Report Example: Short EMP Study

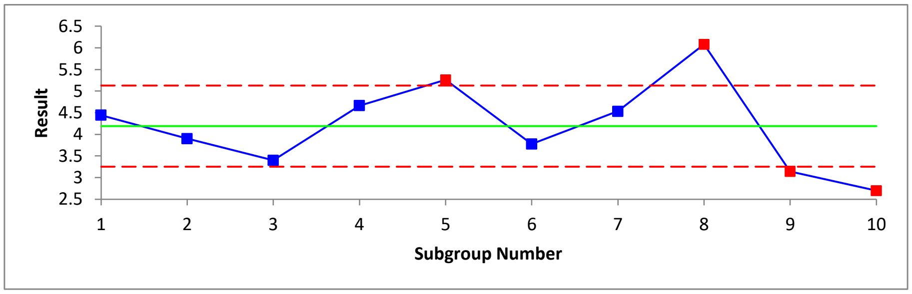
Description of Output

Date: 12/31/2018	Analysis by: Bill
Gage: 702	USL: 8
Characteristic: Wheeler Data	LSL: 1
Process Avg.:	Meas. Increment: 0.01
Process Sigma: 2	Operator: Sam

Print out of information entered by the user

Average and Range Control Charts

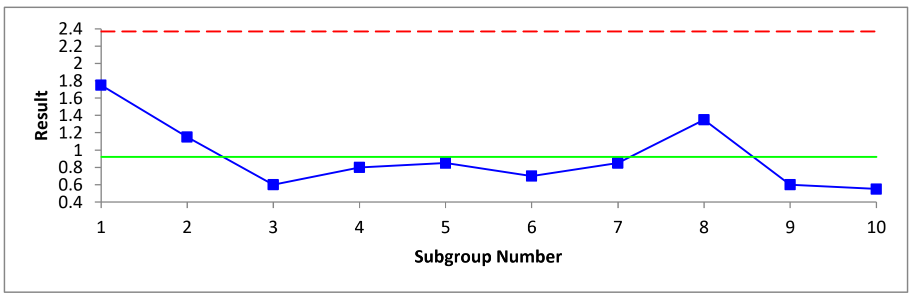
Subgroup Averages ($\bar{X}$) Chart



The $\bar{X}$ chart is a plot of the subgroup averages. 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 replicates).

The average and control limits are calculated and added to the chart.

Subgroup Range (R) Chart



The R chart is a plot of the range of values within each subgroup. Each range value is a measure of the repeatability of the test method. The average range and upper control limit 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 = $\bar{\bar{X}} + A_2\bar{R}$
	4.190	3.248	5.131
<u>R Chart</u>	$\bar{R}$	LCL = $D_3\bar{R}$	UCL = $D_4\bar{R}$
	0.920	-	2.368

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 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 $\bar{X}$ chart also shows the product variation - the variation between subgroups.
The product variation should exceed 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.

There are 4 out of control points on the subgroup averages 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

Each range value is a measure of the within subgroup variation.
The within subgroup variation is a measure of the test-retest error (pure error).
The range chart should not have any out of control points.
Out of control points are indications that there are special causes present.

There are no out of control points on the range chart.
The ranges are consistent.
The repeatability standard deviation value is valid.

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 18.4 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.

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Repeatability (Test-Retest Error)

d_2	$\sigma_{pe} = \bar{R}/d_2$
1.693	0.54341406

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

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

Probable Error (PE) and Measurement Increment

PE	0.367	Probable Error ($0.675\sigma_{pe}$)
0.2(PE)	0.0734	Smallest Effective Measurement Increment
2(PE)	0.734	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.

Watershed Specifications[1] and Precision to Tolerance Ratio

Watershed USL =	8.005
Watershed LSL =	0.995
Watershed Tol. =	7.01

% Mfg. Specs [2]	*PE Used to Tighten Specs* [3]	*Mfg. LSL* [4]	*Mfg. USL* [4]	*Precision to Tolerance Ratio* [5]
85.0%	1	1.36180449	7.63819551	10.47%
96.0%	2	1.72860898	7.27139102	20.93%
99.0%	3	2.09541347	6.90458653	31.40%
99.9%	4	2.46221796	6.53778204	41.86%

[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

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.

Overall Variance and Product Variance

Assumption: process sigma entered represents variation in the production process.

Process Sigma	2	σ_x
Total Variance	4.000	σ_x^2
Product Variance	3.705	$\sigma_p^2 = \sigma_x^2 - \sigma_{pe}^2$

Summary	**Variance**	**% of Total**
Measurement	0.295	7.38%
Product	3.705	92.62%
Total	4.000	

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

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.

Intraclass Correlation Coefficient (ρ_{pe})

$\rho_{pe} = \sigma_p^2/(\sigma_p^2+\sigma_{pe}^2) =$ 0.9262

The intraclass coefficient is calculated.

Type of Class Monitor

ρ_{pe}	**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 = 0.962
0.5 to 0.8	Second Class	From 10% to 30%	>88% with Rule 1	Up to Cp50 = 1.52
0.2 to 0.5	Third Class Monitor	From 30% to 55%	>91% with Rules 1, 2, 3, & 4	Up to Cp20 = 1.923

The type of class monitor is determined based on the intraclass coefficient. The row for the class monitor for the intraclass coefficient based

0.0 to 0.2	Fourth Class Monitor	Greater than 55%	Rapidly Vanishes	Unable to Track

on repeatability is highlighted in yellow. If one or more specification is entered, the various Cp values are determined.

[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.

Data

Optional Data Table

Subgroup Number	X1	X2	X3	Comments
1	3.66	4.26	5.41	
2	4.50	3.85	3.35	
3	3.63	3.03	3.53	
4	4.28	5.08	4.63	
5	5.66	4.81	5.31	
6	3.36	3.91	4.06	
7	4.20	4.35	5.05	
8	6.95	5.60	5.70	
9	3.41	2.81	3.21	
10	2.43	2.98	2.68	