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Accredited Calibration Laboratory for Sound Measurements

Abstract

The article presents basic concepts related to accredited calibration laboratories in accordance with ISO/IEC 17025. It describes in detail one of the only few existing in Poland calibration laboratories which deals with instruments for sound measurements. This laboratory is an interesting case as it is the only one in Poland, located in a company developing new instruments, producing, selling them and conducting their service in all over the world. Thanks to this location, the laboratory is able to provide their services not only in Poland but also abroad, which could affect revenues. In the paper laboratory equipment is presented and the innovative ways to increase measurement throughput is discussed. The calibration and measurement capability developed on the basis of uncertainty budgets is given. The activities carried out during the calibration are presented as well as the contents of the first page of the certificate. In the conclusions the strengths of the laboratory are listed.

Keywords: ISO / IEC 17025 standard, accreditation of calibration laboratory, calibration of sound level meter, acoustic calibrator, band-pass filters, personal sound exposure meter.

1. Calibration laboratory in accordance with ISO/IEC 17025

Accreditation of calibration laboratory is a formal recognition of its competence to carry out specific calibration. The certificate of accreditation is a document issued by an authorized organization to a laboratory that has met the conditions and criteria for accreditation. A current Certificate of Accreditation, accompanied by a Scope of Accreditation, may be used as proof of accredited status. In Poland, the body authorized to accreditation of such laboratories is the Polish Centre for Accreditation (PCA). Accredited laboratory must meet a number of specific requirements, both technical and organizational, contained in the ISO/IEC 17025: 2005 standard [1], and other documents issued by the PCA. So-called DA documents describe and in detail regulate the system of accreditation (DA-01, [2]), rules for accreditation symbols (DA-02, [3]), the politics concerning assurance of traceability DA-06, [4]), the rights and obligations of accredited subjects (DA-08, [5]). Laboratory accreditation entails numerous benefits. Accredited laboratories, compared to non-accredited institutions become more competitive, thereby increasing their credibility in the eyes of customers. Accredited laboratories also have the "exclusive right" to deliver "significant" results in areas regulated by law (i.e. environmental conditions, noise pollution, building acoustics). In addition to the many benefits, accredited laboratory bears also a number of additional responsibilities and costs associated with the fact of having accreditation. One of them is the necessity of special care of the technical condition of laboratory equipment. It requires to maintain an extensive program of quality management and testing of the equipment.

The accreditation certificate together with the individual identification (AP xxx) is given, after the very careful and detailed assessment made by PCA auditors, for a period of four years. During this period, every year PCA carried out an audit of technical competence and quality control of the laboratory. Accredited laboratory has also to pass interlaboratory comparisons, which means organization, performance, and evaluation of tests or calibrations on the same or similar items or materials by two or more laboratories in accordance with predetermined conditions.

The calibration service is carried out in Poland:

- by the organs of measure administration (Central Office of Measures, which is considered to be the primary source of standards in Poland) – on the basis of the Law on Measures;
- calibration laboratories accredited by the PCA – based on the Polish edition of ISO 17025 standard and the Law on conformity assessment system;
- non-accredited calibration laboratories and users of measuring instruments – on the basis of the Act on freedom of economic activity (as the activity of calibration is not licensed).

Measurements in the calibration laboratory performs qualified, competent laboratory personnel according to established procedures and approved under specific, reference conditions (eg. a fixed temperature, humidity, ambient pressure, etc.).

The purpose of calibration is to determine the metrological condition of calibrated instrument determining its suitability to perform the measurements. It includes the transfer of measure units and certification that the calibrated instrument meets certain metrological requirements. The result of the calibration is given in the calibration certificate. During the calibration the measurement traceability (information about primary patterns or standards allowing one to link with national or international standard of measurement) must be maintained.

The ISO/IEC 17025 standard itself consists of five elements:

- **Scope** *It states what type of testing and calibration is covered; who it is applicable to; the purpose for the standard; what is not covered; and how it relates to ISO 9001.*
- **Normative references** *It states that both ISO/IEC 17000 and the International Vocabulary of Metrology (VIM), [6], are vital to applying the standard.*
- **Terms and definitions** *It states that relevant terms found in the standard can be defined via ISO/IEC 17000 and VIM, [6].*
- **Management requirements** *Detailing the operation and effectiveness of the quality management system within the laboratory. The requirements for the operational effectiveness of a laboratory's quality management system are stated in part four of the standard and are broken down into 15 subsections, marked from 4.1. to 4.15. and named, respectively: Organization; Management system; Document control; Review of requests, tenders and contracts; Subcontracting of tests and calibrations; Purchasing services and supplies; Service to the customer; Complaints; Control of nonconforming testing and/or calibration work; Improvement; Corrective action; Preventive action; Control of records; Internal audits; Management reviews*.
- **Technical requirements** *Detailing the factors which determine the correctness and reliability of the tests and calibrations performed in laboratory. The requirements for staff competence, methodologies, equipment testing and calibration, and test methods are broken down into 10 following subsections, marked from 5.1. to 5.10. and named, respectively: General; Personnel; Accommodation and environmental conditions; Test and calibration methods and method validation; Equipment; Measurement traceability; Sampling; Handling of test and calibration items; Assuring the quality of the test and calibration results; Reporting the results.*

Conducting laboratory requires adherence to the management rules, very precisely defined in the standard ISO/IEC 17025, and requires investment in equipment proportionate to the scope of accreditation.

Each laboratory should prepare a quality manual that includes individual ways to implement the provisions of the fourth (management) and fifth (technical) chapter of ISO/IEC 17025 standard. It includes also a commitment to good practice and research quality of services provided to customers, the declaration of the service level, which conforms with the objectives of quality systems. Laboratory personnel involved in calibration should be

familiar with the above and apply it in their practice. The laboratory management undertakes to follow the rules of this standard and supervises employees. Among the employees should be the manager of technical affaires and manager of quality system.

The laboratory must have a legal responsibility, organizational structure and management. An important issue is the independence of the laboratory (no conflict of interest). The laboratory must establish, implement and maintain a quality system which describes, among other things, how exercise supervision over documents, how take preventive and corrective actions, policy of purchasing materials and services, etc. The laboratory should clearly understand customer requirements and provide resources for their implementation.

The scope of calibration instrumentation for the measurement of sound, consists of calibration of: sound level meters, sound calibrators, personal sound exposure meters and 1/1 & 1/3 octave filters. In Poland, seven laboratories (AP 006, AP 027, AP 081, AP 083, AP 086, AP 087 and AP 146) cover scope of sound level meters and acoustic calibrators. Scope of 1/1 and 1/3 octave band-pass filters is covered by five laboratories: (AP 006, AP 027, AP 086, AP 087 and AP 146) and scope of personal sound exposure meters – by four laboratories: (AP 027, AP 086, AP 087 and AP 146). Identifications AP 081, AP 083, AP 086, AP 087 belongs, respectively, to District Office of Measures in Warsaw, Wrocław, Gdańsk and Łódź; AP 006 – to Central Mining Institute (Katowice), AP 027 – Haik sp. z o. o. (Poznań), and AP 146 – Svantek sp. z o. o. (Warsaw).

Company Svantek, [7], was established in 1990 by five persons who were associated with the Institute of Radioelectronics (IR), Warsaw University of Technology. Few of them cooperated with IR for years. Up to now, in the company works few graduates of the IR. Company designs and manufactures professional instrumentation for sound & vibration measurements and analysis. Their instruments are well known around the globe for their accuracy and reliability. After few years of training and document preparation, in 2012 the company established the calibration laboratory – AP 146, which successfully passed in PCA the validation process and obtained certificate of accreditation, [8]. Since that date, every sound or vibration instrument offered by Svantek can be delivered with an ISO/IEC 17025 calibration certificate. The accredited laboratory uses state-of-the-art calibration technology and instrumentation and offers the highest levels of knowledge and competence with all its services.

The important issue is the accommodation and environmental conditions in the laboratory space. Office and laboratory, both should be air conditioned. Additionally, AP 146 laboratory has floor separated from the walls. Thanks to that the building vibrations are not transmitted which is the crucial factor in the case of vibration instrumentation to be calibrated. Very useful from a practical point of view is compressed air used for cleaning calibrated instruments. In the laboratory there are several measurement stations for different types of calibrations (cf. Fig. 1), racks for the equipment and instruments to be calibrated and those after calibration.

As it was said, the scope of AP 146 laboratory covers all the potential needs of the users of instrumentation for measuring sound. Each method of calibration refers to the relevant standards and is described in details in the work instructions. These instructions, prepared by the laboratory workers, are part of the quality system. In Tab. 1, the work instructions, named as IN-01, IN-02, IN-03 and IN-04, together with the reference standards are listed.

In order to perform the necessary measurements the laboratory must have precisely defined equipment that efficiency and validity of the certificates of calibration is strictly controlled. First of all, the laboratory must have primary and working standards. The primary standards are designated or widely acknowledged as having the highest metrological qualities and whose value is accepted without reference to other standards of the same quantity.

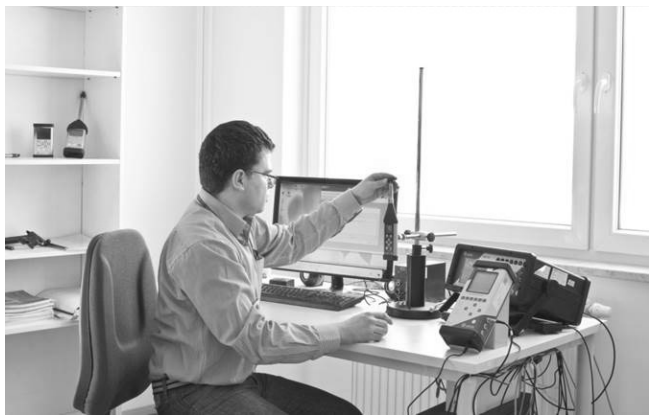


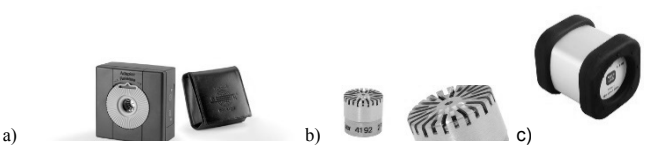
Fig. 1. Measurement station for the calibration of instruments for sound measurements in AP 146 accredited calibration laboratory

Tab. 1. Types of calibration performed in the case of instruments for sound measurements

Type of measuring instrument	Method's identification
Sound calibrators	IN-01 (IEC 60942, [9])
Sound level meters	IN-02 (IEC 61672-3, [10])
1/1 and 1/3 octave filters	IN-04 (IEC 61260, [11])
Personal sound exposure meters	IN-03 (IEC 61652, [12])

Working standard is used routinely to calibrate or check material measures, measuring instruments, or reference materials. In the field of sound measurements AP 146 has two **primary standards**:

- *Sound calibrator, B&K 4231, which is very robust and stable, and conforms to EN/IEC 60942 Class LS and Class 1, and ANSI S1.40-1984 (Fig. 2a).*
- *Pressure-field microphone, B&K 4192 which works in the range 3.15 Hz ÷ 20 kHz and has 200 V polarization (Fig. 2b).*



a) b) c)

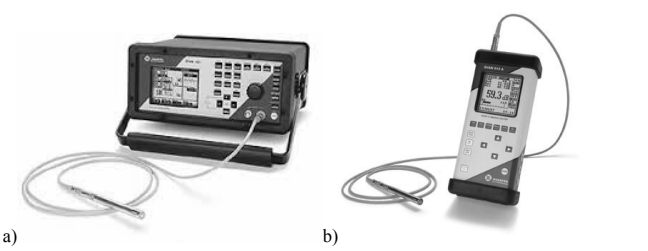
Fig. 2. Primary standards: a) sound calibrator, b) pressure-field microphone, c) working standard – sound calibrator

As the **working standards** two calibrators are used:

- *Sound calibrator, B&K 4231 (Fig. 2a),*
- *Sound calibrator, SV 30A (Fig. 2c).*

Other equipment which is necessary to perform the calibration of instrumentation for sound measurements and which has to be calibrated externally is as follows:

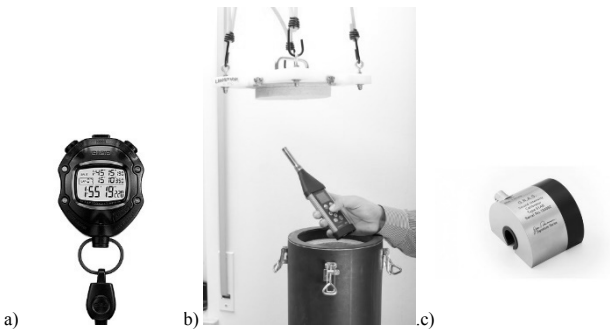
- *Generator with special functions required for conducting tests described in proper standards, SVAN 401 (Fig. 3a).*
- *Sound level meters, total harmonic distortion (THD) meters and voltmeters with internal amplifier: modified SVAN 912AE (Fig. 3b).*



a) b)

Fig. 3. A) Specialized generator, b) sound level meter, harmonic distortion meter and voltmeter

- *Electrostatic Actuator Amplifier, G.R.A.S., model 14AA with Electrostatic Actuator RA0014.*
- *Thermometer, hygrometer & barometer, Label, model LB-706B.*
- *Stopwatch, Casio, model 80TW-1 (Fig. 4a).*
- *Low noise measurement chamber, Svantek, SA 40, (Fig. 4b).*
- *Sound Intensity Calibrator, G.R.A.S., type 51AB, (Fig. 4c).*
- *Impedance replacements for the calibrated instruments, Svantek ST02, ST104.*
- *Microphone preamplifier, Svantek SV 01A.*



a) b) c)

Fig. 4. a) Exemplary stopwatch, b) low noise measurement chamber, c) sound intensity calibrator

Performing all necessary measurements for considering that the calibrated instrument meets the requirements of a standard is a very time consuming task. The acceleration of this process is possible in case of investing in stations to automatically or partially automatically performance of the required measurements. One can remotely enforce setting the calibrated instruments and devices that generate signals and instruments to measure them. Thanks to that it becomes possible automatic reporting of the measurements, and on the basis of these reports – preparation of calibration certificates. It was done in the case of instruments produced by the company (different types of sound level meters, sound calibrators and personal sound exposure meters). Also special protocols were prepared for manual measurements of 1/1 and 1/3 octave filters. All programs for automatization of measurements were properly tested and validated.

The instruments manufactured by other producers can also be calibrated but their settings should be made manually which takes at least two times longer than made automatically.

For each type of calibration the uncertainty budget of measurements was prepared and on the basis of that the calibration and measurement capability (CMC) was specified. CMC is the smallest uncertainty of measurement a laboratory can achieve within its scope of accreditation. The scope of accreditation of each accredited laboratory, together with the CMC values are available on the PCA web pages in the similar form to the presented in Tab. 2.

The laboratory can also perform measurements for different reasons than preparation of calibration certificate. Their results can be, for example, given in so-called factory calibration certificate. The measurements of sound level meter performed during accredited calibration and during factory calibration are summarized in Tab. 3.

During the calibration process one can distinguish several stages:

- Getting started (cleaning, identification and air conditioning of calibrated instruments).
- Assessment of the technical condition (check the operation, completeness).
- Check and reporting of the metrological characteristics (it includes electrical and acoustic measurements).
- Necessary adjustments.
- Final work with devices (maintenance, packaging, shipping).
- Documenting results (calculation of measurement uncertainty, preparation of calibration certificate).

Tab. 2. Types of calibration performed in the case of the instruments for sound measurements

Name of the physical quantity and type of measuring instrument	**Measurement range**	**Calibration and Measurement Capability (CMC)**
Sound calibrators:		
- sound pressure level	90 dB ÷ 120 dB (rel. to 20 μPa) nominal frequency: 1 kHz	0.08 dB
Sound level meters:		
response to a signal from the sound calibrator	90 dB ÷ 120 dB (rel. to 20 μPa)	0.2 dB
response to the electrical measurement signals	0 dB ÷ 140 dB (rel. to 20 μPa) frequency range: 20 Hz ÷ 20 kHz	0.2 dB
frequency response of the sound level meter in the free field	20 Hz ÷ 20 kHz; frequencies: 125 Hz, 1 kHz, 4 kHz, 8 kHz	0.3 dB 0.4 dB
1/1 and 1/3 octave filters:		
relative attenuation	0 dB ÷ 100 dB; ≤ 70 dB; > 70 dB centre frequency of the filter: 20 Hz ÷ 20 kHz	0.2 dB 0.3 dB
Personal sound exposure metres		
response to signal from sound calibrator	Sound pressure level of the calibrator: 90 dB ÷ 120 dB, measurement time: 60 s ÷ 120 s	4.0 %
response to electrical measurement signals	0.3 Pa^2h ÷ 105 Pa^2h	3.0 %
frequency characteristics in the free field, expressed in dB, rel. to 20 μPa	63 Hz ÷ 4 kHz 4 kHz ÷ 8 kHz	0.4 dB 0.6 dB

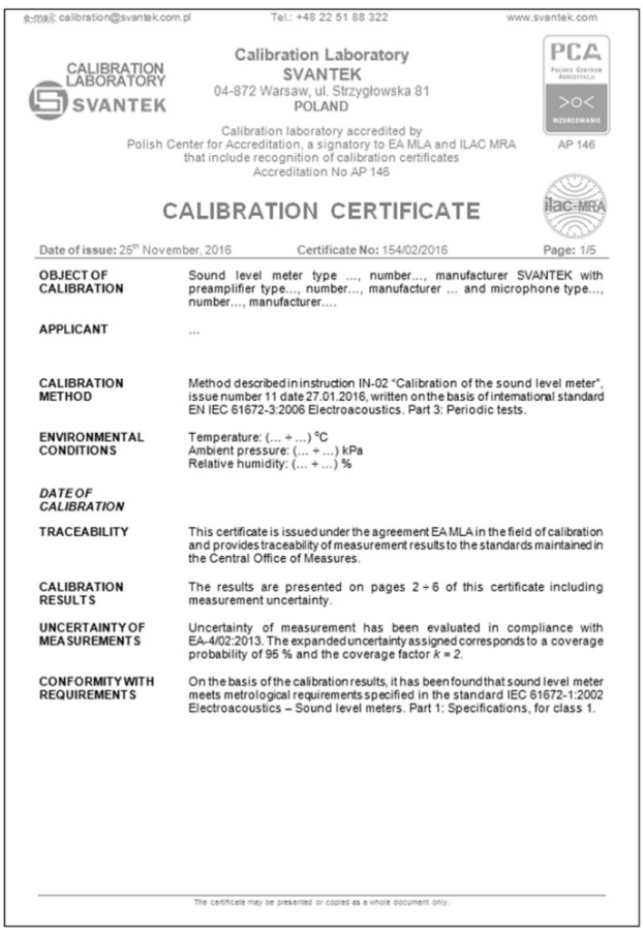
Tab. 3. The set of measurement performed during certified and factory calibration

Certified (IEC 61672-3)	**Factory**
Electrical measurements (measured on the reference level range): • A, C and Z characteristics • Linearity for one frequency (8 kHz → 22 dB ÷ 137 dB, reference range) • Indication for 1 kHz for all weighting character. • Response for impulse tones • Noise • PeakC indication • Over-range indication	Electrical measurements (measured on LOW and HIGH ranges): • Indication for reference frequency • Linearity (for 3 frequencies) (LOW: 31.5 Hz → 20 dB÷80 dB, 1 kHz → 20 dB÷120 dB, 8 kHz → 20 dB÷119 dB; HIGH: 31.5 Hz → 28 dB÷97 dB, 1 kHz → 28 dB÷137 dB, 8 kHz → 28 dB÷136 dB) • HP and Z characteristics • Response for impulse tones (2 ranges) • Noise
Acoustic measurements: • Indication at the calibration check frequency (sound calibrator) • Self-generated noise with installed microphone • Frequency characteristic with the microphone (made with actuator)	Acoustic measurements: • Indication with the microphone for reference frequency • Self-generated noise with installed microphone

In addition to the standard set, usually there are some activities that are provided, i.e. marking label with the date of the calibration, recording devices in the database, if necessary any repairs made in the service department.

The calibration certificate should meet the requirements of ISO/IEC 17025. The approved pattern of the certificate can be downloaded from the web pages of PCA. The first page (cf. Fig. 5) is the identification, where going from the top, one will find such information as: the unit issuing the document along with the PCA sign of accredited laboratory and the ILAC-MRA (*International Laboratory Accreditation Cooperation – Mutual Recognition Arrangement*) sign; date and number of the document; calibrated object (name, type, manufacturer, serial number, year of production, etc.); customer's data (the owner of the device); calibration method (usually it is an internal document in which the calibration is described in details); environmental

conditions (temperature, ambient pressure, relative humidity); date of calibration; traceability; calibration results (usually presented on the following pages); uncertainty of measurements (method of evaluation, the results presented on the following pages); conformity with requirements (i.e, that sound level meter meets metrological requirements specified in the standard IEC 61672-3:2005 *Electroacoustics – Periodic tests*, for class 1). At the bottom of the first page the calibration certificate should be stamped and signed by the authorized representative (*individual who is authorized by the laboratory or parent organization to sign the accreditation application and commit the laboratory to fulfill the accreditation criteria*). The following pages contain the results of calibration with theirs uncertainty. The presentation methods vary depending on the type of instrument and the issuing laboratory.



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PCA

Calibration laboratory accredited by
Polish Center for Accreditation, a signatory to EA MLA and ILAC MRA
that include recognition of calibration certificates
Accreditation No AP 146

AP 146

ilac-MRA

CALIBRATION CERTIFICATE

Date of issue: 25th November, 2016 Certificate No: 154/02/2016 Page: 1/5

OBJECT OF CALIBRATION	Sound level meter type ..., number..., manufacturer SVANTEK with preamplifier type..., number..., manufacturer ... and microphone type..., number..., manufacturer....
APPLICANT	...
CALIBRATION METHOD	Method described in instruction IN-02 "Calibration of the sound level meter", issue number 11 date 27.01.2016, written on the basis of international standard EN IEC 61672-3:2006 Electroacoustics. Part 3: Periodic tests.
ENVIRONMENTAL CONDITIONS	Temperature: (... ÷ ...) °C Ambient pressure: (... ÷ ...) kPa Relative humidity: (... ÷ ...) %
DATE OF CALIBRATION	
TRACEABILITY	This certificate is issued under the agreement EA MLA in the field of calibration and provides traceability of measurement results to the standards maintained in the Central Office of Measures.
CALIBRATION RESULTS	The results are presented on pages 2 ÷ 6 of this certificate including measurement uncertainty.
UNCERTAINTY OF MEASUREMENTS	Uncertainty of measurement has been evaluated in compliance with EA-4/02:2013. The expanded uncertainty assigned corresponds to a coverage probability of 95 % and the coverage factor $k = 2$.
CONFORMITY WITH REQUIREMENTS	On the basis of the calibration results, it has been found that sound level meter meets metrological requirements specified in the standard IEC 61672-1:2002 Electroacoustics – Sound level meters. Part 1: Specifications, for class 1.

The certificate may be presented or copied as a whole document only.

Fig. 5. The first page of the AP 146 calibration certificate of sound level meter

The ILAC-MRA sign is very important for these laboratories which calibrate the instruments for the abroad customers. On the basis of mutual recognition agreements ILAC MRA signed by the PCA, accredited laboratories are entitled to use the mark ILAC MRA. This mark was introduced to provide around the world easy and uniform identification of accredited services provided by the signatories to the ILAC MRA agreement. It was registered in all the countries participating in the agreement, including Poland. As a result, it was possible to sign a license agreement between ILAC and the PCA authorizing the use of the combined ILAC / PCA signs, as well as to sign sub-license agreements between PCA and PCA-accredited entities.

2. Conclusions

After a few years of hard work, stuff training, preparing quality documents, establishing quality system, fulfilling the accreditation criteria and passing the PCA assessment, laboratory received from PCA certificate of accreditation and obtained individual identification – AP 146. Thanks to the implementation of ISO/IEC 17025 standard in the AP 146 laboratory which as the only one in Poland, constitutes the part of the company established for the development and manufacturing the measuring equipment, each instrument can be delivered with the accredited calibration certificate. AP 146 laboratory uses state-of-the-art calibration technology and instrumentation and offers the highest levels of knowledge and competence with all its services.

AP 146 laboratory staff is also highly trained in identifying any instrument malfunctions, which is an important benefit that saves considerable time if repairs are required. Laboratory staff has the direct contact with repair service department. Accredited laboratory as part of the equipment manufacturer, increases customer confidence in the company. Those who calibrates instruments are confident that they will be quickly and comprehensively served, and submitted to the laboratory equipment will return to them certainly fit. Thanks to the automation of the calibration process in AP 146 laboratory the lead time is rather short and the relation between price and performance is very competitive.

AP 146 laboratory, placed in the production company and having the ILAC-MRA sub-license, obtains access to multiple foreign customers. The calibration services for these customers are a significant part of revenues.

3. References

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