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MEASURING EQUIPMENT CALIBRATION AND DETERMINATION OF THE INITIAL CALIBRATION INTERVAL

Abstract:

To optimize measurement procedures in laboratories, in terms of the balance between economics and risk, determination of the optimal calibration interval for measuring equipment has significant importance. This paper will show an approximate, but effective method for determination of initial calibration interval, regarding "ILAC" guidelines and original recommendations based on authors' experience. The presented applied method is adapted for the equipment used in a laboratory for building materials and structural testing, and the results of its application are shown on the examples of several different instruments. Impact factors on calibration intervals are analyzed, and the basic recommendations for revision of the initial calibration intervals are given.

Keywords: calibration, measuring equipment, initial calibration interval, ILAC guidelines

КАЛИБРАЦИЈА МЈЕРНЕ ОПРЕМЕ И ОДРЕЂИВАЊЕ ПОЧЕТНОГ ИНТЕРВАЛА КАЛИБРАЦИЈЕ

Сажетак:

Да би се извршила оптимизација поступака мјерења у лабораторијима, у смислу баланса између трошкова и ризика, одређивање оптималног интервала калибрације мјерне опреме има велики значај. У овом раду, у циљу одређивања почетног интервала калибрације, приказана је приближна, али ефективна метода, која је у складу са "ILAC" смјерницама и оригиналним препорукама заснованим на искуству аутора. Презентована примјењена метода је прилагођена опреми која се користи у подручју испитивања материјала и конструкција, а резултати њене примјене приказани су на примјерима неколико различитих инструмената. Анализирани су фактори који утичу на интервале калибрације и дате су основне препоруке за ревизију почетног интервала.

Кључне ријечи: калибрација, мјерна опрема, почетни период калибрације, смјернице ILAC

1. INTRODUCTION

Every measurement is accompanied by errors, and the causes of these errors may be different. A common classification of measurement errors is: random, system and gross. Random errors are a result of imperfections of measuring instruments and imperfections of the senses of a person performing the measurements. They are always of a different sign and they are considered as inevitable. Gross errors are caused by an insufficient attention of a laborant and they must be excluded not to affect the test result. System errors, discussed in this paper, are the errors that occur as a result of the uncalibrated measuring instruments. In repeated measurements, such errors have the same sign and, approximately, the same intensity. It is important to note that, generally, their causes can be eliminated or reduced to a fair extent. Regarding this, this paper points out that the calibration and the determination of adequate calibration interval is of the utmost importance for the elimination of system errors.

During any scientific or commercial testing within accredited laboratories, to ensure the proper functioning of the equipment during its operation, its reliability and the required precision in the measurement and testing processes, laboratories should use only calibrated measuring equipment. This is strictly defined by the standards EN ISO/IEC 17025: *General requirements for the competence of testing and calibration laboratories,* and EN ISO 10012:2004 *Measurement management systems - Requirements for measurement processes and measuring equipment* [1], [2].

In addition to the status of calibration, i.e. determination of measurement traceability, standards [1], [2], require defining equipment management process, instructions for handling and maintenance, keeping servicing records and controlling measuring and environmental conditions. All mentioned needs to be defined in general and specific laboratory instructions for the equipment in use.

Based on the stated above, as well as on the experiential processes in the building material and structural testing laboratories, a schematic overview of the equipment management system within a testing laboratory is shown in Figure 1.

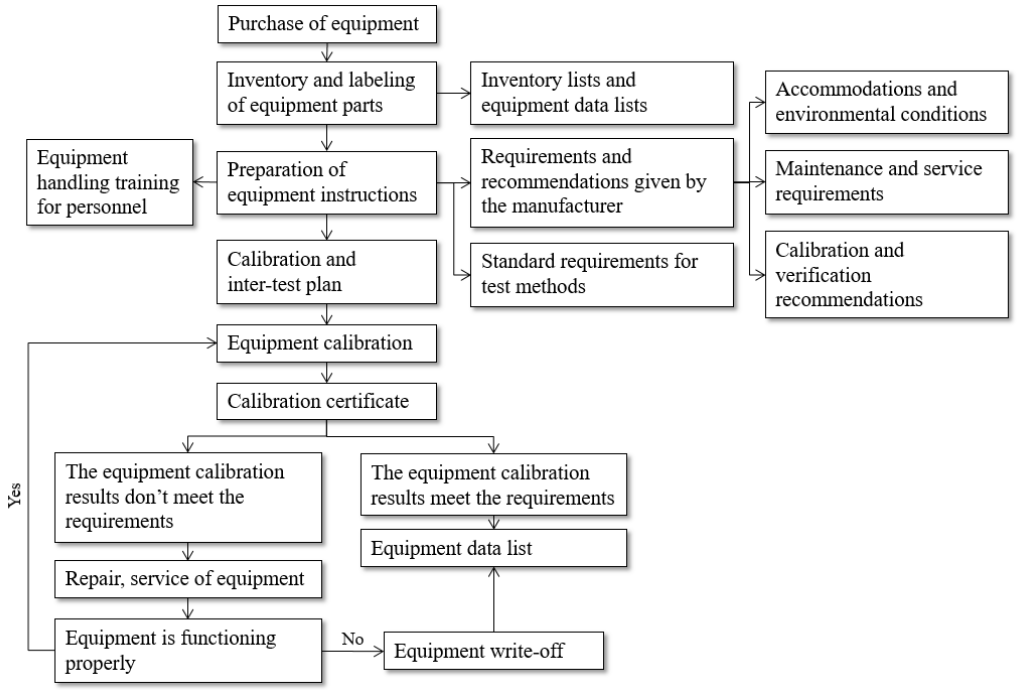

Figure 1. *Equipment management system scheme within a testing laboratory* [3]

Calibration ensures that in established intervals, measurements taken with a piece of equipment will remain in-tolerances, regarding defined measurement uncertainty between calibrations. Frequent calibration can ensure the quality of measurements, but if the interval is not optimal it leads to unnecessary costs. Factors to consider in calibration plan, as well as possible methods for determination of calibration intervals, are given in guidelines ILAC- G27:06 *Guidance on measurements performed as part of an inspection process* [4].

So, to reduce the risk of errors, but also the cost of calibration, it is in the interest of laboratories to determine the optimal calibration interval.

In this regard, in this paper, an orientational, but effective initial calibration interval calculation algorithm is presented. This algorithm for determining the initial calibration period was developed by the Brazilian Calibration Group (https://www.grupocalibracao.com.br/), and it is demonstrated on the example of the calibration period determination for the equipment used in the pharmaceutical industry [5] and for the equipment used for geodetic measurements [6]. Method is adapted for building materials and structural testing laboratories (mostly regarding defining wider scope of qualitative parameters) by the author of this paper, and following instructions given by ILAC [4].

Subject modified method, applied in document [3], was revised during the accreditations of the laboratory of the Public institution *Institute for urbanism, civil engineering and ecology of Republic of Srpska*, it's Business unit *Institute for materials and construction testing* and also "*GIM-TEST*" *ltd Banja Luka* laboratory.

The obtained results for the initial time intervals, according to the proposed model, are compared to the maximum initial intervals prescribed by the corresponding standards and/or manufacturer's recommendations for a specific group of laboratory equipment for testing of building materials and structures. Given the existence of the equipment for which there are no instructions or recommendations defined by the standards, or given by the manufacturer, it is of the utmost importance development and elaboration of such models. Also, recommendations for revision of calibration time interval are given.

2. CALIBRATION OF MEASURING EQUIPMENT

The standard EN ISO/IEC 17025: *General requirements for the competence of testing and calibration laboratories*, emphasizes establishing calibration programs for measuring equipment and/or parts of measuring equipment that have an impact on measurement results. For a valid measurement result, the measuring equipment must be calibrated using standards for which traceability to the Internacional System of Units can be shown, by the means of a documented unbroken chain of calibrations, each contributing to the measurement uncertainty [1].

To ensure traceability, equipment calibration is performed only in accredited calibration laboratories. In Figure 2. traceability pyramid scheme for the measuring equipment is given [7].

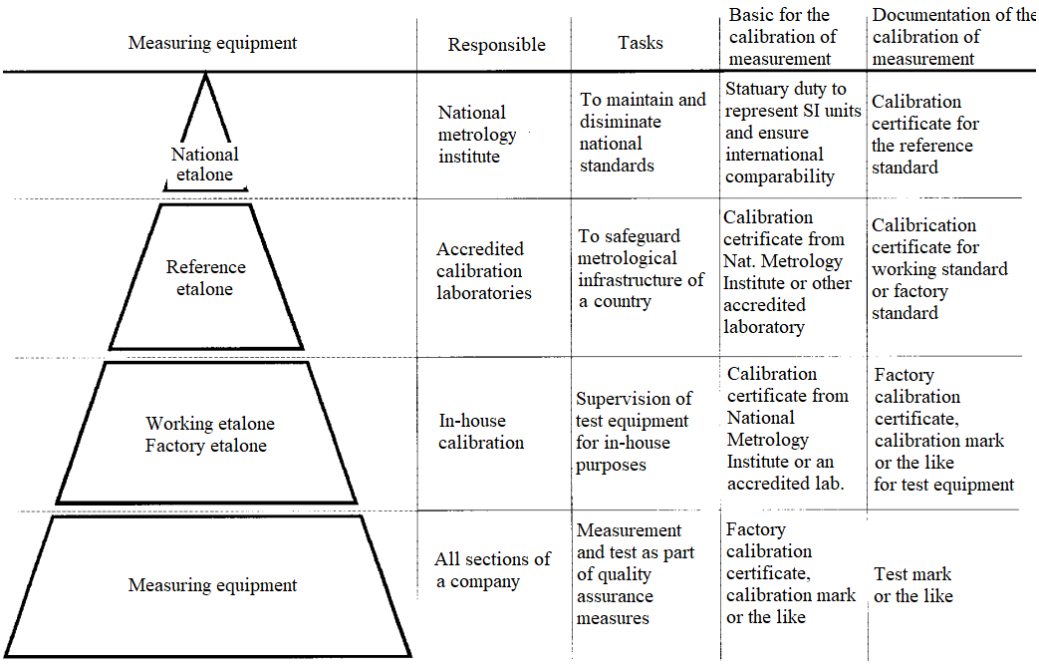

Figure 2. *The traceability pyramid with the basic characteristics of each pyramid stage* [7]

2.2. Measurement reliability

The purpose of a periodic calibration is to decrease deviation between a reference value and the value obtained using a measuring equipment, to define the uncertainty in this deviation, and also to

indicate an eventual occurrence of some technical changes in the measuring equipment that would affect measurement results [4].

The calibration interval should be established by the analysis of instrument measurement reliability which changes in time, and the instrument needs to be calibrated before its measurement uncertainty reaches an unacceptable limit, for example concerning the requirement of a standard for a testing result [8]–[10].

Measurement reliability of measuring equipment can be calculated for individual equipment, using experimental data. At any given time since calibration, the probability that equipment measuring parameters are in tolerated limits can be checked by performing a number of calibrations n (t) at different time intervals. If the number of calibrations for which the parameter was found in-tolerance is represented by the variable g (t), then the sampled measurement reliability $\tilde{R}(t)$ for time t, as defined in [9], is:

$$\tilde{R}(t) = \frac{g(t)}{n(t)} \tag{1}$$

In experimental researches [9], [10], number of calibrations were performed at different time distances from the initial reference calibration and measurement results were arranged in ascending time interval to gain observed measurement reliability time series, as shown in the example on Figure 3.

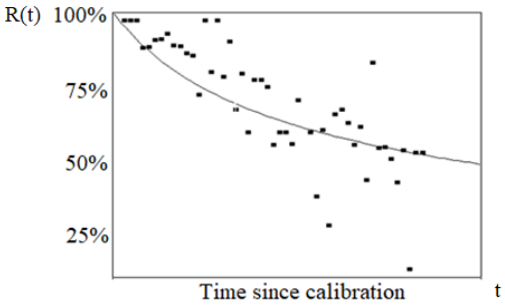

Figure 3. *Measurement reliability time series* [10]

2.3. Parameters affecting the calibration interval

Laboratories should take into account a large number of factors which influence the allowed time interval between calibrations, and according to [4], some of the most relevant ones are:

- measurement uncertainty required by the laboratory,
- risk of a measuring instrument exceeding the maximum permissible error when in use,
- risk of necessary correction measures costs if an instrument is not working with required measurement uncertainty,
- the instrument's type of and a tendency to wear and drift,
- extent of use,
- recommendation given by the manufacturer of the instrument,
- environmental conditions (temperature, humidity, vibration, etc.),
- data obtained from previous calibrations,
- frequency and quality of inter-tests against other reference standards or measuring devices,
- transportation arrangements and risk,
- training of personnel performing measurements.

3. DETERMINATION OF THE OPTIMAL CALIBRATION INTERVAL

Optimal calibration intervals are those which can be established to provide measurement reliability objectives in maximum periods between adjacent calibrations. The process for determination of optimal interval is a statistical process, requiring accurate and sufficient data taken during the monitoring of equipment behavior [9], [11]–[13].

There appears to be no universally applicable single best practice for establishing and adjusting the calibration intervals, which is why every laboratory needs to be familiar with its equipment

measuring parameters and understand the calibration interval determination process. Also, for the range of measuring instruments, no single method is ideally suited [4], [11]–[13].

The equipment calibration time interval is determined in two phases, namely [4]:

- initial determination of the calibration interval and
- revision of the calibration interval.

Guided by the requirements of the standards [1], [2], every accredited laboratory should have a general equipment-related procedure, which includes a method for determining the initial and revised calibration interval.

Initial interval determination can be based on requests given in standards, recommendations in guidelines and manufacturer's instructions, if available. If not, a laboratory needs to develop or adopt own internal method. Initial interval is later modified after revising calibration certificates and eventual inter-tests and taking into account the changes in relevant impact factors used in defining the initial period.

3.1. Initial calibration interval

In the following, a method for determining the initial calibration interval (applied in the accredited testing laboratory "GIM-TEST" ltd Banja Luka) is presented, taking into account all parameters, according to the requirements of "ILAC" guidelines [4] and based on experience.

In the initial determination of calibration interval, it is important to consider particular instrument characteristics, measurement process, methods and standards used for measurements.

To determine the initial calibration interval (Pi), the following order of activity is suggested [3]:

- Review of the requirements in standards regarding all test methods in which the subject equipment is used. If the standard for the test method specifies the calibration interval for the equipment used, it is taken as the initial and no further analysis is necessary. In a case where one instrument is used for several different test methods, according to different standards, and if those standards prescribe different calibration intervals, then a more stringent requirement, i.e. shorter calibration interval, is adopted as the initial.
- If the calibration interval is not defined in the specific standard for the test methods in which the equipment is used, it is necessary to check the series of standards to whom the standard in question belongs. If there is a standard in the series that defines the correct calibration time interval, it is adopted and no further analysis is necessary.
- If referent standards do not define calibration intervals and they are given in the manufacturer's instructions, they shall be adopted as a starting point for further analysis, which shall include consideration of coefficients based on qualitative factors.
- If the referent document defining the calibration intervals does not exist, as in many testing methods, laboratory internal calibration interval is determined and defined in the laboratory instruction.

In this paper, the initial calibration interval method was applied for the equipment listed in Table 1, where, in addition to the name of the equipment, information is provided on the manufacturer, specific equipment model, measuring range and precision, referring the imperfection of measuring instruments.

Table 1. *Equipment list to which the proposed initial interval calculation model was applied*

No	Equipment	Manufacturer	Model	Measuring range	Precision
1	Digital scale 0-30kg	KERN	FKB30K1A	0-30000 g	1 g
2	Digital scale 0-6 kg	KERN	PCB 6000-1	0-6000 g	0.1 g
3	Position transducer	NovoTechnik	TR-0010 PIN	0-11 mm	0.001mm
4	Caliper	INSIZE	1108-300W	0-300 mm	0.01mm
5	Digital comparator	INSIZE	2314-10A	10 mm	0.01mm
6	Glass thermometer	TLOS Zagreb	100	-2 - +100ºC	0.2ºC

7	Hydrometer	UTEST	UTGP-1240	20 do 99 %	1.0 %
8	Digital stopwatch	UTEST	UTGT-1580	0-9999 s	0.01 s
9	Shear machine	UTEST	UTS-2060	100-400 kPa	0.01 kN
10	Compression testing machine	MATEST	C089-08	0-3000 kN	0.01 kN
11	Air-entrainment meter	HEMMER	LP-0017	0-100 %	0.1 %

Following the above-stated sequence of activities for determination of the initial calibration interval, an analysis of all applicable standards and documentation provided by the equipment manufacturer was carried out. So, as confirmed through the sample given in Table 1, not all measuring equipment in laboratories has prescribed calibration intervals in standards in use. For such equipment, it is important to have a calculation model for the interval determination.

For measuring equipment numbered 1-6 and 8 in Table 1, there are instructions given in reference standards regarding maximum calibration interval, while for the equipment numbered 7 and 9-11 that information is missing. Although, following the suggested order of activities, for determination of the initial period, the application of calculation model for instruments numbered 1-6 and 8, is not needed, it was performed, to compare the intervals obtained using the below described algorithm and those limited by the standard.

In the determination of an initial period of calibration, guided by the developed algorithm used in [5], [6], all quantitative and qualitative factors were defined [14] that affect the subject equipment. The algorithm considers general quantitative and qualitative influences, and more detail defining of these influences, such as the thermohygrometric conditions in which the equipment is used, the test field, the type of measured quantity, etc, which relate to the field of building materials and structural testing and the specific equipment, are suggested in the following sections.

3.1.2. Quantitative factors

According to the model for determination of Pi, presented in the paper, quantitative factors that influence the determination of the calibration interval, imply external influences which may cause physical damage to the measuring equipment and its parts.

The influence of quantitative factors on a determination of the initial calibration time interval is defined by a total factor TF, which is obtained from the following expression:

$$TF = F_t \times F_u \times F_e \quad (2)$$

Where:

F_t – equipment transportation factor, with values:

- 9 - 10 when equipment is transported daily before the use,
- 6 - 8 when the equipment is transported once to three times a month,
- 3 - 5 when the equipment is transported once to three times a year,
- 1 - 2 when the equipment is transported only inside the laboratory or not at all;

F_u – equipment utilization factor, with values:

- 9 - 10 when equipment is used daily,
- 6 - 8 when the equipment is used once to five times a month,
- 3 - 5 when the equipment is used several times a year,
- 1 - 2 when the equipment is used once a year or not used at all;

F_e – a factor of external impact on equipment, with values:

- 9 - 10 when the impact on the equipment is very high (extreme thermohygrometric variations conditions, exposure to the possibility of physical damage ...),
- 6 - 8 when the impact on the equipment is moderate (moderate variation in thermohygrometric conditions, dust ...),
- 3 - 5 when the impact on the equipment is small (rare exposure to moderate variations in thermohygrometric conditions, less possibility of contact with dust…),

1 - 2 when the impact on the equipment is very small (controlled conditions).

After a determination of the value TF, an initial calibration interval is adopted, according to Table 2. Maximum period of 156 weeks, or 3 years, is given by the recommendations of the Brazilian Calibration Group [5], [6].

Table 2. *Times in weeks for different values of quantitative factor TF [5], [6]*

The range of TF	Initial time interval	The range of TF	Initial time interval
800 ≤ TF < 1000	4 weeks	**63 ≤ TF < 100**	65 weeks
525 ≤ TF < 800	13 weeks	**38 ≤ TF < 63**	78 weeks
320 ≤ TF < 525	26 weeks	**18 ≤ TF < 38**	91 week
160 ≤ TF < 320	39 weeks	**10 ≤ TF < 18**	104 weeks
100 ≤ TF < 160	52 weeks	**TF <10**	156 weeks

The adopted maximum period was retained herein, as it remains on the safe side, comparing to the proposals given in certain European standards for methods in the field of building materials and structural testings, regarding the maximum intervals for some instruments. For example, for calipers or thermometers in the group of standards for bitumen testing (according to EN 932) maximum calibration period defined is 5 years.

As can be seen, for the same type of equipment, quantitative factors can be different, thus the initial calibration period. Also, differences in values of these factors greatly affect the number of weeks taken as the initial time interval, so in a case of doubt, it is recommended to adopt values to be on the safe side.

For the equipment considered herein, the values of the quantitative factors, as well as the initial period in weeks, determined up to this point, are given in Table 3.

Table 3. *Quantitative factors and initial interval for a considered group of equipment*

No	Equipment	F_t	F_u	F_e	TF	Weeks	Days
1	Digital scale 0-30kg	1	10	1	10	104	728
2	Digital scale 0-6 kg	1	7	1	7	156	1092
3	Position transducer	2	7	2	28	91	637
4	Caliper	3	8	6	144	52	364
5	Digital comparator	1	8	1	40	78	1092
6	Glass thermometer	1	5	8	40	78	455
7	Hydrometer	2	10	2	40	78	546
8	Digital stopwatch	2	8	4	64	65	455
9	Shear machine	1	8	1	8	156	1092
10	Compression test. mach.	1	10	2	20	91	637
11	Air-entrainment meter	6	4	4	96	65	455

3.1.3. Qualitative factors

Qualitative factors refer to the parameters that directly affect the process of measurements, i.e. processes that lead to the weakening of the measuring equipment. Their intensity affects the calibration interval in terms of the correction of the interval based on the quantitative factors.

Qualitative factors are defined by the factor Q, which may extend or shorten the calibration interval obtained by quantitative factors, or the period adopted based on the recommendations of the equipment manufacturer.

Factor Q represents a scope of all defined effects on the calibration interval, expressed by the coefficients q, by the expression:

$$Q = q_1 \times q_2 \times q_3 \times ...q_n \quad (3)$$

Where:

q_1 – the impact proportional to the ratio of the required precision according to the standard and the precision of the instrument with the measurement uncertainty included,

q_2 – the impact of the equipment based result on the overall result,

q_3 – possibility of the influence of equipment loading,

q_4 – the impact of the time weakening of the equipment characteristics,

q_5 – operator influence impact, if the equipment operator can influence the measurement result,

q_n – other possible impacts.

The values of the coefficients q are determined based on impact intensity, so if the factor does not affect the calibration interval, it extends the calibration interval and vice versa:

- 0.80 for critical impact,
- 0.90 for great impact,
- 1.00 for normal impact,
- 1.10 for low impact,
- 1.20 no impact.

Regarding stated, practical examples for the values of particular coefficients q_i are given, namely:

- a value for q1 of 0.8 is taken if the precision of the instrument is the same as required by the standard, and if the precision of the instrument is higher, the coefficient increases proportionally,
- for q2, on the example of a compression testing machine, which has a critical impact on the final result, adopted value is 0.80, while for a stopwatch used indirectly for certain methods, a value of 1.00 is taken,
- value of 0.80 for q3 is taken if a force measuring equipment is used up to the maximum measuring range, which is a critical influence, whereas, in the case of using a thermometer for measuring ambient temperature in the laboratory, this value can be taken at 1.20.
- data needed for the determination of the factor q4 are given by the manufacturer's recommendations, and can also be determined by an experience with a related instrument, eg constant use of some types of comparators can affect their precision, so the recommended value is 0.80, for scales or presses of modern manufacturers, this influence is moderate and the coefficients of 0.90-1.10 can be assigned, whereas this is not the case for a rulers or thermometres where a factor of 1.10-1.20 is normally taken,
- a value of 1.20 is defined for the factor q5, for the compression or shear machine, which are not susceptible to the operator's influence, while during a dimension measurement with a caliper, the operator's influence is large, and thus a coefficient of 0.80 is to be assigned,
- qn - during the development of the calibration plan, other possible influences, not listed herein, may affect the equipment and should be taken into account through a detailed analysis of the characteristics of specific equipment, manufacturer's recommendations and available literature for the same or similar equipment.

Table 4. *Qualitative factors for initial interval correction for the considered set of equipment*

No	Equipment	q_1	q_2	q_3	q_4	q_5	Q
1	Digital scale 0-30kg	0.9	0.8	1.2	0.9	1.2	0.9331
2	Digital scale 0-6 kg	0.8	0.8	1.2	0.9	1.2	0.8294
3	Position transducer	0.8	0.8	1.2	1	1.2	0.9216
4	Caliper	0.9	0.8	1.2	1	0.8	0.6912
5	Digital comparator	0.8	0.8	1.2	1	1	0.7680

6	Glass thermometer	0.8	0.8	1.2	1.1	1	0.8448
7	Hydrometer	1.2	0.8	1.2	0.9	1.2	1.2442
8	Digital stopwatch	1.2	1	1.2	1.2	1.2	2.0736
9	Shear machine	1	0.8	0.9	1	1.2	0.8640
10	Compression test. mach.	0.8	0.8	1.2	0.9	1.2	0.8294
11	Air-entrainment meter	1	0.8	1.2	0.9	1	0.8640

According to [5] and [6], only 3 qualitative characteristics are defined, but herein, regarding requirements needed for accreditation [1], and guided by "ILAC" [4], qualitative influences are elaborated in much more detail.

3.1.4. Estimated calibration initial interval

Final initial calibration interval Pi, is obtained from the expression:

$$Pi = TF \times Q \tag{3}$$

Table 5 shows initial calibration intervals obtained using the algorithm presented.

Table 5. *Final initial calibration period obtained for the considered set of equipment*

No	**Equipment**	**TF**	**Days**	**Q**	**Pi** (days)	**Requirements given in standards**
1	Digital scale 0-30kg	10	728	0.933	679	<730
2	Digital scale 0-6 kg	7	1092	0.829	906	<730
3	Position transducer	28	637	0.922	587	<365
4	Caliper	144	364	0.691	252	<365
5	Digital comparator	40	1092	0.768	419	<365
6	Glass thermometer	40	455	0.845	384	<1825
7	Hydrometer	40	546	1.244	679	-
8	Digital stopwatch	64	455	2.074	943	<365
9	Shear machine	8	1092	0.864	943	-
10	Compression test. mach.	20	637	0.829	528	-
11	Air-entrainment meter	96	455	0.864	393	-

Most of the initial calibration intervals obtained using the algorithm are shorter than the maximum intervals defined by the standards, but that there are also some with longer intervals obtained. This is understandable because each laboratory has its specific conditions of use, workload, transportation, and similar, that must be taken into account.

The biggest difference is seen for the glass thermometer. This is because the maximum calibration interval, according to Table 2 is 3 years, and, as mentioned, in a group of standards for the methods which apply this instrument, the maximum defined interval is 5 years.

3.2. Revision of the calibration interval

Once the initial calibration interval has been established, which relied on the adequate impact factors, but also on "engineering intuition", to optimize the balance of risks and costs, this interval must be adjusted in later use, taking into the account monitored instrument behavior [9]–[11].

It is expected that the intervals initially selected do not give the desired optimal results in long term, since the instruments can be less reliable than expected, the usage may not be as anticipated, or any other factor can differ from the expected factor that affected initial interval determination, or can change after a certain period.

The revision of the equipment calibration interval is performed based on the equipment characteristics, considering the results of previous calibrations and the results of inter-tests.

For reviewing and precise determination of calibration interval impact factors, and modification of initial interval, several methods are described and recommended by "ILAC" guidelines [4]:

- automatic adjustment or "staircase" ,
- control chart,
- "in-use" time,
- in service checking, or "black-box" testing,
- other statistical approaches.
- The methods chosen differ according to several factors, for example, their suitability for different types of equipment. The overview is given in Table 6.

Table 6. *Comparison of methods for reviewing calibration interval [4]*

	"Staircase"	Control chart	"In-use" time	"Black box"	Other approaches
Reliability	*Medium*	*High*	*Medium*	*High*	*Medium*
Effort of application	*Low*	*High*	*Medium*	*Low*	*High*
Work-load balances	*Medium*	*Medium*	*Bad*	*Medium*	*Bad*
Applicability for particular devices	*Medium*	*Low*	*High*	*High*	*Low*
Availability of equipment	*Medium*	*Medium*	*Medium*	*High*	*Medium*

As a method that responds to the problems in testing laboratories in the field of building materials and structures, an easily applicable, the "staircase" method is discussed herein. The revision of the intervals, using this method, performed on the basis of the calibration results, is carried out by monitoring the constancy of the equipment regarding its accuracy. If the calibration results, obtained in equipment calibration certificates, deviate within the limits of 80% of the maximum allowed measurement error (for example, given in standards for methods), the initial calibration interval Pi can be multiplied by a factor > 1.0. Otherwise, the adopted calibration initial interval is divided by a factor > 1.0 [4]. This system treats the instruments individually and they are sent for recalibration at different periods.

The risk of a measuring instrument exceeding the maximum permissible error when in use is reduced using defined procedures for ensuring the proper functioning and calibration status of the measuring instruments between calibrations. Between calibrations, it is necessary to monitor the changes in measurements through an inter-tests, using certified reference materials and/or calibrated standards. The revision of the calibration intervals based on the results of the inter-tests should be carried out only if a constant decrease in the characteristics of the equipment is shown. It is suggested that, if the results show a constant drop, beyond the 60% limit of the maximum permissible error required for measurement, the equipment should be sent for extraordinary calibration. Inter-tests time intervals are determined within the laboratory, based on the adopted calibration time interval, in such a way that they are allocated at regular time intervals, and the minimum time interval is determined according to the utilization factor of the equipment F_u.

4. CONCLUSIONS

To gain a reliable measurement results, and to ensure measurement traceability, measurements must be carried out using reliable equipment. Regarding this, measuring equipment must be monitored and calibrated regularly.

Calibration intervals are established to meet measurement reliability objectives, but to reduce unnecessary calibrations, and thereby costs, an optimal calibration interval should be implemented.

Knowledge in the functioning of laboratory equipment and monitoring its operation are key factors in determining the optimal interval. To manage these intervals, many probabilistic methods have been developed. These methods depend on the type of equipment and measuring conditions.

This paper presents an application of the algorithm for the approximate optimal initial calibration interval determination. Used algorithm is modified, considering all relevant factors which meet the recommendations given by the "ILAC" guidelines, and based on the authors' experience. The contribution stated in this paper is an elaboration of parameters considered, which is not covered by the standards defining the calibration periods, by the technical data sheets of the manufacturers of the measuring devices, or by the guiding algorithm. They are based on specific problems in the field of using equipment for building material and structural testing.

The determination of the initial period is described in the example of a set of measuring devices from a laboratory for building materials and structural testing. To determine the initial calibration period, quantitative and qualitative parameters that affect this period are elaborated and defined, and examples are given for determining their values. In terms of defining qualitative factors, a more detailed classification is given, compared to the existing in guiding algorithm.

Also, methods for determination of the revised calibration interval are discussed, which is performed based on all previous calibrations of the equipment and monitoring its consistency. The methods for revision of the calibration period differ according to several factors, for example, their suitability for different types of instruments.

LITERATURE

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