Measurement System Assurance (MSA) Notebook Pages IV-32 to 43

(Based on ASTM (American Society for Testing and Materials) Definitions)

- PRECISION: The extent to which an instrument or person repeats its results when making repeated measurements on the same unit (of product or process).

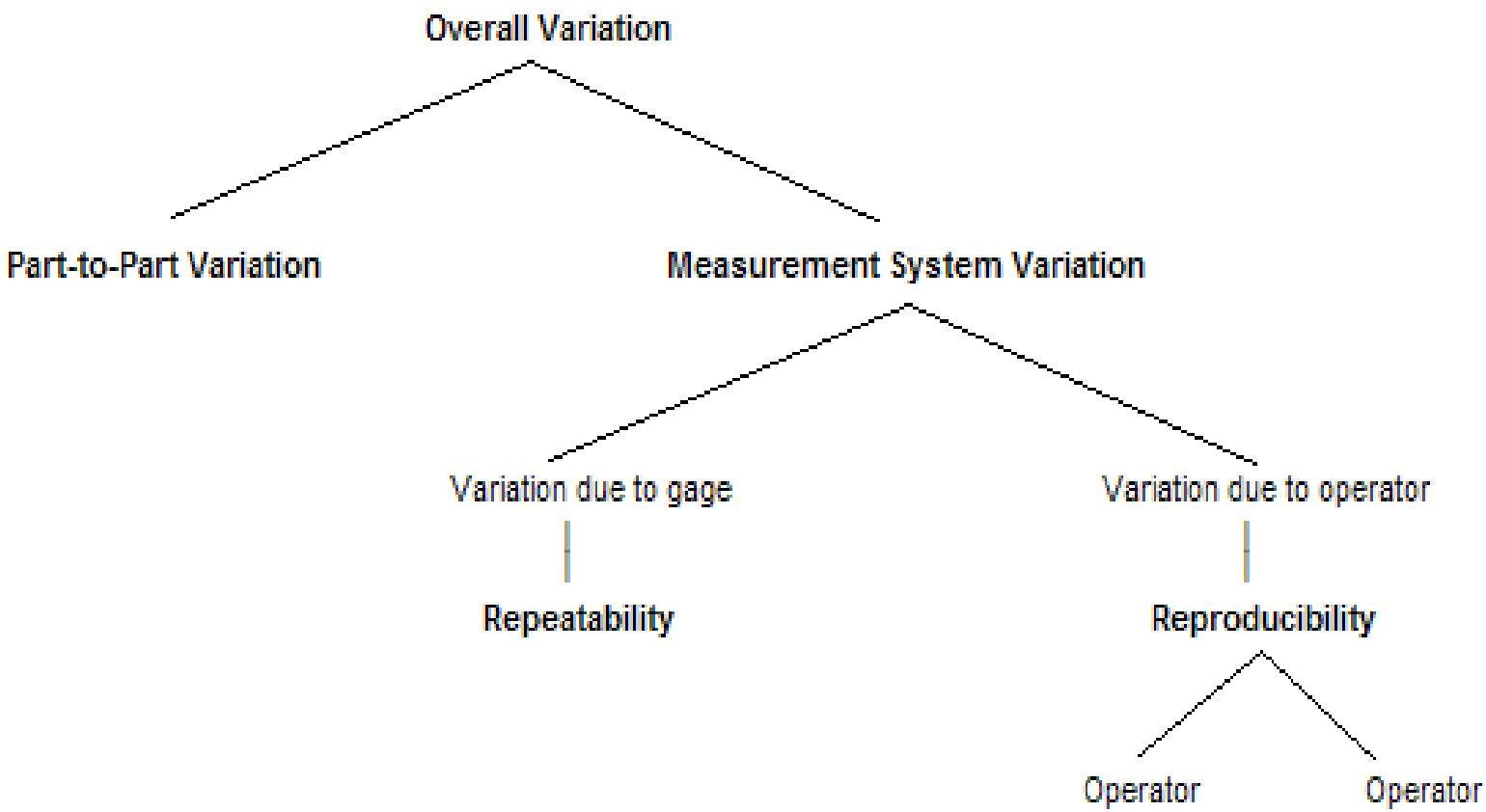
- BIAS: The extent to which the average of a long series of repeated measurements made by an instrument or person on a single unit (of product or process) differs from the "true" value.

- ACCURACY: Accuracy depends on the precision and bias of the test. It is generally recommended that separate statements of bias and precision be used to evaluate a measurement system rather than combining information into a single numerical measure of accuracy.

PRECISE, BUT BIASED (NOT ACCURATE)		UNBIASED, BUT NOT PRECISE (NOT ACCURATE)		UNBIASED AND PRECISE (ACCURATE)	
.017	XXXX	.017		.017	
.016	XXXXX XXXXX	.016	X	.016	
.015	XXXXX XXX	.015	X	.015	
.014	XXXX	.014	XX	.014	
.013		.013	XXX	.013	
.012		.012	XXX	.012	
.011		.011	XXXXX	.011	XXXXX XX
.010	**("TRUE" VALUE)**	**.010**	**XXX**	**.010**	**XXXXX XXXXX XX**
.009		.009	XXX	.009	XXXXX XX
.008		.008	XX	.008	
.007		.007	X	.007	

Sources of Measurement Variation

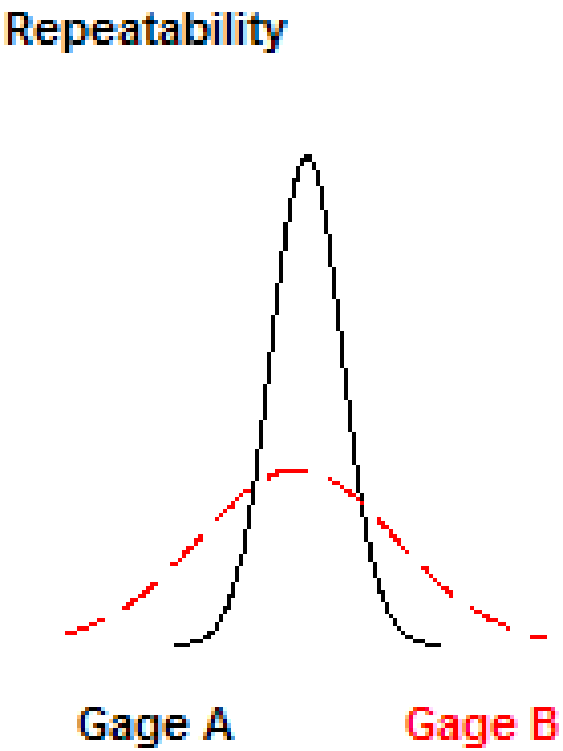
- Within-Operator Variation (Fatigue, Variation in technique, etc.)
- Between-Operator Variation (Technique, Experience, Physical Characteristics, etc.)
- Material Variation (Changes with time, Changes between destroyed units, etc.)
- Test Equipment Variation (Environmental factors, Power changes, Wear, etc.)
- Test Procedure Variation (Interpretation of methods, results, etc.)
- Between-Facilities Variation (Interpretation of methods, different equipment, etc.)



SOURCE: MINITAB 15 STATGUIDE

Repeatability

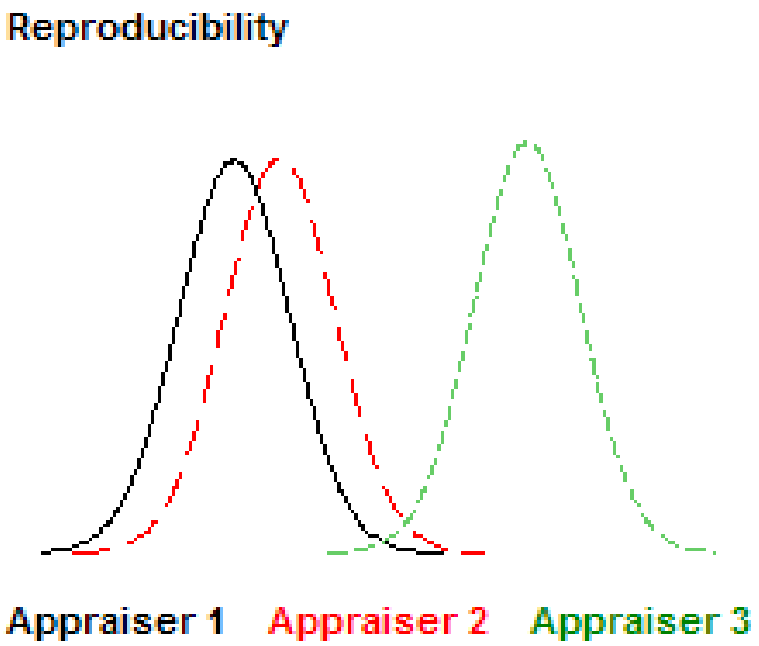
- The closeness of agreement among measurements or data values obtained by one tester or one person on one instrument at one time in one location.



SOURCE: MINITAB 15 STATGUIDE

Reproducibility

- The closeness of agreement among measurements or data values obtained by more than one tester or more than one person using more than one instrument over an extended period of time in one or more locations.



SOURCE: MINITAB 15 STATGUIDE

Gage R&R Studies

- Repeatability and Reproducibility are best evaluated with Gage “R & R” (for Gage “Repeatability and Reproducibility”) studies.

- Their purpose is to determine how much variation in the results is associated with the measurement system, and to compare this variation to the total variation being attributed to the process under evaluation.

- In other words, a Gage R&R study will break the total variation down into the variation actually due to the product or process, and the variation caused by the measurement system:

$$\sigma^2_{total} = \sigma^2_{process} + \sigma^2_{measurement\ system}$$

- The measurement system variation can be broken down further into:

$$\sigma^2_{\text{measurement system error}} = \sigma^2_{\text{repeatability}} + \sigma^2_{\text{reproducibility}}$$

- The typically guideline used today for measurement variability is that the ratio of measurement variability to total variability should not exceed 10% for critical measurements and 25% for all others:

$$\frac{\sigma_{\text{measurement}}}{\sigma_{\text{total}}} \leq .10$$

CONDUCTING A GAGE R&R STUDY FOR CONTINUOUS MEASUREMENTS

Most people follow the automotive industry's (www.AIAG.org) model for conducting Gage R & R studies:

- Ten Parts are each measured by
- Three Times (Three Trials) by
- Three Operators

Example

The weight in ounces of 10 different ball bearings is measured 3 times each by 3 different operators, each using the same measurement device. The results are shown in the following table:

PART:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
OPERATOR 1										
Trial 1:	11	12	10	11	11	13	12	11	13	12
Trial 2:	11	13	11	11	10	12	12	10	14	11
Trial 3:	12	12	11	10	10	12	13	11	13	12
AVG:	11.3	12.3	10.7	10.7	10.3	12.3	12.3	10.7	13.3	11.7
RANGE: 1	1	1	1	1	1	1	1	1	1	

$\overline{\overline{X}}_1 = 11.56$ $\overline{R}_1 = 1.0$

OPERATOR 2

Trial 1:	10	12	12	11	12	13	10	11	12	11
Trial 2:	12	11	13	11	14	13	10	9	12	10
Trial 3:	10	13	12	10	12	12	11	11	13	10
AVG:	10.7	12.0	12.3	10.7	12.7	12.7	10.3	10.3	12.3	10.3
RANGE:	2	2	1	1	2	1	1	2	1	1

$\overline{\overline{X}}_2 = 11.43$ $\overline{R}_2 = 1.4$

OPERATOR 3

Trial 1:	11	13	11	13	12	12	10	11	12	12
Trial 2:	10	13	10	14	12	11	9	9	11	13
Trial 3:	10	14	11	15	11	12	9	9	13	12
AVG:	10.3	13.3	10.7	14.0	11.7	11.7	9.3	9.7	12.0	12.3
RANGE:	1	1	1	2	1	1	1	2	2	1

$\overline{\overline{X}}_3 = 11.50$ $\overline{R}_3 = 1.3$

Gage R&R Study - XBar/R Method

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.53070	49.64
Repeatability	0.53070	49.64
Reproducibility	0.00000	0.00
Part-To-Part	0.53839	50.36
Total Variation	1.06909	100.00

Process tolerance = 6

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.72849	4.37094	70.46	72.85
Repeatability	0.72849	4.37094	70.46	72.85
Reproducibility	0.00000	0.00000	0.00	0.00
Part-To-Part	0.73375	4.40252	70.96	73.38
Total Variation	1.03397	6.20381	100.00	103.40

Number of Distinct Categories = 1

This system is unacceptable:

(1) the measurement system accounts for 49.64% of the total variation;

(2) the measurement system varies by 72.85% of the tolerance interval.

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What is giving us the most trouble?

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The repeatability – the ability of the operator to get the same results consistently on the same part!

The reproducibility is very good – the operators are all doing essentially the same thing.

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What could you do to address repeatability problems?

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Look to something that affects all operators the same way:

- The measurement device could be difficult to use / interpret.
- It could also “fluctuate” too much.

Gage R&R "Six Pack"