1.2 Methods of Measurement:

1) **Method of direct measurement**: The value of the quantity to be measured is obtained directly without the necessity of carrying out supplementary calculations based on a functional dependence of the quantity to be measured in relation to the quantities actually measured.

Example: Weight of a substance is measured directly using a physical balance.

2) **Method of indirect measurement**: The value of the quantity is obtained from measurements carried out by direct method of measurement of other quantities, connected with the quantity to be measured by a known relationship. *Example:* Weight of a substance is measured by measuring the length, breadth & height of the substance directly and then by using the relation

Weight = Length x Breadth x Height x Density

3) **Method of measurement without contact**: The sensor is not placed in contact with the object whose characteristics are being measured.

4) **Method of combination measurement closed series**: The results of direct or indirect measurement or different combinations of those values are made use of & the corresponding system of equations is solved.

5) **Method of fundamental measurement**: Based on the measurements of base quantities entering into the definition of the quantity.

6) **Method of measurement by comparison**: Based on the comparison of the value of a quantity to be measured with a known value of the same quantity (direct comparison), or a known value of another quantity which is a function of the quantity to be measured (indirect comparison).

7) **Method of measurement by substitution**: The value of a quantity to be measured is

replaced by a known value of the same quantity, so selected that the effects produced in the indicating device by these two values are the same (a type of direct comparison).

8) **Method of measurement by transposition:** The value of the quantity to be measured is in the beginning, balanced by a first known value A of the same quantity, then the value of the quantity to be measured is put in place of this known value and is again balanced by another known value B. If the position of the element indicating equilibrium is the same in both the cases, the value of the quantity measured is equal to A & B.

9) **Method of differential measurement**: Based on the comparison of the quantity to be measured with a quantity of the same kind, with a value known to be slightly difference from that of the quantity to be measured, and the measurement of the difference between the values of these two quantities.

10) **Method of measurement by complement**: The value of the quantity to be measured is complemented by a known value of the same quantity, selected in such a way that the sum of these two values is equal to a certain value of comparison fixed in advance.

11) **Method of measurement by interpolation:** It consists of determining value of the quantity measured on the basis of the law of correspondence & known values of the same quantity, the value to be determined lying between two known values.

12) **Method of measurement by extrapolation:** It consists of determining the value of the quantity measured on the basis of the law of correspondence & known values of the same quantity, the value to be determined lying outside the known values.

1.2.1 Elements of Metrology

SWIPE is a mnemonic which stands for the following influencers of total measurement performance:

S- The Standard, is it certified and when, is it the proper class. For example, in setting a bore gage to gage a 1″ hole having a .0005″ Bandwidth tolerance, if one were to use a class Y tolerance master, the uncertainty of the master alone could be as much as .0001″ which is 20% of the total tolerance of the hole to begin with. The roundness of the master may be up to .00005″ which is already 10% of the Gage R&R.

W- The Workpiece, every part varies, some more than others. Are the R&R operators aware of the variation within a part? Does the part have intrinsic taper, out of roundness conditions, surface finish variations etc. that can affect the measurements. Just by not making measurements in the same place or zone on the part repeatedly can cause the R&R to suffer significantly. A .0001″ out of roundness condition can consume 20% of the total part tolerance using the example above.

I- The Instrument itself obviously has linearity, and repeatability characteristics. Whatever they may be, clearly, they add to the gaging uncertainty. In addition, certain instruments are more prone to operator loading, use and care.

P- The Personnel and their ability to adapt the gage to the part is an ever-important factor. Surely the gages vulnerability to operator influence can be considered the gage's fault. However, one should not discount the variation in touch and experience that the operator brings to these tests. With some operators and their influence there may be no gages or inspection equipment made to perform the measuring task at hand. Surely an enigma, but best handled when best understood.

E- The Environment. Parts that are dirty, oily, or hot or even cold are poor candidates for R&R testing methods. They may represent the real-world conditions but offer no stable ground on which to buyoff on a gage's ability.

So, there you have it, the SWIPE scenario. The answer may very well be that considering all of the variables, the only one that can be rectified is the gage's intrinsic accuracy and repeatability. In this case it becomes necessary to obtain gages of a higher order. This may mean changing from Mechanically applied hand tools to Electronic or Air Gage

tooling. These tools permit higher resolution and linearity and repeatability. They limit operator influence and offer output to SPC and signalling modules. The cost may increase but the value per item measured makes these types of tools irreplaceable.