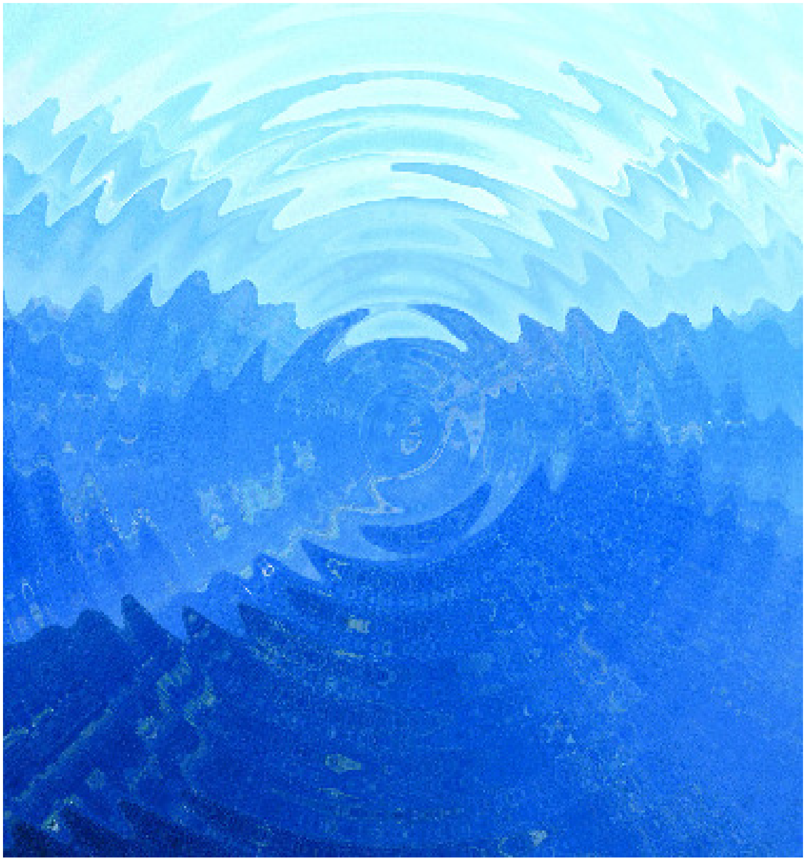
GLAUNACH

THE SILENCER HANDBOOK

NOISE

A GENERAL INTRODUCTION INTO NOISE AND ITS PREVENTION

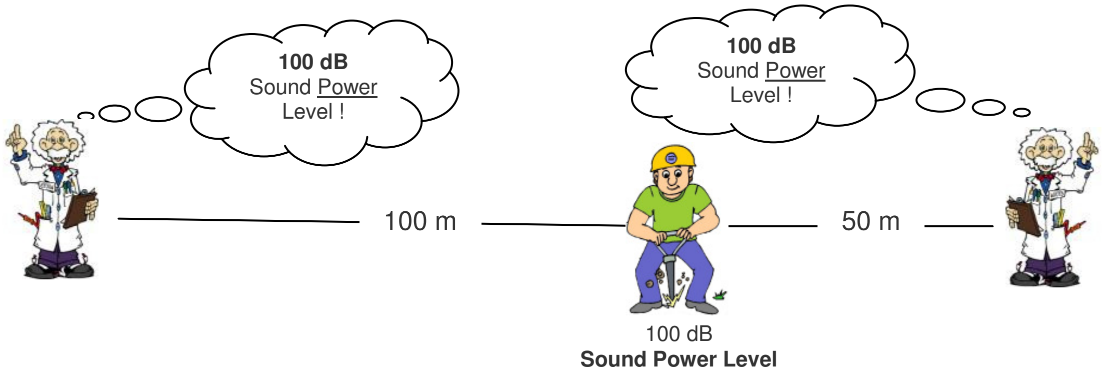


1. NOISE LEVEL MEASURES

Acoustic energy is commonly characterised by two different, often confused terms: **Sound Power Level** and **Sound Pressure Level**. The two parameters share the dimension unit Decibel [dB] and the term Sound Level. To comprehend how to specify, measure and reduce sound, it is important to understand the difference between these properties, which must not be interchanged.

1.1 SOUND POWER LEVEL (L_W, SWL)

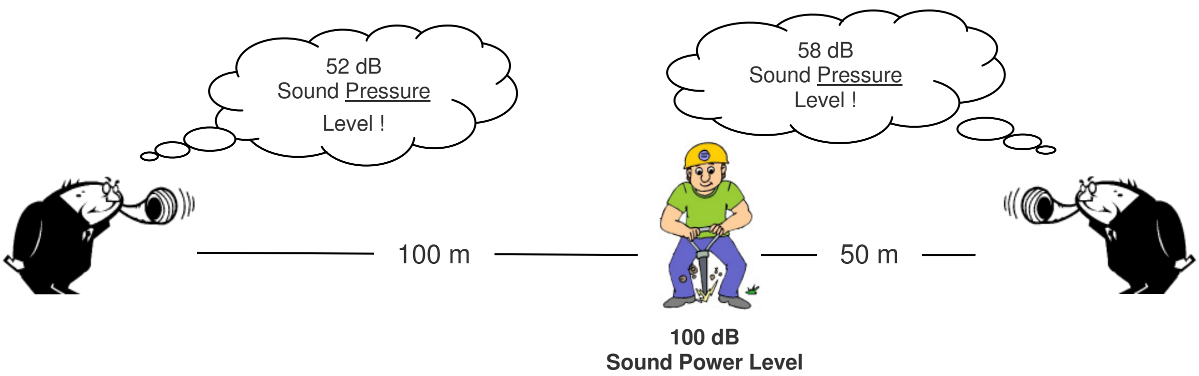
The sound power level is the acoustical energy emitted by the sound source. It is an absolute value that is not affected by the environment, and it is independent of distance.



An optical analogue of the sound power level is the (optical) wattage of a light bulb, i.e. the integrated, total energy radiated in all spatial directions.

1.2 SOUND PRESSURE LEVEL (L_p, SPL)

Sound pressure is what ears hear, and what sound meters measure. The sound pressure levels specify the pressure disturbance in the atmosphere. The intensity of this parameter is influenced not only by the strength of the source, but also by the surroundings and the distance from the source to the receiver.



RULE OF THUMB

each doubling of distance equals 6 dB noise (pressure level) reduction

Again using the analogue of the light bulb, the corresponding parameter would be the brightness. Brightness is more than a matter of wattage; it is critically influenced by distance, shading, (selectively) absorbing (=coloured) / reflecting surfaces, etc. The same applies to sound: distance reduces the sound pressure and thus the noise level, and different sound frequencies are perceived differently by human hearing.

2. FREQUENCIES AND FREQUENCY SCALES

In the most general definition, frequency is a parameter for how often per time unit a repeating event repeats itself. The standard unit is the Hertz [Hz], i.e. one oscillation per a second [1)]. In acoustics, the oscillating event is a vibration of a sound-carrying medium, and the frequency equals the number wave crests passing by per time unit.

> The frequency range of human hearing is approximately
> **20 Hz to 20,000 Hz**

The human ear is unequally sensitive to different acoustic frequencies; some frequencies are perceived differently, e.g. louder, than others. This has two important effects. First, sound measurements should take this into account, requiring some form of sensitivity correction, or scaling. Second, by changing the acoustic frequencies emitted by an object, the whole sound impression can be changed. This is used in sound engineering, and may also be exploited to great effect in silencer design.

2.1 Frequency Scaling

The point in frequency scaling is to adjust the measured sound pressure levels to the (average) frequency response of the human ear. The most commonly used scale, in particular when measuring loud sounds, is the A-weighted scale [2)].

To measure noise levels, one can either use a sound level meter that already measures A-weighted decibels (a dedicated electrical circuit gives the meter the same sensitivity to sound at different frequencies as the average human ear), or use fixed, standardised correction factors to adjust the measured absolute sound pressure band levels to A-weighted values. The overall A-weighted sound level can then be calculated by combining the corrected band levels according to:

$$\mathbf{L_{PA} = 10\times\log_{10}(\Sigma\ 10^{LpA/10})}$$

1) Correspondingly, a kilohertz (kHz) is 1,000 Hertz or 1,000 oscillations per second

2) In addition, there are also B-weighted and C-weighted scales employing different scaling factors, in particular for lower frequencies.

Example Calculation of an A-weighted Octave Band

Frequency [Hz]	Measured L_p [dB]	A-Scale Correction [dB]	Corrected L_{pA} [dB]
31.5	94	-39	55
63	95	-26	69
125	92	-16	76
250	95	-9	86
500	97	-3	94
1,000	97	0	97
2,000	102	+1	103
4,000	97	+1	98
8,000	92	-1	91

For this example, the overall A-weighted sound pressure level is thus

L_{PA} = 105.5 dB(A)

Selected Noise Sources and their Sound Power and Sound Pressure Levels

Noise Source	typ. Sound Power Level	Sound Pressure Level		
			@ distance	
	dB	*dB(A)*	*m*	*ft.*
rustle of leaves	15	10 – 20	1	3
mosquito buzzing	45			
normal conversation	55	40 - 60	1	3
birdsong	60			
vacuum cleaner	70			
street traffic	80	70	15	50
highway traffic	90	80 - 90	10	33
air compressor	90			
passenger car (at motorway speed)	100	60 – 80	10	33
diesel truck engine	105	90 - 100	10	33
freight train	110	100	60	200

pneumatic riveter	110	100 - 115	1	3
jackhammer	120	110	1	3
		90	15	50
hard-rock music	120 – 140	120	2	7
portable media player (@ full volume)	130	100 - 110	0 (ear)	0 (ear)
siren	150	120	30	100
jet plane taking off	150 - 160	180	0.3	1
		140	30	100
		120	150	500
		110	300	1000
shotgun	160	140	1	3
fireworks		160	1	3
rocket during lift off	180			
cannon shot	180	150	150	500
love song of blue whales	190	*- underwater sound -*		
navy sonar (@ 3kHz)	200	*- underwater sound -*		

2.2 PEAK FREQUENCY

To reduce noise intensity, knowledge of the peak frequency is important. A simple method to estimate the frequency peak of a gas streaming out of a circular opeing is Strouhal's method:

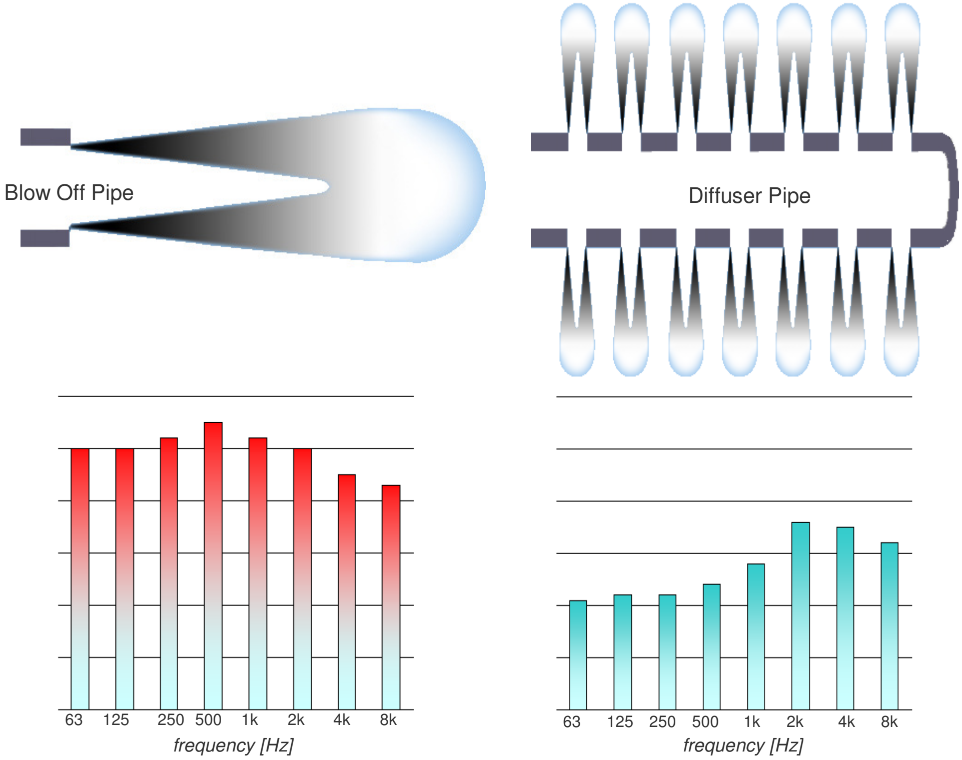
$$\mathbf{f} = \mathbf{s} \times \frac{\mathbf{w}}{\mathbf{d}} \text{ [Hz]}$$

f: *peak frequency [Hz]*
s: *Strouhal's number [-]*
w: *gas speed [m/s]*
d: *orifice diameter [m]*

NOTE: The acoustic peak frequencies of vent silencers usually fall outside the validity range of Strouhal's approximation, which is applicable in particular for lower frequencies, and other contributions may also significantly affect the peak frequency. Still, Strouhal's formula gives a useful first estimate and shows clearly that the peak frequency can be increased by decreasing the outlet diameter.

2.3 PEAK FREQUENCY SHIFTING

GLAUNACH silencers use diffuser pipes with small borings. In addition to achieving a high noise level reduction already in the diffuser, this shifts the peak frequency to higher values, which are significantly easier to (further) attenuate than the lower frequencies emitted by diffusers with larger, die-cut holes.



Sound level distributions emitted by an open blow-off pipe end (left) and a GLAUNACH small-bore radial diffuser (right). For an identical mass flow, the comparison clearly shows a significant noise reduction and a peak frequency shift to higher values when using the radial diffuser pipe.

3. VALVE NOISE

Valves are a primary source of noise in installations for gaseous media. Still, there is no internationally accepted standard for the calculation of valve noise. Based on extensive experience in the field, GLAUNACH uses several methods to estimate unknown valve noise levels. For most applications, these estimates are complemented with reliable values from our extensive internal database, which contains a large amount of highly specialised information gained from on-site tests with a wide range of different valves and media.

For a rough first estimation of the non-silenced valve noise level, we recommend two formulas [1)]:

Estimation acc. to VDI 2713

The - cancelled [2)] - VDI guideline "*Noise Reduction in Thermal Power Stations*" specifies the following formula for the determination of the sound power level of exhaust valves:

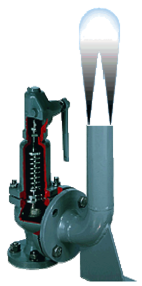
$$L_{W0} = 17 \times \log(M) + 50 \times \log(T_0) - 15 \text{ [dB]}$$

In this model, the only determining factors are the mass flow M and the temperature T_0. While giving a useful first estimate - when compared to actual measurements, the figures derived by the VDI-formula tend to be on the high side - more recent studies of exhaust valves have shown that the mainly decisive factor is the pressure difference over the valve [3)].

Estimation acc. to ANSI/API RP 521

$$L_{p30m} = L + 10 \times \log(0.5 \times M \times C^2) \text{ [dB]}$$

This official model takes the upstream/downstream pressure ratio into account, but is more complicated and requires the use of tables contained in the – commercially available – ANSI/API standard 521 - *Guide for Pressure-Relieving and Depressurising Systems*.



Noise from valves can be expected
to be in the range L_W = 130 - 170 dB

1) For a more detailed coverage, please refer to Part IV – *Dimensioning* of THE SILENCER HANDBOOK

2) This standard has been formally cancelled without direct replacement, but the model is still widely used to quickly estimate valve noise.

3) This to a certain extend implicitly contained in the VDI model, as increases of quantity and temperature cause the pressure difference to rise.

4. NOISE REDUCTION

With more and more stringent environmental and occupational safety directives, noise reduction requirements continue to increase. Design and construction of valves, silencers, and piping systems therefore have to be constantly improved.

TYPICAL NOISE LIMITS

- **USA**: Codified in 29 CFR part 1910.95 - *Occupational Noise Exposure,* US law sets an exposure-time dependent limit of **90 to 115 dB(A)** to steady sound exposure, and **140 dB** (peak) to impulsive noise.
- **EU**: The European directive 2003/10/EC on *Minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise)* limits the permanent noise exposure at the work place to **87 dB(A)** and the impulsive noise to 200 Pa (**140 dB(C)** peak); the directive also stipulates that *properly fitting individual hearing protectors* can be employed to minimise noise exposure, but ***collective protection measures have priority over individual protection measures***.

→ To prevent permanent hearing damage,
noise limits should be in the range L_W = 100 to 125 dB

EFFICIENT NOISE REDUCTION APPROACHES

Traditional vent silencer designs use absorption elements to attenuate the noise emitted at the vent outlet. The expanded gas travels between linear or ring-shaped baffles, which reduce noise through flow-splitting and viscous friction. This requires long flow paths. Furthermore, this design necessitates an expansion chamber, installed upstream of the baffles, in which the turbulent gas flow from the pipe can be calmed. While effective, such constructions hence tend to be bulky, resulting in very large and heavy silencers.

Modern silencers allow noise to be more efficiently attenuated

a) *by transferring a portion of the pressure drop from the valve to a silencer*. Spring-loaded safety valves functioning automatically can be operated at a back pressure of typically 10 - 40 % of the set pressure; when exploiting this, that part of the pressure difference can be absorbed in a controlled process within the silencer.

b) *by using diffuser pipes with small holes* (< ∅ 8mm) that shift the peak frequency to higher values. Higher acoustic frequencies can be attenuated easier and more efficiently than low frequencies, permitting building more compact silencers. Additionally, a very high noise reduction can be achieved through several concentrically arranged pressure stages.

c) *by combining diffuser technology with traditional absorbing technology*. Through the arrangement of absorptions material immediately after the pressure stages, whirl formation is reduced and the remaining flow noise partially absorbed.