| | RK:QM ***Ltd*** ***Quality System*** |
|---|---|
| **Classic Gauge R&R Study Procedure** | MES / 01 |

# 1. Contents



# 2. Objective of a gauge study

The objective of an R&R study (Repeatability & Reproducibility) is to provide a quantitative estimate of the error in a gauge; also known as the variability experienced when using the gauge.

By comparing this variability with the tolerance of the part being measured, a decision can be taken as to the suitability of the gauge's precision for controlling the process.

This procedure (Classic gauge) covers the study of gauges which are non-destructive to the product and can measure the same piece many times without changing its dimensions.

**NOTE**: Accuracy of the gauge is checked and improved where necessary with a calibration procedure.

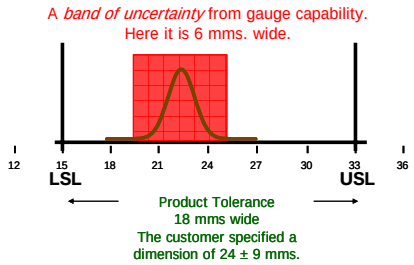
# 3. Responsibility

Quality and Production departments have the combined responsibility of carrying out the study. All inspectors and operators who use the gauge on a regular basis should be included in the study (see sample size section 5.2 page 3)

# 4. Definition of R&R%

**4.1 R&R%** is a statistic estimating the precision of a gauge. It is expressed as the ratio of the gauge error (5.15 standard deviations[1]) and the tolerance of the part being measured.

[1] some industries have changed this element of the formula to 6 std devs as gauge quality has improved.




$$\text{R\&R\%} = \frac{\text{"Uncertainty" x 100}}{\text{Product Tolerance}} = \frac{\text{6 mms x 100}}{\text{18 mms}} = 33.3\%$$

The study will separate out the repeatability error and the reproducibility error. Repeatability error is that due to the gauge; gauge wear, abuse, and environmental conditions. Reproducibility error is that due differences in technique by the people using it. In the illustration above, these two errors are combined into one band of uncertainty.

An R&R% is specific to an individual gauge and a particular part. For example a Sylvac height gauge when measuring the height of a 500ml stock bottle reference S500FD.

# 5. Procedure for carrying out studies

**5.1**

**Prepare**

Establish the current specification for the product to be measured. Target and tolerance.

The specification may be one-sided or target less if required.

Target = ...

Lsl = ...

Usl = ...

Collect six pieces of the product to be studied. If possible, select samples from across the whole of the tolerance, even just outside it. This will check the gauge across the whole of its operating band.

**NOTE:** six pieces are a reasonable quantity of samples to carry out a first study. If the final confidence limits around the R&R % are unacceptable (see section 5.5 page 6), further samples can be measured and included in the study.

Decide

* who will measure the samples: ... ... ...
  *inspectors*
* who will pass samples to the inspectors:
  *controller* ... ... ...
* who will record the result:
  *recorder*

All people who use the gauge for measuring this part should be *inspectors* in the study. A minimum of two inspectors is required. ... ... ...

**5.2**

**Mark the samples**

Give each of the six samples a different identity of A, B, C, D, E and F. The marks should be indelible and on a location of the part which the *inspector* cannot see when measuring.

This prevents the *inspector* knowing which sample he is measuring and hence any chance of remembering a previous dimension rather than providing a new, slightly different measurement.

Mark indelibly on each sample the location to be measured. For example where the height is to be measured on each of the bottles.

**5.3 Measure the samples**

The *controller* randomly passes the six samples, for the two measurements (replicates) of each part to the first of the *inspectors*.

For example a random order may be:

E, B, C, C, F, D, A, B, F, A, E, D

The *inspector* measures the part and returns it to the *controller*. He tells the *recorder* the result of the measurement.

The *recorder* records the result against the appropriate sample identity. A typical results table is shown below.

| | | Operators | | |
|---|---|---|---|---|
| Sample | Replicate | X | Y | Z |
| A | 1 | | | |
| | 2 | | | |
| B | 1 | | | |
| | 2 | | | |
| C | 1 | | | |
| | 2 | | | |
| D | 1 | | | |
| | 2 | | | |
| E | 1 | | | |
| | 2 | | | |
| F | 1 | | | |
| | 2 | | | |

The same procedure is carried out for each of the remaining *inspectors* included in the trial.

## 5.4 Analyse

**5.4.1 Prepare data**

Convert the data into a format suitable for Minitab:

| Sample | Replicate | Inspector | Result |
|---|---|---|---|
| A | 1 | X | ... |
| A | 2 | X | ... |
| B | 1 | X | ... |
| B | 2 | X | ... |
| C | 1 | X | ... |
| through to | | | |
| E | 2 | Z | ... |
| F | 1 | Z | ... |
| F | 2 | Z | ... |

Copy and paste into Minitab

**5.4.2**

## Analyse data

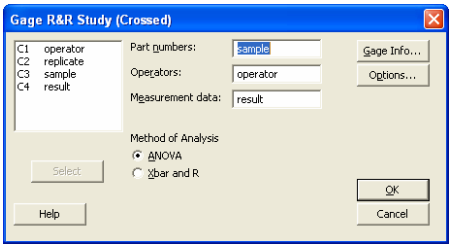
Using Minitab:

**Stat ▸ Quality Tools ▸Gage Study ▸ Gage R&R Study (Crossed) ▸**

Part or batch numbers: `sample`
Operators: `inspector`
Measurement data: `result`

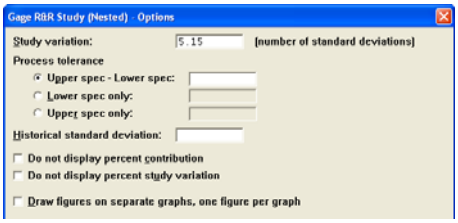
Method of analysis:
⊙ ANOVA

Options…




Study variation: `5.15`
*this needs to be changed from the default of 6*

Process tolerance:
*insert the tolerance specified in 5.1 above*




Use ***rkqm gauge study.xls*** to calculate confidence limits around R&R%.

You will need

* Standard deviation ... ... ...
* N° of samples ... ... ...
* N° of inspectors ... ... ...
* N° of replicates ... ... ...
* Tolerance ... ... ...

Decide if more samples are required to reduce range of possible R&R% to an acceptable band.

**5.5**

## Interpretation

### Session page output

| Source | StdDev (SD) | Study Var (5.15 * SD) | %Study Var (%SV) | %Tolerance (SV/Toler) |
|---|---|---|---|---|
| **Total Gage R&R** | 0.0816920 | 0.420714 | 98.80 | **21.04** |
| Repeatability | 0.0241169 | 0.124202 | 29.17 | **6.21** |
| Reproducibility | 0.0780510 | 0.401962 | 94.40 | **20.10** |
| plant | 0.0780510 | 0.401962 | 94.40 | 20.10 |
| **Part-To-Part** | 0.0127752 | 0.065792 | 15.45 | **3.29** |
| Total Variation | 0.0826848 | 0.425827 | 100.00 | 21.29 |

Number of Distinct Categories = 1

The R&R% for the gauge system is 21%.

Gauge error is low at 6%, but the error from operators is relatively high at 20%. The part-to-part variation of the samples used is low, this is not good; we should have used samples of a greater difference across the tolerance band.

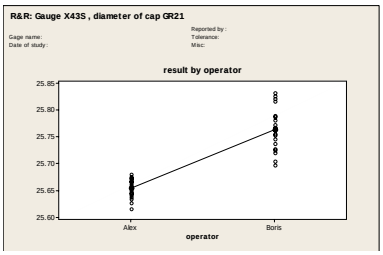
The number of distinct categories at 1 is unacceptable. There is a motor industry standard that says this should be a minimum of 5. Using samples of greater difference would help this. It is saying that the gauge, although giving different results, can only categorise the parts used into 1 category.

***rkqm gauge study.xls*** The confidence limits around 21%, based on
SD = 0.0816920, samples = 10, inspectors = 2, replicates = 2, tolerance = 2

R&R% = 21%, -6% +16% (lowest value 15% highest 37%) This would be an unacceptable range as one end is greater than 30%. A further inspector should be invited to measure the samples.

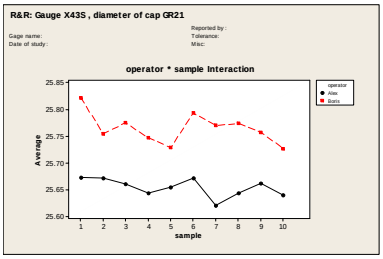
### Result by Operator

Boris is using the gauge in a way that is giving higher results than Alex. He also has greater variability in his results.



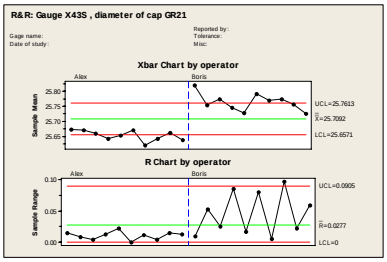

### operator * sample Interaction

This shows how the operators measure the samples differently




### Xbar and R charts for operator

These charts illustrate the difference in average results and variability seen by the two operators



**5.6 Actions**

### Improve the reproducibility

These three charts indicate that the low reproducibility needs investigation to find out why there is large difference between the operators.

Potentially the R&R can be improved by finding the cause of this difference.

Record the result on a gauge map

A matrix with ...
- y axis showing gauges in use
- x axis the parameters measured

... should be created to show the results of all R&R studies carried out. By colour coding each result ( red > 30%, orange 20% to 30%, green 10% to 20%, blue < 10% ) , this matrix will act as a means of prioritising improvement work on gauges.

# 6. Industry Standards

Standard for gauge error is 5.15 standard deviations (packaging industry)

Standards for bands of acceptability are:

| | | R&R% |
|---|---|---|
| **Not acceptable** | Red | >30% |
| **Borderline** | Orange | 20% to 30% |
| **Acceptable** | Green | 10% to 20% |
| **World-Class** | Blue | <10% |