Lumens and loudness:

Projector noise in a nutshell

Jackhammers tearing up the street outside; the neighbor's dog barking at squirrels; the hum of the refrigerator: noise is a fixture in our daily lives, and projectors are no exception. Like many high-tech devices, they depend on cooling systems that remove excess heat before it can cause permanent damage, and these systems unavoidably produce noise.

In this white paper, we're going to take a closer look at projector noise: what causes it, how to measure it, and how to keep it to a minimum.

Why do projectors make noise?

There's more than one source of projector noise, of course, but **cooling fans** are by far the major offender—and there's no way around them. Especially projector bulbs give off a lot of heat. This warmth must be continuously removed or the projector will overheat, resulting in serious damage to the system. The fans that keep air flowing through the projector, removing heat before it can build to dangerous levels, make noise.

Fans can't help but make noise: they are designed to move air, and **the movement of air is what makes sound.** How much sound they make depends on their construction: the angle of the blades, their size, number and spacing, their surface quality, and the fan's rotational speed. Moreover, for projector manufacturers it's also key not to place a fan too close to an air vent or any kind of mesh, or they'll end up with the siren effect: very annoying high-frequency, pure-tone noise caused by the sudden interruption of the air flow by the vent bars or the mesh wires.

So are solid-state projectors, which produce less heat due to the absence of bulbs, less noisy than their lamp-based counterparts? They are. Yet also these projector types use fans so they can't bring the noise down to zero.

How much noise do projectors make?

First, a relative observation: the brighter the light source in the projector, the more heat it produces, and the more powerful its cooling fans must be. Put simply, more lumens equals more noise.

Beyond that, the answer gets a little complex. We can objectively measure the **sound pressure**—the local pressure deviation from the average air pressure—that a projector generates, but how much noise we actually hear is just as dependent on how human beings perceive sound as well as other factors like the impact of the surface the projector is on or - the acoustics in - the room where the sound is produced.

How do human beings hear?

Sound is produced by the movement of air (or other medium, such as water). This movement causes our eardrums to vibrate, passing a signal through a complex system of bones and liquid to our brains, where it is interpreted and we ultimately "hear" the sound.

The tone we hear depends on how fast our eardrums vibrate: that is, on the frequency of the sound wave. The higher the frequency, the higher the pitch we hear. How loud the sound seems depends on how much pressure the movement exerts on our eardrums: that is, on the amplitude of the sound wave. Here's where things start to get complex. The human auditory system doesn't respond to all frequencies equally. Some sounds are easy to hear even when they're faint; others must exert more pressure on our eardrums before we'll notice them.

Our hearing also has a second interesting feature: it's nonlinear. That's what gives us our marvelously huge dynamic range. Our acoustic threshold of pain—the sound intensity that causes permanent damage upon short exposure—is 10 trillion times as strong as the quietest sound our ears can hear.

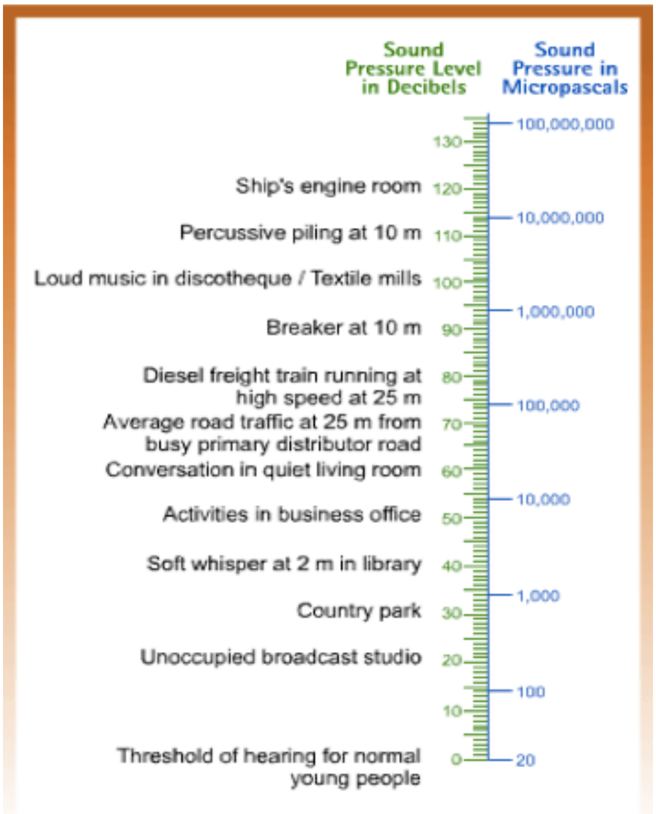
How do we measure noise?

There are different ways of measuring noise. As explained above, we can objectively measure the **sound pressure levels** (SPL). Yet there is a difference between that sound pressure and how much noise people actually hear. **A-weighting** is a common method for adding in this information.

Decibels: the basics

The **decibel** (abbreviated **dB**) is the unit used to measure the intensity of a sound. Decibels are a logarithmic measure of the ratio between two numbers: a variable measurement and a fixed reference.

For **sound pressure levels** the reference number is the lowest sound pressure the human ear can detect, also called the threshold of hearing. This number determines the zero point on the scale.

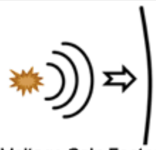


Relation between sound pressure in micropascals and sound pressure level in decibels re 20 µPa.

Just imagine how tall this chart would be if we plotted it to scale using absolute sound pressure values instead of decibels.[1]

Because decibels are a logarithmic and not a linear unit, they don't follow our usual intuition: an increase in dB represents multiplication, not addition. To double the sound pressure level, you increase it by 6 dB. That means that 12 dB is twice as strong as 6 dB—but also that 126 dB is twice as strong as 120 dB.

The SPL scale is a pretty good approximation, but it doesn't precisely reflect our perception of loudness. Roughly speaking, it takes 10 dB rather than 6 dB to double our perception of a sound's loudness.

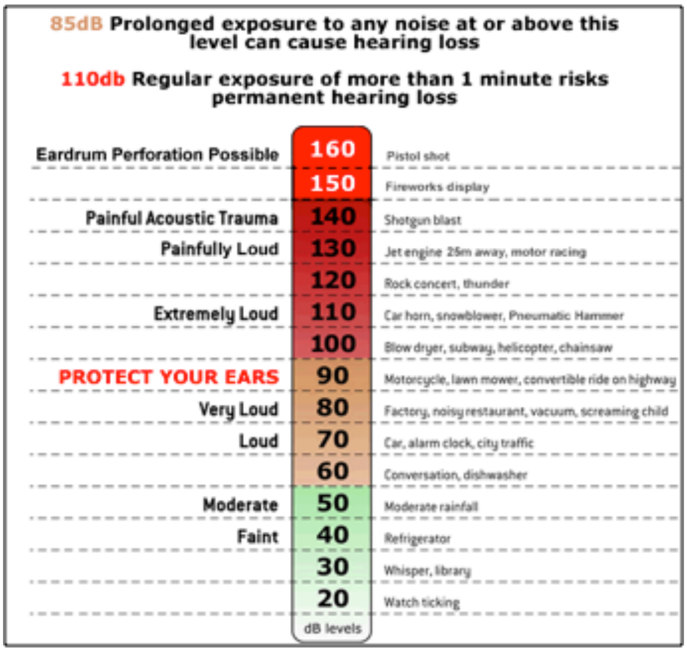
Change of Level	Loudness Perception	Sound Pressure Effect	Sound Intensity Cause
			
Decibels	Loudness Gain Factor	Voltage Gain Factor	Power Gain Factor
+ 20 dB	4.000	10.000	100.000
+ 10 dB	2.000 •	3.160	10.000
+ 6 dB	1.516	2.000 •	4.000
+ 3 dB	1.232	1.414	2.000 •
± 0 dB	1.000	1.000	1.000
- 3 dB	0.812	0.707	0.500 •
- 6 dB	0.660	0.500 •	0.250
- 10 dB	0.500 •	0.316	0.100
- 20 dB	0.250	0.100	0.010

Raising the sound pressure level by 6 dB doubles its strength, but doesn't double how loud we think it is. It takes a 10-dB increase to do that.

[1] Source: http://www.epd.gov.hk/epd/noise_education/web/ENG_EPD_HTML/m1/intro_5.html

[2] Source: http://www.epd.gov.hk/epd/noise_education/web/ENG_EPD_HTML/m1/intro_5.html

The SPL decibel scale lets us display the entire range of human hearing from the softest sound to the loudest in a compact form. That makes it ideal for useful charts such as this one, which relate sound pressure levels to real-world events.



The difference between 120 and 140 dB may seem small, but in fact a nearby shotgun blast is four times as loud as standing near the stage at a rock concert.

A-weighting: decibels + 'frequency'

Sound pressure levels measured in decibels are a good start, but they don't take into account people's varying sensitivity to different frequencies. The most common method used in noise measurement is therefore **A-weighting**, which cuts off the lower and higher frequencies that the average person cannot hear. **dBA or A-weighted decibels** sums the measured sound pressure level (in dB) with a specific value (also in dB) that correlates with how sensitive we are to that frequency. Because A-weighted measurements better represent the perceived loudness at different frequencies, they are preferred over the SPL scale for measuring noise coming from a specific source, such as a projector.

Other factors that contribute to projector noise

So far we've focused on how loud a noise sounds and how we can measure that loudness. Of course, metrics are vital in the objective assessment of sound, but they must be used carefully. The decibels and A-weighted decibels measured are not a real indication of how disturbing a noise – and the device that emits it – can be.
After all, loudness is just one factor that can make a sound undesirable. All noise is not created equally, nor is it perceived in the same way. Sound quality metrics like sharpness, modulation and tones are important complements to metrics such as loudness and A-weighted sound pressure level. Moreover, some noises are far more annoying than others depending on the environment – e.g. the room - and the person perceiving that noise. These four factors greatly contribute to projector noise:

Acoustic sharpness

Acoustic sharpness refers to the "annoyance factor" of the high-frequency component of the noise; high-pitched whining generally bothers us more than low-pitched rumbling. The rotating color wheels used by some DLP projectors can generate a high-pitched whine, for example.

Modulation

The modulation refers to the pulsing or rhythmic beating that can occur when you have more than one source of noise, such as multiple fans cooling a high-brightness projector.

The presence of tones (tonal noise)

Tonal noise is generated by rotating equipment at a predictable frequency relating to the rotational speed of the shaft and the number of compressor vanes, fan blades, etc. Noise that contains such a noticeable or discrete, continuous note, such as hums, hisses, screeches, drones, etc., is often perceived as more annoying or disturbing.

The acoustics of the environment

The human brain keeps sounds in memory for up to a tenth of a second. That may seem short, but it's actually pretty long in brain-time. In smaller rooms, that means the sound reflected off the walls, floor and ceiling can reach a person's ear before their brain has forgotten the initial sound. The result is a sound perceived to last longer than it really does: a reverberation. In larger rooms, the reflected sound reaches the ear more than 0.1 seconds later, resulting in a repeat of the original sound: an echo. Some construction material, like glass, concrete and steel have a low absorption scale, meaning that noise is easily reflected off these materials.

Smart tips to minimize projector noise

Choose your projector carefully

Not all projectors are created equal, so the best way to minimize projector noise is to choose your projector carefully. Keep in mind that not all manufacturers measure sound in the same way, so make sure to choose a trusted supplier. To minimize overall noise, compare the dBA ratings for all the models you're considering—and remember that a 10-dBA difference means *twice* the perceived loudness.

It bears repeating here that **more lumens = more noise.** No matter how well designed, brighter projectors are always going to give off more noise than their less powerful cousins. So when you look at dBA ratings, be sure you're comparing apples and apples.

Embrace cleanliness

Dirt and dust can reduce air flow to your projector and make its cooling system work harder to keep it from overheating—and working harder means more noise. To keep noise to a minimum, regularly check your projector's fan and remove any dirt or dust that has built up. Clean its filters at least every three months, more often if it's in a dusty environment. And make sure the area around the projector is free of clutter, so the air can get to it. Alternatively, you can choose a projector with a sealed engine and a filter-free design. In this way, you won't need any filters, while the sealed enclosure prevents dust from intruding in the DLP cinema chip and deforming your images.

Keep your distance

Acoustic pressure decreases as you move away from a sound source—meaning it sounds quieter the farther away you get. Projector noise ratings reflect the sound pressure level 1 meter away. Every time you double the distance, the SPL drops by 6 dBA. Try to install your projector far enough from the audience to bring the SPL below the noise level of your air conditioning and ventilation systems, which are typically the highest noise generators within an office environment (35 – 40 dBA).

Soften up your venue

Hard surfaces reflect sound more strongly than soft ones. To cut down on noise, use well-padded carpeting or linoleum flooring instead of concrete or wood, and install acoustic ceiling tiles. Curtains, fabric-covered partitions and, believe it or not, plants also absorb noise.

Want to know more?

We hope you've found this short guide to projector noise useful. If you have any questions or you'd like to learn more, please don't hesitate to contact us at Barco.