New Hampshire Ball Bearings, Inc.
A Minebea Company

Granite State ASQ 0104

MSA – an alternative method for estimating % Tolerance

April 18, 2012

Jack Meagher - NHBB

New Hampshire Ball Bearings

New Hampshire Ball Bearings, Inc.
A Minebea Company

- Founded in 1946 in Peterborough, NH
- Acquired by Minebea (Japan) in 1985
- Three U.S. manufacturing facilities
  - Precision Division, Chatsworth, CA
  - Astro Division, Laconia, NH
  - HiTech Division, Peterborough, NH
- First bearing company to register all of our manufacturing divisions to ISO 9000 and the first company to register at least one division to ISO 9001.

Before we start

New Hampshire Ball Bearings, Inc.
A Minebea Company

Why are you here?

- Curiosity?
- Obtain guidelines?
- Understand the concerns with AIAG methods?
- Much needed (Gage) R&R?

Before we start

Note:

I am an Engineer – NOT - a Math Major or a Statistician. The method proposed here is intended to be of practical use when conducting MSA's.

Before we start

Note:

Having been trained as a Six Sigma Black Belt, you are taught to let the data lead you. Let's see where the data presented here leads us.

Individuals who supported this project:

Donald Wheeler, well known Statistician and Author

Philip J. Ramsey Ph.D.
North Haven Group
University of New Hampshire

Roy Geiger, NHBB Operations Manager, Peterborough, NH

Donald Wheeler, well known Statistician and Author (spcpress.com)

New Hampshire Ball Bearings, Inc.
A Minebea Company

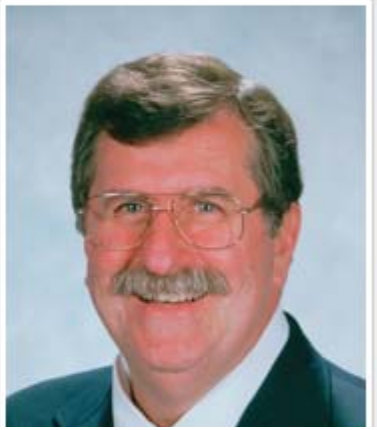
SPC PRESS &
STATISTICAL PROCESS CONTROLS, INC.

Home | Books | Seminars | Other Products | Reading Room

Welcome to the website of Dr. Donald J. Wheeler

SPC Press offers you today's best books on Statistical Process Control, Six Sigma, Data Analysis, and Quality Improvement, including:

- Understanding Variation
- Understanding Statistical Process Control
- EMP III: Evaluating the Measurement Process
- Reducing Production Costs



Read the article – "Problems with Gauge R&R Studies"

Note: JMP is incorporating Wheeler's concepts into their Gauge R&R analysis option.

Philip J. Ramsey Ph.D.
North Haven Group
University of New Hampshire

When asked if there was any test in statistics that uses a ratio of standard deviations, the answer was NO.

Note: $F = \sigma_1^2/\sigma_2^2$
(ratio of Variances!)

Example:

Variances

$F = \sigma_1^2/\sigma_2^2 = 2^2/10^2 = 4/100 = 0.04$

Standard Deviations

"F" $\neq \sqrt{\sigma_1^2}/\sqrt{\sigma_2^2} = 2/10 = 0.2$

Before we start

New Hampshire Ball Bearings, Inc.
A Minebea Company

A short exercise to set the tone for this presentation –

Circles in the air.

Objectives:

Offer an alternative method of obtaining a value for % Tolerance

Identify and address specific concerns within the AIAG MSA Fourth Edition relating to % Study Variation and % Tolerance

Note: All results shown are from using Minitab to analyze the data

Agenda:

New Hampshire Ball Bearings, Inc.
A Minebea Company

A preview and questions

Guidelines for MSA studies

Importance of chart outputs

Various sample analyses

Variance vs. Standard Deviation

Donald Wheeler's studies

Forced variation – FOR REFERENCE ONLY!

Questions/comments

A preview of what is to follow. This is where we "draw the line"

New Hampshire Ball Bearings, Inc. A Minebea Company

Gage R&R

Source	VarComp	%Contribution (of VarComp)
Total G		
Repea		
Repro		
Ope		
Operator*Part	0.012642	2.13
Part-To-Part	0.567397	95.62
Total Variation	0.593400	100.00

Proportion

These are the "Honest" Gage R&R results as identified by Donald
oportions add up to

Definition of proportion: A part considered in relation to the whole.

Process tolerance = 2

Definition of ratio: A part to part relationship, not to the whole.

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.161253	0.96752	20.93	48.38
Repea				.68
Repro				.73
Ope				.00
Ope				.73
Part-To-Part	0.753258	4.51955	97.78	225.98
Total Variation	0.770324	4.62195	100.00	231.10

Ratio

Ratios based of values that are square root sum of squares?

Note: The value of .4838 [(6*Std Dev/(USL - LSL)] is the reciprocal of the Cp value!

Cp = (USL - LSL)/6*Std Dev = 2.07 (Capability)

A few questions

What number(s) do you look at when you run an MSA?

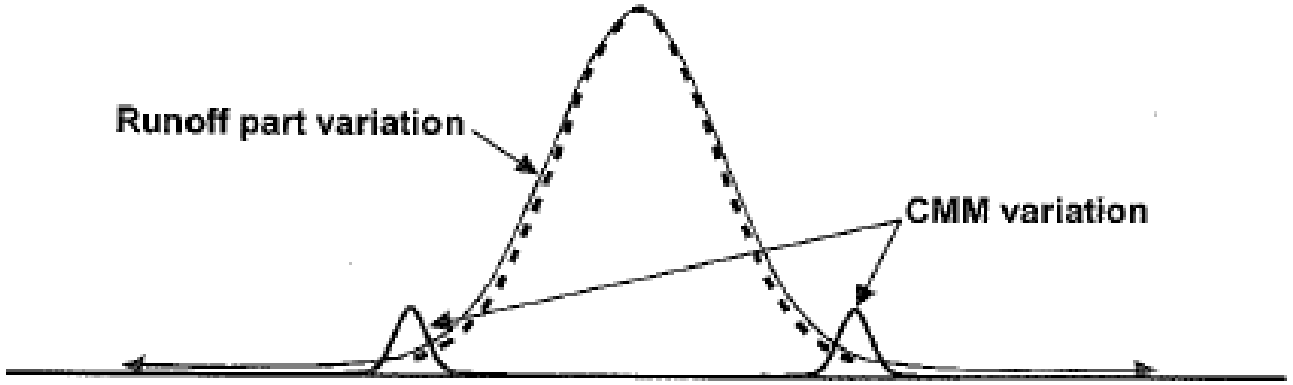
Have you ever questioned the results?
(% Tolerance looks very high)

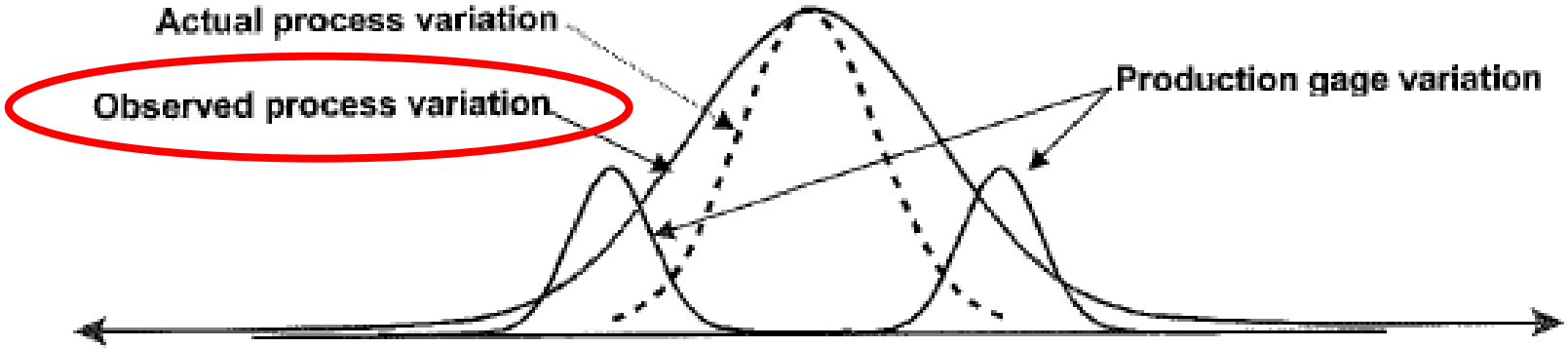
Have you ever modified and/or removed gauging systems based on these results?

Have you not found parts that span the entire tolerance?

Are these depictions accurate?

The area under the curve always equals 1 – and – gage variation adds to the variation across the board, not just out near the spec limits.





Opening statements:

New Hampshire Ball Bearings, Inc.
A Minebea Company

You should utilize Gage R&R's for YOUR benefit. Only give the customer(s) what they ask for (just like any audit).

Develop the mindset that MSA's are just like capability studies, you need to run them on a regular basis.

Start with gage families – calipers, micrometers, air gages, etc.

Opening statements (continued):

Keep the parts you use in Gage studies as "standards" (if at all possible).

Use these "standards" for evaluating new operators, new gages or just as a yearly audit check on the process.

To check new gages, use most consistent operator and label "gages" as "operators".

Before we get started -

New Hampshire Ball Bearings, Inc.
A Minebea Company

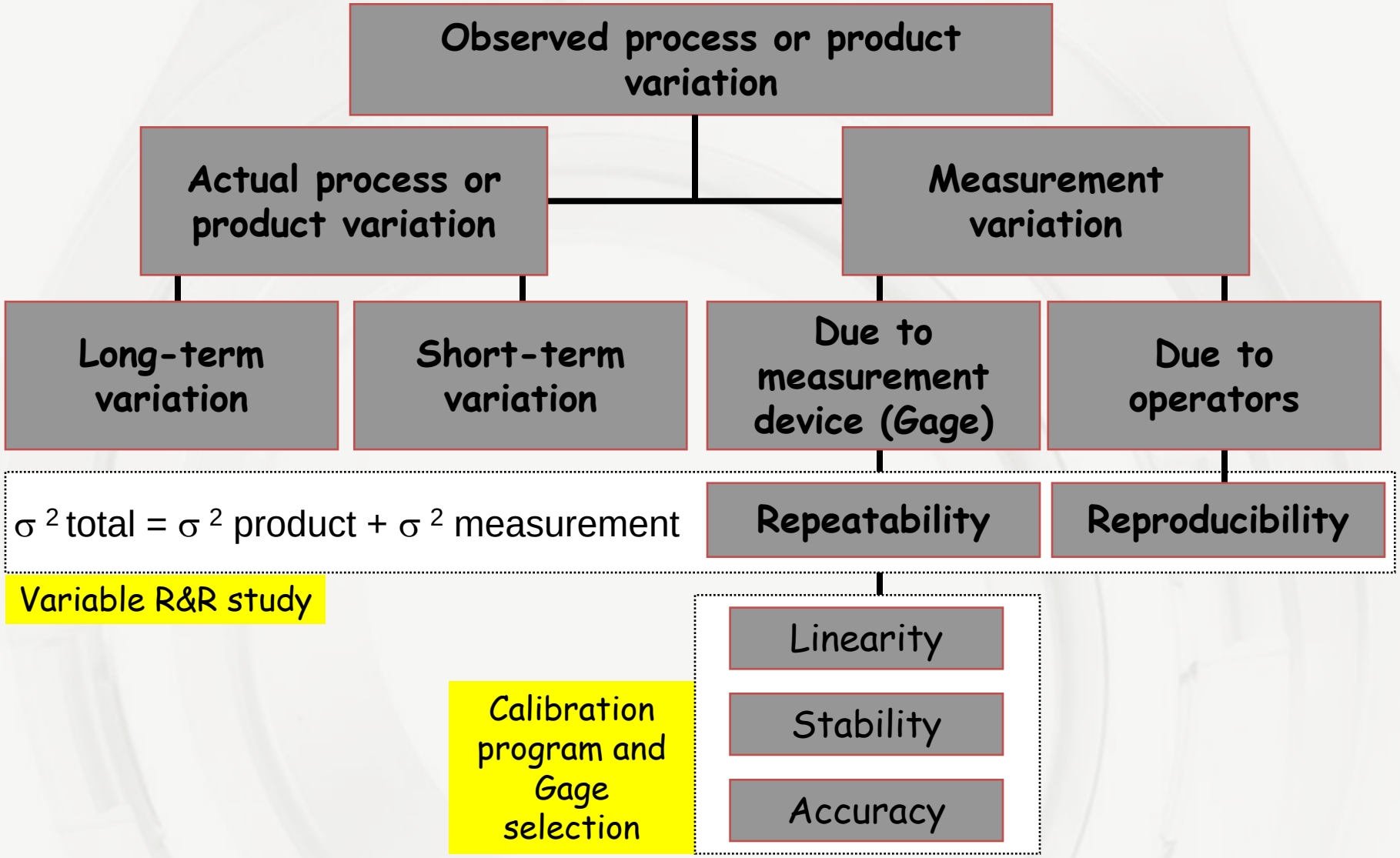
A Gage R&R should NOT be conducted without a prior understanding of your gaging system in regards to:

Bias (Accuracy) - difference between the observed average of measurements and the reference value. (NHBB utilizes masters on the shop floor. They must reach equilibrium (temperature) before being used.)

Linearity - difference in the bias (accuracy) through the expected range of the gage.

Stability - total variation in the measurements over an extended period of time.

Possible Sources of Variation



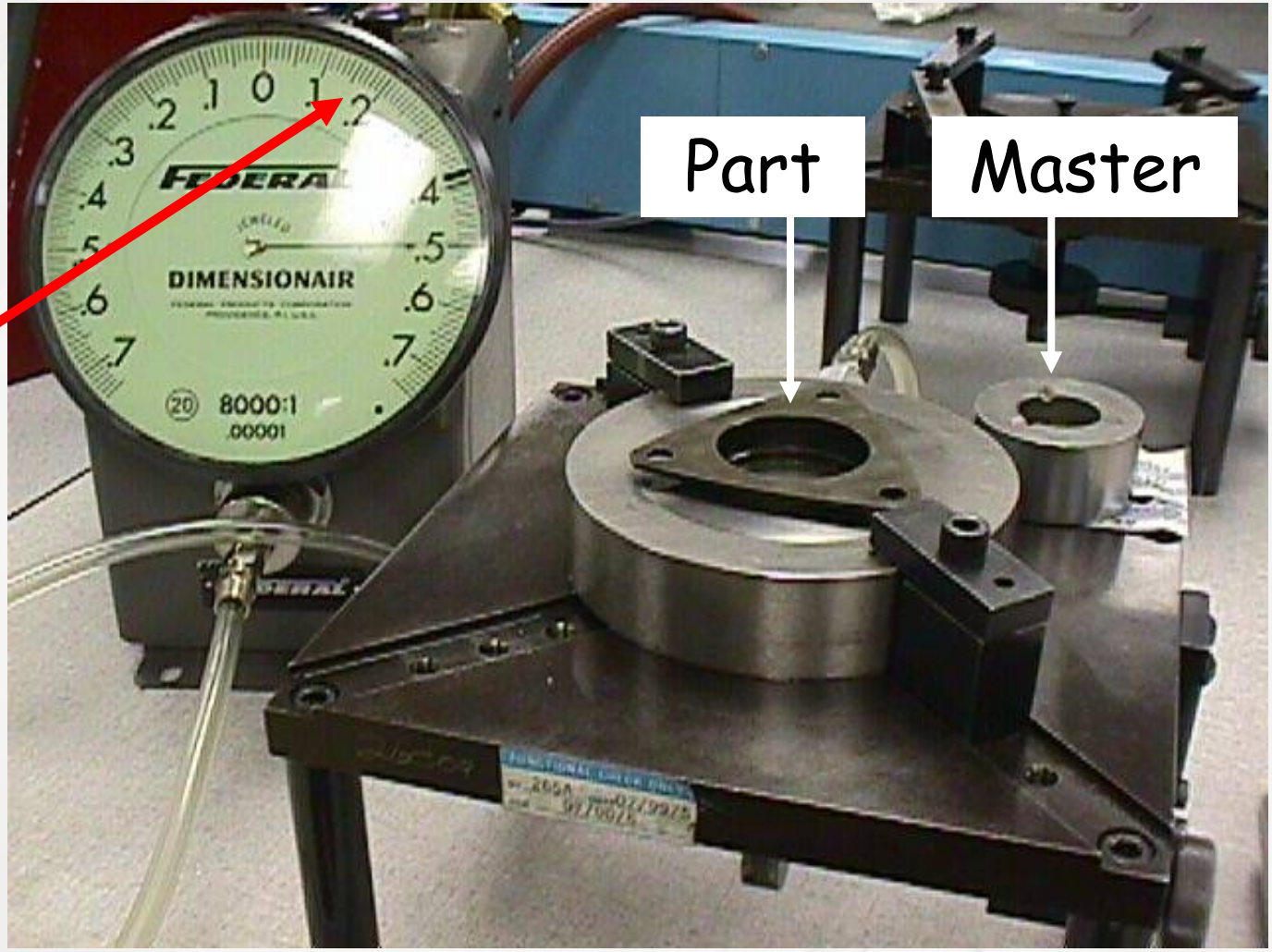
Question – do you mark where to measure your parts???

Typically, we (NHBB) do mark our parts because we do not want within-part variation to come into play. We measure other characteristics such as roundness, taper, etc. utilizing other measurement devices which will have their own Gage R&R's. However, we have rotated parts to get the "average" diameter and used that for our response.

We measure our product using gages like these ...

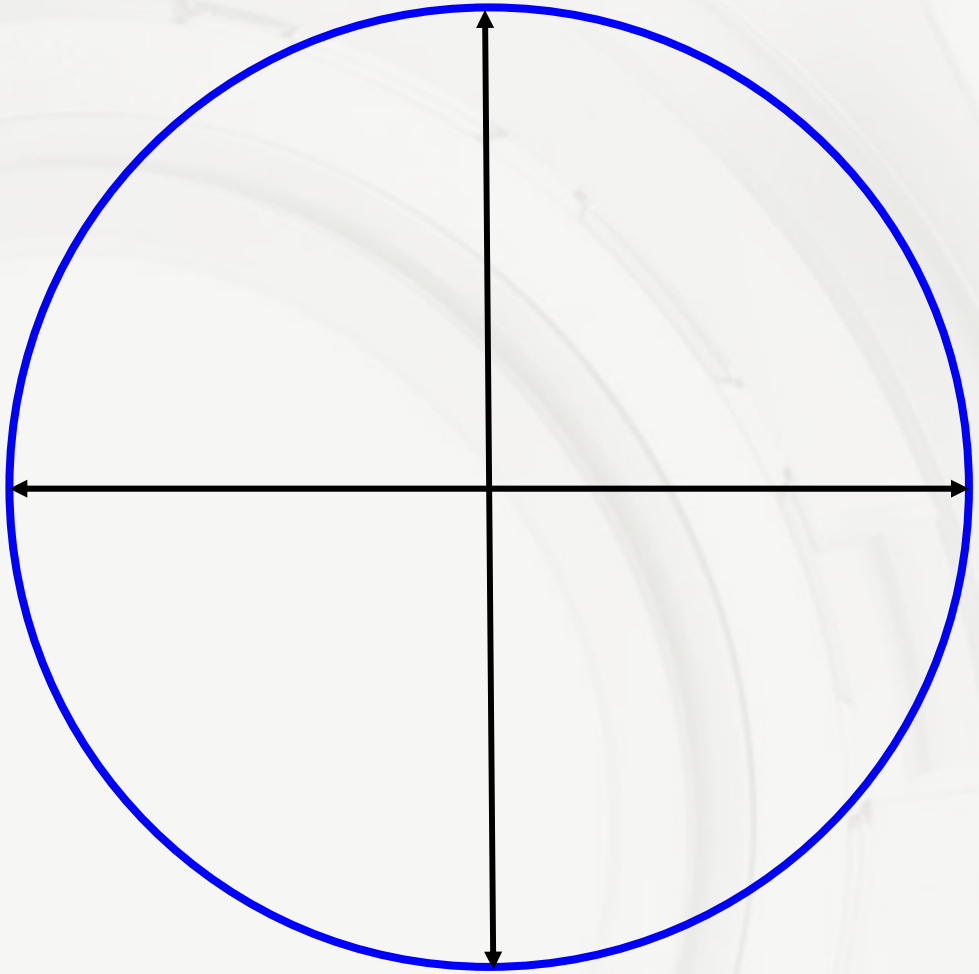
New Hampshire Ball Bearings, Inc.
A Minebea Company

Note: Resolution on gage is 10 millionths (0.000010).



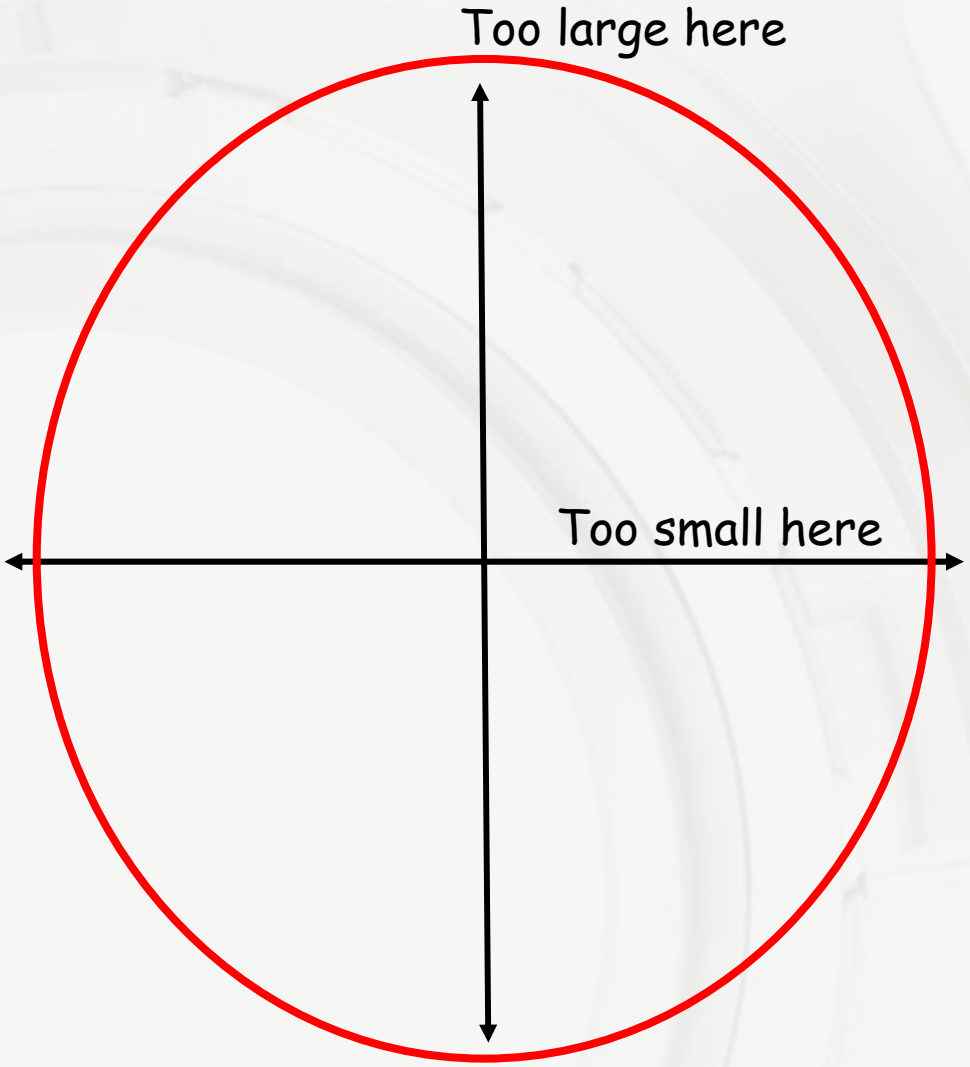
Question – do you mark where to measure your parts???

Measuring an OD on a nice round part is not an issue because the measurement should be the same in any location.



Question – do you mark where to measure your parts???

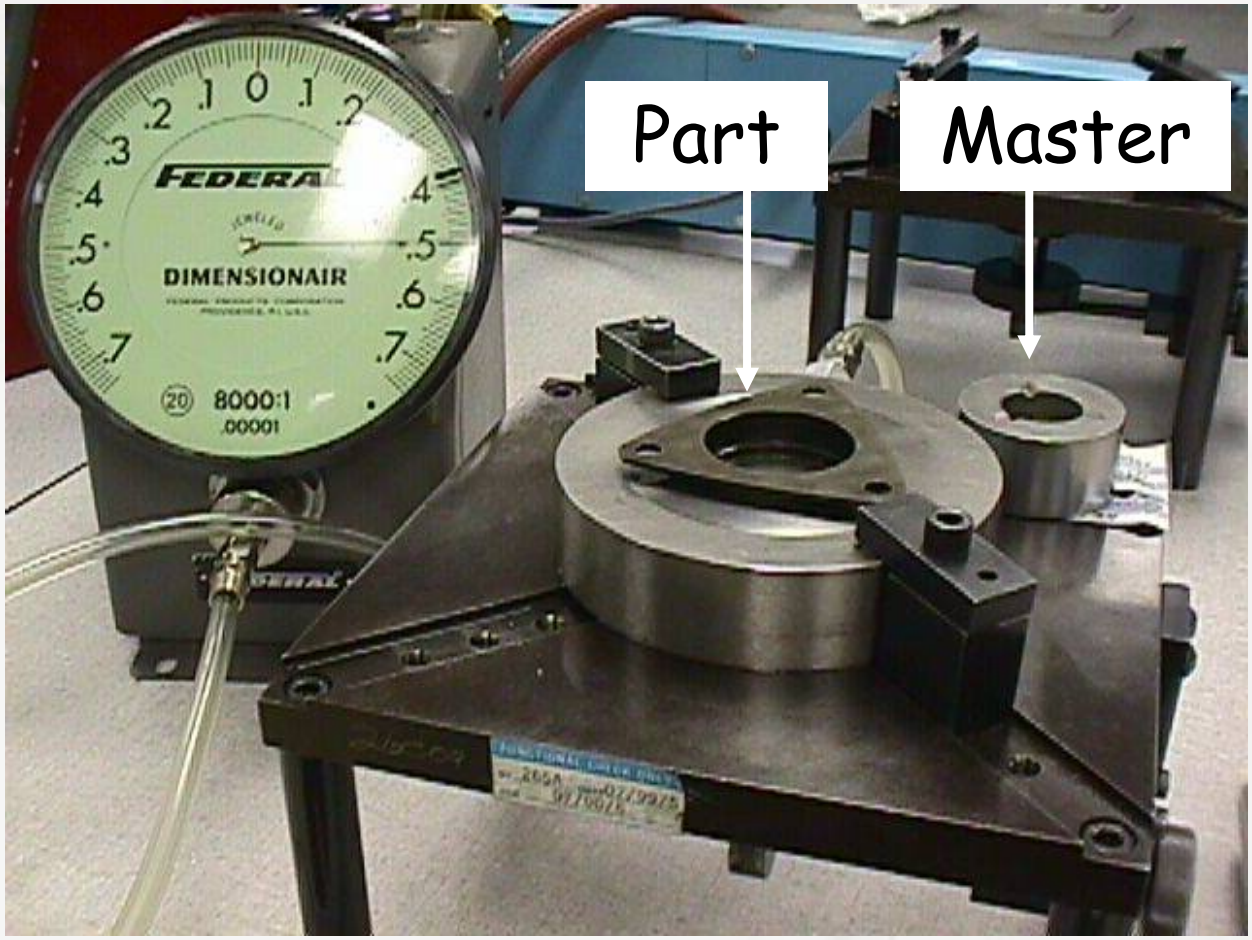
If your part is out-of-round, you would now be adding within-part variation into all of the readings.



All components must be at the same temperature!

New Hampshire Ball Bearings, Inc.
A Minebea Company

With an expansion rate of 6 millionths per degree per inch and a tolerance of 0.000200" on a 6" diameter, temperature differences become critical!



A temperature difference of just 2 degrees can equate to 0.000072"!

Gage R&R Guidelines:

Gages should be **designed** to **remove operator influence** as much as possible (Reproducibility).

Gages should be **calibrated** and have at least some history in regards to **bias**, **linearity** and **stability**.

Try to keep this analysis a "**blind**" study. The operators should **not** know the identification of the parts they are measuring. Do this by **randomizing** the order of the parts being measured.

Gage R&R Guidelines:

Randomize operators. Only do one operator for one trial and then move on to the next operator.

Try to complete the measurements in a **timely manner**. Don't drag it out for days. You may have to retake some measurements!

Appraisers should be the ones who normally operate the gages. However – if you are capable of operating the gage properly, you might consider becoming one of the operators.

Gage R&R Guidelines:

Observe every operator very carefully to detect the **slightest differences** that may show up as indications in the results.

The study should be observed and/or recorded by an individual who recognizes the **importance** of the **detail** required to conduct a reliable study. (DOE – lack of execution!)

If one operator shows **more consistency** than the others, find out what they are doing and share that with everyone.

Variable Gage R&R Recording Sheet

NHBB Precision Ball Bearings, Inc.
A Minebea Company

NHBB Gage Repeatability and Reproducibility Report
Random Order Recording Format

Part Description: _____ **Gage Type:** _____ **Date:** _____

Part Number: _____ **Gage Number:** _____ **Performed By:** _____

Operator Names:

A: _____ **Characteristic:** _____

B: _____ **Specification:** _____

C: _____ **Enter the overall tolerance (± 1.5 = 3.0):** _____

Operator A:			Operator B:			Operator C:		
Part #	Trial #	Measurement	Part #	Trial #	Measurement	Part #	Trial #	Measurement
5	1		5	1		5	1	
1	1		1	1		1	1	
4	1		4	1		4	1	
2	1		2	1		2	1	
3	1		3	1		3	1	
4	2		4	2		4	2	
3	2		3	2		3	2	
2	2		2	2		2	2	
5	2		5	2		5	2	
1	2		1	2		1	2	
2	3		2	3		2	3	
4	3		4	3		4	3	
1	3		1	3		1	3	
3	3		3	3		3	3	
5	3		5	3		5	3	

Notes: When running the analysis, go to PB_ENG\Six Sigma\Gage R&R Data Recording Forms\NHBB Random Order GRR.MPJ
Open the file and input your information for Operator and Measurement. The Part and Trail columns are already filled in.
After you run the analysis, Save Project As… a DIFFERENT file name so you do NOT overwrite this file!
If using a Master for the gage, include the Gage Setup Check form included in the GRR Forms Minitab Format.xls file.

Part Order Sheet

New Hampshire Ball Bearings, Inc.
A Minebea Company

Part Order for Gage R&R

1	2	3	4	5

Minitab Gage R&R Worksheet

New Hampshire Ball Bearings, Inc.
A Minebea Company

Operator	Part	Trial	Measurement
	5	1	
	1	1	
	4	1	
	2	1	
	3	1	
	4	2	
	3	2	
	2	2	
	5	2	
	1	2	
	2	3	
	4	3	
	1	3	
	3	3	
	5	3	

Guidelines for Acceptability (per AIAG)

New Hampshire Ball Bearings, Inc.
A Minebea Company

Guidelines:	% Contribution	% Study Variation or % Tolerance
No Issues	< 1%	< 10%
Marginal	1% to 9%	10% to 30%
Needs Work	> 9%	> 30%

Guidelines:	Distinct Categories
No Issues	> 10
Marginal	4 to 9
Needs Work	< 4

Still the same guidelines!

New Hampshire Ball Bearings, Inc.
A Minebea Company

For measurement systems whose purpose is to analyze a process, a general guidelines for measurement system acceptability is as follows:

GRR	Decision	Comments
Under 10 percent	Generally considered to be an acceptable measurement system.	Recommended, especially useful when trying to sort or classify parts or when tightened process control is required.
10 percent to 30 percent	May be acceptable for some applications	Decision should be based upon, for example, importance of application measurement, cost of measurement device, cost of rework or repair. Should be approved by the customer.
Over 30 percent	Considered to be unacceptable	Every effort should be made to improve the measurement system. This condition may be addressed by the use of an appropriate measurement strategy; for example, using the average result of several readings of the same part characteristic in order to reduce final measurement variation.

Table II-D 1: *GRR* Criteria

Where to start?

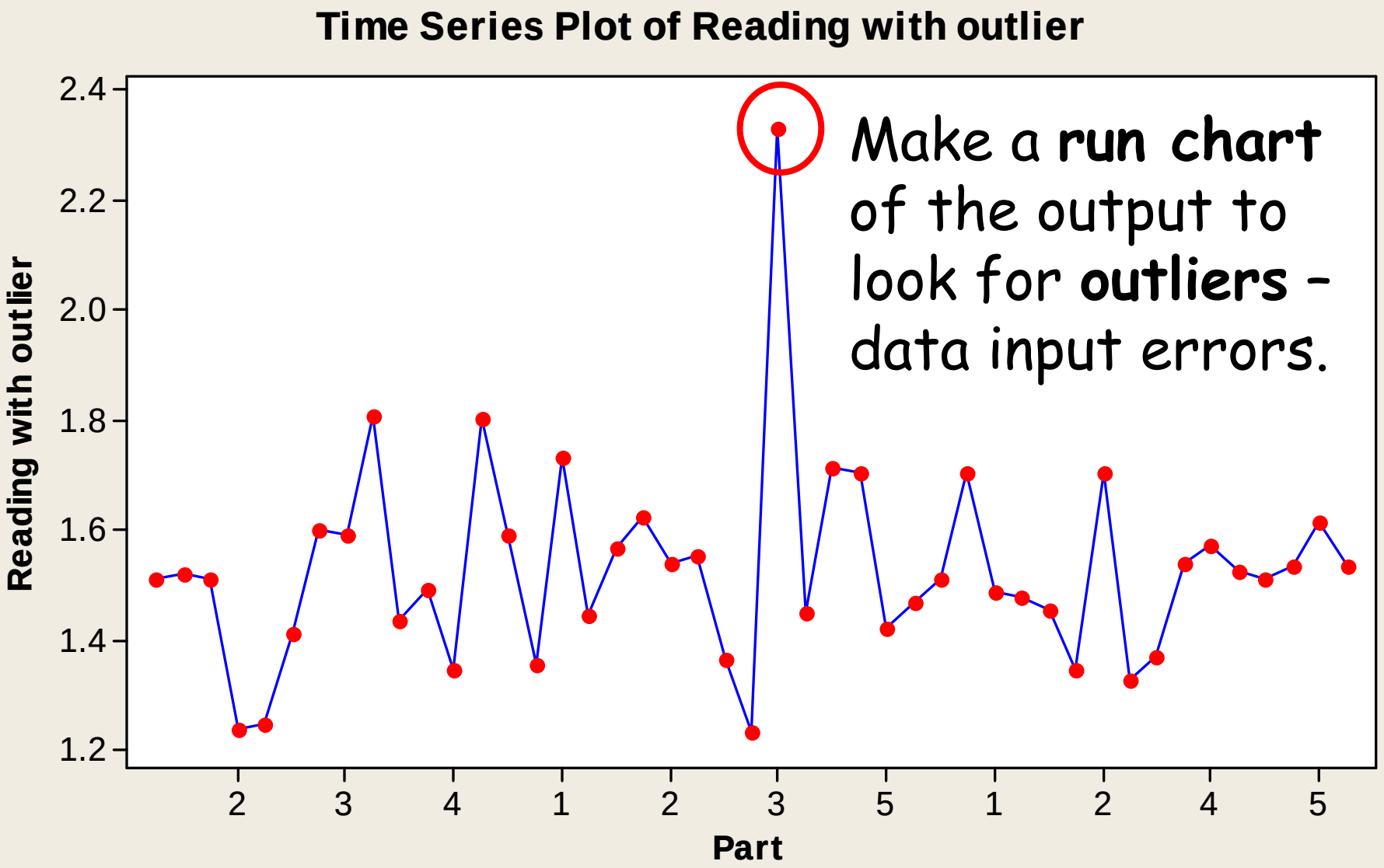
Do **NOT** automatically go to the statistics.

Before you even think of looking at the statistics, you should **review** the **Minitab charts** for quick **visual clues** as to where any issues reside.

You should identify and **correct any obvious issues** before running additional analyses to quantify gage performance.

Where to start?

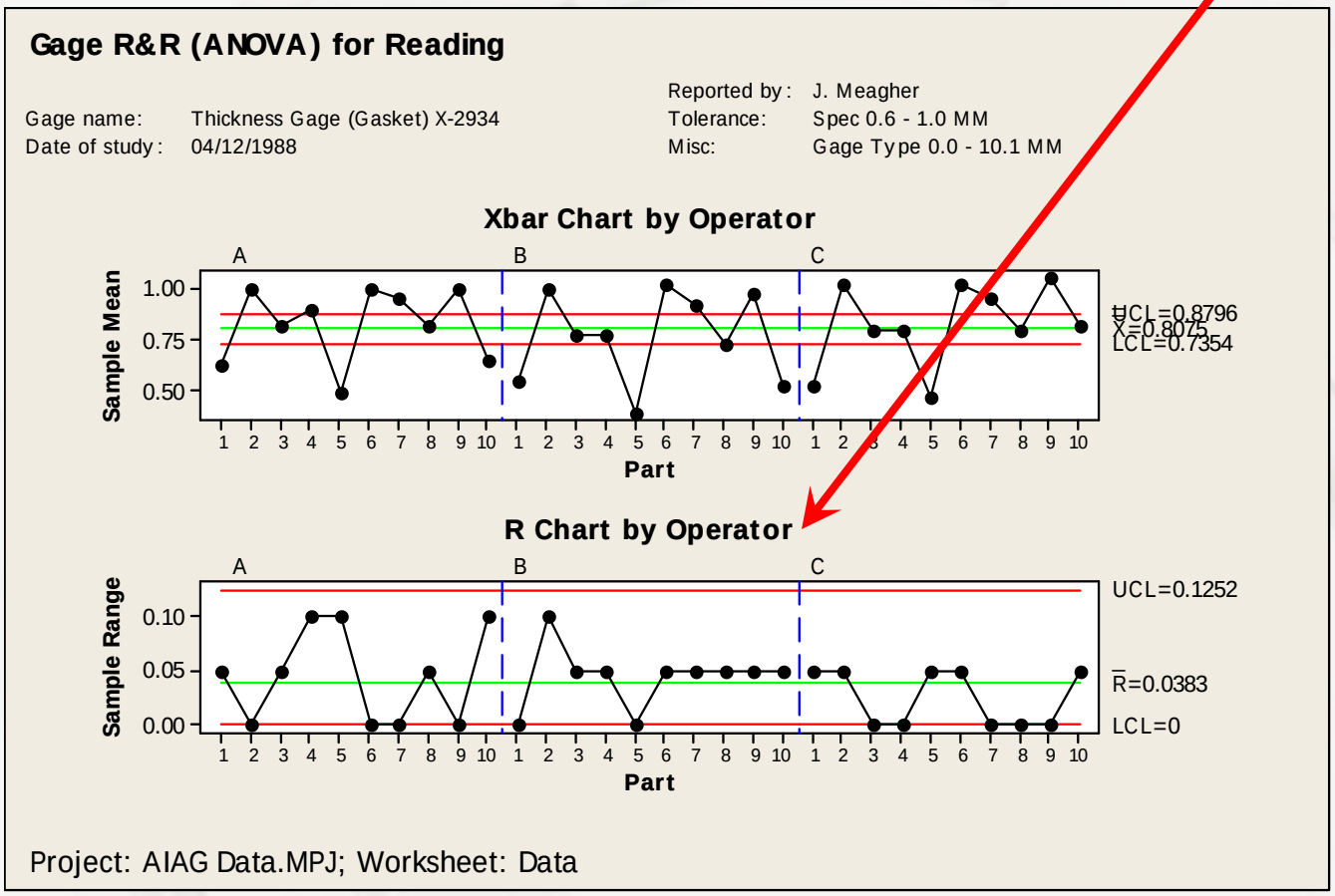
New Hampshire Ball Bearings, Inc.
A Minebea Company



Project: PART TO PART GRR MODIFIED.MPJ; Worksheet: Worksheet 2

What to look for on the R Chart

New Hampshire Ball Bearings, Inc.
A Minebea Company



Range Chart:

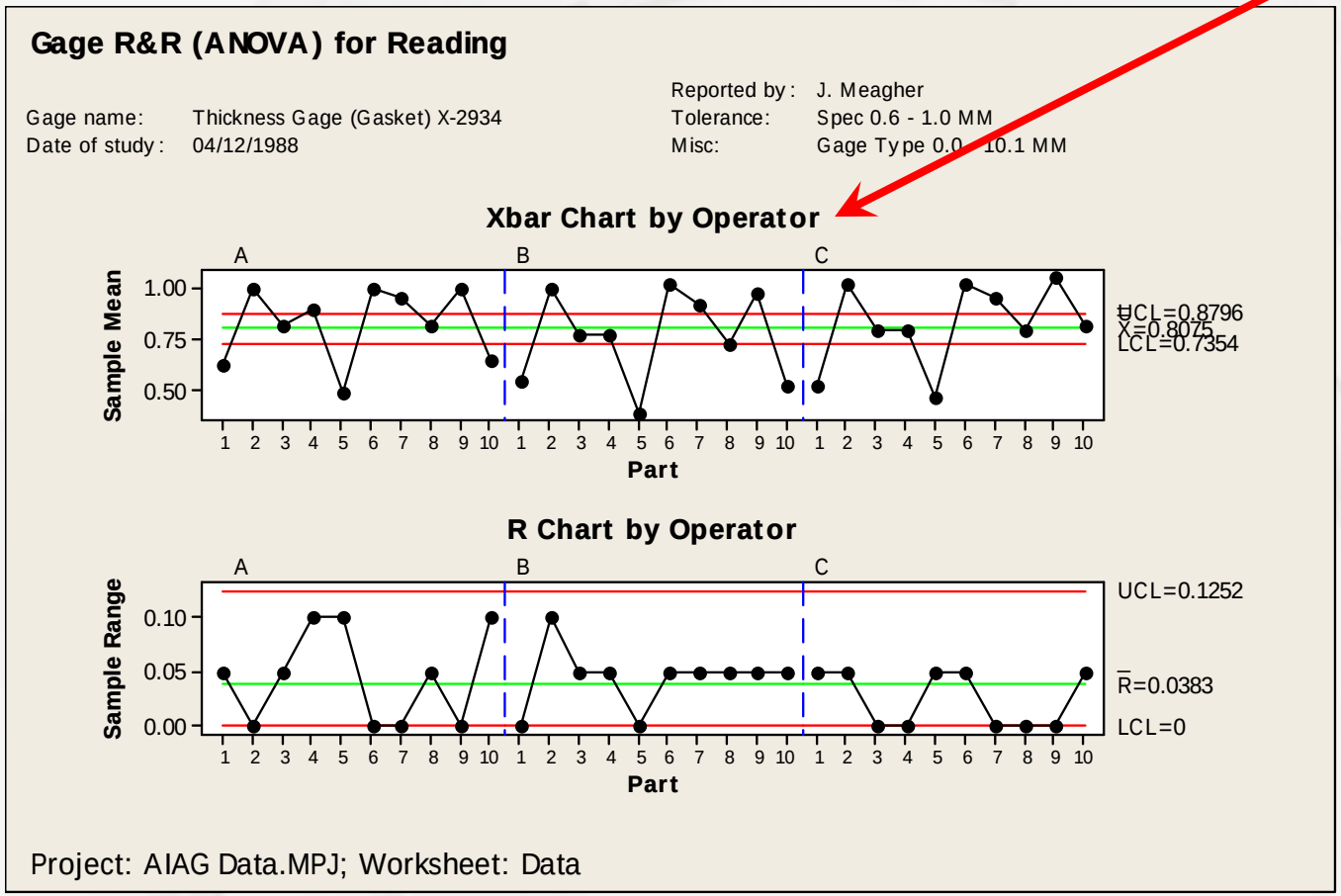
This is the **first** chart you should look at. This is your Repeatability or gage variation.

If you have any range points out-of-control, you should either rerun the entire GR&R, rerun just that operator or rerun just that operator for that part.

If the number of **zero values** on the R Chart **exceeds 25%** of the total number of values, **discrimination** may be **inadequate**!

What to look for on the Xbar Chart

New Hampshire Ball Bearings, Inc.
A Minebea Company



Xbar (Average) Chart:

You want to see **50% or more** of readings **outside the control limits**! If the gage variation (the control limits based on the range values) overwhelms the part variation, you might not be able to identify differences between parts.

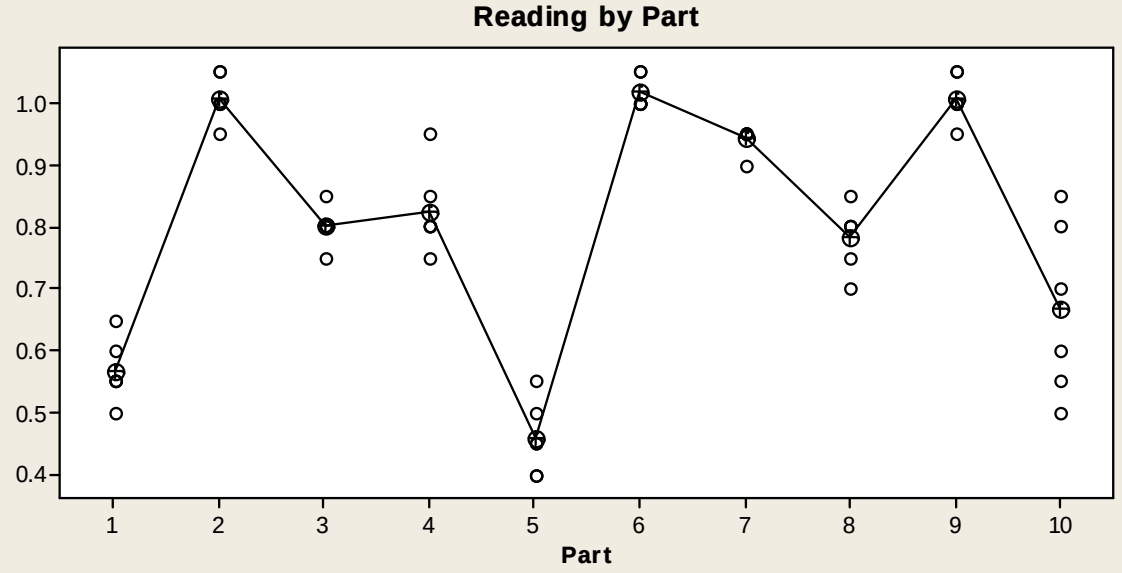
You also want to see a repeating pattern for all operators – and – all on the same plane.

What to look for on the Reading by Part Chart

New Hampshire Ball Bearings, Inc.
A Minebea Company

Gage R&R (ANOVA) for Reading

Gage name: Thickness Gage (Gasket) X-2934
Date of study: 04/12/1988
Reported by: J. Meagher
Tolerance: Spec 0.6 - 1.0 MM
Misc: Gage Type 0.0 - 10.1 MM



Project: AIAG Data.MPJ; Worksheet: Data

Reading by Part Chart:

You want to see the parts span the tolerance zone (if possible).

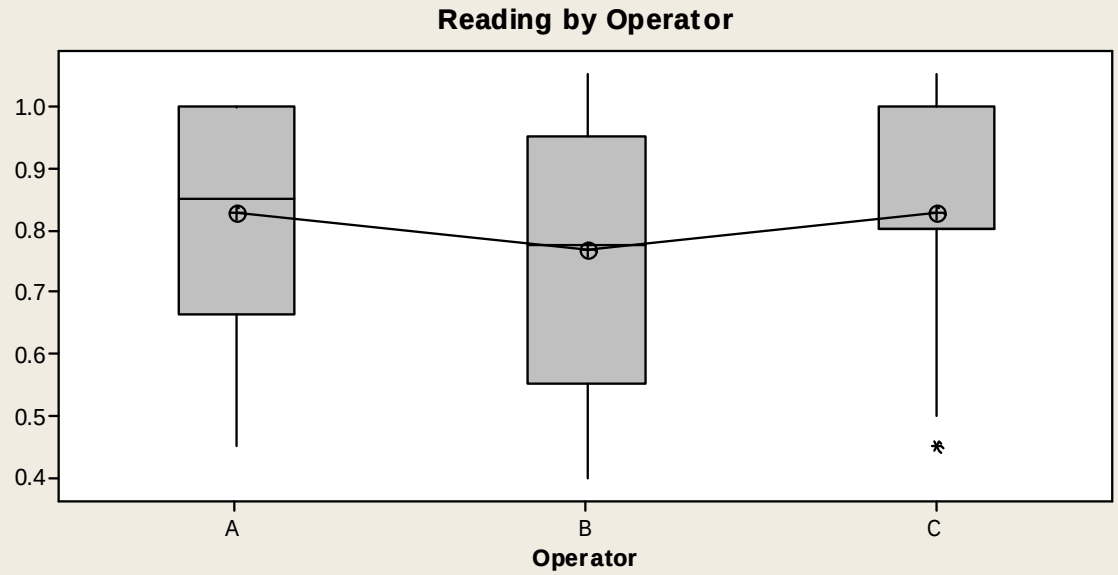
If any parts show a lot of scatter in relation to other parts, those parts may be more difficult to measure than the other parts. Try to find out why.

What to look for on the Reading by Operator Chart

New Hampshire Ball Bearings, Inc.
A Minebea Company

Gage R&R (ANOVA) for Reading

Gage name: Thickness Gage (Gasket) X-2934
Date of study: 04/12/1988
Reported by: J. Meagher
Tolerance: Spec 0.6 - 1.0 MM
Misc: Gage Type 0.0 - 10.1 MM



Project: AIAG Data.MPJ; Worksheet: Data

Reading by Operator Chart:

You want to see a straight line here. That would indicate all operators have the same overall average for all parts.

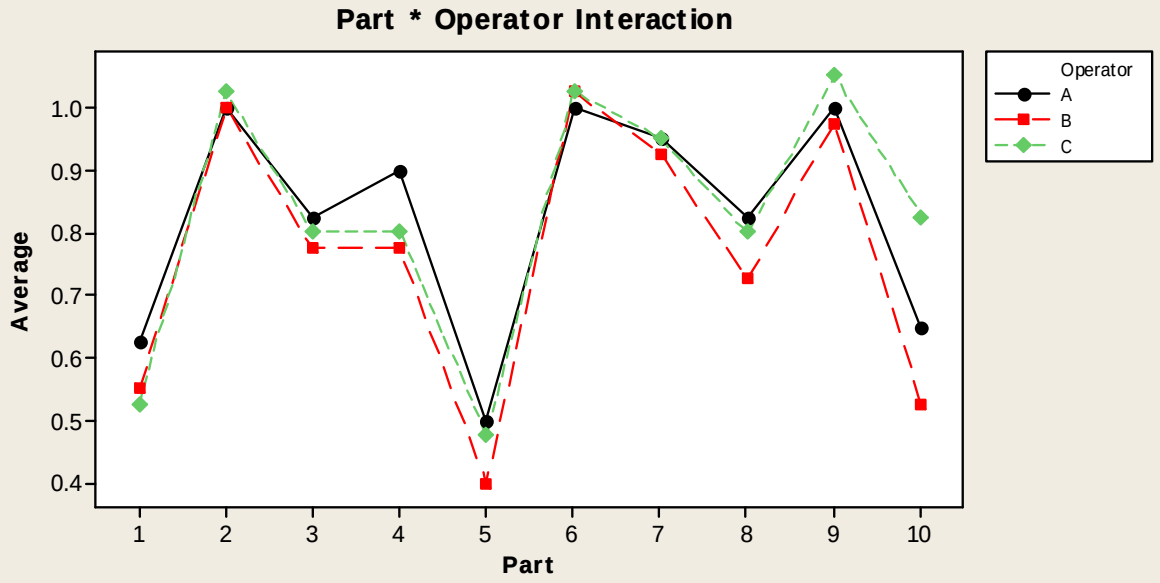
If any operators show a lot of scatter in relation to other operators, those operators may be using a different technique. Try to find out why the difference exists.

What to look for on the Operator * Part Interaction Chart

New Hampshire Ball Bearings, Inc.
A Minebea Company

Gage R&R (ANOVA) for Reading

Gage name: Thickness Gage (Gasket) X-2934
Date of study: 04/12/1988
Reported by: J. Meagher
Tolerance: Spec 0.6 - 1.0 MM
Misc: Gage Type 0.0 - 10.1 MM



Project: AIAG Data.MPJ; Worksheet: Data

Reading the Operator * Part Interaction Chart:

You want to all these lines overlap as much as possible. That would indicate all operators read all parts the same way.

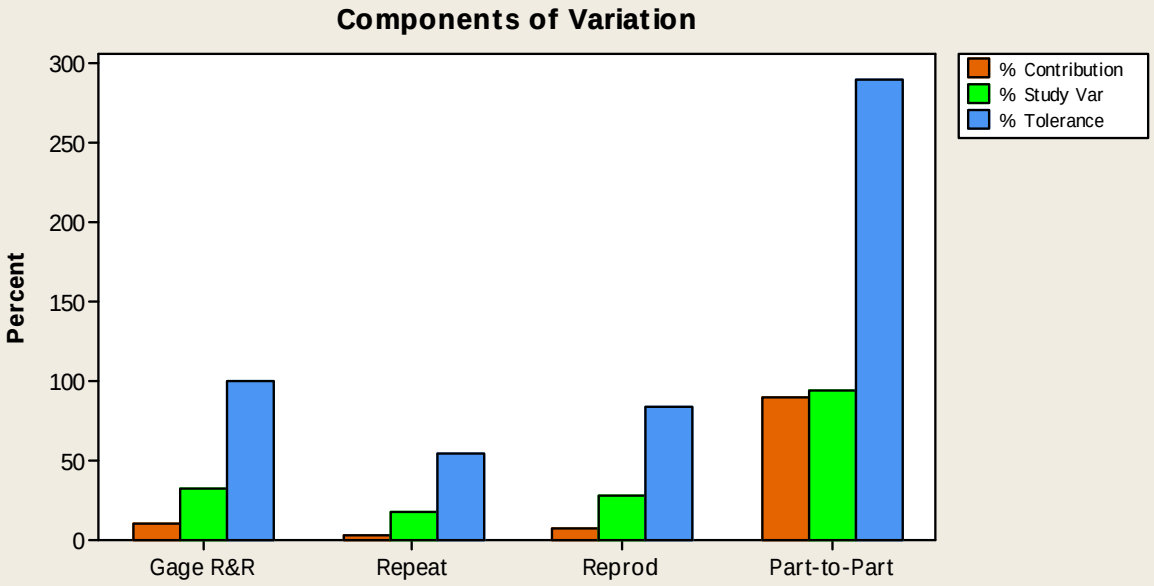
Any separation would indicate a difference in technique or an issue with certain parts themselves.

What to look for on the Components of Variation Chart

New Hampshire Ball Bearings, Inc.
A Minebea Company

Gage R&R (ANOVA) for Reading

Gage name: Thickness Gage (Gasket) X-2934
Date of study: 04/12/1988
Reported by: J. Meagher
Tolerance: Spec 0.6 - 1.0 MM
Misc: Gage Type 0.0 - 10.1 MM



Project: AIAG Data.MPJ; Worksheet: Data

Components of Variation Chart:

You want to see most of your variation in the Part-to-Part columns.

Also, you can get a visual indication of the relationship between the gage (Repeatability) variation and the operator (Reproducibility) variation.

Dial Caliper Measuring OD of Outer Ring (Centerless Ground)

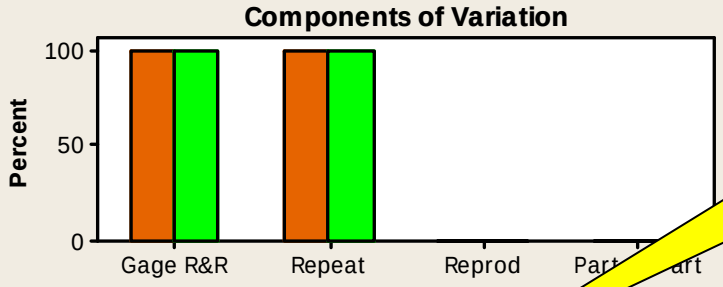
New Hampshire Ball Bearings, Inc.
A Minebea Company

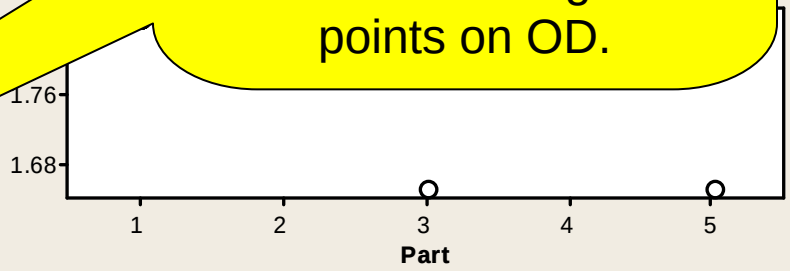
Blueprint Reading Gage R&R Presentation

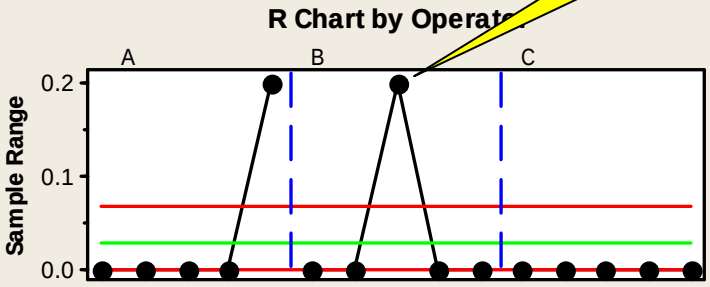
Gage name: Dial Caliper
Date of study: 04/13/06

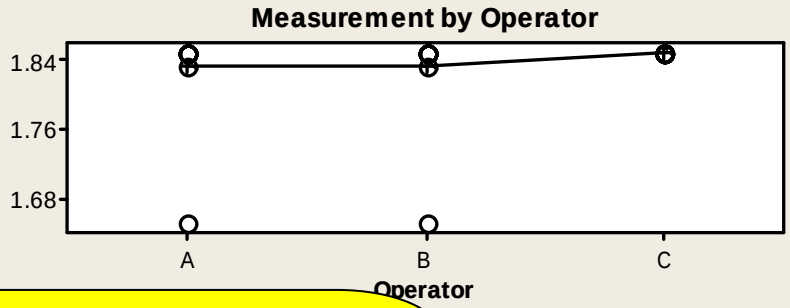
Reported by: J. M
Tolerance:
Misc: Me

Example of improper technique. Calipers were held perpendicular to OD, not parallel. Not measured at highest points on OD.

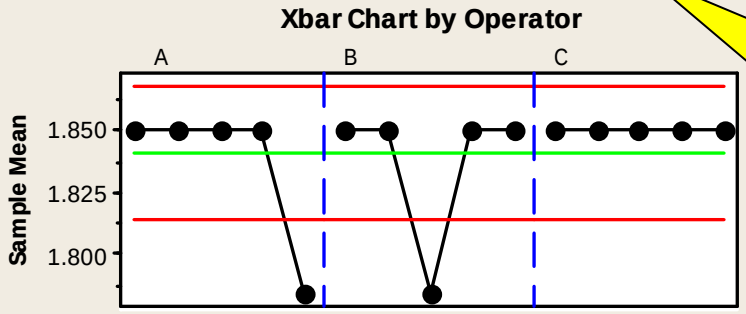


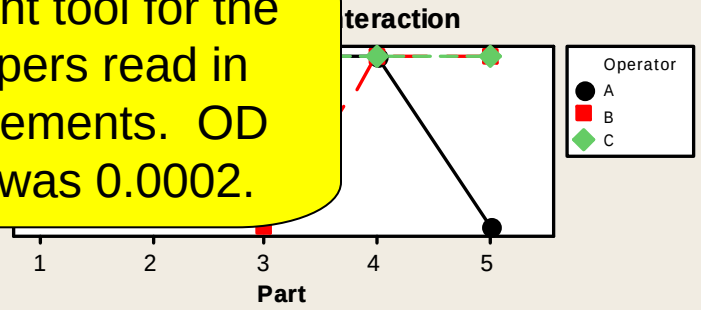






Not the right tool for the job. Calipers read in 0.001 increments. OD variation was 0.0002.





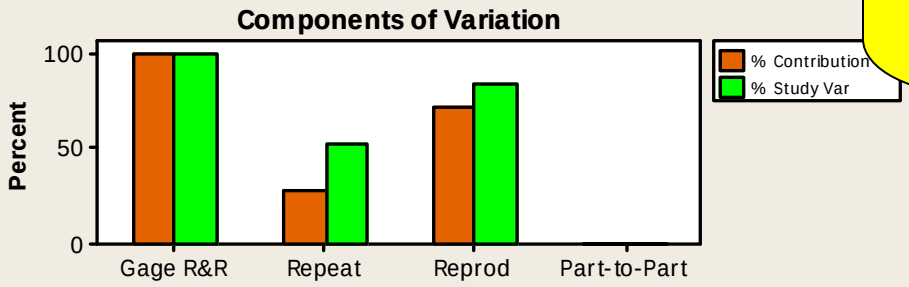
Digital Caliper Measuring OD of Outer Ring (Centerless Ground)

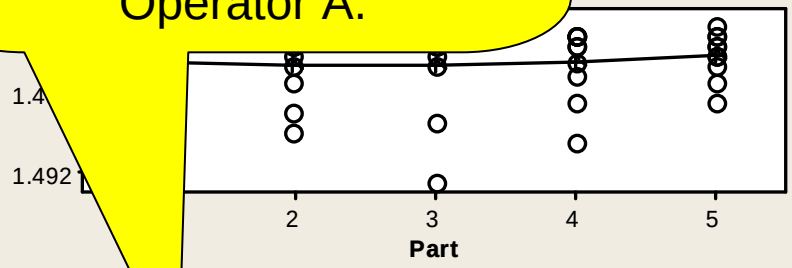
New Hampshire Ball Bearings, Inc.
A Minebea Company

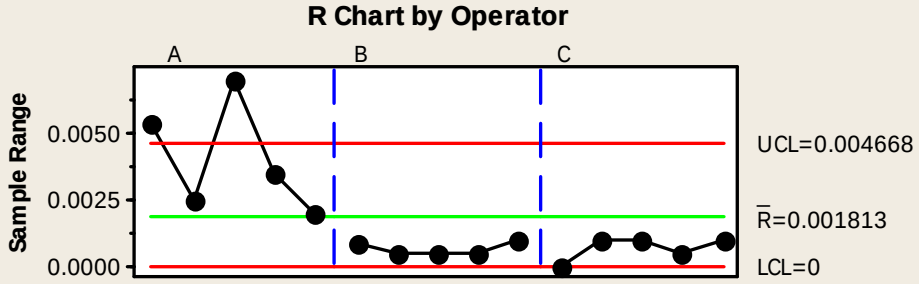
Blueprint Reading Gage R&R Presentation

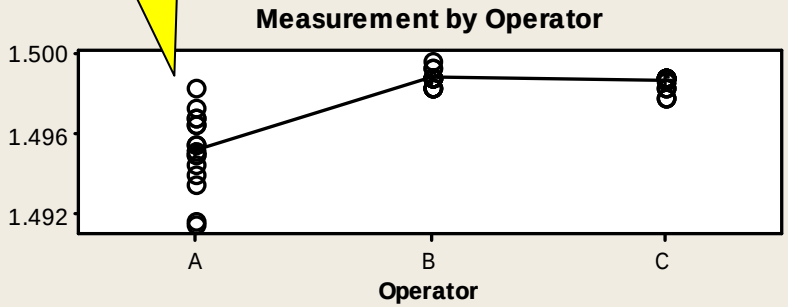
Gage name: Digital Caliper
Date of study: 04/13/06

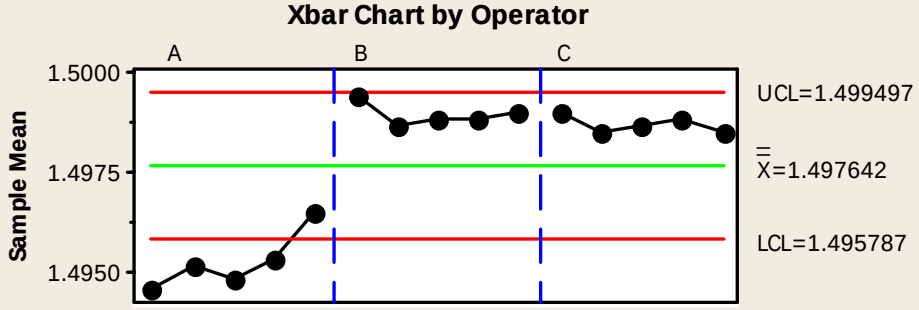
Differences in technique? One operator read parts different than the other two. A lot of variation for Operator A.

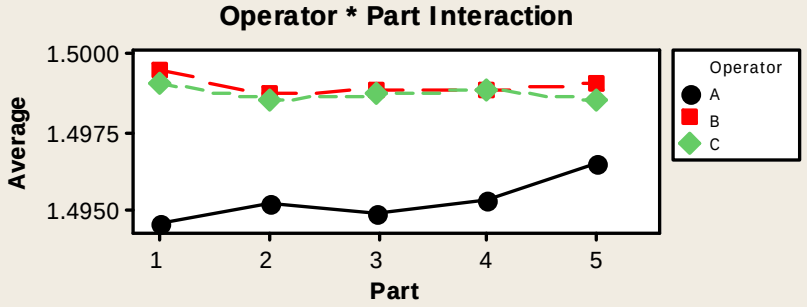












Micrometer Measuring Across Flats of Hex Nut

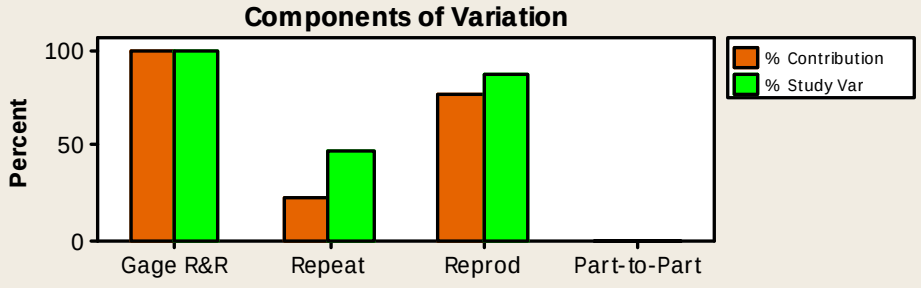
New Hampshire Ball Bearings, Inc.
A Minebea Company

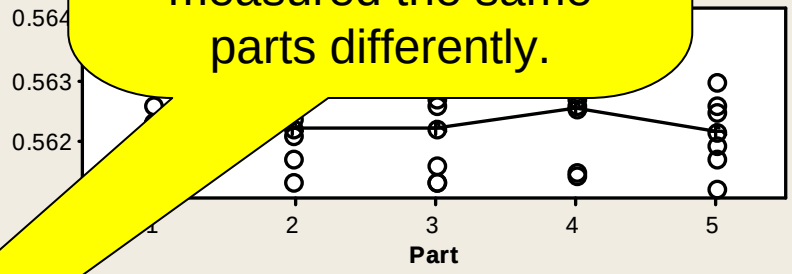
Blueprint Reading Gage R&R Presentation

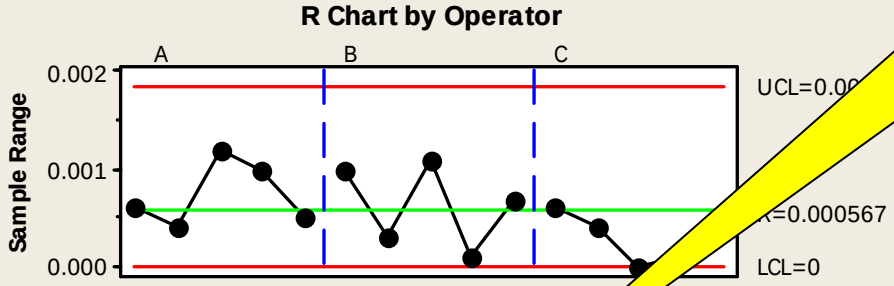
Gage name: Micrometer #2
Date of study: 04/13/06

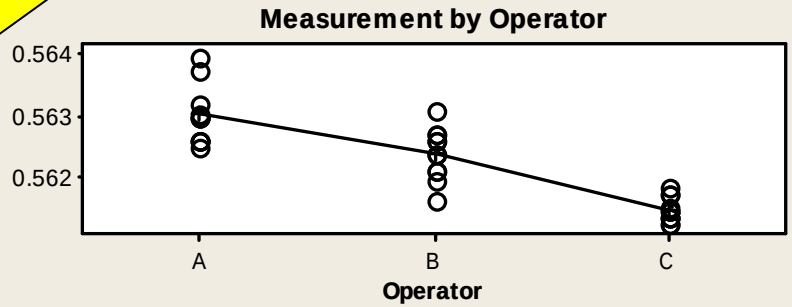
Reported by
Tolerance:
Misc:

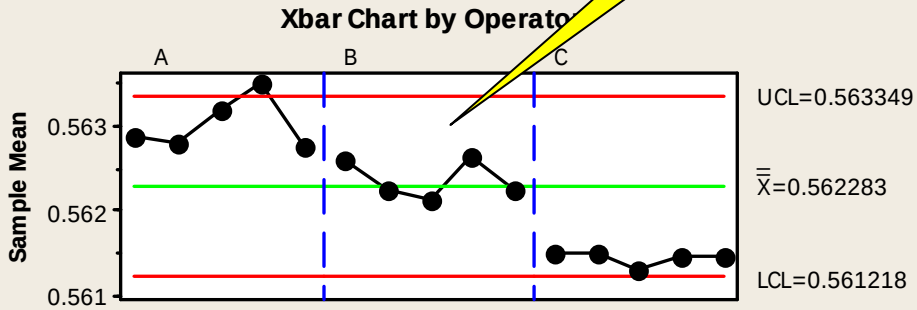
This gage may have been inappropriate for measuring this characteristic. Operators measured the same parts differently.

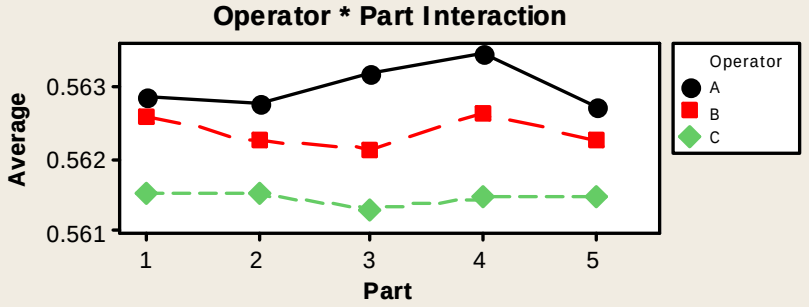












Micrometer Measuring Thickness of Flat Washer

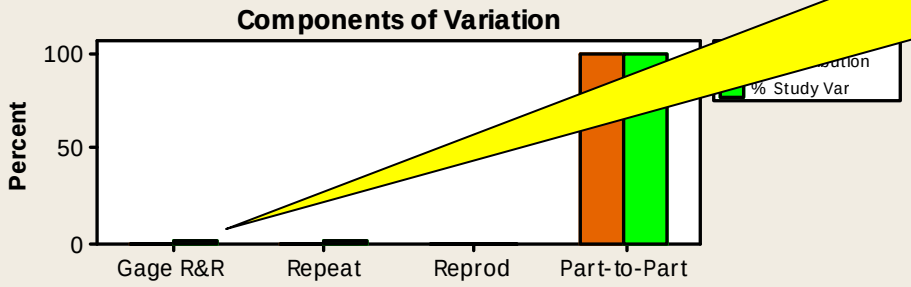
New Hampshire Ball Bearings, Inc.
A Minebea Company

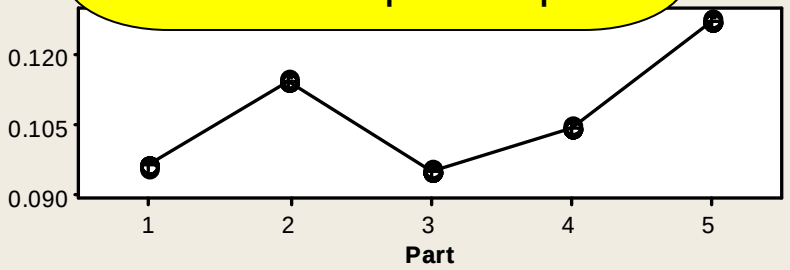
Blueprint Reading Gage R&R Presentation

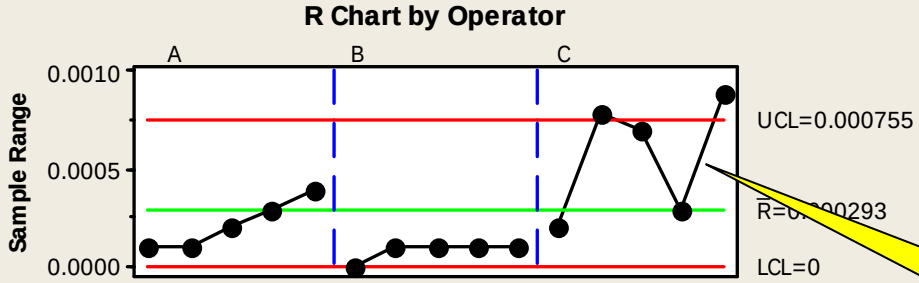
Gage name: Micrometer #1
Date of study: 04/13/06

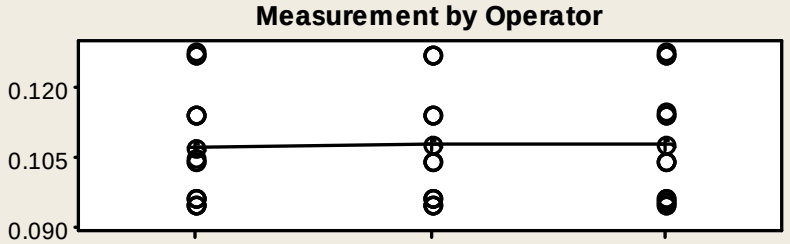
Reported by
Tolerance:
Misc:

This gage is acceptable for measuring this characteristic. Very little variation due to gage, almost all in part-to-part.

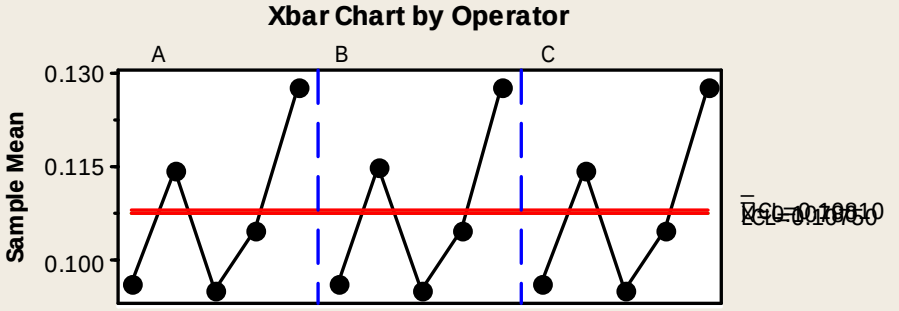


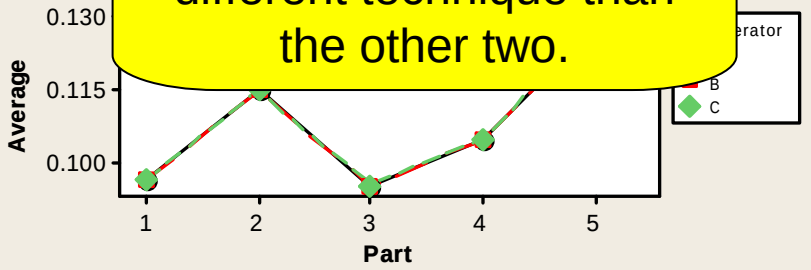






Operator C had a different technique than the other two.





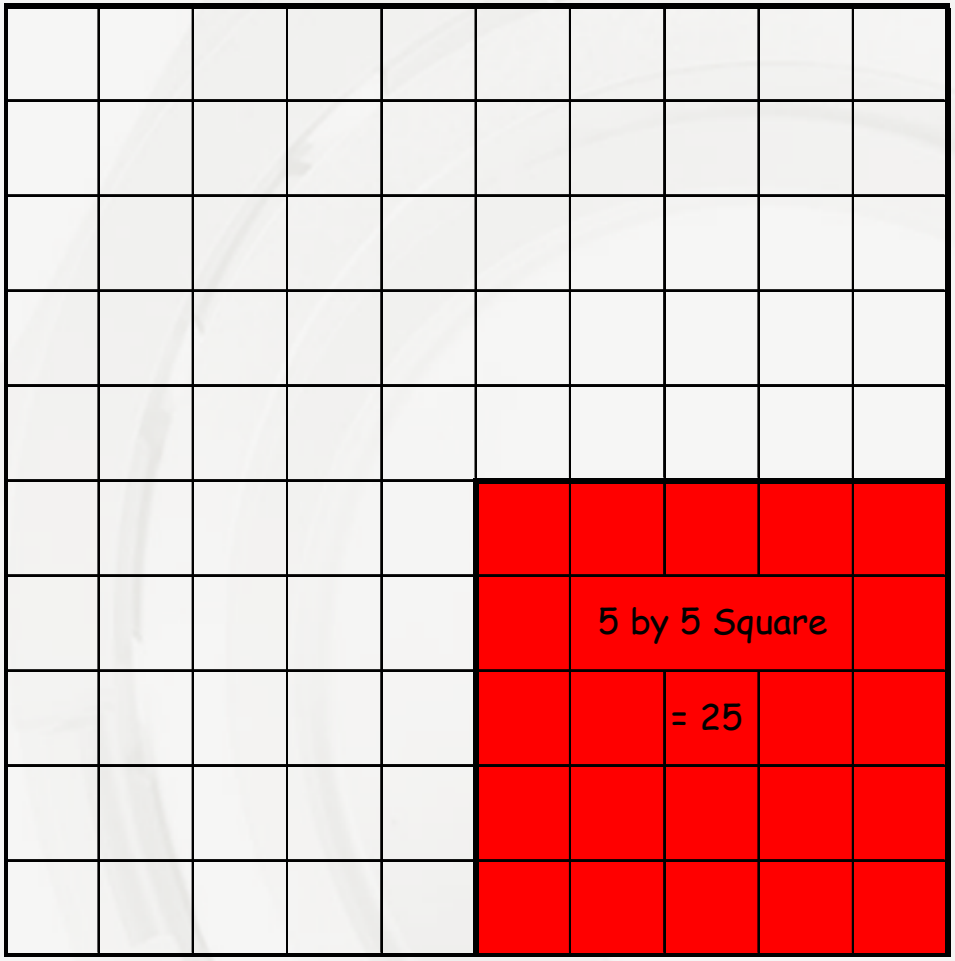
Before we review Minitab outputs –

Time for a good stretch and a quick mental exercise (1-2-3).

Bottom line – use something of what you learned today in the next week - or - you will lose it

Variance is like an area

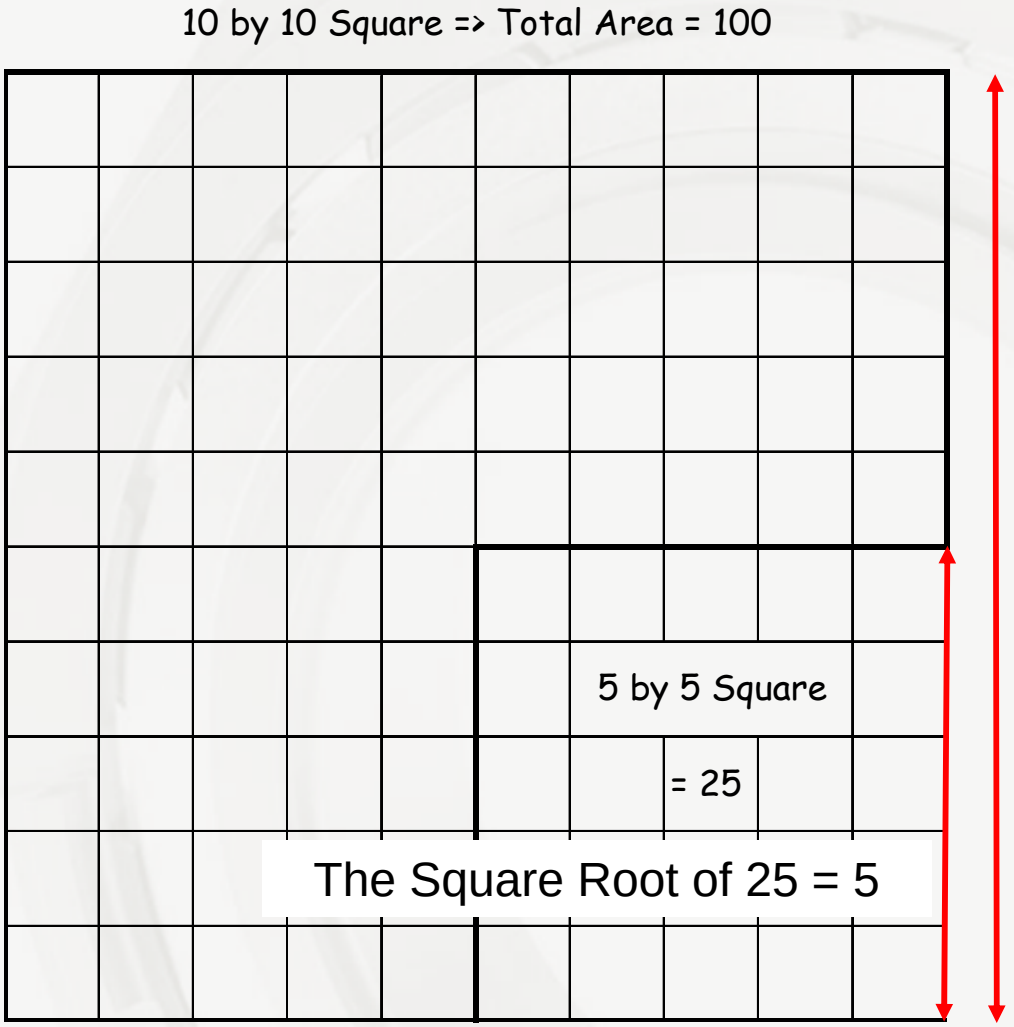
10 by 10 Square => Total Area = 100



Percentage of 5 by 5 Square to Total Area

25/100 = 0.25 = 25%

Standard Deviation is like a side (square root of area equals side)



Percentage of 5 by 5 Square to Total Area

25/100 = 0.25 = 25%

Percentage of Side to Total Length

5/10 = 0.50 = 50%

Length of one side equals 5

Analysis by Donald Wheeler

New Hampshire Ball Bearings, Inc.
A Minebea Company

An Honest Gauge R&R Study

Donald J. Wheeler

January 2009

WHY THESE "PERCENTAGES" DO NOT ADD UP

The %*EV* and %*AV* do not add up to the %*GRR* because they are not proportions. Likewise, the %*GRR* and the %*PV* do not add up to 100% because they are not proportions. They are instead trigonometric functions. Figure 1 shows how the five estimates found in Step 2 through Step 6 are related.

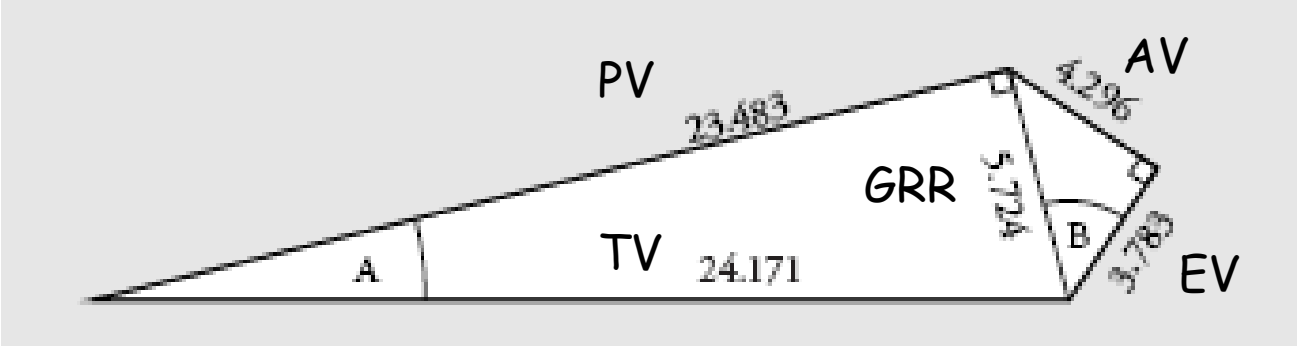


Figure 1: The Quantities Used for the Ratios in Steps 7, 8, 9, & 10

From AIAG FAQ's

What is the difference between "% contribution" and "% study" in terms of GRR performance?

% Contribution is determined by multiplying by 100 the proportion of the GRR variance to the total study variance. % Study is determined by multiplying by 100 the proportion of the GRR standard deviation to the total study standard deviation. ***Thus, a level of 20% study is equivalent to a level of 4% contribution (.2 x .2 = .04).*** Not true in regards to proportions!!!

Variance vs. Standard Deviation

Interpreting your results

Using variance versus standard deviation

Because %Contribution is based on the total variance, the column of values adds up to 100%.

Minitab also displays columns with percentages based on the standard deviation (or square root of variance) of each term. These columns, labeled %StudyVar and %Tolerance, typically do not add up to 100%. Because the standard deviation uses the same units as the part measurements and the tolerance, it allows for meaningful comparisons. ???

typically do not add up to 100%. Because the standard deviation uses the same units as the part measurements and the tolerance, it allows for meaningful comparisons.

Note | Minitab displays the column %Process if you enter a historical standard deviation in Options.

AIAG admits the percentages do not equal to 100% - without explanation??

New Hampshire Ball Bearings, Inc.
A Minebea Company

Indices

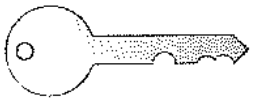
Once the variability for each factor in the gage study is determined, it can be compared to the total variation (*TV*). This is accomplished by performing the calculations on the right side of the gage report form (Figure III-B 16) under "% Total Variation."

The percent the equipment variation (*%EV*) consumes of the total variation (*TV*) is calculated by 100[*EV/TV*]. The percent that the other factors consume of the total variation can be similarly calculated as follows:

$$\%AV = 100\,[AV/TV]$$

$$\%GRR = 100\,[GRR/TV]$$

$$\%PV = 100\,[PV/TV]$$



THE SUM OF THE PERCENT CONSUMED BY EACH FACTOR WILL NOT EQUAL 100%.

The results of this percent total variation need to be evaluated to determine if the measurement system is acceptable for its intended application.

[51] for example, see Chrysler, Ford, and GM, *PPAP Manual*.

Distinct Categories – another issue?

Note: The Number of Distinct Categories is calculated by:

$1.41 \times (\sigma_p/\sigma_m)$ ← Another ratio of standard deviations!

or

$1.41 \times (PV/R\&R)$

Semiconductor industry questions AIAG metrics

New Hampshire Ball Bearings, Inc.
A Minebea Company

Semiconductor Industry Measurement System Analysis Practices

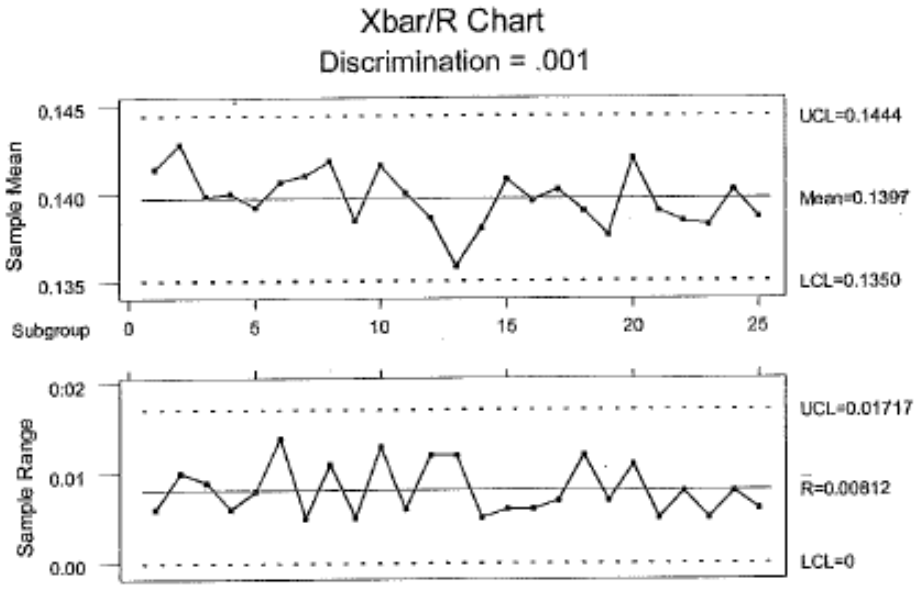
1. PTR and PTV are not appropriate metrics for measurement system analysis studies. Variabilities need to be dealt with in quadrature. Replace all ratios calculated from standard deviations with proportions calculated from variances.

7. The metric NDC is obsolete. Wheeler [2] states that NDC is an estimation of the classification ratio and provides a simple approximation to the discrimination ratio. However, neither one has a "simple practical interpretation." ISMI representatives agree on using the Intraclass Correlation Coefficient to classify the measurement system along with estimates of the probable error (to identify the minimum number of digits to record). The number of possible values (NPV) could provide non-conflicting supplemental information.

For further discussion on the topics in this paper, contact Diane Michelson at di.michelson@ismi.sematech.org or 512-356-3238.

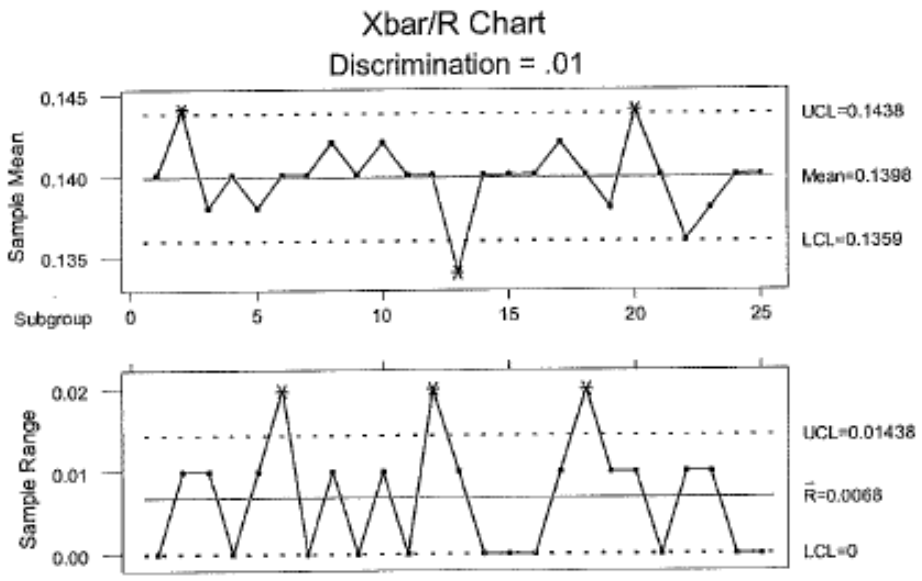
New Hampshire Ball Bearings, Inc.
A Minebea Company

A



<17

B



<2

Figure I-E 4: Process Control Charts[21]

Distinct Categories – can be estimated from the divisions in the Range Chart

A preview of what is to follow. This is where we "draw the line"

New Hampshire Ball Bearings, Inc.
A Minebea Company

Gage R&R

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.026003	4.38
Repeatability	0.013361	2.25
Reproducibility	0.012642	2.13
Operator	0.000000	0.00
Operator*Part	0.012642	2.13
Part-To-Part	0.567397	95.62
Total Variation	0.593400	100.00

These are the "Honest" Gage R&R results as identified by Donald Wheeler! Proportions add up to 100%.

Definition of proportion: A part considered in relation to the whole.

Process tolerance = 2

Definition of ratio: A part to part relationship, not to the whole.

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.161253	0.96752	20.93	48.38
Repeatability	0.115590	0.69354	15.01	34.68
Reproducibility	0.112435	0.67461	14.60	33.73
Operator	0.000000	0.00000	0.00	0.00
Operator*Part	0.112435	0.67461	14.60	33.73
Part-To-Part	0.753258	4.51955	97.78	225.98
Total Variation	0.770324	4.62195	100.00	231.10

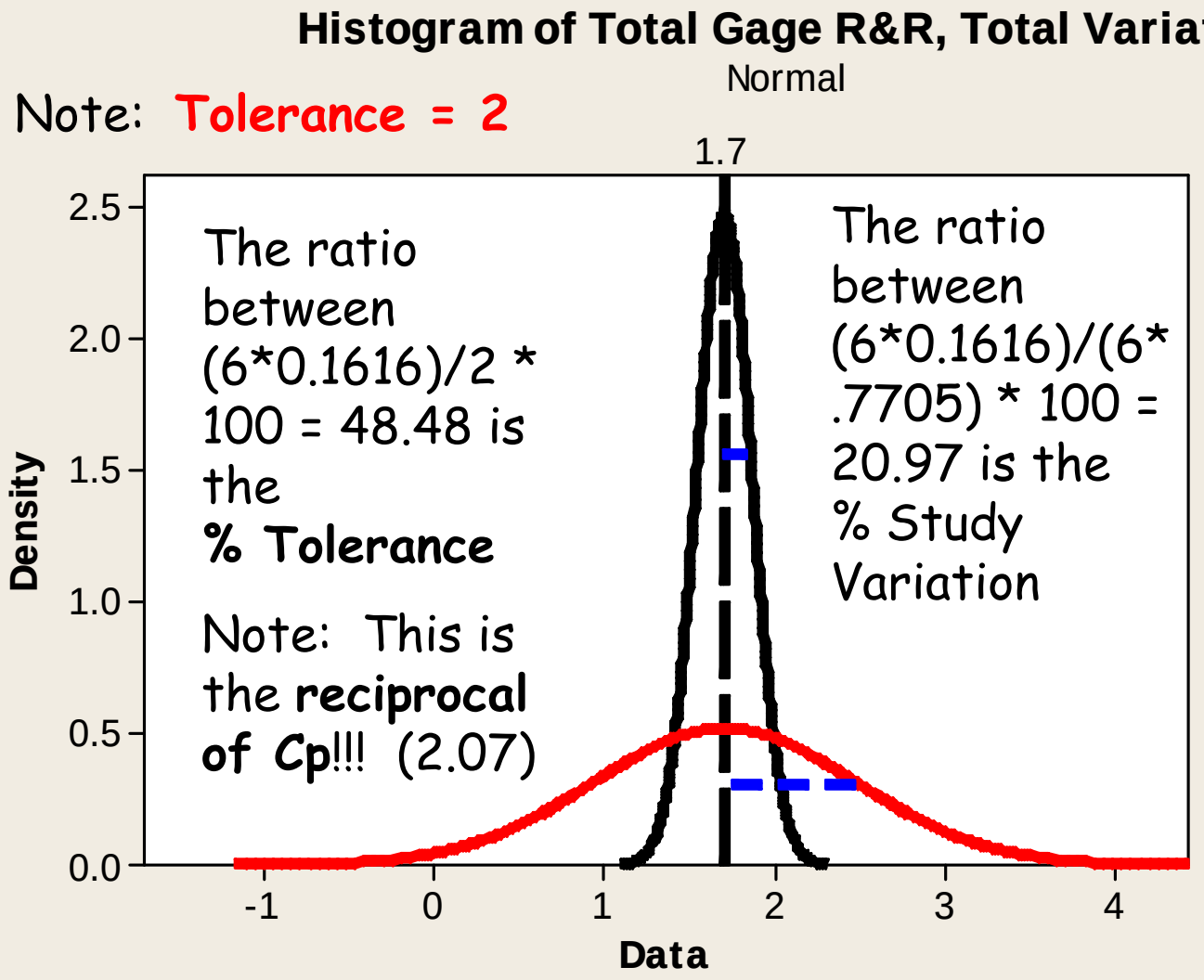
Ratios based of values that are square root sum of squares?

Note: The value of .4838 [(6*Std Dev/(USL – LSL)] is the reciprocal of the Cp value!

Cp = (USL – LSL)/6*Std Dev = 2.07 (Capability)

Standard deviations and normal distributions

New Hampshire Ball Bearings, Inc.
A Minebea Company



Variable
Total Gage R&R
Total Variation

Mean	StDev	N
1.701	0.1616	10000
1.704	0.7705	10000

You are still comparing the length of the lines or the width of the distributions - nothing else!!!

Project: Sample Distributions.MPJ; Worksheet: Data

% Tolerance – proportion??

New Hampshire Ball Bearings, Inc.
A Minebea Company

Assessing the measurement system

Use a Gage R&R study (crossed) to assess:

- How well the measuring system can distinguish between parts
- Whether the operators measure consistently

Tolerance

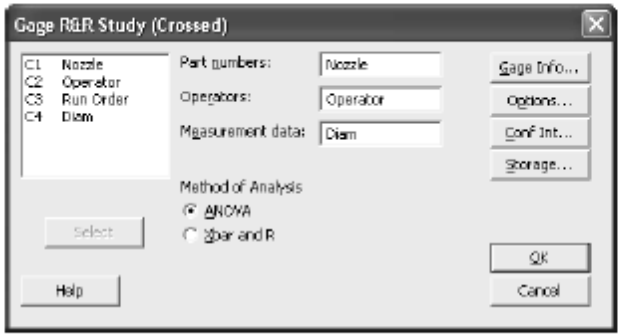
The specification limits for the nozzle diameters are 9012 ± 4 microns. In other words, the nozzle diameter is allowed to vary by as much as 4 microns in either direction. The tolerance is the difference between the specification limits: 9016 – 9008 = 8 microns.

By entering a value in Process tolerance, you can estimate what proportion of the tolerance is taken up by the variation in the measurement system.

Gage R&R Study (Crossed)

1 Choose **Stat ➤ Quality Tools ➤ Gage Study ➤ Gage R&R Study (Crossed)**.

2 Complete the dialog box as shown below.



3 Click **Options**

By entering a value in Process tolerance, you can estimate what proportion of the tolerance is taken up by the variation in the measurement system.

Variance vs Standard Deviation

New Hampshire Ball Bearings, Inc.
A Minebea Company

From RSD associates web site (http://www.rsd-associates.com/mesa.htm)-

"Evaluating The Measurement Process" by Donald J. Wheeler and Richard W. Lyday (ISBN 0-945320-06-X)

•Wheeler (1992) also points to technical deficiencies in the R&R approach. Sources of variation are commonly expressed as a percentage of either tolerance bands or of total variation, but this is done without squaring the values involved, and hence these "percentages" can be very misleading and will not, of course, add up to 100%. The percentages used in R%R studies can be even more misleading when expressed as a percentage of a tolerance spread."

AIAG MSA Manual (Chapter II – Section C on Page 74) States:

"… **the sample parts must be selected from the process and represent its entire operating range**. … If the sample parts DO NOT represent the production process, TV must be ignored in the assessment. Ignoring TV does not affect assessments using tolerance …"

Is this the only option you have left???
What if you have concerns with this metric???

So ….

is there any other way to judge

% Tolerance?

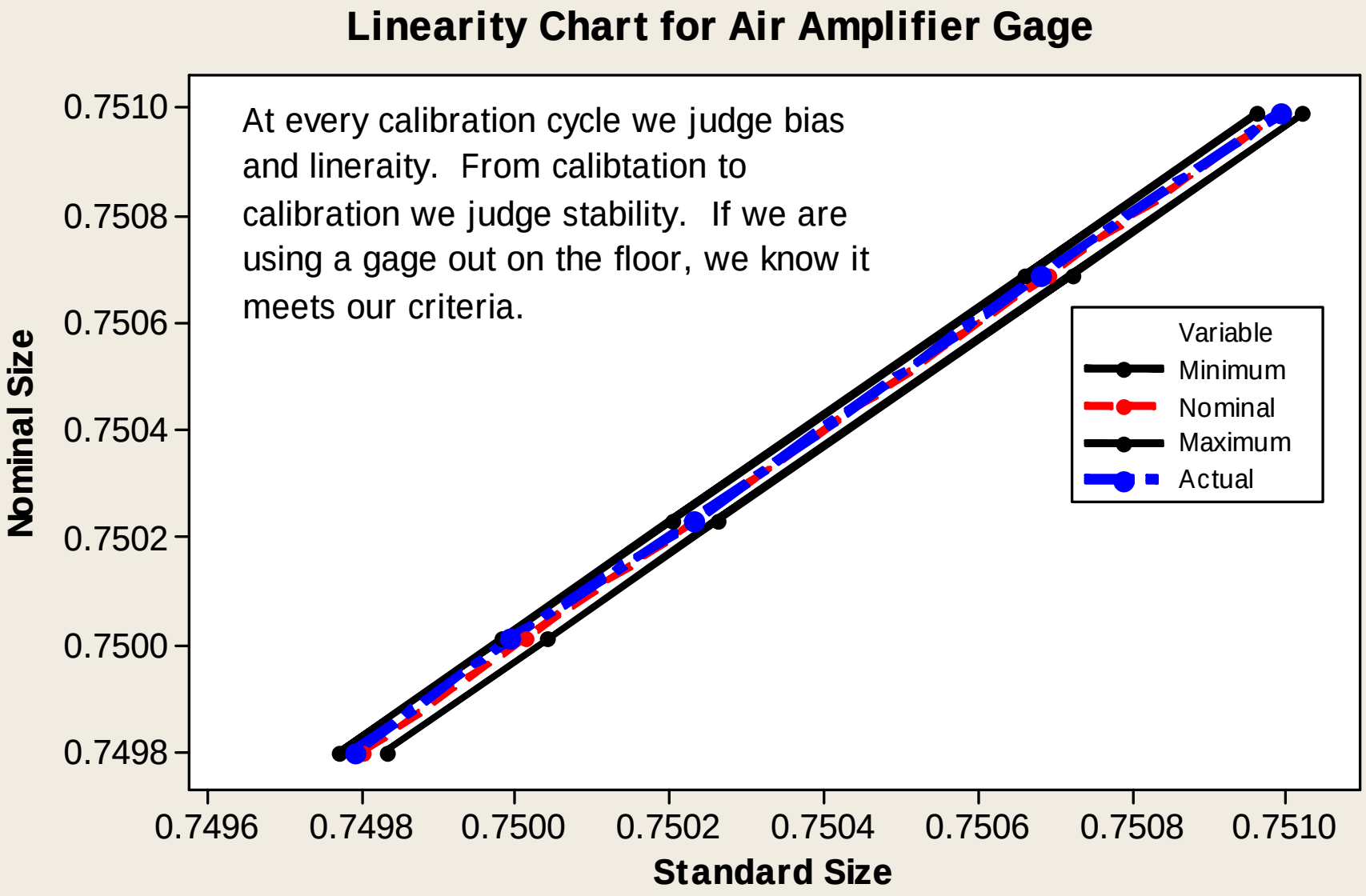
The following analysis is

FOR REFERENCE ONLY!!!

This method is no more of a stretch than judging gage capability based on a 5 or 10 pc sample.

NHBB Bias & Linearity Chart

New Hampshire Ball Bearings, Inc.
A Minebea Company



Project: NHBB GAGE LINEARITY.MPJ; Worksheet: Air Amplifier Gage

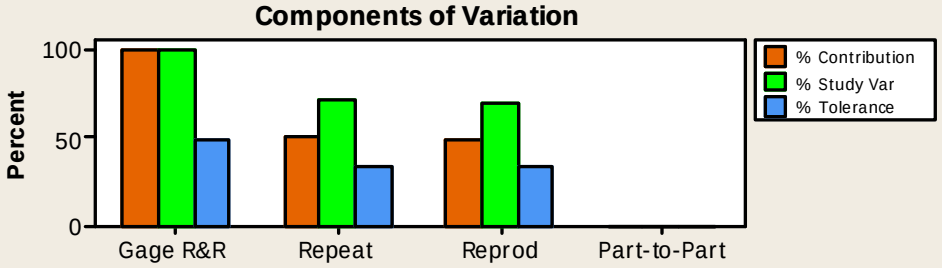
Chart Output - Original Data

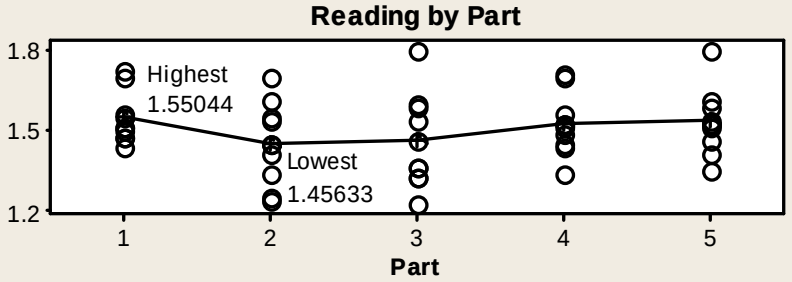
New Hampshire Ball Bearings, Inc.
A Minebea Company

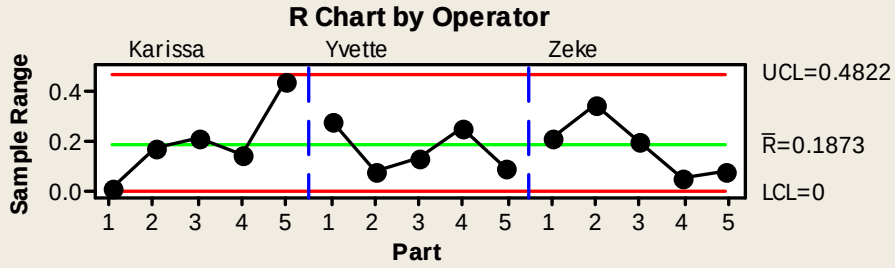
Gage R&R (ANOVA) for Reading

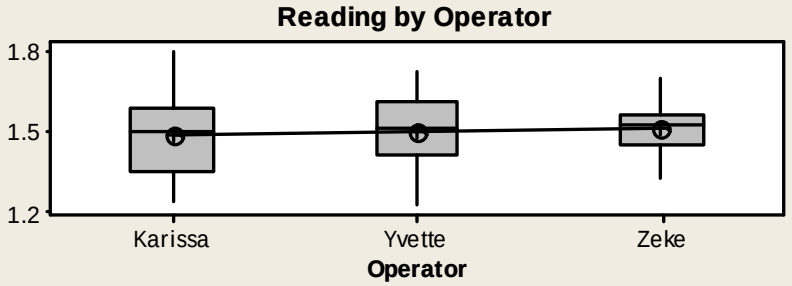
Gage name: Notch Angle
Date of study: Open

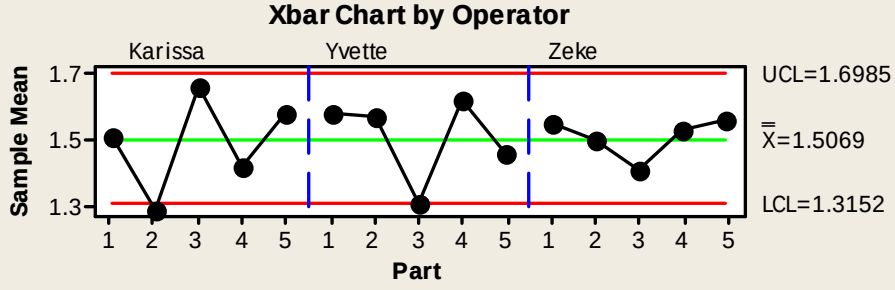
Reported by: J Meagher
Tolerance: 2 Degrees
Misc: Data as received

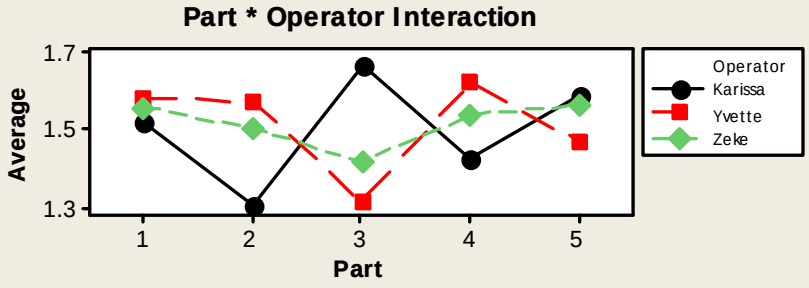












Project: PART TO PART GRR MODIFIED.MPJ; Worksheet: Data

Chart Output – Original Data

New Hampshire Ball Bearings, Inc.
A Minebea Company

Have we painted ourselves into a corner?

What if we had parts that spanned the tolerance?

Can we get there from here?

Operator	Part	Trial	Reading	Overall Part Average	High/Low Limit	Difference from Limit	Forced Variation
Karissa	1	1	1.513	1.55044	3	1.44956	2.96256
Karissa	1	2	1.52	1.55044	3	1.44956	2.96956
Karissa	1	3	1.509	1.55044	3	1.44956	2.95856
Karissa	2	1	1.235	1.45633	1	-0.45633	0.77867
Karissa	2	2	1.247	1.45633	1	-0.45633	0.79067
Karissa	2	3	1.412	1.45633	1	-0.45633	0.95567

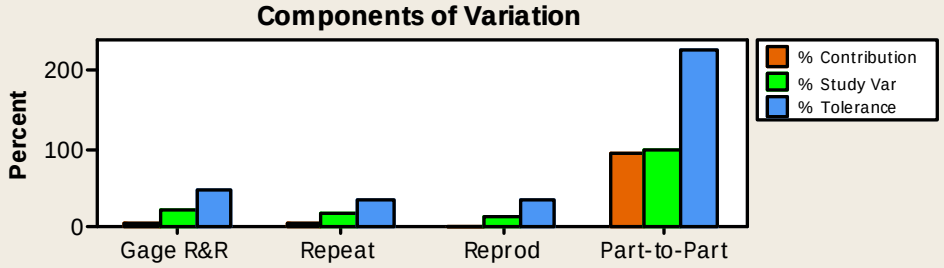
Chart Output – Forced Variation

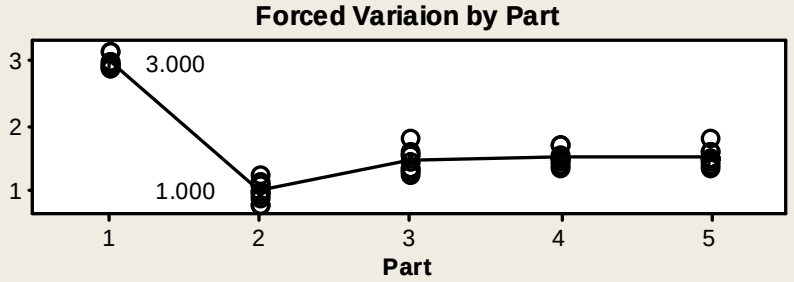
New Hampshire Ball Bearings, Inc. A Minebea Company

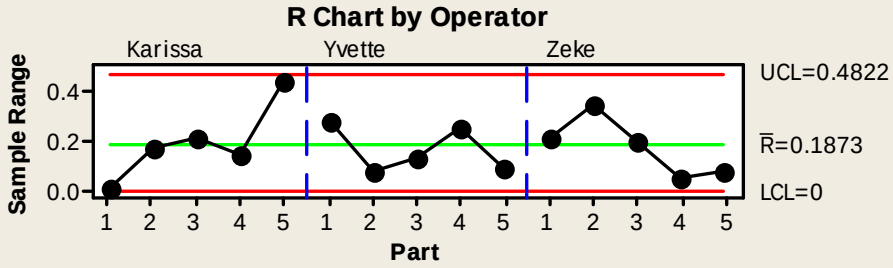
Gage R&R (ANOVA) for Forced Variaion

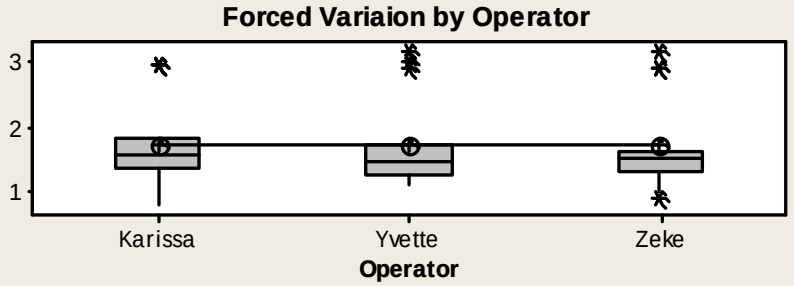
Gage name: Notch Angle
Date of study: Open

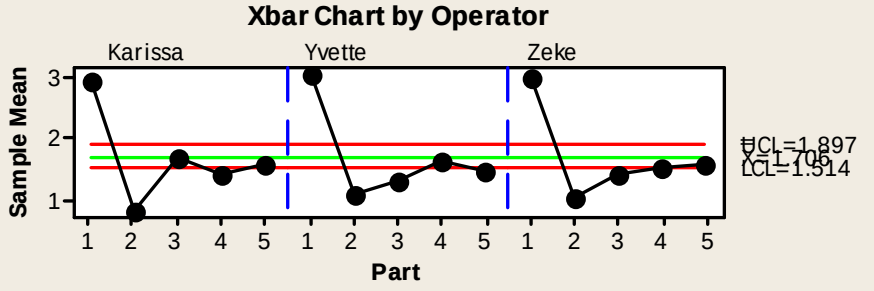
Reported by: J Meagher
Tolerance: 2 Degrees
Misc: Forced Variation

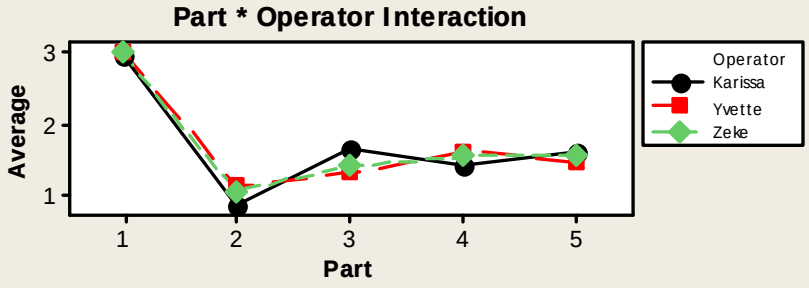












Project: PART TO PART GRR MODIFIED.MPJ; Worksheet: Data

Session Output Comparison

New Hampshire Ball Bearings, Inc.
A Minebea Company

Gage R&R - Original Data

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.0260026	100.00
Repeatability	0.0133611	51.38
Reproducibility	0.0126415	48.62
Operator	0.0000000	0.00
Operator*Part	0.0126415	48.62
Part-To-Part	0.0000000	0.00
Total Variation	0.0260026	100.00

Gage R&R - Forced Variation

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.026003	4.38
Repeatability	0.013361	2.25
Reproducibility	0.012642	2.13
Operator	0.000000	0.00
Operator*Part	0.012642	2.13
Part-To-Part	0.567397	95.62
Total Variation	0.593400	100.00

Note: The ONLY change to the analysis is the Part-to-Part Variation! Since the part variation now equals the tolerance spread, the Total Gage R&R value given estimates the % Tolerance.

Session Output Comparison

New Hampshire Ball Bearings, Inc.
A Minebea Company

Original Data

Gage R&R

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.0260026	100.00
Repeatability	0.0133611	51.38
Reproducibility	0.0126415	48.62
Operator	0.0000000	0.00
Operator*Part	0.0126415	48.62
Part-To-Part	0.0000000	0.00
Total Variation	0.0260026	100.00

Process tolerance = 2

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.161253	0.967519	100.00	48.38
Repeatability	0.115590	0.693540	71.68	34.68
Reproducibility	0.112435	0.674608	69.73	33.73
Operator	0.000000	0.000000	0.00	0.00
Operator*Part	0.112435	0.674608	69.73	33.73
Part-To-Part	0.000000	0.000000	0.00	0.00
Total Variation	0.161253	0.967519	100.00	48.38

Number of Distinct Categories = 1

Forced Variation

Gage R&R

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.026003	4.38
Repeatability	0.013361	2.25
Reproducibility	0.012642	2.13
Operator	0.000000	0.00
Operator*Part	0.012642	2.13
Part-To-Part	0.567397	95.62
Total Variation	0.593400	100.00

Process tolerance = 2

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.161253	0.96752	20.93	48.38
Repeatability	0.115590	0.69354	15.01	34.68
Reproducibility	0.112435	0.67461	14.60	33.73
Operator	0.000000	0.00000	0.00	0.00
Operator*Part	0.112435	0.67461	14.60	33.73
Part-To-Part	0.753258	4.51955	97.78	225.98
Total Variation	0.770324	4.62195	100.00	231.10

Number of Distinct Categories = 6

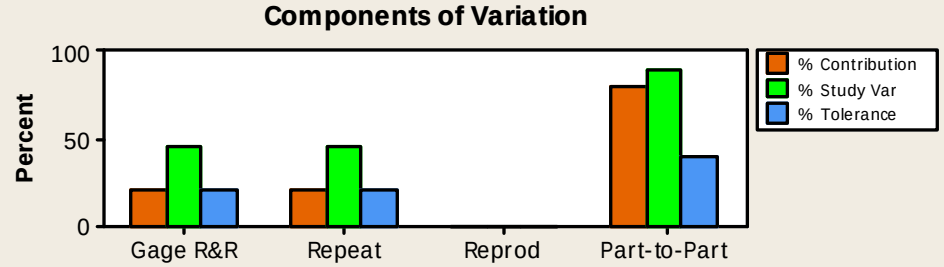
Chart Output – Original Data

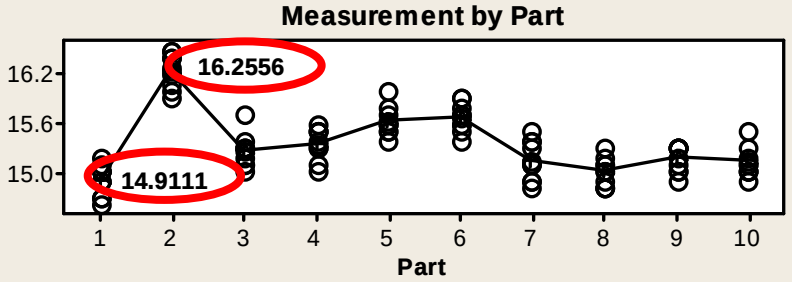
New Hampshire Ball Bearings, Inc. A Minebea Company

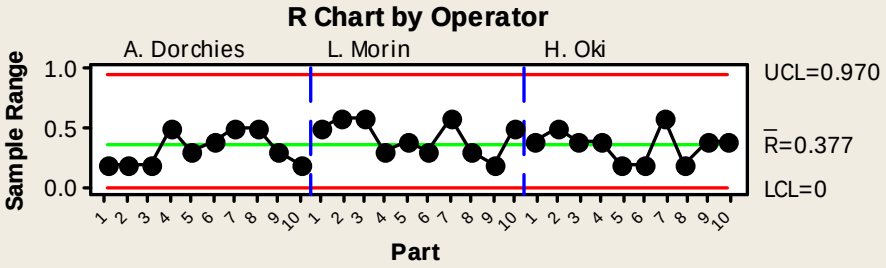
Gage R&R (ANOVA) for Measurement

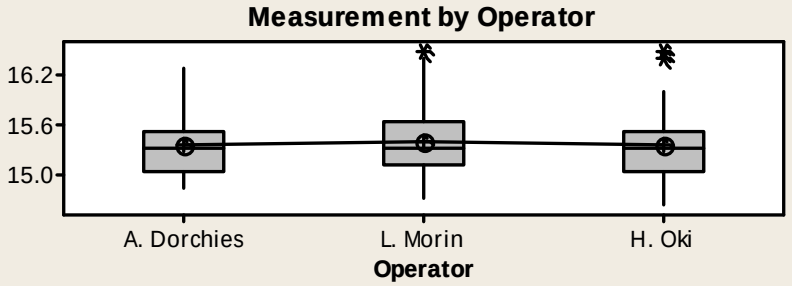
Gage name: ADCAMS C/A Gage
Date of study: 10/19/2009

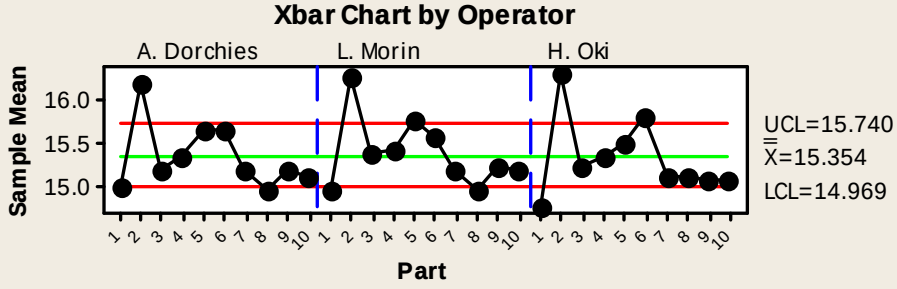
Reported by: A. Dorchies
Tolerance: 13 to 19 = 6 Degrees
Misc: Contact Angle K112134

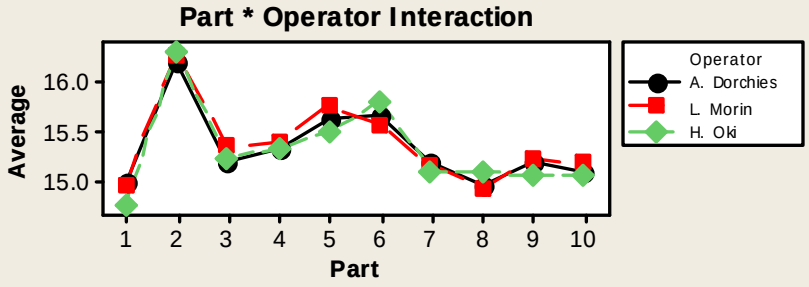












Project: CONTACT ANGLE FORCED VARIATION.MPJ; Worksheet: 10 Part Random Order

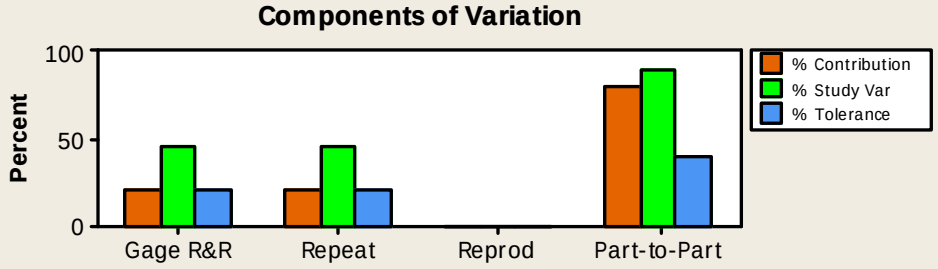
Chart Output – Original Data

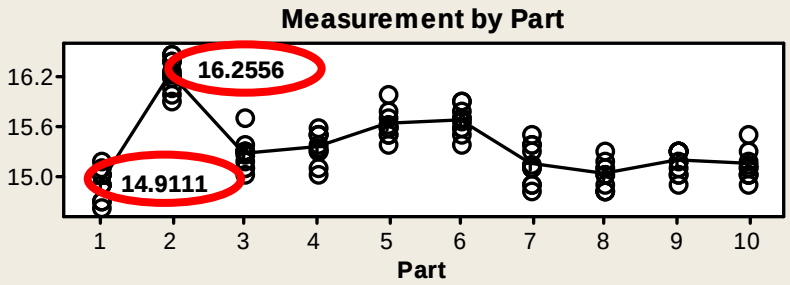
New Hampshire Ball Bearings, Inc.
A Minebea Company

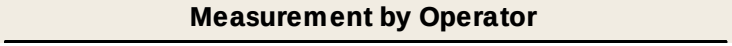
Gage R&R (ANOVA) for Measurement

Gage name: ADCAMS C/A Gage
Date of study: 10/19/2009

Reported by: A. Dorchies
Tolerance: 13 to 19 = 6 Degrees
Misc: Contact Angle K112134







P/N 1	Current 1	Offset 1	Forced Part 1	P/N 2	Current 2	Offset 2	Forced Part 2
1	15.1	-1.9111	13.1889	2	16.2	2.7444	18.9444
1	14.9	-1.9111	12.9889	2	16.1	2.7444	18.8444
1	15.0	-1.9111	13.0889	2	16.3	2.7444	19.0444
1	15.2	-1.9111	13.2889	2	15.9	2.7444	18.6444
1	14.7	-1.9111	12.7889	2	16.4	2.7444	19.1444
1	15.0	-1.9111	13.0889	2	16.5	2.7444	19.2444
1	14.6	-1.9111	12.6889	2	16.4	2.7444	19.1444
1	15.0	-1.9111	13.0889	2	16.5	2.7444	19.2444
1	14.7	-1.9111	12.7889	2	16.0	2.7444	18.7444

Project: CONTACT ANGLE FORCED VARIATION.MPJ; Worksheet: 10 Part Random Order

Chart Output – Forced Variation

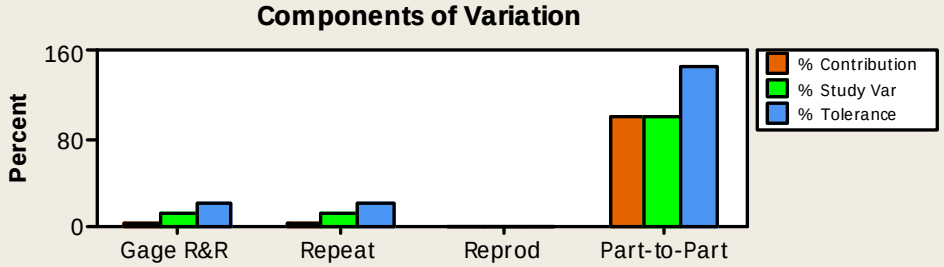
New Hampshire Ball Bearings, Inc. — A Minebea Company

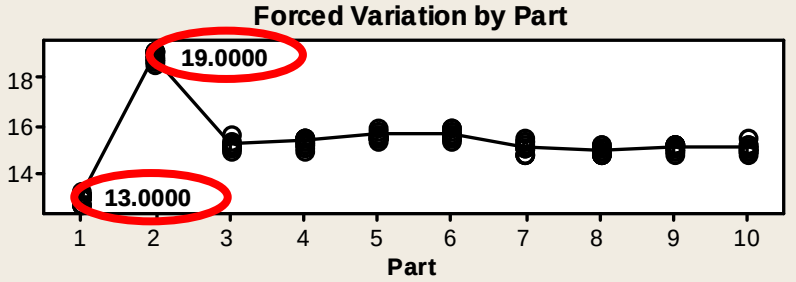
Gage R&R (ANOVA) for Forced Variation

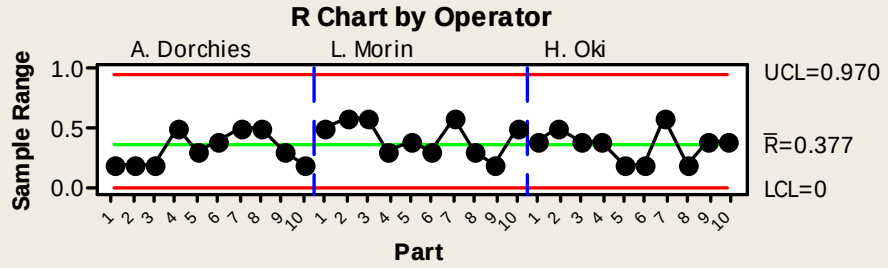
For Reference Only!

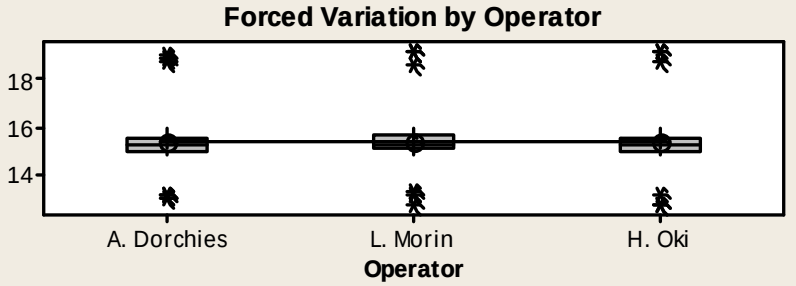
Gage name: ADCAMS C/A Gage
Date of study: 10/19/2009

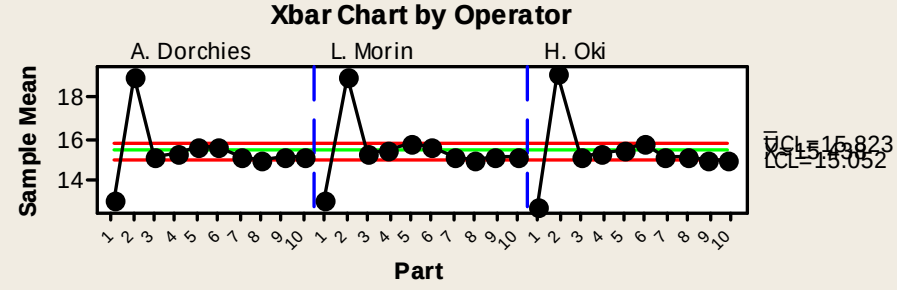
Reported by: A. Dorchies
Tolerance: 13 to 19 = 6 Degrees
Misc: Contact Angle K112134

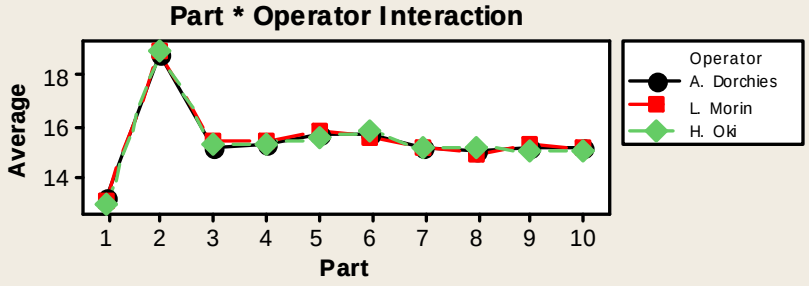












Project: CONTACT ANGLE FORCED VARIATION.MPJ; Worksheet: 10 Part Random Order

Session Output Comparison

New Hampshire Ball Bearings, Inc.
A Minebea Company

Gage R&R – Original Data

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.039895	20.26
Repeatability	0.039895	20.26
Reproducibility	0.000000	0.00
Operator	0.000000	0.00
Part-To-Part	0.157006	79.74
Total Variation	0.196901	100.00

Gage R&R – Forced Variation

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.03989	1.84
Repeatability	0.03989	1.84
Reproducibility	0.00000	0.00
Operator	0.00000	0.00
Part-To-Part	2.12980	98.16
Total Variation	2.16969	100.00

Note: The ONLY change to the analysis is the Part-to-Part Variation! Since the part variation now equals the tolerance spread, the Total Gage R&R value given estimates the % Tolerance.

Session Output Comparison

New Hampshire Ball Bearings, Inc.
A Minebea Company

Gage R&R - Original Data

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.199736	1.19842	45.01	19.97
Repeatability	0.199736	1.19842	45.01	19.97
Reproducibility	0.000000	0.00000	0.00	0.00
Operator	0.000000	0.00000	0.00	0.00
Part-To-Part	0.396240	2.37744	89.30	39.62
Total Variation	0.443735	2.66241	100.00	44.37

Number of Distinct Categories = 2

Gage R&R – Forced Variation

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.19974	1.19842	13.56	19.97
Repeatability	0.19974	1.19842	13.56	19.97
Reproducibility	0.00000	0.00000	0.00	0.00
Operator	0.00000	0.00000	0.00	0.00
Part-To-Part	1.45938	8.75630	99.08	145.94
Total Variation	1.47299	8.83793	100.00	147.30

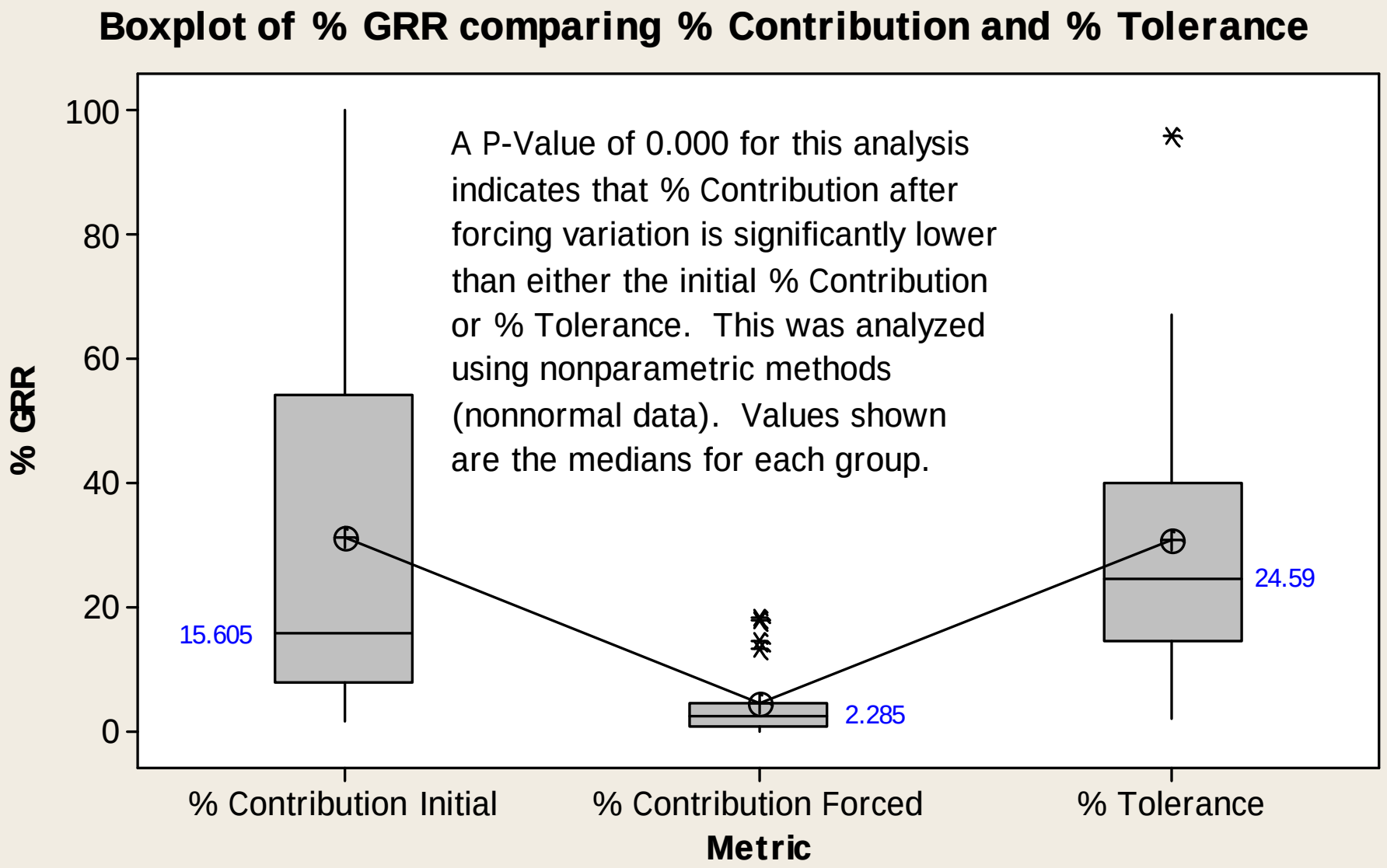
Number of Distinct Categories = 10

In Conclusion:

If you have not altered the gage Repeatability (gage variation) or the Reproducibility (operator variation) and you have only altered the Part-to-Part Variation - you can now judge your gage variation against the total tolerance.

In Conclusion:

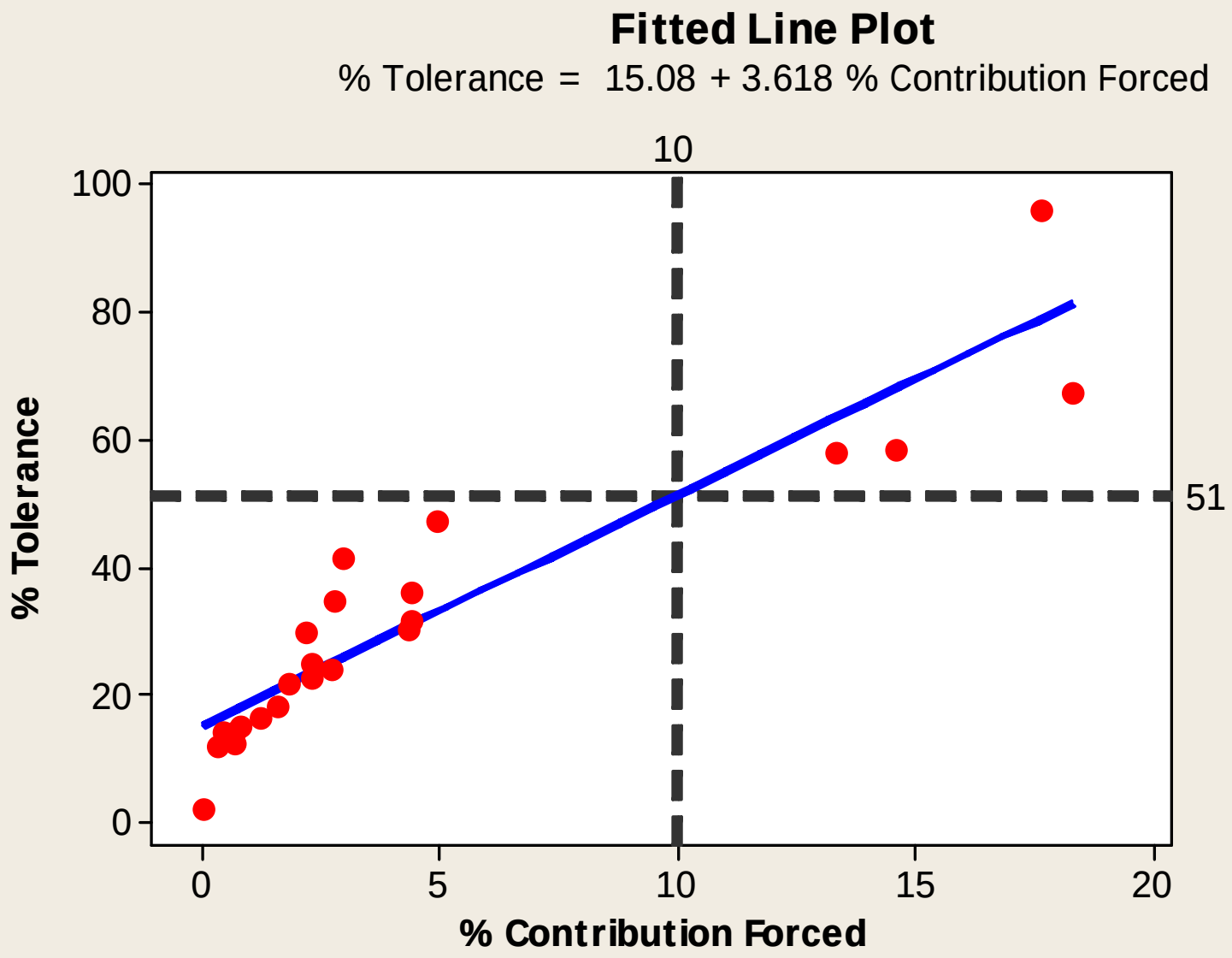
New Hampshire Ball Bearings, Inc.
A Minebea Company



Project: COMPARISON OF % TOLERANCES.MPJ; Worksheet: Data

In Conclusion:

New Hampshire Ball Bearings, Inc.
A Minebea Company



Note: A 10% Contribution (Forced Variation) equates to a 51 % Tolerance!
% Tolerance is 5 times greater than % Contribution when forcing part variation to match the full tolerance.

Project: Comparison of % Tolerances.MPJ; Worksheet: Data

"Forced Variation" Comments

New Hampshire Ball Bearings, Inc.
A Minebea Company

This procedure should not be used blindly. You must know your product and your gaging system and judge when this method is appropriate.

If you consider using this method, you should record what the original results are and then document what the forced variation results are so you can explain the analysis and the reasoning behind the analysis to your customer(s).

Closing Comments

Any and all comments would be greatly appreciated.

An article is being authored and will be submitted to either Quality Progress (ASQ) or Quality Digest to allow the ideas expressed in this presentation to be debated in an open forum.

Thank you for coming.

Comments/questions?

Contact information:
jmeagher@nhbb.com