

## DETERMINING RECALIBRATION INTERVAL FOR LABORATORY EQUIPMENT

### UTVRĐIVANJE INTERVALA REKALIBRACIJE LABORATORIJSKE OPREME

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**SUMMARY**

*This paper describes the application of international standards, recommendations and guides, as well as other input data, to determine the interval of recalibration of laboratory equipment in the laboratory for testing the product safety testing LIND in Zenica, Bosnia and Herzegovina. An example of a pressure sensor on a 4-axis device for measuring the geometry of furniture, a detailed analysis of the recalibration interval was performed, which had to be shortened from 5 to 3 years.*

*Stručni rad*

**REZIME**

*Ovaj rad opisuje primjenu međunarodnih standarda, prepruka i vodiča, kao i drugih ulaznih podataka, za određivanje intervala rekalkibracije laboratorijske opreme u laboratoriji za ispitivanje sigurnosti proizvoda LIND u Zenici, Bosna i Hercegovina.*

*Na primjeru jednog senzora pritiska na 4-osnom uređaju za mjerenje koordinata geometrije namještaja, izvršena je detaljna analiza intervala rekalkibracije, koji je morao biti skraćen sa 5 na 3 godine.*

## 1. INTRODUCTION

A number of authors investigated this topic for different measuring equipment, from torque meters to atomic clocks.

Vasilevskyi in [1] presented a method for determining the recalibration interval of measurement tools, based on the measurement uncertainty analysis of experimental data with the metrological certification. He used the results of testing procedures to determine the recalibration interval for equipment measuring motor torque.

Natalinova et al. in [2] presented the calibration interval calculation of the potentiometer according to the verifications for the 4 year period in the aviation plant. The calibration interval increased according to the calculation of its reliability and stability of metrological characteristics.

Nunzi et al. in [3] compared three different methods for the establishment of optimal

calibration intervals of atomic clocks: one based on a stochastic model, the others pertained to the class of the reactive methods, determining the optimal interval based on the last calibration outcomes.

Wang et al. in [4] proposed an approach for evaluating the optimal calibration interval of automatic test equipment on the basis of the metrology chain. The calibration interval of a single instrument is determined by a grey prediction model, using out of tolerance-calibration matrix to calculate the metrology contribution rate, according to the multi-signal flow model.

The process of determining calibration intervals is a complex mathematical and statistical process requiring accurate and sufficient data taken during the calibration process. There appears to be no universally applicable single best practice for establishing and adjusting the calibration intervals. This has created a need for better

understanding of the calibration interval determination. As no single method is ideally suited for the whole range of measuring instruments, some of the simpler methods of assigning and reviewing the calibration interval and their suitability for different types of instruments are covered in OIML Guide [5] and in NCSL Recommended Practice [6].

The NCSL Recommended Practice RP-1 [6] provides a guide for the establishment and adjustment of calibration intervals for equipment subject to periodic calibration. It provides information needed to design, implement and manage calibration interval determination, adjustment and evaluation programs.

Bare in [7] simplified the methods from [6] for laboratories with limited calibration histories. His algorithm uses a calibration laboratory management database with 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 [7].

Zhenlin et al. in [8] performed the dynamic optimization of measuring instrument calibration interval, predicting the history calibration data by modelling. They used the improved moving average method to predict the development trend of parameters, BP neural network to compensate the predicted residual sequence, and gave the improved MA-BP prediction model to optimize the calibration interval dynamically.

## 2. ABOUT THE LABORATORY FOR PRODUCT SAFETY TESTING "LIND" ZENICA

The Laboratory LIND was created as a result of the project MENTOR financed from the European Union Development Funds for Bosnia and Herzegovina. The project implementation was co-funded by the City of Zenica, Ministry of Economy of the Zenica-Doboj Canton, Regional Development Agency REZ, and the Federal Ministry of Development, Entrepreneurship and Crafts.

Initially, the laboratory performed only furniture testing [9], and through the time, it has grown into the Laboratory for Product Safety Testing, including the testing of children's playgrounds.

The project MENTOR 2, expanded the testing area to the building construction elements (doors, windows and facade elements). Figure 1 shows the interior of the laboratory.



*Figure 1. Laboratory for furniture testing [9]*

### 2.1. Equipment maintenance

The laboratory management and staff in LIND keeps control of the equipment conditions within their responsibilities. In order to maintain the proper conditions of the laboratory equipment, a maintenance plan and a calibration plan for each year is prepared according to adopted forms, in accordance with the manufacturer's instructions, OIML D10 Guidelines for the determination of calibration intervals of measuring instruments, examples of recommended calibration intervals given by BATA (Accreditation Institute of Bosnia and Herzegovina), and Appendix A of the standard BAS EN ISO 10012-1:2004 [10].

These plans are developed in accordance with the procedures of Equipment Maintenance and Equipment Calibration. Testing machines and equipment are handled by trained and authorized laboratory staff. Each test device and equipment, is accompanied with a brief instruction manual.

### 2.1. Equipment documentation

For all machines, equipment, and, if necessary, parts of this equipment, the basic data is recorded in the official form. Records of overhauls and repairs of machines and equipment are recorded in the form "Plan and Equipment Maintenance Record" and are kept with the appropriate device record. Records of the resulting failures of calibration equipment are recorded on the form "Record of incurred defects in machinery and equipment".

For every piece of equipment, a traceability chart is provided in the appropriate form, which shows the calibration traceability of this device to the

national or international standards. Traceability charts are kept with the appropriate lists. For all devices that are calibrated, a record of the calibration history is recorded in the form "Plan and Record of Equipment Calibration". Completed and updated form of the calibration history of the machine/equipment/standard is part of the official documentation and serves as the documented definition of the recalibration period.

Calibration certificates for test machines and equipment are stored in the registry "Calibration Certificates of Machines and Equipment".

Laboratory personnel is responsible for the correctness and condition of testing machines and equipment in the laboratory. If equipment or part of the equipment is damaged during the use, the personnel shall comply with the Maintenance procedure for machinery and equipment.

Any piece of equipment or device that has suffered an overload or is found to be defective, is handled in accordance with the Maintenance procedure for machinery and equipment, and marked with the label "OUT OF ORDER".

## 2.2. Equipment calibration

For each testing machine and equipment, there are appropriate Plan and records on performed calibrations, in which the following elements are recorded, monitored, checked and analysed:

- Equipment name, inventory number, manufacturer;
- Measurement range;
- Calibration range;
- Measurement uncertainty;
- Date of valid calibration;
- Recommended calibration period from the device manufacturer for 100% utilization;
- Equipment utilization (%);
- Valid period of regular calibration (years);
- Date of extraordinary calibration;
- Description of realized jobs;
- Date of planned calibration;
- Person who performed the calibration / ID code of the report / certificate;
- Responsible person.

Each test device has a label with the latest calibration dates and the certificate number.

Equipment checks between two regular calibrations are performed in the framework of additional quality assurance as defined by the procedure of Quality Assurance of Testing and Calibration Results.

The test machines in the laboratory which are operated by software have computer programs LAB CONTROL and BERT PRO installed, which are used to perform the tests. No other software is allowed to be installed on these computers. Access to computers and equipment is granted only to LIND staff.

## 3. EQUIPMENT MAINTENANCE

Quality Manager and Laboratory Manager of LIND are in charge to make a maintenance plan and equipment maintenance record at the end of the current year for the next year in the form, "Plan and Record of Equipment Maintenance", approved by the CEO of the Agency to which Laboratory belongs.

Only periodic maintenance of the equipment or its parts is planned, as stated in the technical documentation provided by the laboratory equipment manufacturer.

Table 1 shows an example of the form "Plan and Record of Equipment Maintenance", in which the updating, planning, recording and checking the accuracy of test equipment with calibrated control devices is performed once every six months. This form records the performed tasks within the planned and unplanned maintenance of the equipment.

If there is a deviation from the plan and record of equipment maintenance (e.g. due to objective reasons of an approved internal/external supplier, due to write-off of equipment or parts of equipment, procurement of new equipment or part of equipment, ...), the Laboratory Manager makes a revised plan and record of equipment maintenance in the same way as the plan and record of equipment maintenance at the end of the current year for the next year.

**Table 1.** Headers of the form "Plan and Record of Equipment Maintenance"

No.	Name of equipment or its part	Description of tasks to be done	Maintenance interval recommended by the manufacturer	Final term for performing the task	Internal checking device	Date of performing the task	Performer	Responsible person

During the managerial review, the status of the test equipment is analysed based on the reports prepared according to the "Plan and Record of Equipment Maintenance", which has the effect of improving the quality management system in the Laboratory.

### 3.1. Maintenance preparation

Internal maintenance activities of the equipment are entrusted to LIND personnel in accordance with the procedure for reviewing the contract and the instructions for the functioning of the protocol. These activities are carried out in accordance with the adopted maintenance schedule. In the case of requests for maintenance of the equipment or its servicing, where external suppliers and executors are needed, the LIND Manager submits the procurement request of the given service to the General Affairs Division.

### 3.2. Irregular maintenance

In all cases of sudden failure in the equipment, equipment operators also make records in the form "Record of Equipment Faults", and then inform the manager or technical manager of the LIND about the resulting fault, and they verify it in the appropriate form cell.

If the laboratory equipment failure occurs during the warranty period, the CEO of the Agency shall be notified, who then contacts the authorized service by means of the General Affairs Division. After the repair, the service is obliged to issue a certificate of the equipment. For the repair of equipment with the warranty period expired, approved suppliers or LIND services may be engaged, if any.

The minutes about the performed repairs and servicing of the equipment, are compiled and signed by the representative of the supplier (repair / servicing equipment technician) and the (technical) manager of LIND.

### 3.3. Additional quality assurance of test results

Additional quality assurance of test results is possible in several ways:

- additional equipment checking through regular maintenance every six months, as well as a device reliability check through an analysis of the period of regular equipment calibration;
- internal quality control service;
- inter-laboratory comparison;
- participation in laboratory testing programs by comparing test results of related

laboratories (simpler procedure than inter-laboratory comparison);

- repeat testing using the same or different methods;
- re-examining the same / similar objects;
- conducting internal staff training for those methods that were not carried out for a certain period of time in the laboratory;
- regular check of the edition of the standard;
- correlation of test results for different characteristics of the tested sample / subject of the test.
- by repeating the test using the same or different methods for methods where this is possible according to the standard in the framework of internal training of LIND staff.

In order to carry out the examinations for internal training, identical steps are undertaken as for regular commercial tests, with additional analysis of the test results in accordance with the defined criteria for the admissibility of test results. Testing will be repeated where possible, according to standards, where the standard deviation of these measurements and the comparison of the obtained test results according to the parameters are given in the test standards. In order to carry out the internal training, it is obligatory to conduct repetition of tests for those methods for which measurement uncertainty is required with the calculated uncertainty budget. In case a LIND supervisory staff's suspects the results of the investigation, a re-examination on the same subject shall be carried out, if possible. In this case, the presence of the LIND Manager is required during the entire test process.



**Figure 2.** Laboratory equipment

All the above-mentioned internal quality assurance measures for testing results in the LIND laboratory (except PT/ILC schemes implemented separately), are planned and monitored in the form "Plan and record of internal quality assurance / result quality control". The planning and recording of internal quality assurance / quality control measures is

reviewed on a regular (and, as appropriate, extraordinary) review by the management. If it is determined after the analysis that the data are out of the defined criteria, corrective or preventive measures are being taken.

## 4. EQUIPMENT CALIBRATION

### 4.1. Creating a Plan and Equipment Calibration Records

LIND holds lists of equipment that are calibrated externally. These lists are attached to the appropriate specific procedures. The technical director of LIND, at the end of the current year, is planning a calibration plan for equipment for the next year in the form "Plan and Record of Equipment Calibration", for both internally or externally calibrated equipment. The plan is approved by the Agency CEO.

If there is a deviation from the plan and equipment calibration records (due to the write-off of the equipment or part of the equipment, i.e. the purchase of new equipment or part of the equipment, or due to the inability of an external approved supplier to perform the calibration in the planned term, or uninsured financial assets by the management of LIND or the Agency,...) the LIND Manager makes a revised plan and records the equipment calibration.

### 4.2. Planned Calibration

Planning and recording equipment calibration in the Laboratory are conducted in the form "Plan and Record of Equipment Calibration". The form defines elements that are monitored, analysed and periodically checked to precisely define the calibration period with each individual equipment and parts of the LIND equipment, which are:

- Equipment name, inventory number, manufacturer;
- Measurement area;
- Calibration area;
- Measurement uncertainty;
- Date of valid calibration;
- Recommended calibration period from the device manufacturer for 100% utilization;
- Equipment utilization (%);
- Planned period of regular calibration;
- Date of extraordinary calibration;
- Description of tasks;
- Calibration executor / Identification code of the report / certificate;
- Responsible person.

When planning the period of regular calibration and maintenance of equipment, one must always

follow the guidelines defined in the documents: OIML D10 Guidelines [5], BATA recommendation as a mandatory document, recommendations of the manufacturer of equipment and some examples of recommended calibration intervals, as well as in the Appendix A of the standard BAS EN ISO 10012:2004.

The analysis and updating of the form "Plan and record of equipment calibration" is performed as compulsory every six months on a regular basis, as well as in the cases of increased number of furniture tests.

Following the analysis of all elements, a report on the status of the test equipment in the laboratory is made. During the managerial review within the framework of the analysis item eleven, which refers to resources, i.e. equipment, the use of equipment is analysed in order to define or revise the calibration terms of the equipment based on the analysis and the reports made according to the "Plan and records of equipment calibration".

The Laboratory also envisages the extraordinary / unplanned calibration of equipment, which is carried out in the following cases:

- when the results of the test are suspected because they deviate more than usual, and in case when they are not caused by the characteristics of the test subject or the work of the examiner,
- when there are defects in equipment or parts of equipment that are otherwise calibrated,
- changes in the performance of the test equipment as a result of its servicing,
- purchase of new equipment and its first calibration,
- large deviations in test results due to the intensive use of some equipment and machines.

The frequency of use of equipment and machines (Table 2) is monitored and recorded at each individual test through the records of equipment used in the work order for testing, as well as in the form "Plan and records of equipment maintenance".

Calibration of equipment that is performed as the preparation of test equipment, before each individual or pre-series test, is not subject to this procedure.

These calibrations are performed according to the instructions for handling the equipment and/or the instructions for carrying out the test according to the testing standard in order to ensure the quality of the test results.



**Table 2.** Times of equipment use

No.	Equipment name ID Manufacturer	Date of valid calib- ration	PI/ 14/13	PI/ 01/14	PI/ 08/13	PI/ 18/13	...	...	Total time used (hours)
1.	Pressure force sensor, on 4-axis machine - pneum. cyl. - side; Step length: L=500 mm, Diameter: D=63 mm; Serial no.: 41011207 ID no.: 119 Hegewald & Peschke	17.07. 2013.	5 min.	5 min.	0 min.	0 min.	...	...	<b>87 h 50 min.</b>

### 5. DETERMINING RECALIBRATION INTERVAL

The recalibration period (planned calibration) is defined for the equipment to be calibrated, and if the equipment is part of the legal metrology, the defined recalibration period (indicated in the valid calibration certificate) is taken into consideration. Based on the recalibration period, the date of the planned calibration is determined and entered in the form "Plan and Record of Equipment Calibration" for each year.

When planning and determining the period of calibration and maintenance of equipment

(Example - Table 3), according to the guidelines and recommendations, one must take into account the following factors:

- Recommendation of the manufacturers of measuring and testing equipment;
- Expected frequency and conditions of use;
- Environmental impact;
- Required measurement uncertainty;
- Settings of the individual instruments, or changes that occur in them;
- Summary or published data about the same or similar devices.

**Table 3.** The calibration period calculated by the utilization of the equipment

No.	Equip- ment ID	Date of valid calib- ration	Manufacturer's recommendations				Local laboratory parameters					Calib- ration interval
			Working temp. (°C)	Rel. humidity (%)	Maintenance period	Calibration interval for 100% capacity per shift*	Rel. humidity (%)	Maintenance period	Calibration interval for 100% capacity	Total usage time (h)	Usage ratio <sup>a)</sup> (%)	
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Pressure sensor ID no. 119 Hegewald & Peschke	17.07. 2013.	10 - 30 °C	10- 85%	1 year	1 year * for 265 working days per year i.e. 2120 h	from min. 15,7 °C to max. 23,8 °C	from min. 48,8 % to max. 51,5 %	6 mont hs	87,83	<b>4,14</b>	<b>24,15</b>

In addition to the above-mentioned factors for determining the equipment calibration interval in LIND, a simplified analysis of the calibration

interval (NCSL Recommended Practice RP-1) is taken into account, simplified and calculated.

The last calibration has the greatest contribution/influence.

$$(IK)_n = (IK)_s \times (W1 \times X + W2 \times Y + W3 \times Z)$$

Where:

(IK)<sub>n</sub> = new calculated calibration interval;

(IK)<sub>s</sub> = the old calibration interval;

W1 = impact factor of the last calibration;

W2 = impact factor of the second calibration;

W3 = impact factor of previous calibration;

X = multiplier related to the result of the last calibration;

Y = multiplier referring to the result of the second calibration;

Z = multiplier referring to the result of the previous calibration;

The final, adopted new calibration interval for all LIND equipment is determined taking into account the following:

- date of valid calibration of LIND equipment;
- the equipment calibration interval recommended by equipment manufacturer - (IK)<sub>man</sub>;
- calculated calibration interval for the use of LIND equipment - (IK)<sub>LIND</sub>;

- equipment calibration interval defined by another laboratory of the same activity that owns the same type of equipment from the same supplier - LIN Zagreb - (IK)<sub>LIN</sub>;
- defined - old interval of calibration of LIND equipment - (IK)<sub>s</sub>;
- the calibration interval of LIND equipment determined according to the NCSL RP-1 method - (IK)<sub>n</sub>;
- calculated average interval of calibration of LIND equipment - (IK)<sub>avg</sub>;
- adopted new interval of calibration of LIND equipment - (IK)<sub>new</sub>.

(IK)<sub>n</sub> for conditions in LIND is calculated as follows:

$$(IK)_s \times (W1 \times X)$$

where: W1 = 0.8; X = 1

The new adopted equipment calibration interval in LIND is calculated as follows:

$$(IK)_{avg} = [(IK)_{man} + (IK)_{LIN} + (IK)_s + (IK)_n] / 4$$

Based on calculated (IK)<sub>avg</sub>, a new calibration interval is adopted: (IK)<sub>new</sub> (Table 4).

**Table 4.** The new adopted calibration interval

No.	Equip-ment ID	Date of valid calibration	Recommended calibration interval by manufacturer for 100% utilisation in one shift* 1 year (265 working days per year i.e. 2120 h) (IK) <sub>man</sub> .	Calculated calibr. interval by equipment utilisation (%)	Calibr. interval defined by similar laboratory (year) (IK) <sub>LIN</sub>	Old calibr. interval of LIND equipment (year) (IK) <sub>s</sub>	Calibr. interval by NCSL RP-1 (year) (IK) <sub>n</sub>	Calculated average calibr. interval (year) (IK) <sub>avg</sub>	Adopted new calibr. interval (year) (IK) <sub>new</sub>
1	2	3	4	5	6	7	8	9	10
1.	Pressure sensor ID no. 119 Hegewald & Peschke	17.07. 2013.	1	24,15	5	5	4	3,75	3

On the basis of a detailed analysis of all the above factors for determining the calibration interval for LIND equipment, defined equipment calibration intervals, records and data (values) data in the free table form will be defined. The

Plan and Records of equipment calibration will be updated accordingly in the future in LIND laboratory.

The new form will contain the following data:

- Measurement range

- Calibration range
- Measurement uncertainty
- Date of valid calibration
- Recommended calibration interval as recommended by the manufacturer for 100% equipment utilization (%)
- Valid interval of regular calibration
- The date of irregular calibration
- Description of tasks realized
- Date of planned calibration
- Person who performed the calibration / ID code of the report / certificate
- Responsible person

## 6. CONCLUSION

Taking into account a number of influences and parameters, a new recalibration interval for one piece of laboratory equipment was determined. The calibration interval was reduced from 5 to 3 years, according to the influence factors, such as utilisation rate, experiences from similar laboratories, manufacturer's recommendations, ISO standard, NCSL recommendation RP-1, OIML guide D10, etc.

The methodology can and will be used for all other devices and laboratory equipment which has to be calibrated.

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