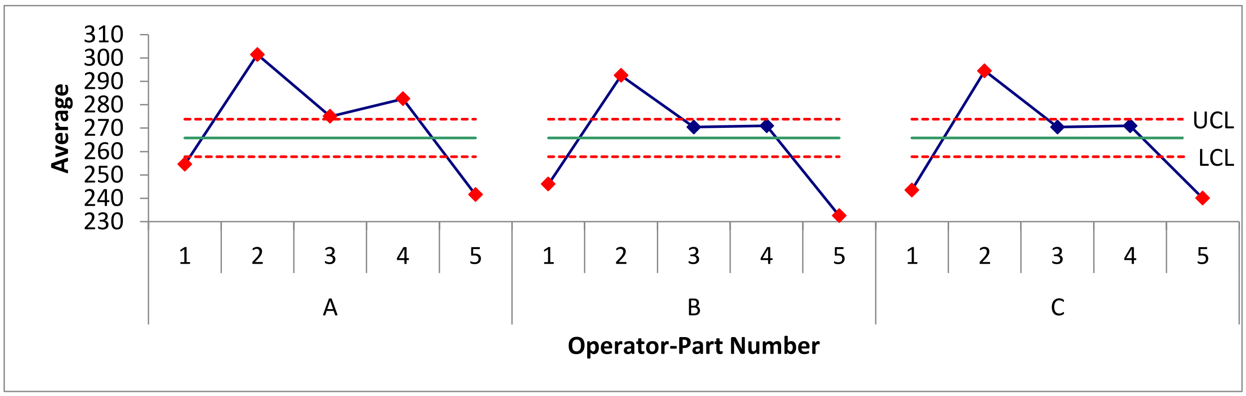
Basic EMP Study

Date: 6/18/2018
Gage: Micrometer
Characteristic: Width
Operators (o): 3
Parts (p): 5
Trials (n): 2

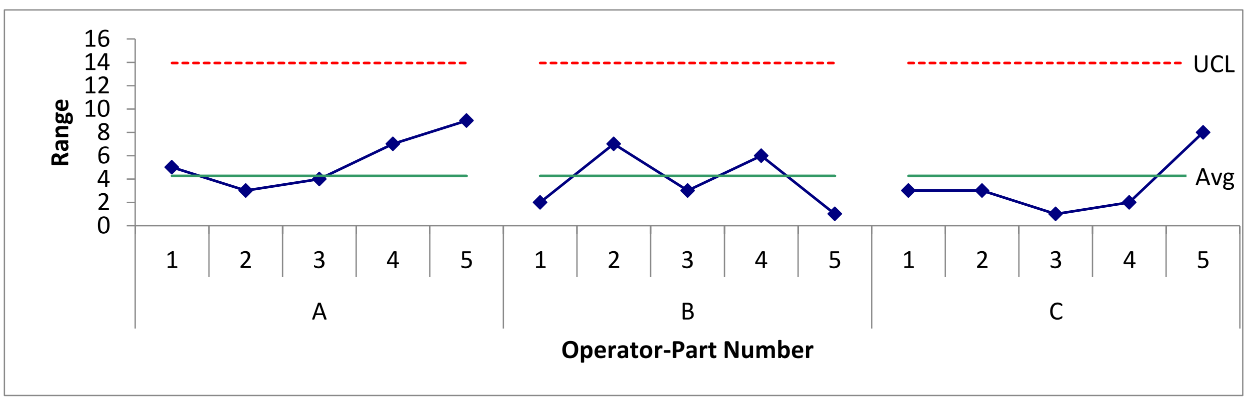
Analyzed by: Bill
USL: 305
LSL: 225
Process Average:
Process Sigma:
Meas. Increment: 1

Operator-Part Control Charts

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



R Chart for Operator-Part Ranges



Control Chart Calculations

$\bar{X}$ Chart	$\bar{\bar{X}}$	LCL = $\bar{\bar{X}} - A_2\bar{R}$	UCL = $\bar{\bar{X}} + A_2\bar{R}$
	265.8	257.8	273.8
R Chart	$\bar{R}$	LCL = $D_3\bar{R}$	UCL = $D_4\bar{R}$
	4.3	-	13.9

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

A_2	D_3	D_4
1.881	-	3.267

$\bar{X}$ 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.

11 out of 15 points are out of control on the chart.

R Chart Analysis

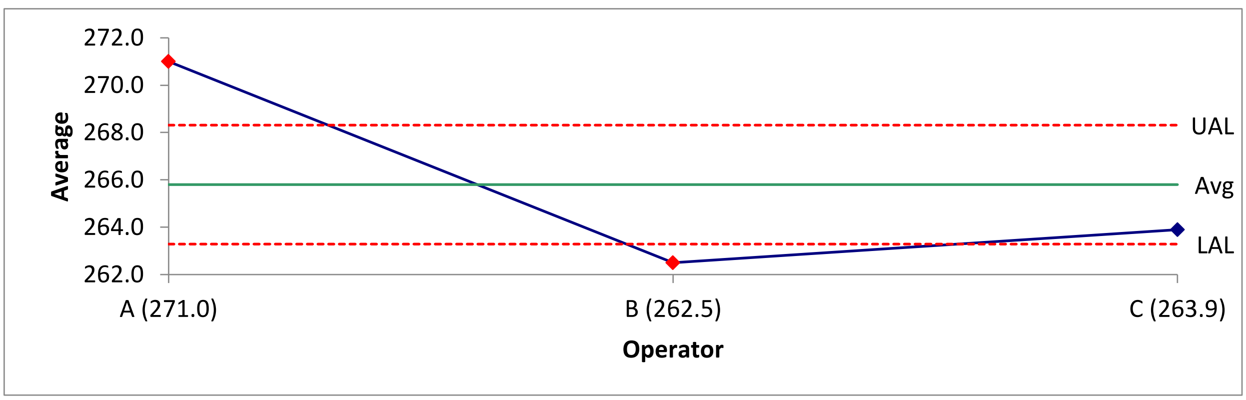
The R chart shows the results for the repeated measurements for each operator for each part.
It is a check of the consistency of the measurement process between the operators.

There are 0 out of control points on the R chart.
The ranges are consistent.

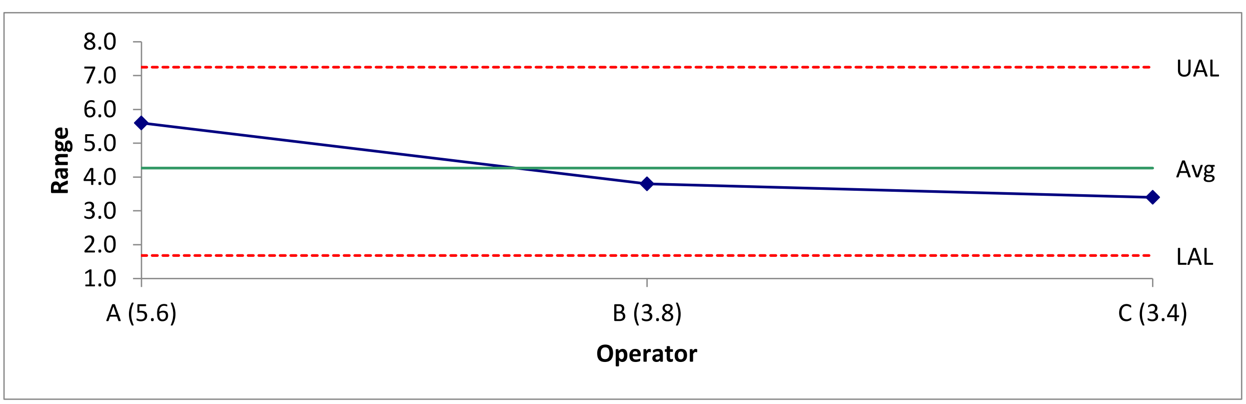
There are 13.4 degrees of freedom associated with the average range.
It is recommended to have at least 10 degrees of freedom.

ANOM Charts for Bias and Repeatability

Main Effects (0.05 ANOME) Chart



Mean Range (0.05 ANOMR) Chart



ANOM Calculations

<u>Main Effects</u>	$\bar{\bar{X}}$	LAL = $\bar{\bar{X}}$ - $ANOME_{0.05}\bar{R}$	UAL = $\bar{\bar{X}}$ + $ANOME_{0.05}\bar{R}$
	265.8	263.3	268.3
<u>Mean Range</u>	$\bar{R}$	LAL = $LMR_{0.05}\bar{R}$	UAL = $UMR_{0.05}\bar{R}$
	4.3	1.7	7.2

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

$ANOME_{0.05}$	$LMR_{0.05}$	$UMR_{0.05}$
0.589	0.394	1.699

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.

Mean Range Chart Analysis

This chart plots 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 no difference in the test-retest error between the operators.

Repeatability (Test-Retest Error)

d_2	$\sigma_{pe} = \bar{R}/d_2$
1.128	3.78250591

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

Probable Error (PE) and Measurement Increment

PE	2.553	Probable Error ($0.675\sigma_{pe}$)
0.2(PE)	0.511	Smallest Effective Measurement Increment
2(PE)	5.106	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 (1) is adequate since it is between 0.2PE and 2 PE.

Variance Components

Component	*Variance*	*% of Total*	*Estimates:*		*Sigma*
Repeatability	14.31	2.5%	σ_{pe}^2	Repeatability (pure error) variance	3.783
Reproducibility	19.34	3.4%	σ_o^2	Reproducibility variance	4.398
R&R	33.65	6.0%	σ_e^2	Combined R&R variance	5.801
Product	530.6	94.0%	σ_p^2	Product variance	23.03
Total	564.2		σ_x^2	Total variance	23.75

Product variance based on parts used in the study.

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

Intraclass Correlation Coefficients

Intraclass Correlation Coefficient (Repeatability) = 0.9737

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

Intraclass Correlation Coefficient (Repeatability & Reproducibility) = 0.9404

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

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 = 1.596
0.5 to 0.8	Second Class	From 10% to 30%	>88% with Rule 1	Up to Cp50 = 2.524
0.2 to 0.5	Third Class Monitor	From 30% to 55%	>91% with Rules 1, 2, 3, & 4	Up to Cp20 = 3.192
0.0 to 0.2	Fourth Class Monitor	Greater than 55%	Rapidly Vanishes	Unable to Track

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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 = 305.5
Watershed LSL = 224.5
Watershed Tol. = 81

% 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	227.053191	302.946809	6.30%	9.67%
96.0%	2	229.606383	300.393617	12.61%	19.34%
99.0%	3	232.159574	297.840426	18.91%	29.00%
99.9%	4	234.712766	295.287234	25.22%	38.67%

[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

Run No.	Operator	Part	Result	Comment
1	A	1	257	
16	A	1	252	
2	A	2	300	
17	A	2	303	
3	A	3	277	
18	A	3	273	
4	A	4	279	
19	A	4	286	
5	A	5	246	
20	A	5	237	
6	B	1	245	
21	B	1	247	
7	B	2	296	
22	B	2	289	
8	B	3	272	
23	B	3	269	
9	B	4	274	
24	B	4	268	
10	B	5	233	
25	B	5	232	
11	C	1	242	
26	C	1	245	
12	C	2	296	
27	C	2	293	
13	C	3	270	
28	C	3	271	
14	C	4	270	
29	C	4	272	
15	C	5	236	
30	C	5	244	