The Static and Dynamic Calibration Method of a Pressure Sensor

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ABSTRACT
The correct measurement of a ship’s hydrodynamic signature is important because the measured values of the ship’s hydrodynamic field are an indication of the estimated level of susceptibility of the ship to an underwater explosion initiated by the trigger level of pressure influence channel of sea mines. The calibration of the hydrodynamic channel is therefore an important element in measuring technology and is required for the measurement equipment used to measure the pressure signatures of military ships. The article presents the successive stages of calibration: hydrodynamic sensor in laboratory and industrial conditions, hydrodynamic channels in conditions on land or on board of the measurement ship and in water, in a test tank as well as in real sea conditions. The description includes methods of static and dynamic tests.

Keywords: underwater sensor calibration, pressure gauge calibration, pressure transducer calibration, pressure ship signature

I-INCE Classification of Subjects Number(s): 54.3

1. INTRODUCTION
The calibration of the pressure sensor and pressure measurement channel and the entire measuring system is an essential preparation for the measurement of the pressure signature of a military ship. These problems are partially contained in standard documentation but advances in measurement technology in recent years is so vast that in addition to traditional methods, there are new solutions based on digital, microprocessor technology adapted in measurement devices. From 2012 The Polish Naval Academy take part in an international research project SI RAMIS, carried out in the framework of the European Defence Agency. The objective of this project is to improve the understanding of ship signature interaction with multi influence sensors in relevant and realistic scenario's. This paper describes selected results of metrological checking of the measuring system before the sea trials, and selected results of comparison mutual during sea trial. Produced by the Polish Naval Academy mobile multi-influence multi-sensor measurement module IGLOO is equipped with one pressure sensor with parameters given in Figure 1 and second pressure sensor mounted inside Valeport miniSVS Sound Velocity Sensor. Comparison of the two sensors during the measurement gives quick information about possible damage to the sensors [1,2].

![Figure 1 – Overview of IGLOO system for the measurement of hydrodynamic pressure](image)

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2. METROLOGY AND METHODOLOGY OF PRESSURE MEASUREMENT
SYSTEM TESTING

2.1 Checking environmental requirements

The environmental conditions (environmental influences or external influences) should not exceed the limits set out in the measured values of the environment parameters. Keeping these values when doing calibration ensures a repeatable metrological check. The first step is to check the measurement area which is to be tested together with the sensors and measuring devices for compliance with the requirements of the environmental parameters. The measurement system should be checked at the control environmental conditions specified in Table 1.

Table 1 – Physical parameters of liquids

<table>
<thead>
<tr>
<th>No.</th>
<th>Control parameters</th>
<th>Value of parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ambient temperature</td>
<td>15 °C - 25° C</td>
</tr>
<tr>
<td>2</td>
<td>Relative humidity</td>
<td>30% - 80%</td>
</tr>
<tr>
<td>3</td>
<td>Atmospheric pressure</td>
<td>960 hPa - 1060 hPa</td>
</tr>
<tr>
<td>4</td>
<td>Changing the voltage in with respect to the nominal value</td>
<td>± 5%</td>
</tr>
<tr>
<td>5</td>
<td>Changes in voltage frequency power with respect to the nominal value</td>
<td>± 1%</td>
</tr>
<tr>
<td>6</td>
<td>Testing depth of sensor in water</td>
<td>Description</td>
</tr>
</tbody>
</table>

A good solution is to monitor the environmental parameter conditions required on-line using the master recording system to verify the metrological parameters (wired or wireless).

2.2 Checking the technical condition of the measurement system

The measurement system checks should include the following:

a) Visual inspection:
   - Check the documentation (measurement system operating manual), and complete the equipment checks in accordance with the documentation;
   - Check to see if the measuring system has any mechanical defects or malfunctions or if there are any components negatively affecting its functioning;
   - Check whether the measuring systems are shipshape maintained;
   - Check whether the measurement systems are properly identified;
   - Check the legibility of inscriptions on the components on the front panel;
   - Check the technical condition of the casings, sockets, plugs, wires.

Any negative results of the external visual inspection (detection of faults which hinder or impede calibration or operating the station in accordance with the specifications) should be the basis for withdrawal from further checking.

b) Initial checks:
   - Turn on the power and check that it is possible to activate the measuring system, its reset and compensation, if those activities are provided for manual;
   - Check the working elements (assemblies), control and switching.

A negative result in the initial checks should be the basis for withdrawal from further checking.

2.3 Metrological checking of the measurement system

a) Check the hydrostatic pressure of the pressure sensors: the sensors should be checked using the measurement system consistent with the metrological check procedure contained in the standardization documents or system calibration manual. Static pressure should be measured in the reference calibrated pressure gauge. The pressure should be measured with accuracy (due to of the permissible error of span) of no more than 0.1 %. The checking of sensors for measuring static and hydrodynamic pressure should be done in a measuring system that is used when measuring hydrodynamic field of ships in real conditions. During the measurements of the pressure signature of the ship measurement the relative error should not exceed 1%.

b) Check sensors for small increments of hydrostatic pressure: for the hydrodynamic pressure
measuring range: -3000 daPa to +1000 daPa control calibration measurements of small increments of hydrostatic pressure $HP$ should be carried out in the measurement system in accordance with the procedure for metrological checks. Due to the fact that the measurements of the hydrodynamic field of the ship can be made at different depths of measurement, the calibration measurements of sensors should be performed not only at a static pressure equal to atmospheric ($1.01325 \times 10^4$ daPa), but also at the static pressures which occur at measurement extremes. Therefore, on the test bench should allow for the opportunity to measure increments of pressure $\Delta p$ at various static pressures (usually measuring depth range changes from 7 to 50 m). Before performing the calibration, static pressure measurements must be compensated using a reference pressure gauge e.g. pressure increments measured by a measuring standard U-tube or.

- checking the hydrodynamic measurement channel in sea water or coast (deck of ship/platform conditions):

General requirements for the validation of the metrological measurement path hydrodynamic field are in [1]. Because of the mobility pressure range it is recommended to use the following methods to metrological check in sea water or coastal conditions (e.g. using the pool test):

- For the hydrodynamic field metrological checking of a measurement system (including sensors, amplifiers, filters, A/D converters and registration system) it should be done by the static method, by asking a constant pressure by dipping on a known depth. It is recommended to use several modules measuring and comparing the results obtained from measurements system;

- Checking of the measurement channel of hydrodynamic field of mobile measurement system should be done with a stable platform, e.g. a dedicated ship or merchant vessel of considerable displacement of the moving known route and the known parameters established before the movement and specifically identified hydro-meteorological conditions. It is recommended to use several modules measuring and comparing the results obtained from measurement system (as presented in Figure 2). Any differences should be calculated on the spot and require the ability of the measurement system to perform "a first look analysis" during measurements (this prevents a possible fluctuation of reference conditions);

Metrological checking carried out in accordance with [3,4] as above or by reading and writing results using the GUI console. It is recommended to check the measurements performed always in the same location and environmental conditions appropriate for measuring the hydrodynamic field in accordance with national or international requirements. All results of metrological check should be reported.

![Figure 2](image-url) – The example of calibration measurement of dedicated ship by four different pressure sensors.
3. CONCLUSIONS

Despite the good results of the comparison of measurements of pressure signature on the example of a ship, some measurements deviate significantly from the theoretical results. Due to the lack of reproducibility of these deviations may be due to errors in reading real position of underwater measurement modules IGLOO. This comparison allows increasing the reliability of further calculations based on the results of measurements, and it is expected that the development of this method allows determining the real values of parameters of the pressure under the hull at any point situated at a distance of not more than 1 meter from the seabed. During calibration measurements with using different measurement pressure systems presented in Figure 2 relative error does not exceed 10%.

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REFERENCES