DGA-TM-08

Guideline for the Determination of

Calibration Intervals of Measuring Equipment *

* This is a revised version of OIML-Document D10 "Guideline for the determination of recalibration intervals of measuring equipment used in testing laboratories".

1. Introduction

An important aspect for maintaining the traceability of a calibration system is the determination of the maximum period between successive calibrations (recalibrations) of reference standards and measuring equipment. Clause 5.5.2 of ISO/IEC 17025:2005 contains the requirement: "Calibration programmes shall be established for key quantities or values of the instruments where these properties have a significant effect on the results".

Therefore the purpose of a periodic calibration is:

- to improve the estimation of the reference standard's or measuring equipment's deviation from a reference value and the uncertainty in this deviation at the time the reference standard or equipment is actually used,
- to reassure the uncertainty that can be achieved with the reference standard or measuring equipment.

A large number of factors influence the time interval between calibrations and should be taken into account by the laboratory. The most important factors are:

- uncertainty of measurement required or declared by the laboratory,
- the risk of a measuring instrument going out of tolerance when in use,
- type of equipment,
- tendency to wear and drift,
- manufacturer's recommendation,
- extent and severity of use,
- environmental conditions (climatic conditions, vibration, ionizing radiation etc.),
- trend data obtained from previous calibration records,
- recorded history of maintenance and servicing,
- frequency of cross-checking against other reference standards or measuring devices,
- frequency and quality of intermediate checks in the meantime,
- transportation arrangements and risk,
- degree to which the serving personnel is trained.

Although the cost of calibration cannot normally be ignored in determining the calibration intervals, the increased measurement uncertainties arising from longer intervals may mitigate against the apparently high cost of a calibration.

It is obvious from all these stated factors that a list of calibration intervals which can be universally applied cannot easily be constructed. It is more useful to present guidelines on how calibration intervals may be established, and then reviewed once calibration on a routine basis is under way.

The laboratory should select appropriate methods that have been published in standards (e.g. [2]), or by reputable technical organizations (e.g. [5], [7]), or in relevant scientific journals. A selection of such methods is presented in this document for the initial selection of calibration intervals and the readjustment of these intervals on the basis of experience. Laboratory-developed methods or methods adopted by the laboratory may also be used if they are appropriate and if they are validated.

The laboratory should document the methods used. Calibration results should be collected as history data, in order to base future decisions for calibration intervals of the equipment.

Independently from the determined calibration intervals the laboratory should have an appropriate system to ensure the proper functioning and calibration status of the reference standards and measuring equipment between calibrations (see Clause 5.6.3.3 of ISO/IEC 17025:2005).

2. Initial choice of calibration intervals

The initial decision in determining the calibration interval is based on the following factors:
- the instrument manufacturer's recommendation,
- expected extent and severity of use,
- the influence of the environment,
- the uncertainty of measurement required,
- maximum allowed deviation (e.g. by legal metrology),
- adjustment (change) of the individual instrument,
- influence of the measured quantity (e.g. high temperature effect on thermocouples),
- pooled or published data about the same or similar devices.

The decision should be made by someone with experience of measurements, in general, or of the instruments to be calibrated, in particular, and preferably with knowledge of the intervals used by other laboratories. This person should make an estimate for each instrument or group of instruments as to the length of time it is likely to remain within tolerance after calibration.

3. Methods of reviewing calibration intervals

Once calibration on a routine basis has been established, adjustment of the calibration intervals should be possible in order to optimise the balance of risks and costs as stated in the introduction. It will probably be found that the intervals initially selected are not giving the desired optimum results; instruments may be less reliable than expected; the usage may not be as anticipated; it may be sufficient to carry out a limited calibration of certain instruments instead of a full calibration, the drift determined by the recalibration of the instruments may show that longer calibration intervals may be possible without increasing risks, and so on.

A range of methods is available for reviewing the calibration intervals. They differ according to whether:

- instruments are treated individually or as groups (e.g. by manufacturer's model or by type),
- instruments go out of calibration by drift over time or by usage,
- instruments show different types of instabilities,
- instruments undergo adjustments (making history records to be evaluated in a different way),
- data are available and importance is attached to the history of calibration of the instruments.

The so-called engineering intuition which fixed the initial calibration intervals, and a system which maintains fixed intervals without review, are not considered as being sufficiently reliable and are therefore not recommended.

Method 1: automatic adjustment or "staircase" (calendar-time)

Each time an instrument is calibrated on a routine basis, the subsequent interval is extended if it is found to be within e. g. 80 % of the tolerance band that is required for measurement, or reduced if it is found to be outside this tolerance band. This "staircase" response may produce a rapid adjustment of intervals and is easily carried out without clerical effort. When records are maintained and used, possible trouble with a group of instruments indicating the desirability of a technical modification, or preventive maintenance, will be known.

A disadvantage of systems treating instruments individually may be that it is difficult to keep the calibration work-load smooth and balanced, and that it requires detailed advanced planning.

It would be inappropriate to take an interval to extremes using this method. The risk associated with withdrawing large numbers of certificates issued, or redoing large numbers of jobs may ultimately be an unacceptable.

Method 2: control chart (calendar-time)

Control charting is one of the most important tools of Statistical Quality Control (SQC) and well-described in publications (e.g. [3], [4]). In principle, it works as follows: Significant calibration points are chosen and the results are plotted against time. From these plots, both scatter and drift are calculated, the drift being either the mean drift over one calibration interval, or in case of very stable instruments, the drift over several intervals. From these figures, the optimum interval may be calculated.

This method is difficult to apply, in fact, very difficult in the case of complicated instruments and can virtually only be used with automatic data processing. Before calculations can commence, considerable knowledge of the law of variability of the instrument, or similar instruments, is required. Again, it is difficult to achieve a balanced workload. However, considerable variation of the calibration intervals from the prescribed is permissible without invalidating the calculations; reliability can be calculated and in theory at least it gives the efficient calibration interval. Furthermore, the calculation of the scatter will indicate if the manufacturer's specification limits are reasonable and the analysis of drift found may help in indicating the cause of drift.

Method 3: "in-use" time

This is a variation on the foregoing methods. The basic method remains unchanged but the calibration interval is expressed in hours of use, rather than calendar months. The instrument is fitted with an elapsed time indicator, and is returned for calibration when the indicator reaches a specified value. Examples of instruments are thermocouples, used at extreme temperatures, dead weight tester for gas pressure; length gauges (i.e. instruments that may be subject to mechanical wear). The important theoretical advantage of this method is that the number of calibrations performed and therefore the costs of calibration varies directly with the length of time that the instrument is used.

Furthermore, there is an automatic check on instrument utilisation. However, the practical disadvantages are many and include:

- it cannot be used with passive instruments (e.g. attenuators) or standards (resistance, capacitance, etc.),

- it should not be used when an instrument is known to drift, or deteriorate when on the shelf, or when handled, or when subjected to a number of short on-off cycles,
- the initial cost of the provision and installation of suitable timers is high, and since users may interfere with them, supervision may be required which again will increase costs,
- it is even more difficult to achieve a smooth flow of work than with the methods mentioned above, since the (calibration) laboratory has no knowledge of the date when the calibration interval will terminate.

Method 4: in service checking, or ”black-box” testing

This is a variation on methods 1 and 2, and is particularly suitable for complex instruments or test consoles. Critical parameters are checked frequently (once a day or even more often) by portable calibration gear, or preferably, by a ”black box” made up specifically to check the selected parameters. If the instrument is found out of tolerance by the ”black box”, it is returned for a full calibration.

The great advantage of this method is that it provides maximum availability for the instrument user. It is very suitable for instruments geographically separated from the calibration laboratory, since a complete calibration is only done when it is known to be required. The difficult is in deciding on the critical parameters and designing the ”black box”.

Although theoretically the method gives a very high reliability, this is slightly ambiguous, since the instrument may be failing on some parameter not measured by the ”black box”. In addition, the characteristics of the ”black box” itself may not remain constant.

Examples of instruments suitable for this method are density meters (resonance type); Pt-resistance thermometers (in combination with calendar-time methods); dosimeters (source included); sound level meters (source included).

Method 5: other statistical approaches

Methods based on statistical analysis of an individual instrument or instrument type can also be a possible approach. These methods are gaining more and more interest, especially when they are used in combination with adequate software tools. An example of such a software tool and its mathematical background is described by A. Lepek [9].

When large numbers of identical instruments i.e. groups of instruments are to be calibrated, the calibration intervals can be reviewed with the help of statistical methods. Detailed examples can be found for example in the work of L.F. Pau [7].

Method comparison

No one method is ideally suited for the full range of instruments encountered (Table 1). Furthermore, it should be noted that the method chosen will be affected by whether the laboratory intends to introduce planned maintenance. There may be other factors which will affect the laboratory’s choice of method. The method chosen will, in turn, affect the form of records to be kept.

	Method 1 'staircase'	**Method 2** control chart	**Method 3** 'in-use' time	**Method 4** 'black box'	**Method 5** other statistical approaches
Reliability	medium	high	medium	high	medium
Effort of application	low	high	medium	low	high
Work-load balanced	medium	medium	bad	medium	bad
Applicability with respect to particular devices	medium	low	high	high	low
Availability of instruments	medium	medium	medium	high	medium

Table 1: Comparison of methods reviewing calibration intervals

4. Bibliography

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