Machine Sound Power: ISO 3744 Measurement & Fan Noise Estimate

machine_sound_power_a ver 1.0 by Tom Irvine

1. ISO 3744 sound power from sound pressure (engineering grade, free field over a reflecting plane)

Hemisphere, radius r $\quad S = 2\pi r^2$

Box on the floor, reference box $l_1 \times l_2 \times l_3$ $\quad S = 4(ab + bc + ca), \quad a = \dfrac{l_1}{2} + d, \quad b = \dfrac{l_2}{2} + d, \quad c = l_3 + d$

Surface average of N microphones $\quad \overline{L'_p} = 10 \log_{10}\left[\dfrac{1}{N}\sum_{i=1}^{N} 10^{0.1 L'_{p,i}}\right]$, same for $\overline{L_p(B)}$

Background noise correction $\quad K_1 = -10 \log_{10}\left(1 - 10^{-0.1\,\Delta L_p}\right), \quad \Delta L_p = \overline{L'_p} - \overline{L_p(B)}$

$\Delta L_p > 15$ dB: $K_1 = 0$; $\quad \Delta L_p < 6$ dB: $K_1 = 1.3$ dB and L_W is only an upper bound

Environmental correction $\quad K_2$ entered, or $K_2 = 10 \log_{10}\left(1 + 4\dfrac{S}{A}\right), \quad A = 0.16\,\dfrac{V}{T_{60}}$ (m^2, m^3, s); $K_2 \le 4$ dB

Sound power level $\quad L_W = \overline{L'_p} - K_1 - K_2 + 10 \log_{10}\dfrac{S}{S_0}, \qquad S_0 = 1$ m^2

A-weighted and total levels $\quad L_{WA} = 10 \log_{10} \textstyle\sum_k 10^{0.1(L_{W,k} + C_k)}, \qquad L_W(\text{total}) = 10 \log_{10} \textstyle\sum_k 10^{0.1 L_{W,k}}$

K_1 is applied in each octave band (63 Hz to 8 kHz) or to the overall level. K_2 is one broadband value here. An overall level keeps the weighting of the measured data. ISO 3744 starts with 10 microphone positions on a hemisphere.

A-weighting C_k (IEC 61672-1), 63 Hz to 8 kHz: $-26.2,\ -16.1,\ -8.6,\ -3.2,\ 0,\ +1.2,\ +1.0,\ -1.1$ dB

2. Fan noise estimate (total sound power from the duty point, split into octave bands)

Total sound power $\quad L_W = 40 + 10 \log_{10}\dfrac{Q}{Q_0} + 20 \log_{10}\dfrac{P}{P_0}, \qquad Q_0 = 1$ m^3/s, $\quad P_0 = 1$ Pa

Imperial form (published) $\quad L_W = 55 + 10 \log_{10} q + 20 \log_{10} h, \qquad q$ cfm, h in.wg (exact conversion gives 54.67)

Octave band levels $\quad L_{W,k} = L_W + \Delta_k(\text{fan type}) + \delta_k(\text{tonal})$

Blade pass frequency $\quad f_{BP} = \dfrac{BN}{60}$ Hz; $\delta_k = +5$ dB in the octave with f_{BP}, $+3$ dB with $2f_{BP}$ (editable)

Octave containing f $\quad f_c/\sqrt{2} \le f < \sqrt{2}\, f_c$

Spectrum corrections Δ_k (dB)	63	125	250	500	1k	2k	4k	8k
Centrifugal, backward-curved	-4	-6	-9	-11	-13	-16	-19	-22
Centrifugal, forward-curved	-2	-6	-13	-18	-19	-22	-25	-30
Centrifugal, straight radial	-3	-5	-7	-7	-8	-11	-16	-18
Axial	-7	-9	-7	-7	-8	-11	-16	-18

P is the fan static pressure. The Graham / ASHRAE specific sound power method (K_w tables with blade frequency increment) could not be confirmed from a public source, so this simpler total-power method is used. Treat it as an estimate; use the fan manufacturer's data where available. Blade pass harmonics and shaft orders: blade_pass_frequencies_a.

Units

English: dimensions ft, A ft^2, V ft^3, Q cfm, P in.wg. Converted internally: 1 ft = 0.3048 m, 1 cfm = 4.7195×10^{-4} m^3/s, 1 in.wg = 249.09 Pa (1000 kg/m^3 $\times$ $g_n\times$ 0.0254 m). So English and metric inputs give the same L_W.

metric: dimensions m, A m^2, V m^3, Q m^3/s, P Pa. $\quad L_p$ dB re 20 μPa, $\quad L_W$ dB re 10^{-12} W.

References and checking status

1. ISO 3744:2010, *Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Engineering methods for an essentially free field over a reflecting plane.* The standard text was not available. The formulas above are from public summaries (HEAD acoustics application note, Sound Power Part 3; ECMA-425 and ECMA TR-107 for the 1.3 dB K_1 limit; on-line ISO 3744 calculators). **Check against ISO 3744**: the box formula, K_2 (Annex A), the 4 dB limit.
2. IEC 61672-1, *Electroacoustics – Sound level meters – Part 1*, A-weighting (octave values checked with the analytic formula).
3. Engineering ToolBox, *Fan Noise*: total-power formulas (SI and imperial) and octave spectrum corrections per fan type.
4. Arup, Strutt help *Fan Noise* (citing the ASHRAE Handbook): $L_W = 20 \log P + 10 \log V + 40$ and the +5 / +3 dB blade pass increments ("first harmonic" is taken here as $2f_{BP}$). 5. UFC 3-450-01 / TM 5-805-4, eq. C-5 (Graham type K_w method, not used).