What are ULTRASONICS *and* ULTRASONIC PROCESSING?

SONICS

INTRODUCTION

High-Intensity Ultrasonic Liquid Processing is being explored and applied in various fields, across many industries. It is replacing many standard methodologies in application areas as diverse as sample prep and analysis, research and development, and even manufacturing. To date, the growing list of markets utilizing Ultrasonics includes biotechnology, analytical chemistry, environmental testing, industrial processing, pharmaceuticals and many others.

To better understand this technology, ***Sonics*** has compiled this backgrounder on what Ultrasonics is and what **High-Intensity Ultrasonic Liquid Processing** can do.

ABOUT ULTRASONICS

Although sound is the sensation perceived by the sense of hearing, it's not always audible. **Ultrasound, often referred to as Ultrasonics, literally means beyond sound, or above the human audible spectrum.** The human ear is most sensitive to frequencies in the 1 to 5 kHz range, with lower and upper limits of 0.3 and 19 kHz, respectively. Ultrasonics refers to sound above 19 kHz.

Around 1915, Langevin – a pioneer in the field of Ultrasonics – designed, built and experimented with high-power, magnetostrictive Ultrasonic equipment. In the decade that followed progress was relatively slow, and it was not until 1927 that significant developments came about. That year, Wood and Loomis, both chemists, recognized **the effects of intense sound waves traveling through a liquid**, and published their observations regarding the effects of Ultrasonics on emulsification, dispersion of colloids, fragmentation of small and fragile bodies, destruction of red blood corpuscles, and various effects due to frictional heating. Although their work generated great interest, it was not until the 1950s, when high-efficiency piezoelectric transducers were mass-produced, that high-power, low-cost Ultrasonic equipment became readily available for research and industrial applications.

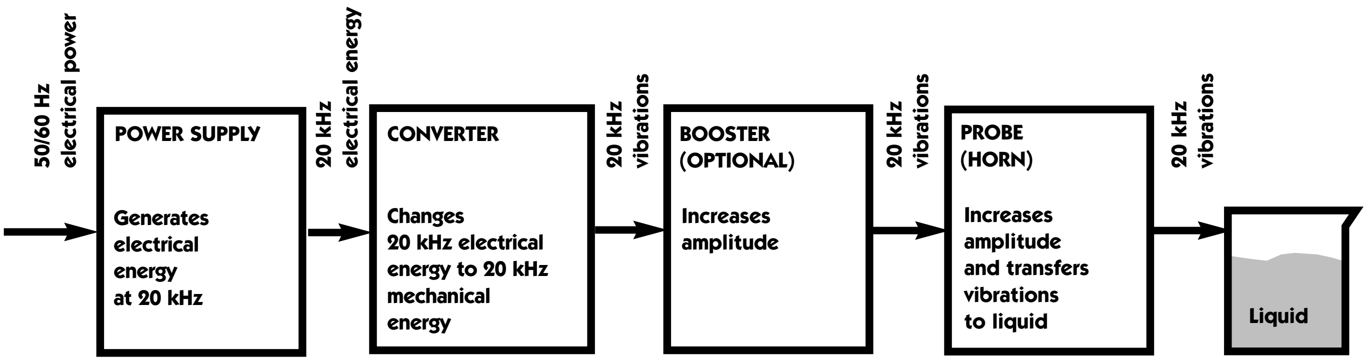
The two main products to use piezoelectric technology for high-intensity ultrasonic applications are ultrasonic baths and Ultrasonic Liquid Processors. Baths work well for most cleaning applications, however their low, fixed and uneven intensity somewhat limits their utilization. Ultrasonic Processors, on the other hand, are more versatile and are the instruments of choice for applications requiring high-intensity Ultrasonic energy.

ULTRASONIC PROCESSORS

Ultrasonic Processors consist of three major components:

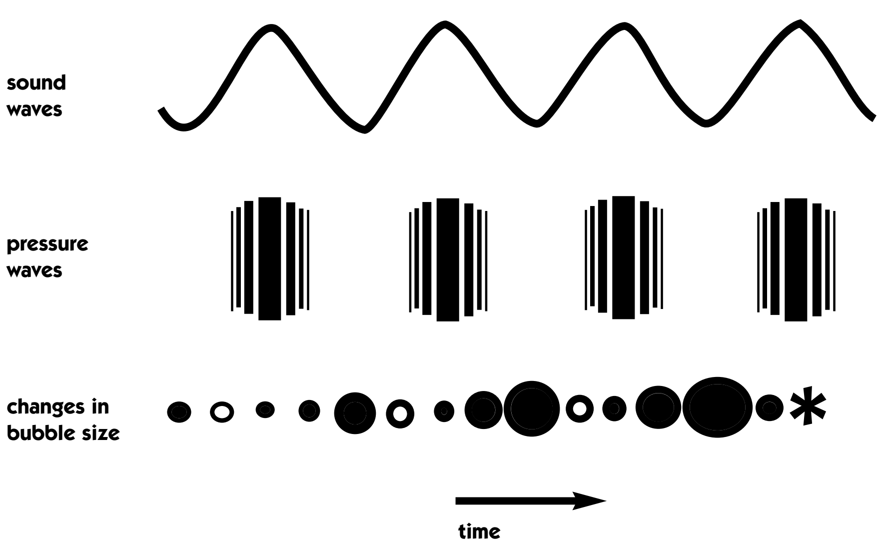
an Ultrasonic Power Supply (generator), a Converter (transducer) and a Probe (horn).

Additionally, a variety of accessories can be used to expand the capabilities of Ultrasonic Processors.



The ultrasonic power supply converts 50/60 Hz voltage to high-frequency (20 kHz) electrical energy. This voltage is applied to the piezoelectric crystals within the converter, where it is changed to small mechanical vibrations. The converter's longitudinal vibrations are amplified by the probe and transmitted to the liquid as Ultrasonic waves consisting of alternate compressions and rarefactions. These pressure fluctuations cause the liquid to fracture or tear into the rarefaction stage due to negative pressures, creating millions of microscopic bubbles (cavities). As the wave front passes and the bubbles are subjected to positive pressures in the compression stage, they oscillate and eventually grow to an unstable size (up to 100 microns in diameter). Finally the bubbles implode, creating millions of shock waves and eddies to radiate outwardly from the site of collapse, as well as generating extremes in pressures and temperatures at the implosion sites. During cavitational collapse, intense heating of the bubbles occurs. The localized hot spots have temperatures in the range of 5,000 ºC, pressures approaching 500 atmospheres, lifetimes of a few microseconds, and heating and cooling rates greater than 10^9 K/s. **Although this phenomenon, know as cavitation, lasts but a few microseconds, and the amount of energy released by each individual bubble is minimal, the cumulative amount of energy generated is extremely high.**

THE CAVITATION CYCLE



POWER SUPPLY

The power supply transforms conventional 50/60 Hz electrical power into high-frequency electrical power at 20,000 Hz. Power supplies are typically rated in watts of output power. It should be noted that using a power supply with a higher wattage rating does not mean that more power will automatically be transmitted to the liquid. Rather, it is the resistance to the movement of the probe (horn) that determines how much power will be delivered into the liquid. Load is determined by three factors: sample volumes, sample viscosity, probe size; and, in some cases, a pressurized environment. Under identical loading conditions, the wattage delivered by two power supplies with different power ratings will be the same (provided both have sufficient power capability).

The speed control on an automobile, can, to a certain extent, be compared to an Ultrasonic Processor. The speed control is designed to maintain the vehicle rate of travel constant. As the terrain changes, so do the power requirements. The speed control senses these requirements, and automatically adjusts the amount of power delivered by the engine, in order to compensate for these ever-changing conditions. The steeper the incline, the greater the resistance to the movement of the vehicle, and the greater the amount of power that will be delivered by the engine, to overcome that resistance.

The Ultrasonic Processor is designed to deliver constant amplitude (peak-to-peak displacement at the probe tip). As the resistance to the movement of the probe increases, so do the power requirements. The power supply senses these requirements, and automatically increases the amount of power delivered, in order to maintain the excursion at the probe tip constant.

The amplitude control allows the Ultrasonic vibrations at the probe tip to be set to any desired level. Although the degree of cavitation required to process the sample could readily be determined by visual observation, the amount of power required cannot be predetermined. A sensing network continuously monitors the output requirements, and automatically adjusts the power to maintain the amplitude at the preselected level. Negligible power is required to keep an Ultrasonic probe resonating when operated in air. The greater the resistance to the movement of the probe due to higher viscosity, deeper immersion of the probe into the sample, larger probe diameter, or higher pressure, the greater the amount of power that will be delivered to the probe. Setting the amplitude control fully clockwise will not cause the maximum power to be delivered to the sample. The maximum power any Ultrasonic Processor is capable of delivering is only delivered when resistance to the movement of the probe is high enough to draw maximum wattage.

This phenomenon can be demonstrated as follows: Depress a probe down against a piece of wood while observing the power monitor; as the down pressure (resistance) is increased, the amount of power delivered by the power supply will increase accordingly.

CONVERTER

The converter changes the high-frequency electrical energy from the power supply into mechanical vibrations. Converters contain lead zirconate titanate piezoelectric ceramic discs. When an alternating voltage is applied to the opposing faces of the discs, they expand and contract with the change in polarity. As the alternating high frequency voltage is applied to the discs, they vibrate at that frequency. The entire assembly is designed to resonate at a predetermined frequency, and its length is typically equal to one-half wavelength of the applied frequency – about 5 inches (130 mm) at 20 kHz.

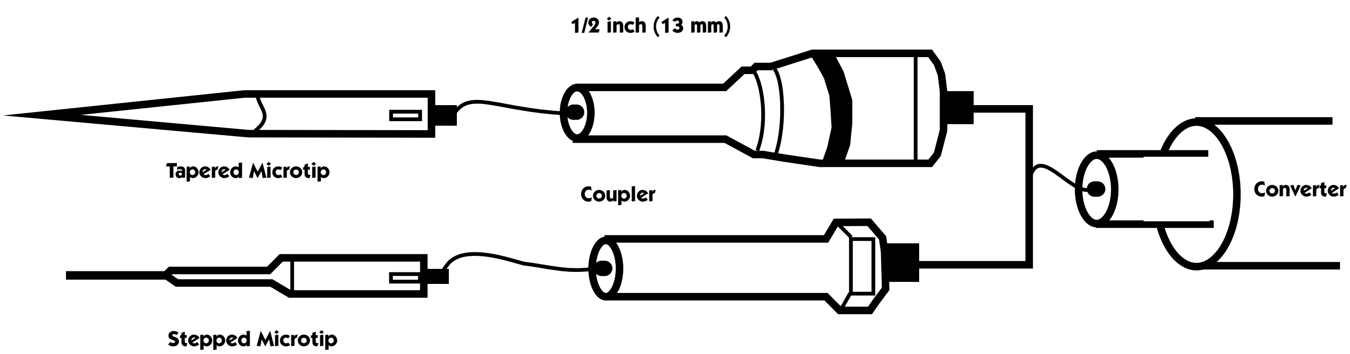
ULTRASONIC PROBES

Probes are also one-half-wavelength-long sections that act as mechanical transformers to increase the amplitude of vibration generated by the converter. The greater the mass ratio between the upper section and the lower section (tip), the greater the amplification factor. Probes with smaller tip diameters produce greater intensity of cavitation, but the energy released is restricted to a narrower, more concentrated field immediately below the tip. Conversely, probes with larger tip diameters produce lesser intensity, but the energy is released over a greater area. The larger the tip diameter, the larger the volume that can be processed, but at lower intensity. High-gain probes produce higher intensity than standard probes, and are usually recommended for processing larger volumes or difficult applications. Probes are fabricated from high-grade titanium alloy TI-6AL-4V because of its high strength-to-weight ratio, good acoustical properties at ultrasonic frequencies, high resistance to corrosion, low toxicity and excellent resistance to cavitation erosion. They are autoclavable, and are available with threaded ends to accept replaceable tips, microtips and extenders.

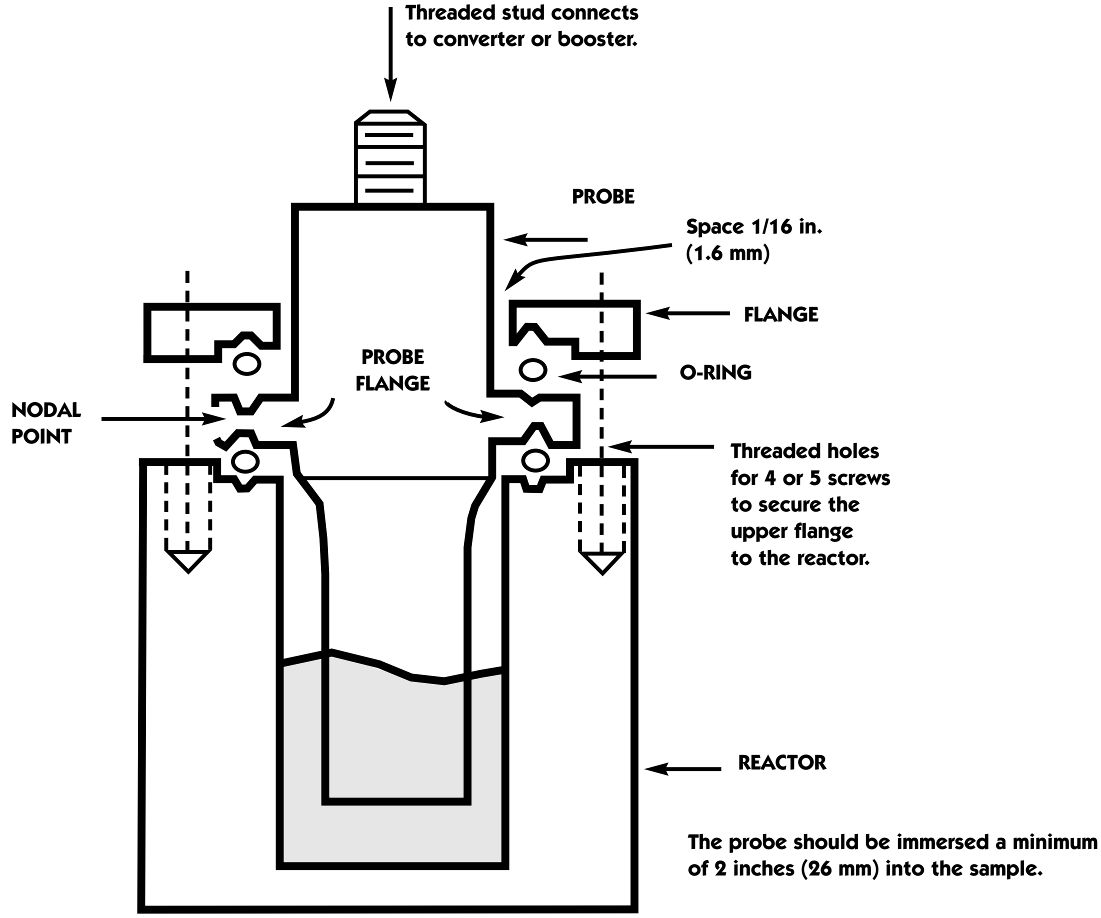
All probes, including those with replaceable tips, are tuned to resonate at 20 kHz ± 100 Hz. If the replaceable tip is removed or isolated from the rest of the probe, that element will no longer resonate at 20 kHz and the power supply will fail. Low-surface tension liquids penetrate the interface between the probe and the replaceable tip, and carry the particulates into the threaded section, isolating the tip from the probe. When working with low-surface tension liquids, such as solvents, ***always*** use a solid probe.

Microtips can process small samples at very high intensity. The tapered microtip screws into the 1/2 inch (13 mm) threaded end probe in place of the replaceable tip. The stepped microtip assembly consists of two parts, and screws into the converter in place of the probe. Capable of reaching into narrower vessels than the tapered microtip, the stepped microtip assembly can process volumes as small as 250 microliters. Microtips are fabricated from titanium alloy TI-6AL-4V and are autoclavable.

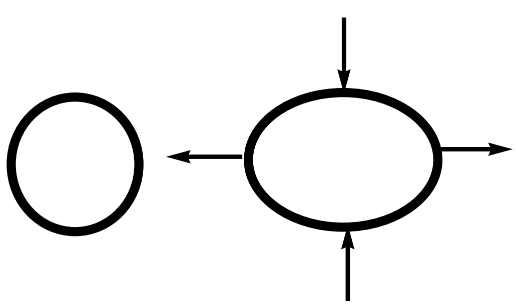
CAUTION: DO NOT exceed the "MICROTIP LIMIT" on the Power Supply when using a Microtip!



NODAL POINT / FLANGED PROBES



With Ultrasonics, nothing can come in contact with the probe, except at the point of no activity – the nodal point. A flange or threaded section can be machined onto the probe at the nodal point so it can be affixed to a pressure vessel. For leak-proof operation and safety considerations when working with high-pressure applications, probes are commonly flanged instead of threaded. During operation, the top and bottom of the probe expand and contract longitudinally about the nodal point causing the diameter of the probe around the flange to expand and contract radically (same as a water-filled balloon).



For that reason the inside diameter of the reactor, where the flange is located, should be made slightly larger than the probe's outside diameter (~1/16 in. [1.6 mm]), to preclude the possibility of the probe flange contacting the reactor as it expands and contracts during operation. The flange is isolated from the reactor with O-rings, which isolate the probe from the reactor and help center the probe into the reactor. When the flange is bolted down, it contacts the reactor and slightly compresses the O-rings. Compressing the O-rings too much – so as to cause them to deform – will eventually cause the system to fail.

BOOSTERS

When working with a difficult application, the use of a booster may be recommended. When interposed between the converter and the probe, the booster will increase the amplitude of vibration at the probe tip. Boosters should not be used with microtips, cup horns or high-gain probes.

COMMONLY ASKED QUESTIONS

What is Ultrasonics?

Everything that makes a sound vibrates, and everything that vibrates makes a sound. However, not all sounds are audible. Ultrasound literally means beyond sound; sound above the human audible spectrum. Using 19,000 Hertz (cycles per second) as the approximate limit of human hearing, Ultrasonics refers to sound above that frequency.

What are the differences between an Ultrasonic Processor and an Ultrasonic Bath?

The intensity within a bath is fixed, low, location-dependent and inconsistent, due to the fluctuation in the level and temperature of the liquid. With an Ultrasonic Processor, processing is fast and highly reproducible. The energy at the probe tip is high (at least 50 times that produced in a bath), focused and adjustable.

At what frequency does an Ultrasonic Processor operate?

Standard Ultrasonic Processors operate at a nominal frequency of 20 kHz or 20,000 cycles per second (cps).
The auto-tune feature actually moves the frequency within a small range during operation to optimize performance.

20 kHz versus 40 kHz

40 kHz are often used for ultrasonic atomization because the droplet size at that frequency is half that generated at 20 kHz.
On the other hand, the frequency of choice for most Ultrasonic Liquid Processing applications is 20 kHz, because the amplitude at the probe tip and the resulting cavitation is twice that generated at 40 kHz.

With Ultrasonic Processing, are there any limitations?

Yes. Viscosity, temperature and liquid characteristics. As the viscosity of material increases, its ability to transmit vibrations decreases. Typically, the maximum viscosity at which a material can be processed effectively is 5,000 cps. With standard systems, the practical upper limit on temperature is approximately 100 ºC. Solid probes can safely be used with both aqueous solutions and low-surface tension liquids (e.g., solvents), however probes with replaceable tips should ***never*** be used with surface tension liquids.

Which instrument should I use?

The 500- and 750-watt units are the most versatile because they can process both large and small volumes on a batch basis, as little as 250 microliters (µL) with a microtip, and as much as 1 liter with a 1 in. (25 mm) probe. On a flow-through basis, up to 10 liters per hour. However, since every instrument will perform equally well up to a certain volume, we recommend the 130-watt unit for samples up to 150 mL.

Which probe is best suited for my application?

The larger the probe diameter, the larger the volume that can be processed, but at lesser intensity. ***Always*** use a solid probe when working with low-surface tension liquids.

Can probes be manufactured to any length?

No, they cannot. Probes are made to resonate at a specific frequency (half a wavelength or multiple thereof). 20 kHz probes are typically 5 in. (127 mm) long and can be made longer in 5-inch increments. 40 kHz probes are typically 2.5 in. (63.5 mm) long and can be made longer in 2.5-inch increments.

When should I change the replaceable tip on the probe?

Ultrasonic Processing causes probe erosion. This phenomenon is often referred to as "titanium migration into the sample". Over time, this results in light pitting. Tips can be polished with sandpaper or emery cloth – that is, until the probe no longer resonates at the right frequency. When this happens, the probe will be difficult to tune. As tips are relatively inexpensive, it is recommended that they be changed after several polishings.

Why must the amplitude (power) be set below 40% when a microtip is in use?

Microtips are used to process small volumes and are therefore quite thin, making them more susceptible to stress cracking at higher amplitudes.

What factors must I consider to effectively process my sample size?

The two primary factors for effective processing of a given sample size are probe diameter and volume.

What is a "booster" and when is it used?

A "booster" is a device that is inserted between the converter and the probe to mechanically increase the probe's amplitude. They are typically used in difficult applications or flow-through applications where exposure time is very limited.

Can I process more toxins or bio-hazardous materials safely?

Hazardous materials may be safely processed with a sealed atmosphere chamber. This device isolates the sample in a sealed chamber during the entire cycle and is available with a cooling jacket to inhibit temperature elevations.

How can I process large volumes of material?

For processing larger volumes, *Sonics* offers flow-through processing cells. These specialized chambers channel the continuous flow of material through a high-intensity Ultrasonic field. They are recommended for the treatment of low-viscosity samples, which do not require extended exposure to Ultrasonics.

Do all manufacturers rate their instruments the same way?

Unfortunately not. Unlike some other manufacturers, we at *Sonics* use the RMS rating – the amount of power, measured in watts, that a unit is capable of delivering continuously. Most of our competitors use a Peak Power rating – the maximum amount of power, measured in watts, that a unit is capable of delivering for only a short time.

ULTRASONICS AT WORK

Chemistry

Ultrasonics is used in analytical chemistry for many common procedures, including breaking of chemical bonds, formation of free radicals, polymersion and depolymerization of long-chain molecules, catalysis of reactions (e.g., reduction, alkylation, ester hydrolysis and acylation or aromatics), preparation of catalyst and activation of catalyst. The science of Sonochemistry is well characterized and employed throughout the world.

Biology

Ultrasonics is commonly used for the releasing of enzymes and proteins from cells. This method of extraction commonly produces more active material than other methods. Disruption is often very fast and complete. In biotechnology, the manufacturing of products such as enzymes, fine chemicals and therapeutic reagents requires the fermentation of microorganisms. The use of Ultrasonics has been used in these instances for cell disruption as well as enzyme purification. It helps in the lysing of bacteria, viruses, yeast and tissue cells for the extraction of protein, DNA, RNA, enzymes and other cellular components. The cup horns are high-intensity water baths that allow Ultrasonic Processing while preventing cross-contamination of samples.

Industrial

Many industrial applications require high volumes of liquids to be emulsified, dispersed or homogenized. This can be accomplished through the use of a continuous flow cell for in-line processing.

Pharmaceutical

The pharmaceutical industry routinely uses Ultrasonics for processes such as sample premixing, dispersion and suspension, crack enteric coatings for dissolution testing, tablet pressing operations to reduce tablet size, and degassing and homogenization of slurry in production. The continuous flow cell is a popular accessory for processing larger volumes up to 20 liters/hour.

Environmental

Environmental testing laboratories use Ultrasonic Processors to process soil and sediment samples according to U.S. EPA methods (U.S. EPA Test Method 3550). This is done in lieu of Soxhlet extraction methods due to significant time and material savings. Utilizing probe ultrasonics can save hours of costly sample extractions.

LEADING APPLICATIONS FOR ULTRASONIC PROCESSING

Sample Prep	**Cell Lysing**	**Disaggregation**	**Emulsification**
Communition	**Extraction**	**Dissolution**	**Sonochemistry**
Homogenization	**Mixing**	**Synthesis**	**Catalysis**
Microencapsulation	**Hydrolyzation**	**Degassing**	**Cleaning**
Dispersion	**Disruption**	**Atomization**	**OEM Applications**

TO LEARN MORE

about **High-Intensity Ultrasonic Liquid Processing**, please visit
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