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.

1.3 ELEMENTS OF A GENERALIZED MEASUREMENT SYSTEM

The various elements of measurement system are,

1. Primary sensing Element
2. Variable conversion element.
3. Variable manipulation element
4. Data transmission element.
5. Data processing Element
6. Data presentation element.

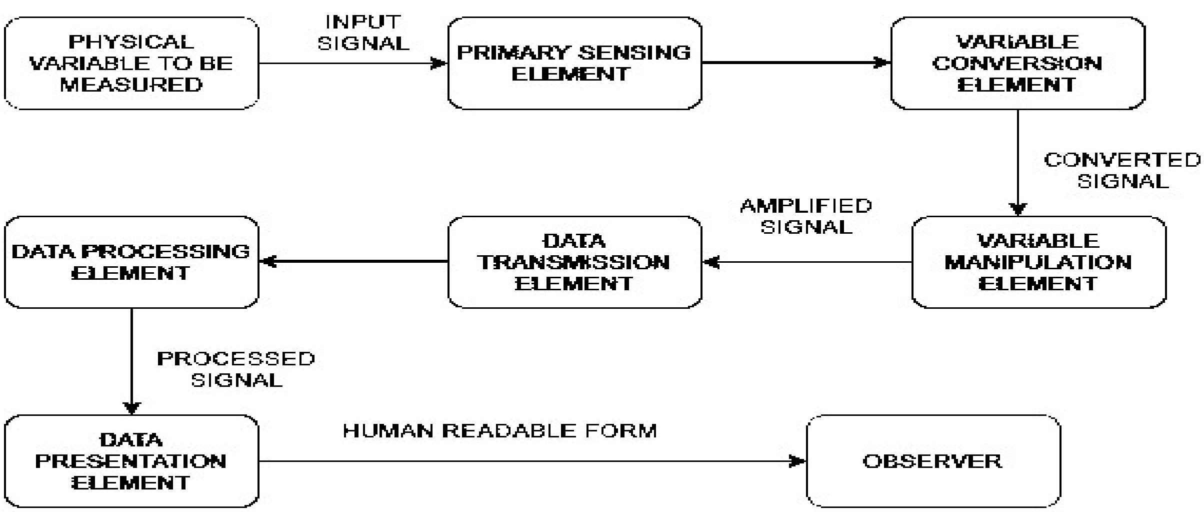

Fig 1.1 Elements of Generalized Measurement system

[source: “Metrology & Measurements”, Dr.G.K. K Vijayaraghavan., page-1.12]

1.3.1 PRIMARY SENSING ELEMENT

it is the first element which receives energy from the measured medium and it produces an output corresponding to the measurand. This output is then converted into an analogous electrical signal by a transducer.

1.3.2 VARIABLE CONVERSION ELEMENT.

It converts the output electrical signal of the primary sensing element into a more suitable form signal without changing the information containing in the input signal. In some instruments, there is no need of using a variable conversion element while some other instruments require the variable conversion element.

1.3.3 VARIABLE MANIPULATION ELEMENT

This element is used to manipulate the signal presented to it and preserving the original nature of the signal. In other words, it amplifies the input signal to the required magnification. For example, an electronic voltage amplifier receives a small voltage as input and it produces greater magnitude of voltage as output. A variable manipulation element does not necessarily follow a variable conversion element and it may precede it.

1.3.4 DATA TRANSMISSION ELEMENT.

It transmits the data from one element to the other. It may be as shaft and gear assembly system or as complicated as a telemetry system which is used to transmit the signal from one place to another.

1.3.5 DATA PROCESSING ELEMENT

It is an element which is used to modify the data before displayed or finally recorded. It may be used for the following purposes.

i. To convert the data into useful form
ii. To separate the signal hidden in noise
iii. It may provide corrections to the measured physical variables
iv. to compensate for zero offset, temperature error, scaling etc

1.3.6 DATA PRESENTATION ELEMENT

These are the elements that they finally communicate the information of measured variables to a human observer for monitoring, controlling or analysing purposes. The value of measured variables may be indicated by an analog indicator, digital indicator, or by a recorder

1.4 PROCESS OF MEASUREMENT

Good measurement begins with a clear conceptual description of the theory to be measured. Measurement tools provides better lives and safer, and they enhance the quality and quantity of life. Possibly, the ability to measure physical properties accurately has incredible existence value that gives humans an adaptive, evolutionary advantage improved through many years of natural selection.

There are four major steps involved in measurement process.

1. Decision making on whether to use an existing measure or create own.

2. Describing multiple strategies to identify and locate existing measures of psychological theories.

3. Describing several general principles for creating new measures and for implementing existing and new measures.

4. Creating a simple plan for assessing the reliability and validity of an existing or new measure.

Step 1: Decision making

Conceptual definition is considered to analyse the measurement process. A measurement process needs a prerequisite of clear and complete conceptual description of a concept. Now, there are two options available generally in measurement process such as using an existing measure or creating a new or own measure. The decision should be made on the basis of the availability of existing measures and their adequacy for the purpose. For example, there is no way to change the parameters involved in metrology such as length, width, height, velocity, acceleration etc. but the way of measurements could be changed according to the need and situation in the particular applications.

(i) Using an existing measure

Generally, using an existing measure is a good idea which has been used successfully in measurements because it saves time, greatly reduces trouble of creating own system, has some evidence to ensure the validity of measure and measure results can more easily be compared with existing results. Even if an existing measure is chosen, several alternatives should be chosen from available measures in order to select the right measure to ensure reliability and validity with evidences.

(ii) Creating own measure:

Instead of using an existing measure, an own measure can be created to improve performance and reliability to make the process easy and simple. If there is no existing measure for the particular parameter, creating own measure will be the right option and need. But, it may be difficult and time-consuming process to use due to lack of supporting evidences such performance and reliability in the form of converged validity. Initially, it may be more useful in random measurement process. In actual process, most new measures in psychology are variations of existing measures. At the same time, the procedure should be simple with a set of clear instructions using simple language when the own measure is created.

Step 2: Implementing the measure

Next step is to implement existing measure or new measure which is selected for the measurement to maximize its reliability and validity. In most cases, measure should be tested under similar conditions which are quiet and free of distractions.

Step 3: Evaluating the measure

When the selected measure is used on a sample of measurements with a set of scores, the performance should be evaluated thoroughly in terms of reliability and validity. Even if the measure has been used extensively by other persons with shown evidence of reliability and validity, it may not be the best and right measure for the particular testing conditions. So, the additional evidence may need on the reliability and validity of the measure. For a new measure, a study should be designed to assess its test-retest reliability.

1.5. ROLE IN QUALITY CONTROL

Quality is defined as the fitness for the use or purpose. Quality control is used to check the fulfilment of needs. Sometimes, measurement processes and quality control are interchangeably used. Metrology is the science of measurement but quality control is a process monitoring and maintaining laboratory standards. The results of measurements can be compared all over the world with the same standards because good quality-controlled process will lead to minimize the rejection thereby increasing quality with profit maximization.

1.6. GOOD MEASUREMENT PRACTICE

As per NPL guidelines, there are six principles of good measurement practice as follows.

1. Right measurements refer to satisfy agreed and well specified requirements.

2. Right tools indicate the selection of equipment and methods to fit for the purpose,

3. Right people refers that the measurement staff should be competent, properly,

qualified and well-informed.

4. Regular review means both internal and independent assessment of the technical performance of all measurement's facilities and procedures.

5. Demonstratable consistency focuses that the measurements made in one location

Should be consistent with the same measurement anywhere and across time.

6. Right procedures. It is a well-defined procedure consistent with national or international standards should be used for all measurements.

Make better measurements by:

1. Using the International System of Units (SI)
2. Ensuring the measurements validity
3. Understanding the concepts:

(i) Precision, accuracy and uncertainty

(ii) Repeatability and reproducibility

(iii) Acceptance criteria (tolerance)

(iv) Traceability and calibration

(v) Estimating the overall uncertainty of the measurements

4.. Applying geometrical tolerances.

1.7. TERMINOLOGIES USED IN MEASUREMENT

(1) Range:

Range is the minimum value and maximum value of a quantity for which an instrument is designed to measure. For example, a load cell may have the range from 10 kN to 100 kN.

(2) Span:

Span is the difference between maximum value and minimum value of the quantity to be measured.

Span =Maximum value of the input -Minimum value of the input

e.g., Taking the above example of 10 kN to 100 kN force range, the span is 100- 10 = 90 Kn

(3) Error:

The deviation of the true value from the desired value is called error.

Error = Measured value - True value

For example, a temperature measurement has its measured value as 34°C and true value as 33°C which leads to an error of 1°C (34°C- 33°C).

(4) Accuracy:

Accuracy may be defined as the ability of an instrument to respond to a true value of a measured variable under the reference conditions. It refers to how closely the measured value agrees with the true value.

(5) Precision:

Precision is defined as the degree of exactness for which an instrument is designed or intended to perform. It refers to repeatability or consistency of measurement when the measurements are carried out under identical conditions at a short interval of time.

(6) Sensitivity:

Sensitivity may be defined as the rate of displacement of the indicating device of an instrument with respect to the measured quantity. It denotes the smallest change in the measured variable to which the instrument responds.

(7) Stability:

The ability of an instrument to retain its performance throughout its specified operating life and storage life is termed as stability.

(8) Scale interval:

It is the difference between two successive scale marks in units of the measured quantity. In the case of numerical indication, it is the difference between two consecutive numbers.

The scale interval is an important parameter that determines the ability of the instrument to give an accurate indication of the value of the measured quantity.

(9) Hysteresis:

Hysteresis defines the difference in the output for a given input when this value is approached from the opposite direction. This phenomenon occurs in any mechanical, electrical, physical and chemical processes. In mechanical terms, hysteresis means that both the loading and unloading curves do not coincide. Hysteresis is particularly noted in instruments having elastic elements. The phenomenon of hysteresis in materials is mainly due to the presence of internal stresses. It can be considerably reduced by a proper heat treatment.

(10) Threshold:

The minimum value below which no output change can be detected when the input of an instrument is increased gradually from zero is called threshold of the instrument.

(11) Resolution:

It is the smallest change in a measured variable to which an instrument will respond. It can also be defined as the minimum value of the input signal (non-zero value) required to cause an appreciable change or an increment in the output. It is known as resolution.

(12) Calibration:

Calibration is the process of checking the dimensions and tolerances of a gauge or the accuracy of a measuring instrument by comparing it to a instrument/gauge that has been certified as a standard of known accuracy. Calibration is done by detecting and adjusting any discrepancies in the instrument's accuracy to bring it within acceptable limits.

(13) Dead zone and Dead time:

Dead zone is the largest range of values of a measured variable to which the instrument does not respond. It may occur due to friction in the instrument which does not allow the pointer to move till the sufficient driving force is developed to overcome the friction loss.

The time taken by an instrument to begin its response for a change in the measured quantity is called dead time.

(14) Backlash:

Backlash is the lost motion or free play of the mechanical elements such as gears, linkage etc.

(15) Bias:

The constant error which exists over the full range of measurement of an instrument is known as bias.

(16) Tolerance:

It is the maximum allowable error in the measurement.

(17) Drift:

The variation of change in output for a given input over a period of time is known as drift.

(18) Zero drift:

The change which occurs in output when there is zero input is known as zero drift. The drift may be expressed as a percentage of the full range output.

(19) Overshoot:

The maximum amount by which the moving parts move beyond the steady state is known as overshoot.

(20) Response time:

Response time refers to the rapidity with which a measurement system responds to a change in the measured quantity. It is the time which elapses after a sudden change in the measured quantity until the instrument gives an indication differing from the true value by an amount less than a given permissible error.

1.8 Terms in Measurement

1.8.1 Sensitivity

Sensitivity of the instrument is defined as the ratio of the magnitude of the output signal to the magnitude of the input signal.

a. It denotes the smallest change in the measured variable to which the instruments respond.
b. Sensitivity has no unique unit. It has wide range of the units which dependent up on the instrument or measuring system.

1.8.2 Readability

Readability is a word which is frequently used in the analog measurement. The readability is depending on the both the instruments and observer.

a. Readability is defined as the closeness with which the scale of an analog instrument can be read.
b. The susceptibility of a measuring instrument to having its indications converted to a meaningful number. It implies the ease with which observations can be made accurately.
c. For getting better readability the instrument scale should be as high as possible.

1.8.3 Repeatability

Repeatability may be defined as the closeness of agreement among the number of consecutive measurements of the output for the same value of input under the same