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Establishing a service for calibration of low frequency transfer standard microphones in the frequency range 10 mHz to 250 Hz

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INTRODUCTION AND MAIN RESULTS

In this presentation, the steps in the development of a calibration service for reference microphones from 10 mHz to 250 Hz are described.

The challenges encountered on the way, and verification of the methods are briefly presented and discussed.

Which microphone types that are suitable for the steps in the traceability chain from the primary calibration to field calibration and the necessary corrections etc. for the practical use are also touched upon.

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Introduction

In 2017 CTBTO approached the CIPM Consulting Committee for Acoustics, Ultrasound and Vibration asking for low frequency references for the IMS. This led to the EURAMET project Infra-AUV where low frequency calibration methods were developed. HBK-DPLA worked with calibration of microphones and seismometers, and we demonstrated that reciprocity calibration as well as comparison calibration of microphones could be made down to 40 mHz.

During and after the Infra-AUV project it has become clear to us that calibrated transfer standards with known dependence of static pressure can fill a gap in the IMS traceability chain. Such standards can be used in portable calibration equipment and potentially coupled directly to the measurement stations.

Therefore, HBK-DPLA decided to extend already existing low frequency services to cover frequencies down to 10mHz as required for the IMS and to establish the static pressure dependence of the relevant transducers.

The service is presently not covered by the scope of HBK-DPLA's accreditation.

The service

What we offer is calibration of pressure sensitivity from 10 mHz to 250 Hz of Low frequency microphone, Brüel & Kjær Type 4193-L-004. The complex sensitivity expressed as level in dB re 1 V/Pa and phase in ° (degree) and evaluated uncertainty of the results are reported.

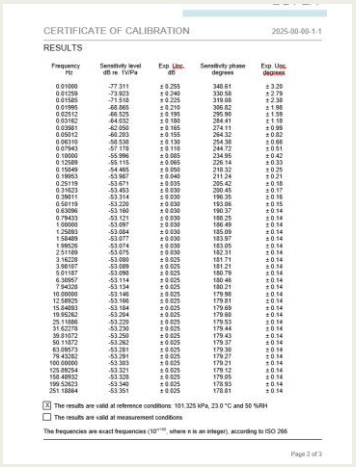
The calibration is made at reference environmental conditions, i.e. 23 °C, 101.325 kPa and 50 % relative humidity within reasonable tolerances. The actual conditions during the calibration are reported.

With information on static pressure dependence of Type 4193-L-004 (that is, for Type 4193) available, the sensitivity at altitudes with static pressure deviating from reference static pressure can be calculated from the calibration results. Static pressure dependence of Type 4193 has been determined as a step in establishing this service.

In the case of other microphone types or microphone configurations, we will evaluate before the calibration whether it is meaningful for that type or configuration.

The service


CERTIFICATE OF CALIBRATION


CERTIFICATE OF CALIBRATION
RESULTS


CERTIFICATE OF CALIBRATION
CALIBRATION CONDITIONS
CALIBRATION EQUIPMENT
REMARKS
COMMENTS

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Steps in development of the service

Laboratory standard, LS1, microphone Brüel & Kjær Type 4160 chosen as primary standard

Low frequency microphone Brüel & Kjær Type 4193-L-004 chosen as transfer standard microphone

Reciprocity calibration method developed from the standard method to cover the full range from 10 mHz to 10 kHz for LS1 microphones

Low frequency comparison system modified to cover the frequency range from 10 mHz to 250 Hz

Static pressure dependence of LS1 measured using the reciprocity method

Static pressure dependence of transfer standard microphones measured by comparison with LS1 microphone using the low frequency comparison system

As far as possible, the methods are verified with independent methods, theoretical models and comparisons in the Infra-AUV project. The work with consolidation continues.

Primary calibration – reciprocity calibration

Well established for decades for the frequency range 20 Hz to 10/ 25 kHz (LS1/LS2 microphones)

Calibration couplers modified couplers for well controlled pressure equalization.

Methods for verification of coupler sealing and identification of outlying measurements developed

Reproducibility very satisfying

Consistent with actuator response measurement

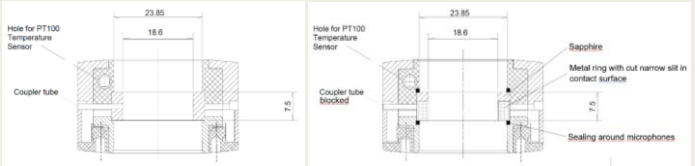
Consistent with physics of microphone

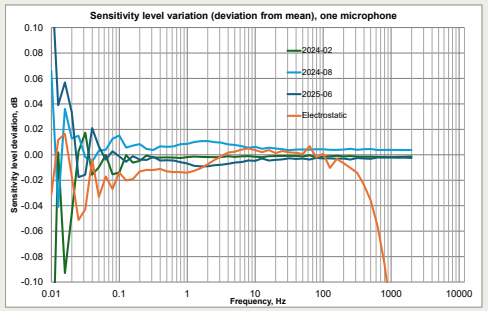
Comparison calibration in Infra-AUV project was partially successful. Extension is agreed upon but pending

Challenges:
None serious, but outmost care is required.
Low noise polarisation required due to low levels.
Small deviations (less than 0.02 dB) from actuator measurements unresolved

Publication under preparation (delayed)

Reciprocity calibration





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Selection of transfer standard microphone

In the laboratory, measurement setups for primary as well as for secondary calibration of microphones can be placed in closed chambers with controlled static pressure and minimal external noise.

This is not the case in the field where the transfer standard microphone may be coupled to a comparison coupler – or directly to a calibration port in an IMS station. Therefore, to avoid influence of external noise or errors due to static pressure differences, the external opening of its static pressure equalization system must be placed in the sound field.

This is easily and securely achieved with a front vented microphone. A front vented microphone is preferable, as any additional volume coupled to the static pressure equalization system will influence the response at low frequencies, and this influence can be substantial.

A drawback of having both sides of the pressure equalization system of the transfer standard microphone in the sound field is that the sensitivity of the microphone rolls off towards low frequencies. However, this is only a problem if it is not possible to achieve sufficient signal to noise ratio during calibration in the field.

Secondary calibration – comparison calibration

Low frequency coupler (Brüel & KJær WB-3570, part of Low Frequency Calibration System Type 9757

Comparison of 4193-L-004 to reciprocity calibrated 4160

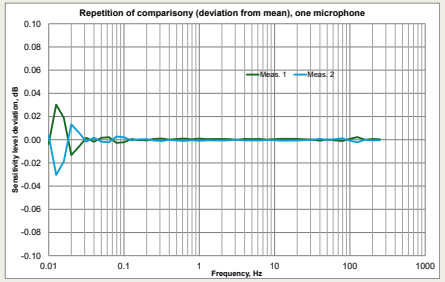
Consistent across microphones

Reproducibility very satisfying

Comparison calibration in Infra-AUV project was partially successful, but the combination of microphones and power supply provided caused noise and instabilities of the results at frequencies below 0.2 Hz. The results were stable with another power supply.
Root cause analysis, and repetition and extension of comparison is agreed upon, but pending

Challenges:
Acoustic crosstalk from back volume of comparison coupler to back cavity of LS1 microphone. The back volume in comparison coupler is large as compared to the volume in chamber with setup. Solved by balancing front and back volume pressure equalization systems in coupler.

Secondary calibration – comparison calibration



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Dependence of static pressure

The static pressure dependence of Type 4193 microphones was measured by comparison with Type 4160 microphones at different static pressures. The static pressure dependence of Type 4160 microphones was first determined by reciprocity calibration at different static pressures.

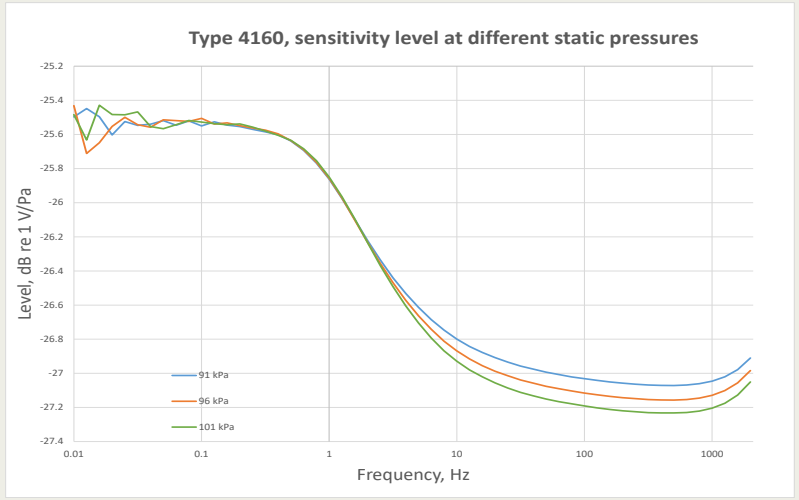
For both microphone types a theoretical model was made for the static pressure dependence at low frequencies. The models utilised a combination of simple analytical calculations and numerical calculation of heat conduction in the microphones' back cavities.

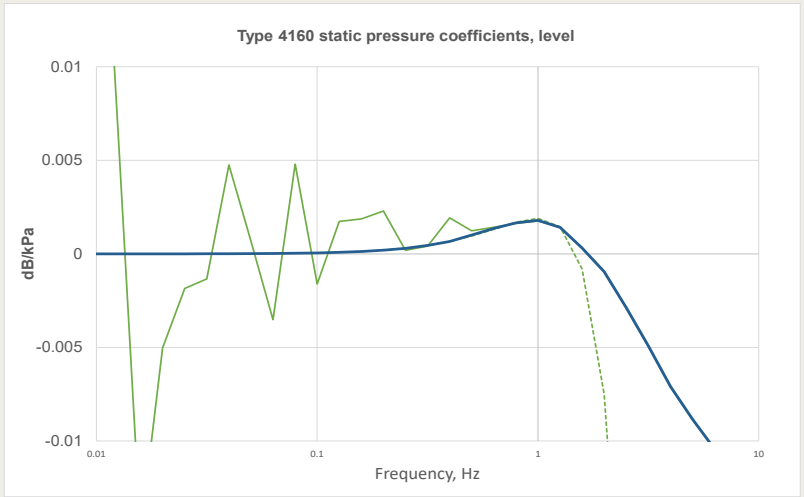
The dependence of static pressure of microphones behaves significantly different with frequency depending on whether the vent is exposed to the sound field or not. Therefore, different models were necessary.

The measurement results were consistent with the model calculations. This supports results and use of smoothing of data for best possible information for practical use of results.

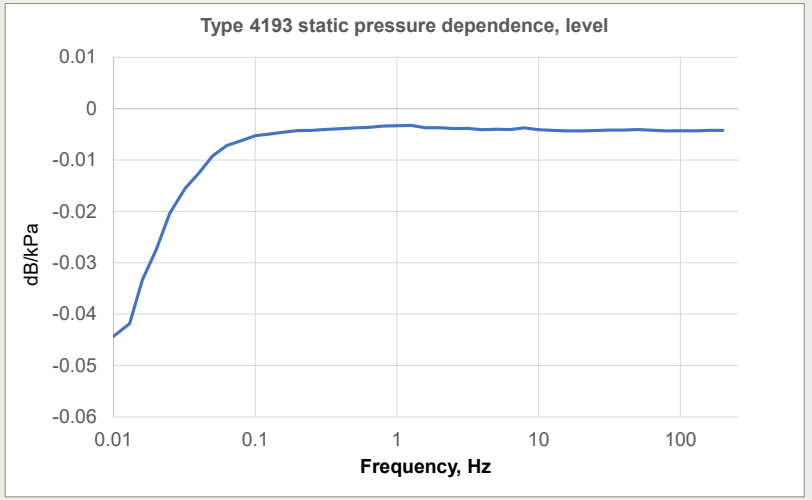
Publication under preparation (delayed)

Dependence of static pressure





Dependence of static pressure



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Supplementary remarks

For completeness:
As an alternative to the methods mentioned in this presentation, the transfer standards can be calibrated in a (laser) pistonphone, either by comparison to a primary standard or by direct calculation of the sound pressure. However, not many have such equipment, and the frequency range is limited to around 20 Hz.

Other primary methods were also worked with in the Infra-AUV project, but with higher uncertainty and further limitations in the frequency range.

Reference to the Infra-AUV project

Material on the Infra-AUV project, including references to publications from the project can be found on

https://www.ptb.de/empir2020/infra-auv/home

EMPIR EURAMET
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

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