Quality Assurance in Measurement

Module 4 - Planning for Quality Measurement

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PLANNING for QUALITY of MEASUREMENT

1.0 Introduction

Quality of measurement is fundamental to the realisation of quality products. It is essential for ensuring appropriate control of manufacturing processes and the attainment of right first time manufacture. Defining what is exactly meant by quality of measurement is, however, somewhat difficult. Uncertainty of measurement and the capability of the measurement process, provide a quantitative basis for assigning quality to measurement. But this is only part of the quality ethic, since other factors arising from a series of actions, starting with an analysis of the needs and the requirements of the measurement process and proceeding to the determination of the capability of the process influence the quality that is finally achieved. To establish and maintain quality of measurement, therefore, requires attention to all aspects of the measurement process. And that means information, equipment and people. To compromise on one may obviate the effects of the others.

The ISO Standard, 9002 (1987), "Quality Systems - Model for Quality Assurance in Production and Installation", provides the international standard for Quality Systems. The UK equivalent, BS5750 part 2 (1987) draws attention to the following requirements that need to be satisfied in seeking to improve the quality of measurement;

- to ensure that all measurements critical to quality are identified
- to ensure that instruments are correctly chosen to meet measurement requirements
- to ensure that instruments are clearly labelled and calibrated, with traceability to National Standards in suitable environmental conditions
- to ensure that instruments are correctly applied by trained operators and that uncertainty of measurement Is consistent with the required measurement capability
- to ensure that the instruments and their application are regularly monitored, and
- to ensure that the appropriate documentation and procedures are applied and suitable records are maintained.

A minimum acceptable level of quality may be considered to have been achieved when these requirements have been satisfied. But to get to this stage requires planning, and this module is concerned with this aspect of a PLANNING, ACTION and PROVE Quality Assurance strategy.

Central to the whole issue of achieving quality of measurement are the principles for calculating uncertainty of measurement and capability of the measurement process, and planning of its content, quality measurement Is concerned with the identification, quantification and characterisation of the measurement process and the factors that influence uncertainty. In more general terms planning is concerned wit the identification of priorities, development of strategy, setting of objectives and procedures and the procurement requirements and allocation of resources. From a total quality viewpoint the planning for quality measurement should exercise due consideration for all appropriate aspects of the company structure, function and management, and the services and products that the company produces. Effective planning for quality of measurement demands attention to both skills and knowledge-base requirements, the latter concerning the measurement process and the factors that influence the measurement process. As far as planning skills are concerned these may be summarised under the following headings:

- Identification of needs, with due consideration for the requirements of manpower and training, environment, management, processes, timing and costs.
- Recognition of available resources and required resources.
- Problem solving.
- Formulation of procedures ih line with corporate strategy and policy on quality.
- Formulation and use of appropriate documentary structure.
- These skills are essentially those of effective management and whilst of importance they are beyond the scope of detailed consideration here. Within this module attention is confined to the more specific aspects of planning based upon knowledge of the measurement process and associated issues, including:
- The measuring instrument, chain or system (ICS).
- Uncertainty of measurement.
- Traceability of the measurement result.
- Capability of the measurement process.

2.0 Ambient Conditions

Having introduced the concept of evaluation for the ICS under variable conditions, it is now appropriate to consider particular guidelines for specifying the ambient or surrounding conditions under which the ICS is used and/or evaluated.

2.1 Identification of ambient conditions

The range of conditions likely to be experienced in performing a particular measurement can have a marked influence upon the uncertainty of the measurement process. It is therefore important to specify these conditions and evaluate the corresponding uncertainty.

The identification of the ambient conditions relies upon a detailed consideration of the needs for a particular ICS or measurement process from which a list of conditions can be specified. It is also appropriate to classify the main conditions in accordance with the recommendations of the International Electrotechnical Commission (IEC) in document CEI 654-1.

In general the conditions identified as ambient include:

- temperature
- relative humidity
- atmospheric pressure
- vibrations and shocks
- dust
- electromagnetic conditions

Variability of power supplies may also be considered under the heading of ambient conditions.

The CEI classification of ambient conditions (CEI 645-) includes reference to location and delineation of classes into sub-classes on the basis of conditions.

2.1.1 Temperature, humidity and atmospheric pressure

CEI 654-1 is concerned with classification corresponding to the specification of limits on temperature, relative and absolute humidity and atmospheric or barometric pressure. Four classes are identified;

- Class A - air conditioned locations, in which the temperature is regulated to ± 2°C
- Class B - closed conditions, which are heated and/or refrigerated
- Class C - sheltered locations
- Class D - exterior locations.

The appropriate sub classification on the basis of conditions are summarised in Table 1.

<table>
<tr><th>Class</th><th>Temperature
Limits
(°C)</th><th>Relative
Humidity Limits
(%)</th><th>Absolute
Humidity Limits
(@ 101.3 KPa)
(g H20/kg dry air)</th></tr>
<tr><td>A1</td><td>+18 to +27</td><td>35 to 75</td><td rowspan="3">No limits
defined</td></tr>
<tr><td>A2</td><td>+18 to +27</td><td>20 to 80</td></tr>
<tr><td>Ax</td><td>Other</td><td>Other</td></tr>
<tr><td>B1</td><td>+15 to +30</td><td>10 to 75</td><td rowspan="2"><20</td></tr>
<tr><td>B2</td><td>+5 to +40</td><td>10 to 75</td></tr>
<tr><td>B3</td><td>+5 to +40</td><td>5 to 95</td><td><28</td></tr>
<tr><td>Bx</td><td>Other</td><td>Other</td><td>Occasional Condensation
Possible</td></tr>
<tr><td>C1</td><td>-25 to +55</td><td>5 to 100</td><td rowspan="3"><28
Condensation possible</td></tr>
<tr><td>C2</td><td>-40 to +85</td><td>5 to 100</td></tr>
<tr><td>Cx</td><td>Other</td><td>Other</td></tr>
<tr><td>D1</td><td>-25 to +70</td><td>5 to 100</td><td rowspan="3"><50
Condensation & direct
damping possible</td></tr>
<tr><td>D2</td><td>-40 to +85</td><td>5 to 100</td></tr>
<tr><td>Dx</td><td>Other</td><td>5 to 100</td></tr>
</table>

Table 1

The facility is included for open classification, permitting specification of unforeseen combinations, but are only used on an exceptional basis, for very specific cases.

The concept of temperature change can be associated with the classes listed in table 1 so that the speed of temperature variation can also be accommodated within a specification of ambient conditions.

For the purposes of classifying atmospheric pressure, two specific classes are identified (table 2).

Table2

Class	**Range**
1	from 86 kPa (860 mbar) to 108 kPa (1080 mbar)
2	from 66 kPa (660 mbar) to 108 kPa (1080 mbar)
3	do not conform to these specifications

2.1.2 Vibrations and shocks

CEI 654-3 deals with the classification of vibration and shock conditions. Classification is on the basis of frequency and severity of vibration.

Two ranges of frequency have been distinguished for classification by frequency (tables 3 and 4); a high frequency range (10Hz to 10kHz) and a low frequency range (0.1 Hz to 150 Hz). Within each range a 'transition frequency' is defined, for the purposes of identifying where it is appropriate to consider peak for the purposes of identifying where it is appropriate to consider peak acceleration associated with the vibration. For the low frequency range the transition frequency is from 8 to 9 Hz and for the high frequency range, from 58 to 62 Hz. Below the transition frequencies the peak value of displacement is considered. Above the transition frequencies the peak acceleration value is also taken into account.

In using the classification it is important to note the ranges of peak-to-peak displacement represented in each class; larger displacements in the lower frequency class, with transition at 0.35 mm to the lower displacements represented in the higher frequency range.

As far as the severity of vibration is concerned, classification (table 5) is according to speed of displacement, the justification being that it is indicative of the kinetic energy conveyed by the displacement.

Table 3

Class	Peak to Peak Movement [mm] (if below the transition frequency)	Peak to Peak Acceleration [m/s2] (above the transition frequency)
VH1	< 0.015	< 2
VH2	< 0.032	< 5
VH3	< 0.075	< 10
VH4	< 0.15	< 20
VH5	< 0.20	< 30
VH6	< 0.35	< 50
VHx	> 15.0	> 50

Table 4

Class	Peak to Peak Movement [mm] (if below the transition frequency)	Peak to Peak Acceleration [m/s2] (above the transition frequency)
VH1	< 0.015	< 2
VH2	< 0.032	< 5
VH3	< 0.075	< 10
VH4	< 0.15	< 20
VH5	< 0.20	< 30
VH6	< 0.35	< 50
VHx	> 15.0	> 50

Table 5

Class	Speed (mm s-1)	Examples
VS1	< 3	Ordinary manufacturing environment
VS2	< 10	Hardware installed outside
VS3	< 30	Hardware installed outside
VS4	< 300	In transportation
VSx	> 300	Material in shipments

Account is taken of the duty cycle in the classification by expressing it as a percentage of the relative duration, with preferred values of 100% (class VT1), 10% (class VT2) and 1% (VT3).

In dealing with shocks the criterion for classification in the severity of shock classified either on the basis of amplitude and duration of acceleration or height of free fall onto a flat surface (table 6).

Table 6

Class 1	Combination of the amplitude and duration of acceleration Accelerations of 20, 40, 70, 100, 250, or > 250 ms-2 Durations of 5, 10, 20, 50 or 100 ms
Class 2	Height of free fall on flat surface Heights of 25, 50, 100, 250, 500, 1000, or > 1000 mm

2.1.3 Protection against ingress of solids and liquids

Dust, liquid, dispersal and working conditions in which larger objects may come into contact with measuring Instruments (ICS) may pose a threat to the functional integrity of the instrument. CEI 529 is concerned with the classification of instruments in terms of the protection they provide against ingress or penetration of dust, liquids and objects. The classification includes a letter/figure designation to indicate the type of protection afforded by the Instrument and the type of insult to which it relates. The letters IP are used followed by two figures to represent the type of protection afforded by the instrument and the type of insult to which it relates. For example, a classification of IP41 specifies protection against the penetration of solid objects greater than 1 mm in size and from vertical fall of drops of water.

The figure classification may be followed by a further letter, S or M, to indicate the conditions of test relating to the classification specified. The S represents a static test or test at rest and M a mechanically functioning condition. A classification of IP35S, for example, specifies protection against the penetration of solid objects greater than 2.5 mm in size and spurts of water, the protection test being performed at rest.

Where a figure is not included in the classification a letter X is inserted. Reference should be made to CEI 529 for further details of the classification scheme, including the appropriate test conditions.

2.1.4 Electromagnetic compatibility

The influence of the electromagnetic environment upon the function or performance of electronic measuring instrumentation should be considered whenever a measurement, requiring such equipment, is planned and implemented. It is necessary, in these situations, to identify the conditions under which the instrument is expected to operate and the immunity of the instrumentation to interference or modification of performance by the electromagnetic environment. CEI 801-1, 2 and 3 draw attention to the conditions that may exist within a working environment of an instrument (ICS) and the classification of environments on the basis of these conditions.

Although somewhat wider issues may be recognised concerning conducted, induced, capacitatively coupled and radiated fields, two aspects of general importance with respect to measuring instrumentation are electrostatic discharges and radio frequency interference.

The electrostatic discharge classifications are essentially concerned with the static build-up of charge on operator clothing and the corresponding test voltages suitable for determining the immunity of an instrument to representative static discharge (table 7).

Table 7

Level of Severity	**Test Voltage (±10%)**
1	2 kV
2	4 kV
3	8 kV
4	15 kV

Since the build-up of charge is dependent upon the type of fabric (type of clothing), insulation from ground (type of shoe materials), mechanism for the frictional generation of charge and relative humidity in the ambient air, in seeking to identify the severity for a given location and procedure for operation it will be necessary to consider these issues.

As far as radio interference is concerned, four levels of severity (table 8) are recognised within CEI 801-3, which should be considered with due attention to the fact that the intensity of the electromagnetic field, expressed in V m -1 will vary in inverse proportion to the distance from the source.

Table 8

Classification of Severity for Radio Emissions	
Class 1	Environment characterized by low level radio frequency emissions e.g. local broadcast transmissions within a 1 km radius and low power transmitters.
Class 2	Environment characterized by moderate radio frequency interference, e.g. portable or mobile transmitters situated within 1 m of the equipment.
Class 3	Environment characterized by intense radio frequency interference e.g. from high powered transmitters situated in close proximity to the equipment.
Class 4	Open category including all environments characterized by very intense radio frequency interference.

2.1.5 Power supply regulation

Where power supplies are required in a measuring instrument or use with a measuring instrument (ICS) the regulation or quality of the supply should be considered, since variations in value may introduce significant errors in the measurement result. CEI 654-2 is concerned with both AC and DC power supply regulation.

2. 1.5.1 AC Power supplies

For AC power supplies deviations with respect to both voltage and frequency are taken as the bases for classification. The deviation in voltage is specified relative to nominal values;

- Class AC1 : ±1%
- Class AC2 : ± 10%
- Class AC3: -15% to + 10%
- Class AC4 : -20% to + 15%

A special category may be specified for ratings outside these ranges.

Deviations In frequency are specified relative to nominal values, with categories identified for ±0.2%, ±1%, ±5% and ±5%.

Distortion is also included for the purposes of classification, in terms of the power distortion factor, F,

$$\text{where } F = \frac{\sqrt{\sum_{i=2}^{10} h_i^2}}{h_1}$$

h_i is the amplitude of the i^{th} harmonic.

Preferred categories for specification of distortion are: 2%, 5%, 10%, 20% or 20%.

Where multi-phased operation is involved deviation of phase in degrees, compared with nominal out-of-phasing, may be specified, with preferred categories being 1, 2, 5 or 5 degrees.

In situations where auxiliary power supplies are identified deviations may be specified as a basis for switching to auxiliary source, these values being ± 10%, ±20%, -50% and -95%. Maximum switching times should also be specified in such cases, the preferred categories being 3, 10, 20, 200, 1000 or 10000ms.

2.1.5.2 DC Power supplies

For DC power supplies voltage deviations, relative to nominal values, and 'ripple' characteristics may be specified. The classification for voltage deviations are:

- Class DC1: ±1%
- Class DC2: -15% to + 10%
- Class DC3: -20% to + 15%
- Class DC4: -25% to + 30%

The ripple characteristic for the power supply is expressed In terms of the ratio;

$$\frac{\text{peak-to-peak value of ripple component}}{\text{average value of voltage}}$$

with preferred categories of 0.2%, 1 %, 5%, 15% or 15%.

2.2 Elementary errors of the ICS under ambient conditions

As with the identification of elementary errors for the ICS under variable conditions evaluation reports and manufacture's data can be used to identify errors due to variable ambient conditions. The treatment of these errors also follows the approach adopted for the ICS under variable conditions. Thus each of the errors must initially be considered individually and expressed as systematic or random in character with associated estimates of uj or si values. The characterisation procedure summarised in figure 3.2 (section 3.4) may be followed for this purpose and the estimates recorded in an "error table" of the type described in section 3.5 (figure 3.4).

Once the errors have been determined and characterised for ambient conditions they may then be combined to obtain the uncertainty for the ICS under ambient conditions, and in accordance with the rules for statistically independent and dependent quantities.

In dealing with the uj and si values it is useful to note that if the resultant of the errors is judged to be too large, an analysis of the summed uj and summed si components may identify uj components that can be acted upon by applying correction factors to reduce or eliminate them from the equation.

Where the values of elementary errors due to variable ambient conditions are unknown, or need to be confirmed, it may be necessary to design and undertake experiments to provide this information.

2.3 Calibration and Traceability of the ICS

The purpose of calibration is to evaluate the errors inherent in the instrument or ICS and verify that they remain within predetermined limits. By comparison with a standard one is able to evaluate the systematic error of the ICS and, where appropriate, subsequently reduce this component of error by performing an adjustment. Recalibration is then performed to confirm the effect of adjustment.

Traceability of an instrument or ICS is achieved through the calibration. The measurements are made upon a standard and the values obtained provide a conventional true value (CTV). By use of appropriate standards traceability is achievable to national standards.

3.0 Traceability of a Measurement Result

Traceability is an uninterrupted series of comparisons that relate measured values back to national and international standards or reference values in situations where no standards currently exist. It is a means whereby measurements can be confidently and meaningfully compared and applied so that products, reliant in their manufacture upon good measurement, can be produced to the same specification and level of quality irrespective of where in the world they are made.

Three particular schemes may be identified for dealing with majority of measurements generally encountered,

- through the use of a conventional true value (CTV)
- through the use of a certified reference value (CRV), and
- through the use of a reference value (RV)

The choice is dependent upon the nature of the measurement and the availability of standards or reference materials.

3.1 Traceability through use of a CTV

Where a CTV is available, the result of a measurement can be related to national and international standards (SI) through a chain of uninterrupted comparisons. The diagram below (figure 3.1) illustrates the traceability

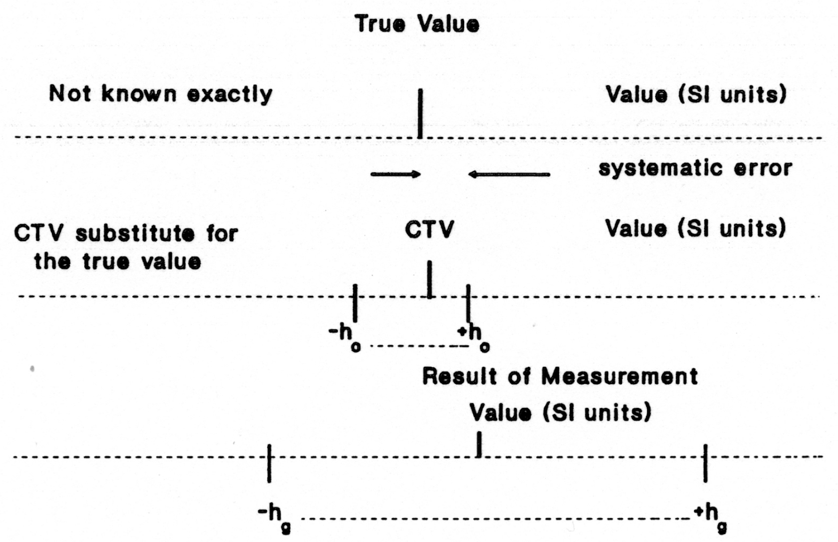


Figure 3.1

The traceability diagram illustrates the relations between,

- the true value
- its conventional true value (CTV)
- the result of the measurement, and
- the uncertainty of the measurement, h_g

The CTV provides the important link with the national and International standards. It is determined by the Metrology Department and is achieved by measurement upon a "piece" by trained operators of the Metrology Laboratory, against a working, standards, and using another measurement process, on-site, that has an uncertainty of measurement, ho, much smaller than that of the "on-site" measurement.

When the measurement is performed against a working standard, the uncertainty, h_o, associated with the CTV is equal to the maximum error, e_o, of the standard ($h_o = e_o$). However, if the CTV is supplied by a superior measurement process, using a standard with an error, e_{so}, the uncertainty, h_o, on the CTV is greater than e_{so} ($h_o > e_{so}$).

3.2 Traceability through use of a CRV

In dealing with certain measurements involving physico-chemical quantities it is not always possible to obtain a conventional true value (CTV) that exhibits negligible uncertainty. It is appropriate In these circumstances to identify a reference value, with a small, but accountable, uncertainty as a link with the national and international standards. The reference values derived in this way, based upon certified reference materials, are referred to as Certified Reference Values (CRV). The relationships between the elements in the traceability scheme are illustrated in the diagram of figure 3.2.

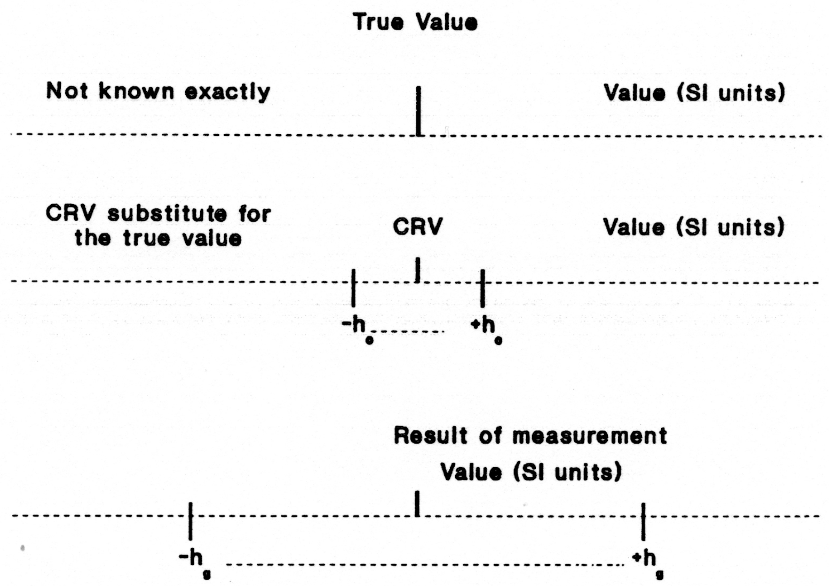


Figure 3.2

The diagram illustrates the relationship between;

- the true value
- the certified reference value (CRV)
- the measurement result, and
- the uncertainty of measurement

The responsibility for providing the CRV is vested in the Methods Office, or equivalent, of the organisation, which have to ensure that there is a link between the reference and national and international standards.

3.3 Traceability through use of a RV

There are occasions when it is not possible to relate the result of a measurement to a national or international (SI) standard, simply because an appropriate standard for the quantity being measured does not currently exist. Sizes specific to rubber products is an example.

Traceability under these circumstances requires a reference value as a link between the true value and the measurement result. This reference is determined by the Methods Office, or equivalent within a company, by specifying a reference material and a procedure that will minimise the systematic error that invariably exists between the reference value and the true value. It is generally obtained through a witness or external validation of the procedure by a calibration laboratory.

The Methods Office also specifies the conditions of use for the reference value and the uncertainty, which has to be taken into account when considering the measurement process. The scheme for reference value traceability is illustrated in figure 3.3.

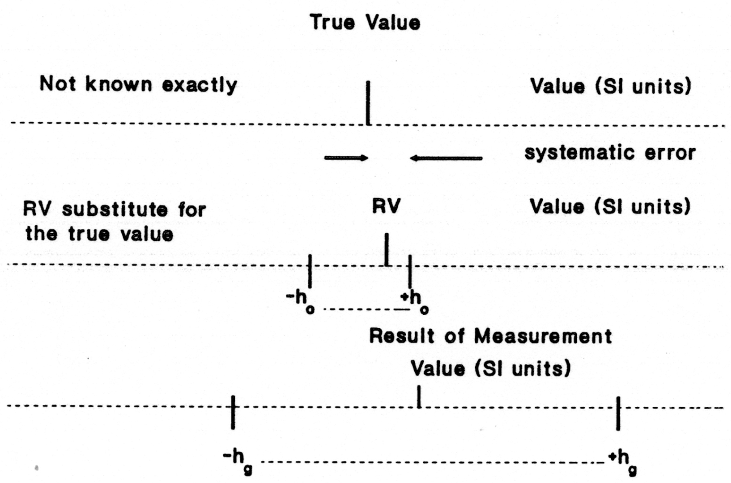


Figure 3.3

In this diagram the relationship is illustrated between

- the true value of a quantity
- the reference value, RV and its uncertainty, ho
- the result of the measurement, and
- the uncertainty of the measurement.

4.O Capability of the Measurement Process

To be of any value at all a measurement process must be capable of performing the task to which it is being applied. Whilst this is perhaps stating the obvious it is nevertheless important and requires consideration in more quantitative terms. We need to have some way of expressing the suitability of the measurement process for the measurements that have to be performed on-site in the practical process situation.

The basis for a quantitative indication of capability is provided In the estimates that we have for uncertainty (expressed in relation to systematic and random process errors) of the measurement process and the tolerance limits specified for the process. Using this information it is possible to define capability indicators, that not only indicate the suitability of the measurement process, but can also be put to good use in controlling the manufacturing process to which the measurements relate.

4.1 Cp and Cpk Capability Indicators

Two particular capability Indicators encountered In common usage for process control purposes are the dispersion indicator, C_p, and bias error indicator, C_{pk}.

These are calculated using the formulae:

$$C_p = \frac{T_u - T_l}{6s_g}$$

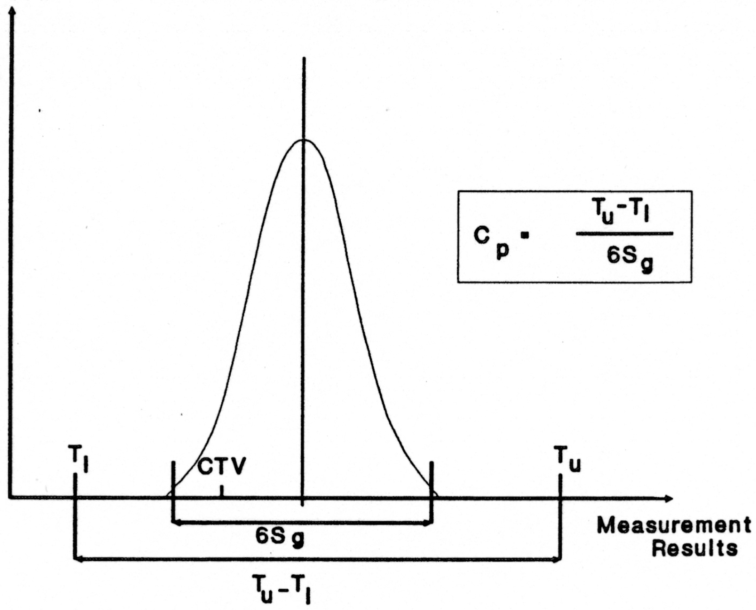
where T_u and T_l are the upper and lower tolerance limits respectively.

$$C_{pk} = \frac{C_p - | d_g |}{3s_g}$$

where d_g represents the bias (systematic) error.

The value of these indicators, and the basis of which they have been formulated, can be readily appreciated by graphical representation, as shown in figures 4.1 and 4.2.

Figure 7.1



In figure 4.1, illustrating the components within the dispersion indicator, C_p, it can be seen that C_p is effectively comparing the dispersion associated with the measurement process with the tolerance range of the manufacturing process.

Figure 7.2

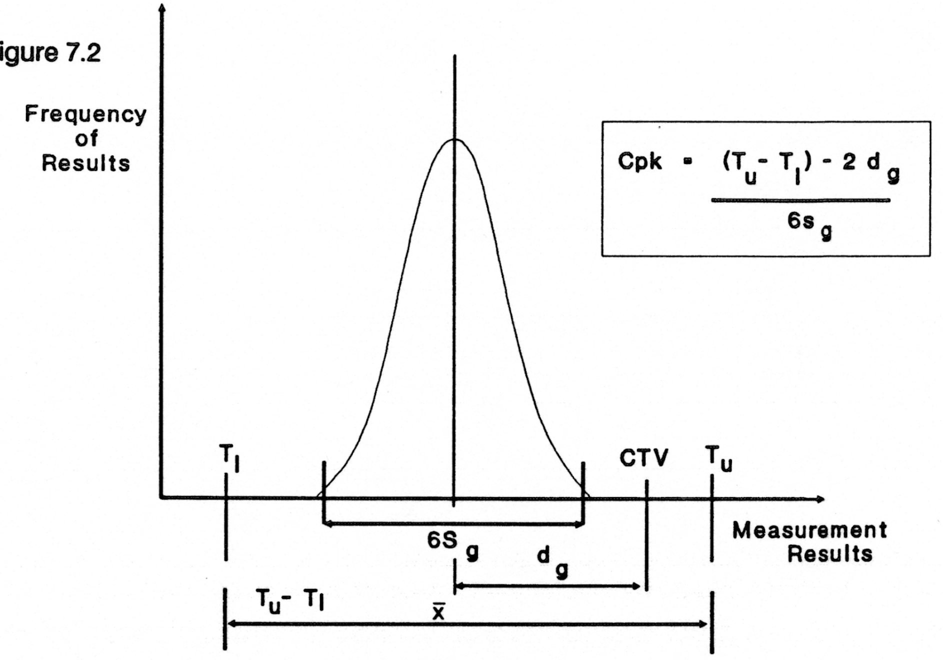


Figure 4.2 illustrates the components within the bias error indicator C_{pk}, which is effectively comparing the difference between the tolerance range and the bias error with respect to the dispersion in the measurement process.

Using the C_p and C_{pk} values decisions can be made concerning the measurement process. By convention it is generally accepted that the following rules apply in assessing the measurement process, on the basis of these particular indicators:

If $C_p > 10$ and $C_pk > 10$ the measurement process is considered to be GOOD.

If $3 < C_p < 10$ and $3 < C_{pk} < 10$ the measurement process is considered to be PASSABLE.

If $C_p < 3$ or $C_{pk} < 3$ the measurement process is considered to be POOR and unacceptable.

What this effectively amounts to is an indication of whether the population of results for the measurement performed, using the measurement process under consideration, is within 0.1 to 0.3 of the tolerance range, $(T_u - T_l)$, specified for the manufacturing process.

Further Inspection of the indicator formulae prompt one or two useful observations. For example C_p can only be greater or equal to C_{pk}, never smaller. If C_p is significantly greater than C_{pk} it points to the fact that the systematic error of the measurement process is considerably larger than the random error, and it may be necessary to effect a correction to the result.

Where the capability of a measurement process is found to be too low it suggests that the various errors due to the variable conditions of reproducibility are collectively too great. The planning stage should, however, obviate the occurrence of this problem.

4.2 Summary and Analysis Indicators

Although the C_p and C_{pk} indicators are widely used as capability indicators in statistical process control they are somewhat less expressive than other indicators for contrasting measurement process and production characteristics.

Summary and Analysis indicators have been introduced to express measurement process to production process ratios as a percentage. The summary indicator contrasts the uncertainty of the measurement process, h_g, with the product tolerance range, $T_u – T_l$,

$$\% \text{ PM} = \frac{2h_g \times 100}{T_u - T_l}\%.$$

Three Analysis Indicators have been defined. The first compares the systematic error, d_g, of the measurement process with the product tolerance range,

$$\% d_g = \frac{d_g \times 100}{T_u - T_l}\%$$

The second indicator in this group concerns the repeatability of the measurement process and is expressed as,

$$\% \, 6s_r = \frac{6sr \times 100}{T_u - T_l}\%$$

The third indicator of the group compares the standard deviations of the measurement, s_g and production process, s_p,

$$\frac{s_g}{s_p}$$

For each of the summary and analysis indicators it can be seen that the smaller the value or percentage the more acceptable is the arrangement.

4.3 Case Study - Measurement of a Tenon Component using a Vernier Caliper

To determine the capability of the vernier caliper used in the measurement, the following procedure was adopted. Three different operators were used, each taking 100 readings of the tenon dimensions, spread over a period of 20 days. Each day measurements were taken at specified times, {0200, 0400, 1000, 1800, 2300) at a temperature of 20°C and two operator conditions:

a) where no instructions were given as to where the component should be placed between the anvils of the vernier
b) where Instructions were given to place the component In the middle of the anvils and measurement taken along its length.

Considering the results obtained under condition a) and taking just one of the three sets of results, the average of the measured values, $\bar{x}$, and the average of the averages, $\bar{\bar{x}}$, can be calculated. Similarly, the range values w and average value $\bar{w}$ can also be obtained.

Representative results are presented in the table T2. From the table the $\bar{\bar{x}}$ and $\bar{w}$ can be obtained.

$\bar{\bar{x}}$ = 19.5Omm
$\bar{w}$ = 0.0535mm

Using these values, the standard deviation may be obtained using the expression,

$$s_r = \frac{\bar{w}}{d_n}$$

In this case,

$$s_r = \frac{0.0535}{2.326} \text{ mm}$$

$$= 0.023 \text{ mm}$$

where d_n is obtained from statistical tables and n denotes the size of the sub-group.

Knowing that the conventional true value (CTV) Is 19.492 mm for the component dimension concerned, the systematic error component of uncertainty may be obtained.

$$e_s = \bar{\bar{x}} – CTV = 19.50 - 19.492 = 0.008 \text{ mm}$$

Whence the uncertainty of the measurement process may be obtained using the expression,

$h_r = | e_s | + 3s_r$

$h_r = 0.008 + 3(0.0230) = 0.077\text{mm}$

Using the information obtained the capability indicators may be determined. The first of these is,

$$C_p = \frac{T_u - T_l}{6s_r}$$

The difference between the tolerance limits T_u and T_l for the process considered is 0.6. Hence, for a value of $s_r = 0.023\text{mm}$, $C_p = 4.35$.

$$C_{pk} = \frac{C_p - | d_g |}{3s_g}$$

Substituting the values derived above $C_{pk} = 4.23$.

On the basis of the criteria defined for these capability indicators, the process may be considered passable.

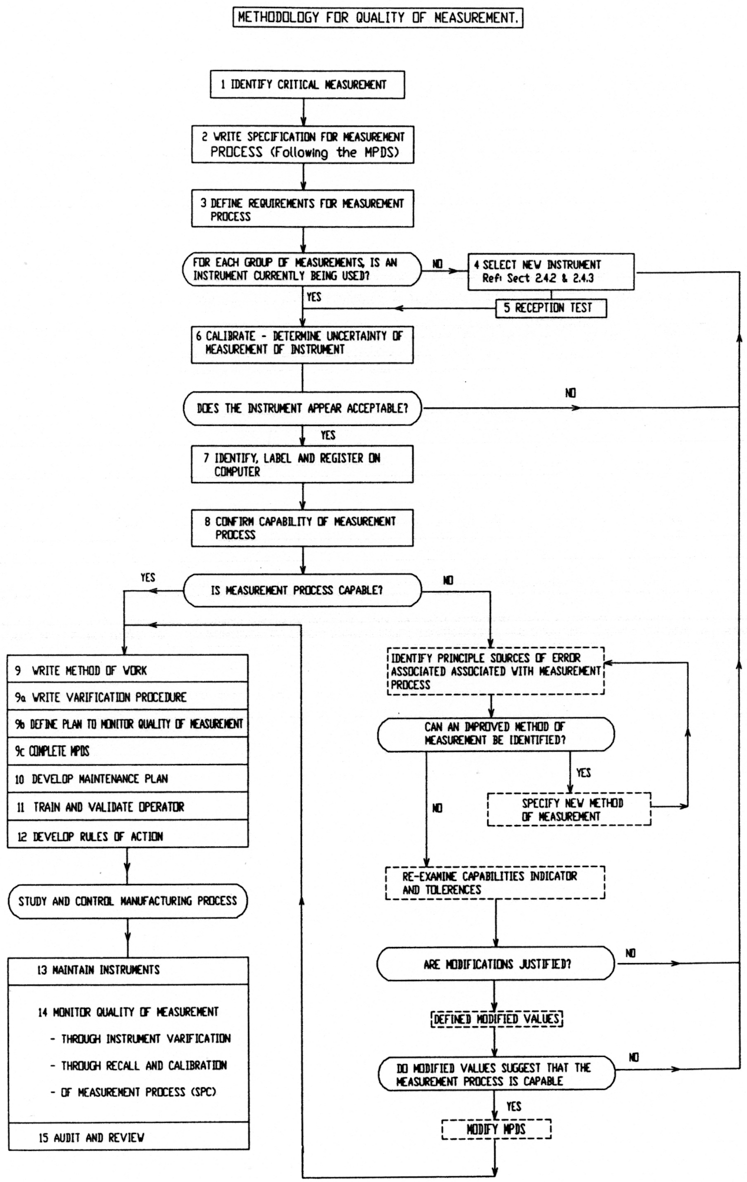
5.0 Actions for Quality

Planning for quality of measurement not only requires the specification of uncertainty and capability of the measurement process, but also the structure for maintaining, monitoring and reviewing the measurement process. We need to identify a methodology that embraces these actions for quality in a logical and systematic manner. A summary for such a methodology is presented in figure 8.1. Within this structure can be seen the actions necessary for the complete specification, implementation and control of the measurement process.

The foundations for achieving an effective methodology include

- a comprehensive Measurement Process Documentary Structure (MPDS), that details all aspects of the measurement process, including, methods, plans and procedures, recording and presentation of results, and the assignment of responsibilities, procedures for selection, acceptance testing, calibration and maintenance of instruments,
- an instrumentation management system, including facilities for identification, labelling and registration of instruments, and
- an audit and review structure.

The detail specification of the organisational and documentary structure for achieving quality of measurement needs to be tailored to meet the individual requirements of the company or organisation concerned. However, the methodology is summarised below and the foundation issues stated above may be expected to fulfil the core requirements for the majority of organisations involved In measurement. The actions and methodology are dealt with in more detail in modules 5 and 6.


METHODOLOGY FOR QUALITY OF MEASUREMENT.
1 IDENTIFY CRITICAL MEASUREMENT
2 WRITE SPECIFICATION FOR MEASUREMENT PROCESS (Following the MPDS)
3 DEFINE REQUIREMENTS FOR MEASUREMENT PROCESS
FOR EACH GROUP OF MEASUREMENTS, IS AN INSTRUMENT CURRENTLY BEING USED?
NO
4 SELECT NEW INSTRUMENT Ref: Sect 2.4.2 & 2.4.3
YES
5 RECEPTION TEST
6 CALIBRATE - DETERMINE UNCERTAINTY OF MEASUREMENT OF INSTRUMENT
DOES THE INSTRUMENT APPEAR ACCEPTABLE?
NO
YES
7 IDENTIFY, LABEL AND REGISTER ON COMPUTER
8 CONFIRM CAPABILITY OF MEASUREMENT PROCESS
YES
IS MEASUREMENT PROCESS CAPABLE?
NO
9 WRITE METHOD OF WORK
9a WRITE VARIFICATION PROCEDURE
9b DEFINE PLAN TO MONITOR QUALITY OF MEASUREMENT
9c COMPLETE MPDS
10 DEVELOP MAINTENANCE PLAN
11 TRAIN AND VALIDATE OPERATOR
12 DEVELOP RULES OF ACTION
STUDY AND CONTROL MANUFACTURING PROCESS
13 MAINTAIN INSTRUMENTS
14 MONITOR QUALITY OF MEASUREMENT
- THROUGH INSTRUMENT VARIFICATION
- THROUGH RECALL AND CALIBRATION
- OF MEASUREMENT PROCESS (SPC)
15 AUDIT AND REVIEW
IDENTIFY PRINCIPLE SOURCES OF ERROR ASSOCIATED ASSOCIATED WITH MEASUREMENT PROCESS
CAN AN IMPROVED METHOD OF MEASUREMENT BE IDENTIFIED?
YES
SPECIFY NEW METHOD OF MEASUREMENT
NO
RE-EXAMINE CAPABILITIES INDICATOR AND TOLERENCES
ARE MODIFICATIONS JUSTIFIED?
NO
DEFINED MODIFIED VALUES
DO MODIFIED VALUES SUGGEST THAT THE MEASUREMENT PROCESS IS CAPABLE
NO
YES
MODIFY MPDS