Report Example: Basic EMP Study

Description of Output

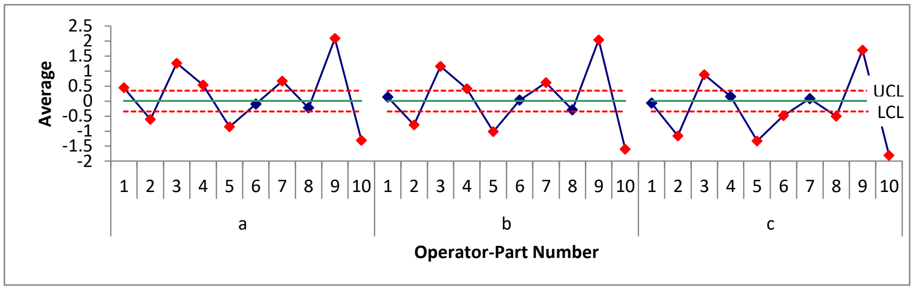
Date: 7/31/2018
Gage: My Gage
Characteristic: Thickness
Operators (o): 3
Parts (p): 10
Trials (n): 3

Analyzed by: Bill
USL: 3
LSL: -3
Process Average:
Process Sigma: 2.5
Meas. Increment: 0.01

Print out of information entered by the user

Operator-Part Control Charts

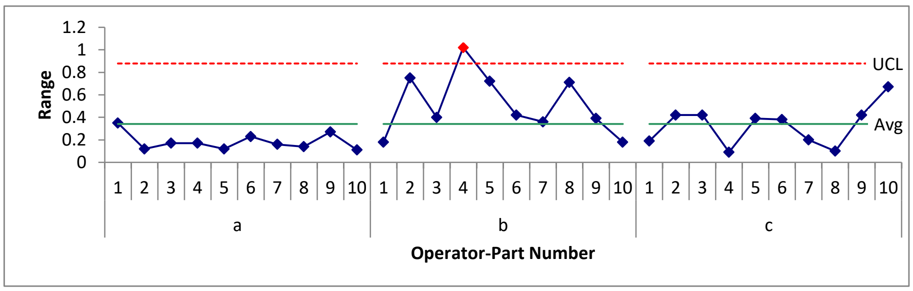
$\bar{X}$ Chart for Operator-Part Averages



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

<u>$\bar{X}$ Chart</u>	$\bar{\bar{X}}$	LCL = $\bar{\bar{X}}$ - $A_2\bar{R}$	UCL = $\bar{\bar{X}}$ + $A_2\bar{R}$
	0.001	-0.348	0.351
<u>R Chart</u>	$\bar{R}$	LCL = $D_3\bar{R}$	UCL = $D_4\bar{R}$
	0.342	-	0.880

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

The control chart calculations are given.

$\bar{X}$ Chart Analysis

The $\bar{X}$ chart shows the average value for each operator for each part.
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 $\bar{X}$ chart is analyzed. The control limits on this chart are based on the average range from 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.

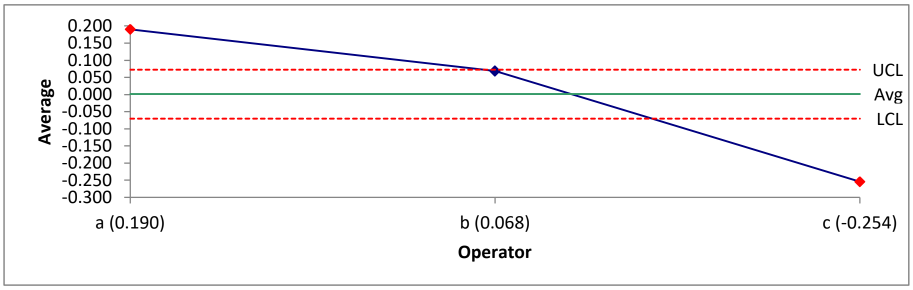
The R chart is analyzed. This checks the consistency between the operators. There should be no out of control points. If there are, the reason should be found and eliminated and the study repeated.

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

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

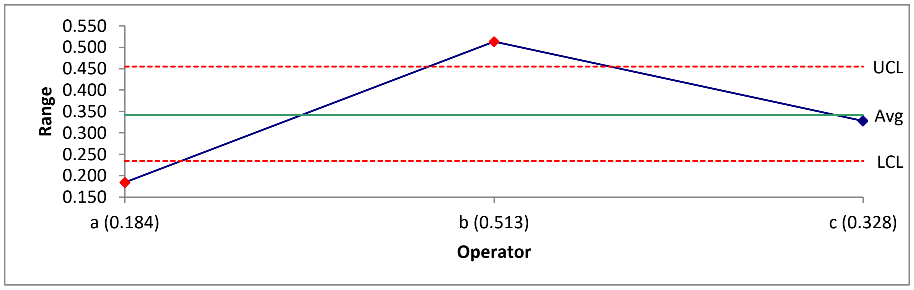
ANOM Charts for Bias and Repeatability

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$_{0.05}\bar{R}$
	0.001	-0.070	0.073
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.

Repeatability (Test-Retest Error)

d_2	$\sigma_{pe} = \bar{R}/d_2$
1.693	0.20181138

where d_2 is a control chart constant depending on subgroup size.

The repeatability (standard deviation) of the test method is determined from the average range.

Probable Error (PE) and Measurement Increment

PE	0.136	Probable Error (0.675σ_{pe})
0.2(PE)	0.0272	Smallest Effective Measurement Increment
2(PE)	0.272	Largest Effective Measurement Increment

PE is the minimum medium error of the measurement process.
50% of the measurements will fall within +/- one PE.
PE defines the effective resolution of the measurement process.
The resolution should be between 0.2(PE) and 2(PE).

The measurement increment (0.01) is less than 0.2(PE),
increase the measurement increment so it is between 0.2PE and 2PE.

The probable error (PE) is calculated to determine if the measurement increment is adequate. The measurement increment should be between 0.2PE and 2PE. If the measurement increment is too small, round up and rerun the analysis. If it is too large, look at ways to decrease the measurement increment.

Variance Components

Component	*Variance*	*% of Total*	*Estimates:*		*Sigma*
Repeatability	0.0407	0.7%	σ_{pe}^2	Repeatability (pure error) variance	0.202
Reproducibility	0.0514	0.8%	σ_o^2	Reproducibility variance	0.227
R&R	0.0922	1.5%	σ_e^2	Combined R&R variance	0.304
Product	6.158	98.5%	σ_p^2	Product variance	2.481
Total	6.250		σ_x^2	Total variance	2.500

The variance components are calculated and the % of total variance for the various components is given.

Product variance estimated from the process sigma entered.

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

$\sigma_o^2 = s_o^2 - (o/n\ o\ p)\sigma_{pe}^2$ where s_o^2 = variance of operator averages.

$\sigma_p^2 = \sigma_x^2 - \sigma_e^2$

The equations used in the calculations are given.

Intraclass Correlation Coefficients

Intraclass Correlation Coefficient (Repeatability) = 0.9934

$\rho_{pe} = \sigma_p^2/(\sigma_p^2+\sigma_{pe}^2)$

Intraclass Correlation Coefficient (Repeatability & Reproducibility) = 0.9853

$\rho_e = \sigma_p^2/(\sigma_p^2+\sigma_e^2)$

Two interclass coefficients are calculated: one based on the repeatability and one based on both the repeatability and reproducibility

Type of Class Monitor

Based on Repeatability: This is a First Class Monitor

Based on Repeatability and Reproducibility: This is a First Class Monitor

ρ	**Type of Monitor**	**Reduction of Process Signal**[a]	**Chance of Detecting ± 3 Std. Error Shifts**[b]	**Ability to Track Process Improvements**[c]
0.8 to 1.0	First Class	Less than 10%	>99% with Rule 1	Up to Cp80 = 2.22
0.5 to 0.8	Second Class	From 10% to 30%	>88% with Rule 1	Up to Cp50 = 3.51
0.2 to 0.5	Third Class Monitor	From 30% to 55%	>91% with Rules 1, 2, 3, & 4	Up to Cp20 = 4.439
0.0 to 0.2	Fourth Class Monitor	Greater than 55%	Rapidly Vanishes	Unable to Track

The type of class monitor is determined for each intraclass coefficient. The row for the class monitor for the intraclass coefficient based on repeatability is highlighted in yellow. If one or more specification is entered, the various Cp values are determined.

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[a]A signal occurring on a control chart is reduced in strength by 1 - square root of ρ_o.

[b]The probability that the measurement process can detect a significant shift.
Rule 1: Point beyond the control limits.
Rule 2: 2 out of 3 consecutive points on the same side of the average are > 1 sigma from the average.
Rule 3: 4 out of 5 consecutive points on the same side of the average are > 2 sigma from the average.
Rule 4: 8 consecutive points on the same side of the average.

[c]The process capability where the measurement process will move down to a lower class.

Watershed Specifications[1] and Precision to Tolerance Ratio

Watershed USL = 3.005
Watershed LSL = -3.005
Watershed Tol. = 6.01

% Mfg. Specs [2]	*PE Used to Tighten Specs* [3]	*Mfg. LSL* [4]	*Mfg. USL* [4]	*Precision to Tolerance Ratio* [5]	*Precision + Bias to Tolerance Ratio* [6]
85.0%	1	-2.86877732	2.86877732	4.53%	6.82%
96.0%	2	-2.73255464	2.73255464	9.07%	13.64%
99.0%	3	-2.59633196	2.59633196	13.60%	20.46%
99.9%	4	-2.46010927	2.46010927	18.13%	27.28%

If at least one specification is entered, the watershed specifications and precision to tolerance ratio are determined. The watershed specifications are used to determine manufacturing specifications that take into account measurement error (probable error). The ratio is given for repeatability only and for both the repeatability and reproducibility

The precision to tolerance ratio describes the % of the tolerance that is consumed by the probable error adjustment to the watershed specifications.

[1]Watershed specification limits take into account the measurement increment.
Watershed USL = USL + 0.5(measurement increment)
Watershed LSL = LSL - 0.5(measurement increment)
Watershed Tolerance = Watershed USL - Watershed LSL

[2]*% Mfg Specs* is the probability that an item, with a measured value that falls between the Mfg. LSL and Mfg. USL, conforms to specifications.

[3]*PE Used to Tighten Spec* s is the number of PE units used to reduce the watershed specifications.

[4]*Mfg. LSL* and *Mfg. USL are* the specifications based on the PE adjustments.
Example: 96%, Mfg. LSL = Watershed LSL + 2(PE) and Mfg. USL = Watershed USL - 2(PE)

[5]*Precision to Tolerance Ratio* is the % of the watershed tolerance consumed

by the PE adjustment.
Example: For 96% Mfg. Specs, P/T = 4(PE)/Watershed Tolerance

[6]*Precision + Bias to Tolerance Ratio* is the % of the watershed tolerance consumed by the PE adjustment using both the repeatability and reproducibility.

Data

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