

GAGE R&R STUDY

Instructions for this form:

- 1) Type only in the shaded blocks.
- 2) Be sure to write the Upper & Lower Tolerances.
- 3) This spreadsheet is set up for either a **5-parts (Short study)** or **10-parts (Long study)** MSA. **Do not use for any other quantity!!**
 - Short study requires 2 Appraisers x 2 Replications
 - Long study requires 3 Appraisers x 3 Replications
- 4) "Appraiser Names" MUST be filled in for the form to work properly.
 - For 'Short study' keep in blank the space of "Appraiser C"

Gage Name: 	Part Name: 	Date:
Gage No.: 	Operation No.: 	Performed By:
Graduations: 	Characteristic: 	Area:
Zero Equals: 	Upper Tolerance: 2.26	Appraiser A: Hugo
Unit of Measure: 	Nominal: .05	Appraiser B: Paco
Part No: 	Lower Tolerance: -2.16	Appraiser C: Luis

Short / Long study
Short / Long study
Long study

Instructions for data collection:

- 1) Select **5-parts (Short study)** or **10-parts (Long study)** at random and marking/identifying them 1 through "n".
- 2) Have **2 Appraisers (Short study)** or **3 Appraisers (Long study)** measure each part independently, two or three times each. Record results below.
- 3) Analyze the results to determine variability due to both Repeatability and Reproducibility.

Appraiser A: Hugo					Appraiser B: Paco					Appraiser C: Luis				
Sample Number	Replications			R (Range)	Sample Number	Replications			R (Range)	Sample Number	Replications			R (Range)
	1	2	3			1	2	3			1	2	3	
1	0.290	0.410	0.640	0.3500	1	0.080	0.250	0.070	0.1800	1	0.040	-0.110	-0.150	0.1900
2	-0.560	-0.680	-0.580	0.1200	2	-0.470	-1.220	-0.680	0.7500	2	-1.380	-1.130	-0.960	0.4200
3	1.340	1.170	1.270	0.1700	3	1.190	0.940	1.340	0.4000	3	0.880	1.090	0.670	0.4200
4	0.470	0.500	0.640	0.1700	4	0.100	1.030	0.200	1.0200	4	0.140	0.200	0.110	0.0900
5	-0.800	-0.920	-0.840	0.1200	5	-0.560	-1.200	-1.280	0.7200	5	-1.460	-1.070	-1.450	0.3900
6	0.020	-0.110	-0.210	0.2300	6	-0.200	0.220	0.060	0.4200	6	-0.290	-0.670	-0.490	0.3800
7	0.590	0.750	0.660	0.1600	7	0.470	0.550	0.830	0.3600	7	0.020	0.010	0.210	0.2000
8	-0.310	-0.200	-0.170	0.1400	8	-0.630	0.080	-0.340	0.7100	8	-0.460	-0.560	-0.490	0.1000
9	2.260	1.990	2.010	0.2700	9	1.800	2.120	2.190	0.3900	9	1.770	1.450	1.870	0.4200
10	-1.360	-1.250	-1.310	0.1100	10	-1.680	-1.620	-1.500	0.1800	10	-1.490	-1.770	-2.160	0.6700
Totals	1.9400	1.6600	2.1100	1.8400	Totals	0.0100	1.1500	0.8900	5.1300	Totals	-2.2300	-2.5600	-2.8400	3.2800
X (Means)	0.1940	0.1660	0.2110	0.1840	X (Means)	0.0010	0.1150	0.0890	0.5130	X (Means)	-0.2230	-0.2560	-0.2840	0.3280
	Xbar ₁	Xbar ₂	Xbar ₃	Rbar _A		Xbar ₁	Xbar ₂	Xbar ₃	Rbar _B		Xbar ₁	Xbar ₂	Xbar ₃	Rbar _C
	Xbar _A = $\frac{Xbar_1 + Xbar_2 + Xbar_3}{\text{Replications}}$					Xbar _B = $\frac{Xbar_1 + Xbar_2 + Xbar_3}{\text{Replications}}$					Xbar _C = $\frac{Xbar_1 + Xbar_2 + Xbar_3}{\text{Replications}}$			
	Xbar _A = 0.1903					Xbar _B = 0.0683					Xbar _C = -0.2543			

Test for Statistical Control of Ranges

$$Rbar_1 = \frac{Rbar_A + Rbar_B + Rbar_C}{\text{Operators}} = \frac{1.0250}{3} = \mathbf{0.3417}$$

$$UCL_R = D_4 * Rbar_1 = 2.574 * 0.3417 = \mathbf{0.8795} = \text{Range Upper Control Limit}$$

Note: D₄ is based on the number of Replications (see table below)

Gage R&R Study Analysis

Repeatability (EQ - Equipment Variation)

$$S_{EV} = \frac{Rbar_1}{d_2} = \frac{0.3417}{1.6930} = \mathbf{0.2018}$$

$$\text{StudyVar (S}_{EV} * 6) = 0.2018 * 6 = \mathbf{1.2109}$$

Note: d₂ is based on the number of Replications (see table below)

Percent of Engineering Tolerance Consumed by the Equipment / Gage:

$$\text{Repeatability} = \frac{100 (6.00 * S_D)}{\text{Eng. Tolerance}} = \frac{1.2109}{4.4200} = \mathbf{27.40\%}$$

Reproducibility (AV - Appraiser Variation)

$$Rbar_2 = Xbar_{Largest\ of\ ABC} - Xbar_{Smallest\ of\ ABC} = 0.1903 - (-0.2543) = 0.4447$$

$$S_{Ov} = Rbar_2 / d_2^* = 0.4447 / 1.912 = 0.2326$$

Note: d_2^* is based on the number of Operators (see table below)

Number of parts = 10
 Number of trials = 3
 $d_2^* = 1.912$

Percent of Engineering Tolerance consumed by Appraiser / Operator:

$$Reproducibility = \frac{100 (6.00 * S_{Ov})}{Eng. Tolerance} = \frac{1.3778}{4.4200} = 31.17\%$$

$$StudyVar (S_{Ov} * 6) = (Rbar_2 * (6.00/d_2^*))^2 - ((Repeatability)^2 / (No. parts * No. trials)) = 1.3778$$

Combined Reproducibility and Repeatability (Measurement System)

$$S_{MV} = S_{Ov}^2 + S_{GV}^2 = 0.2326^2 + 0.2018^2 = 0.3079$$

Product Sigma

* SPECIAL SUPPLIER NOTE: Supplier needs to enter "Product Sigma" into HS Process Certification Database when creating a new Gage File for any HS defined KPCs/TKCs. Enter the Product Sigma into the database field entitled "Gage RR Std

1) Percent of Engineering Tolerance consumed by Measurement system:

$$Gage\ R\ \&\ R = \frac{100 (6.00 * S_{MV})}{Eng. Tolerance} = \frac{1.847522}{4.4200} = 41.80\%$$

2) Percent of Process Tolerance (Combined Variability) consumed by Measurement system:

$$(Repeatability)^2 + (Reproducibility)^2 = 1.8342$$

CAUTION: Percent Process Tolerance value is only valid for 5-part (Short study) or 10-part (Long study) MSA.

$$Gage\ R\ \&\ R = \frac{Percent\ Process\ Tolerance\ (Combined\ Variability) = (R\ \&\ R) / (6/d_2) * Rbar_{CV}}{21.0667} = 26.80\%$$

Gage R&R Study Evaluation Guideline

1) Gage Capability for Product Acceptance (% of Engineering Tolerance)

GC as a % of Eng. Tolerance = (Gage R&R / Total Eng. Tolerance Range) * 100 =

41.80%

% Tolerance (SV/Toler)

2) Gage Capability for Control Chart purposes (% of Process Tolerance)

% of Process Tolerance = (R&R / 6 x Sigma_{CV}) * 100 =

26.80%

% Study Var (% SV)

Legend	ACCEPTABLE	MARGINAL	UNACCEPTABLE
Eng. Tolerance	0 - 20 %	-	> 20 %
Process Tolerance	0 - 19 %	20 - 30%	> 30 %

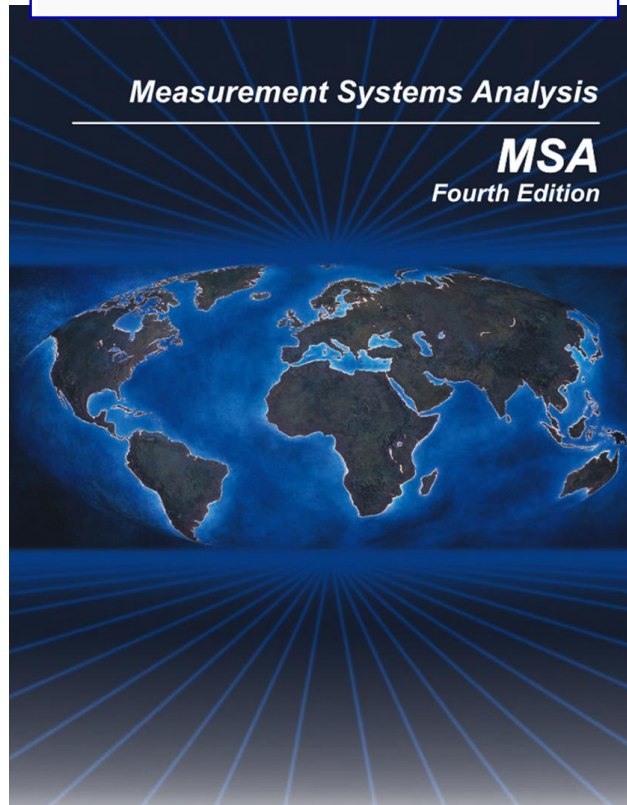
Table of Factors used in calculations.

n	D ₄	d ₂	d ₂ [*]
2	3.267	1.128	1.414
3	2.574	1.693	1.912
5		2.326	
10		3.078	

Study Observation

INSTRUCTIONS: Please record any significant observations, such as Operator/Inspector methodical differences, environmental factors (i.e., lighting, temperature, vibration, distractions, etc.), difficulties in using the measurement system (i.e., obtaining readings, gage readability, ability to easily hold gage and/or part, etc.) that could influence the study results.

★ XS-MSA-4 - Measurement Systems Analysis



Chapter III - Section B
Variable Measurement System Study - Guidelines

Gage Repeatability and Reproducibility Data Collection Sheet

Appraiser / Trial #	PART										AVERAGE	
	1	2	3	4	5	6	7	8	9	10		
1 A	1	0.29	-0.56	1.34	0.47	-0.80	0.02	0.59	-0.31	2.26	-1.36	0.194
	2	0.41	-0.68	1.17	0.50	-0.92	-0.11	0.75	-0.20	1.99	-1.25	0.166
	3	0.64	-0.58	1.27	0.64	-0.84	-0.21	0.66	-0.17	2.01	-1.31	0.211
4	Average	0.447	-0.607	1.260	0.537	-0.853	-0.100	0.667	-0.227	2.087	-1.307	$\bar{X}_A = 0.1903$
	Range	0.35	0.12	0.17	0.17	0.12	0.23	0.16	0.14	0.27	0.11	$R_A = 0.184$
6 B	1	0.08	-0.47	1.19	0.01	-0.56	-0.20	0.47	-0.63	1.80	-1.68	0.001
	2	0.25	-1.22	0.94	1.03	-1.20	0.22	0.55	0.08	2.12	-1.62	0.115
	3	0.07	-0.68	1.34	0.20	-1.28	0.06	0.83	-0.34	2.19	-1.50	0.089
9	Average	0.133	-0.790	1.157	0.413	-1.013	0.027	0.617	-0.297	2.037	-1.600	$\bar{X}_B = 0.0683$
	Range	0.18	0.75	0.40	1.02	0.72	0.42	0.36	0.71	0.39	0.18	$R_B = 0.513$
11 C	1	0.04	-1.38	0.88	0.14	-1.46	-0.29	0.02	-0.46	1.77	-1.49	-0.223
	2	-0.11	-1.13	1.09	0.20	-1.07	-0.67	0.01	-0.56	1.45	-1.77	-0.256
	3	-0.15	-0.96	0.67	0.11	-1.45	-0.49	0.21	-0.49	1.87	-2.16	-0.284
14	Average	-0.073	-1.157	0.880	0.150	-1.327	-0.483	0.080	-0.503	1.697	-1.807	$\bar{X}_C = -0.2543$
	Range	0.19	0.42	0.42	0.09	0.39	0.38	0.20	0.10	0.42	0.67	$R_C = 0.328$
16	Part Average	0.169	-0.851	1.099	0.367	-1.064	-0.186	0.454	-0.342	1.940	-1.571	$\bar{X} = .0014$
	Part Range											$R_p = 3.511$
17	$[(R_A = 0.184) + (R_B = 0.513) + (R_C = 0.328)] / [n \text{ OF APPRAISERS} = 3] = 0.3417$											
18	$[\text{Max } \bar{X} = 0.1903] - [\text{Min } \bar{X} = -0.2543] = \bar{X}_{\text{diff}} = 0.4446$											
19	* $[\bar{R} = 0.3417] \times [D_4 = 2.58] = UCL_R = 0.8816$											

* $D_4 = 3.27$ for 2 trials and 2.58 for 3 trials. UCL_R represents the limit of individual R 's. Circle those that are beyond this limit. Identify the cause and correct. Repeat these readings using the same appraiser and unit as originally used or discard values and re-average and recompute \bar{R} and the limiting value from the remaining observations.

Notes:

Figure III-B 15: Completed GR&R Data Collection Sheet

Gage R&R Using 6.0 Standard Deviations (99.7%)

Source	Study Variation	% Study Variation	% of Tolerance
Total Gage R&R	1.8348	26.68%	41.51%
Repeatability	1.2114	17.62%	27.41%
Reproducibility	1.3782	20.04%	31.18%
Part to Part	6.6276	96.38%	149.95%
Total Variation	6.8766	100.00%	155.58%

Number of Distinct Categories = 5

Chapter III - Section B
Variable Measurement System Study - Guidelines

Gage Repeatability and Reproducibility Report

Part No. & Name: _____ Gage Name: _____ Date: _____
 Characteristics: _____ Gage No: _____ Performed by: _____
 Specifications: _____ Gage Type: _____

From data sheet: $\bar{R} = 0.3417$ $\bar{X}_{\text{diff}} = 0.4446$ $R_p = 3.511$

Measurement Unit Analysis

Measurement Unit Analysis	% Total Variation (TV)
Repeatability - Equipment Variation (EV) $EV = \bar{R} \times K_1$ $= 0.3417 \times 0.5908$ $= 0.20188$	$\%EV = 100 [EV/TV]$ $= 100 [0.20188/1.14610]$ $= 17.62\%$
Reproducibility - Appraiser Variation (AV) $AV = \sqrt{(\bar{X}_{\text{diff}}^2 \times K_2) - (EV^2 / (n \times 3))}$ $= \sqrt{(0.4446^2 \times 0.5231^2) - (0.20188^2 / (10 \times 3))}$ $= 0.22963$	$\%AV = 100 [AV/TV]$ $= 100 [0.22963/1.14610]$ $= 20.04\%$
Reproducibility & Reproducibility (GRR) $GRR = \sqrt{EV^2 + AV^2}$ $= \sqrt{(0.20188^2 + 0.22963^2)}$ $= 0.30575$	$\%GRR = 100 [GRR/TV]$ $= 100 [(0.30575/1.14610)]$ $= 26.68\%$
Part Variation (PV) $PV = R_p \times K_3$ $= 3.511 \times 0.3742$ $= 1.10456$	$\%PV = 100 [PV/TV]$ $= 100 [1.10456/1.14610]$ $= 96.38\%$
Total Variation (TV) $TV = \sqrt{GRR^2 + PV^2}$ $= \sqrt{(0.30575^2 + 1.10456^2)}$ $= 1.14610$	$ndc = 1.41 [PV/GRR]$ $= 1.41 [1.10456/0.30575]$ $= 5.094 \sim 5$

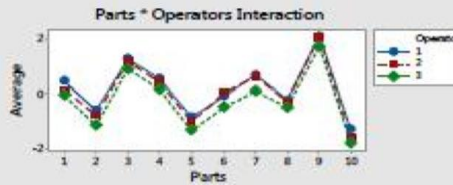
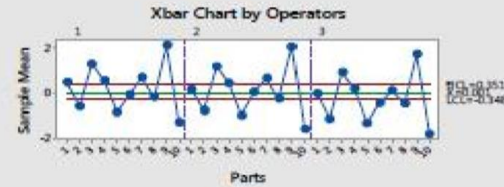
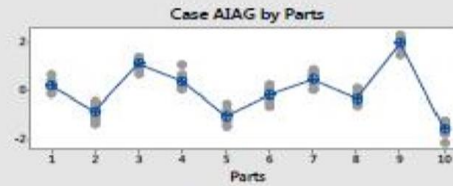
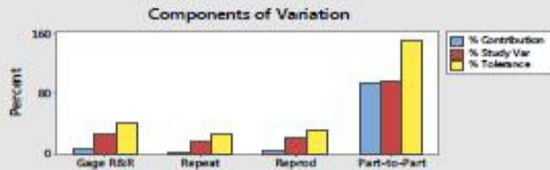
For information on the theory and constants used in the form see MSA Reference Manual, Fourth edition.

Figure III-B 16: Gage Repeatability and Reproducibility Report

Comparison study, Minitab 18 Vs. ASG Spreadsheet based on AIAG

Gage name: Per AIAG
Date of study: 4/20/2020

Reported by: Advanced Quality Team
Tolerance: -2.16 / +2.26
Misc: Comparison study, Minitab 18 Vs. ASG Spreadsheet



Gage R&R Study - XBar/R Method Gage R&R for Case AIAG

Variance Components

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.09350	7.12
Repeatability	0.04075	3.10
Reproducibility	0.05275	4.02
Part-To-Part	1.21982	92.88
Total Variation	1.31332	100.00

Process Tolerance = 4.42

Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.30578	1.83469	26.68	41.51
Repeatability	0.20186	1.21118	17.61	27.40
Reproducibility	0.22968	1.37810	20.04	31.18
Part-To-Part	1.10445	6.62672	96.37	149.93
Total Variation	1.14600	6.87601	100.00	155.57

Number of Distinct Categories = 5

Gage R&R for Case AIAG