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Simplified Calibration Interval Analysis

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There are various procedures for assigning calibration recall cycles. Unfortunately many are complicated and cumbersome. A simplified method has been developed for laboratories with limited calibration histories. The method may easily be modified to meet metrology program reliability goals.

Calibration laboratories and their customers are both interested in establishing and adjusting calibration intervals and thus maximizing efficiency. As a result, all have a vested interest in selecting an effective means to establish the best calibration intervals. This paper will discuss a method developed to analyze calibration history with regard to both the simple as found condition (in or out of tolerance) and the degree of an out of tolerance condition should one exist (out of tolerance greater than 1x the tolerance, greater than 2x the tolerance, greater than 3x the tolerance, etc.). Analysis of these two variables indicates key factors, that when evaluated historically, may be developed into an algorithm for adjusting calibration cycles in accordance with the unique requirements of an individual metrology program.

The method presented here is a modification of existing algorithms stated in NCSL Recommended Practice 1 (RP 1). This paper will discuss the selection of calibration intervals and the application of this interval algorithm in relationship to observed results and in relationship to the algorithms of NCSL RP 1.

In most metrology labs we are under direction from many sources. ISO 17025, ANSI/NCSL Z540, ISO 9001 and unique customer requirements dictate in many ways how we are to do business. Quality programs are implemented to ensure that we follow all applicable requirements. One item of importance to calibration suppliers and users of calibration services alike is calibration recall cycles. These standards, along with calibration customers, determine requirements related to calibration intervals. Often we assign calibration intervals based on manufacturer's recommendations, or we have a larger organization making recommendations based on large samples of measurement and test equipment. However, when we follow these methodologies are we making the most efficient use of our resources? Every time an item is taken out of service for calibration, the resulting down time results in under utilization. If an item is left in service too long between calibrations, will it remain in calibration? If not, what is the associated cost due to the out of tolerance condition? It is obvious then as to why the assignment of calibration recall cycles are important to those involved with the calibration process and those who use measurement and test equipment.

What do the standards say about calibration intervals?

ISO 17025 – “A calibration certificate (or calibration label) shall not contain any recommendation on the calibration interval except where this has been agreed with the customer. This requirement may be superseded by legal regulations.”

ANSI/NCSL Z540 – “M&TE requiring calibration shall be calibrated or verified at periodic intervals established and maintained to assure acceptable reliability, where reliability is defined as the probability that M&TE will remain in tolerance throughout the interval.”

ISO-9001 – “Where necessary to ensure valid results, measuring equipment shall … be calibrated or verified at specified intervals, or prior to use…”

MIL-STD-45662A – "[MTE] and measurement standards shall be calibrated at periodic intervals established and maintained to assure acceptable accuracy and reliability, where reliability is defined as the probability that the MTE and measurement standard will remain in-tolerance throughout the established interval. Intervals shall be shortened or may be lengthened, by the contractor, when the results of previous calibrations indicate that such action is appropriate to maintain acceptable reliability. The contractor shall establish a recall system for the mandatory recall of MTE and measurement standards to assure timely recalibrations, thereby precluding use of an instrument beyond its calibration due date..."

Interestingly enough, the MIL-STD-45662A says more on the subject of calibration intervals than the current standards do.

In addition most quality organizations have specific requirements regarding the assignment of calibration intervals. They may sometimes set specific minimums or maximums and they may also set goals or metrics regarding end use reliability. Reliability is the ratio of instruments found to be in tolerance to the total number of instruments calibrated. Therefore, as calibration intervals are reduced, reliability should increase due to a higher percentage of in tolerance calibration results.

Several questions must first be asked in regards to calibration intervals. What items require calibration? What are the unique equipment/instrumentation requirements? How is the item to be used? What are the safety requirements? Why might I not want to calibrate an instrument? If these questions are answered, then it is established that the piece of M&TE requires or doesn’t require calibration and what type of calibration interval is required. Individual equipment requirements will sometimes indicate the calibration interval to be minimized or even calibrate before use when the risks associated with having an out of tolerance condition are high. Sometimes an instrument is used for indication only, which usually indicates a lack of a need for calibration. When an item is used in harsh conditions, many times a short calibration interval is in order. In safety critical operations, special care is required to assign an interval that will help to reduce the risk of injury to personnel or damage to equipment and capital assets. Occasionally, calibration customers may request that an item be removed from recall and placed in a “no calibration required” status. The appropriate response to those should indicate that if the data results are important to production results, safety or instrument failure, calibration should be required.

RP1 give several examples of items that do not require periodic calibration “No Periodic Calibration Required”. Some of the justifications include the following:

1. The instrument does not make measurements or provide known outputs.
2. The instrument is used as a transfer device whose measurement or output value is not explicitly used.
3. The instrument is a component of a calibrated system or function.
4. The instrument is fail-safe in that failure to operate within specified performance limits will be evident to the user.
5. The instrument makes measurements or provides known outputs which are monitored by a calibrated device, meter, or gage during use.
6. The instrument makes measurements which are required only to provide an indication of operational condition rather than **a** numerical value.
7. The instrument is disposed of after a short life cycle within which it is its measurement reliability holds to an acceptable level.
8. Fundamental (e.g., quantum-mechanical) standards.

Calibration intervals are established to meet a specified end-of-period reliability as determined by calibration history, vendor manuals and usage. The reliability target can be developed in house or may be established by a larger organization such as a customer or even a manufacturer. Reliability has been defined earlier as the probability that M&TE will remain in tolerance throughout the interval. This helps the user to have some level of confidence that their instruments will measure within a specified tolerance or uncertainty band for some period of time. That period of time is referred to as the calibration interval. Calibration at an established interval helps to ensure that measurements taken with a given piece of equipment will remain in tolerance between calibrations. Many organizations set reliability goals that may be achieved through the adjustment of calibration intervals.

Calibration recall cycles are established through manufacturer's recommendations, in-house engineering reviews, external engineering reviews and through customer requests. All four of these methods should rely on some type of engineering analysis, the differences center around who is making the analysis and what their goals are. Manufacturers have very large samples along with all their design engineering to make recommendations for calibration cycles. As such they are very good references for establishing calibration recall cycles. However, since the manufacturer has such a large sample population there are bound to be "dogs" and "gems", (those items that don't quite meet the population mean and those that exceed the manufacturer's expectations respectively). As a result many organizations may choose to review an instrument's performance and establish calibration cycles independent of the manufacturer. This may be performed on an internal basis for a particular organization or on a grander scale for a large multi-location organization.

A potential problem may exist when an in-house engineering review does not have as large a data population for making recommendations. However, because the analysis is unique to a particular customer or laboratory, this type of analysis can be tailor made to meet unique internal requirements and goals, providing unique insight into the performance of equipment for a specific user. Why is this important? An individual user has local environmental and use concerns that will impact the performance of their equipment.

Certain risks are inherent in any calibration recall cycle. Risk mitigation is a goal of calibration intervals. An appropriate recall cycle reduces the risk associated with using a measurement standard that is out of tolerance. There is little risk of calibrating a customer's piece of equipment with a standard that is "out of tolerance" when calibration cycles are short. A drawback associated with short calibration intervals however, is the risk of over calibrating and spending too much of the calibration budget on maintaining such a high reliability. Lengthy calibration intervals however, result in a higher risk of using a calibration standard that is "out of tolerance". Uncertainty is generally reported at time of test. As time progresses following calibration, the uncertainty of the standard must also follow some progression, the progression being an increased uncertainty band.

Theoretically, we should assign calibration intervals by analyzing a standard's measurement uncertainty including drift with time, and recalibrating when the uncertainty has increased to the point it has become unacceptably large. Unfortunately, this is impractical in most cases. A systematic approach can be made to establish and adjust calibration intervals with the objective of assigning the "best" calibration interval. Data available to most calibration laboratories makes it possible to analyze how a given measurement standard is performing historically and assigning a new calibration interval.

The RP1 describes various methodologies for calculating calibration intervals. Some are more complicated than others. Possibly the simplest to implement is the reactive method. The reactive method is just as it states – it is reactive to the most recent calibration. If the calibration is found to be "in tolerance" the interval is increased and if it is found to be "out of tolerance" it is decreased. The method to be described here takes this practice a step further by looking at the history of three previous calibrations and the degree of any "out of tolerance" conditions. The use of a calibration management laboratory database system simplifies the process required to establish a system such as this. The laboratory database system is used to access historical calibration results (in or out of tolerances) and reduces the results to assign a calibration interval.

The Algorithm

A review of an instrument's calibration history reveals something about how the instrument might be expected to perform in the future. If an instrument's calibration record indicates a history of remaining in tolerance it might be expected that the instrument might have a higher likelihood of remaining in tolerance. Likewise if it has performed poorly, it may have a higher probability of being found to be out of tolerance. However, if an adjustment was performed, the instrument should have a higher probability of remaining in tolerance. As a result the algorithm that has been developed calculates calibration intervals based on the condition received at calibration along with a historical weighting. The most recent calibration has the highest weighting and the previous two calibrations each have lower weightings. The example algorithm is as follows:

$$NI = CI \times (W1 \times X + W2 \times Y + W3 \times Z)$$

where: *NI = the new calculated interval*
CI = the old calibration interval
W1 = the weighting for the most recent calibration
W2 = the weighting for the previous calibration
W3 = the weighting for the previous calibration

X = the multiplier for the as found condition at the most recent calibration
Y = the multiplier for the as found condition at the previous calibration
Z = the multiplier for the as found condition at the previous calibration.

The multipliers are selected to perform the calibration interval adjustment desired by the laboratory. Each multiplier can be varied to meet the desired reliability outcome. In our example the multipliers used are as follows:

A = M&TE found "In Tolerance" = 1
B = M&TE found "Out of Tolerance" < 1x the tolerance band = 0.8
C = M&TE found "Out of Tolerance" > 1x the tolerance band but < 2x the tolerance band = 0.6
D = M&TE found "Out of Tolerance" > 2x the tolerance band but < 4x the tolerance band = 0.4
E = M&TE found "Out of Tolerance" > 4x the tolerance band but < 4x the tolerance band = 0.3.

The weightings are also selected to perform the calibration interval adjustment desired by the laboratory. Each weighting can be varied to meet the desired reliability outcome. In our example the weightings used are as follows:

W1 = Most recent calibration = 0.8
W2 = Previous calibration = 0.2
W3 = Previous calibration = 0.1.

These numbers are provided as an example only and should be varied to meet each individual laboratory's required reliability. The advantages to such a system as this are the ease of performing the calculation and the limited calibration history required to achieve valid numbers. In practice this algorithm has been used to produce the following results:

M&TE No.	Item	X	Y	Z	OLD CI	NEW CI
C59755	FLOWMETER	A	A	A	6.00	6.60
C58715	PRESSURE GAGE	A	A	A	12.00	13.20
015185	ANALYTICAL BALANCE	C	E	A	6.00	3.84
C61140	TORQUE WRENCH	A	A	A	6.00	6.60
1539309	CALIBRATOR	D	A	A	3.75	2.33
M76202	TRANSDUCER	B	A	A	12.10	11.37

Results in a typical lab should indicate over time those items which are not able to maintain a desired or requested tolerance. This data can then be used as a management tool to assist in the justification for replacement equipment. Additionally, with time, a cost saving should be observed through increased calibration intervals.

<u>Implementing the Algorithm</u>

Nearly all organizations use some type of calibration maintenance database. This algorithm can be used with many databases to perform automated adjustments to calibration intervals through the use of simple programming. The database must maintain a record of in or out of tolerance data along with the capability to track the degree to which the results were out of tolerance. The database must have fields available to indicate the condition received over each of the past three calibrations. Codes are used to indicate the condition received. The codes used in the example above (A, B, C, D, E), are sufficient to track the calibration condition received. Once enough data is available, three examples in this case, laboratory personnel can evaluate the algorithm on their unique data to ensure that results fit within the requirements of their quality system. At each calibration a recommended interval will be determined. An engineering review process determines if the new interval is appropriate or not. Observation of the results over time will indicate if reliability goals are being achieved and if further refinements are required to be made to the algorithm coefficients.

Upon implementation of any calibration interval algorithm, special care must be taken to avoid altering any calibration cycle that may not need adjustment. For instance, certain items may be required to have a maximum cycle not greater than some “x” months. Another potential problem may occur with poor performing instruments. An instrument with a poor calibration history will, if left unchecked, continue to decreasingly small calibration cycles, eventually approaching zero. Care must be taken to ensure that calibration cycles do not decrease beyond the minimum permitted cycle. Likewise, it is common place to have a maximum allowable calibration cycle. Restricting maximum and minimum calibration cycles can easily be achieved through the use of calibration laboratory management software and databases. Each organization should have requirements in place that dictate their individual requirements regarding establishment of calibration intervals and what their limitations are.

This algorithm is easily implemented with a calibration laboratory management database using historical fields for “out of tolerance” or “in tolerance” conditions along with the degree of any out of tolerance condition. A drawback to this is that in most cases data entry is required to indicate the degree of out of tolerance. This can be done by either entering the calibration results as a whole into the database or through the entry of specific out of tolerance conditions into the database. Database entry errors are possible in either case and appropriate reviews should take place to ensure the accuracy of data entered into the database. Of course the greatest advantage is the speed and resources required to actually perform the data reduction and assignment of new calibration intervals.

Summary

Calibration intervals are vital to the overall calibration management system in any organization. Care and thought must be given to any process for the establishment and adjustment of calibration intervals. Resulting calibration recall cycles will have one of three outcomes. They will be too restrictive, too loose or just right. Those that are too restrictive may result in over calibration of M&TE. Those that are too loose may result in out of tolerance conditions and subsequent reverse traceability issues. Identification of an ideal calibration interval is rewarding to the organization as a whole. There is no simple method for assigning calibration intervals. However, as stated here, the methodology may be simplified. Appropriate planning will result in calibration intervals that will meet the individual needs of the calibration management system. This will be of benefit to end users through appropriate levels of reliability and to management through efficient use of resources.

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References

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