BS 5781

Measurement and calibration systems

BS 5781 : Part 1

Specification for system requirements

Foreword

The establishment of a reputation for quality products and services depends upon the ability to demonstrate conformity to specified requirements. The control of manufacturing processes and the assessment of product quality and conformance almost invariably involves measurement of some kind. The integrity of all such measurement work is founded on the selection and correct use of suitable measuring equipment and its validation by a system of control and calibration. Therefore, any organization working to the requirements of BS 5750 or any other formal series of quality system standards, has to be able to demonstrate the ability to measure adequately and to certify that the results obtained can be relied upon.

This British Standard is based on UK Defence Standard 05–26, published June 1976, 'Measurement and calibration system requirements for industry'. It specifies requirements for a calibration system that can be used in the fulfilment of the requirements of BS 5750, or for the supply of calibration services.

This standard can be used for the following purposes.

(a) As a basis for evaluating the capability of a supplier's calibration system, either by a potential purchaser or by a third party, in order to provide assurance to interested parties. This may be prior to the establishment of a contract.

(b) Where invoked in a contract, to specify the calibration requirements appropriate to the particular materiel or service.

NOTE. It may be necessary for the contract to be supplemented by additional quality assurance documents that define how the requirements of this standard will be met.

(c) In other documents (e.g. product standards or process specifications) where reference to a calibration system is appropriate.

Guidance on the use of this standard is given in BS 5781 : Part 2.

1. Scope

This British Standard specifies requirements for a system for selecting, using, calibrating, controlling and maintaining measurement standards and measuring equipment used in the fulfilment of specified requirements.

2. References

The titles of the standards publications referred to in this standard are listed on the inside back cover.

3. Definitions

For the purposes of this British Standard, the following definition together with those given in BS 4778 and BS 5233 apply.

specified requirements. Either:

(a) requirements prescribed by the purchaser in a contract or order for materiel or services; or

(b) requirements prescribed by the supplier that are not subject to direct specification by the purchaser.

4. Requirements

4.1 Calibration system. The supplier shall establish and maintain an effective system for the control and calibration of measurement standards and measuring equipment used in the fulfilment of specified requirements. The system shall be designed to ensure that all measurement resources have the capability of making measurements within limits designated as appropriate to these requirements. It shall provide for the prevention of inaccuracy by prompt detection of deficiences and timely action for their correction.

NOTE. Complete in-plant measurement or calibration capability is not essential if these services are obtained from sources that comply with the requirements of this standard.

Objective evidence that the system is effective shall readily be available to the purchaser or his authorized representative, hereinafter referred to as the 'Purchaser's Representative'.

4.2 Periodic review of the calibration system. The system established in accordance with the requirements of this standard shall be periodically and systematically reviewed by the supplier to ensure its continued effectiveness and the results shall be recorded.

4.3 Planning. The supplier shall review the technical requirements specified at the earliest practicable stage before commencing new work on materiel or services, and shall establish a programme to ensure that measurement standards and measuring equipment necessary for the completion of this work are available and are of the accuracy, stability and range appropriate for the intended application. In particular, identification and timely action shall be taken to report, to the Purchaser's Representative, any measurement requirement that exceeds the known 'state of the art' or any new measurement capability that is needed but is not available.

4.4 Measurement limits. All measurements, whether made for purposes of calibration or product characteristic assessment, shall take into account all the errors and uncertainties in the measurement process that are attributable to the measurement standard or measuring equipment, and, as appropriate, those contributed by personnel, procedures and environment.

4.5 Documented calibration procedures. Documented calibration procedures shall be prescribed and shall be available for reference and use, as necessary, for the calibration of all measurement standards and measuring equipment used.

NOTE. Procedures may be, but are not necessarily, limited to the compilation of published standard measurement practices and purchaser's or instrument manufacturer's written instructions. Exceptions may be allowed for measuring equipment when it is uneconomical and technically unnecessary to require a detailed procedure.

The exceptions given in the above note shall be recorded. Procedures shall contain sufficient instruction to provide data adequate to ensure valid measurement when the equipment is used for the measurement of product or process characteristics or calibration.

4.6 Records. The supplier shall maintain records of all measurement standards and measuring equipment used to establish conformance to specified requirements. These records shall demonstrate that each measurement standard and item of measuring equipment is capable of performing measurements within the designated limits. When measurement standards or measuring equipment are found to be outside these limits, the extent of the errors shall be recorded and appropriate action taken.

NOTE. The amount of data to be recorded is dependent on the nature of the measuring equipment, the measurement standards in use and on their application.

Functionally simple and rugged measuring equipment shall be the subject of records (individual or collective) or other means of showing that they are within their calibration interval and designated limits.

All other measuring equipment and measurement standards shall be the subject of records which shall always include the following information:

(a) the description of equipment and unique identification;

(b) the date on which each calibration was performed;

(c) the results obtained from calibration;

(d) the planned calibration interval;

and, when appropriate, the following additional information:

(e) the designated permissible limits of error;

(f) the reference to calibration procedures;

(g) the source of calibration used to establish traceability;

(h) the environmental condition for calibration and the measurement data as measured and as corrected to reference conditions;

(j) a statement of the cumulative effect of uncertainties on the data obtained in the calibration;

(k) details of any maintenance (servicing, adjustment, repairs) or modifications that could affect the calibration status;

(l) any limitations in use.

4.7 Calibration labelling. All measurement standards and measuring equipment shall be labelled, coded or otherwise identified to indicate their calibration status. Any limitation of calibration or restriction of use shall be clearly indicated on the equipment. When neither labelling nor coding is practicable, or is not considered essential for control purposes, other procedures shall be established to ensure conformance to these requirements.

4.8 Sealing for integrity. Access to adjustable devices on measurement standards and measuring equipment, which are fixed at the time of calibration, shall be sealed or otherwise safeguarded to prevent tampering by unauthorized personnel. Seals shall be so designed that tampering shall destroy them.

NOTE. This requirement does not apply to adjustable devices that are intended to be set by the user without needing external references, e.g. zero adjusters.

4.9 Intervals of calibration. Measurement standards and measuring equipment shall be calibrated at periodic intervals established by the supplier on the basis of stability, purpose and usage. Intervals shall be established so that re-calibration occurs prior to any probable change in accuracy that is of significance to the use of the equipment. Depending upon the results of preceding calibrations, intervals of calibration shall be shortened, if necessary, to ensure continued accuracy.

NOTE. The intervals may be lengthened if the results of previous calibrations provide definite indications that such action will not adversely affect confidence in the accuracy of the equipment.

4.10 Invalidation of calibration. The supplier shall provide for the immediate removal, or conspicuous identification to prevent use, of any measurement standard or measuring equipment that is:

(a) outside its designated calibration period; or

(b) has failed in operation; or

(c) is suspected of being or is known to be outside its designated limits; or

(d) shows evidence of physical damage that may affect its accuracy.

The Purchaser's Representative shall be notified immediately if suspected or actual equipment failures affect the acceptability of the product.

Details of such invalidation of calibration requiring corrective action shall be recorded.

4.11 Sub-contractors. The supplier shall ensure that sub-contractors employ a system which complies with the requirements of this standard.

4.12 Storage and handling. The supplier shall establish and maintain a system for handling, transporting and storing all measurement standards and measuring equipment to prevent abuse, misuse, damage or change in dimensional or functional characteristics.

4.13 Traceability. All measurement standards and measuring equipment shall be calibrated using measurement standards that are traceable to national or international measurement standards, except where they have been derived from acceptable values of natural physical constants or by the ratio type of self-calibration techniques.

NOTE. Measurement standards in use need not be referred directly to national measurement standards, but may be calibrated against intermediate standards provided that the requirement for traceability is satisfied.

All measurement standards used in the calibration system shall be supported by certificates, reports or data sheets attesting to the date, accuracy, and conditions under which the results were obtained and are valid. All such documents shall be signed by a responsible person.

4.14 Cumulative effect of errors. The cumulative effect of the errors in each successive stage of a calibration chain shall be taken into account for each measurement standard or item of measuring equipment calibrated. Action shall be taken when the total uncertainty is such that it significantly compromises the ability to make measurements within the required limits. The details of the components of the total uncertainty shall be recorded. The method of combining these shall also be recorded.

4.15 Environmental control. Measurement standards and measuring equipment shall be calibrated and used in an environment controlled to the extent necessary to ensure valid measurements. Due consideration shall be given to temperature, rate of change of temperature, humidity, lighting, vibration, dust control, cleanliness and other factors affecting measurement. When pertinent, these factors shall be continuously monitored and recorded, and, when necessary, compensating corrections shall be applied to measurement data. Records shall contain both the original and the corrected data.

4.16 Evaluation of calibration system. Where specified in a contract, the calibration system shall be open to evaluation by the Purchaser's Representative and reasonable access and facilities shall be made available for this purpose.

4.17 Training. All personnel performing calibration functions shall have appropriate experience or training.

BS 5781 : Part 2
Guide to the use of BS 5781 : Part 1 'Specification for system requirements'

Foreword

If a manufacturer wishes to establish a reputation for quality products and services, he has to be able to demonstrate that he can comply with specified requirements. The control of manufacturing processes and the assessment of product quality and conformance with specification almost invariably necessitates measurement of some kind. The integrity of all such measurement work depends on selecting and using, in the correct manner, suitable measuring equipment and validating it by a system of control and calibration. Therefore any organization working to the requirements of BS 5750 or any other formal series of quality system standards, has to be able to demonstrate that it is able to measure adequately and to certify that the results obtained can be relied upon.

BS 5781 : Part 1 specifies requirements for a measurement and calibration system. This guide, which is based on Defence Standard 05-27 issue 2, gives reasons for these requirements and offers guidance for evaluating and/or reviewing working systems. Appendix A lists the typical questions that should be answered when reviewing and/or evaluating a measurement and calibration system.

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0. Introduction

Manufacturers are being faced to an increasing extent with demands for certification relating the conformance of their product to a specification. Most products require the application of accurate measurement during manufacture and in order to prove conformance to specification. It is essential that the manufacturer should be able to demonstrate that his equipment is capable of, and provides precise measurement, before he can give any assurance of conformance. The need for this assurance generally requires the manufacturer to possess equipment that is capable of an accuracy higher than that achieved in the product being certified.

Calibration is defined in BS 4778 and BS 5233 as 'all the operations for the purpose of determining the values of the errors of a measuring instrument (and, if necessary, to determine other metrological properties)'.

Any measuring equipment (and this term includes items such as standard resistors and gauge blocks as well as voltmeters and volumetric glassware) has at some time during its life been adjusted or graduated to the required accuracy, within known limits. For almost all measuring equipment, this will have occurred as one of the final steps of the manufacturing process. If, in addition, its errors have been determined and recorded, this activity constitutes a calibration and, in cases where the ultimate user requires it, these figures can be given to him on a signed certificate called a 'calibration certificate'.

In order to achieve harmony between measurements made in different locations and using different measuring equipment, equipment should initially have been correctly adjusted using traceable values. Unfortunately this by itself is rarely sufficient as almost everything is subject to change. Some of these changes are *slow ageing drifts* such as are common with resistors and capacitors; some are caused by wear such as usually occurs with gauge blocks and micrometers; and some are associated with reliability (wear out) failures that can occur with valves and electrolytic capacitors. In addition, some changes are caused by abuse such as overloading or shock (knock) loading, and some erratic changes are caused by either defective design and/or faulty construction.

It should not therefore be assumed that just because a device was once 'correct' it will remain so forever. The chance of its doing so is greater if it is simple, rugged and is well treated. For example, a master gauge block, kept in a controlled environment and used only on rare occasions by a skilled operator, is much more likely to remain unchanged than a voltmeter used by partially trained labour in a field trials section.

A problem with some measuring equipment is that it can become seriously erroneous but still appear to be functioning correctly. Suspicion may fall on a piece of equipment because it produces results different from other similar equipment but, if it is the only one of its kind and range available, it may continue to be used with completely unjustified confidence. Thus the cost of the damage that can be done may be enormous. It may involve recalling units that have already been sold, in order to modify or adjust them, and it can have a bad effect on the reputation of the organization.

In order to be certain that a piece of equipment is still working correctly, it is therefore necessary to check it. Ideally it should be checked immediately before and after each occasion of use. The pre-check will prevent a faulty instrument from being used and thus producing incorrect results, and the post-check will detect if any changes have occurred during the period of use. If there are indications that changes have taken place, it may be necessary to repeat all the measurements for which it has been used.

However, this is a policy of perfection, which would usually be too time-consuming and costly to be practicable. Stable equipment can, in the absence of damage, normally be relied on for periods measured in months. If a particular specimen or type of equipment is found to have become inaccurate after only a few days or weeks, it should be considered to be unreliable, as a result of faulty design or construction, and should be replaced by more stable equipment.

For equipment in regular use, either installed in connection with some process or in use in a factory or laboratory, checking at regular intervals of time provides a good assurance that measurements taken with its aid will be satisfactory. The intervals at which calibration is desirable will vary with the nature of the device, the conditions under which it is used, and the seriousness of the consequences if it produces incorrect results.

The magnitude of errors and their rapidity of occurrence in a piece of equipment change will vary according to its design and construction: whether it has an inherent wear-out process, or is subject to wear in use.
Some instruments incorporate components that alter their properties with changes in temperature, humidity, time lapse or duration of use. All of these factors may significantly affect the uncertainty of the measurement. For the purpose of assessing the calibration interval, it is

the time-dependent phenomena that should be considered. For example, a hardened steel gauge block can be expected to be very stable and to be subject to very little wear with normal use. A cast iron gauge block can be expected to show the usual growth phenomenon of cast iron and so be unstable. A mild steel gauge block would probably wear significantly in use and become inaccurate.

Irrespective of the apparent stability of a piece of equipment, there is always the possibility of damage causing either a step-change or random variability in the error. For example, some damage is not apparent, such as over-heating a sealed resistor or overloading a Weston cell, and the resultant errors may be completely unsuspected. Such damage may be random in its time of occurrence, but is likely to be more frequent the lower the grade of labour and the more arduous the conditions of use.
Regular calibration is therefore necessary in such cases.

1. Scope

This British Standard provides guidance for organizations seeking to comply with the requirements of BS 5781 : Part 1. For each of the main elements the requirement of BS 5781 : Part 1 has been repeated, followed by guidance on implementation.

Appendix A lists typical questions which may be found useful when carrying out a review or evaluation of a measurement and calibration system.

2. References

The titles of the standards publications referred to in this standard are listed on the inside back cover.

3. Definitions

For the purposes of this British Standard, the definitions given in BS 4778 and BS 5233 apply.

4. Requirements and guidance

4.1 Calibration system

4.1.1 *Requirement of BS 5781 : Part 1.* The supplier shall establish and maintain an effective system for the control and calibration of measurement standards and measuring equipment used in the fulfilment of specified requirements. The system shall be designed to ensure that all measurement resources have the capability of making measurement within limits designated as appropriate to these requirements. It shall provide for the prevention of inaccuracy by prompt detection of deficiences and timely action for their correction.

NOTE. Complete in-plant measurement or calibration capability is not essential if these services are obtained from sources that comply with the requirements of this standard.

Objective evidence that the system is effective shall readily be available to the purchaser or his authorized representative, hereinafter referred to as the 'Purchaser's Representative'.

4.1.2 *Guidance.* Any measurement work is valueless unless its results are known to be valid and sufficiently accurate for the intended purpose. The provision of a measurement facility necessitates the selection of suitable equipment with instructions for its use, the availability of appropriate skills and means of establishing the initial and continuing validity of the measurement processes. Experience in industry generally has indicated that ad hoc arrangements for dealing with the calibration of equipment often results in unintentional neglect. The likely consequences are out of date calibrations, lack of traceability to standards of reference and inadequate records, leading to loss of confidence in product or service compliance with customer requirements.

Validation of measurement work is best achieved by operating an orderly system in which responsibility for controlling the calibration of all measuring equipment and measurement standards used is assigned to designated personnel. The system should include documents and records to provide evidence of measurement integrity, of any limitations of use and of occurences affecting confidence in the serviceability of the equipment. Such records are a valuable reference in cases of dispute e.g. relating to measurement or product rejection, particularly in relation to product liability and warranty aspects. These records are also useful in assessing drift, wear and other variations in equipment performance. Such data provide a basis for decisions on equipment maintenance, repair and replacement economics.

4.2 Periodic review of calibration system

4.2.1 *Requirement of BS 5781 : Part 1.* The system established in accordance with the requirements of this standard shall be periodically and systemically reviewed by the supplier to ensure its continued effectiveness and the results shall be recorded.

4.2.2 *Guidance.* The effective operation of the established measurement and calibration system is a responsibility of management. Planned comprehensive reviews of the system are the best means by which its continued suitability can be assessed, and from which management can be confident that their product or service fully complies with technical requirements.

It is essential that these reviews are systematic and not merely casual or superficial enquiries. In order to perform a review adequately, it is essential that procedures be defined, namely, who will perform the review, its periodicity, how and where it will be done, how the results will be reported and how corrective action will be instituted. Some aspects of the system will require review more frequently than others. All results from the review should be recorded and be available for inspection.

NOTE. Appendix A indicates the types of question that may be useful in the evaluation/review of a calibration system.

4.3 Planning

4.3.1 *Requirement of BS 5781 : Part 1.* The supplier shall review the technical requirements specified at the earliest practicable stage before commencing new work on materiel or services, and shall establish a programme to ensure that measurement standards and measuring equipment necessary for the completion of this work are available and are of the accuracy, stability and range appropriate for the intended application. In particular, identification and timely action shall be taken to report, to the Purchaser's Representative, any measurement requirement that exceeds the known 'state of the art' or any new measurement capability that is needed but is not available.

4.3.2 *Guidance.* A significant factor is planning for the inspection of a product, or for the provision of a measurement service, is the determination of what measurement equipment will be required, what its accuracy should be, and when, where and how the necessary measurement and calibration will be performed.

The requirement refers to this activity as a programme, but it is recognized that the activity may be undertaken in conjunction with the planning of other functions; therefore, a definitive plan dealing solely with the measurement and calibration system may not exist. This procedure is acceptable, provided it can be demonstrated that, within

the overall system, the measurement and calibration requirements have been planned for all phases of the work, i.e. design, development, manufacture and installation, etc., as appropriate.

Occasions may arise where the specified requirements cannot be satisfied, either because the measurement requirement excedes the 'known state of the art', or because a particular measurement capability is not available. In such cases, the person responsible for quality should be informed. When establishing the programme, the need for controlled environments should be considered. The skills required of personnel performing calibration should be taken into account in order to ensure that suitable personnel with adequate expertise will be available, particularly when planning for product measurements which require a greater than average level of skill.

4.4 Measurement limits

4.4.1 *Requirement of BS 5781 : Part 1.* All measurements, whether made for purposes of calibration or product characteristic assessment, shall take into account all the errors and uncertainties in the measurement process that are attributable to the measurement standard or measuring equipment, and, as appropriate, those contributed by personnel, procedures and environment.

4.4.2 *Guidance.* Errors and uncertainties are inherent in all measurement processes, whether performed for the purposes of calibrating measuring instruments or measuring product characteristics. Valid estimates of the amount of error and uncertainty can be made and should be taken into account as appropriate, not only in the use of measurement standards in subsequent calibrations, but also in the use of measuring equipment when deciding whether measured values of product characteristics are within specified limits. The total error and the uncertainty, which may be expressed in appropriate units, percentages or fractions, may comprise individual errors and uncertainties arising from inaccuracy and lack of repeatability and resolution of the measurement standards and measuring equipment, the methods of measurement, variations in environmental conditions, and operator ability. (See **4.14** for further information.)

NOTE. The term 'measurement standard' embraces any measuring equipment used as a reference.

When a product characteristic is being assessed for compliance with specified limits, the total error and the uncertainty should be taken into account if their significance in relation to the product characteristic limits is likely to compromise product acceptance. At every stage in the production to inspection process where measurement is made, a method of achieving this conformity is to apply the appropriate correction for total measurement error, and then work to 'inspection limits'. These inspection limits may be established by tightening the specified product characteristic limits by the residual uncertainty. In the determination of total measurement error and the estimation of residual uncertainty, allowance should also be made for any significant differences between the environmental conditions of measurement and those for which the product characteristic limits are specified.

4.5 Documented calibration procedures

4.5.1 *Requirement of BS 5781 : Part 1.* Documented calibration procedures shall be prescribed and shall be available for reference and use, as necessary, for the calibration of all measurement standards and measuring equipment used.

NOTE. Procedures may be, but are not necessarily, limited to the compilation of published standard measurement practices and purchaser's or instrument manufacturer's written instructions. Exceptions may be allowed for measuring equipment when it is uneconomical and technically unnecessary to require a detailed procedure.

The exceptions given in the above note shall be recorded. Procedures shall contain sufficient instruction to provide data adequate to ensure valid measurement when the equipment is used for the measurement of product or process characteristics or calibration.

4.5.2 *Guidance.* Written procedures for the calibration of measurement standards and measuring equipment are essential in order to establish:

(a) the application of acceptable techniques and practices; and

(b) control over changes in calibration techniques.

Adequately documented calibration procedures should be available for the calibration of all measurement standards and measuring equipment. However, the requirement acknowledges that, for some equipment, it may not be economical or technically necessary to provide a detailed procedure. The identification of such equipment is a matter of judgement. Similar considerations may apply when the method of calibration consists of basic and simple principles that would be expected to be known and frequently practised by all calibration personnel.

If, in developing written procedures, the supplier utilizes published standard practices or manufacturers' written instructions, these should then form part of the suppliers' written procedure. The amount of detail to be included in a procedure will vary and depend upon the nature of the equipment and its complexity. As a guide, the written procedure should, as necessary, include:

(a) identification of the device or group of devices to which the procedure is applicable;

(b) identification of all standards and accessory equipment to be used to perform this calibration;

(c) adequate calibration instructions;

(d) an indication of the measurement or calibration data to be recorded and how such data is to be tabulated and treated;

(e) the environmental conditions in which the calibration is to be made and the minimum stabilization period prior to calibration;

(f) a statement on the estimated uncertainty of the calibration process; and

(g) an issue number and/or date of issue.

Copies of the calibration procedures relating to all equipment should ideally be kept together in one place. The procedures should be available, for reference, to all personnel employed on calibration work, but there is no need for copies to be immediately available at the point of calibration when the work is being done by competent and trained personnel.

4.6 Records

4.6.1 *Requirement of BS 5781 : Part 1.* The supplier shall maintain records of all measurement standards and measuring equipment used to establish conformance to specified requirements. These records shall demonstrate that each measurement standard and item of measuring equipment is capable of performing measurements within the designated limits. When measurement standards or

measuring equipment are found to be outside these limits, the extent of the errors shall be recorded and appropriate action taken.

NOTE. The amount of data to be recorded is dependent on the nature of the measuring equipment, the measurement standards in use and on their application.

Functionally simple and rugged measuring equipment shall be the subject of records (individual or collective) or other means of showing that they are within their calibration interval and designated limits.

All other measuring equipment and measurement standards shall be the subject of records which shall always include the following information:

(a) the description of equipment and unique identification;

(b) the date on which each calibration was performed;

(c) the results obtained from calibration;

(d) the planned calibration interval;

and, when appropriate, the following additional information:

(e) the designated permissible limits of error;

(f) the reference to calibration procedures;

(g) the source of calibration used to establish traceability;

(h) the environmental condition for calibration and the measurement data as measured and as corrected to reference conditions;

(j) a statement of the cumulative effect of uncertainties on the data obtained in the calibration;

(k) details of any maintenance (servicing, adjustment, repairs) or modifications that could affect the calibration status;

(l) any limitations in use.

4.6.2 *Guidance.* Records are the objective evidence that all measurement standards and measuring equipment that are provided by the supplier are in a known state of calibration. Records constitute a history of the calibration of a device. These may be evaluated and used as a basis for changing calibration intervals or measurement procedures, or taking other corrective action.

The retention and analysis of the results obtained from calibrations may indicate the need to reduce, or permit the extension of calibration intervals. There is an overall requirement for records to be maintained of any errors that exceed designated limits so that appropriate corrective action can be taken. This action may include the investigation of the effect of such errors on the acceptability of products.

The extent of the calibration information to be recorded depends on the nature and use of the equipment. For some equipment, the detail listed in 4.6.1(a) to (d) will suffice, but if, for example, the measurement standard or measuring equipment is used to calibrate other equipment, or is used for measurements requiring a high accuracy, the additional information of 4.6.1(e) to (l) may be needed.

The supplier is responsible for deciding the extent to which records should be maintained for each equipment within the provisions of this requirement. In the case of functionally simple and rugged equipment, the organization is obliged to show only that it is within its calibration interval and designated limits, and can do so by any means provided that the requirement is satisfied. It is a matter of judgement whether an equipment can reasonably be described as functionally simple and rugged. This judgement will vary with the industry and technology involved.

The supplier is responsible for maintaining records where the calibrations are performed either by him or by others on his behalf. The supplier may maintain these records in any suitable form, provided that they contain the appropriate information.

4.7 Calibration labelling

4.7.1 *Requirement of BS 5781 : Part 1.* All measurement standards and measuring equipment shall be labelled, coded or otherwise identified to indicate their calibration status. Any limitation of calibration or restriction of use shall be clearly indicated on the equipment. When neither labelling nor coding is practicable, or is not considered essential for control purposes, other procedures shall be established to ensure conformance to these requirements.

4.7.2 *Guidance.* The purpose of this requirement is to provide a means of determining the calibration status of measurement standards and measuring equipment used. Although entitled 'Calibration labelling', the requirement recognizes that there are many methods of establishing adequate control over equipment, and leaves the choice to the supplier. It is accepted that it is not always practicable or essential to provide a physical identification of calibration status on the equipment but, whatever method is adopted, it should ensure that it is capable of providing ready identification of the calibration status of equipment. The phrase 'calibration status' refers to the information that indicates that the measurement standard or measuring equipment was within its designated limits when last calibrated, and that it is within its calibration interval and may also identify the origin of the calibration.

Where any measuring equipment is not in use, calibration need not be carried out. In this case, however, calibration has to be carried out before re-use if the validity of the previous calibration has expired. To ensure that such equipment is not used accidentally, procedures for its control and segregation, if possible, should be maintained, and the equipment should be clearly identified, preferably by the use of a label. Calibration records should also indicate any equipment that falls into this category.

When it is not intended to use the full capability of a measurement standard or measuring equipment, because part of the equipment is unserviceable or because of limited calibration, any restriction should be readily apparent to the operator. Examples of use where there is no need for full calibration are:

(a) where not all equipment ranges are required for use; or

(b) the equipment is used as a null indicating device; or

(c) the equipment is used only as an indicator and is not used for precise measurement.

4.8 Sealing for integrity

4.8.1 *Requirement of BS 5781 : Part 1.* Access to adjustable devices on measurement standards and measuring equipment, which are fixed at the time of calibration, shall be sealed or otherwise safeguarded to prevent tampering by unauthorized personnel. Seals shall be so designed that tampering shall destroy them.

NOTE. This requirement does not apply to adjustable devices that are intended to be set by the user without needing external references, e.g. zero adjusters.

4.8.2 *Guidance.* The purpose of this requirement is to provide an additional safeguard for the integrity of measurement by precluding errors that can occur if calibrated measurement standards or measuring equipment are tampered with. The interpretation of the term 'adjustable devices' used in the requirement should be subject to the exercise of common sense and good judgement. For instance, micrometer type attachments are often provided with a special tool for adjustment purposes, and are outside the scope of this requirement. Similarly, when the overall device is safeguarded from tampering, it is not intended that all components that are subject to adjustment should be individually protected. However, there is nothing to preclude such interpretation if it is found that individual protection is the only way in which a supplier can maintain the required integrity.

4.9 Intervals of calibration

4.9.1 *Requirement of BS 5781 : Part 1.* Measurement standards and measuring equipment shall be calibrated at periodic intervals established by the supplier on the basis of stability, purpose and usage. Intervals shall be established so that re-calibration occurs prior to any probable change in accuracy that is of significance to the use of the equipment. Depending upon the results of preceding calibrations, intervals of calibration shall be shortened, if necessary, to ensure continued accuracy.

NOTE. The intervals may be lengthened if the results of previous calibrations provide definite indications that such action will not adversely affect confidence in the accuracy of the equipment.

4.9.2 *Guidance.* Except with respect to natural physical constants, no measurement standard or measuring equipment remains in a constant state. Even when such devices are stored unused, change may take place through natural physical or chemical causes. All measurement standards and measuring equipment should therefore be calibrated and, if necessary, serviced, adjusted or otherwise re-worked at periodic intervals, to preserve the integrity of product measurement.

The interval between calibrations varies from case to case and largely depends on such factors as the conditions of storage, the method and extent of use, the accuracy of measurement required, the effect of wear and the inherent stability of the device. When devices are used that are new to a supplier, the interval of calibration can be assessed only arbitrarily. The supplier should, however, take cognizance of his experience of using similar devices and the various factors associated with the measurement. He should, where there is doubt, set the interval shorter than he expects the interval will eventually be, up-dating his estimate with information obtained from subsequent calibrations. However, over-frequent calibration is both time-consuming and costly. The ideal interval before calibration is, of course, as expressed in the wording of the requirement 'prior to any probable change in accuracy which is of significance to the use of the equipment'. In this statement the word 'significance' is used as a realistic recognition that some change is inevitable.

This requirement makes the supplier responsible for an organized approach to the establishment and maintenance of satisfactory intervals for the calibration of the measurement standards and measuring equipment. It also makes a supplier responsible for the removal, or isolation from use, of any measuring equipment that has not been calibrated within the established interval of calibration.

4.10 Invalidation of calibration

4.10.1 *Requirement of BS 5781 : Part 1.* The supplier shall provide for the immediate removal, or conspicuous identification to prevent use, of any measurement standard or measuring equipment that is:

(a) outside its designated calibration period; or

(b) has failed in operation; or

(c) is suspected of being or is known to be outside its designated limits; or

(d) shows evidence of physical damage that may affect its accuracy.

The Purchaser's Representative shall be notified immediately if suspected or actual equipment failures affect the acceptibility of the product.

Details of such invalidation of calibration requiring corrective action shall be recorded.

4.10.2 *Guidance.* This requirement emphasizes the importance of ensuring that any measurement standard, or any measuring equipment used for the assessment of product quality conformance is maintained in the required state of calibration and is performing within its designated limits. Although in any system there is a possibility that errors in the calibration state of equipment may go undetected until re-called for calibration, this requirement places a responsibility on the supplier for ensuring that his system is capable of detecting, and isolating from use, any measurement standard or measuring equipment known to be, or suspected of being, outside its designated capability.

In the event of an equipment failure being detected or suspected, or where there is evidence of damage, the supplier should take positive action to determine the likely effect on product quality. A supplier should consider isolating or identifying recently tested products, in the first instance, in case the extent of the equipment failure or damage is such as significantly to compromise previous acceptance decisions. When acceptability of output is in doubt, the supplier should immediately notify the purchaser who should consider any proposed corrective action or the need for further measures. Records of all actions taken should be maintained by the supplier.

4.11 Sub-contractors

4.11.1 *Requirement of BS 5781 : Part 1.* The supplier shall ensure that sub-contractors employ a system which complies with the requirements of this standard.

4.11.2 *Guidance.* Suppliers do not always have the capability or the full range of facilities to discharge all of their contract or service requirements for a measurement and calibration system. They therefore expand their capacity by sub-contracting for:

(a) the testing of materiel made by the supplier or his sub-contractors;

(b) calibration of the supplier's measurement standards and/or measuring equipment, and possibly those to be used by his sub-contractors.

If the measurement and calibration system is established under the provision of BS 5750 : Parts 1 and 2, the supplier may incorporate such use of sub-contractors in his procedures for complying with the requirements of this clause.

The requirement of **4.1.1** indicates that the measurement and calibration system established by the supplier should encompass all resources used by him. The supplier should

therefore give thorough consideration, early in the progress of the contract or service, to the capabilities of potential sub-contractors of any materiel or services. The choice of sub-contractors may be influenced to a great extent by their ability to comply with the requirements of BS 5781. When appropriate, the supplier should ensure that the contracts with his sub-contractors contain a reference to the calibration requirements. This may be done by specifying:

(a) BS 5750 : Parts 1 or 2 for the supply of material or services; or

(b) BS 5781 for the supply of calibration services; or

(c) their own requirements; or

(d) their sub-contractors' procedures, if they are acceptable.

4.12 Storage and handling

4.12.1 *Requirement of BS 5781 : Part 1.* The supplier shall establish and maintain a system for handling, transporting and storing all measurement standards and measuring equipment to prevent abuse, misuse, damage or change in dimensional or functional characteristics.

4.12.2 *Guidance.* All measuring equipment should be handled and used carefully and should be stored and transported under conditions compatible with its vulnerability.

Measuring instruments, including measurement standards, may have their performance impaired by careless use (e.g. overloading a resistance standard, damaging the anvils of a micrometer), by poor storage conditions (e.g. extremes of temperature, humidity causing rusting and/or mould growth, sunlight causing degrading of plastics) and by vibration, shocks and temperature cycling or poor transport conditions. Some standards, e.g. standard cells, need to be hand carried using a reliable courier, whereas small gauge blocks, if adequately packed, can be sent by parcel post.

4.13 Traceability

4.13.1 *Requirement of BS 5781 : Part 1.* All measurement standards and measuring equipment shall be calibrated using measurement standards that are traceable to national or international measurement standards, except where they have been derived from acceptable values of natural physical constants or by the ratio type of self-calibration techniques.

NOTE. Measurement standards in use need not be referred directly to national measurement standards, but may be calibrated against intermediate standards provided that the requirement for traceability is satisfied.

All measurement standards used in the calibration system shall be supported by certificates, reports or data sheets attesting to the date, accuracy, and conditions under which the results were obtained and are valid. All such documents shall be signed by a responsible person.

4.13.2 *Guidance.* No practical measurement can be exact: its accuracy depends on the effect of various sources of error, usually expressed as an uncertainty of measurement, including the error of any measurement standard used as a reference. Similarly, the uncertainty in the value of this measurement standard depends on that of the measurement standard used to calibrate it. The ultimate reference in the chain of measurement standards is a national measurement standard linked to those of other countries by international comparisons.

Traceability is provided by an unbroken chain of comparisons through measurement standards of successively better accuracy up to the national measurement standard. This ensures that measurements, wherever made, are compatible within the uncertainty range associated with each. This uncertainty may be assessed by experiment or analysis, as appropriate, and should be associated with a confidence level, i.e. a probability, usually close to 100 %, that the actual error in a particular measurement is within the uncertainty stated. Without such a traceability chain, the size of a unit of measurement may differ from place to place. It is clear that traceability is essential to meet interface requirements between manufactured items and to provide a common base for the assessment of product quality and performance in accordance with specification.

It is not usually necessary for measuring equipment and measurement standards to be calibrated directly against national measurement standards. A lower point in the traceability chain having a sufficiently small uncertainty will satisfy the need. For each item of measuring equipment or measurement standard used for in-house calibration work, traceability should be demonstrated by a calibration certificate issued by an authoritative source. This certificate should be sufficiently recent to have current validity after allowing for drift subsequent to calibration and show a sufficient range of measurements at an appropriately low uncertainty to allow use of the measurement system at the required level of accuracy. As a guide, the following information should be shown on the certificate:

(a) identification of equipment calibrated;

(b) results obtained;

(c) uncertainty of measurement;

(d) the authority under which the certificate is issued;

(e) any limitations on use of the equipment;

(f) date of calibration.

In general, calibration satisfying the dual requirements of *authentic* certification and traceability is available in several fields of *metrology* through the approved laboratories of the British Calibration Service (BCS), a national service set up by the Government to provide authenticated calibration of instruments and other *measurement* services. The service provided by the BCS approved laboratories are supplied on a normal commercial basis; details of such laboratories can be obtained from BCS headquarters at the National Physical Laboratory.

Certain calibration services required by a supplier may not be available from BCS sources, but may be available from a laboratory at the national level. Advice on such services may be available from the BCS in appropriate cases.

4.14 Cumulative effect of errors

4.14.1 *Requirement of BS 5781 : Part 1.* The cumulative effect of the errors in each successive stage of a calibration chain shall be taken into account for each measurement standard or item of measuring equipment calibrated. Action shall be taken when the total uncertainty is such that it significantly compromises the ability to make measurements within the required limits. The details of the components of the total uncertainty shall be recorded. The method of combining these shall also be recorded.

4.14.2 *Guidance.* Any measurement is liable to errors of various kinds and from different causes, and hence the results of measurements are always subject to uncertainty. It may sometimes happen that the true value is obtained, but it can never be recognized as such. A measurement

process is therefore one of estimation in which the likely magnitude of errors, i.e. the uncertainty, is assessed and allowed for to an extent and in a manner appropriate to the purpose.

Some types of error appear consistently in a given measurement system. These are usually known as 'systematic errors' and are characterized by their persistence and bias. If such errors can be identified and quantified, their effect can be eliminated by adjustment of the equipment or by applying corrections to the indicated (measured) values.

Another distinctly different category is 'random errors'. Their occurrence is unpredictable and, when present, their magnitudes are variable and equally likely to be of either sign. This category accounts for the unrepeatability in the results of measurements made under ostensibly constant conditions and is often due to uncontrolled variations in environmental influence, physical operation and dynamic behaviour of the equipment. Measurement results that are subject to random effects follow the 'normal or Gaussian distribution' in which values close to the mean value occur more frequently than those having a greater deviation from the mean. Random errors cannot be eliminated by adjustment or correction but, if repeated measurements can be made under constant conditions, averaging the results will improve the estimate of the true value.

Since the distribution of individual results is not uniform, the accuracy of the results of a single measurement can be stated only in statistical terms. This approach gives a statement of a range of values (an interval) and a percentage probability of single results occurring within that range. Any level of probability may be chosen according to the degree of confidence to be claimed for the accuracy of the declared results. Clearly the width of the stated range of values (or length of interval) and the confidence level are inversely related.

In a given measurement system the maximum estimated values of all likely errors are often added together to give a 'worst case' overall figure for the system. This approach ignores the variable behaviour of random errors and assumes that all the individual errors will combine in the most adverse manner. In practice it is unlikely that errors will often combine in this way: it is a matter or probability. However, the cumulative effect of errors in a calibration chain obtained by simple addition is acceptable if the overall effect is small compared with the accuracy required for product testing. Ideally the error attributable to calibration should be no more than 1/5 and preferably 1/10 of the accuracy required for the calibrated equipment when in use. In the latter case, the calibration error is usually ignored. If, on the other hand, the effect of calibration errors is such as to compromise the adoption of realistic limits of product performance, or to make the product measuring equipment unuseable, the following alternative approaches should be considered.

(a) Shortening the calibration chain, in order to reduce the uncertainty of measurement of the product measuring equipment.

(b) Reducing the interval between calibrations and use in order to take advantage of short term stability.

(c) Seeking alternative calibration equipment and/or methods having greater accuracy.

(d) Widening the acceptance limits of the product.

In the last resort, if the cumulative errors of calibration are within the limits of product test but not small enough to be ignored and it is impracticable further to reduce (tighten) the product test limits, the risk of isolated (individual) values resulting in incorrect product acceptance should be assessed by suitable statistical methods. In such circumstances the results of product test can be given as 'measured values', the uncertainty of measurement being stated. However, absolute product conformity to specification can be claimed only when results, even allowing for the worst case of uncertainty, do not exceed specification limits.

The possibility of accepting some risks in incorrect product assessment is, like sampling risks, a matter for agreement between the supplier and the purchaser and cannot be assumed by calibration and measurement engineers.

Where new and complex methods of calibration are required to be evaluated, the inherent uncertainty should be assessed by mathematical means and the repeatability determined by a series of properly conducted trials. The analysis of results and the combination of error elements normally necessitates the use of statistical methods for which the supplier should use appropriate statistical expertise. The confidence levels used in the final assessment of overall uncertainty should be stated and recorded.

NOTE. For guidance on determinating the repeatability and reproducibility of a standard test method, see BS 5497.

4.15 Environmental control

4.15.1 *Requirement of BS 5781 : Part 1.* Measurement standards and measuring equipment shall be calibrated and used in an environment controlled to the extent necessary to ensure valid measurements. Due consideration shall be given to temperature, rate of change of temperature, humidity, lighting, vibration, dust control, cleanliness and other factors affecting measurement. When pertinent, these factors shall be continuously monitored and recorded, and, when necessary, compensating corrections shall be applied to measurement data. Records shall contain both the original and the corrected data.

4.15.2 *Guidance.* Any measurement is affected to some degree by the environmental conditions under which it is carried out. The attainment of stable environmental conditions can be extremely costly. This requirement makes a realistic approach by demanding that the nature and degree of environmental control be chosen to suit the intended application.

If measuring equipment, because of size or other factors, cannot be moved into a controlled environment for calibration, provision should be made for its calibration in situ, and for necessary compensating corrections to be applied. In some circumstances the effect of environmental factors on calibration of measurement accuracy may be mitigated or even discounted. For example, the use of calibration standards or measuring equipment with an accuracy many times greater than the parameter tolerance being measured may, depending on the stability of the measuring equipment or product characteristic being measured, greatly reduce the impact of the environmental influence on the measurement. This can be achieved by making the correct choice of calibrating equipment and ensuring that all such measurement standards are calibrated in a well controlled environment. However, at the other extreme, environmental factors may necessitate strict control of calibration, measurement and even the test areas in order to achieve valid product measurements.

If such environmental factors are of importance, they should, as appropriate, be monitored, recorded and applied as compensating corrections.

4.16 Evaluation of calibration system

4.16.1 *Requirement of BS 5781 : Part 1.* Where specified in a contract, the calibration system shall be open to evaluation by the Purchaser's Representative and reasonable access and facilities shall be made available for this purpose.

4.16.2 *Guidance.* The purpose of the evaluation is to assure the initial and continuing effectiveness of the supplier's system for the calibration and control of measurement standards and measuring equipment used in fulfilment of specified requirements. The extent of the evaluation may be limited by the conditions of the contract and the supplier should agree on any such limitation with the purchaser.

Facilities should be provided to the purchaser's representative to enable this work to be accomplished.

NOTE. Appendix A indicates the typical questions that may be found useful in the evaluation/review of a calibration system.

4.17 Training

4.17.1 *Requirement of BS 5781 : Part 1.* All personnel performing calibration functions shall have appropriate experience or training.

4.17.2 *Guidance.* The requirement that all personnel performing calibration functions shall have appropriate experience or training means that the supplier should assure himself of the competence of the staff engaged on calibration work. Personnel should have experience or training in the type of calibration work to be undertaken. Thus for example, experience in an electrical standards laboratory may not be adequate training for the calibration of gauge blocks. Additional skills may be required if work on new material or services is undertaken, and it may be appropriate to review the staff competence at the time of planning. (For further information see 4.3.)

Training of staff may be obtained from suitable courses at universities, colleges or summer schools supported by on-the-job training. The appropriate professional institution or trade association may give advice on this subject.

Appendix A

Typical questions

The following series of questions may be found useful as a guide when carrying out a review and/or evaluation of a measurement and calibration system. The questions contained in this appendix essentially invite a YES or NO answer. It is emphasized that, obtaining answers to these questions only, may not provide a thorough and complete review and/or evaluation of a system. The questions are intended only to serve as indicators and reminders of important points to pursue in the objective review and/or evaluation of the system. It is futher emphasized that an affirmative for all questions may not be necessary. The numbering relates to the relevant subclause of BS 5781 : Parts 1 and 2, i.e. **A.1** relates to **4.1**.

A.1 Calibration system

(a) Are there prescribed procedures for the control and calibration of all measurement standards and measuring equipment?

(b) Is it effective and complied with?

(c) Are the appropriate management responsibilities documented?

(d) Does the system provide for the prompt detection of deficiencies to prevent subsequent inaccuracies?

(e) Is there a procedure to ensure corrective action?

(f) Does the supplier have properly defined and appropriate limits of calibration uncertainty?

A.2 Periodic review of the calibration system

(a) Is the procedure for review of the measurement and calibration system documented?

(b) Does it cover all facets of the system and is it effective and complied with?

(c) Are the reviews conducted systematically and is the periodicity satisfactory?

(d) Are records of the reviews maintained and do they provide objective evidence of the effectiveness of the system?

(e) Is senior management informed of the results of the review and is corrective action taken?

A.3 Planning

(a) Are the needs of calibration and measurement properly planned before starting new work?

(b) Are the necessary measurement standards and measuring equipment determined?

(c) Has the availability of all required equipment been determined?

(d) Are the calibration and measurement requirements reviewed to determine special, unusual or 'state of art' needs?

(e) Is there an appropriate area allocated for carrying out all in-house calibration work?

(f) Has the level of skill and training required by the calibration and measurement personnel been determined?

(g) Are controlled environments provided where necessary?

(h) Are there any measurement requirements that cannot be satisfied that are relevant to the products?

(i) Are reports of corrective action used to update planning schedules?

(j) Have the particular needs of automatic test equipment (ATE) been allowed for, and what plans exist for the verification of software?

A.4 Measurement limits

(a) Does the calibration system identify the source and magnitude of uncertainties associated with calibration and product characteristic measurements?

(b) In specifying product characteristic limits, are errors of practical significance taken into account as appropriate?

(c) Does the system identify the particular techniques used for the determination of errors and uncertainties of measurement?

A.5 Documented calibration procedures

(a) Are there prescribed procedures for controlling the calibration of measurement standards and is measuring equipment available and used for product verification?

(b) Where there are no in-house procedures, are appropriate and identifiable published standard practices or manufacturers' written instructions prescribed?

(c) Is there a clearly identified procedure for each item of measuring equipment?

(d) Is the latest issue of procedures identified and available?

(e) Is a check carried out to ensure that written procedures are adhered to?

(f) Where a sub-contractor is used in the measurement chain and special measurement procedures are required of him, are they adequately prescribed?

(g) Are procedures prescribed for the control and/or measurement of special environmental requirements, if appropriate?

A.6 Records

(a) Is there a system of record keeping that is appropriate to the calibration and measurement system in use?

(b) Are all the records required by **4.6** of BS 5781 : Part 1 : 1979 maintained?

(c) Do the records, as necessary, include details of calibration controls, environmental data, designated error limits and information necessary to establish traceability?

(d) Is simple and rugged measuring equipment included in the records?

(e) Do the records indicate that the equipment is capable of performing measurements within the designated limits?

(f) Does the record system allow for calling forward, at the appropriate interval, equipment requiring calibration?

(g) Does the record system indicate those equipments that are calibrated only in part?

(h) Does the system include the retention of calibration certificates or data used in support of all calibration of measuring equipment?

(i) Do the records document the software used for automatic calibration and test equipment procedure?

(j) Is the change procedure, relating to calibration and measurement, documented?

A.7 Calibration labelling

(a) Is there a prescribed system of labelling or coding that identifies the calibration status of measurement standards and measuring equipment?

(b) Is equipment that is not fully calibrated or has limited use fully identified?

(c) Is there a prescribed system to ensure compliance with requirements where labelling is not practicable?

A.8 Sealing for integrity

(a) Are there adequate procedures for sealing against misuse or accidental shift of present controls?

(b) Have any adjustable devices on measurement standards and measuring equipment that are not necessary to the normal operation of the equipment been fully sealed or safeguarded at the time of calibration?

(c) Are the methods and materials used for sealing such that any tampering will be noticeable?

(d) Is the sealing such as to prevent access into the equipment?

A.9 Intervals of calibration

(a) Have calibration intervals been established for all measurement standards and measuring equipment?

(b) Have the calibration intervals been established from the equipment manufacturer's recommendations or knowledge of equipment stability, purpose, degree of usage, calibration records and experience?

(c) Are calibration intervals adjusted on the basis of trend data obtained from previous calibration records?

(d) Are calibration intervals adjusted on the basis of the usage of the equipment?

A.10 Invalidation of calibration

(a) Do the prescribed procedures ensure the immediate removal from use, or conspicuous identification of any measurement standard or measuring equipment that

(1) has not been calibrated in accordance with the established time scale?

(2) has failed in operation in any measurement parameter?

(3) shows evidence of physical damage?

(4) is suspect for any reason?

(b) Are the procedures effective and complied with?

(c) Do the procedures provide for immediate notification of equipment failures or damage likely to have compromised product quality?

(d) What procedures or embargoes are in operation to prevent the unofficial use of privately owned equipment that is not covered by the calibration system?

(e) What safeguards are prescribed to ensure that equipment is not brought into use without adequate checking and calibration?

A.11 Sub-contractors

(a) Do procedures ensure that a sub-contractor employs a measurement and calibration system that complies with the requirements of BS 5781 : Part 1?

(b) Is the responsibility accepted by the supplier for ensuring that the procedures employed by a sub-contractor for calibration and measurement work are suitable and are properly documented?

(c) Is there a system for continuously evaluating sub-contractors?

A.12 Storage and handling

(a) Is there an adequate system for the handling, transporting and storing of measurement standards and measuring equipment?

(b) Is the system under the control of the calibration department?

(c) Do the procedures include a requirement for reporting damage, abuse or deterioration?

(d) Are storage and handling arrangements reviewed, particularly in respect of increased equipment sophistication?

A.13 Traceability

(a) Can all calibrations performed in-house or by sub-contractors be traced through an unbroken chain of properly conducted calibrations to a national or international measurement standard?

(b) Are calibrations involving the use of natural physical constants or ratio type self-calibration techniques adequately controlled?

A.14 Cumulative effect of errors

(a) Do the procedures take into account the cumulative effect of errors and uncertainties in carrying out calibrations?

(b) Is suitable corrective action taken when the total uncertainty could compromise calibration or measurement capability?

(c) Is defined method used in respect of the manner in which the various errors and uncertainties of equipment or a system are determined?

(d) Is the total calibration or measurement uncertainty given on all certificates of calibration?

A.15 Environmental control

(a) Is environmental control provided where necessary?

(b) Are the environmental conditions provided appropriate to the uncertainty level of the calibration and measurement work undertaken?

(c) Are controlled environment areas properly laid out, monitored and controlled?

(d) Are environmental monitoring devices properly maintained and calibrated?

(e) Are environmental compensating corrections applied to calibration and measurement data when necessary?

(f) Do the procedures for calibration and measurement of the equipment indicate the required environment?

A.16 Evaluation of calibration system

(a) Is reasonable access made available for the evaluation of the system?

(b) Are adequate facilities provided?

A.17 Training

(a) Have all personnel performing calibration functions the appropriate experience or training?

(b) Is the experience or training applicable to the type of calibration work undertaken?

(c) Are calibration personnel sent on training courses?

(d) Is the competence of staff reviewed at the planning stage?