CCAUV/04-14

A Russian-Chinese comparison of hydrophone calibration methods in the low-frequency range

A.M., Enyakov, S.M., Likhachev (Russia),
Yuan Wenjun, Chen Yi (China)

VNIIFTRI

The first comparisons of the Russian and Chinese Underwater Pressure National Standards were conducted by the Hangzhou Applied Acoustics Research Institute (HAARI) and the All-Russian Scientific and Research Institute for Physical-Technical and Radio-technical Measurements (VNIIFTRI) in 1997/98. This comparisons have been carried out for the frequencies 1 Hz to 630 kHz, i.e. in the main range of the piezoceramic hydrophones application

A second step of these international comparisons was its expansion to an infrasonic range, where the measurements during the reproduction of the sound pressure unit dimension and a hydrophone calibration have a specificity.

This comparisons were performed in 2002/03.

ВНИИФТРИ VNIIFTRI

HYDROPHONES USED IN THE COMPARISONS

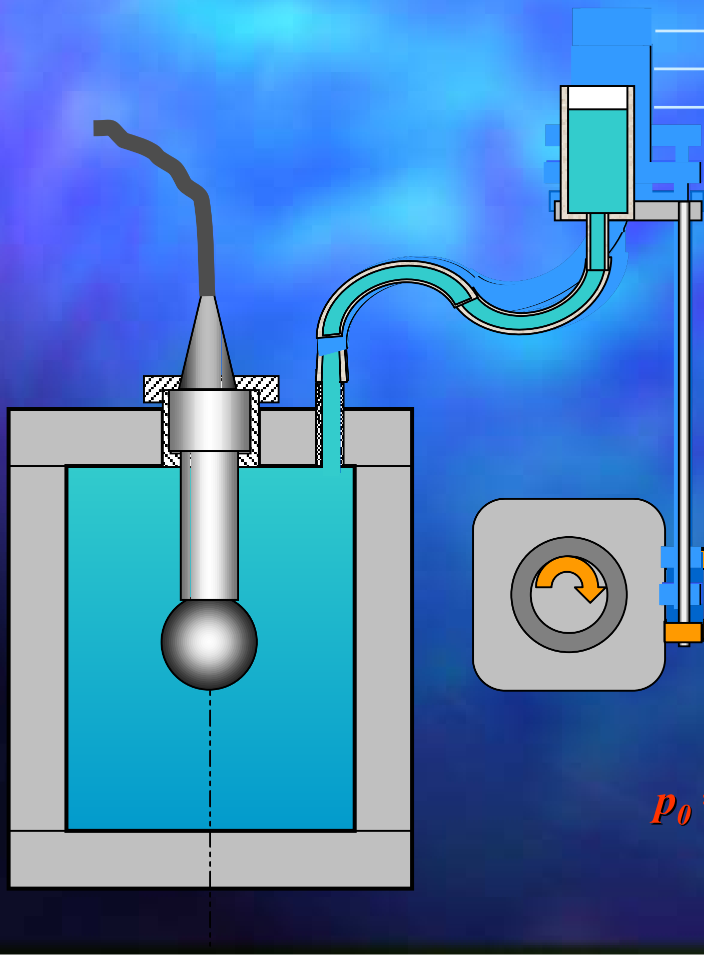
Model No. Ser. No.	Made by	Active element	Nominal capacity, nF
LHA ser. No 03	HAARI	Two parallel-connected piezoceramic cylinders 40 mm in diameter	250
LH1 ser. No 01 ser. No 03	HAARI	Two parallel-connected piezoceramic cylinders 30 mm in diameter	65
HS2 ser. No 210	VNIIFTRI	A piezoceramic sphere 20 mm in diameter	10
HI19 ser. No 366	VNIIFTRI	A piezoceramic sphere 40 mm in diameter	30

Method of hydrostatic excitation

This method is used in Underwater Pressure National Standards of both countries

In a closed measuring chamber filled of water, a hydrophone is mounted. The chamber is connected by means of a flexible tube with an open small vessel with the water level in the vessel always higher then the chamber.

By means of an electromechanical oscillator, the open vessel moves vertically at a harmonic frequency ω with an amplitude h_0



Variation of the water level in the vessel produces an alternating hydrostatic pressure p in the closed chamber $p = p_0 \cos\omega t$

which is used as an equivalent pressure to calibrate hydrophones. At low frequencies (less than 0,5 Hz) the amplitude p_0 can be calculated from:

$$p_0 = \rho\, g\, h_0$$

where ρ is the dencity of water and g is the gravitational constant. At high frequencies, the pressure p is influenced by both the Helmholtz resonance of the system and the inertia of the water in the vessel and flexible tube. As a result, p_0 in chamber is determined as:

$$p_0 = \rho g h_0 \; \underbrace{(1 + \omega^2/\omega_o^2)}_{\text{resonance}} \; \underbrace{(1 - \omega^2 H_e/g)}_{\text{inertia}}$$

VNIIFTRI

Some features of achievement of the method of hydrostatic excitation for both participant

	VNIIFTRI	HAARI
Oscillator and driver for vibration of vessel	Electromechanical oscillator with manual setting of frequency	Two-channel oscillator HP8904A, two electric motors connected with differential gear, automatic setting of frequency
Input circuit	Preamplifier with input impedance 5 GΩ and 70 πF	Amplifier SR 560 with input impedance 0,3 GΩ and series band-pass filter TA3635
Voltage measurement conditions	The conditions approach open-circuit voltage	For taking into account frequency response of the amplifier, it needs its additional calibration using a capacity equivalent of hydrophone
Voltage measurement device	Oscilloscope with 8-bit AD converter	Analyzer Solatron 1250 with 12-bit AD converter
Determination of the equivalent height H_e	Alternating hydrostatic pressure null method	Two frequencies method

VNIIFTRI

Both participants carried out measurements of the end-of-cable open-circuit voltage sensitivity of the hydrophones using the “Procedure for the Intercomparison” developed and agreed by them.

This document outlines all steps of the calibration (care of the hydrophone, its mounting and orientation, measurements to be made, standard frequencies, assessment of the uncertainties, report with results).

Hydrophones were measured in the frequency range 0,01 Hz to 0,1 Hz with steps 0,01 Hz and in the frequency range 0,1 Hz to 1,0 Hz with steps 0,1 Hz.

In order to obtain a precise value of the sensitivity and the evaluation of Type A uncertainty, each measurement was repeated 5 times or more with the hydrophones removed from the chamber and dried out before the calibration was repeated.

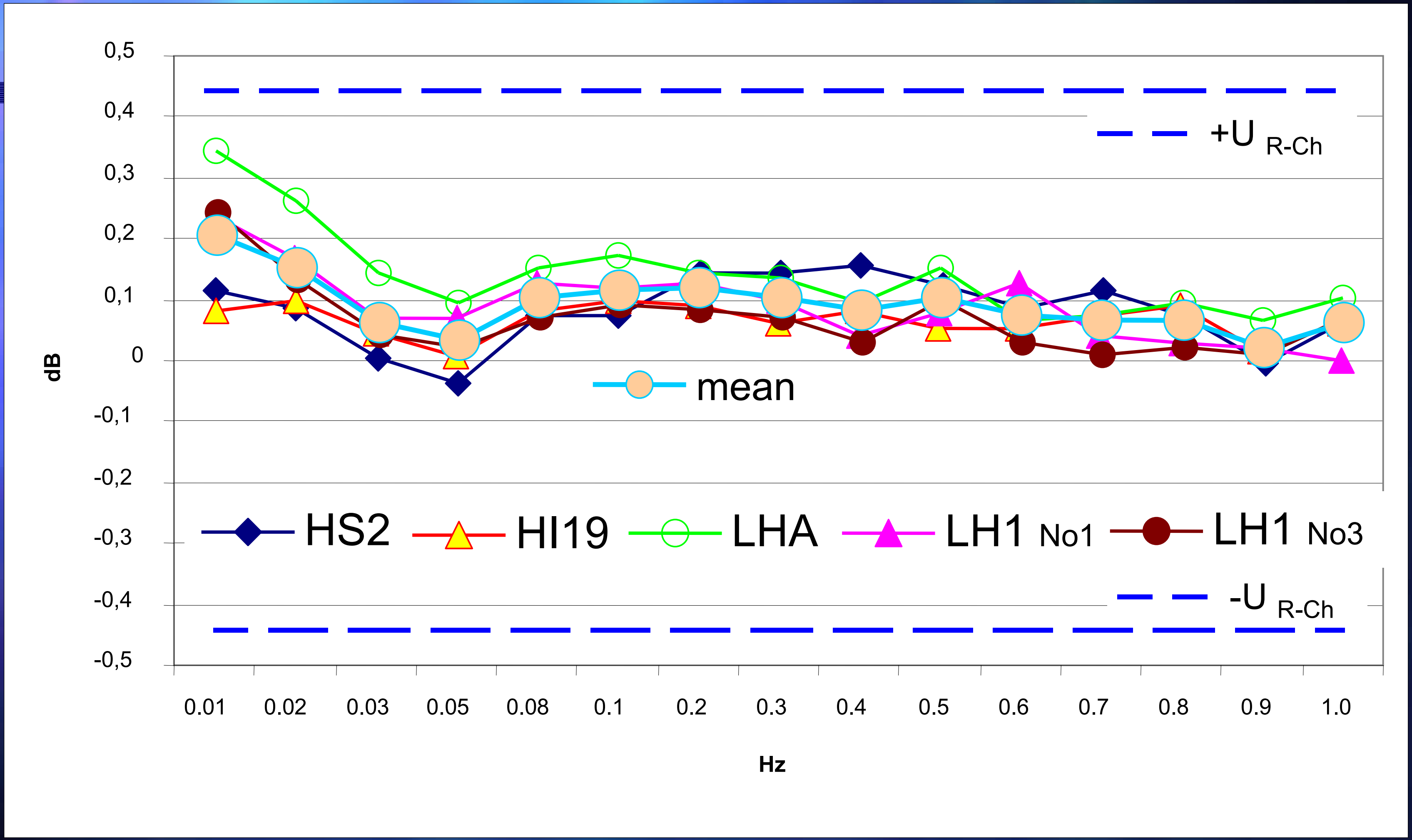
The hydrophones were supplied without sensitivity data during passing them to other participant. An interchange of calibration results and discussion took place in the meeting of participants in August 2003 in VNIIFTRI.

VNIIFTRI

Uncertainty contributions in low-frequency calibration

Source of uncertainty	SRD in %	
	VNIIFTRI	HAARI
Incorrect **density of water** assumed (type B)	0,012	0,12
Incorrect **gravitational constant** assumed (type B)	< 0,01	< 0,01
Incorrect **amplitude** of displacement measured (type B)	0,14	0,28
Incorrect **frequency** adjusted (type B)	0,21	0,06
Incorrect **resonance frequency** determined (type B)	0,03	0,05
Incorrect equivalent height of water column assumed (type B)	0,36	0,5-1,0
Total standard uncertainty of generated sound pressure	0,45	1,0
Voltage incorrectly measured (type B)	1,8	0,13
Incorrect **calibration** of receiving circuit (type B)	0,35	0,32
Standard uncertainty of measurements of sensitivity (type A)	1,5	0,3
Expanded uncertainty (coverage factor k=2)/ dB	**0,32**	**0,30**

Discrepancy of calibration results $\Delta = M_{VNIIFTRI} - M_{HAARI}$



VNIIFTRI

C O N C L U S I O N S:

Bilateral comparisons achieved a good conformity of calibration results and confirmed metrological characteristics of national standards declared by both participants

National Metrological Institutes of Russia and China are ready to participate in future key comparisons CCAUV.W-K2 in low frequency range.