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TECHNICAL SPECIFICATION

colour inside

Measurement of cavitation noise in ultrasonic baths and ultrasonic reactors

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MEASUREMENT OF CAVITATION NOISE IN ULTRASONIC BATHS AND ULTRASONIC REACTORS

FOREWORD

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Technical Specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

Technical Specification IEC 63001 has been prepared by IEC technical committee 87: Ultrasonics.

The text of this Technical Specification is based on the following documents:

Draft TS	Report on voting
87/681/DTS	87/693A/RVDTS

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

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

Terms in **bold** in the text are defined in Clause 3.

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- transformed into an International Standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

Ultrasonically induced **cavitation** is used frequently for immersion cleaning in liquids. There are two general classes of ultrasonically induced cavitation. **Transient cavitation** is the rapid collapse of bubbles. **Stable cavitation** refers to persistent pulsation of bubbles as a result of stimulation by an ultrasonic field. Both **transient cavitation** and **stable cavitation** may create significant localized streaming effects that contribute to cleaning. **Transient cavitation** additionally causes a localized shock wave that may contribute to cleaning and/or damage of parts. Both types of cavitation create acoustic signals which may be detected and measured with a **hydrophone**. This document provides techniques to measure and evaluate the degree of cavitation in support of validation efforts for ultrasonic cleaning tanks and cleaning equipment, as used, for example, for the purposes of industrial process control or for hospital sterilization.

MEASUREMENT OF CAVITATION NOISE IN ULTRASONIC BATHS AND ULTRASONIC REACTORS

1 Scope

This document, which is a Technical Specification, provides a technique of measurement and evaluation of ultrasound in liquids for use in cleaning devices and equipment. It specifies

- the cavitation measurement at $2{,}25f_0$ in the frequency range 20 kHz to 150 kHz, and
- the cavitation measurement by extraction of broadband spectral components in the frequency range 10 kHz to 5 MHz.

This document covers the measurement and evaluation of the cavitation, but not its secondary effects (cleaning results, sonochemical effects, etc.).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
averaging time for cavitation measurement
t_{av}
length of time over which a signal is averaged to produce a measurement of cavitation

Note 1 to entry: Averaging time for cavitation is expressed in seconds (s).

3.2
cavitation
formation of vapour cavities in a liquid

3.2.1
transient cavitation
inertial cavitation
sudden collapse of a bubble in a liquid in response to an externally applied acoustic field, such that an acoustic shock wave is created

3.2.2
stable cavitation
oscillation in size or shape of a bubble in a liquid in response to an externally applied acoustic field that is sustained over multiple cycles of the driving frequency

3.3
end of cable loaded sensitivity
$M_L(f)$
<of a **hydrophone** or **hydrophone assembly**> modulus quotient of the Fourier transformed output **voltage** $U(f)$ at the end of any integral cable or output connector of a **hydrophone** or **hydrophone-assembly**, when connected to a specific electric load impedance, to the Fourier transformed acoustic pressure $P(f)$ in the undisturbed free field of a plane wave in the position of the reference centre of the **hydrophone** if the **hydrophone** were removed, at a specified frequency

Note 1 to entry: The Fourier transform is in general a complex-valued quantity but for this document only the modulus is considered, and is expressed in volt per pascal, V/Pa,

Note 2 to entry: The term 'response' is sometimes used instead of 'sensitivity'.

3.4
end of cable loaded sensitivity level
$M_{L.dB}$
twenty times the logarithm to the base 10 of the ratio of the modulus of the **end of cable loaded sensitivity** $M_L(f)$ to a reference sensitivity of M_{ref}.

Note 1 to entry: $M_{L,dB} = 20 \log_{10} \frac{|M_L|}{M_{ref}}$ dB .

Note 2 to entry: The value of reference sensitivity M_{ref} is 1 V/Pa.

3.5
hydrophone
transducer that produces electric signals in response to waterborne acoustic signals

[SOURCE: IEC 60050-801:1994, 801-32-26] [1]

3.6
hydrophone assembly
combination of **hydrophone** and **hydrophone pre-amplifier**

[SOURCE: IEC 62127-3: 2007, 3.10] [2]

3.7
number of averages
N_{av}
number of waveforms captured and averaged in a **cavitation** measurement

3.8
operating volume
part of the liquid volume where cavitation effects are intended

3.9
operating frequency
f_0
driving frequency of ultrasound generator

Note 1 to entry: Operating frequency is expressed in hertz (Hz).

3.10
relative cavitation measurements
measurements made for purposes of comparison between two different cleaning environments or different locations within a cleaning environment, such that the **end-of-cable loaded sensitivity** of the **hydrophone** may be assumed to be identical in both cases

Note 1 to entry: Care should be taken to ensure that changes in hydrophone sensitivity do not affect the measurement.

3.11
sampling frequency
f_s
number of points per second captured by a digital waveform recorder

Note 1 to entry: Sampling frequency is expressed in hertz (Hz).

3.12
size of the capture buffer
N_{cap}
total number of points captured at a time by a digital waveform recorder

3.13
capture time
t_{cap}
length of time to capture N_{cap} points at a sampling frequency of f_s

Note 1 to entry: Capture time is expressed in seconds (s).

3.14
cavitation noise level
L_{CN}
level calculated from the cavitation noise at a frequency of 2,25 f_0

Note 1 to entry: Cavitation noise is expressed in decibels (dB).

3.15
reference sound pressure
P_{ref}
sound pressure, conventionally chosen, equal to 20 μPa for gases and to 1 μPa for liquids and solids

Note 1 to entry: Reference sound pressure is expressed in pascals (Pa).

[SOURCE: IEC 60050-801:1994, 801-21-22] [1]

3.16
averaged power spectrum
$\overline{P^2}(f)$
power spectrum of the **instantaneous acoustic pressure** averaged over N_{av} measurements

Note 1 to entry: Averaged power spectrum is expressed in Pa^2.

3.17
median of acoustic pressure
P_n
median value of amplitude values of spectral lines within B_f

Note 1 to entry: Median of acoustic pressure is expressed in pascals (Pa).

3.18
band filter
B_f
band filter located at a centre frequency of 2,25 f_0

Note 1 to entry: Band filter is expressed in hertz (Hz).

3.19
direct field acoustic pressure
P_0
portion of the RMS acoustic pressure signal arising directly from the ultrasonic driving excitation, at the **operating frequency** of the device

Note 1 to entry: RMS direct field acoustic pressure is expressed in pascals (Pa).

3.20
spectral acoustic pressure
$P(f)$
Fast Fourier Transform of the hydrophone voltage divided by the end-of-cable loaded sensitivity

Note 1 to entry: Spectral acoustic pressure is expressed in pascals (Pa).

3.21
stable cavitation component
P_s
portion of the RMS acoustic pressure signal arising from stable cavitation

Note 1 to entry: The stable cavitation component is expressed in pascals (Pa).

3.22
transient cavitation component
P_t
portion of the RMS acoustic pressure signal arising from transient cavitation

Note 1 to entry: The transient cavitation component is expressed in pascals (Pa).

3.23
voltage
$u(t)$
instantaneous voltage measured by analyser

Note 1 to entry: Voltage is expressed in volts (V).

3.24
voltage spectrum
$U(f)$
Fast Fourier Transform of the voltage

Note 1 to entry: Voltage spectrum is expressed in volts (V).

3.25
frequency spacing
Δf
distance of spectrum samples of a Fast Fourier Transform

Note 1 to entry: Frequency spacing is expressed in hertz (Hz).

3.26
indexed frequency
f_k
frequency of index k at which the Fast Fourier Transform is evaluated

Note 1 to entry: f_k $(k – 1)\,\Delta f$, where $k = 1, 2, \ldots, N_{cap}$.