APPENDIX C—ULTRASOUND

Ultrasound is any sound whose frequency is too high for the human ear to hear. (The upper frequency that the human ear can detect is approximately 15 to 20 kilohertz, or kHz, although some people can detect higher frequencies, and the highest frequency a person can detect normally declines with age.) Most of the audible noise associated with ultrasonic sources, such as ultrasonic welders or ultrasonic cleaners, consists of subharmonics. Even though the ultrasound itself is inaudible, the subharmonics it generates can affect hearing and produce other health effects.

C.1 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.

Subharmonics are sound waves with frequencies that are a fraction (e.g., one-half, one-quarter) of the original ultrasound frequency. Because they are lower than the ultrasound, the human ear can detect them.

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 100 kHz) are designed to prevent possible hearing loss caused by the subharmonics of the set frequencies, rather than the ultrasound itself. These exposure levels represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effects on their ability to hear and understand normal speech. (Table C–1)

ACGIH also offers recommendations for measuring or verifying ultrasound levels, which requires a precision sound level meter equipped with a suitable microphone of adequate frequency response and a third-octave filter. CSHOs considering evaluating ultrasound levels should consult the CTC for assistance in selecting a suitable instrument.

ACGIH also notes that:

> *Subjective annoyance and discomfort may occur 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. (ACGHI, 2012)*

Table C–1. Select Examples of Threshold Limit Values for Ultrasound Measured in Air

1/3 Octave Band Frequency (kHz)		
	Ceiling Values (dB)[a, b]	8-Hour TWA (dB)[a, b]
10	*105*	*88*
20	*105*	*94*
25	*110*[a]	—
50	*115*[a]	—

[a] *re: 20 µ Pa (head in air)*
[b] *ACGIH set the ceiling values assuming that the worker has no direct contact with the ultrasound source, but that the worker does have contact with water or other media that can transfer the sound waves.*

For additional information on ultrasound exposure levels, ceiling values, and 8-hour TWAs that apply to other frequencies, as well as ceiling values measured underwater, refer to the complete ACGIH TLV for ultrasound (see ACGIH. 2012. Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices. American Conference of Governmental Industrial Hygienists).

C.2 Controls

High-frequency noise is highly directional and is associated with short wavelengths. This means that it is easily reflected or blocked by any type of barrier. The wavelength of a 16-kHz tone, for example, is about 3/4 inch. A modest barrier, extending just 1 to 2 inches beyond the source, is generally sufficient to reflect noise of approximately the same frequency away from a nearby worker. High-frequency audible noise is also easily absorbed by many acoustical materials, such as glass fiber or foam.

C.3 International Ultrasound Exposure Limit Recommendations

Over the past decades, several countries have set exposure limits or recommended levels for ultrasound at various frequencies. The differences in limits are great and reflect differences in the interpretation and analysis of studies on ultrasound and human health. Table C–2 lists ceiling values measured in air in dB, as opposed to 8-hour TWAs or ceiling values measured in water in dB. Though ultrasonic frequencies are not audible to the human ear, it is clear that the international community is concerned about the effects that subharmonic frequencies have on human health.

Table C–2. Examples of International Occupational Exposure Sound Pressure Level Ceiling Limits (in dB) for 1/3-Octave Bands

Frequency (kHz)	Decibel Limits Proposed By:					
	Japan (1971)	USSR (1975)	Sweden (1978)	ACGIH (2003)	Canada (1991)	European Union (2002)
8	*90*	—	—	—	—	—
10	*90*	—	—	*105*	—	—
12.5	*90*	*75*	—	*105*	—	—
16	*90*	*85*	—	*105*	*75*	—
20	*110*	*110*	*105*	*105*	*75*	*105*
25	*110*	*110*	*110*	*110*	*110*	*105*
31.5	*110*	*110*	*115*	*115*	*110*	*115*
40	*110*	*110*	*115*	*115*	*110*	*115*
50	*110*	*110*	*115*	*115*	*110*	*115*

Adapted from: Health Canada. 2008. Guidelines for the Safe Use of Ultrasound: Part II—Industrial & Commercial Applications—Safety Code 24. http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/safety-code_24-securite/guidelines-principes-eng.php.

For a detailed review of ultrasound effects on human hearing, published literature, international ultrasound standards, and recommendations for future directions, see:

Lawton, B.W. 2001. Damage to Human Hearing by Airborne Sound of Very High Frequency or Ultrasonic Frequency. Health and Safety Executive. http://www.hse.gov.uk/research/crr_pdf/2001/crr01343.pdf.

The report concludes: There is not sufficient data in the literature to support, or even contemplate, a dose response relation between occupational exposure to VHF noise and resultant hearing risk.