
Welcome to
Don't be Foiled!
Monitor your Ultrasonic Cleaning Process
Featuring Petrie Yam, ONDA Corp
product quality cleaning workshops
We will begin soon…
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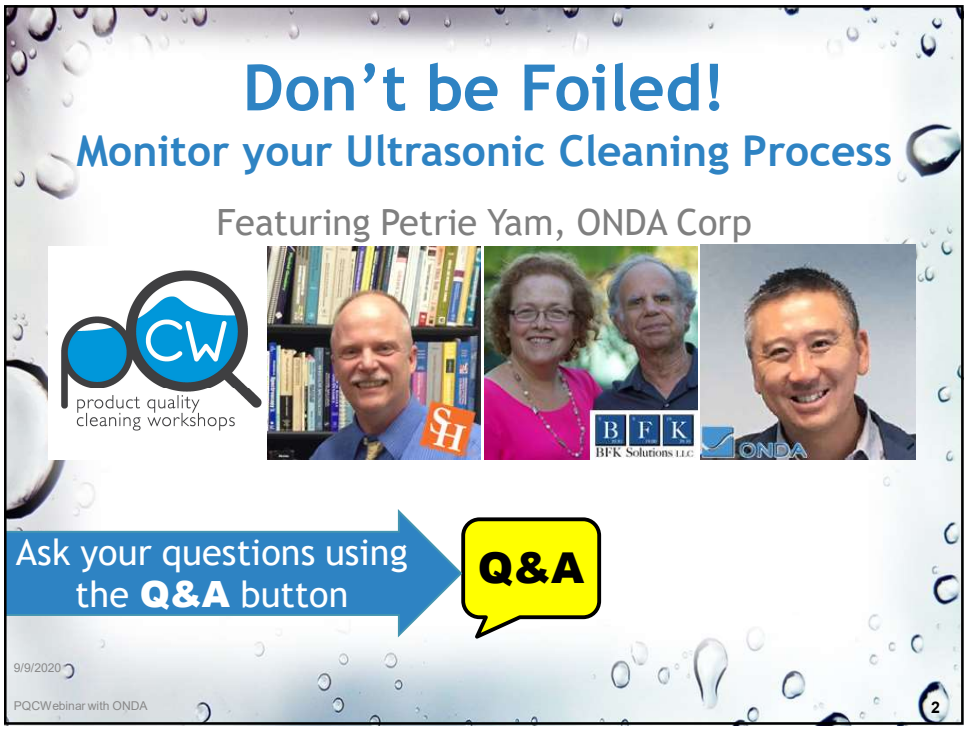
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Ask your questions using the Q&A button
Q&A
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Monitor your Ultrasonic Cleaning Process

Featuring Petrie Yam, ONDA Corp

The PQCW offers practical, hands-on and independent, training in cleaning.

More Info
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Webinar Hosts

The PQCW Team

Barbara and Ed Kanegsberg – "The Cleaning Lady and the Rocket Scientist"

- BFK Solutions - Consultants in Critical Cleaning
- Authors and Editors of the two-volume CRC Handbook for Critical Cleaning
- Independent evaluations and recommendations
- Co-chairs of the Product Quality Cleaning Workshops
- barbara@bfksolutions.com and ed@bfksolutions.com

Darren Williams – "The Professor"

- Professor of Physical Chemistry at Sam Houston State University
- Leader of the Cleaning Research Group
- Co-chair of the Product Quality Cleaning Workshops
- Performs cleaning trials and formulates cleaning chemistries
- williams@shsu.edu

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Product Quality Cleaning Workshops

- Workshops
- Webinars
- Resources for more effective cleaning processes
- More information
  - shsu.edu/pqcw
  - bfksolutions.com/manufacturing-minds-pqcw/

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Our Speaker

Petrie Yam of ONDA Corporation

- Vice President of Sales and Marketing at ONDA Corporation – an ultrasound measurement instrument company.
- MBA with marketing experience
- BSc in Materials Science Engineering
- Operations Manager focused on making a positive impact with customers
- Method development to characterize novel ultrasonic devices
- 6 years experience in product management
- 10 years experience in high-tech product development and marketing
- 20 years experience in metrology and inspection in high-tech industries with various leadership roles

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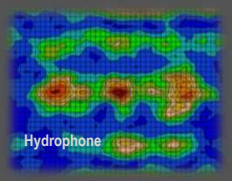
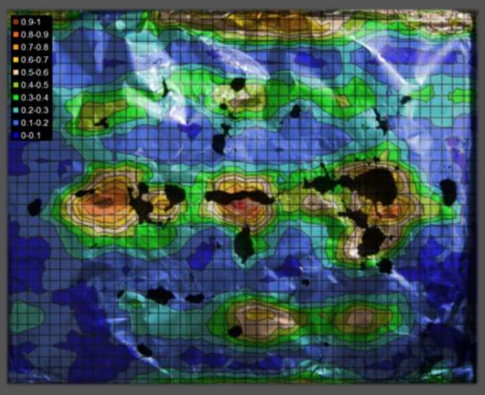
Don't be Foiled!

Monitor Your Ultrasonic Cleaning Process

Petrie Yam





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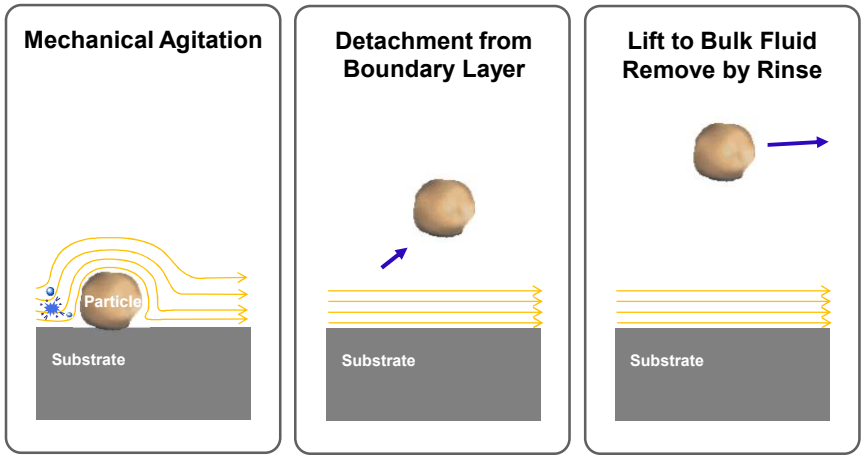
How does ultrasonic cleaning work?



Wet clean processes are complex, but it boils down to the following mechanisms

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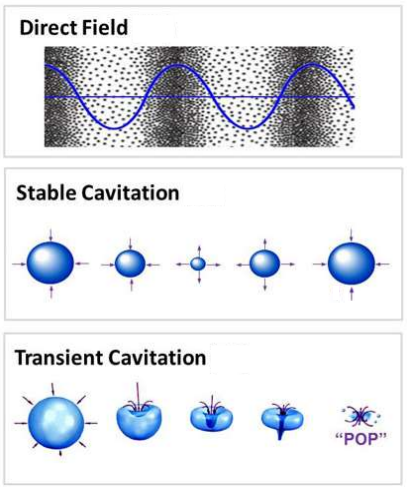
"Mechanical Agitation" from Ultrasound:

1. Sound wave
2. Cavity oscillation
3. Cavity implosions



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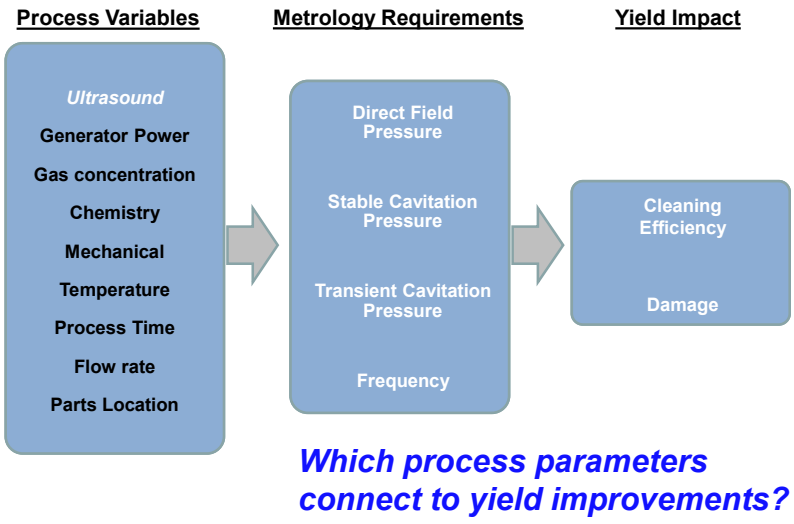
Connecting Ultrasound with Cleaning



Which process parameters connect to yield improvements?

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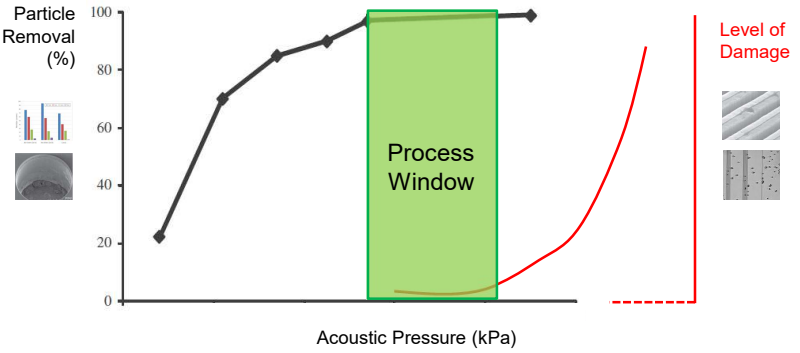
Control Your Process Window



Holy Grail … Determine Y = F(X)
i.e., how ultrasound relates with cleaning

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What is the ideal yardstick?

	Optical Defect Inspection	Aluminum Foil / Ceramic Ring	Sonoluminiscence	Hydrophone	Hydrophone + Scanner
Correlation to Cleaning	✓	-	-	✓	✓
Sensitive	✓	-	-	✓	✓
Repeatable	✓	-	✓	✓	✓
			-	✓	✓
			-	-	-
			-	-	-
				✓	✓
			-	-	-

Onda: 2013

IEC 60886: Investigations on test procedures for ultrasonic cleaners. NPL National Physical Laboratory

Technique	Implementation	Findings
Quantitative removal of a standard soil	*Rings with standard soil, weighed.*	Reproducibility poor, even within the same laboratory. Inconsistent soil properties.
		Amount of erosion not always linked to cleaning effect. With temperature increase, cleaning increases, decreases in erosion observed.
		Intra-lab – repeatable; but not inter-lab. Highly nonlinear. Cleaning increases with acoustic power not mirrored by probe output.
		Qualitative nature; arbitrary scale of 0 to 12, not considered suitable as the basis of an IEC standard.

NPL: 2013

Cavitation Evaluation Techniques

Test	Ease of Application	Equipment Requirement	Unit of Measurement	Repeatability	Relationship to Cleaning	Bath Contamination	Provides Distribution Information
Standardized Soil	Difficult and Time Consuming	Laboratory, analytical balance, other equipment	Yes – Weight Loss	Good using standardized technique	Relates well to some cleaning tasks	Yes	Minimum
Chlorine Release	Difficult and Time Consuming	Laboratory, special equipment	Yes – Chlorine Released	Good using standardized technique	Relates well to some cleaning tasks	No	No. Test is designed to average results
Aluminum Foil Test	Very Easy	Aluminum Foil, holding frame	No – Subjective, Comparative	Varies depending on conditions and interpretation	Relates well to some cleaning tasks	Yes Aluminum particles	Yes
Ceramic Ring Test	Easy	Rings, pencil, comparison chart	No – Subjective, Comparative	Varies depending on conditions and interpretation	Relates well to some mechanical cleaning tasks	Yes (minimum graphite residue)	Minimum
Hydrophone	Moderately easy to difficult	Hydrophone and analysis device. Positioning equipment in some cases	Relative Scale related to Watts/In^2 or Watts/Gallon	Varies depending on conditions and procedure	Questionable	No	Yes when mapping procedures are used
Lead Erosion	Easy	Lead coupons, analytical balance	Yes – Weight Loss per unit of Time	Moderate to good depending on conditions and procedures	Relates well to some cleaning tasks	Yes Lead particles	Minimum
Calorimetric	Varies	Temperature measuring device	Yes – Temperature Increase per Unit of Time	Good using standardized technique	None	No	No

BNY: 2002

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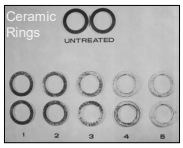
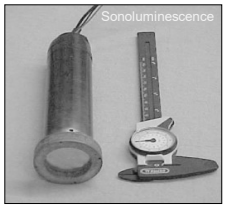
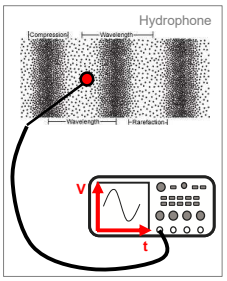
Qualitative



Quantitative





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Commercial Hydrophones

- Over 40 commercial “probes” available
- More than half offered by tank manufacturers
- Only 2 follow a standard method (IEC 63001)

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Cleanliness Standards

- **HTM 2030** Operations management guidance of washers-disinfectors for processing medical devices.
- **EN ISO 15883** Washer-disinfectors – Part 1
- **ASTM F2459** Sta… n Metallic Medical C… nalysis
- **ASTM F2847** Sta… t of Residues on Sing…
- **ASTM E2314** Sta… Effectiveness of C… ruments Using a Microbiologic Method (Simulated Use Test)
- **ASTM D7225** Standard Guide for Blood Cleaning Efficiency of Detergents and Washer-Disinfectors
- …

Many standards exist describing how to clean for specific applications

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Cavitation Measurement Standards

IEC 60886: 1987 *Investigations on test procedures for ultrasonic cleaners*

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

DIN spec 40170: 2013 *Me…*

- Deutsches Institut Fur …
- Driven by Bandelin & E…
- Described method to q…

Limited # of standards describing method to test ultrasonics

IEC/TS 63001: 2019 *Meas… ultrasonic reactors*

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

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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 2,25f_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.).

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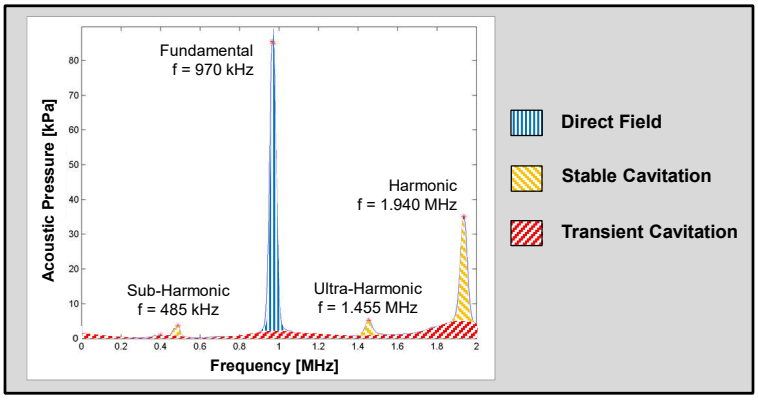
Anatomy of Acoustic Spectrum



Different pressure components contribute to cleaning and damage

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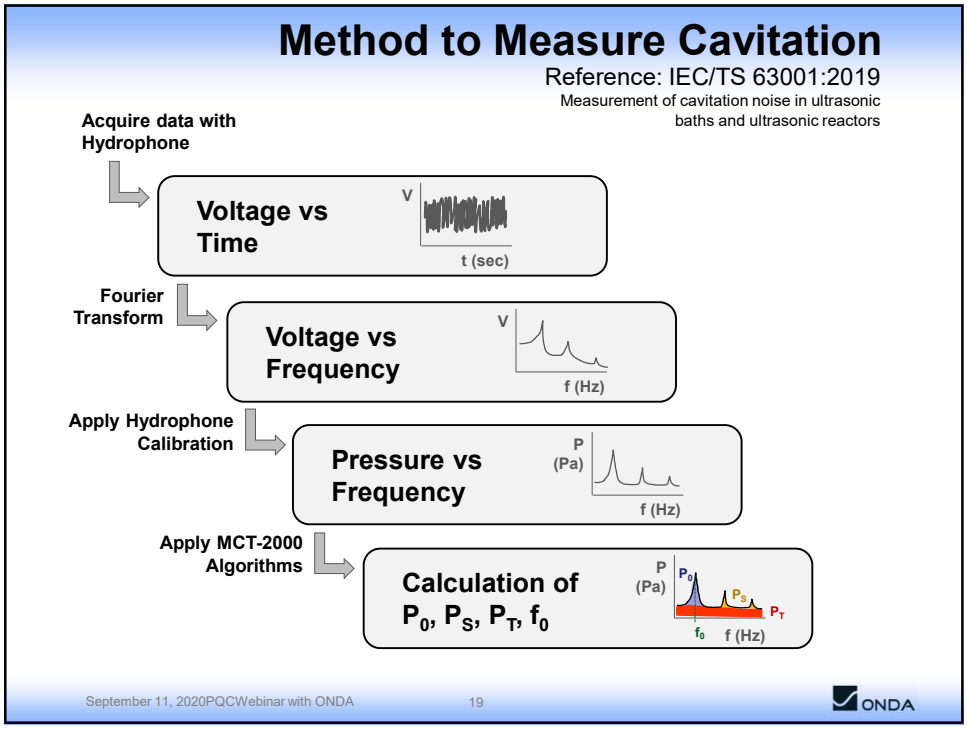
Method to Measure Cavitation
Reference: IEC/TS 63001:2019
Measurement of cavitation noise in ultrasonic baths and ultrasonic reactors
Acquire data with Hydrophone
Voltage vs Time
V
t (sec)
Fourier Transform
Voltage vs Frequency
V
f (Hz)
Apply Hydrophone Calibration
Pressure vs Frequency
P (Pa)
f (Hz)
Apply MCT-2000 Algorithms
Calculation of P0, PS, PT, f0
P (Pa)
P0
PS
PT
f0
f (Hz)
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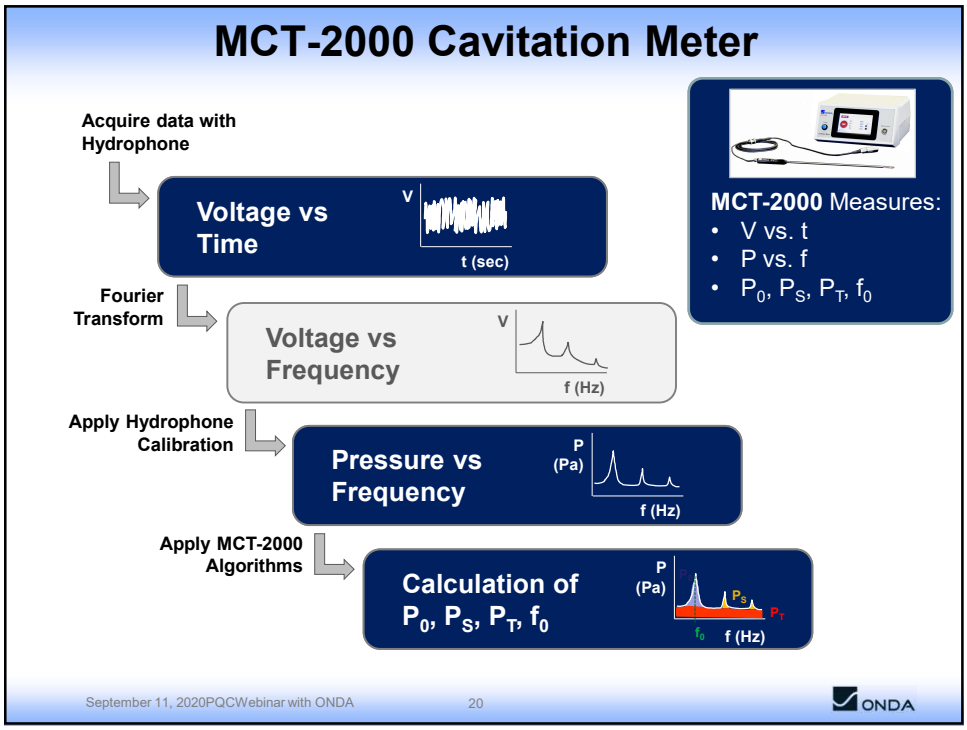
MCT-2000 Cavitation Meter
Acquire data with Hydrophone
Voltage vs Time
V
t (sec)
Fourier Transform
Voltage vs Frequency
V
f (Hz)
Apply Hydrophone Calibration
Pressure vs Frequency
P (Pa)
f (Hz)
Apply MCT-2000 Algorithms
Calculation of P0, PS, PT, f0
P (Pa)
PS
PT
f0
f (Hz)
MCT-2000 Measures:
• V vs. t
• P vs. f
• P0, PS, PT, f0
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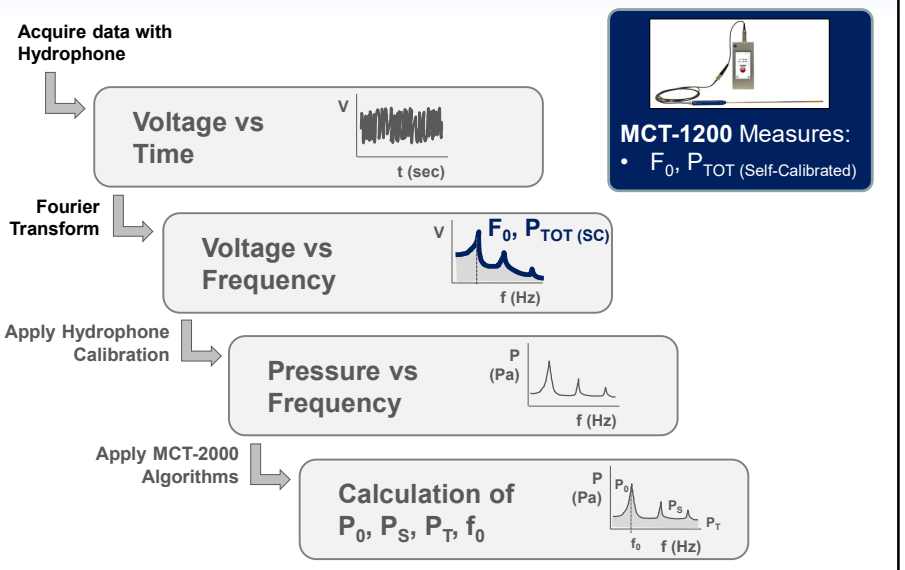
MCT-1200 Digital Pressure Meter



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Control Your Process with a Combined Solution

MCT-2000		MCT-1200
R&D, Absolute Reference	APPLICATION	Process Monitoring
Cavitation Pressure & Frequency (P0, Ps, Pt, F0)	PARAMETERS	Total Pressure & Frequency (Ptot, F0)
Conforms with IEC/TS 63001:2019	METHOD	--
External-calibration to achieve traceability and matching	CALIBRATION	Self-calibration to achieve matching
Data saved to local memory	AUTOMATION	Real-time data transfer for continuous monitoring
Higher Performance	VALUE	Lower Cost

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All Great but… Why Test

Qualify Equipment

- Manufacturers' Validation
- Installation & Commissioning
- Daily/Weekly Routine Checks
- Quarterly/Annual Preventive Maintenance

Monitor Cleaning

- Verify particles are removed
- Verify damage is minimal
- Optimize cleaning cycle time/cost
- Control / improve yield

… and How

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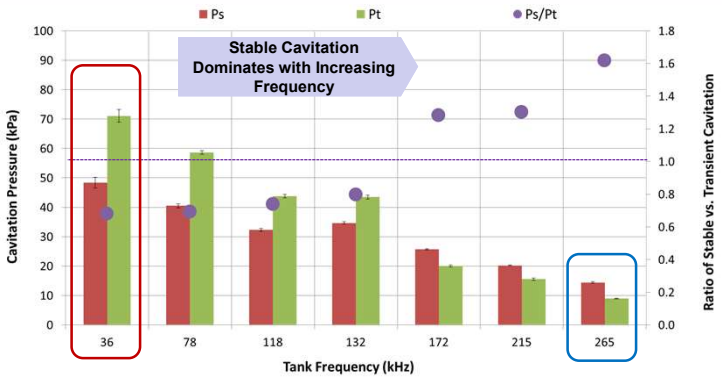
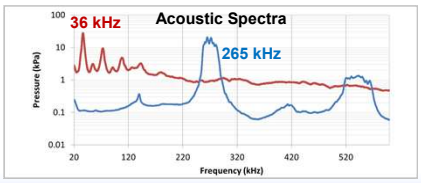
Cavitation vs. Frequency





Multi-frequency tank driven at 960 W in DIW

Process Variables:

- ✓ *Frequency*
- ❑ Generator Power
- ❑ Gas concentration
- ❑ Chemistry
- ❑ Temperature
- ❑ Process Time
- ❑ Parts Location
- ❑ Loading Effects

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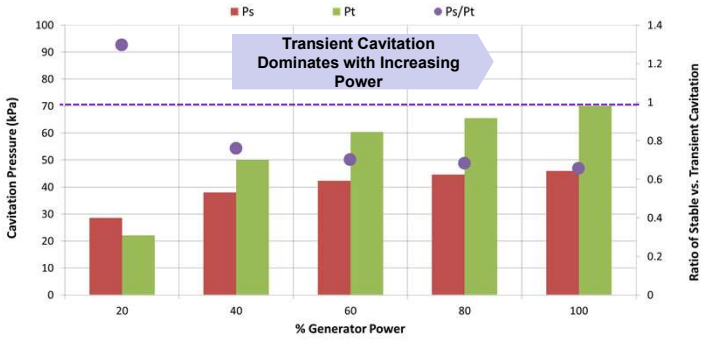
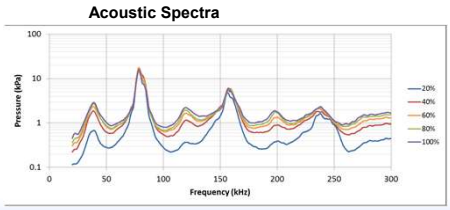
Cavitation vs. Generator Power





Multi-frequency tank driven at 78 kHz at 5 power levels (max 960 W) in DIW

Process Variables:
- ✓ Frequency
- ✓ *Generator Power*
- ❑ Gas concentration
- ❑ Chemistry
- ❑ Temperature
- ❑ Process Time
- ❑ Parts Location
- ❑ Loading Effects

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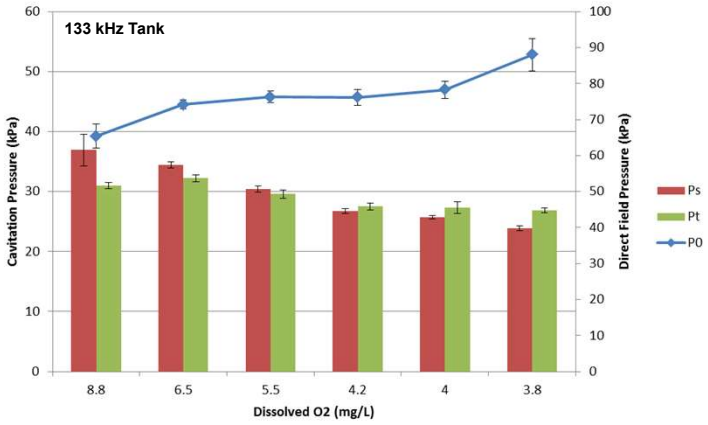
Cavitation vs. Gas Concentration



With degassing (at 23 C):
- Direct field pressure increases
- Stable and transient cavitation decreases
- Stable cavitation decreases at a quicker rate

Process Variables:
- ✓ Frequency
- ✓ Generator Power
- ✓ *Gas concentration*
- ❑ Chemistry
- ❑ Temperature
- ❑ Process Time
- ❑ Parts Location
- ❑ Loading Effects

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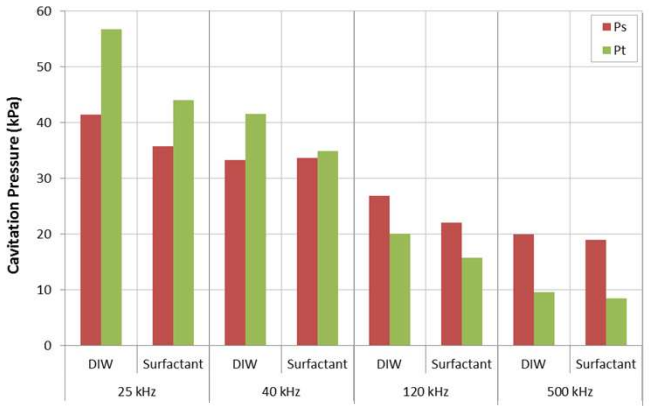
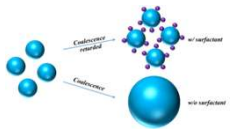
Cavitation vs. Chemistry

Process Variables:
- ✓ Frequency
- ✓ Generator Power
- ✓ Gas concentration
- ✓ *Chemistry*
- ❑ Temperature
- ❑ Process Time
- ❑ Parts Location
- ❑ Loading Effects





- Two chemistries evaluated:
  - DIW
  - Surfactant: 31E-3% Triton X-100, CMC at 15E-3%
- Stable and transient cavitation pressure decreased with surfactant
- Hypothesis: surfactant retards bubble coalescence, suppressing cavitation

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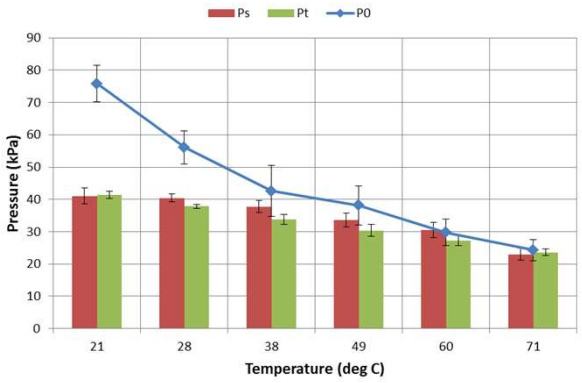
Cavitation vs. Temperature

Process Variables:
- ✓ Frequency
- ✓ Generator Power
- ✓ Gas concentration
- ✓ Chemistry
- ✓ *Temperature*
- ❑ Process Time
- ❑ Parts Location
- ❑ Loading Effects



- Cavitation decreases with increasing temperature
- Changes to gas concentration, sound velocity, and surface tension

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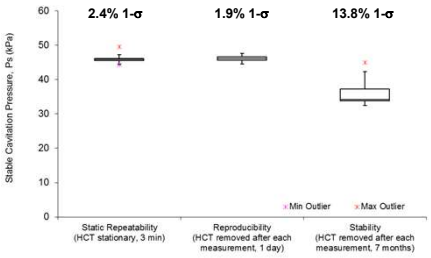
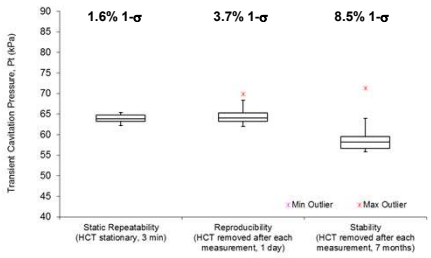
Cavitation vs. Time

Process Variables:
- ✓ Frequency
- ✓ Generator Power
- ✓ Gas concentration
- ✓ Chemistry
- ✓ Temperature
- ✓ *Process Time*
- ❑ Parts Location
- ❑ Loading Effects

Stable Cavitation



Transient Cavitation



- *Static Repeatability*: 19 data points acquired over **3 min**; HCT is stationary
- *Reproducibility*: 15 data points acquired over **1 day**; HCT is placed into tank, then removed
- *Stability*: 7 data points acquired over **7 months**; HCT is placed into tank, then removed

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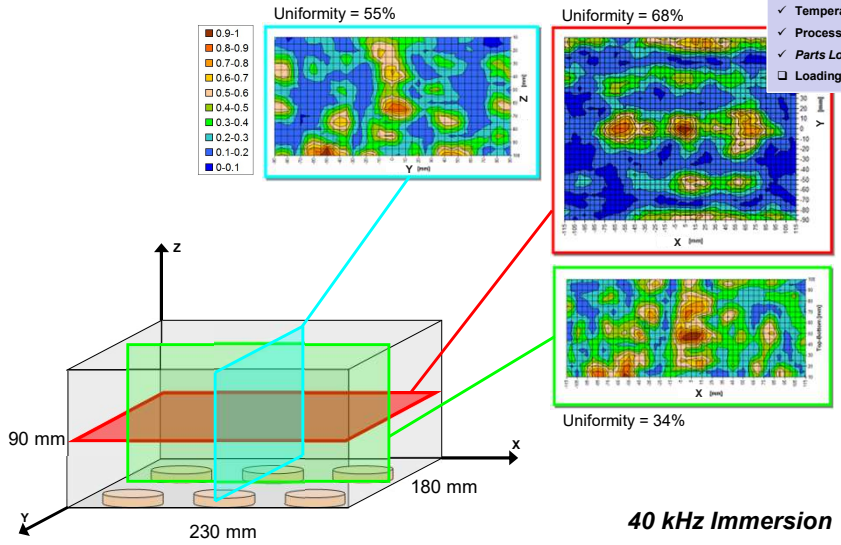
Cavitation vs. Location

Process Variables:
- ✓ Frequency
- ✓ Generator Power
- ✓ Gas concentration
- ✓ Chemistry
- ✓ Temperature
- ✓ Process Time
- ✓ *Parts Location*
- ❑ Loading Effects



40 kHz Immersion

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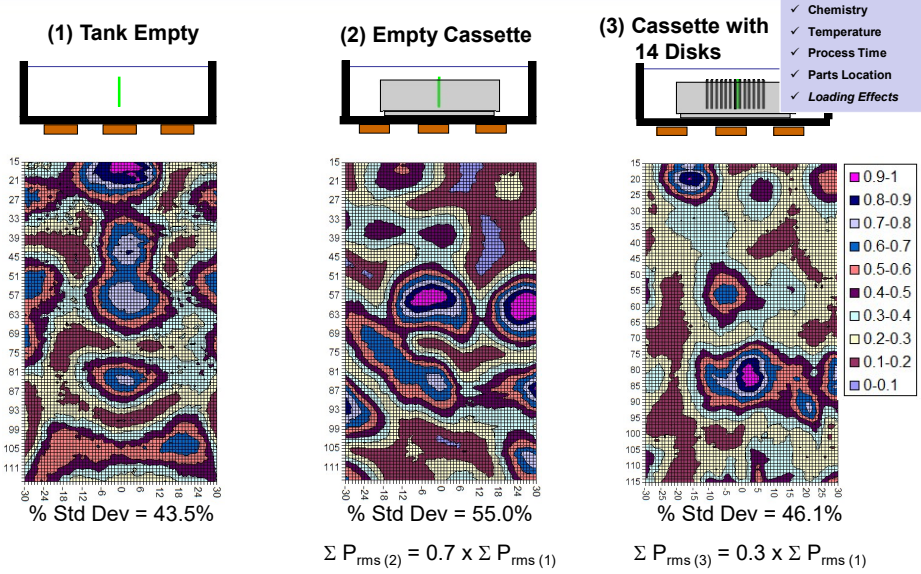
Cavitation vs. Loading



% Std Dev = 43.5%

% Std Dev = 55.0%

% Std Dev = 46.1%

$\Sigma P_{rms\,(2)} = 0.7 \times \Sigma P_{rms\,(1)}$

$\Sigma P_{rms\,(3)} = 0.3 \times \Sigma P_{rms\,(1)}$

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Summary

- Ultrasonic cleaning systems perceived by many as a “black box” since it is such a dynamic process with many process variables.
- Of all the parameters (e.g., gas concentration, pH level, temperature, flow rate), the characterization of the ultrasound field remains most elusive
- Onda has developed innovative measurement technology to quantify the acoustic cavitation performance inside the tank in physical SI units.
- Acoustic cavitation pressure vary as a function of frequency, power, gas, temperature, position, loading configuration, and other variables.
- Establishing a routine and continuous monitoring strategy is needed to control your cleaning process

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Don't be Foiled!

Monitor your Ultrasonic Cleaning Process

Featuring Petrie Yam, ONDA Corp

The PQCW offers practical, hands-on and independent, training in cleaning.
More Info
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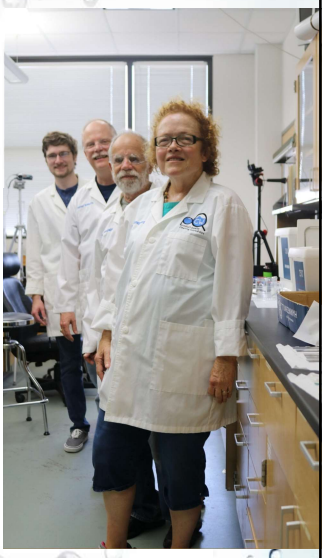
Product Quality Cleaning Workshops



COME TO THE PQCW

- **When?** To Be Announced
- **Where?** Sam Houston St. Univ., Huntsville TX
- **More Info?** Visit http://shsu.edu/pqcw

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