PRECISION ACOUSTICS LTD

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UNITED KINGDOM

HYDROPHONE CALIBRATION CERTIFICATE

This certificate provides traceability of measurement to recognised national standards and to units of measurement realised at the National Physical Laboratory or other recognised national standards laboratories. Precision Acoustics Ltd is certified to the ISO 9001 standard.

Device Identification

Hydrophone SN	3197
Sensor Type	Needle
Sensor Diameter	0.2 mm
Preamplifier SN	PA19154
DC Coupler SN	DCPS938

Calibration Conditions

Date	25Feb2020
Water Temperature	22.0 degC
Water Treatment	De-ionised, de-gassed, filtered
Acoustic Path Length	375-420 mm
Source Signal Type	25 cycle Toneburst
Source Signal Amplitude	600mVpp
Calibration Frequency	1MHz
Cable Type	RG58, 1.5m
Electrical Impedance	50 Ohms

Test Equipment Used

Oscilloscope	DSOX3024A SN:MY52492255
Signal Generator	KeySight 33500B SN:MY52500465
Power Amplifier	PA40-12 SN:176

Calibrated by:	Checked by:
Julian Swinburne	David Bell

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HYDROPHONE CALIBRATION PROCEDURE

All hydrophones are calibrated using a substitution calibration technique. Substitution techniques are well established from one device to another, and the technique used for this calibration is based upon a shocked wave method (Smith and Bacon (1990)). In summary, a transducer is driven at sufficiently high power that the resultant acoustic pressure within the water exceeds the limit of linearity of the medium. The subsequent non-linear propagation process causes the shape of the acoustic waveform to change, and significant harmonic content to be generated within the acoustic signal as it propagates. A reference hydrophone that has been previously calibrated at the UK National Physical Laboratory (NPL) is placed at a number of locations within the acoustic field and the waveforms obtained at each of these positions are stored. The waveforms produced by the hydrophone to be calibrated at the same measurement locations are also recorded. The frequency response of the test device can then be calculated from the comparison of the two sets of measurement data. A second reference hydrophone that has been independently calibrated at NPL is then measured, which allows a direct comparison of the two sets of derived sensitivity data to be carried out.

The accuracy of this calibration method is dependent on the ability to accurately place both the reference and test hydrophones at the same position within the acoustic field. Hydrophones are placed at a pre-specified propagation delay away from the source transducer. Measurement positions are then uniquely obtained by moving the hydrophone in the two directions orthogonal to the acoustic axis of the source transducer, in order to maximize the received the hydrophone signal. The hydrophone is rotated about the same two orthogonal axes (centered on the active element of the hydrophone) to correct for any directional response that the hydrophone may exhibit. Maximum sensitivity occurs when the incident waveforms are normally incident upon the active element of the hydrophone. The source transducer has a broad beam profile at its fundamental frequency, but the beam width becomes increasingly narrow at higher harmonic frequencies. This fact is exploited to improve the accuracy of the repositioning operation. A 35 MHz band-pass filter is inserted between the data acquisition unit and the hydrophone, to allow the hydrophone to be aligned to the maximum of the much narrower beam of the 35 MHz harmonic component. The filter is removed once alignment is complete.

Measurement uncertainty is calculated from the quadrature combination of both Type A and Type B uncertainties. Type A uncertainties are established via statistical methods, and in the case of this calibration are derived from the standard deviation of at least four separate measurements of hydrophone frequency response. Type B uncertainties are obtained via other (non-statistical) methods and in this case includes, but is not limited to, the calibration of the reference hydrophone used in the substitution calibration. The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k = 2$, providing a level of confidence of approximately 95%. The calculation of uncertainties follows the guidelines established in publication JCGM 100: 2008.

Smith R.A and Bacon D.R. (1990). A Multiple-Frequency Hydrophone Calibration Technique. J. Acoust.Soc.Am. Vol 87 (5), pp. 2231-2243.

M3003 (1997), The Expression of Uncertainty and Confidence in Measurements. Edition 1, United Kingdom Accreditation Service, London.

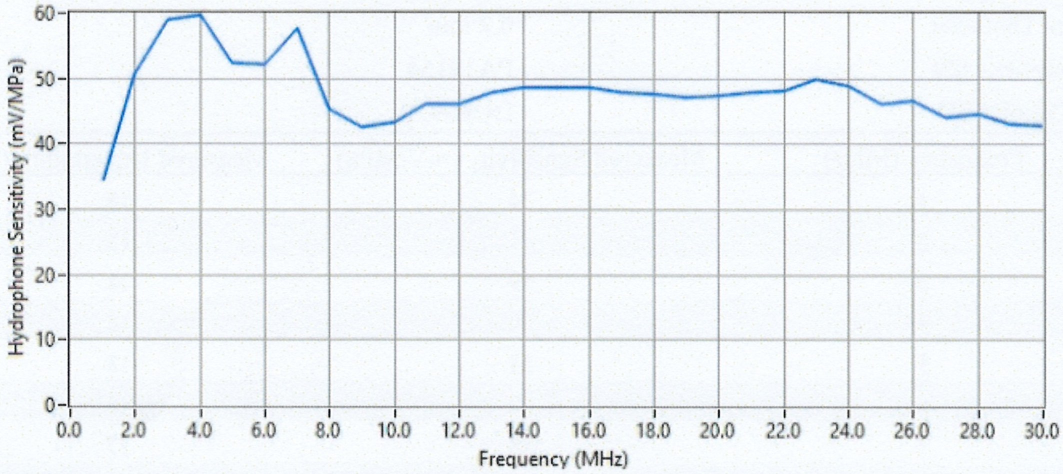
JCGM 100: 2008 Evaluation of measurement data - Guide to the expression of uncertainty in measurement.

HYDROPHONE CALIBRATION DATA

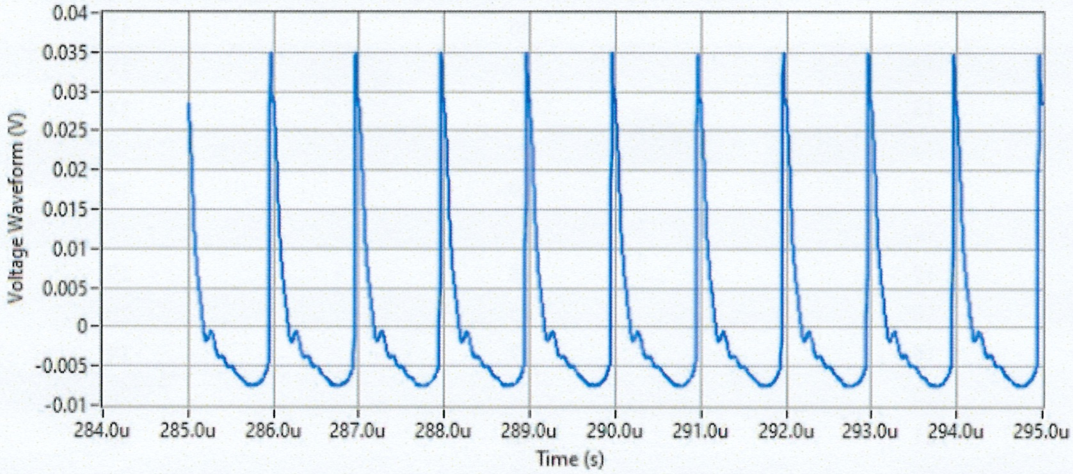
Hydrophone SN	3197
Sensor Type	Needle
Sensor Diameter	0.2 mm
Preamplifier SN	PA19154
DC Coupler SN	DCPS938

Frequency (MHz)	Measured Sensitivity (mV/MPa)	Measured Uncertainty (%)
1	34	18
2	51	18
3	59	18
4	60	18
5	53	18
6	52	18
7	58	17
8	45	18
9	43	18
10	43	17
11	46	18
12	46	18
13	48	18
14	49	18
15	49	18
16	49	18
17	48	19
18	48	20
19	47	19
20	47	20
21	48	20
22	48	20
23	50	20
24	49	20
25	46	20
26	47	20
27	44	20
28	45	20
29	43	21
30	43	20

Hydrophone Sensitivity (mV/MPa) vs. Frequency (MHz) for system comprising preamplifier SN: PA19154, DC Coupler SN: DCPS938 and 0.2 mm Needle hydrophone SN: 3197.



Voltage Waveform (V) vs. Time (s) for system comprising preamplifier SN: PA19154, DC Coupler SN: DCPS938 and 0.2 mm Needle hydrophone SN: 3197.



Profile - VSI vs. Time (min) for system comprising preamplifier SN: PA19154, DC Coupler SN: DCPS938 and 0.2 mm Needle hydrophone SN: 3197.