ONDA

Putting Confidence in Ultrasound

Another Look at Methods & Units of Measure

Cavitation Metrology

March 17, 2020

This document address the following questions:

- ❑ What standard methods are internationally accepted to measure cavitation?
- ❑ What units of measure (UOM) are scientifically valid to quantify acoustic cavitation?
- ❑ Which UOM(s) best represents cleaning?
- ❑ Why are calibrations important?

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Cavitation Measurement Standards

<u>IEC 60886: 1987</u> *Investigations on test procedures for ultrasonic cleaners*

- International Electrotechnical Commission
- Several methods described but poor reproducibility; only Al foil was practical

<u>DIN spec 40170: 2013</u> *Measurement and judgment of the cavitation noise*

- Deutsches Institut Fur Normung E.V. (German standard)
- Driven by Bandelin & Elma‘s interest to support cleaning for medical apps
- Described method to quantify amplitude at 2.25 x F0 up to 150 kHz

<u>IEC/TS 63001: 2019</u> *Measurement of cavitation noise in ultrasonic baths and ultrasonic reactors*

- WG3 in TC87: High Power Transducers; other WG’s mostly medical ultrasound devices.
- Captures method from DIN and addressed several objections; a second approach was added based on broadband spectral analysis up to 5 MHz

IEC 63001: 2019

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 $2,25 f_0$ 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.).

Full Technical Specification HERE

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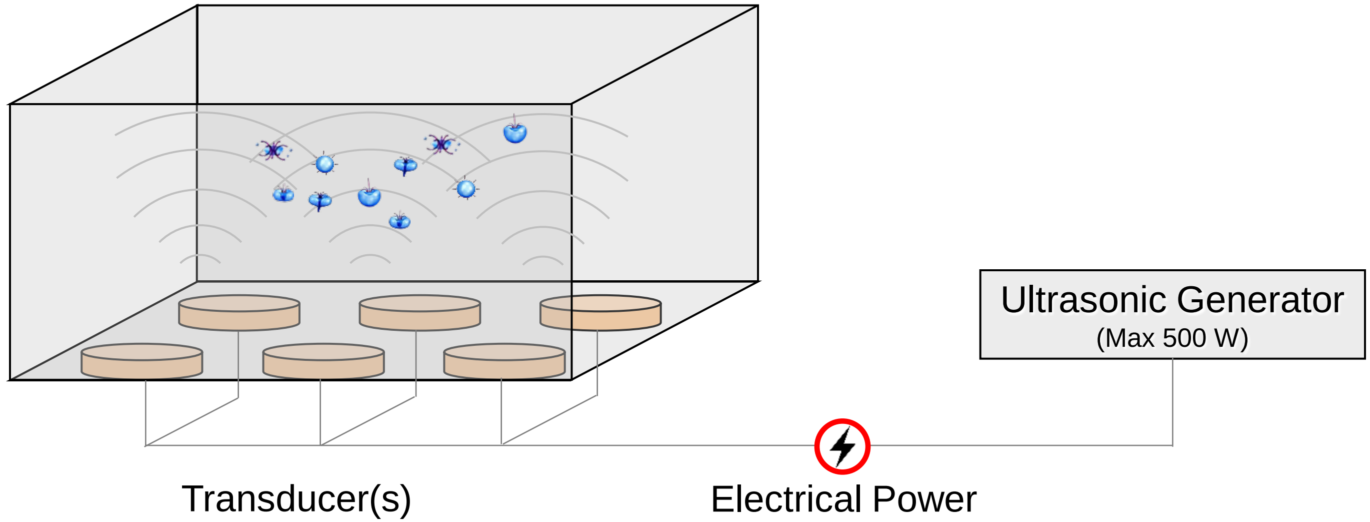
Which Unit of Measure(s) are Scientifically Valid?

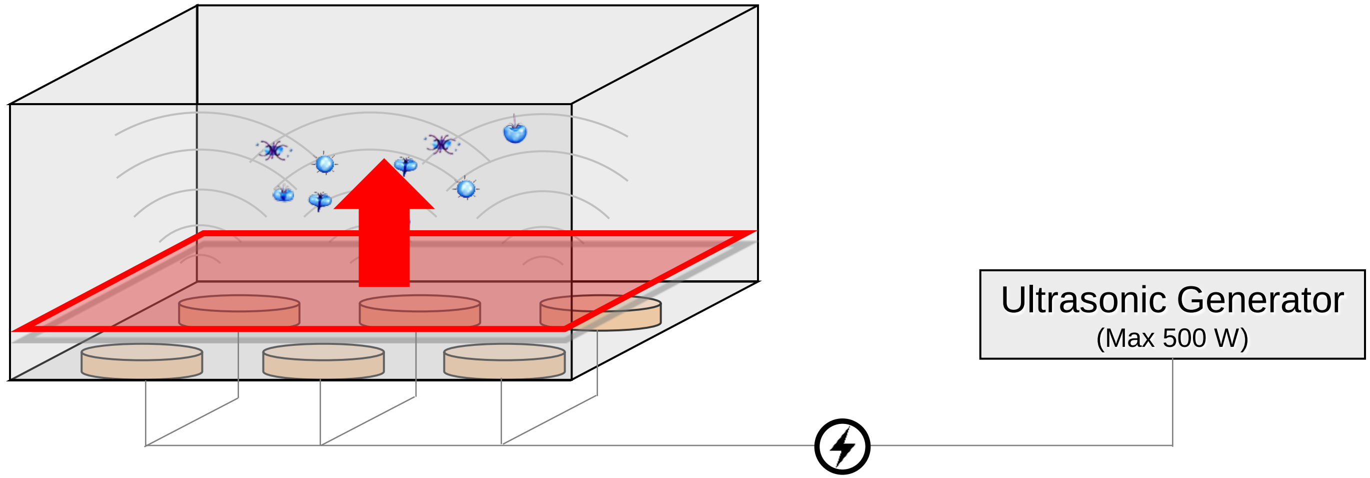
Parameter	UOM	Attribute
Acoustic Pressure	***kPa***	***A derived SI unit traceable to a primary measurement***
Acoustic Intensity	W/cm^2	Only valid for infinitely deep tank (i.e., no reflection). Relies on knowing impedance of medium and must be “away” from source. Area refers to the radiating area which is not uniform.
(Electrical) Power density	W/cm^2	W often refers to the *electrical* power delivered to the transducers. Does not account for transducer efficiency. Area is the radiating area (e.g., bottom tank surface if shoot-up config)
(Electrical) Power per Volume	W/gal	W often refers to the *electrical* power delivered to the transducers. Does not account for transducer efficiency. Tank volume does not account for shape which significantly affects field.
Energy	W-s	See Acoustic Intensity above.
Voltage	V	Relative measurement. Does not account for hydrophone sensitivity.
Frequency	***Hz***	***A derived SI unit traceable to a primary measurement***

Units of Measure: Electrical Power



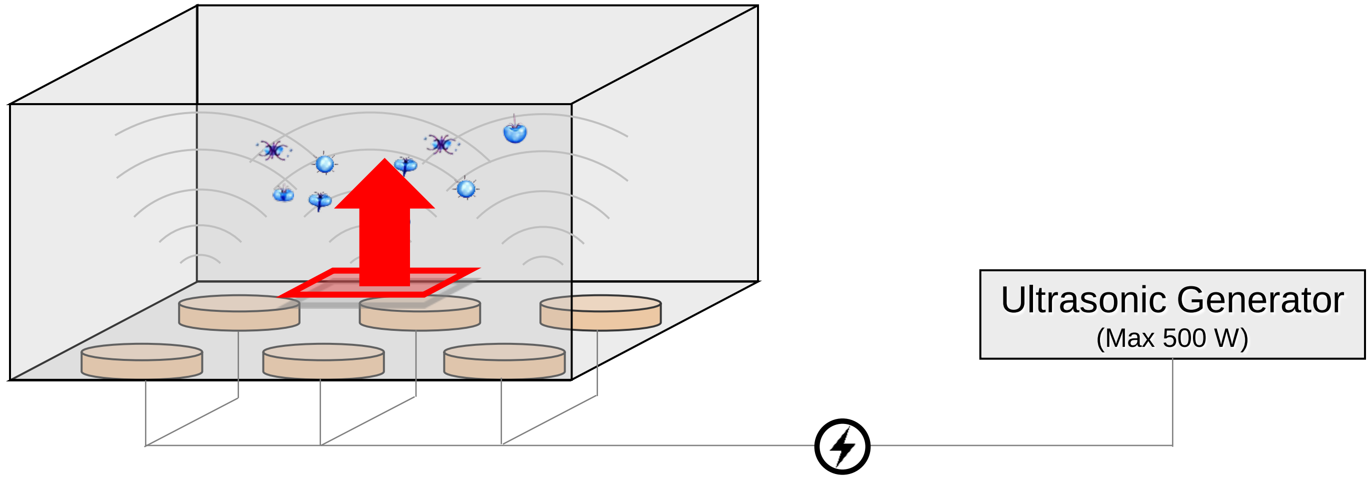
"Power" often refers to the Electrical Power [W] from the generator delivered to the transducers. Some vendors offer a "Watt Meter" to measure this. This does not account for the transducer efficiency.

Units of Measure: Acoustic Power



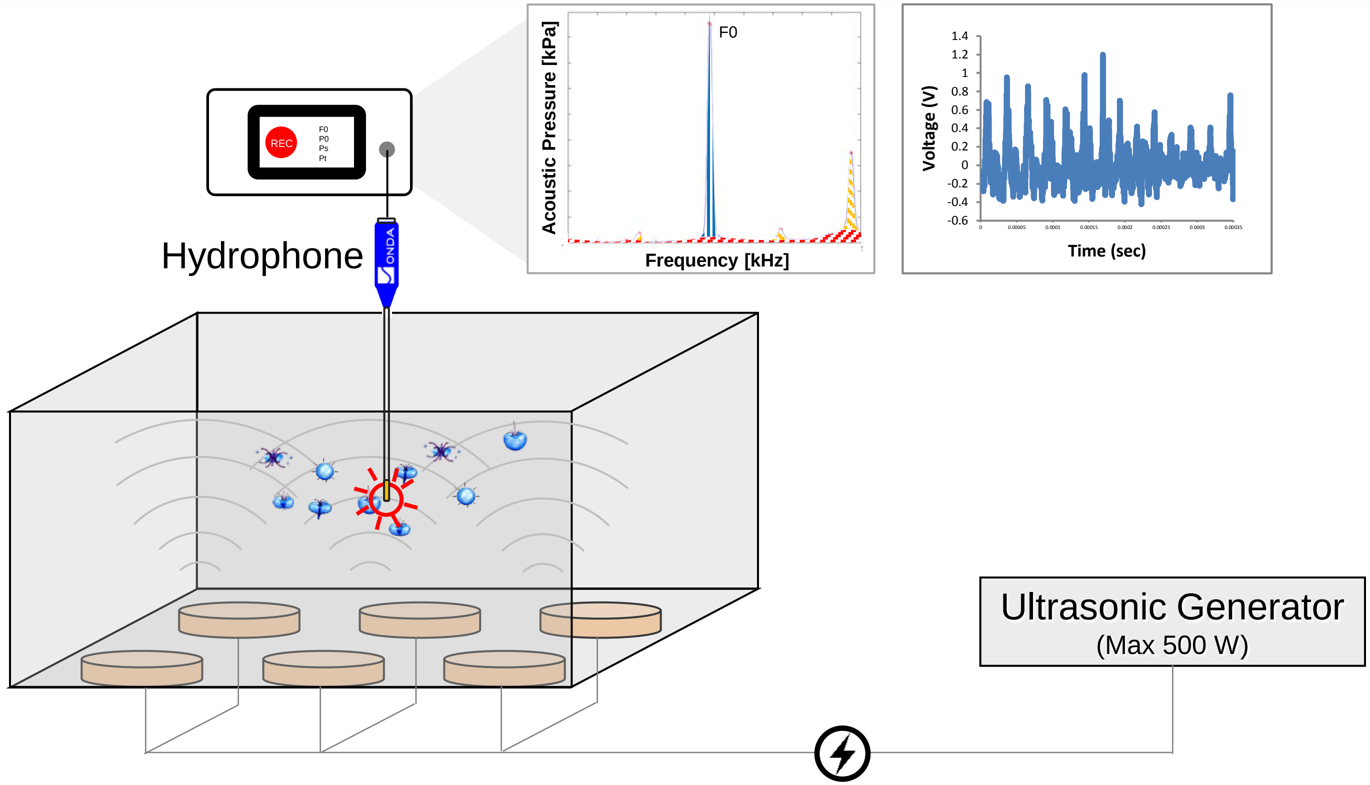
Measuring the Acoustic Power [W] is valid only when sound waves propagate in one direction (i.e., no reflections from surface or side walls), which is NOT the case for most cleaning tanks. The Acoustic Power should account for the total radiating area. If transducers are mounted across the bottom of the tank, the area can be estimated from the bottom surface dimensions of the tank.

Units of Measure: Acoustic Intensity



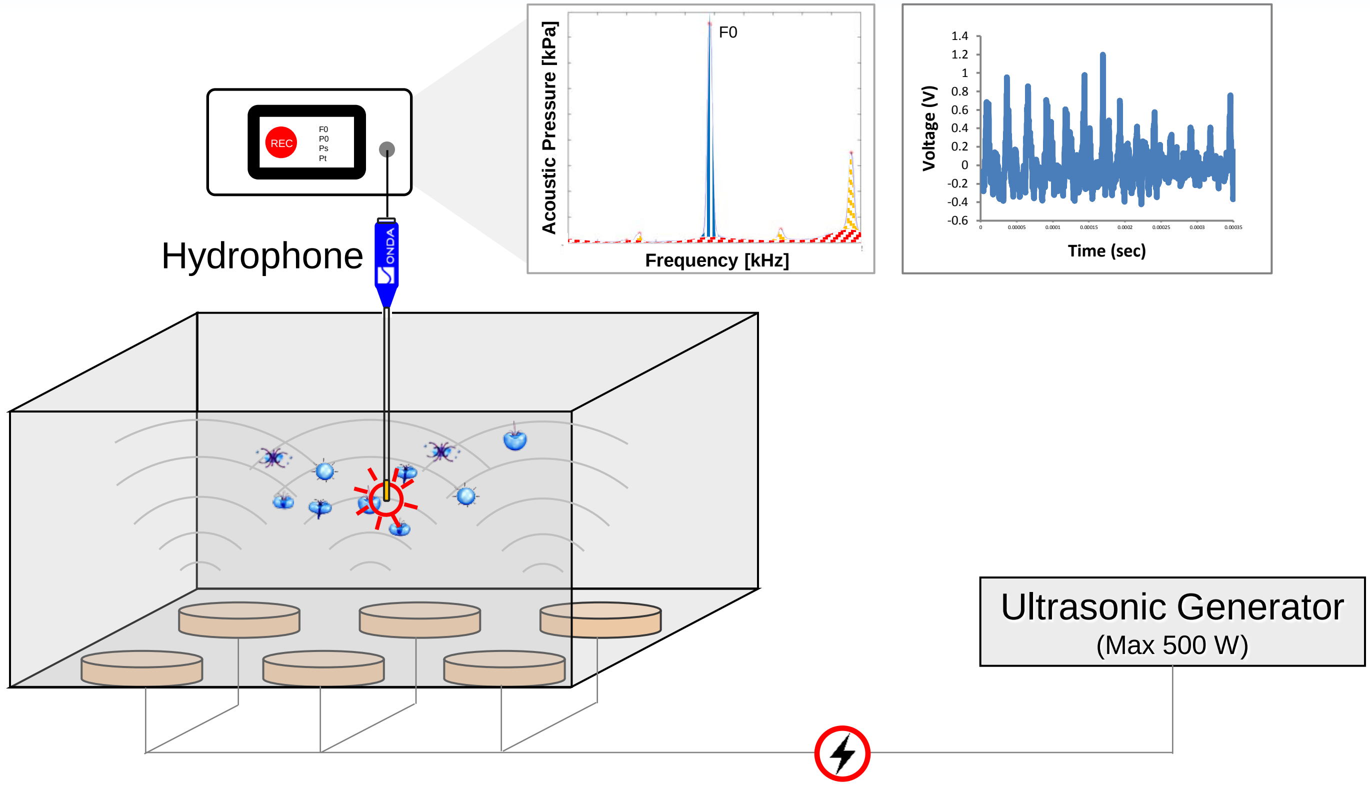
The same issues apply when measuring the Acoustic Intensity [W/cm^2], which is defined by the acoustic power over a defined radiating area in the direction perpendicular to that area. It should be noted that the acoustic field is typically NOT uniform.

Units of Measure: Voltage & Acoustic Pressure



Most hydrophones are based on a piezoelectric transducer that generates an electrical signal or a Voltage [V] when subjected to a change in Acoustic Pressure [kPa]. Ideal hydrophone designs enable measurements to be sensitive from all directions at a single point. Hydrophone calibrations enable measurements of absolute Acoustic Pressure. Pressure is the unit of measure most representative of what “cleans” parts.

Units of Measure: Frequency



There are a few ways to measure Frequency (kHz). Some inline meters measure frequency by "counting" the oscillations from the drive signal delivered to the transducers. Hydrophones can detect the acoustic emissions and measure the voltage amplitude over time. From this, the frequency can be determined by either counting oscillations from the acquired voltage waveform (time-domain) or through spectral analysis (frequency-domain). Analysis in frequency-domain has the advantage where the broadband content of the signal can also be used to quantify the cavitation pressure.

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IEC 63001: 2019

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Full Technical Specification HERE

Useful, but…

Connecting Cavitation with Cleaning

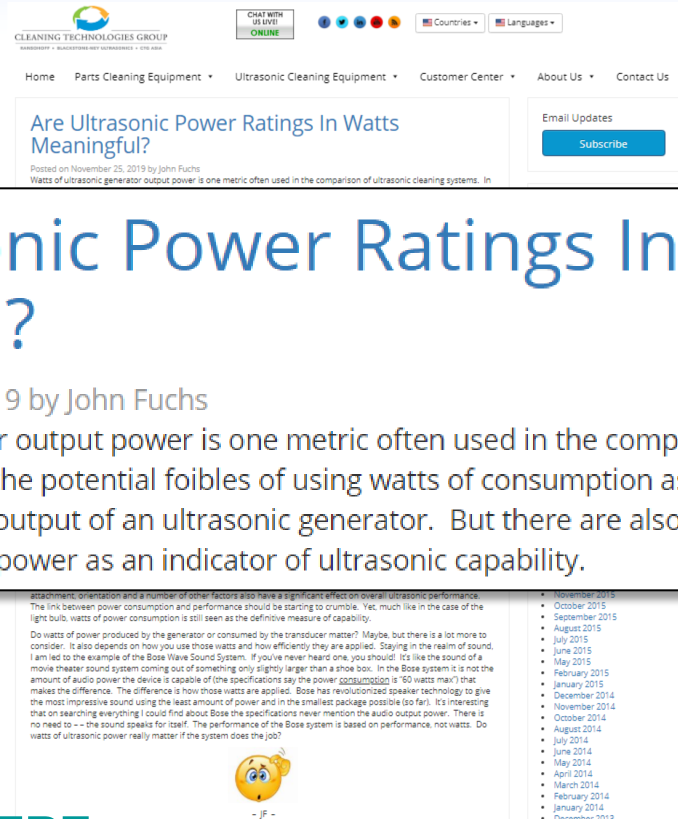
- Various studies (anecdotal and scientific) confirm there is correlation between *acoustic cavitation* and other process variables – e.g., frequency, power, chemistry, gas, temperature, etc.
- Validation of a *cleaning* process is more ambiguous, because each cleaning process is uniquely developed for the application. Typically, the criteria relies on: (1) particle removal and (2) damage.
- Common methods to verify cleaning performance include:
  - Particle count
  - Visual inspection
  - Materials analysis

How do you define “Clean”?

Cleanliness Standards

- **HTM 2030** Operations management guidance of washers-disinfectors for processing medical devices.
- **EN ISO 15883** Washer-disinfectors – Part 1
- **ASTM F2459** Standard Test Method for Extracting Residue from Metallic Medical Components and Quantifying via Gravimetric Analysis
- **ASTM F2847** Standard Practice for Reporting and Assessment of Residues on Single Use Implants
- **ASTM E2314** Standard Test Method for Determination of Effectiveness of Cleaning Processes for Reusable Medical Instruments Using a Microbiologic Method (Simulated Use Test)
- **ASTM D7225** Standard Guide for Blood Cleaning Efficiency of Detergents and Washer-Disinfectors
- … many more

No one size fits all.
Many applications = many standards.



Are Ultrasonic Power Ratings In Watts Meaningful?

Posted on November 25, 2019 by John Fuchs

Watts of ultrasonic generator output power is one metric often used in the comparison of ultrasonic cleaning systems. In a previous blog, I discussed the potential foibles of using watts of consumption as a measure of comparison as there is no standard for measuring the output of an ultrasonic generator. But there are also other potential flaws in using the ultrasonic generator output power as an indicator of ultrasonic capability.

Full Blog Post HERE

Good blog cautioning you to measure what is meaningful to cleaning

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Why Calibrate?

Calibrations are done:

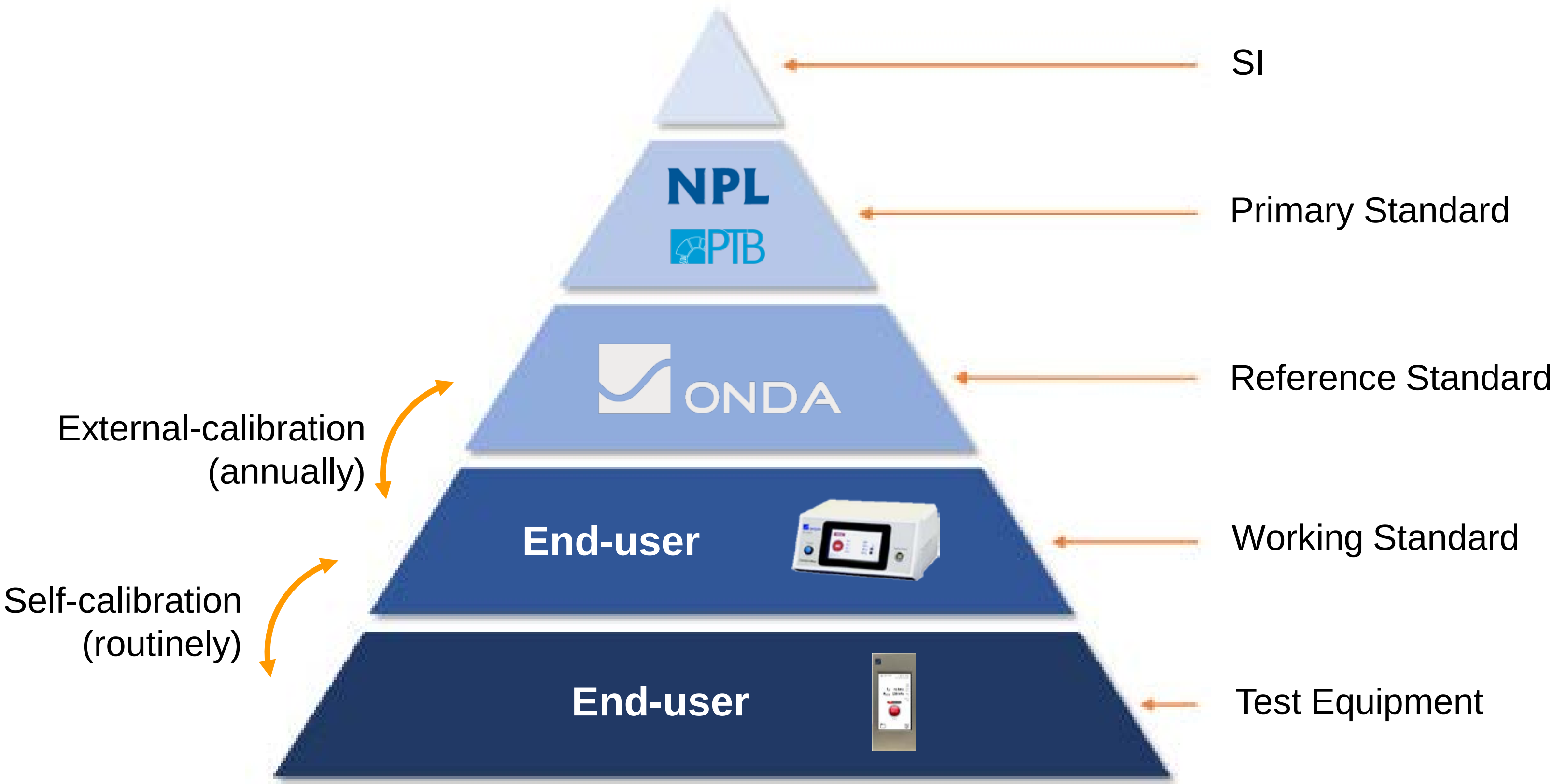
1. To make sure measurements are accurate and comply with standard methods that are universally accepted

2. To verify the accuracy and stability of the measurement system

3. To account for local test conditions

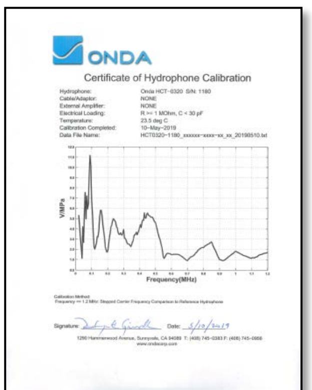
4. To create confidence

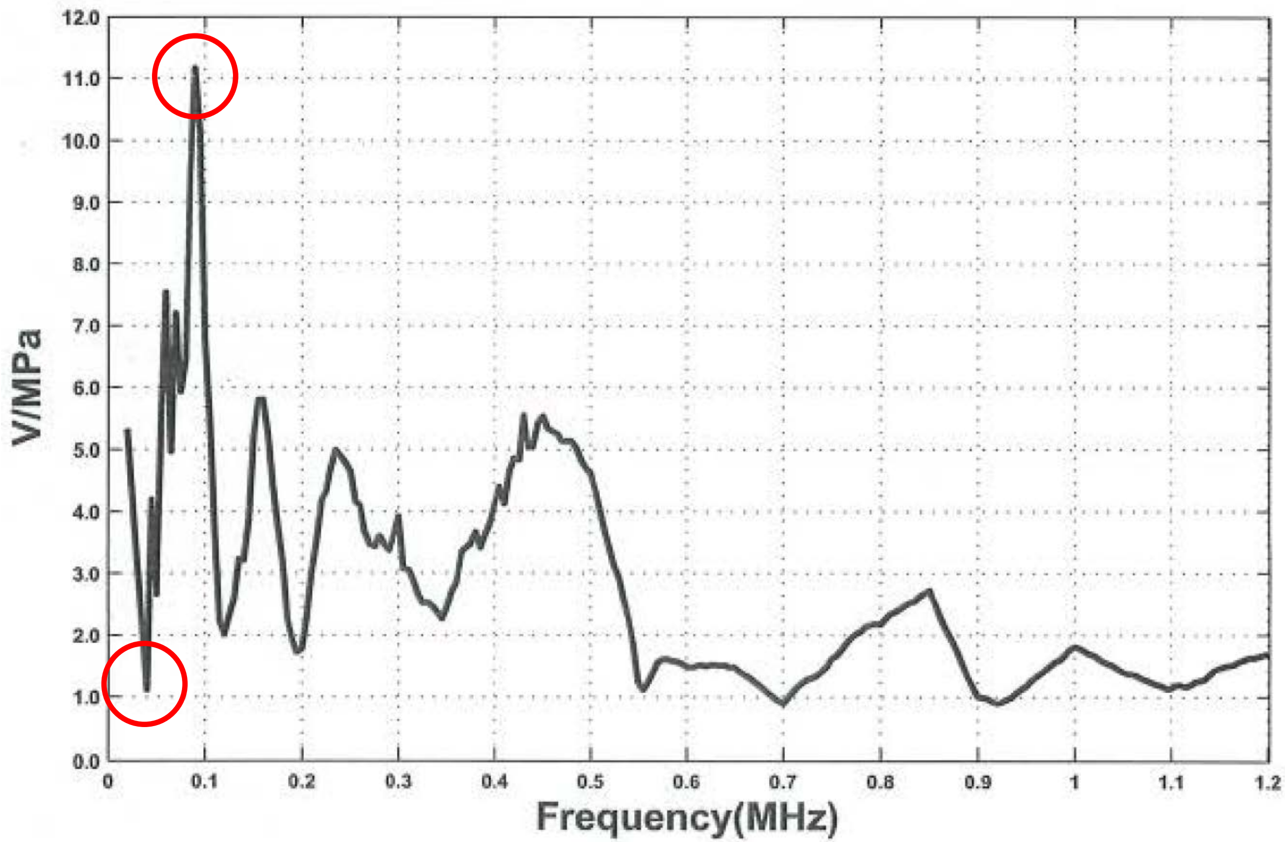
Measurement Traceability Pyramid



<u>Traceability</u> to ensure absolute accuracy and compliance with standard methods that are universally accepted

HCT Hydrophone Calibration





Voltage does not represent Pressure

EX: 1V at 40 kHz is equivalent to a pressure of 1 MPa; 1V at 90 kHz is equivalent to a pressure of 0.1 MPa

Method to Measure Cavitation

Reference: IEC/TS 63001:2019

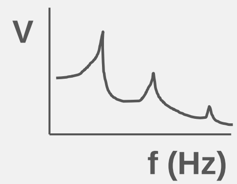
Measurement of cavitation noise in ultrasonic baths and ultrasonic reactors

Acquire data with Hydrophone

Voltage vs Time

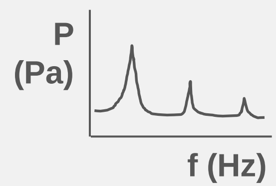
Fourier Transform

Voltage vs Frequency



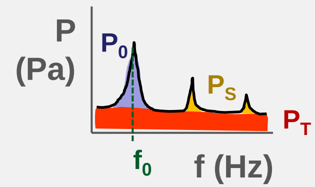
Apply Hydrophone Calibration

Pressure vs Frequency



Apply MCT-2000 Algorithms

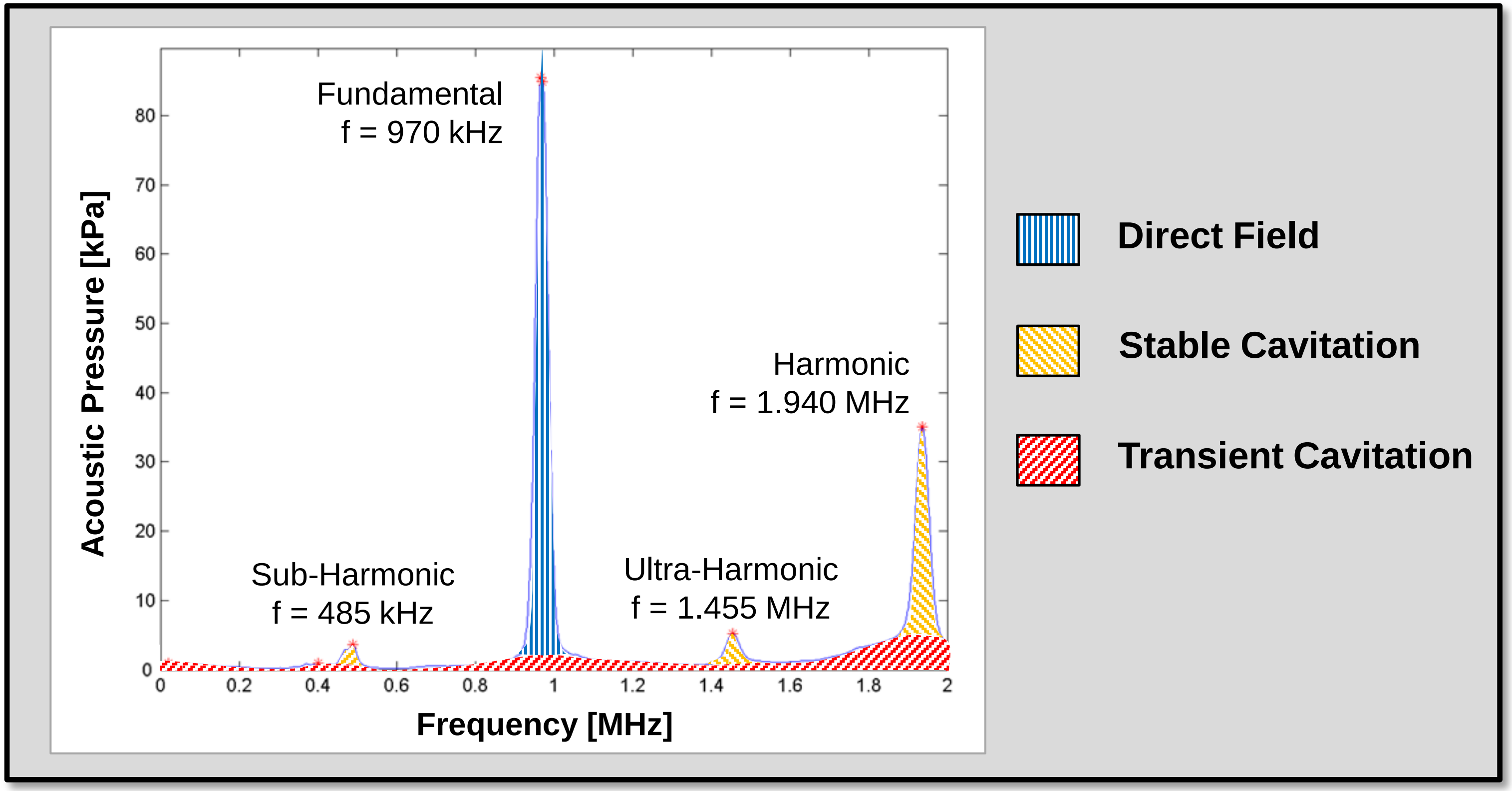
Calculation of P_0, P_S, P_T, f_0



Relative Pressure

Absolute Pressure

Anatomy of Acoustic Spectrum



Different pressure components contribute to cleaning and damage

Externally Calibrate Hydrophones (Annually)

External Calibration (annually)

<u>Includes</u>

- ✓ Conformance Test
- ✓ Traceable Calibration to National Lab
- ✓ Calibration Certificate
- ✓ Calibration Connector Re-programmed
- ✓ MCT software upgrades

Annual external calibrations complement routine checks to verify measurement accuracy and stability

Summary

- An international standard describing a method to measure cavitation pressure was published in 2019. This was motivated by meeting the regulatory burden from ultrasonic cleaning of medical devices.

- A review of units of measure determined acoustic pressure is the most scientifically valid to quantify acoustic cavitation.

- Numerous studies correlating cavitation pressure with other process parameters have been successfully conducted, which indirectly correlates with cleaning performance

- Absolute measurements of pressure allow one to make direct comparisons of different conditions (e.g., tank frequency)