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OVERVIEW ON ACOUSTICAL CALIBRATION AND STANDARDS

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ABSTRACT

The standard requirements for type testing, calibration and field-check of acoustical instruments and transducers are described, together with some calibration procedures and the implementation of traceability with an acceptable uncertainty. Factors which determine the calibration schedule or the frequency of calibration are discussed.

SOMMAIRE

On décrit les besoins typiques pour l' étalonnage et la vérification (type et performance) d'instruments acoustiques et transducteurs, ainsi que quelques procédures d'étalonnage et la mise en pratique du raccordement avec une incertitude acceptable. Les facteurs déterminant le nombre d'étalonnage ou la fréquence d'étalonnage sont discutés.

1.0 INTRODUCTION

In the field of acoustical metrology one often encounters the following questions :

(1) **WHY** do we need calibration ?

(2) **HOW** does one select an acceptable calibration procedure to implement traceability with a finite uncertainty ? ; and

(3) **WHEN** or how often does an instrument need to be calibrated in order to maintain valid measurements with an acceptable calibration schedule ?

The aim of this article is to provide answers to the above questions such that the acoustics community can have a better understanding of the subject of acoustical calibration and standards.

2.0 CALIBRATION OF MEASURING INSTRUMENTS AND TRANSDUCERS

In order to have confidence in measurements, the overall measuring system should be calibrated from time to time in accordance with the requirements of a standard or an acceptable procedure.

When we examine the international and national standards on acoustical instruments, it is often difficult to differentiate between the following procedures :

(1) Type testing,

(2) Calibration, and

(3) Field-check, sometimes called "field calibration".

The truth is that almost none of the existing acoustical standards define the "test procedures" as stated in the above categories.

Let us clarify the above test categories :

2.1 Type testing

Type testing refers to tests which are essential to verify the design integrity of the instrument; such as :

(1) The directional characteristics of the microphone and the external shapes of sound level meters, which influence the sound diffraction pattern around the instruments, and

(2) Sensitivity to various environments, including mechanical vibrations and the effects of magnetic and electric fields.

The above type-tested instrument characteristics are very unlikely to change during the life of the instrument. Type testing is very expensive and time consuming; reputable manufacturers usually have their instruments type-tested before making final plans for manufacture.

2.2 Calibration

Calibration refers to test procedures which are usually performed in a laboratory. The tests are designed to monitor instrument operational performance which may change with the passage of time.

For example, in the case of sound level meters :

(1) The sensitivity and the frequency response of the microphone,

(2) The time-weighting (impulse, fast and slow responses) and the frequency-weighting (A, B & C characteristics) of the instrument, and

(3) Linearity over the stated dynamic range, the uncertainty of the attenuators and the performance of the squaring circuit.

Calibration should be scheduled according to the amount of use and the operating time-span of the instrument.

2.3 Field-Check

A field-check is a relatively simple procedure which can be performed in situ, to give some indication of whether the instrument is operational. Field-checks are not intended to replace laboratory calibration procedures. In most cases, field-checks are performed with an acoustical calibrator which generates a known sound pressure level at a reference frequency, usually 1000 Hz. If necessary, acoustical calibrators which generate sound pressure levels at several frequencies can be used to check the frequency weighting response at discrete points.

In general, calibration is a means of assuring that the readings given by a particular instrument are valid and can be accepted for international trade or in a court of law.

3.0 CALIBRATION PROCEDURES AND TRACEABILITY

To select a suitable calibration procedure is not a simple matter. National and international acoustical standards give formal guidelines on calibration methods for acoustical instruments. Due to the rapid advancement of technology, acoustical standards published in recent years and those that exist in draft forms tend to "recommend" calibration methods, and specifically state that other test methods are acceptable as long as they can be shown to verify compliance with the requirements of the standards. For example, a manufacturer may replace the recommended procedures with several tests during the manufacturing phase, plus a simplified computerized check after assembly.

To implement traceability is a completely different matter. A calibration laboratory may have followed all the recommended test procedures and can fail to maintain or to provide proper traceability.

Some of the requirements for the implementation of traceability are as follows :

(1) Direct proof confirming that the particular reference device has been calibrated at a national laboratory or at an accredited laboratory.

(2) The recipient laboratory of the reference device has to demonstrate the capability to transfer the traceability, i.e. to calibrate other devices with an accepted uncertainty.

(3) The accredited laboratory should have the ability to determine whether its working standard device, i.e. the device used as the reference during calibration of other devices, requires verification.

(4) The accredited laboratory must maintain proper records on the calibration schedule of all reference devices or instruments; and to employ staff qualified for performing calibrations for which the laboratory is certified.

3.1 Implementation

Let us look more closely at the above, in order to determine what are the detailed requirements for the implementation of traceability :

(1) "Direct Proof" usually means a calibration certificate or a calibration report from a national laboratory or an accredited laboratory.

For accreditation in electrical measurements, calibrated instruments of the laboratory may include DC and AC voltmeters or generators of known voltages. However, for acoustical calibrations, laboratory microphones with known sensitivities, and reference sound sources with known sound pressure levels are essential.

From time to time, suggestions have been made that commercial apparatus used for reciprocity microphone calibration is able to perform absolute calibration of condenser microphones. It must be pointed out that the above commercial apparatus is unable to provide ABSOLUTE calibration.

The absolute reciprocity calibration of condenser microphones requires the measurement of a number of physical quantities, such as the DC polarising voltage, an electrical impedance which can be a capacitance or a resistance, and the ratios of AC voltages. Based on the knowledge of the above physical quantities and several physical constants such as the speed of sound and the ratio of specific heats, the absolute sensitivity of the microphone can be deduced.

In the case of a commercial reciprocity microphone calibration apparatus, it is not possible to calibrate the ability of the apparatus to assess individually each of the above physical quantities. If the commercial instrument can demonstrate that it is capable of obtaining the same result for a calibrated microphone, then the apparatus is acceptable as a means to implement traceability.

(2) Calibration for the implementation of traceability may exist in two general formats : (a) direct measurement and (b) by comparison.

As an example, the calibration of the linearity of a sound level meter can be performed as follows :

(a) With direct measurement, a sinusoidal signal with its amplitude changed between known levels is applied to the test instrument,

(b) With the comparison method, a sinusoidal signal with its amplitude changed to various levels, is applied simultaneously to the test instrument and a calibrated reference instrument, which can be a high-grade measuring amplifier.

The differences between the above two methods are that in the first case, the levels of the generator have to be known or calibrated, and in the second case, the reference instrument has to be calibrated. In both cases, proper calibration of the reference standards is essential.

(3) To achieve the ability to determine whether the laboratory reference devices need verification requires careful planning. The route chosen depends on the nature of the particular device and on the frequency of usage of the reference device.

Let us examine the case of the laboratory reference microphone; depending on the implementation technique, the calibration laboratory may require two calibrated reference microphones. For example :

(a) If the laboratory has a commercial reciprocity calibration apparatus, the self check procedure requires that the apparatus verify one of the reference microphones (the working standard) in order to provide some indication that the reciprocity apparatus is giving the correct answer. Depending on the frequency of usage, the answers given by the working standard and the reciprocity apparatus may have both drifted and, in the worse case, drifted in the same direction. Then the apparatus will give the "expected" result, which is incorrect. Under these circumstances, the second reference microphone (the second working standard), which is seldom used, is needed to verify the integrity of the system.

(b) If a comparison method is used to verify the sensitivity of microphones, the procedure involves the application of a stable sound pressure level to a reference microphone (the working standard) and then to the test microphone. Again, depending on the frequency of usage, the second reference microphone (the second working standard) may be needed as a back-up to ensure proper traceability.

The laboratory's aim in the achievement of a specific uncertainty of calibration, will dictate the requirements of the back-up system (which may not be a second working standard).

(4) The maintenance of continuous records on reference devices is relatively simple; however, to ensure proper staff training may be more difficult. There is a misconception that once a calibration procedure is taught to a technical person, he or she is "trained". In reality, a trained calibration person may require several years to acquire the expertise needed to sense that "something is wrong" and to be able to take proper precautions to discover and to rectify the source of the problem which may exist during calibration.

3.2 Uncertainty

During the planning for the implementation of traceability, it is necessary to have an uncertainty audit of the overall calibration system. Some of the sources of uncertainty can be summarized as follows :

(a) The uncertainty of the laboratory reference devices, such as the reference microphones (working standards),

(b) The uncertainty of the instruments used in the calibration procedure, eg. voltmeters and frequency counters,

(c) The uncertainty of the method used for the transfer of traceability, i.e. the calibration method itself, and

(d) Uncertainties due to external influences, such as temperature, barometric pressure and humidity; and those uncertainties due to data manipulation such as statistical processing of sampled readings, and human errors.

From the above, one may conclude that the uncertainty of any device calibrated by an accredited laboratory has to be higher than the working standard of that laboratory, and the uncertainty increases as the "chain" of traceability increases. It means that during each calibration or each transfer, the uncertainties listed in (b) to (d) have to be added to those in item (a).

Item (d) looks straight forward, but it is most difficult to eliminate without some effort. In most standards laboratories, environmental effects are usually dealt with by means of known corrections. One must apply corrections with caution, since the uncertainties in some corrections can be much higher than those related to the entire calibration process.

For example, in the case of the calibration of the pistonphone sound calibrator, the deviation of the barometric pressure from the standard atmosphere must be taken into consideration, and a correction is usually required. This means that the barometric pressure has to be assessed. If the barometer is unreliable, the uncertainty of the barometric correction can be much higher than the inherent uncertainty of the pistonphone.

National and international standards give guidelines to the accredited laboratories on the acceptable value of the uncertainty for instrument calibration. For example, the uncertainty of the sound pressure level generated by an IEC class 0 calibrator is specified to be ± 0.15 dB under the specified reference conditions. For a calibration laboratory, this means that the combined uncertainties of the reference microphone (with a typical sensitivity uncertainty of approximately 0.05 dB), and of the RMS voltmeter which measures the signal from the microphone, plus the uncertainty of the gain of the preamplifier, must not exceed 0.15 dB. In addition, allowances have to be made for environmental corrections.

4.0 CALIBRATION SCHEDULE

The selection of a calibration schedule to ensure proper traceability depends on : (1) The application and nature of the test device, (2) the acceptable penalty for failure of compliance, (3) the particular uncertainty expectation, and (4) the frequency of usage of the calibrated device.

(1) To demonstrate the extremes between the nature of various test devices, let us take the example of a laboratory standard microphone, which is a relatively stable transducer. If it is a reference standard device, it is seldom used; with proper handling, its sensitivity is not expected to change over relatively long periods, such as 6 to 12 months. Therefore the calibration schedule of a laboratory standard microphone can be 12 to 18 months if the calibration record confirms that the particular device has a history of stability.

On the other hand, in the case of a personal sound exposure meter which is used daily in a hostile environment, such as under ground in the mining industry, the instrument may require weekly calibration plus field-checks before and after daily usage in the field.

(2) In a manufacturing company, failure in the compliance to specifications may be of prime concern.

For example, a manufacturer of smoke detector fire alarms may intend to have its products tested for a 90 dB alarm sound level at a certain distance from the device. Every device is tested after assembly, and the factory produces 1000 units per day. Field calibration of the monitoring sound level meter may be required every hour, since deviation from specification, if discovered after only one day, may result in the rejection or the need to retest 1000 manufactured units.

(3) The magnitude of the expected uncertainty in the calibration will greatly influence the calibration schedule.

Take the example of a sound level calibrator which generates a sound pressure level of 94 dB at 1 kHz, with a specified uncertainty of ± 0.3 dB at the reference temperature. Under normal usage in an acoustics laboratory, the calibration schedule can be one year. If the expected calibration uncertainty is ± 0.15 dB, weekly calibrations may be required. The cost of calibration will encourage the use of the more precise pistonphone calibrator which has a better long term stability.

(4) The frequency of usage of the calibrated device is the prime factor in determining the calibration schedule.

For example, consider a sound level meter used by an acoustical consultant for daily noise surveys near an industrial complex. Assuming that the instrument is handled with care and the operator is knowledgeable enough to notice any unusual variations in sensitivity, one may accept daily field-checks, plus having the instrument calibrated every 6 to 9 months, as an acceptable calibration schedule. If the consultant has another means to verify some aspects of the performance of the instrument, then a longer period before re-calibration may be acceptable. Again, the history of calibration of the instrument is able to indicate instrument stability; and may warrant less frequent or more frequent calibrations.

As one can see from the above discussion, expert advice from a knowledgable acoustical consultant on instruments or advice from the national laboratory is often required to formulate acceptable plans and to ensure measurement reliability in a particular situation.

It is of interest to add that calibration laboratories, including national laboratories, can only state in the calibration report the performance of the test device (under laboratory conditions) when it was in the laboratory. The recipient of the test device is expected to have the capability to ensure that the calibration data still applies when the test device is received, before pressing the latter into service.

5. <u>Accreditation</u>

In Canada, the Calibration Laboratory Assessment Service (CLAS) was established by the National Research Council to form, in cooperation with the Standards Council of Canada (SCC), the Canadian Calibration Network (CCN). The CCN enables manufacturers across the country to gain easier access to a variety of calibration services traceable to national and international standards. For more details on accreditation criteria and requirements, one should contact the Standards Council of Canada or the Laboratory for Basic Standards of the National Research Council Canada.

In the United States, the National Voluntary Laboratory Accreditation Program (NVLAB), administered by the National Institute of Standards and Technology (NIST formerly NBS), accredits laboratories for specific tests, or types of tests, in certain product or service areas.

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