Simply

Step-by-Step

Gauge R&R Studies

For Destructive and Non-Destructive Testing

Mario Perez-Wilson

Follow this step-by-step approach at your own pace, and teach yourself how to conduct Gauge Repeatability and Reproducibility Studies .

You will be improving measurement systems right away!

Gauge R&R Studies

- For Destructive and Non-destructive Testing -

Mario Perez-Wilson
President
Advanced Systems Consultants

"Gauge R&R Studies - For Destructive and Non-destructive Testing"

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GAUGE R&R STUDIES

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Introduction

To be able to understand the behavior of a process, that is, a process of developing a product, or a process of producing a product, we need to collect data. Although data can be of two types, attribute or variable, we will only focus on the latter. Data is collected by means of a measurement system that actually measures the characteristic of interest. This measurement is then converted into a numerical value with a particular unit of measurement attached to it. This unit of measurement being from the Metric system (SI-Le Systeme International d'Unites) of measurement or the UK (Imperial) system of measurement.

Let's assume that the measurement generated a numerical value equal to 0.0035 inches. This immediately raises the question. Is 0.0035 the true value of the characteristic measured or is this value influenced by the measurement system? A normal or obvious reaction to this doubt would be to retake (repeat) the measurement of the characteristic without changing anything. Let's say the next measurement yielded a value equal to 0.0036 inches. Since the second value differs from the first measurement, this clearly indicates that there is some level of uncertainty and although it is a know fact that everything is subject to variation, this uncertainty would have to be attributed to the measurement system. Why attribute this uncertainty to the measurement system? Because, everything else was held constant when the second measurement was taken.

Let's say that we decided to quantify this uncertainty and continue taking repeated measurements, holding everything constant, and eventually, quantify this variability. This raises the next question. Is this measurement system's variability too large or too small as compared to the tolerance of the characteristic being measured? Does the measurement system have the capability (potential of capability) to measure the characteristic of interest? How much variability is considered to be too much?

The principal objectives of this book are to define various concepts related to the statistical analysis of measurement system and to present methods to evaluate and quantify the amount of variability present in measurement systems, regardless whether the testing method is destructive or non-destructive. The book could be divided into three main sections. The first presents briefly terminology and concepts related to metrology and statistics. The next section presents step-by-step how to conduct gauge repeatability and reproducibility studies for non-destructive tests, using a short method as well as a long method. The final section presents again a step-by-step approach on how to conduct a destructive gauge repeatability and reproducibility study for obviously destructive tests.

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The Act of Measuring

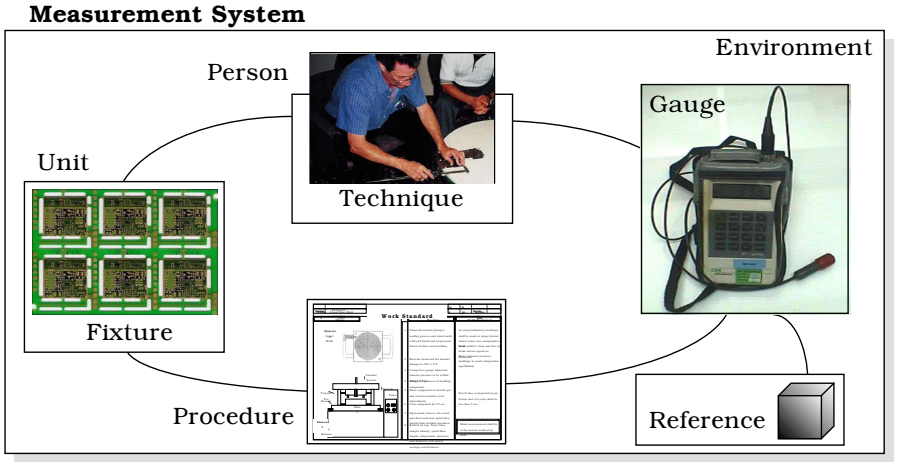
Measuring is an act that involves a system comprised of a number of elements:

1. Unit, or characteristic to be measured
2. Gauge to perform the measurement
3. Person, or individual performing the act
4. Procedure to follow
5. Reference standard used to calibrate the gauge
6. Environment at which the gauge is under
7. Technique of measurement
8. Fixture used to hold the unit, etc.

As we measure a characteristic, the measurement system has a number of elements that can contribute to the measurement variability.

As we evaluate a measurement system it is important to keep all the elements of the system constant, so they do not become a significant source of variability.

The gauge here represents what in the industry is referred to as gage, measuring instrument, device, apparatus, tester, etc. The gauge is only one element of the measurement system, and although it is probably the most important, it may not necessarily be the most influential or the one that dominates the variability.



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Methods to evaluate measurement systems are usually referred to as Gauge Repeatability and Reproducibility Studies (GR&R), Measurement Capability Analysis, Measurement Systems Analysis or Gauge Capability Studies. It is important to note that when these studies are performed, even though they are referred to as "gauge" studies, it is not only the gauge that is being evaluated, but the complete or whole measurement system.

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Measurement Error, Uncertainty and Variance

Every time we use a gauge or measurement system to make a measurement, there is a level of uncertainty from the results obtained.

Let us assume, for the purpose of explanation, that the true value of a characteristic is known with a value of 35.0 and represented by the Greek letter μ. Then, repeated measurements are taken with this gauge, where each measurement is represented by X_i, (or $X_{Measured}$) where i=1,2,3,...,n, and all these individual measurements were averaged and represented by $\bar{X}$.

The results obtained from an individual measurement would be equal to the true value plus the measurement error, $\varepsilon_{Measurement}$.

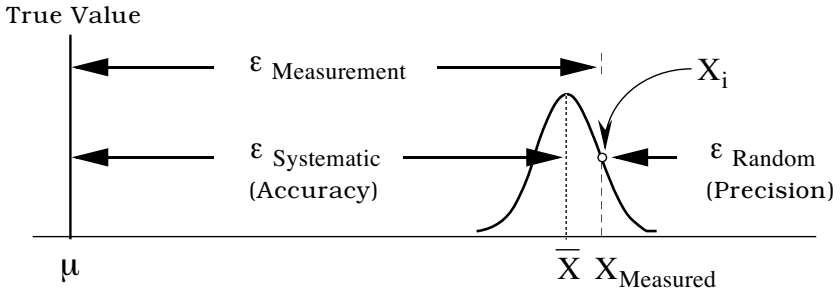
$$X_{Measured} = \mu + \varepsilon_{Measurement}$$

$$X_i = \mu + \varepsilon_i$$

The measurement error can be broken down into two components, **systematic error**, $\varepsilon_{Systematic}$, pertaining to accuracy or bias, or the result of very significant assignable causes, and the other component being **random error**, ε_{Random}, pertaining to precision and resulting from many individually insignificant or minuscule causes and not necessarily identifiable.

$$\varepsilon_{Measurement} = \varepsilon_{Systematic} + \varepsilon_{Random}$$

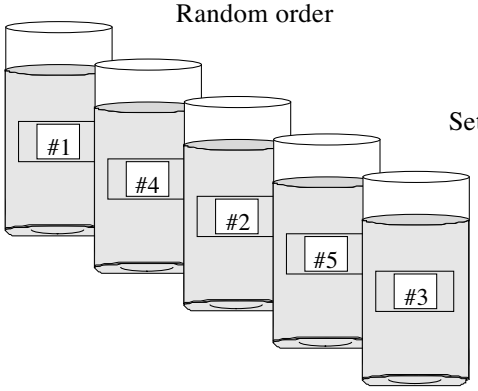
$$\varepsilon_i = \varepsilon_S + \varepsilon_{Ri}$$



c) Proceed to give the five samples to the second operator in random order and perform the test with the samples.

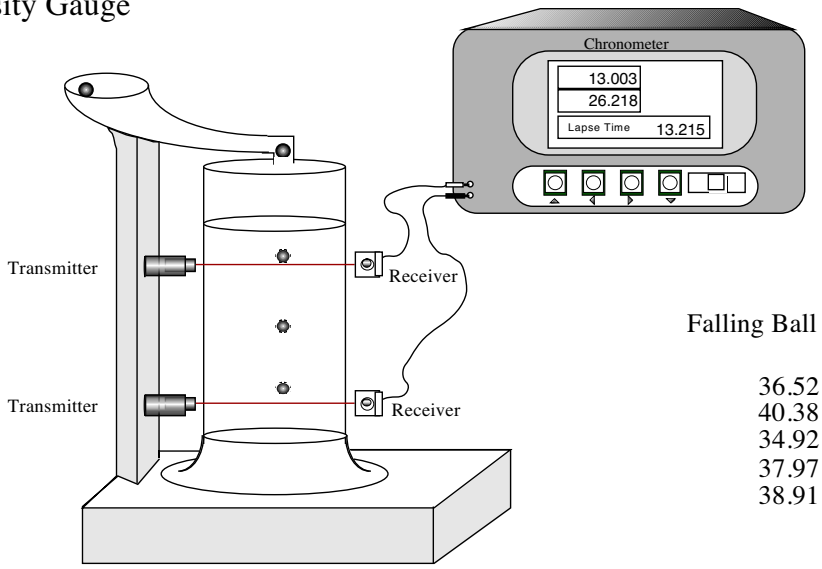
Operator - **B**

Random order



Set of five samples

Viscosity Gauge



Falling Ball Time

36.52
40.38
34.92
37.97
38.91

d) Record the measurement results in column 2.

	Column 1	Column 2	
Samples	Operator A	Operator B	r
1	36.80	36.52	
2	34.30	34.92	
3	37.22	38.91	
4	40.40	40.38	
5	38.82	37.97	

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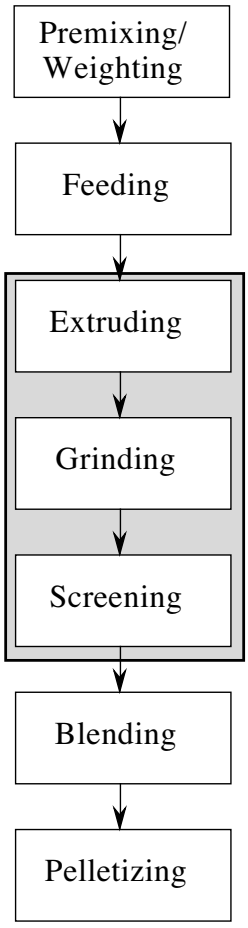
Let's describe the steps of conducting a Destructive Gauge Repeatability and Reproducibility Study with an example of a gauge for thermosetting molding compound.

Molding Compound Process

In the production of molding compound, ingredients are pre-mixed and weighted, then they are fed into an extrusion press, grinded to a specified particle size, screened and blended to finally be pelletized.



During this process, it is of interest to know the flowability of the compound being created. The flowability is a measurement of the combined characteristics of fusion under pressure, melt viscosity and gelation rate under specific conditions.

The flowability is measured by a test procedure which eliminates the sample after it is tested, thus considered a destructive test. The test is done in a transfer molding press, by taking a sample of the molding compound (as loose powder) and placing it into a transfer pot, which is preheated at 302 ± 5°F. The molding compound is plasticized by heat and pressure (from the compression plunger at 1000 ± 25 psi) and injected through an orifice into a standard spiral mold cavity as a hot liquid where the material is cured and harden.

The spiral mold cavity shows the length of the flow of the molding compound in inches and this value is expressed as the flowability of the compound.

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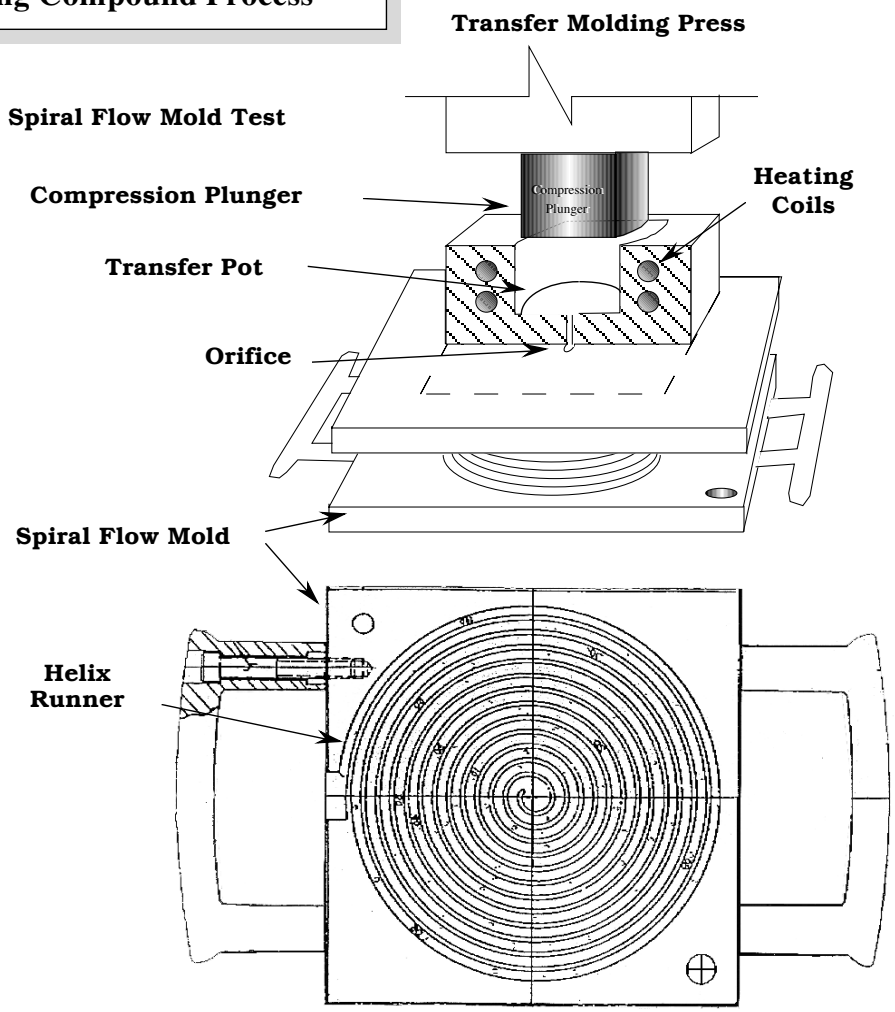
Molding Compound Process



Once the granules come out of the Extruding-Grinding-Screening process, they are tested for flowability.

A random sample of about 0.704 oz. of granules is taken and kept in a container under a control temperature of 73.4ºF (± 3.6ºF), waiting for the spiral flow mold and the compression plunger to reach the temperature of 302º ± 5º F. Once the temperature has been reached, the sample of granules is placed in the transfer pot.

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