Comparative representation of sound field quantities and sound energy quantities

Assumption: German: http://www.sengpielaudio.com/VergleichendeDarstellungVonSchall.pdf

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Sound

Air temperarature = 20°C: (Atmospheric pressure 10,1325 Pa = 1013 hectopascal)
Density of air at 20°C: ρ = 1.204 kg / m³ (At 0°C is ρ = 1.293 kg/m³)
Speed of sound at 20°C: c = 343 m / s (At 0°C is c = 331 m/s)
Specific acoustic impedance Z at 20°C: $Z = \rho \cdot c = \frac{p}{v}$ = 413 N · s / m³ (At 0°C is Z = 428 N·s/m³)

Reference sound **field** quantities*:*
Reference sound pressure p_0 = 2 · 10⁻⁵ N / m² = 2 · 10⁻⁵ Pa (Fixed "threshold of audibility")

Reference sound velocity $v_0 = \frac{p_0}{\rho \cdot c} = \frac{p_0}{Z_0}$ = 5 · 10⁻⁸ m / s (= 4.854 · 10⁻⁸ m / s)

Reference sound **energy** quantities*:*

Reference sound intensity $J_0 = \frac{p_0^2}{Z_0} = Z_0 \cdot v^2$ = 10⁻¹² W / m² (= 0.9685 · 10⁻¹² W / m²)

Reference sound energy density $E_0 = \frac{J_0}{c} = \frac{p_0 \cdot v_0}{c}$ = 3 · 10⁻¹⁵ W · m / s³ (= 2.824 · 10⁻¹⁵ J / m³)

Reference acoustic power $W_0 = J_0 \cdot A$ = 10⁻¹² W = 1 pW bei A = 1 m² (= 0.9685 · 10⁻¹² W)

>>> Given:
A plane sound wave of ***f*** = 1 kHz and the

Sound pressure $\tilde{p}$ = 1 Pa = 1 $\frac{\text{N}}{\text{m}^2}$ = 10 μbar ⇒ 94 dBSPL – We use **always the RMS value.**

Calculated:

Wavelength $\lambda = \frac{c}{f} = \frac{343}{1000}$ = 0.343 m = 34,3 cm

Periodic length $T = \frac{1}{f}$ = 0.001 s = 1 ms

Sound velocity $\tilde{v} = 2 \cdot \pi \cdot f \cdot \tilde{\xi} = \frac{\tilde{p}}{Z_0} = \frac{1}{413}$ = 2.42 · 10⁻³ m / s = 2.42 mm / s

Sound particle displacement $\tilde{\xi} = \frac{\tilde{v}}{2 \cdot \pi \cdot f}$ = 0.385 · 10⁻⁶ m = 0.385 μm

Acoustic intensity $\tilde{J} = \tilde{p} \cdot \tilde{v} = \frac{\tilde{p}^2}{Z_0}$ = 2.42 · 10⁻³ W / m² = 2.42 mW / m² Intensity is not amplitude

Sound energy density $\tilde{E} = \frac{J}{c}$ = 7.06 · 10⁻⁶ W · s / m³ = 7.06 · 10⁻⁶ J / m³

Sound power $\tilde{W}_0$ (mit A = 1 m²) = $\tilde{J} \cdot \tilde{A}$ = 2,42 · 10⁻³ W = 2.42 mW

Level: Differentiate sound field quantities and sound energy quantities.

Sound pressure level $L_p = 20 \cdot \log \frac{p}{p_0} = 20 \cdot \log \frac{1}{2 \cdot 10^{-5}}$ = 94 dB (93.98 dB)

Sound velocity level $L_v = 20 \cdot \log \frac{v}{v_0} = 20 \cdot \log \frac{2.42 \cdot 10^{-3}}{5 \cdot 10^{-8}}$ = 94 dB (93.70 dB)

Acoustic intensity level $L_J = 10 \cdot \log \frac{J}{J_0} = 10 \cdot \log \frac{2.42 \cdot 10^{-3}}{10^{-12}}$ = 94 dB (93.84 dB)

Sound energy density level $L_E = 10 \cdot \log \frac{E}{E_0} = 10 \cdot \log \frac{2.42 \cdot 10^{-3}}{10^{-12}}$ = 94 dB (93.84 dB)

Sound power level $L_W = 10 \cdot \log \frac{L_W}{L_{Wo}} = 10 \cdot \log \frac{2.42 \cdot 10^{-3}}{10^{-12}}$ = 94 dB (93.84 dB)

Don't mix the pressure p with the power P, the sound power level is better called L_W instead of L_P. Theoretically interesting is, what sound level the full modulation of the atmospheric pressure is: $L_p = 20 \cdot \log \frac{1.013 \cdot 10^5}{2 \cdot 10^{-5}}$ = 194 dBSPL ≡ 1000237 Pa (RMS). But this is not the maximum possible pressure!
A previously used sound size was 1 μbar = 0,1 Pa.
Since 1 W · s = 1 N · m, the result for the sound energy density 1 W · s / m³ 1 N / m² and that is the unit of sound pressure! Reminder: W · s = J (Joule). See also: http://www.sengpielaudio.com/RelationshipsOfAcousticQuantities.pdf "Relationship of acoustic quantities".