ONDA
Putting Confidence in Ultrasound

Acoustic Characterization of an Ultrasonic Cleaning Tank:

A Closer Look at Units of Measure

November 7, 2014

Foreword

This document is intended to provide the user a description of the relationship between voltage, pressure, intensity, and power to approximate the acoustic performance of ultrasonic cleaning tanks.

It should be clearly noted however, that cleaning tank environments DO NOT represent ideal conditions. Specifically, the following calculations are valid only for an infinitely deep tank (i.e., without a liquid surface and sidewalls to reflect the waves). Reflections cause standing waves, but radiated power measurements are valid only if the wave propagates in one direction which occurs in the absence of standing waves. The only physical parameters that can be measured are temperature and pressure as a function of time. An RMS (root-mean-square) value can be used to approximate the pressure amplitude over a defined time averaging interval. Acoustic intensity is the product of pressure p and particle velocity v at any location. Since particle velocity can be measured only under very specific conditions (typically not an ultrasonic tank), the approximation that velocity is the pressure divided by the impedance of the medium is commonly used. However, this approximation is only valid when away from the source -- and when the wave propagates "cleanly", which is not the case in the presence of reflections.

Units Conversion: RMS Voltage → Power

1. Acquire Average RMS Voltage from MCT Meter at each measurement location

$$Ave\ V_{RMS} = \frac{1}{N}\sum_{1}^{N} V_{RMS}$$

Units: [V]

2. Convert to Acoustic Pressure by Applying Hydrophone Sensitivity

$$P_{RMS} = \frac{Ave\ V_{RMS}}{M(f)}$$

$$\textit{Units: } [MPa] = \frac{[V]}{[V/MPa]}$$

3. Convert to Acoustic Intensity, or Power Density *

$$I_{RMS} = \frac{W}{A} = \frac{{P_{RMS}}^2}{Z} = 67 \times {P_{RMS}}^2$$

$$\textit{Units: } \frac{[W]}{[cm^2]} = \frac{[MPa]^2}{[Rayls]} = \frac{[MPa]^2}{[N{\cdot}s/m^3]}$$

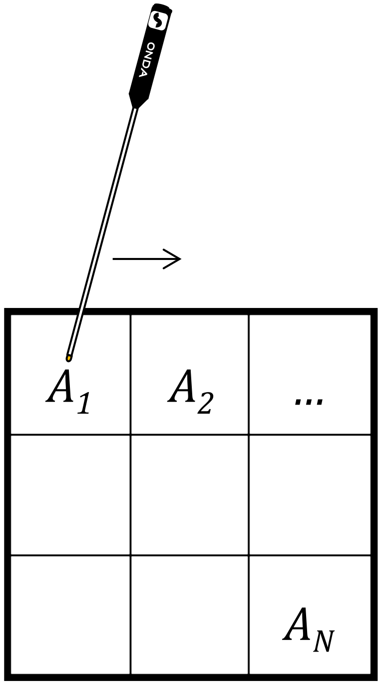
* Refer to Foreword

Units Conversion: RMS Voltage → Power

4. Estimate localized radiating area at the measurement location

$$Total\ Radiating\ Area = A_{Total} = A_1 + A_2 + \cdots + A_N$$

Units: [cm²]



5. Estimate the Total Acoustic Power

$$W_{Total} = W_1 + W_2 + \cdots + W_N = I_1 \times A_1 + I_2 \times A_2 + \cdots + I_N \times A_N$$

$$If\ A_1 = A_2 = \cdots = A_N, then\ W_{Total} = \frac{A_{Total}}{N} \times (I_1 + I_2 + \cdots + I_N) = A_{Total} \times I_{Ave}$$

$$Units: [W] = \frac{[W]}{[cm^2]} \times [cm^2]$$

6. Estimate the efficiency of the tank

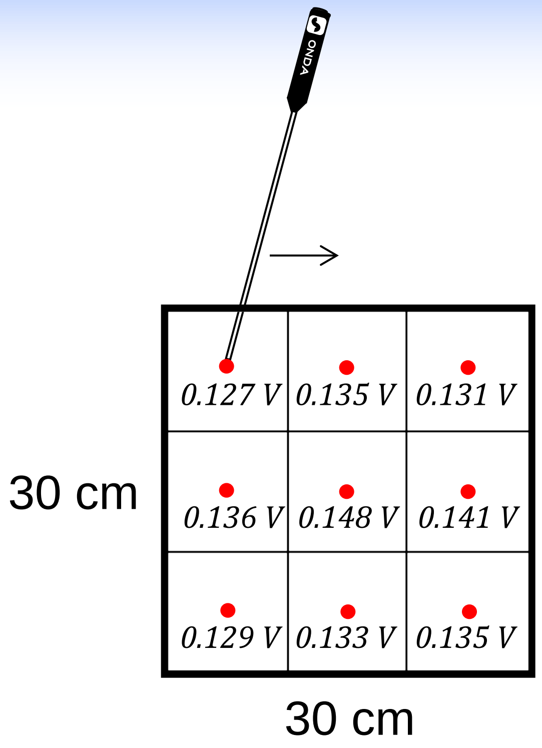
$$\eta = \frac{W_{Total\ Acoustic}}{W_{Total\ Electrical}}$$

Units: [%]

Example

A 40 kHz ultrasonic cleaning tank with a bottom tank area of 30 x 30 cm is acoustically mapped with an HCT-0310 hydrophone in an evenly spaced 3 x 3 grid pattern. The average V_{RMS} readings from the MCT-1010 meter are provided in each field (red dots indicate measurement location). The sensitivity of the HCT-0310 at 40 kHz is 1.1 V/MPa. The generator output is set at 200 W to drive a 9- transducer array.

Determine the total acoustic power in the tank and estimate the power efficiency.



Bottom Tank Area

Example Cont.

$$PRMS = \frac{0.127}{1.1} = 0.115$$

$$I_{RMS} = (0.115)^2 \times 67$$

$$WTotal = 1.011 \times 900$$

V_{RMS} [V]

0.127	0.135	0.131
0.136	0.148	0.141
0.129	0.133	0.135

P_{RMS} [MPa]

0.115	0.123	0.119
0.124	0.135	0.128
0.117	0.121	0.123

I_{RMS} [W/cm²]

0.893	1.009	0.950
1.024	1.213	1.101
0.921	0.979	1.009

W_{Total} [W]

910

Sensitivity at f = 40 kHz	1.1 V/MPa
I_{Ave}	1.011 W/cm²
Tank Area	900 cm²
Acoustic Power	**910 W**
Generator Power	500 W
# of Transducers	9
Electrical Power	4500 W
Efficiency, η	**20%**

Double-click to open worksheet:

Acoustic Units
onversion Workshe