

Gauge R & R

Measurement System Analysis (**MSA**)

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Overview

- **Definitions**
- **What GR&R Tells You**
- **Summary of Terms**
- **Measurement System Error**
- **How to Conduct a GR&R**
- **Gage R Study (P/T Ratio)**
- **Full Gage R & R Study**
- **Demonstration of GR&R Software**



Definition

A Gage Repeatability and Reproducibility Study is a method of determining the suitability of a gage or gaging system for measuring a particular process. Every measurement taken has some error associated with it, and if this error is large compared to the allowable range of values (the tolerance band), the measuring device will frequently accept bad parts and reject good ones¹.

¹MSA Third Edition



CMMs

The measurement process may be viewed as a manufacturing process that produces numbers for its output.

Zeiss Manufactures Data!

Viewing a measurement system this way is useful because it allows us to bring to bear all the concepts, philosophies, and tools that have already demonstrated their usefulness in the area of SPC².

²MSA Third Edition



What GR&R Tells You

A Gage Repeatability and Reproducibility Study conveys 6 basic pieces of information. They are:

- Part Variation
- Repeatability
- Reproducibility
- Repeatability and Reproducibility (R&R)
- Percent of Total Variation
- Percent of Tolerance

Measurement System Errors

Can be classified into 5 categories:

1. **Bias** – difference between the observed average and the reference
2. **Stability** – The change in bias over time
3. **Linearity** – The change in bias over the normal operating range.
4. **Repeatability** – variation in measurements obtained with one measuring instrument used several times by one operator while measuring one part.
5. **Reproducibility** – variation in the average of the measurements made by different appraisers using the same gage when measuring one part.



Summary of Terms

Location Variation

- **Accuracy** – Closeness to the true value
- **Bias** – Difference between the observed average and reference
- **Stability** – The change in bias over time
- **Linearity** – The change in bias over the normal operating range

Width Variation

- **Precision** – Closeness of repeated readings to each other
- **Repeatability** – variation in measurements obtained with one CMM used several times by one operator while measuring one part.
- **Reproducibility** – variation in average of the measurements made by different appraisers using the same CMM measuring one part.
- **GRR** – the combined estimate of Repeatability and Reproducibility



Gage R&R will Focus on Reporting

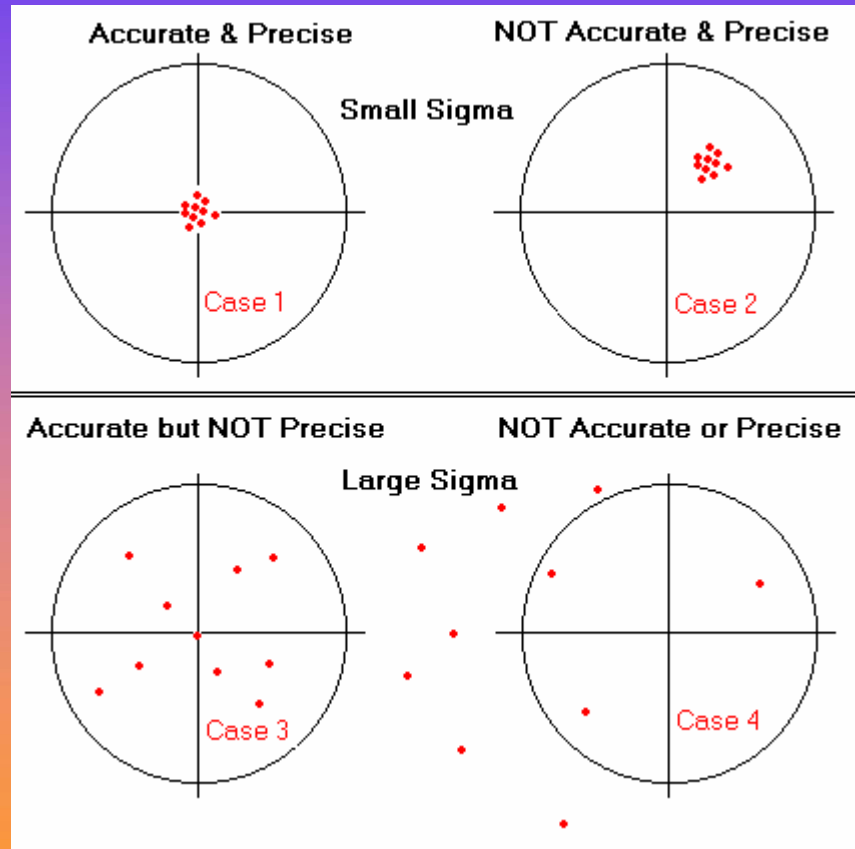
Location Variation

- **Accuracy – Closeness to the true value**
- **Bias – Difference between the observed average and reference**
- **Stability – The change in bias over time**
- **Linearity – The change in bias over the normal operating range**

Width Variation

- **Precision – Closeness of repeated readings to each other**
- **Repeatability – variation in measurements obtained with one CMM used several times by one operator while measuring one part.**
- **Reproducibility – variation in average of the measurements made by different appraisers using the same CMM measuring one part.**
- **GRR – the combined estimate of Repeatability and Reproducibility**

Measurement System Error





Gage Study Types Discussed Today

We will discuss two methods of testing the repeatability of the CMM. Since CMMs are different than hand tools, we need different software to speed up the testing process.

- 1. Gage R Study (P/T Ratio)**
 - Applications
 - Assumptions
 - Analyzed by
- 2. Gage R Study (Range Method)**
 - Applications
 - Assumptions
 - Analyzed by



Gage R Study (P/T Ratio)

Application:

- 1. Offers a preliminary short term gage repeatability**
- 2. May be used for screening before shipment of gage**
- 3. May be used in pre-production when parts are minimal**
- 4. May be used in gage development – quick comparison**
- 5. CANNOT be used for final gage acceptance**



Gage R Study (P/T Ratio)

Assumptions:

1. Process stability and variation is not known
2. Linearity and Bias are not Issues
3. Reproducibility is not considered
4. The part does not change size during the study
5. Quick Study with Very Little Time to Perform

Gage R Study (P/T Ratio)

Analyzed by:

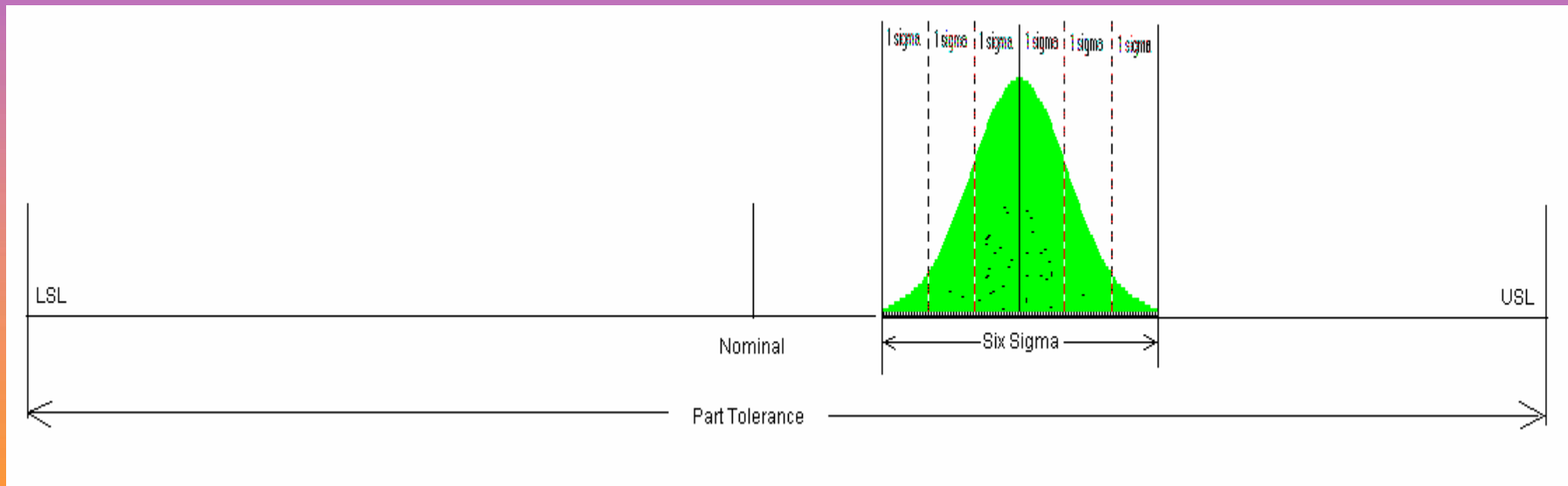
1. Using One Part, One operator, in One Fixture,
2. Repeatedly Measure the Part 10 or more times.
3. You may or may not remove the part each time
4. Calculate Sigma of Measured Values
5. Multiply by 6
6. Divide by Feature Tolerance and multiple by 100
7. Result should be 10% or less (really 3% or less)

$$P / TRatio = 100 * \frac{6 * Sigma}{(USL - LSL)}$$

Gage R Study (P/T Ratio)

$$\text{P/T Ratio} = \frac{6\sigma}{(USL - LSL)} \leq 10\%$$

The width of the gage measurements should not exceed 10% of the total part tolerance





Gage R Study (P/T Ratio)



Full Gage R & R Study

Assumptions:

- 1. Only 2 factors (appraiser & parts) plus the gage are being studied.**
- 2. The effect of variability within each part is negligible**
- 3. There is no statistical interaction between appraiser & parts**
- 4. The parts do not change size during the study**
- 5. Take a lot of Time to Perform**



Full Gage R & R Study

Application:

1. Offers Long Term Gage Repeatability Study
2. Determine Appraiser Capability
3. Determine Part Variation
4. Used for Final Gage Acceptance



Full Gage R & R Study

Analyzed by:

1. Use 5 or More Parts and 2 or More Appraisers
2. Each Appraiser Measures Each Part 2 or More Times
3. You Must Remove the Part Each Time
4. Calculate the Full MSA Calculations



How to Conduct a GR&R

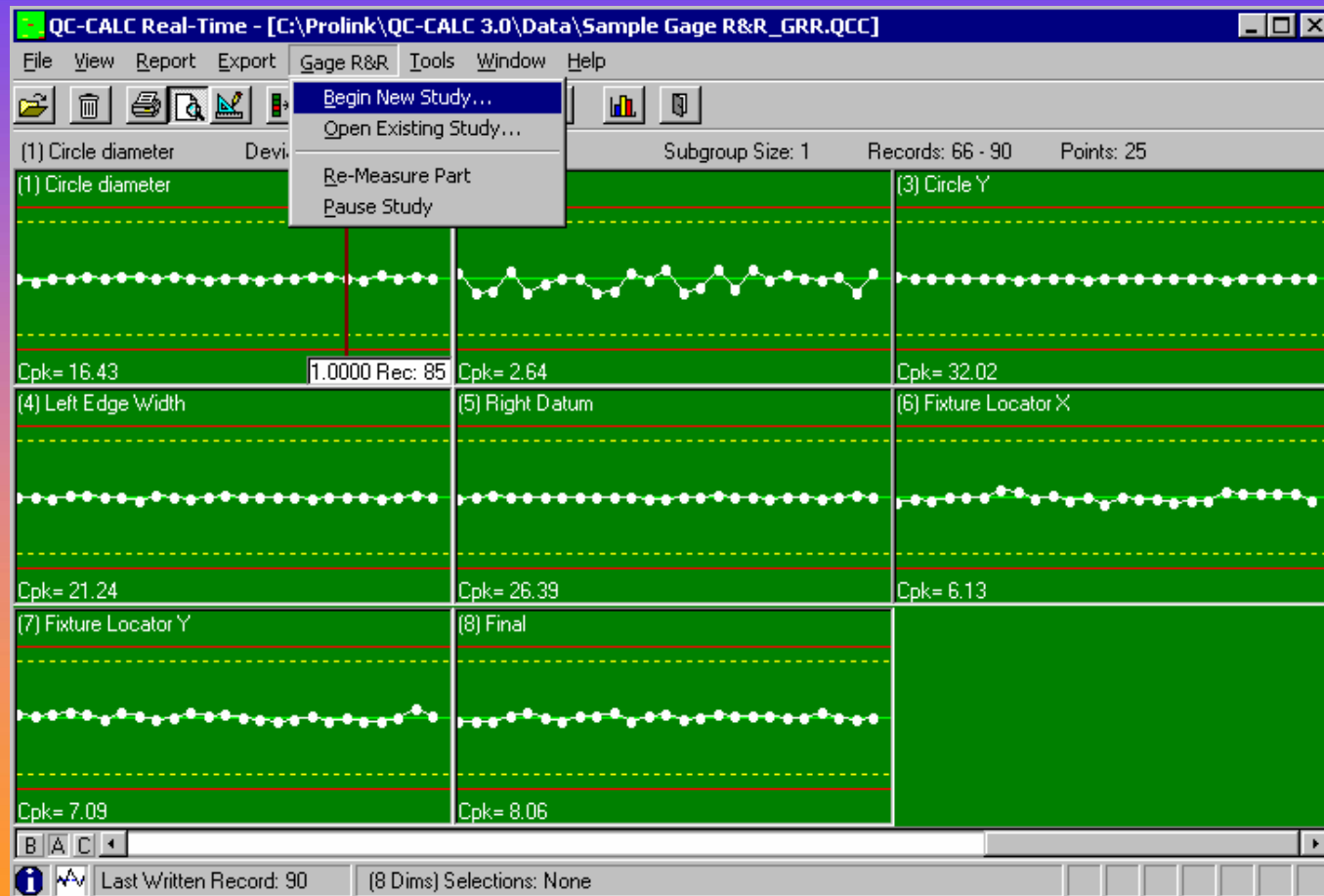
- 1. Obtain and mark 5-10 parts to be measured by the CMM**
- 2. Decide how many operators (2 or 3) will participate**
- 3. Decide how many trials (2 or 3) to measure**
- 4. Run the QC-CALC GR&R Wizard**
- 5. Be sure QC-CALC is in the Waiting Screen – No Active File**
- 6. Run your Calypso part program but remember to use the correct part number and operator displayed in QC-CALC's RT Screen.**
- 7. When the study is complete, select Report – Print Report**
- 8. Now select Gage Report Tabular and Print Report**



Begin QC-CALC GR&R Wizard Demo

Using QC-CALC Real-Time Report

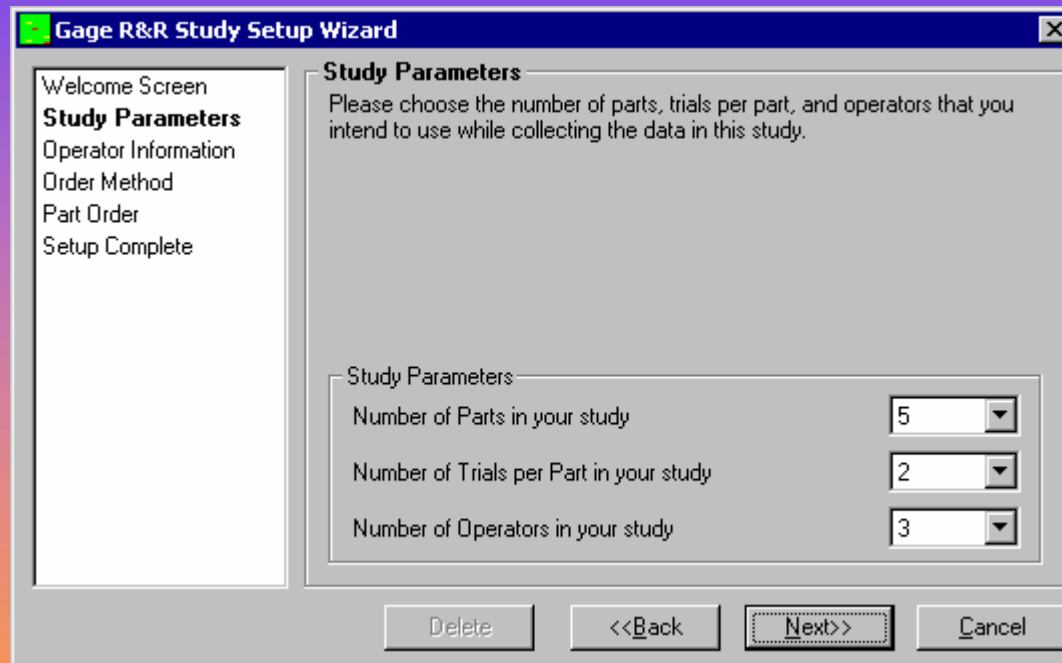
Full Gage R & R Study



Full Gage R & R Study



Full Gage R & R Study



Gage R&R Study Setup Wizard

Welcome Screen
Study Parameters
Operator Information
Order Method
Part Order
Setup Complete

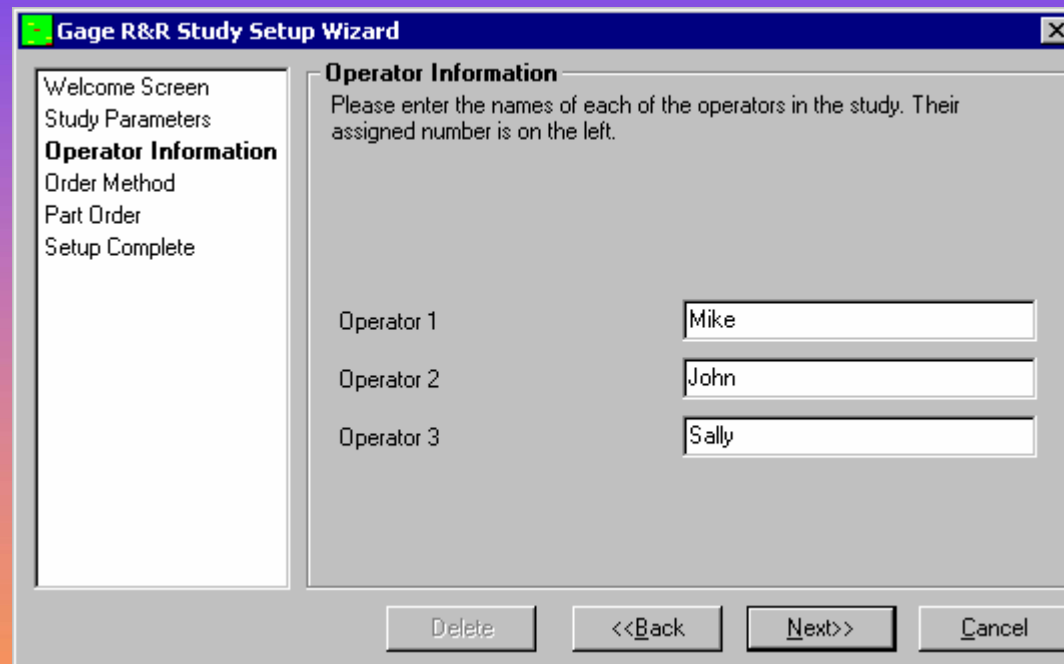
Study Parameters
Please choose the number of parts, trials per part, and operators that you intend to use while collecting the data in this study.

Study Parameters

Number of Parts in your study	5
Number of Trials per Part in your study	2
Number of Operators in your study	3

Delete <<Back Next>> Cancel

Full Gage R & R Study



Gage R&R Study Setup Wizard

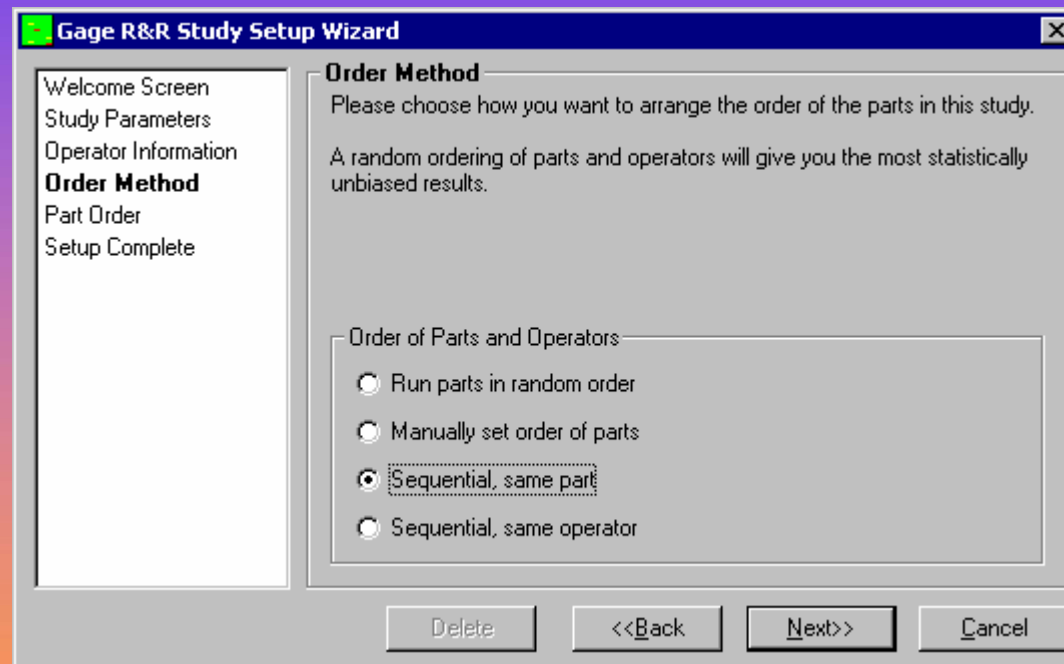
Welcome Screen
Study Parameters
Operator Information
Order Method
Part Order
Setup Complete

Operator Information
Please enter the names of each of the operators in the study. Their assigned number is on the left.

Operator 1	Mike
Operator 2	John
Operator 3	Sally

Delete <<Back Next>> Cancel

Full Gage R & R Study



Gage R&R Study Setup Wizard

Welcome Screen
Study Parameters
Operator Information
Order Method
Part Order
Setup Complete

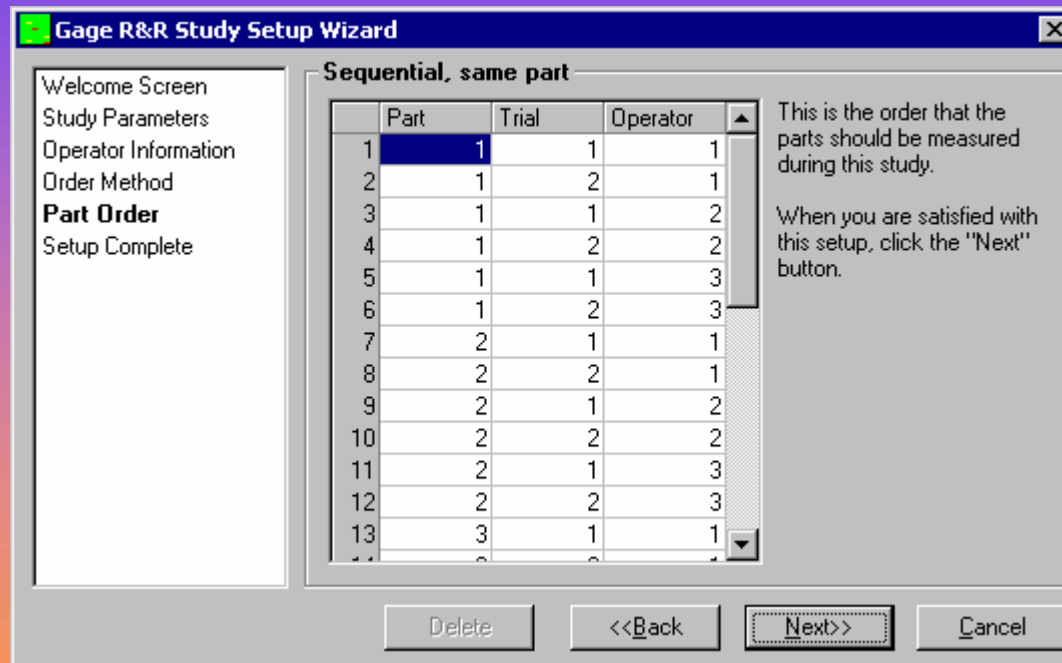
Order Method
Please choose how you want to arrange the order of the parts in this study.
A random ordering of parts and operators will give you the most statistically unbiased results.

Order of Parts and Operators

- Run parts in random order
- Manually set order of parts
- Sequential, same part
- Sequential, same operator

Delete <<Back Next>> Cancel

Full Gage R & R Study



Gage R&R Study Setup Wizard

Welcome Screen
Study Parameters
Operator Information
Order Method
Part Order
Setup Complete

Sequential, same part

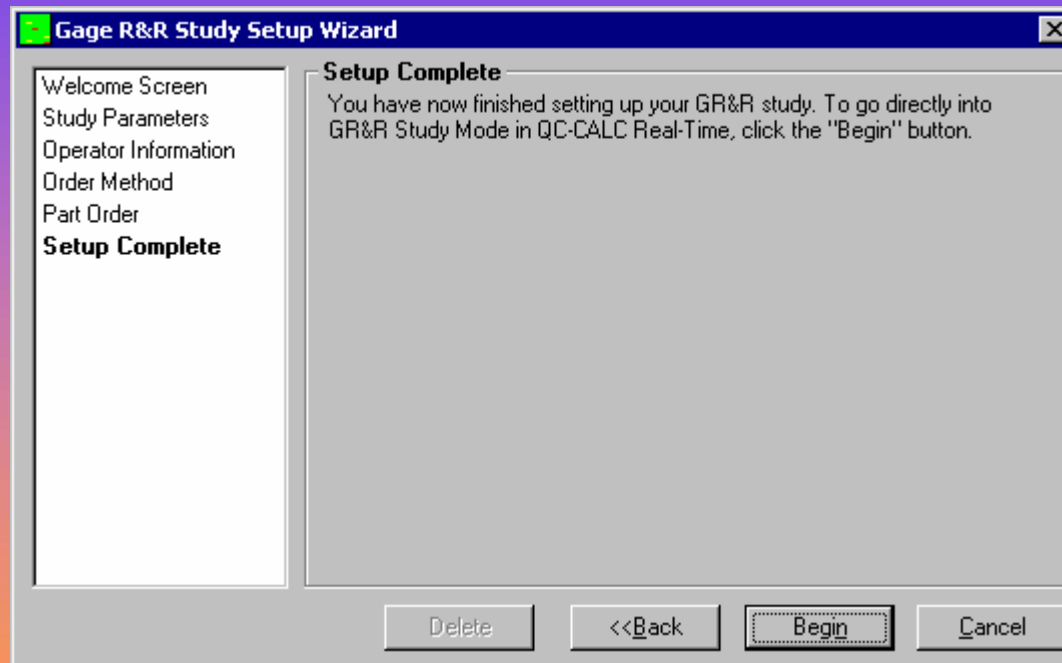
	Part	Trial	Operator
1	1	1	1
2	1	2	1
3	1	1	2
4	1	2	2
5	1	1	3
6	1	2	3
7	2	1	1
8	2	2	1
9	2	1	2
10	2	2	2
11	2	1	3
12	2	2	3
13	3	1	1

This is the order that the parts should be measured during this study.

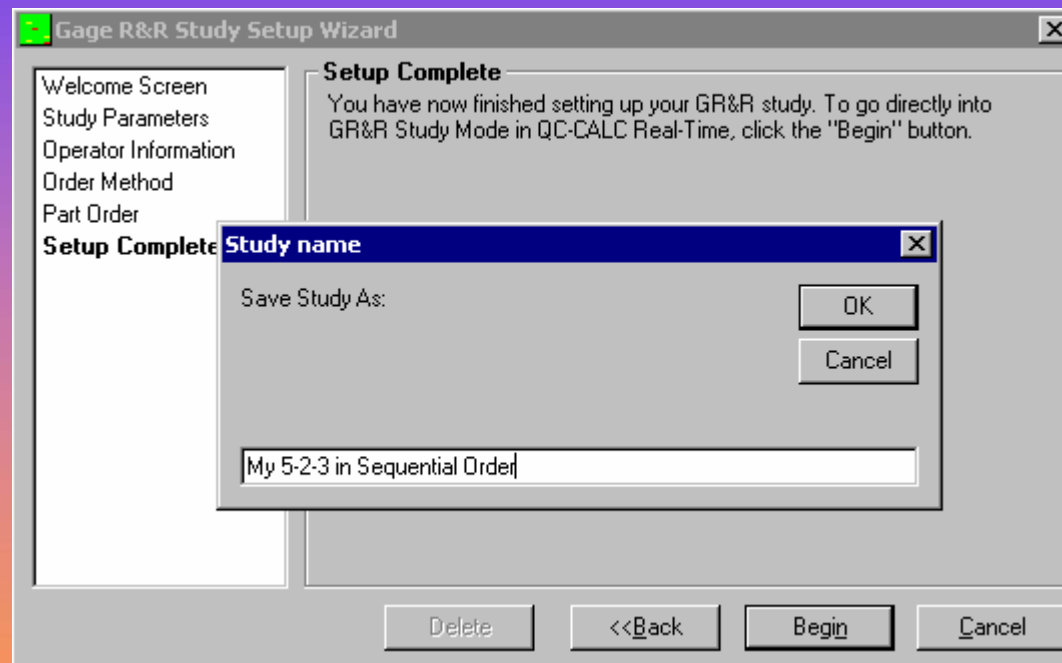
When you are satisfied with this setup, click the "Next" button.

Delete <<Back Next>> Cancel

Full Gage R & R Study



Full Gage R & R Study



Carl Zeiss IMT

Measurement System Analysis (MSA)



We make it visible.

QC-CALC Real-Time - [C:\Prolink\QC-CALC 3.0\Data\Sample Gage R&R_GRR.QCC]

File View Report Export Gage R&R Tools Window Help

No Active File

	Part	Trial	Operator
1	1	1	1
2	1	2	1
3	1	1	2
4	1	2	2
5	1	1	3
6	1	2	3
7	2	1	1

Part 1
Trial 1
Operator 1 - Mike

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We make it visible.

QC-CALC Real-Time - [C:\Prolink\QC-CALC 3.0\Data\Grr-test_GRR.Qcc]

File View Report Export Gage R&R Tools Window Help

(3) Circle Y Subgroup Size: 1 Records: 1 - 1 Points: 30

(1) Circle diameter	(2) Circle X	(3) Circle Y	(4) Left Edge Width
GR&R= 0.0%	GR&R= 0.0%	GR&R= 0.0%	GR&R= 0.0%
(5) Right Datum	(6) Fixture Locator X	(7) Fixture Locator Y	(8) Final
GR&R= 0.0%	GR&R= 0.0%	GR&R= 0.0%	GR&R= 0.0%

	Part	Trial	Operator
1	1	1	1
2	1	2	1
3	1	1	2
4	1	2	2
5	1	1	3
6	1	2	3
7	2	1	1

Part 1
Trial 2
Operator 1 - Mike

Last Written Record: 1 (8 Dims) Selections: None

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We make it visible.

QC-CALC Real-Time - [C:\Prolink\QC-CALC 3.0\Data\Grr-test_GRR.Qcc]

File View Report Export Gage R&R Tools Window Help

Subgroup Size: 1 Records: 1 - 2 Points: 30

(1) Circle diameter GR&R= 0.4%	(2) Circle X GR&R= 4.9%	(3) Circle Y GR&R= 0.4%	(4) Left Edge Width GR&R= 0.9%
(5) Right Datum GR&R= 0.4%	(6) Fixture Locator X GR&R= 3.6%	(7) Fixture Locator Y GR&R= 0.3%	(8) Final GR&R= 0.5%

	Part	Trial	Operator
1	1	1	1
2	1	2	1
3	1	1	2
4	1	2	2
5	1	1	3
6	1	2	3
7	2	1	1

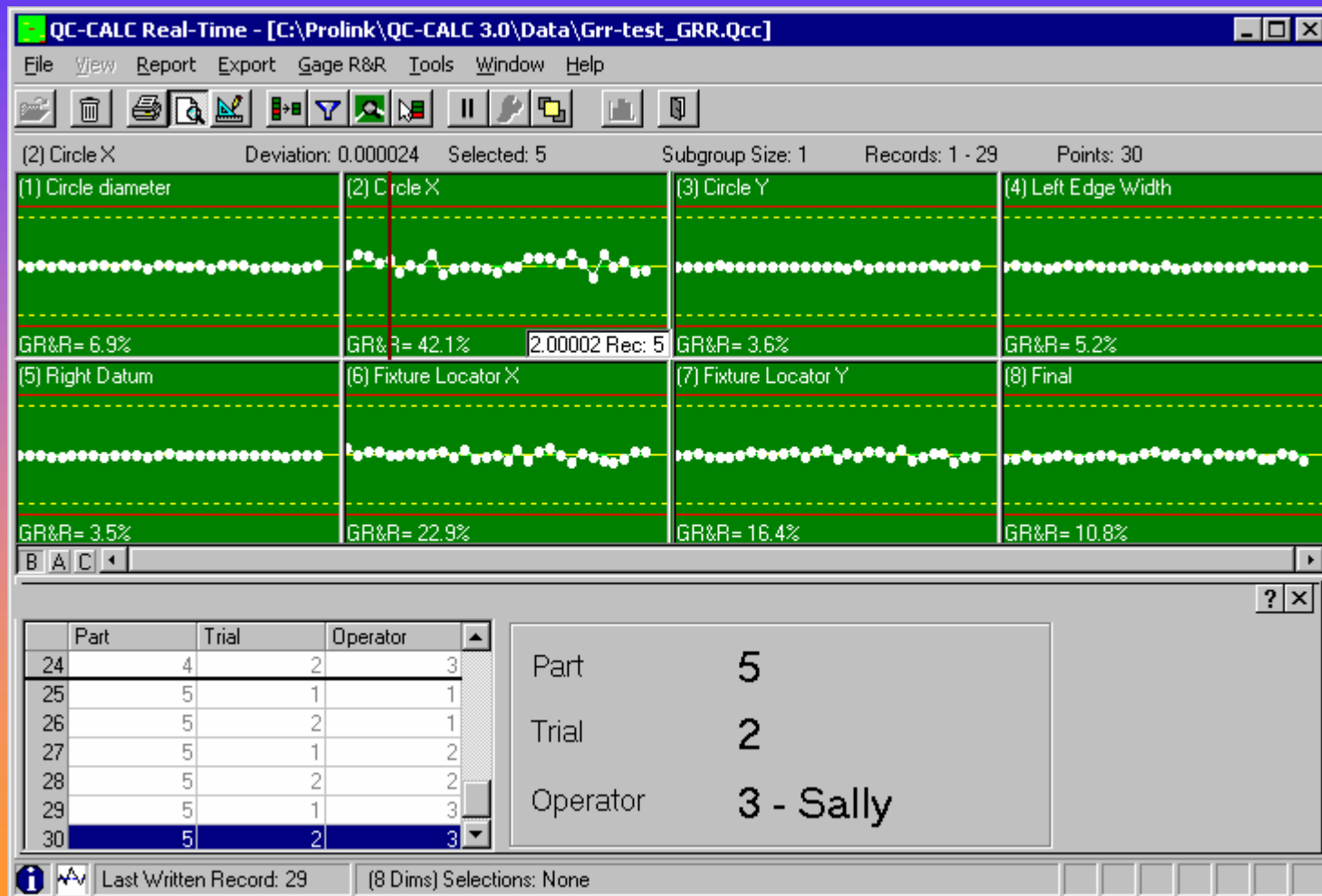
Part 1
Trial 1
Operator 2 - John

Last Written Record: 2 (8 Dims) Selections: None

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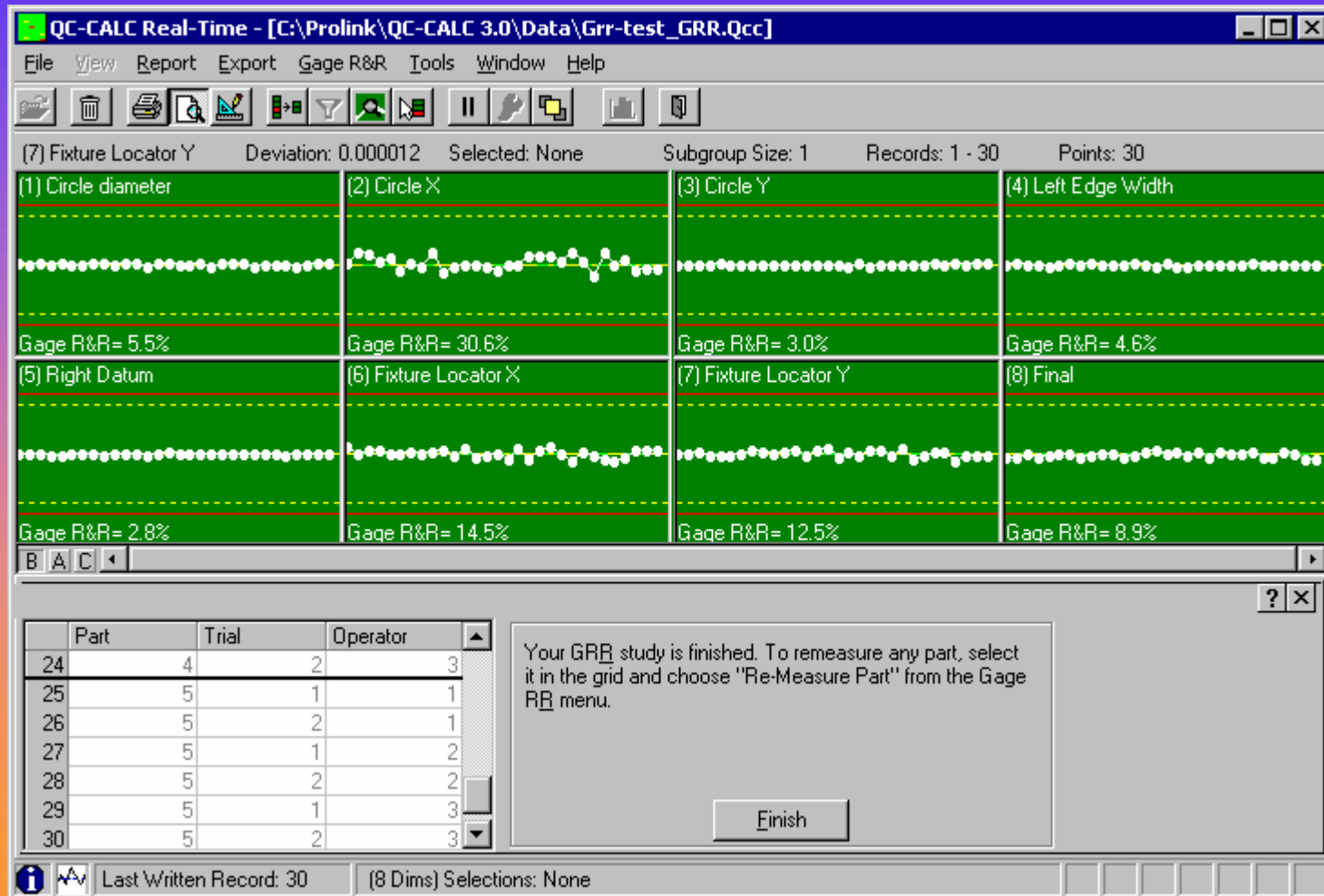
We make it visible.



Carl Zeiss IMT Measurement System Analysis (MSA)



We make it visible.



Carl Zeiss IMT

Measurement System Analysis (MSA)



We make it visible.

QC-CALC Real-Time - [C:\Prolink\QC-CALC 3.0\Data\Grr-test_GRR.QCC]

File View Report Export Gage R&R Tools Window Help

Print Report...

- Automatic Reporting (Off)
- Use Same Report Settings for All Parts
- Setup Automatic Reporting...
- Print Automatic Report Now Ctrl+A
- Reset Auto Report Counter
- Report Notes...
- Modify User Inputs... Ctrl+U
- Design Template...
- Print Preview

Subgroup Size: 1 Records: 1 - 30 Points: 30

(2) Circle X (3) Circle Y (4) Left Edge Width

(1) Circle dia (5) Right Dia (7) Fixture Locator Y (8) Final

Gage R&R= 2.8% Gage R&R= 14.5% Gage R&R= 3.0% Gage R&R= 4.6%

Gage R&R= 12.5% Gage R&R= 8.9%

Part	Trial	Operator
24	4	2
25	5	1
26	5	2
27	5	1
28	5	2
29	5	1
30	5	2

Your GRR study is finished. To remeasure any part, select it in the grid and choose "Re-Measure Part" from the Gage RR menu.

Finish

Last Written Record: 30 (8 Dims) Selections: None

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We make it visible.

Print Report

Select Report Template

Select Report Type
Gage Report Tabular Form

Design Template

Edit Input File

Template File Name
C:\Prolink\QC-CALC 3.0\template\Default\GRR Report.grt

Browse

Always Use The Selected Printer

Range of Records to Report

All Available Records

All Records Displayed

90 Newest Records in File

5 Last Records Displayed

Selected Points

Gage Study

Trials 2 Unique Parts 10

Number of Copies 1

Advanced >> Print Setup Close Print Cancel

Prolink Software

Gage Type:
Gage Size:
Gage Number:

Performed by:
Record Range: 1 - 90

Parts 10
Trials 3
Operators 3
Total Records 90

Part Variation (PV)

Part Variation is a measure of how much the process is actually varying. If an infinite number of parts made by this process were measured using an Ideal Gage, 99.0% (5.15 sigma) of the parts would be within an interval Part Variation wide. This is, of course, only an estimate.

Repeatability (EV)

Equipment Variation is a measure of how much the gage readings vary when the same operator measures the same part several times. A large value might indicate gage wear, improper measurement policy (but all operators are making the same "mistake", it is not a matter of individual operator skill), or a gage without sufficient resolution or with a defect. This number is best used by comparing it with reproducibility.

Reproducibility (AV)

Appraiser Variation is a measure of operator difference. The most common cause of a poor (large) Reproducibility is insufficient operator training. A gage that is sensitive to different techniques or is difficult to use would also cause a large Reproducibility. We believe using a CMM or Vision inspection system eliminates most of the human error. Fixturing should be checked if this value is high.

Gage R&R

Gage R&R is a measure of the combine variation of Repeatability and Reproducibility caused by the gaging system as opposed to the manufacturing process. This number, expressed as a percentage of tolerance, is the most important "warning flag". If R&R is a large percentage of total variation but not a large percentage of tolerance, both the gage and the process are good and the process standard deviation is even smaller than it appears (meaning the process spread is smaller and Cpk larger than reported). This also means a more precise gage would allow tighter control limits for earlier detection of loss of control. The following table shows typical interpretation:

% Of Tol.	Interpretation
0 - 10%	Gage is suitable
10 - 30%	May be acceptable based on importance of the measured part, cost of gage repair, etc. look at R and R separately
Over 30%	Gage system needs improvement

Dimension		Nominal	USL	LSL	Part Average	UCL	LCL	(PV) Part Variation	(EV) Repeatability	(AV) Reproducibility	Gage R&R
1	Circle diameter	1.0000	1.0010	0.9990	1.0000	0.0001	0.0000	2.24%	5.79%	0.00%	5.79%
2	Circle X	2.0000	2.0002	1.9998	2.0000	0.0001	0.0000	11.56%	33.25%	7.13%	34.00%
3	Circle Y	3.0000	3.0020	2.9980	3.0000	0.0001	0.0000	1.00%	3.13%	0.66%	3.20%
4	Left Edge Width	4.0000	4.0020	3.9980	4.0000	0.0001	0.0000	0.93%	3.21%	0.00%	3.21%
5	Right Datum	5.0000	5.0020	4.9980	5.0000	0.0001	0.0000	1.00%	3.15%	0.00%	3.15%
6	Fixture Locator X	6.0000	6.0004	5.9996	6.0000	0.0001	0.0000	4.97%	15.57%	0.00%	15.57%
7	Fixture Locator Y	7.0000	7.0006	6.9994	7.0000	0.0001	0.0000	4.30%	13.10%	1.91%	13.24%
8	Final	8.0000	8.0005	7.9995	8.0000	0.0001	0.0000	2.48%	11.27%	1.78%	11.41%

AIAG Calculations Used in this Report



Full Gage R & R Study

Using QC-CALC SPC Report

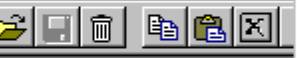


Record	(1) Circle diameter	(2) Circle X	(3) Circle Y	(4) Left Edge Width	(5) Right Datum	(6) Fixture Locator X	(7) Fixture Locator Y	(8) Final	(9) Part	(10) Trial	(11) Operator	
1	0001	1.00002	2.00001	2.99999	4.00000	5.00000	6.00005	7.00000	7.99997	1	1	1
2	0002	1.00001	2.00004	3.00002	4.00006	4.99997	6.00000	7.00001	7.99998	1	2	1
3	0003	1.00002	2.00004	3.00002	4.00000	4.99998	6.00003	7.00002	8.00000	1	1	2
4	0004	1.00000	2.00001	3.00001	3.99999	4.99997	6.00003	6.99998	7.99998	1	2	2
5	0005	1.00003	2.00002	3.00004	3.99995	4.99996	6.00000	6.99999	7.99999	1	1	3
6	0006	1.00000	1.99998	2.99999	4.00001	4.99998	6.00000	6.99999	8.00001	1	2	3
7	0007	0.99999	2.00001	3.00000	4.00005	5.00001	6.00002	7.00001	7.99999	2	1	1
8	0008	1.00002	2.00000	3.00001	3.99998	4.99999	6.00000	7.00004	7.99998	2	2	1
9	0009	1.00002	2.00004	2.99999	4.00005	4.99997	6.00001	7.00003	7.99999	2	1	2
10	0010	1.00000	1.99998	3.00002	3.99999	5.00001	6.00002	7.00000	8.00000	2	2	2
11	0011	1.00004	1.99999	2.99998	4.00002	5.00000	5.99999	7.00001	8.00000	2	1	3
12	0012	1.00003	2.00000	2.99999	3.99998	5.00000	6.00004	7.00004	7.99997	2	2	3
13	0013	0.99997	2.00000	2.99998	4.00004	4.99995	5.99998	6.99998	7.99998	3	1	1
14	0014	1.00002	1.99999	3.00000	4.00000	5.00003	5.99999	7.00003	8.00002	3	2	1
15	0015	1.00003	1.99998	3.00001	3.99996	5.00003	6.00000	7.00005	8.00002	3	1	2
16	0016	1.00000	2.00000	2.99999	4.00004	4.99999	5.99997	6.99997	7.99999	3	2	2
17	0017	1.00001	2.00000	2.99997	3.99992	5.00002	6.00003	7.00001	8.00002	3	1	3
18	0018	1.00004	2.00003	3.00003	3.99996	5.00003	5.99997	6.99998	7.99999	3	2	3
19	0019	0.99996	2.00003	2.99996	4.00000	4.99998	6.00003	7.00003	8.00001	4	1	1
20	0020	1.00003	2.00003	3.00001	4.00001	5.00001	6.00005	7.00004	7.99998	4	2	1
21	0021	1.00003	2.00001	3.00000	4.00002	4.99999	6.00000	6.99998	8.00001	4	1	2
22	0022	1.00003	2.00004	3.00002	4.00002	5.00000	5.99995	7.00006	8.00000	4	2	2
23	0023	0.99997	2.00001	3.00000	3.99998	4.99997	6.00001	6.99995	8.00000	4	1	3
24	0024	1.00000	1.99996	2.99999	4.00003	5.00000	5.99999	6.99998	8.00001	4	2	3
25	0025	0.99999	2.00004	3.00005	4.00000	5.00001	5.99997	7.00002	7.99997	5	1	1
26	0026	0.99999	2.00000	3.00000	3.99998	4.99996	5.99995	7.00001	7.99998	5	2	1
27	0027	0.99998	2.00002	3.00004	3.99999	4.99998	5.99998	6.99993	8.00002	5	1	2
28	0028	1.00000	1.99998	3.00001	4.00002	4.99999	6.00003	6.99998	8.00000	5	2	2
29	0029	1.00002	1.99999	3.00004	3.99998	4.99998	6.00002	6.99998	7.99996	5	1	3
30	0030	1.00002	1.99999	3.00004	3.99998	4.99998	6.00002	6.99998	7.99996	5	2	3
*												



Last Written Record: 30

Records Sorted By: Record Number(Ascending)



- XBar and Range...
- XBar and Sigma...
- Median and Range...
- Individual and Range...
- Individual and Moving Range...
- Moving Average and Range...
- Bivariate Analysis...
- Attribute Charts ▶
- Cpk - Process Capability...
- Raw Data w/ Outlier Detect...
- Correlation and Regression...
- Histogram Analysis...
- Probability Plot...
- Pareto Analysis...
- Gage R & R Report ▶**
- Non-Conformance Report...
- Stat Summary...
- Other Reports... Ctrl+P

Record	(1) Circle diam	Width	(5) Right Datum	(6) Fixture Locator X	(7) Fixture Locator Y	(8) Final	(9) Part	(10) Trial	(11) Operator			
1	0001	1.00002	5.00000	6.00005	7.00000	7.99997	1	1	1			
2	0002	1.00001	4.99997	6.00000	7.00001	7.99998	1	2	1			
3	0003	1.00002	4.99998	6.00003	7.00002	8.00000	1	1	2			
4	0004	1.00000	4.99997	6.00003	6.99998	7.99998	1	2	2			
5	0005	1.00003	4.99996	6.00000	6.99999	7.99999	1	1	3			
6	0006	1.00000	4.99998	6.00000	6.99999	8.00001	1	2	3			
7	0007	0.99999	5.00001	6.00002	7.00001	7.99999	2	1	1			
8	0008	1.00002	4.99999	6.00000	7.00004	7.99998	2	2	1			
9	0009	1.00002	4.99997	6.00001	7.00003	7.99999	2	1	2			
10	0010	1.00000	5.00001	6.00002	7.00000	8.00000	2	2	2			
11	0011	1.00004	5.00000	5.99999	7.00001	8.00000	2	1	3			
12	0012	1.00003	5.00000	6.00004	7.00004	7.99997	2	2	3			
13	0013	0.99997	4.99995	5.99998	6.99998	7.99998	3	1	1			
14	0014	1.00002	5.00003	5.99999	7.00003	8.00002	3	2	1			
15	0015	1.00003	5.00000	6.00000	7.00005	8.00002	3	1	2			
16	0016	1.00000	4.99997	6.00000	6.99997	7.99999	3	2	2			
17	0017	1.00001	5.00002	6.00003	7.00001	8.00002	3	1	3			
18	0018	1.00004	5.00003	5.99997	6.99998	7.99999	3	2	3			
19	0019	0.99996	4.99998	6.00003	7.00003	8.00001	4	1	1			
20	0020	1.00003	2.00003	3.00001	4.00001	5.00001	6.00005	7.00004	7.99998	4	2	1
21	0021	1.00003	2.00001	3.00000	4.00002	4.99999	6.00000	6.99998	8.00001	4	1	2
22	0022	1.00003	2.00004	3.00002	4.00002	5.00000	5.99995	7.00006	8.00000	4	2	2
23	0023	0.99997	2.00001	3.00000	3.99998	4.99997	6.00001	6.99995	8.00000	4	1	3
24	0024	1.00000	1.99996	2.99999	4.00003	5.00000	5.99999	6.99998	8.00001	4	2	3
25	0025	0.99999	2.00004	3.00005	4.00000	5.00001	5.99997	7.00002	7.99997	5	1	1
26	0026	0.99999	2.00000	3.00000	3.99998	4.99996	5.99995	7.00001	7.99998	5	2	1
27	0027	0.99998	2.00002	3.00004	3.99999	4.99998	5.99998	6.99993	8.00002	5	1	2
28	0028	1.00000	1.99998	3.00001	4.00002	4.99999	6.00003	6.99998	8.00000	5	2	2
29	0029	1.00002	1.99999	3.00004	3.99998	4.99998	6.00002	6.99998	7.99996	5	1	3
30	0030	1.00002	1.99999	3.00004	3.99998	4.99998	6.00002	6.99998	7.99996	5	2	3
*												

- Create Gage R & R Report...
- Edit Gage R & R Notes...

Last Written Record: 30

Records Sorted By: Record Number(Ascending)



We make it visible.

Performed by Bruce
Gage Type Zeiss
Gage Size Big
Gage Number 999

File Name = GRR-TEST_GRR.QCC
Dimension Name = Circle diameter
Dimension Number = 1
Tolerance = 0.0020

Overall Part Average = 1.0000083	Average Range = 0.0000244	K1 = 4.480
Range of Part Average = 0.0000172	Total Variation = 0.0001154	K2 = 2.694
Max Operator Average = 1.000014	Upper Ctrl Limit = 0.0000797	K3 = 2.076
Min Operator Average = 1.000001	Lower Ctrl Limit = 0.0000000	D3 = 0.000
Operator Avg Diff. = 0.000013		D4 = 3.267

	Raw	Variation = 0.0001154	Tolerance = 0.0020
Part Variation =	0.0000358	30.9766%	PV = 1.7877%
Repeatability =	0.0001093	94.7081%	EV = 5.4656%
Reproducibility =	0.0000097	8.4160%	AV = 0.4857%
Gage R & R =	0.0001097	95.0813%	GRR = 5.4872%

The calculations circled in red are shown as raw values. The second column is the repeatability based on Total Variation. The third column is repeatability based on the feature tolerance.

The long standing tradition of reporting measurement error only as a percent of tolerance is inadequate for the challenges of the marketplace that emphasize strategic and continuous process improvement. MSA

Oper. #	Part #	Trial 1	Trial 2	Average	Range	Part Avg.
1	1	1.00002	1.00001	1.000013	0.0000150	
1	2	0.99999	1.00002	1.000004	0.0000323	
1	3	0.99997	1.00002	0.999999	0.0000486	
1	4	0.99996	1.00003	0.999997	0.0000710	
1	5	0.99999	0.99999	0.999991	0.0000048	
1	Avg	0.99999	1.00001	1.000001	0.0000343	
2	1	1.00002	1.00000	1.000012	0.0000221	
2	2	1.00002	1.00000	1.000009	0.0000233	
2	3	1.00003	1.00000	1.000011	0.0000280	
2	4	1.00003	1.00003	1.000028	0.0000069	
2	5	0.99998	1.00000	0.999990	0.0000128	
2	Avg	1.00002	1.00000	1.000010	0.0000186	
3	1	1.00003	1.00000	1.000013	0.0000355	1.000013
3	2	1.00004	1.00003	1.000035	0.0000089	1.000016
3	3	1.00001	1.00004	1.000026	0.0000260	1.000012
3	4	0.99997	1.00000	0.999982	0.0000309	1.000003
3	5	1.00002	1.00002	1.000015	0.0000000	0.999999
3	Avg	1.00001	1.00002	1.000014	0.0000203	1.000008

* Out of Control

Carl Zeiss IMT

Measurement System Analysis (MSA)



We make it visible.

Raw	Variation =	0.0001154	Tolerance =	0.0020
Part Variation = 0.0000358		30.9766%		PV = 1.7877%
Repeatability = 0.0001093		94.7081%		EV = 5.4656%
Reproducibility = 0.0000097		8.4160%		AV = 0.4857%
Gage R & R = 0.0001097		95.0813%		GRR = 5.4872%

$$\text{Part Variation\%} = \frac{\text{Part Variation}}{\text{Variation}} * 100 = \frac{0.0000358}{0.0001154} * 100 = 30.9766\%$$

$$\text{Repeatability(EV)\%} = \frac{\text{Re peatability}}{\text{Variation}} * 100 = \frac{0.0001093}{0.0001154} * 100 = 94.7081\%$$

$$\text{Reproducibility(AV)\%} = \frac{\text{Re producibility}}{\text{Variation}} * 100 = \frac{0.000097}{0.0001154} * 100 = 8.4160\%$$

$$\text{Gage R \& R} = \sqrt{EV^2 + AV^2} = \sqrt{94.7081^2 + 8.416^2} = \sqrt{9040.453261} = 95.0813\%$$

The calculations in the middle column are the repeatability values based on the raw values divided by the total variation. See equations.

Viewing the raw value for EV we see 0.0001093. By multiplying this value by 10 we see that the gage is usable to measure parts with tolerances of 0.001

Carl Zeiss IMT

Measurement System Analysis (MSA)



We make it visible.

	Raw	Variation =	0.0001154	Tolerance =	0.0020
Part Variation =	0.0000358		30.9766%		PV = 1.7877%
Repeatability =	0.0001093		94.7081%		EV = 5.4656%
Reproducibility =	0.0000097		8.4160%		AV = 0.4857%
Gage R & R =	0.0001097		95.0813%		GRR = 5.4872%

Calculated on Tolerance

$$PV = \frac{\text{Part Variation}}{\text{Tolerance}} * 100 = \frac{0.0000358}{0.002} * 100 = 1.7877\%$$

$$EV = \frac{\text{Re peatability}}{\text{Tolerance}} * 100 = \frac{0.0001093}{0.002} * 100 = 5.4656$$

$$AV = \frac{\text{Re producibility}}{\text{Tolerance}} * 100 = \frac{0.0000097}{0.002} * 100 = 0.4857$$

$$GRR = \sqrt{EV^2 + AV^2} = \sqrt{5.4656^2 + 0.4857^2} = \sqrt{30.1086} = 5.4871$$

The calculations in the right column are the repeatability values based on the tolerance. This is a much easier method of accepting the gage for use. The GRR is listed a 5.4% when the part tolerance is 0.002.

However, using these numbers can be misleading. As the customer improves their process and tightens the tolerances the gage may become inadequate for future projects.



We make it visible.

The Multi-Dimension
Gage R & R Study Report
is the same as the long
form but allows for 10
dimensions per page.

Circle diameter		Grr-test_GRR.QCC		May 6, 2005	
Dim 1	Number of Parts	5			
	USL	1.00100			
Type	Nominal	1.00000			
Size	LSL	0.99900			
Number	999				
	Part Average	1.00001			
By	PV Part Variation	1.79%			
Operators	EV Repeatability	5.47%			
Trials	AV Reproducibility	0.49%			
	<u>Gage R&R</u>	<u>5.49%</u>			

Circle X		Grr-test_GRR.QCC		May 6, 2005	
Dim 2	Number of Parts	5			
	USL	2.00020			
Type	Nominal	2.00000			
Size	LSL	1.99980			
Number	999				
	Part Average	2.00001			
By	PV Part Variation	8.92%			
Operators	EV Repeatability	29.99%			
Trials	AV Reproducibility	6.28%			
	<u>Gage R&R</u>	<u>30.64%</u>			

Circle Y		Grr-test_GRR.QCC		May 6, 2005	
Dim 3	Number of Parts	5			
	USL	3.00200			
Type	Nominal	3.00000			
Size	LSL	2.99800			
Number	999				
	Part Average	3.00001			
By	PV Part Variation	1.75%			
Operators	EV Repeatability	3.04%			
Trials	AV Reproducibility	0.00%			
	<u>Gage R&R</u>	<u>3.04%</u>			

Left Edge Width		Grr-test_GRR.QCC		May 6, 2005	
Dim 4	Number of Parts	5			
	USL	4.00200			
Type	Nominal	4.00000			
Size	LSL	3.99800			
Number	999				
	Part Average	4.00000			
By	PV Part Variation	1.31%			
Operators	EV Repeatability	4.33%			
Trials	AV Reproducibility	1.47%			
	<u>Gage R&R</u>	<u>4.57%</u>			

Right Datum		Grr-test_GRR.QCC		May 6, 2005	
Dim 5	Number of Parts	5			
	USL	5.00200			
Type	Nominal	5.00000			
Size	LSL	4.99800			
Number	999				
	Part Average	4.99999			
By	PV Part Variation	1.51%			
Operators	EV Repeatability	2.81%			
Trials	AV Reproducibility	0.00%			
	<u>Gage R&R</u>	<u>2.81%</u>			

Fixture Locator X		Grr-test_GRR.QCC		May 6, 2005	
Dim 6	Number of Parts	5			
	USL	6.00040			
Type	Nominal	6.00000			
Size	LSL	5.99960			
Number	999				
	Part Average	6.00000			
By	PV Part Variation	7.98%			
Operators	EV Repeatability	14.53%			
Trials	AV Reproducibility	0.00%			
	<u>Gage R&R</u>	<u>14.53%</u>			

Fixture Locator Y		Grr-test_GRR.QCC		May 6, 2005	
Dim 7	Number of Parts	5			
	USL	7.00060			
Type	Nominal	7.00000			
Size	LSL	6.99940			
Number	999				
	Part Average	7.00000			
By	PV Part Variation	6.63%			
Operators	EV Repeatability	11.87%			
Trials	AV Reproducibility	3.98%			
	<u>Gage R&R</u>	<u>12.52%</u>			

Final		Grr-test_GRR.QCC		May 6, 2005	
Dim 8	Number of Parts	5			
	USL	8.00050			
Type	Nominal	8.00000			
Size	LSL	7.99950			
Number	999				
	Part Average	7.99999			
By	PV Part Variation	4.44%			
Operators	EV Repeatability	8.06%			
Trials	AV Reproducibility	3.72%			
	<u>Gage R&R</u>	<u>8.88%</u>			



Demonstration

This is the end of the PowerPoint Presentation

We will now use QC-CALC to demonstrate GRR.