

# The Effects of Ultrasonic Sound Generated by Ultrasonic Cleaning Systems on Human Hearing and Physiology

Questions about the effects of ultrasonic energy on hearing and other human physiology arise from time to time in discussions with customers. Their concern, of course, is that there may be deleterious effects from the exposure to sounds produced by an ultrasonic cleaner. An extensive search of the internet has again shown that this is a “non-issue.” There have been virtually no references added since 2002 and most studies date back to the 1990’s and earlier.

The consensus is that there is no risk to hearing resulting from air born sound waves above 20 kHz. The studies have explored intensities up to 170 dB and higher. Sound waves at ultrasonic frequencies are highly directional and dissipate rapidly in air. It is true, however, that typical ultrasonic cleaning systems also produce sound at frequencies less than 20 kHz. Some of these low frequency sounds are sub-harmonics of the primary ultrasonic frequency. Additional sources of sound include other mechanical devices which include pumps and blowers, for example. In some cases these lower frequency sounds may be intense enough to be of concern but can often be confined through the use of proper acoustic shielding. These lower frequency sounds fall into a range that is regulated by OSHA and other agencies and must be addressed just as any other source of noise.

## Some Important Things to Know About Sound –

- Sound levels are commonly measured in units called decibels. The decibel scale is logarithmic, not linear, so that an increase of 10 dB (60 dB to 70 dB for example) actually indicates that a sound is generated with 10 times the power and, as a result, is 10 times as intense. Reducing the intensity of a sound by 3 dB requires reducing the power by approximately 50%. More information is available at –

<http://en.wikipedia.org/wiki/Decibel>

- The noise level in an environment is the result of all of the sound sources in the area and can never be lower than that of the highest intensity source. If two sources producing the same sound intensity are present, the resultant sound intensity is higher than that produced by either one individually.

$$60 \text{ dB} + 60 \text{ dB} = 63 \text{ dB}$$

$$80 \text{ dB} + 80 \text{ dB} = 83 \text{ dB}$$

The total sound level produced by two sources with different levels is usually only slightly higher than that of the higher of the two. For Example:

$$60.0 \text{ dB} + 70.0 \text{ dB} = 70.4 \text{ dB.}$$

Introducing an additional sound source to an environment will always result in an increase in overall sound level in that area. In short, if the ambient noise level is already 80 dB, introducing another sound source, even if it operates at 65 or 70 dB, will increase the sound level in the area. Operating 10 machines, each producing 60 dB of sound, does not equal an environment where the sound level is 60 dB.

# OSHA Regulations Regarding Ultrasonic Exposure

The following are the sections from the United States Department of Labor Occupational Safety & Health Administration (OSHA) regarding the effects of ultrasound in the workplace. The website addresses are included for reference

[http://www.osha.gov/dts/osta/otm/noise/health\\_effects/](http://www.osha.gov/dts/osta/otm/noise/health_effects/)

## Section I: What is considered "noise" and what are the potential health effects?



Noise is usually defined as unwanted sound. The following sections provide information related to the origins of noise and its impact on our ability to hear:

[Physics of Sound](#)

[Anatomy and Physiology of the Ear](#)

[Effects of Excessive Exposure](#)

[Ultrasonics](#)

### Physics of Sound

[TOP](#)

Sound is the physical phenomenon that stimulates our sense of hearing. It is an acoustic wave that results when a vibrating source, such as machinery, disturbs an elastic medium, such as air.

In air, sound is usually described as variations of pressure above and below atmospheric pressure. These fluctuations, commonly called sound pressure, develop when a vibrating surface forms areas of high and low pressure, which transmit from the source as sound.



[Additional information](#) (App I:A) on the physics of sound, including basic qualities, sound fields, sound propagation, filtering, loudness, and sound pressure weighting is also available.

## Anatomy and Physiology of the Ear

[TOP](#)

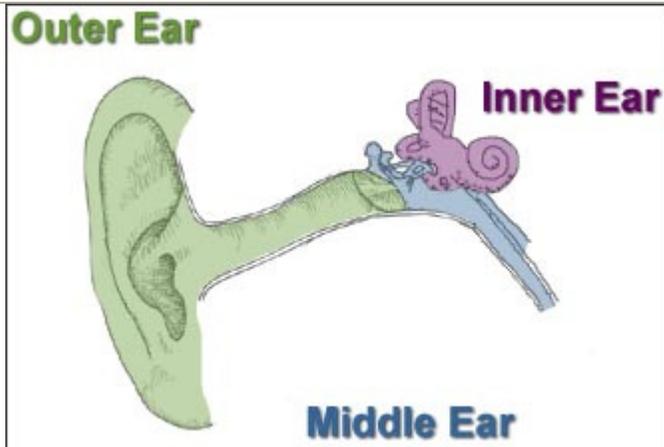
The ear is the organ that makes hearing possible. It can be divided into three sections:

External outer ear  
Air-filled middle ear  
Fluid-filled inner ear

The function of the ear is to gather, transmit, and perceive sounds from the environment.

This involves three stages:

1. *Modification* of the acoustic wave by the outer ear, which receives the wave and directs it to the eardrum.
2. *Conversion and amplification* of the modified acoustic wave to a vibration of the eardrum (transmitted through the middle ear to the inner ear).
3. *Transformation* of the mechanical movement of the wave into nerve impulses that will travel to the brain, which then perceives and interprets the impulse as sound.



[Additional information](#) (App I:B) on outer ear, middle ear and inner ear is also available.

## Effects of Excessive Exposure

[TOP](#)

Although noise-induced hearing loss is one of the most common occupational illnesses, it is often ignored because there are no visible effects, it usually develops over a long period of time, and, except in very rare cases, there is no pain. What does occur is a progressive loss of communication, socialization, and responsiveness to the environment. In its early stages (when hearing loss is above 2,000 Hertz (Hz)) it affects the ability to understand or discriminate speech. As it progresses to the lower frequencies, it begins to affect the ability to hear sounds in general.

The three main types of hearing loss are [conductive](#) (App I:C-1), [sensorineural](#) (App I:C-2), or a combination of the two.

The effects of noise can be simplified into three general categories:

Primary Effects, which includes noise-induced temporary threshold shift, noise-induced permanent threshold shift, acoustic trauma, and tinnitus.  
Effects on Communication and Performance, which may include isolation, annoyance, difficulty concentrating, absenteeism, and accidents.  
Other Effects, which may include stress, muscle tension, ulcers, increased blood pressure, and hypertension.

In some cases, the effects of hearing loss may be classified by cause.

[Additional information](#) (App I:C) about the effects of excessive noise exposure is also available.

Ultrasound is high-frequency sound that is inaudible, or cannot be heard, by the human ear. However, it may still affect hearing and produce other health effects.

Factors to consider regarding ultrasonics include:

The upper frequency of audibility of the human ear is approximately 15-20 kilo-Hertz (kHz).

This is not a set limit and some individuals may have higher or lower (usually lower) limits.

The frequency limit normally declines with age.

Most of the audible noise associated with ultrasonic sources, such as ultrasonic welders or ultrasonic cleaners, consists of subharmonics of the machine's major ultrasonic frequencies.

**Example:** Many ultrasonic welders have a fundamental operating frequency of 20 kHz, a sound that is at the upper frequency of audibility of the human ear. However, a good deal of noise may be present at 10 kHz, the first subharmonic frequency of the 20 kHz operating frequency, and is therefore audible to most persons.

[Additional information](#) (App I:D) on ultrasonics and the applicability of OSHA's Occupational Noise Exposure standard, [1910.95](#), health effects and the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs) is also available.

[http://www.osha.gov/dts/osta/otm/noise/health\\_effects/ultrasonics.html](http://www.osha.gov/dts/osta/otm/noise/health_effects/ultrasonics.html)

### **Applicability of OSHA's Noise Standard, 29 CFR 1910.95**

OSHA's noise [29 CFR 1910.95](#) addresses airborne ultrasonic noise because of OSHA's criterion parameters.

At 20 kilo-Hertz (kHz), an A-weighted sound pressure level is 10 decibels (dB) below an unweighted sound pressure level.

At 50 kHz, an A-weighted sound pressure level is 25 dB below the corresponding unweighted level.

Example: If an A-weighted instrument is used to measure a 50 kHz, 110-dB tone, the instrument will indicate 85 dBA. (Note that the American National Standards Institute's (ANSI) S1.4-1976 or S1.4-1983 standard, which sets the performance and accuracy tolerances that all OSHA sound-level meters must meet, requires a Type II microphone accuracy of only  $\pm 5$  to 4 at frequencies above 10,000 Hz).

### **Health Effects and Threshold Limit Values (TLVs®)**

Research indicates that ultrasonic noise has little effect on general health unless there is direct body contact with a radiating ultrasonic source. Reported cases of headache and nausea associated with airborne ultrasonic exposures appear to have been caused by high levels of audible noise from source subharmonics.

The American Conference of Governmental Industrial Hygienists (ACGIH®) has established permissible ultrasound exposure levels. These recommended limits (set at the middle frequencies of the one-third octave bands from 10 kHz to 50 kHz) are designed to prevent possible hearing loss caused by the subharmonics of the set frequencies, rather than the ultrasonic sound itself.

These TLVs® represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect on their ability to hear and understand normal speech. Previous TLVs® for frequencies in the 10 kHz to 20 kHz range, set to prevent subjective effects, are referenced in a cautionary note below (1). The 8-hour time-weighted average (TWA) values are an extension of the TLVs® for noise, which is an 8-hour TWA of 85 dBA for sound below 10 kHz. The ceiling values may be verified by using an integrating sound level meter with slow detection and 1/3 octave bands. All instrumentation should have adequate frequency response and should meet the specifications of ANSI S1.4-1983 and International Electrotechnical Commission (IEC) 804.

Measuring any source suspected of producing sound at levels exceeding the ACGIH® recommended limits requires the use of a precision sound level meter, equipped with a suitable microphone of adequate frequency response, and a portable third-octave filter set. Consult with the Assistant Regional Administrator for Technical Support for guidance.

TLVs <sup>®</sup> for Ultrasound			
	One-third Octave-Band Level		
	Measured in Air in dB re: 20 µ Pa; Head in Air		Measured in Water in dB re: 1 µ Pa; Head in Water
Mid-Frequency of Third-Octave Band (kHz)	Ceiling Values	8-Hour TWA	Ceiling Values
10	105 <sup>A</sup>	88 <sup>A</sup>	167
12.5	105 <sup>A</sup>	89 <sup>A</sup>	167
16	105 <sup>A</sup>	92 <sup>A</sup>	167
20	105 <sup>A</sup>	94 <sup>A</sup>	167
25	110 <sup>B</sup>	--	172
31.5	115 <sup>B</sup>	--	177
40	115 <sup>B</sup>	--	177
50	115 <sup>B</sup>	--	177
63	115 <sup>B</sup>	--	177
80	115 <sup>B</sup>	--	177
100	115 <sup>B</sup>	--	177

<sup>A</sup> Subjective annoyance and discomfort may occur in some individuals at levels between 75 and 105 dB for the frequencies from 10 kHz to 20 kHz especially if they are tonal in nature. Hearing protection or engineering controls may be needed to prevent subjective effects. Tonal sounds in frequencies below 10 kHz might also need to be reduced to 80 dB.

<sup>B</sup> These values assume that human coupling with water or other substrate exists. These thresholds may be raised by 30 dB when there is no possibility that the ultrasound can couple with the body by touching water or some other medium. [When the ultrasound source directly contacts the body, the values in the table do not apply. The vibration level at the mastoid bone must be used.] Acceleration Values 15 dB above the reference of 1g rms should be avoided by reduction of exposure or isolation of the body from the coupling source. (g = acceleration due to the force of gravity, 9.80665 meters/second; rms = root-mean-square).

**Source:** ACGIH<sup>®</sup> Worldwide. 2003 TLVs<sup>®</sup> and BEIs<sup>®</sup>: Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices, p.107.

## Controls

High frequency noise is very directional and is relatively easily reflected or blocked by any type of barrier. The wavelength of a 16 kHz tone, for example, is about 3/4 inch, so a barrier of one to two inches higher than the source is generally sufficient to reflect noise of approximately the same frequency away from the nearby worker. Such barriers are inherent in some of the machines and surfaces themselves.

High frequency audible noise is also easily absorbed by any of the so-called acoustical materials (for example, glass fiber or foam).

Standard Statement Regarding Sound from the CTGClean website.

**Q - Can ultrasonics cause damage to hearing? Are there any other effects on the body?**

Ultrasonic cleaning equipment utilizes high energy sound waves at frequencies above those audible to humans to enhance the chemical and mechanical cleaning effects of liquids. The ultrasonic energy, although high in power, has no measurable impact on human auditory senses - in fact, there are no established time weighted average exposure limits for frequencies above 20kHz (20,000 cycles per second) . The frequencies of concern are the audible sub-harmonics of the ultrasonic primary frequency. These are produced due to sympathetic resonance of various components of the ultrasonic equipment which may include the cleaning tank, the enclosure panels, lids and other features. Pumps, blowers, and other ancillary equipment also contribute to the overall noise produced by the unit. In that regard, ultrasonic cleaning equipment is no different than a machine tool or any other piece of equipment found in the industrial environment. Ultrasound of the intensity that can be transmitted through the air has no known effect on body tissue. Ultrasound, in fact, is commonly used for imaging of the human body.