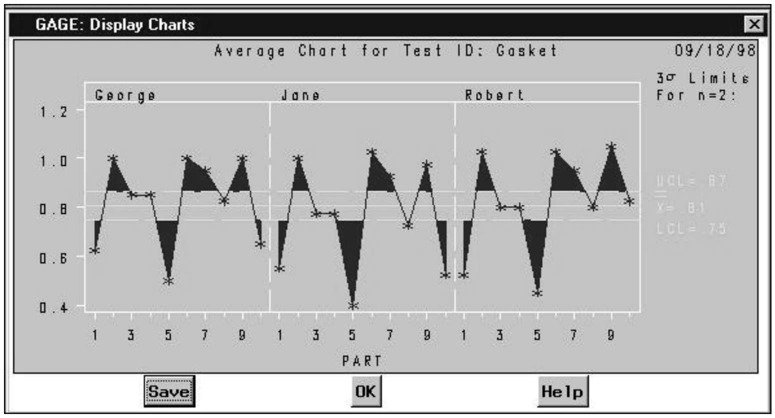
The average chart shows operator variability (reproducibility) and part-to-part variation. Press the [Analysis] button in the Measurements window and select Average Chart. The average chart of the data is displayed, as shown in Display A.11.

Note how most of the averages are beyond the control limits. Also, the out-of-control averages tend to be the same for each operator. This indicates that this study can detect part-to-part variation. If the averages were not outside the control limits, the part-to-part variation would be hidden in the gage variation.

Operator variability can be seen on the average chart by comparing the operator averages for each part. These averages will differ when there is variability.

Note that this is not a standard use of the Shewhart chart. Ordinarily the fact that the points fall outside the control limits would raise concerns that the process is out of control, but here the opposite conclusion is drawn.

Display A.11. Average Chart for Gage Study Gasket



You can save the average chart by pressing the Save button, as described for the range chart. Press the OK button to leave this window.

Selecting a Statistical Method

The range chart indicates that the gage variability is consistent. The average chart indicates that the measurement system is adequate to detect part-to-part variation. Now you can perform a statistical analysis. Which analysis method should you choose: average and range, or variance components?

Since the data for this study are balanced (no data points are missing), the average and range method can be used. But it is not as efficient as the variance components method, and it does not provide information about the interaction between operators and parts. Both methods will be shown to illustrate some of these differences.

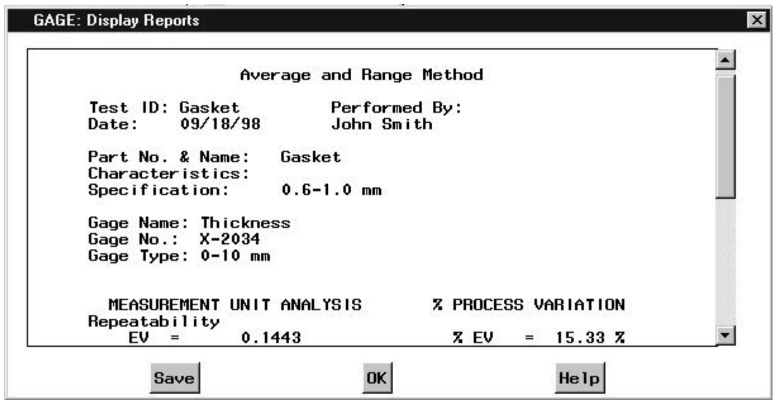
Performing an Average and Range Analysis

Press the Analysis button in the Measurements window and select Average/Range Method. The results are displayed, as shown in Display A.12. You can scroll the report with the vertical scroll bar.

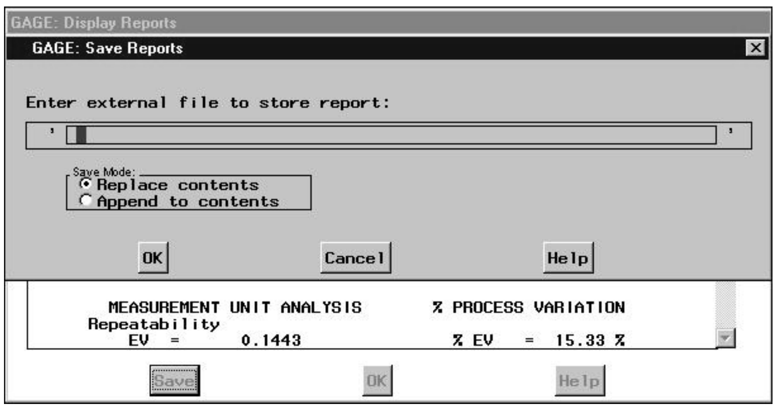
The complete listing of these results is shown in Figure A.4 on page 1828. A percent of tolerance analysis (against a tolerance value of 0.4mm) was requested in the General Information window. This appears on the right side of the report.

As with the charts, you can save this report in a file. Press the Save button to save the report. The Save Reports window appears, as shown in Display A.13.

Display A.12. Average and Range Analysis of Gage Study Gasket



Display A.13. Saving the Average and Range Report



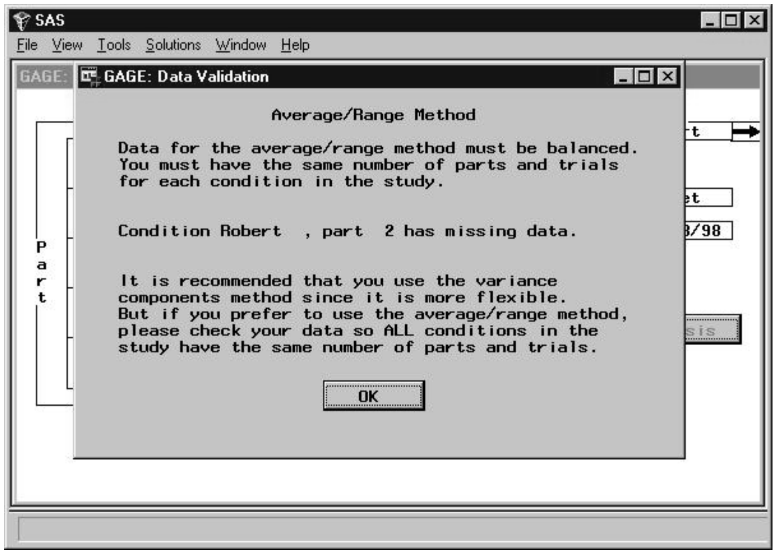
You enter the name of the file in which to store the report. You can select to have this listing replace what is currently in the file (if it exists) or be appended to the information stored in the file.

Press the Cancel button if you decide not to save the report. Press the OK button to save the report.

You return to the window displaying the average and range report. Press the OK button to leave the Display Reports window.

What would happen if you chose this method and there were missing data? Assume that operator Robert was unable to take the second measurement on the second part, and that data point is missing. If you run the average and range method on these data, you receive the message window shown in Display A.14.

Display A.14. Average and Range Message Window

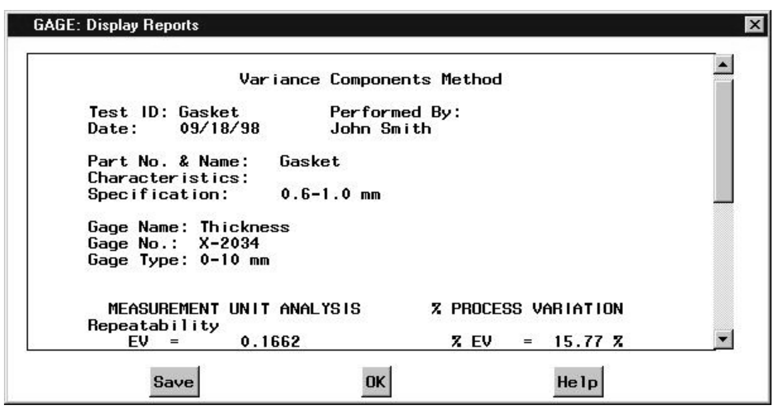


The variance components method can be used for these data.

Performing a Variance Components Analysis

Now perform a variance components analysis on the original data. Press the Analysis button in the Measurements window and select Variance Components. The results are displayed, as shown in Display A.15.

Display A.15. Variance Components Analysis of Gage Study Gasket



The complete listing of these results is shown in Figure A.5 on page 1829. Note that the results you get using the variance components method differ slightly from those you get using the average and range method (see “Variance Components Method” on page 1828).

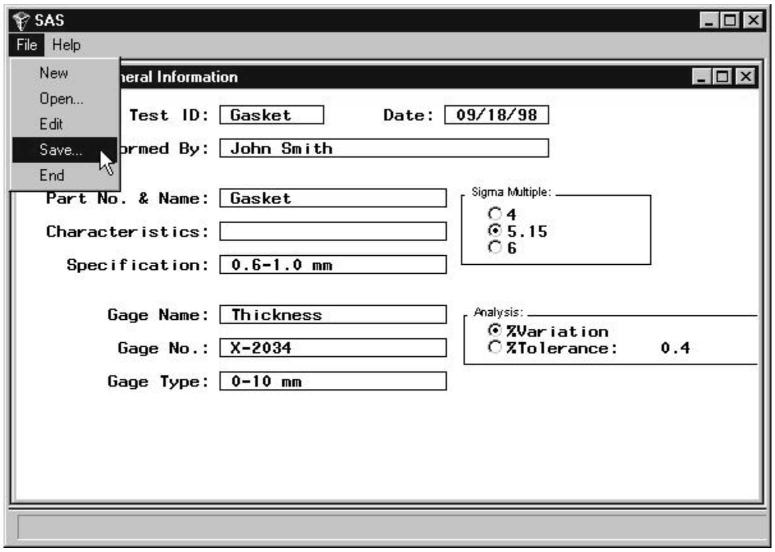
You can save this report by pressing the Save button, as described for the average and range analysis. Press the OK button to leave this window.

Saving the Data

Now that you have entered the data and performed analyses, you can save the data in a SAS data set for later analysis. You save the data by choosing Save from the File menu in either the Measurements window or the General Information window.

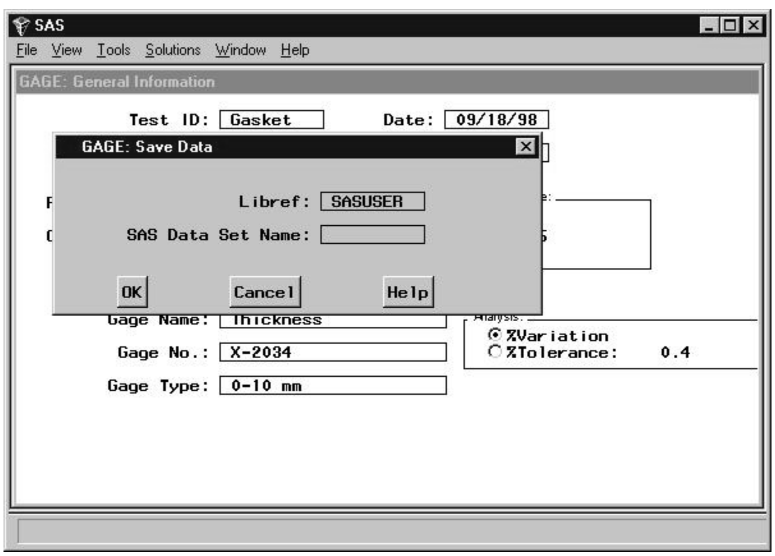
Choose End from the File menu in the Measurements window to return to the General Information window. Then choose Save from the File menu, as shown in Display A.16.

Display A.16. Choosing Save from the File Menu



The Save Data window appears, as shown in Display A.17.

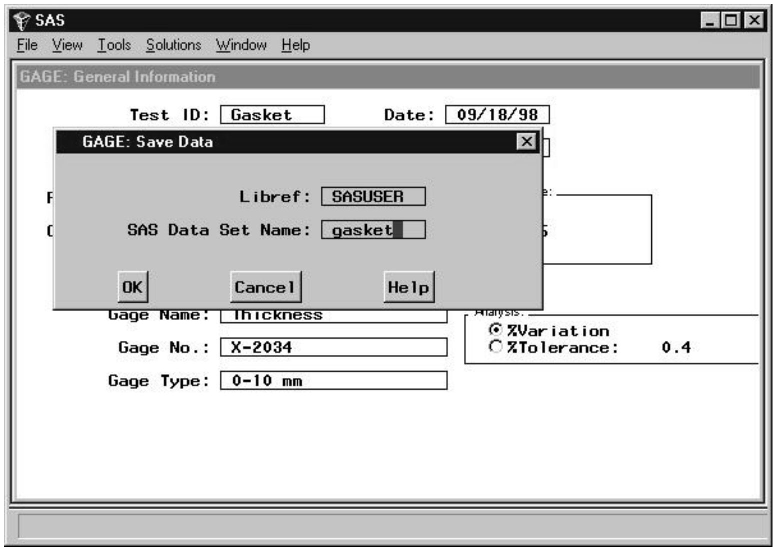
Display A.17. Saving the Data in a SAS Data Set



Libref	tells the SAS System where to store the SAS data set. The libref SASUSER stores the data set in the SASUSER data library, which is created automatically by the SAS System. You must assign other libref locations with the LIBNAME statement.
SAS Data Set Name	is the name of the SAS data set in which to store the data.

Display A.18 shows that the data are to be stored in SASUSER.GASKET.

Display A.18. Saving the Data in a SAS Data Set



Press the Cancel button if you decide not to save the data. Press the OK button to save the data.

You return to the General Information window.

Entering Another Set of Data

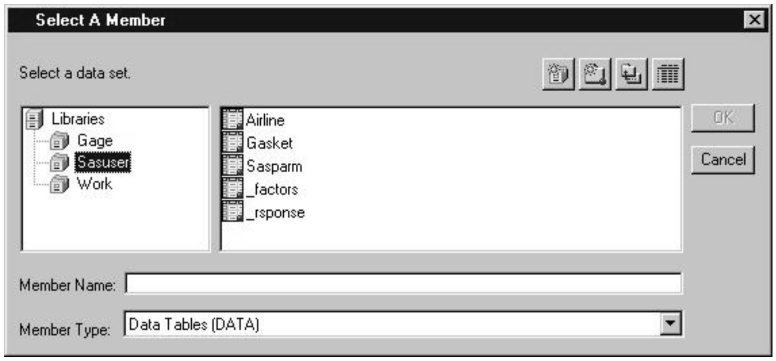
Suppose you have more than one gage study to analyze. You need to clear the current data before entering the new information. You do so by choosing New from the File menu in the General Information window.

Reading Data from a Data Set

You can save your gage study data in a SAS data set, but how do you bring it back in for further analysis?

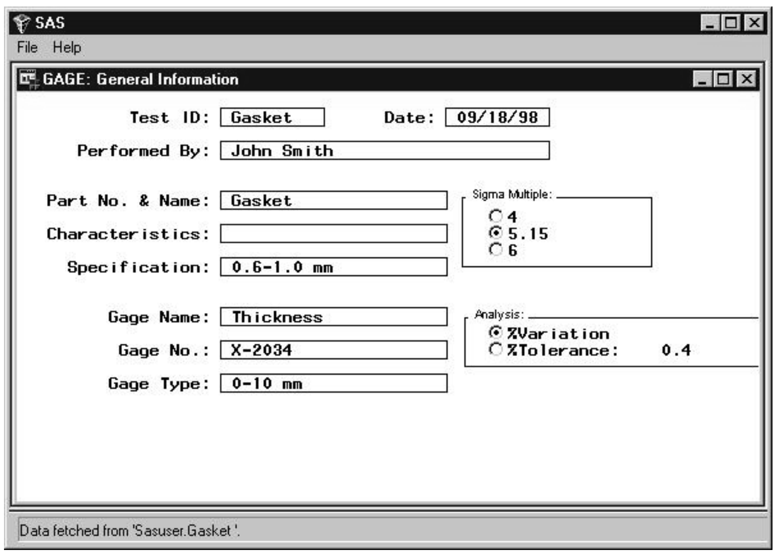
Choose Open from the File menu in the General Information window to read data into the GAGE application. A directory of available SAS data sets appears, as shown in Display A.19.

Display A.19. Selecting a SAS Data Set



Select the data set name from the list. The general information associated with the data is displayed, as shown in Display A.20.

Display A.20. Data Read from a SAS Data Set



Note: The GAGE application reads only SAS data sets that you have previously created using the application.

Details

Range Chart

The range chart is a graphical method for assessing repeatability. It indicates whether the gage variability is consistent. The ranges for each part and each operator are displayed, as shown in Figure A.1.

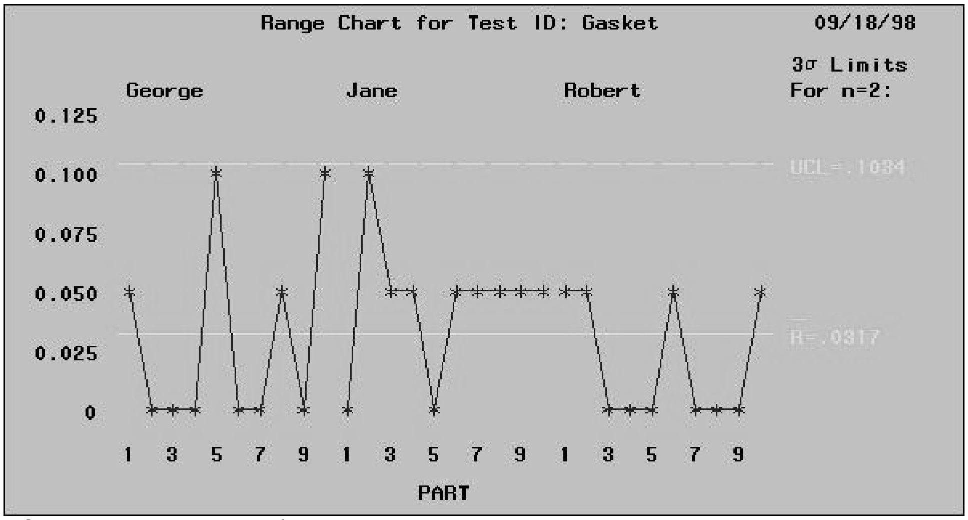


Figure A.1. Range Chart

For example, in Table A.1 on page 1811 the range for operator George, part 1 is calculated as $0.65 - 0.60 = 0.05$. Similarly computed ranges are displayed for each operator and each part.

You should investigate out-of-control points and deal with them before proceeding. If you notice that one operator's ranges are out of control, it implies that his technique differs from the others. If all operators have some out-of-control ranges, you might conclude that operator technique is affecting the measurement system and investigate the need for training.

The range chart is created with the RCHART statement of the SHEWHART procedure. For further information, see Chapter 39, "RCHART Statement."

Average Chart

The average control chart shows both the consistency of operator variability (reproducibility) and part-to-part variation. The averages of the measurements for each part and each operator are displayed, as shown in Figure A.2.

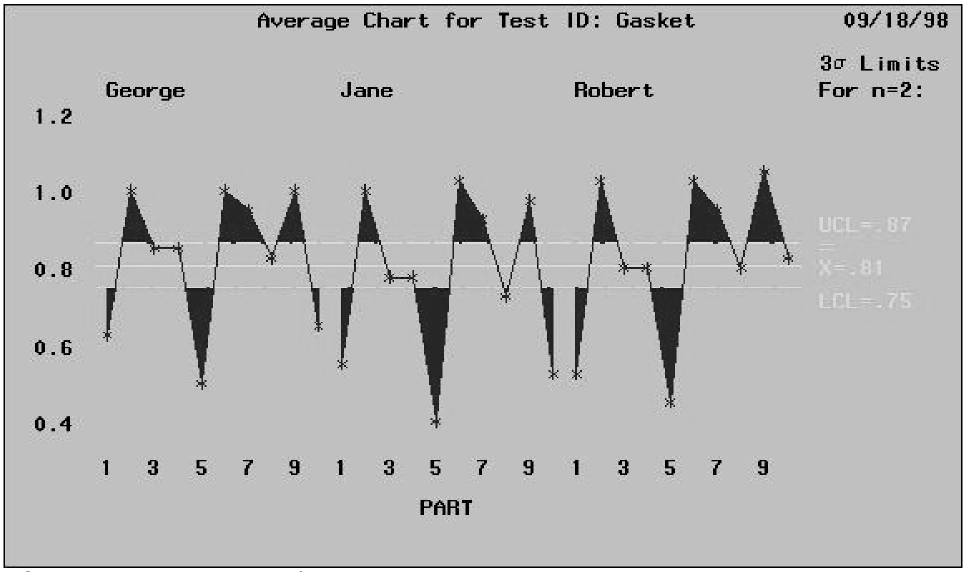


Figure A.2. Average Chart

For example, in Table A.1 on page 1811 the average for operator Jane, part 4 is calculated as $(0.80 + 0.75)/2 = 0.775$. Similarly computed averages are displayed for each operator and each part.

Operator variability can be seen by comparing the operator averages for each part. These averages will differ when there is variation.

The average chart also shows part-to-part differences. The averages should fall outside the control limits since the control limits are based on gage error (repeatability). If the averages do not fall outside the control limits, the part-to-part variation is hidden in the gage variation. The average chart shows the ability of the measurement system to measure parts. The measurement system is generally considered adequate if most of the averages fall outside the limits and if the out-of-control averages tend to be the same for each operator.

Note that this is not a standard use of the Shewhart chart. Ordinarily the fact that the points fall outside the control limits would raise concerns that the process is out of control, but here the opposite conclusion is drawn.

The average chart is created with the XCHART statement of the SHEWHART procedure. For further information, see Chapter 42, “XCHART Statement.”

Average and Range Method

The average and range method is widely used in industry because its calculations can be done by hand. It measures both repeatability and reproducibility for a measurement system.

All calculations described here are based upon a specified multiple of σ, where the multiple ν can be 4, 5.15, or 6. Figure A.3 shows a sample gage report created with the GAGE application using the average and range method.

The measure of repeatability (or equipment variation), denoted by EV, is calculated as

$$EV = \overline{R} \times K_1$$

where $\overline{R}$ is the average range and K_1 is the adjustment factor

$$K_1 = \frac{\nu}{d_2}$$

```
                Average and Range Method

    Test ID: Gasket          Performed By:
    Date:    09/18/98        John Smith

    Part No. & Name:   Gasket
    Characteristics:
    Specification:     0.6-1.0 mm

    Gage Name: Thickness
    Gage No.:  X-2034
    Gage Type: 0-10 mm


      MEASUREMENT UNIT ANALYSIS       % PROCESS VARIATION
    Repeatability
        EV  =      0.1443              % EV   =  15.33 %
    Reproducibility
        AV  =      0.1516              % AV   =  16.11 %
    Gage R&R
        R&R =      0.2093              % R&R  =  22.24 %
    Part Variation
        PV  =      0.9177              % PV   =  97.50 %
    Total Variation
        TV  =      0.9413


         Results are based upon predicting 5.15 sigma.
    (99.0% of the area under the normal distribution curve)
```

Figure A.3. Average and Range Method Sample Report

The quantity d_2 (Duncan 1974, Table M) depends on the number of trials used to calculate a single range. In the GAGE application, the number of trials can vary from 2 to 4. Use of d_2 is valid when $\#operators \times \#parts \geq 16$; otherwise, the GAGE application uses d_2^* (Duncan 1974, Table D3), which is based on the number of ranges calculated from $\#operators \times \#parts$ and on the number of trials.

The measure of reproducibility (or appraiser variation), denoted by AV, is calculated as

$$AV = \sqrt{(\overline{X}_{diff} \times K_2)^2 - \frac{(EV)^2}{nr}}$$

where $\overline{X}_{diff}$ is the difference between the maximum operator average and the minimum operator average, K_2 is the adjustment factor

$$K_2 = \frac{\nu}{d_2^*}$$

n is the number of parts, and r is the number of trials. Reproducibility is contaminated by gage error and is adjusted by subtracting $(EV)^2/nr$. The quantity d_2^* (Duncan 1974, Table D3) depends on the number of operators used to calculate a single range. In the GAGE application, the number of operators can vary from 1 to 4. When there is only one operator, reproducibility is set to zero.

The measure of repeatability and reproducibility, denoted by $R\&R$, is calculated as

$$R\&R = \sqrt{(EV)^2 + (AV)^2}$$

Part-to-part variation, denoted by PV, is calculated as

$$PV = R_p \times K_3$$

where R_p is the range of part averages and K_3 is the adjustment factor

$$K_3 = \frac{\nu}{d_2^*}$$

Here the quantity d_2^* (Duncan 1974, Table D3) depends on the number of parts used to calculate a single range. In the GAGE application, the number of parts can vary from 2 to 15.

Total variation, denoted by TV, is based on gage R&R and part-to-part variation.

$$TV = \sqrt{(R\&R)^2 + (PV)^2}$$

The measures of repeatability, reproducibility, gage R&R, part variation, and total variation are shown in Figure A.3 under the heading "MEASUREMENT UNIT ANALYSIS." The right-hand side of the report shows the "% PROCESS VARIATION" analysis, which compares the gage factors to total variation. The percent of total variation accounted for by each factor is calculated as follows:

$$\begin{aligned}
\%EV &= 100\left[\frac{EV}{TV}\right] \\
\%AV &= 100\left[\frac{AV}{TV}\right] \\
\%R\&R &= 100\left[\frac{R\&R}{TV}\right] \\
\%PV &= 100\left[\frac{PV}{TV}\right]
\end{aligned}$$

Note that the sum of these percentages does not equal 100%. You can use these percentages to determine whether the measurement system is acceptable for its intended application.

Instead of percent of process variation, your analysis may be based on percent of tolerance. For this you must specify a tolerance value. Then $\%EV$, $\%AV$, $\%R\&R$,

and $\%PV$ are calculated by substituting the tolerance value for TV (the denominator) in the preceding formulas. A sample report with “% TOLERANCE ANALYSIS” is shown in Figure A.4.

What is considered acceptable for $\%R\&R$? Barrentine (1991) gives the following guidelines:

10% or less	excellent
11% to 20%	adequate
21% to 30%	marginally acceptable
over 30%	unacceptable

In general, interpretation may be guided by local standards.

```
               Average and Range Method

    Test ID: Gasket         Performed By:
    Date:    09/18/98       John Smith

    Part No. & Name:   Gasket
    Characteristics:
    Specification:     0.6-1.0 mm

    Gage Name: Thickness
    Gage No.:  X-2034
    Gage Type: 0-10 mm                  Tolerance: 0.4


      MEASUREMENT UNIT ANALYSIS       % TOLERANCE ANALYSIS
    Repeatability
        EV  =      0.1443               % EV   =  36.08 %
    Reproducibility
        AV  =      0.1516               % AV   =  37.91 %
    Gage R&R
        R&R =      0.2093               % R&R  =  52.34 %
    Part Variation
        PV  =      0.9177               % PV   = 229.43 %
    Total Variation
        TV  =      0.9413


         Results are based upon predicting 5.15 sigma.
    (99.0% of the area under the normal distribution curve)
```

Figure A.4. Average and Range Method with % Tolerance Analysis

Variance Components Method

As an alternative to the average and range method, you can use the variance components method, which is a more powerful statistical technique for analyzing measurement error and other sources of variation in a gage study. Until recently, this method was underutilized for gage studies because it is computationally more difficult to carry out than the average and range method.

Moreover, the language of variance components analysis is alien to most engineers. To overcome this obstacle, the GAGE report for the variance components method is displayed in the same format as that of the average and range method. This format is a modification of the gage repeatability and reproducibility report given in *Measurement Systems Analysis Reference Manual* (1990). Figure A.5 is a sample GAGE report using the variance components method.

As with the average and range method, calculations for the variance components method are based upon a specified multiple of σ, where the multiple ν can be 4, 5.15, or 6.

The advantages of this method versus the average and range method are:

- Variance components are estimated more efficiently in a statistical sense.
- More information can be obtained, such as the interaction between operators and parts (see Figure A.5).
- There are fewer restrictions on the data.

```
               Variance Components Method

Test ID: Gasket         Performed By:
Date:    09/18/98       John Smith

Part No. & Name:   Gasket
Characteristics:
Specification:     0.6-1.0 mm

Gage Name: Thickness
Gage No.:  X-2034
Gage Type: 0-10 mm


  MEASUREMENT UNIT ANALYSIS       % PROCESS VARIATION
Repeatability
    EV  =      0.1662               % EV   =  15.77 %
Reproducibility
    AV  =      0.1483               % AV   =  14.06 %
Part x Condition
    IV  =      0.2423               % IV   =  22.98 %
Gage R&R
    R&R =      0.3291               % R&R  =  31.21 %
Part Variation
    PV  =      1.0016               % PV   =  95.00 %
Total Variation
    TV  =      1.0543


     Results are based upon predicting 5.15 sigma.
(99.0% of the area under the normal distribution curve)
```

Figure A.5. Variance Components Method Sample Report

The variance components method in the GAGE application uses the MIXED procedure in SAS/STAT software. The MIXED procedure fits mixed linear models, which are a generalization of the standard linear model used in the GLM procedure. Refer to *SAS/STAT User's Guide* for further information on PROC MIXED.

When there is only one operator, PART is a random effect. The MIXED procedure estimates the variance component for PART and for the residual variance (equipment variation) using restricted maximum likelihood (REML).

```
proc mixed;
   class part;
   model meas=;
   random part;
run;
```

When there is more than one operator, there are three random effects: OPERATOR, PART, and OPERATOR*PART. The MIXED procedure uses REML to estimate variance components for these and for the residual variance (equipment variation).

```
proc mixed;
   class operator part;
   model meas=;
   random operator part operator*part;
run;
```

The MIXED procedure creates a table of covariance parameter estimates, including

σ^2_{EV}	the variance component due to equipment variation
σ^2_{AV}	the variance component due to operator variation
σ^2_{IV}	the variance component due to the interaction of operators and parts
σ^2_{PV}	the variance component due to part variation

From these estimates, repeatability (EV), reproducibility (AV), the interaction of operators and parts (IV), and part variation (PV) are calculated.

$$\begin{aligned} EV &= \nu\sqrt{\sigma^2_{EV}} \\ AV &= \nu\sqrt{\sigma^2_{AV}} \\ IV &= \nu\sqrt{\sigma^2_{IV}} \\ PV &= \nu\sqrt{\sigma^2_{PV}} \end{aligned}$$

When using the variance components method, the measure of gage repeatability and reproducibility has another component, the interaction term.

$$R\&R = \sqrt{(EV)^2 + (AV)^2 + (IV)^2}$$

Total variation is calculated similar to the average and range method.

$$TV = \sqrt{(R\&R)^2 + (PV)^2}$$

The results you get using the variance components method will differ slightly from those you get using the average and range method. This is because the variance components method is more precise, and the variance components method incorporates an interaction term in the measure of gage R&R.

As with the average and range method, the right-hand side of the report can be a percent of process variation or a percent of tolerance. $\%EV$, $\%AV$, $\%IV$, $\%R\&R$, and $\%PV$ are calculated similar to the average and range method.

The variance components method is more flexible than the average and range method in terms of the data that it can handle. Data for the average and range method should be balanced with the same number of parts and trials for each operator in the study. For example, if your study is composed of two operators, two trials, and ten parts, each operator should have 20 measurements. If the measurement for operator one, trial two, part three is missing, the average and range method cannot compute the gage measures. However, the variance components method can handle such missing data.

The average and range method also requires that a minimum number of parts be collected depending on the number of operators and the number of trials. Otherwise, the estimates will be imprecise. This is another situation where the variance components method can be used.

Note: The flexibility of the variance components method does not imply that you should not use locally recommended procedures for setting up and collecting data for gage studies.

Only a subset of the capabilities of PROC MIXED is used in the GAGE application. The procedure is capable of analyzing much more sophisticated statistical models. For example, you could fit an extended model to study the variability among several gages.

Creating a Data Set Outside the GAGE Application

Note: This section assumes you have some knowledge of creating SAS data sets.

Suppose your gage study data are stored in an external file, and you want to use the GAGE application but do not want to type in the data. How do you create a SAS data set that can be read by the GAGE application?

Table A.2 lists the SAS variables needed for the general information and the measurements in a GAGE data set.

Table A.2. GAGE Data Set Variables

Description	Variable			
	Name	**Type**	**Length**	**Values**
Test ID	TESTID	character	8	
Date	DATE	numeric	8	
Performed By	WHO	character	30	
Part No. & Name	PART	character	20	
Characteristics	CHAR	character	20	
Specification	SPEC	character	20	
Gage Name	GAGENAME	character	20	
Gage No.	GAGENO	character	20	
Gage Type	GAGETYPE	character	20	
Sigma Multiple	SPREAD	numeric	8	4, 5.15, 6
Analysis	PTYPE	character	1	T, V
Tolerance	TOL	numeric	8	
Operator (condition)	CONDITN	character	8	
Part	SAMPLE	numeric	8	1–15
Trial 1	TRIAL1	numeric	8	
Trial 2	TRIAL2	numeric	8	
Trial 3	TRIAL3	numeric	8	
Trial 4	TRIAL4	numeric	8	

A GAGE data set must have one observation for each combination of values of CONDITN and PART. You can have up to four operators (values of CONDITN), and each must be assigned a unique value. The MMDDYY8. format must be associated with the DATE variable. A PTYPE value of V indicates that you want a percent of process variation analysis. A PTYPE value of T indicates that you want a percent of tolerance analysis. The variable TOL must be assigned a tolerance value when PTYPE = T.

Return to the gasket thickness gage example described on page 1811. Assume you are using the SAS System under Microsoft Windows, and the gasket thicknesses are stored in the external file c:\gage\gthick.dat. A partial listing of the data in gthick.dat is as follows:

```
Columns: 0----+----1----+----2----+----3
          George    1   0.65      0.6
          George    2   1.0       1.0
          George    3   0.85      0.8
          George    4   0.85      0.95
                      .
                      .
                      .
          Robert    7   0.95      0.95
          Robert    8   0.8       0.8
          Robert    9   1.05      1.05
          Robert   10   0.85      0.8
```

The following statements read the data into a GAGE SAS data set named SASUSER.GASKET. The LENGTH statement guarantees that each variable is represented in the data set. For the GAGE application to identify the data set as valid, the TYPE and ALTER data set options must be specified as shown.

```
data sasuser.gasket (type=_GRR alter=_GAGE);
   length testid $8 date 8 who $30 part char spec gagename
          gageno gagetype $20 spread 8 ptype $1 tol 8
          conditn $8 sample trial1 trial2 trial3 trial4 8;
   format date mmddyy8.;
   retain testid   'Gasket'         date     '12apr94'd
          who      'John Smith'     part     'Gasket'
          spec     '0.6-1.0 mm'     gagename 'Thickness'
          gageno   'X-2034'         gagetype '0-10 mm'
          spread   5.15             ptype    'T'
          tol      0.4;
   infile 'c:\gage\gthick.dat';
   input conditn $ 1-8 sample 10-11 trial1 15-18
         trial2 25-28;
run;
```

Figure A.6 is a partial listing of the SAS data set SASUSER.GASKET.

```
OBS TESTID     DATE    WHO      PART  CHAR    SPEC    GAGENAME  GAGENO GAGETYPE

  1 Gasket 04/12/94 John Smith Gasket      0.6-1.0 mm Thickness X-2034 0-10 mm
  2 Gasket 04/12/94 John Smith Gasket      0.6-1.0 mm Thickness X-2034 0-10 mm
  3 Gasket 04/12/94 John Smith Gasket      0.6-1.0 mm Thickness X-2034 0-10 mm
  4 Gasket 04/12/94 John Smith Gasket      0.6-1.0 mm Thickness X-2034 0-10 mm

OBS SPREAD   PTYPE   TOL   CONDITN   SAMPLE   TRIAL1   TRIAL2   TRIAL3   TRIAL4

  1  5.15      T     0.4   George       1      0.65     0.60       .        .
  2  5.15      T     0.4   George       2      1.00     1.00       .        .
  3  5.15      T     0.4   George       3      0.85     0.80       .        .
  4  5.15      T     0.4   George       4      0.85     0.95       .        .
                                    .
                                    .
                                    .
OBS TESTID     DATE    WHO      PART  CHAR    SPEC    GAGENAME  GAGENO GAGETYPE

 27 Gasket 04/12/94 John Smith Gasket      0.6-1.0 mm Thickness X-2034 0-10 mm
 28 Gasket 04/12/94 John Smith Gasket      0.6-1.0 mm Thickness X-2034 0-10 mm
 29 Gasket 04/12/94 John Smith Gasket      0.6-1.0 mm Thickness X-2034 0-10 mm
 30 Gasket 04/12/94 John Smith Gasket      0.6-1.0 mm Thickness X-2034 0-10 mm

OBS SPREAD   PTYPE   TOL   CONDITN   SAMPLE   TRIAL1   TRIAL2   TRIAL3   TRIAL4

 27  5.15      T     0.4   Robert       7      0.95     0.95       .        .
 28  5.15      T     0.4   Robert       8      0.80     0.80       .        .
 29  5.15      T     0.4   Robert       9      1.05     1.05       .        .
 30  5.15      T     0.4   Robert      10      0.85     0.80       .        .
```

Figure A.6. The SAS Data Set SASUSER.GASKET

Extensibility of the Application

The GAGE application was not designed for any particular industry or company. Because many companies have their own techniques and guidelines for gage studies, the application is designed so that you can tailor it to suit your needs.

The interface to the GAGE application was implemented using FRAME entries in SAS/AF software and the SAS Screen Control Language (SCL). The FRAME entries and SCL source code are available in the gage catalog. FRAME entries provide a flexible environment for building graphical user interfaces. SCL is a programming language that enhances the capabilities of SAS/FSP software and SAS/AF software, including FRAME entries.

For further information on FRAME entries and SCL, refer to *SAS Component Language: Reference* and to *SAS Screen Control Language: Reference*.

The correct bibliographic citation for this manual is as follows: SAS Institute Inc., *SAS/QC® User's Guide, Version 8*, Cary, NC: SAS Institute Inc., 1999. 1994 pp.

SAS/QC® User's Guide, Version 8

ISBN 1–58025–493–4

SAS Institute Inc., SAS Campus Drive, Cary, North Carolina 27513.

1st printing, October 1999

The Institute is a private company devoted to the support and further development of its software and related services.