Report Example: Gage R&R ANOVA Report

Date: 7/18/2018
Gage: My Gage
Characteristic: Length
Operators: 3
Parts: 10
Trials: 3

Process Sigma: 2.5
USL: 3
LSL: -3
Analyzed by: Bill

Description of Output

Print out of information entered by the user

ANOVA Table with Interaction

Source	df	SS	MS	F	p Value
Part	9	88.36	9.818	492.291	0.000
Operator	2	3.167	1.584	79.406	0.000
Operator*Part	18	0.359	0.0199	0.434	0.974
Repeatability	60	2.759	0.0460		
Total	89	94.65			

Source: the source of the variation.
df (degrees of freedom): a measure of how much information you have for each SS.
SS (sum of squares): a measure of variation of squared deviations around an average.
MS (mean square): estimate of the variance for the source based on the degrees of freedom.
F: the statistic is used to determine whether the sources of variation are statistically significant.
p-value: is the probability that the source of variation is not statistically significant.
Sources with low p values have a statistically significant impact on the results.
Red p values are less than 0.05.

The Analysis of Variance table is given; the sources are defined below the table. The column to focus on is the p Value column. Values less than 0.05 are considered statistically significant and are turned red. This table includes the interaction term (Operator*Part)

Significance level (alpha) to remove interaction term = 0.05.
*Operator*Part interaction is not significant and is removed in the calculations below.*

If the p value for the interaction term is greater than the value entered by the user, it is removed from the calculations.

ANOVA Table without Interaction

Source	df	SS	MS	F	p Value
Part	9	88.36	9.818	245.614	0.000
Operator	2	3.167	1.584	39.617	0.000
Repeatability	78	3.118	0.0400		
Total	89	94.65			

If the interaction term is removed from the calculations, the Analysis of Variance table is remade without the interaction term.

% Contribution Based on Variance

Source	Variance	% Contribution
Gage R&R	0.0914	1.46%
Repeatability	0.0400	0.64%
Reproducibility	0.0515	0.82%
Operator	0.0515	0.82%
Part-to-Part	6.159	98.54%
Total Variance	6.250	100.00%

Table provides the % variance due to each source based on the total variance.
Total variance based on process sigma entered by user.
AIAG Guidelines for Gage R&R:
% Gage R&R& < 1%: measurement system is acceptable.
% Gage R&R 1% to 9%: measurement system may be acceptable for some applications.
% Gage R&R > 9%: measurement system is not acceptable.

Each source's variance is calculated and the % contribution of each source is determined. The % contribution is the % of the total variance.

If the process sigma is entered by the user, it is used to determine the total variance. If not, the parts used in the study are used to determine the total variance.

AIAG guidelines are used to determine if the measurement system is acceptable.

% Based on Standard Deviation

Source	Standard Deviation (SD)	Study Var (6SD)	% Study Var	% Tolerance (SV/Tol)
Gage R&R	0.302	1.814	12.09%	30.24%
Repeatability	0.200	1.200	8.00%	19.99%
Reproducibility	0.227	1.361	9.07%	22.68%
Operator	0.227	1.361	9.07%	22.68%
Operator*Part				0.00%
Part-to-Part	2.482	14.89	99.27%	248.16%
Total Variation	2.500	15.00	100.00%	250.00%

Table gives the % of spread consumed by each source based on the total variation.
Total variation based on process sigma entered by user.
AIAG Guidelines for Gage R&R:
% Gage R&R& < 10%: measurement system is acceptable.
% Gage R&R 10% to 30%: measurement system may be acceptable for some applications.
% Gage R&R > 30%: measurement system is not acceptable.

The standard deviation from each source is calculated. The study variation is calculated as 6 times the standard deviation. The % of total study variation is calculated for each source.

If the process sigma is entered by the user, it is used for the total variation standard deviation. If not, the parts used in the study are used to determine the total variation standard deviation.

AIAG guidelines are used to determine if the measurement system is acceptable.

Number of Distinct Categories

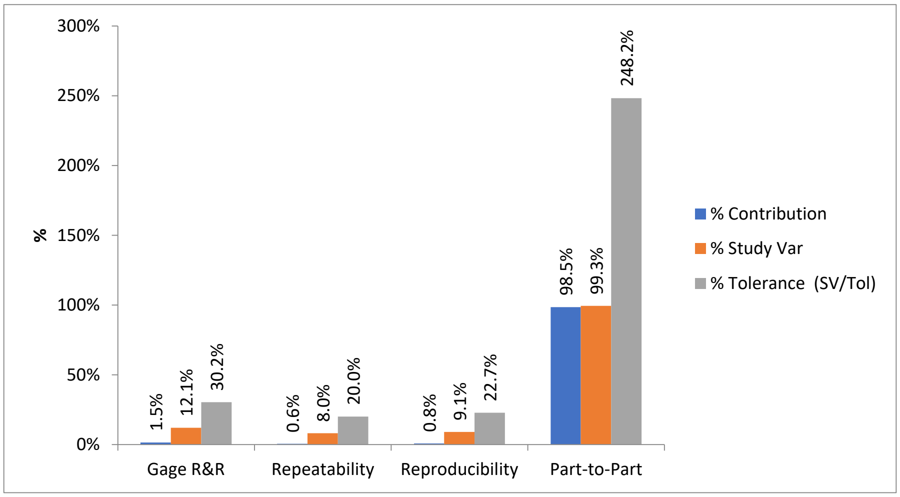
NDC represents the ability of the measurement systems to distinguish between parts.
AIAG Guidelines: NDC greater than or equal to 5.

The number of distinct categories is the number of data classifications that can be reliably

Number of Distinct Categories (NDC) = 11

distinguished by the resolution of the test method.

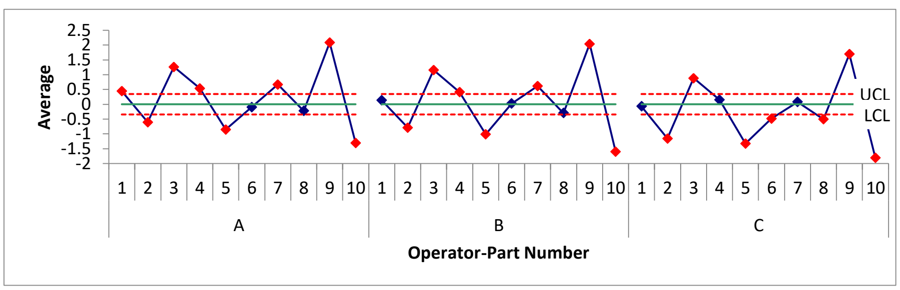
Variance Components Chart



The % of variance and variation are plotted for each source. This is a chart of the results in the two tables above.

Operator-Part Control Charts

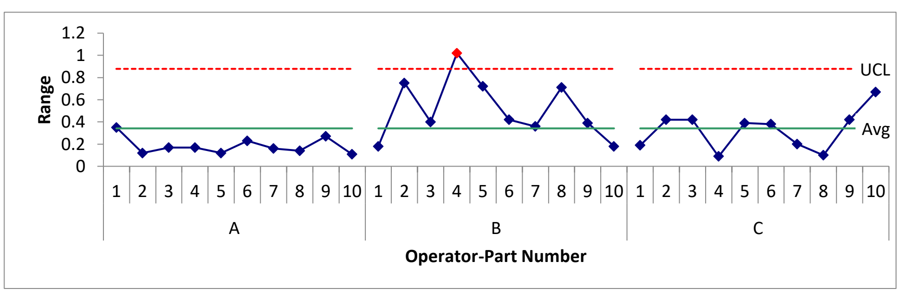
$\bar{X}$ Chart for Operator-Part Averages



The $\bar{X}$ chart is a plot of the subgroup averages for the operator-part number combinations. The first subgroup is made up the results that Operator "a" got for part 1. This operator ran this part three different times (the number of trials).

The average and control limits are calculated and added to the chart. The control limits on this chart depend on the average range from the range chart (see below).

R Chart for Operator-Part Ranges



The R chart is a plot of the range of values within each operator-part number subgroup. Each range value is a measure of the repeatability of the test method. The average range and control limits are calculated and added to the chart.

Control Chart Calculations

$\bar{X}$ Chart	$\bar{\bar{X}}$	$LCL = \bar{\bar{X}} - A_2\bar{R}$	$UCL = \bar{\bar{X}} + A_2\bar{R}$
	0.00144	-0.348	0.351
R Chart	$\bar{R}$	$LCL = D_3\bar{R}$	$UCL = D_4\bar{R}$
	0.342	-	0.880

The control chart calculations are given.

where A_2, D_3, and D_4 are control chart constants depending on subgroup size.

A_2	D_3	D_4
1.023	-	2.574

$\bar{X}$ Chart Analysis

The $\bar{X}$ chart shows the average value for each operator for each part.

The $\bar{X}$ chart is analyzed. The control limits on this chart are based on the average range from

The control limits on the $\bar{X}$ chart are based on the average range.
The average range is representative of measurement error.
The $\bar{X}$ chart control limits represent the variation obscured by measurement error.

The relative utility of the measurement system increases:
* The more out of control points there on are on the $\bar{X}$ chart.
* The further the out of control points are away from the control limits.

22 out of 30 points are out of control on the chart.

the range chart. This average range represents measurement variability. If the test method is good, the measurement variability should be small. So, the average range should be small and the control limits should be tight around the average. The more out of control points the better.

R Chart Analysis

The R chart shows the results for the repeated measurements for each operator for each part.
It is a check of the consistency of the measurement process between the operators.

There is 1 out of control point on the R chart; the ranges are not consistent.
The reason for the out of control point should be corrected and the study repeated.

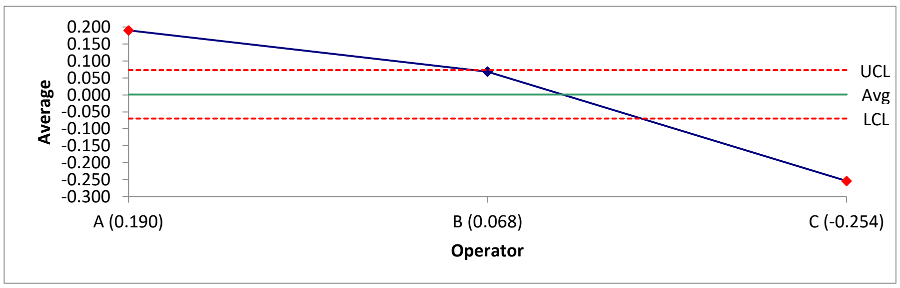
There are 54.7 degrees of freedom associated with the average range.
It is recommended to have at least 10 degrees of freedom.

The R chart is analyzed. This checks the consistency between the operators. There should be no out of control points. If there are, the reason should be found and eliminated and the study repeated.

The study should contain sufficient data (degrees of freedom). This is checked here.

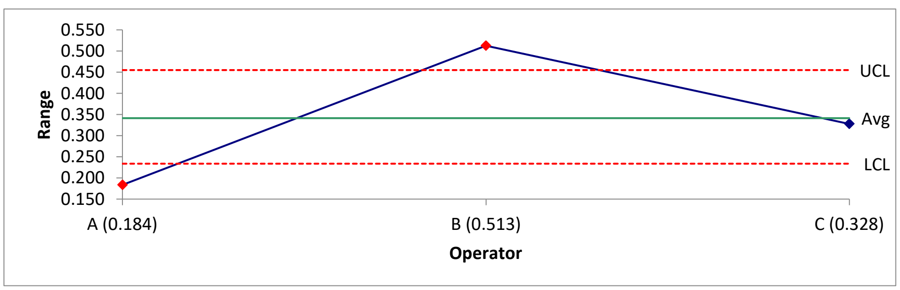
ANOM Charts for Bias and Repeatability

Main Effects (0.05 ANOME) Chart



The Analysis of Main Effects (ANOME) Chart compares the overall averages for the operator. The average for each operator is plotted. The overall average is plotted along with the ANOME upper and lower limits on the chart.

Mean Range (0.05 ANOMR) Chart



The Analysis of Mean Ranges (ANOMR) Chart compares the average range between operators. The average range for each operator is plotted. The overall average and the ANOMR upper and lower limits are added to the chart.

ANOM Calculations

Main Effects	$\bar{\bar{X}}$	$LCL = \bar{\bar{X}} - ANOME_{0.05}\bar{R}$	$UCL = \bar{\bar{X}} + ANOME_{0.05}\bar{R}$
	0.00144	-0.0700	0.0729
Mean Range	$\bar{R}$	$LCL = LMR_{0.05}\bar{R}$	$UCL = UMR_{0.05}\bar{R}$
	0.342	0.234	0.455

where ANOME, LMR, and UMR are scaling factors that depend on the amount of data.

$ANOME_{0.05}$	$LMR_{0.05}$	$UMR_{0.05}$
0.209	0.685	1.331

The ANOME and ANOMR calculations are given.

Main Effects Chart Analysis

This chart plots the average part values for each operator.
The purpose of the chart is to check for operator bias.
Points beyond the control limits are indications that bias exists.

There is evidence of detectable bias between the operators.
Review the ANOME chart for the differences.

The main effects chart is analyzed. There are differences (bias) in the operators if some of the points are beyond the limits.

Mean Range Chart Analysis

This charts plot the average range values for each operator.
The purpose of the chart is to see if the test-retest error is the same for each operator.
Points beyond the control limits are indications that differences in repeatability exist.

There is evidence of differences in the test-retest error between the operators.
Review the ANOMR chart for the differences.

The mean range is analyzed. There are differences in repeatability if some of the points are beyond the limits.

Data Table

Optional Data Table

Run No.	Operator	Part	Result	Comment
1	A	1	0.29	
31	A	1	0.41	
61	A	1	0.64	
2	A	2	-0.56	
32	A	2	-0.68	
62	A	2	-0.58	
3	A	3	1.34	
33	A	3	1.17	
63	A	3	1.27	
4	A	4	0.47	
34	A	4	0.5	
64	A	4	0.64	
5	A	5	-0.8	
35	A	5	-0.92	
65	A	5	-0.84	
6	A	6	0.02	
36	A	6	-0.11	
66	A	6	-0.21	
7	A	7	0.59	
37	A	7	0.75	
67	A	7	0.66	
8	A	8	-0.31	
38	A	8	-0.2	
68	A	8	-0.17	
9	A	9	2.26	
39	A	9	1.99	
69	A	9	2.01	
10	A	10	-1.36	
40	A	10	-1.25	
70	A	10	-1.31	
11	B	1	0.08	
41	B	1	0.25	
71	B	1	0.07	
12	B	2	-0.47	
42	B	2	-1.22	
72	B	2	-0.68	
13	B	3	1.19	
43	B	3	0.94	
73	B	3	1.34	
14	B	4	0.01	
44	B	4	1.03	
74	B	4	0.2	
15	B	5	-0.56	
45	B	5	-1.2	
75	B	5	-1.28	
16	B	6	-0.2	
46	B	6	0.22	
76	B	6	0.06	
17	B	7	0.47	
47	B	7	0.55	
77	B	7	0.83	
18	B	8	-0.63	
48	B	8	0.08	
78	B	8	-0.34	
19	B	9	1.8	
49	B	9	2.12	
79	B	9	2.19	
20	B	10	-1.68	
50	B	10	-1.62	
80	B	10	-1.5	
21	C	1	0.04	
51	C	1	-0.11	

81	C	1	-0.15
22	C	2	-1.38
52	C	2	-1.13
82	C	2	-0.96
23	C	3	0.88
53	C	3	1.09
83	C	3	0.67
24	C	4	0.14
54	C	4	0.2
84	C	4	0.11
25	C	5	-1.46
55	C	5	-1.07
85	C	5	-1.45
26	C	6	-0.29
56	C	6	-0.67
86	C	6	-0.49
27	C	7	0.02
57	C	7	0.01
87	C	7	0.21
28	C	8	-0.46
58	C	8	-0.56
88	C	8	-0.49
29	C	9	1.77
59	C	9	1.45
89	C	9	1.87
30	C	10	-1.49
60	C	10	-1.77
90	C	10	-2.16