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TECHNICAL REPORT

colour inside

Ultrasonics – Conditioning of water for ultrasonic measurements

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ULTRASONICS – CONDITIONING OF WATER FOR ULTRASONIC MEASUREMENTS

FOREWORD

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IEC 62781, which is a technical report, has been prepared by IEC technical committee 87: Ultrasonics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
87/494A/DTR	87/507/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Many ultrasonic measurements are conducted in water, as it provides an inexpensive and readily available medium with characteristic acoustic impedance comparable to biological tissue. However, basic tap water is far from optimum for ultrasonic measurement as it contains many dissolved, absorbed and suspended contaminants. Measurements can be affected in many ways by these impurities. For example:

- dissolved gases readily dissociate from the water in the presence of high rarefactional pressures or heat giving rise to bubble formation. These bubbles not only are unwanted point reflectors but also increase the likelihood of cavitation.
- dissolved ionic components result in a raised conductivity of the water, which in turn can affect the measured output from some unshielded hydrophones. Furthermore experimental equipment left in an ionic solution for any period of time will gradually develop a layer of deposit (e.g. calcium carbonate) on its surface.
- biological activity within an untreated water tank will result in the creation of an unpleasant film on all available surfaces. If left long enough this biological activity will result in an undesirable environment for the operator and may also be a health hazard.

To minimize these effects it is necessary to undertake a water treatment process.

These problems are well known and many IEC standards have sought to address these issues, often by means of an informative annex. This technical report aims to provide a unified resource for operators wishing to establish a water treatment process for ultrasonic measurements. This technical report discusses each of the stages within a water treatment process and provides examples of suitable treatment methods.

ULTRASONICS – CONDITIONING OF WATER FOR ULTRASONIC MEASUREMENTS

1 Scope

This Technical Report describes methods:

- for degassing water to be used in ultrasonic measurements,
- to decrease the ionic content of water to be used in ultrasonic measurements,
- to decrease the biological content of water to be used in ultrasonic measurements,
- to reduce the suspended particulate content of water to be used in ultrasonic measurements.

This technical report is applicable to all measurements of ultrasonic fields where water is the transmission medium. The quality and treatment methods for water used within a radiation force balance (RFB) may be different from that required for hydrophone based acoustic measurements. Chemical based methods of water treatment (e.g. algaecides) may be appropriate for these applications. However, in this document, chemical means are noted but appropriately discouraged for acoustic pressure/intensity measurements.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62127-1, *Ultrasonics – Hydrophones – Part 1: Measurement and characterization of medical ultrasonic fields up to 40 MHz*

3 Dissolved gases

3.1 General

Tap water is often super-saturated with dissolved gases (although not in the same relative quantities as in air). Bubbles can be a cause of major experimental problems since they act as near perfect reflectors of ultrasound. This can perturb the ultrasonic field being measured. Also, if a bubble forms directly in front of the active element of a hydrophone it will prevent any propagating ultrasound from being measured by that hydrophone. Finally acoustic pressures greater than approximately 100 kPa can cause cavitation, i.e. they can bring bubbles out of solution and it is well established that measurements can be strongly affected by acoustic cavitation. Trapped gas on particulate is also a significant source of cavitation and removal of suspended particulates is considered in Clause 6.

Cavitation is the growth, oscillation and collapse of previously existing gas- or vapour-filled micro-bubbles in a medium. This will result in the production of spurious acoustic signals both below and above the driving frequency (for stable and inertial cavitation respectively). Particular care should be taken to avoid inertial cavitation as bubble collapse is a particularly destructive event. If such a collapse happens on the surface of a hydrophone, damage to the hydrophone may occur. It is useful to note that macroscopic bubbles are visible to the naked eye. However, microscopic bubbles may be much harder to visually detect, and can be just as much of a problem. There is thus a need to define means of obtaining a suitable medium in which the effects of cavitation are minimized.

A measurement method to detect the onset of cavitation is described in [1,2][1]. Specifically, the onset of inertial cavitation is often characterized by the presence of the sub-harmonic of the fundamental operating frequency or additional broadband noise. Examples of acoustic spectra acquired using a needle and membrane hydrophones is presented in [3,4].

3.2 Chemical methods

3.2.1 General

Whilst chemical methods of removing dissolved gases can be very effective both in terms of initial degassing rate and rate of subsequent re-gassing, they have a number of drawbacks. Firstly, chemical methods tend to be single gas specific (e.g. removing oxygen only). Secondly, they involve the addition of ionic content to the water; this is in complete contradiction to the attempts in Clause 4 to deionise the water. Thirdly, a number of chemical methods of degassing require the use of strong reducing agents that can be both hazardous to the user and may cause damage to experimental equipment. Finally, disposal of chemically treated water needs to be handled with care to avoid potential environmental harm.

3.2.2 Addition of sodium sulphite

Sodium sulphite (Na_2SO_3) can be added to water to act as an oxygen scavenger. Water saturated with oxygen at 20 °C will contain about 9 mg/l oxygen. To bind the oxygen 0,5 g/l sodium sulphite is needed. The use of Na_2SO_3 for degassing water results in sodium sulphate (Na_2SO_4).

As an example water has been prepared to which Na_2SO_3 is added to give a solution of 0,4 mass % Na_2SO_3. The O_2-content of this water type stays < 4 mg/l during a long period of time, see Figure 1. The speed of re-gassing strongly depends on the dimensions of the water tank. Re-gassing periods > 150 h are observed in tanks with greater dimensions.

The speed of sound in a fluid, c_L, is given by

$$c_L = \sqrt{\frac{K}{\rho}} \quad , \tag{1}$$

where K is the bulk modulus of the fluid and ρ is its density. The change in density after adding Na_2SO_3 in the concentration listed above is < 1 %, and the change in bulk modulus is even smaller. Therefore the change in sound speed is negligible. The electrical conductivity using a mixture of 4 g/l Na_2SO_3 is 5,1 mS/cm.

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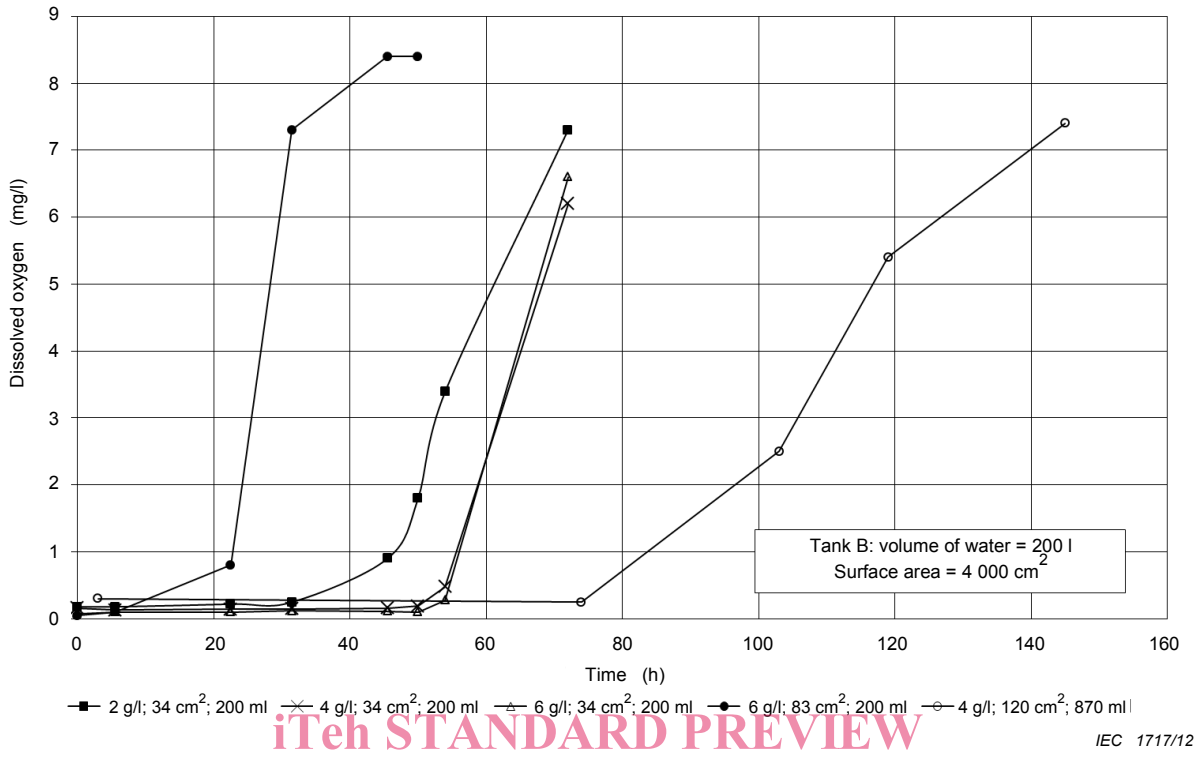
1 Numbers in square brackets refer to the Bibliography.



Measurements started directly after filling the glass. Water temperature (22 ± 1) °C.

Figure 1 – Dissolved oxygen concentration as a function of time for 2, 4 and 6 g/l of sodium sulphite in de-mineralised water and for different surface areas and volumes of water

There are some effects on metals like aluminium and nickel (Na_2SO_3 will act like a base). For example, after 2 h in the solution, a transducer with an aluminium front surface will be corroded somewhat. It is therefore recommended that immersion of these types of metals is carried out over as short a time period as possible.

3.3 Physical methods

3.3.1 General

Unlike chemical degassing methods, physical degassing methods do not add ionic content to the water nor are they single gas specific. A good overview of a selection of physical degassing methods is presented in [5].

3.3.2 Vacuum degassing

When a vacuum (2 kPa to 2,5 kPa) is applied to a standing body of water, the reduced pressure will prevent dissolved gases from remaining in solution. Under these conditions the water will appear to boil as the gas bubbles rapidly expand and then break at the water surface. After a period of 24 h, levels of dissolved oxygen can be as low as 1 mg/l.

3.3.3 Reduced pressure recirculation

Many water conditioning systems employ a pump to circulate water through the treatment system. Choosing a high volume pump and using a small modification at the inlet allows the pump to serve a dual purpose. A reduced pressure degassing system [5] can easily be prepared by attaching a reinforced pipe/rigid tube to the inlet of a high volume pump. A flow