General Classification of SONOREACTORS

We have a number of options to address flow-through Sonochemistry. As you can see there are many elements we can use in our chamber designs. We can offer complete systems built for your needs or for clients with the capability to construct the chamber parts we may also consider selling just the ultrasonic components.

In addition to some standard components you will find that we are offering some very unique technology. For example if you decide on the very high surface power density probe solution please note that ours is the highest power system available. None of the leading industry brands are offering the same level of power output to the liquid. This is very important for some Sonochemical testing where you need to test low power as well as very high power.

Our Pipe-Clamp solution is a technology that will only function with our MMM generators. We can design clamps to fit nearly any size pipe and drive 1 to 5 converters and clamp assemblies from one generator.

SONOREACTORS Group A: HVPD

-High volumetric (typically 5 to 50 W/dm^3) and low surface power density (typically 0.5 to 2 W/cm^2), HVPD, uniformly distributed with lot of cavitation activity: Similar to ultrasonic cleaning systems.
-Large radiating surface/s: Transducer arrays, tubular or Clamp-On transducers, Ultrasonic tanks…
-Multi-frequency, modulated and single frequency systems

SONOREACTORS Group B: HSPD

-High surface-power-density of ultrasonic radiation: HSPD
Typically 100 W/cm^2 or higher (until 500 W/cm^2), non-uniformly distributed (like ultrasonic torch), with significant oscillating amplitudes and insignificant cavitation activity: Ultrasonic mixers & homogenizers.
-Small radiating surface (and very high intensity of ultrasonic radiation)
-Single frequency systems & Single-Probe or single sonotrode Systems.

We need to learn more about your application to give better advice on the equipment that will best meet your needs. Please tell us: What kind of liquid material you wish to treat? Do you prefer to use the effects of even cavitation or a combination high acoustic power plus cavitation to break particles? Will you need to treat a large volume or small volume? Is your need for batch treatment or continuous flow?

Please visit our website for more details and have a look at our production line technology, or contact us directly with any inquiries.

Homepage: http://www.mpi-ultrasonics.com
E-mail: mpi@mpi-ultrasonics.com
mpi@mastersonic.com, mpi@bluewin.ch

Group A): High volumetric and low surface power density ultrasonic treatment: HVPD

Applications: Ultrasonic cleaning in a liquid bath or special reactor cleaning applications, Sonochemistry, Electrochemistry, Surface treatment, Extractions, Nano technologies, Water treatment, Petrochemicals Cracking, Liquid food treatment, Degassing, Defrosting, Impregnation

System solutions may be grouped as follows:

Ultrasonic Baths (1): Such systems are used when it is important to deliver uniform and homogenous ultrasonic energy over a large surface as found in standard bath systems. Using transducer elements with a large radiating surface the power density is usually on the order of 0.5 to 2 Watts per square centimeter. Such power is providing very good cavitation effects and uniform power distribution throughout the liquid bath or special cleaning chamber.

Through the use of **Submersible Box Transducers (2)**, **Plate Mount Transducers (3)**, Tubular Arrays, or a single-transducer with an **Integrated Resonating Bar (4)** or **Flow Thru Clamp-On tube (5)**, we can provide standard bath systems or custom solutions that adapt to an existing cleaning or other liquid-treatment process. We offer both fixed frequency systems and wideband frequency systems using our unique MMM technology.

Advantages of our wideband MMM technology include:

- Uniform distribution of ultrasonic energy throughout the bath.
- Wideband frequency modulations create a wide range of cavitation bubble sizes offering faster and more thorough cleaning of parts.
- Complex MMM modulations eliminate standing waves to improve parts cleaning and reduce damaging hot cavitation zones.
- Reduction of standing waves reduces transducer pitting and extends operational life.
- Faster liquid conditioning and degassing of fresh cleaning solutions.
- Adjustable inductive compensation, available on OEM modules, allows simple adaptability to 3rd party transducers and the possibility for field upgrades to existing systems.
- MMM generators can drive multiple high amplitude clamp-on transducers to make unique radial cleaning chambers of any diameter or length.


(1) Bench Top Bath


(2) Submersible Box

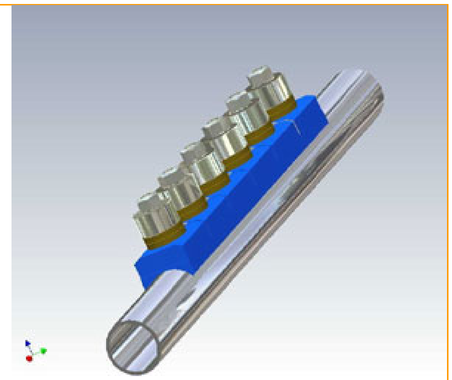

(3) Plate Array


(4) Bar Transducer


(5) Flow Thru Clamp

SonoPipe Ultrasonic Reactor (6)
In-Line (Straight Flow Through)

These unique ultrasonic reactors utilize a patent pending design that allows them to radiate highly efficient ultrasonic energy from all directions around the pipe (360°) when combined with our flexible Multi-Frequency generators. Since the transducers are externally mounted, only the interior of the pipe comes in contact with the treated material providing a clean and straight flow through path.



(6) SonoPipe

Key Features

- Scalable technology:
    - Accommodates various lengths of pipe and power.
    - 200 W to 12,000 W
    - Allows easy adaptation to factory environment.
- Multi-frequency systems reduce excessive spot cavitation and internal erosion providing a very long component life. Eliminating internal sonotrodes means they do not need to be replaced when pitting and erosion make them unusable.
- 360° ultrasonic surface radiation provides thorough penetration of the treated material.
- Straight Flow-through Path provides simple and clean environment.

Tube Single-Transducers (7)
(Lengths from 30 cm to 300 cm)

Our single-transducers ultrasonic tubes can be customized for any length that suits your application. The transducer bar element is made of high grade stainless steel and our multi-frequency generators provide uniform sonication across the entire active surface without standing waves. Their high power and flexible length make them well suited for reactor and cleaning applications.

Key Features

- High power solutions to 3,000 watts per Tube Transducer.
- Custom tube lengths (30 cm to 300 cm)

(7) Tube Single-Transducer

Unit Shown has an Active Element Length of 1,200 mm

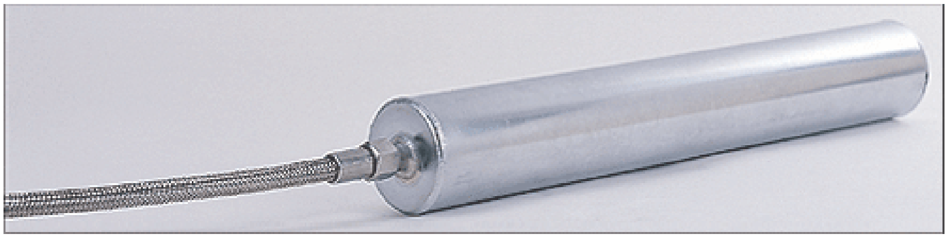
MMM Tube, Multi-Transducers (8)
(Lengths from 30 cm to 200 cm)

Our multi-transducers ultrasonic tubes are constructed to handle very high power for demanding applications. Since they are used exclusively with our Multi-Frequency generators we can construct them to any length (30 cm to 200 cm) to suit your special application.

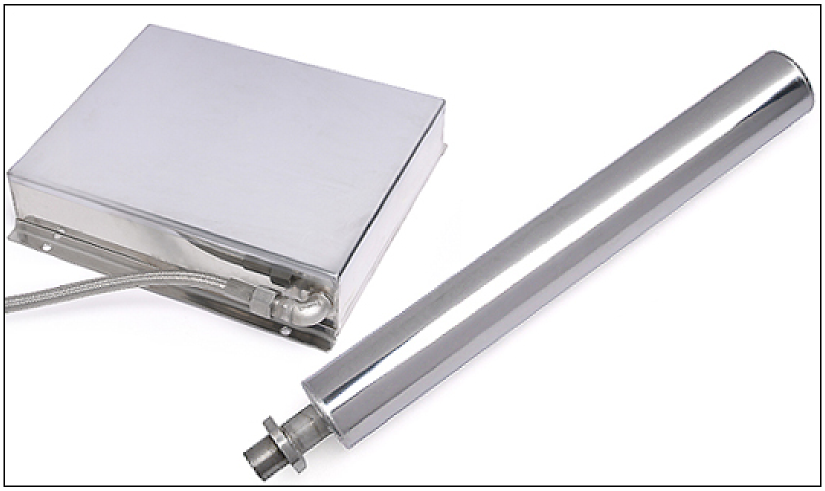
These transducers are made of high grade stainless steel and generate very high amplitudes uniformly across the entire active surface without standing waves. Their high power and flexible length make them well suited for reactor and cleaning applications.

Key Features

- High power solutions to 3,000 watts per Tube Transducer.
- Custom tube lengths (20 cm to 200 cm)

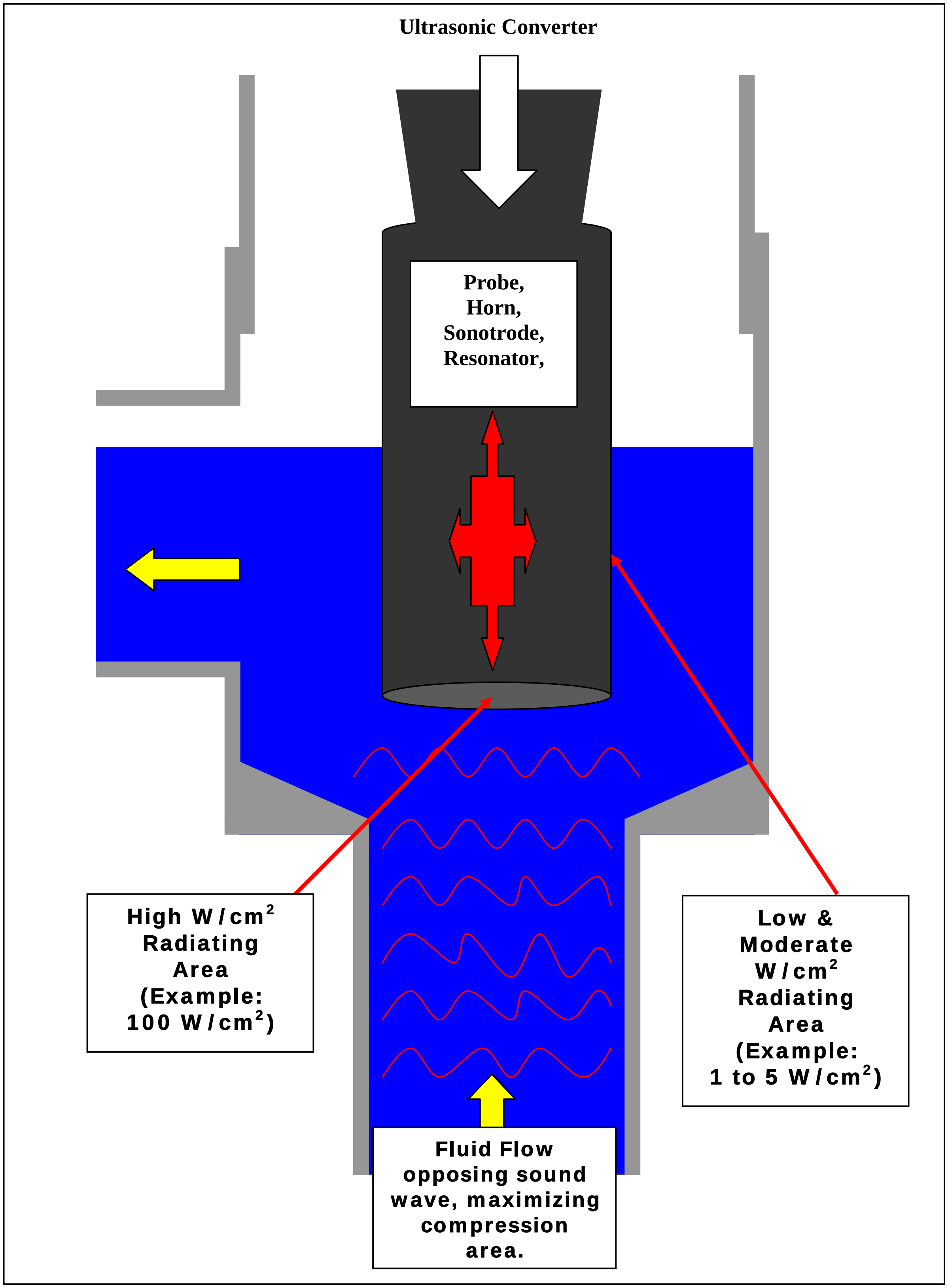


(8) MMM Tube, Multi-Transducers

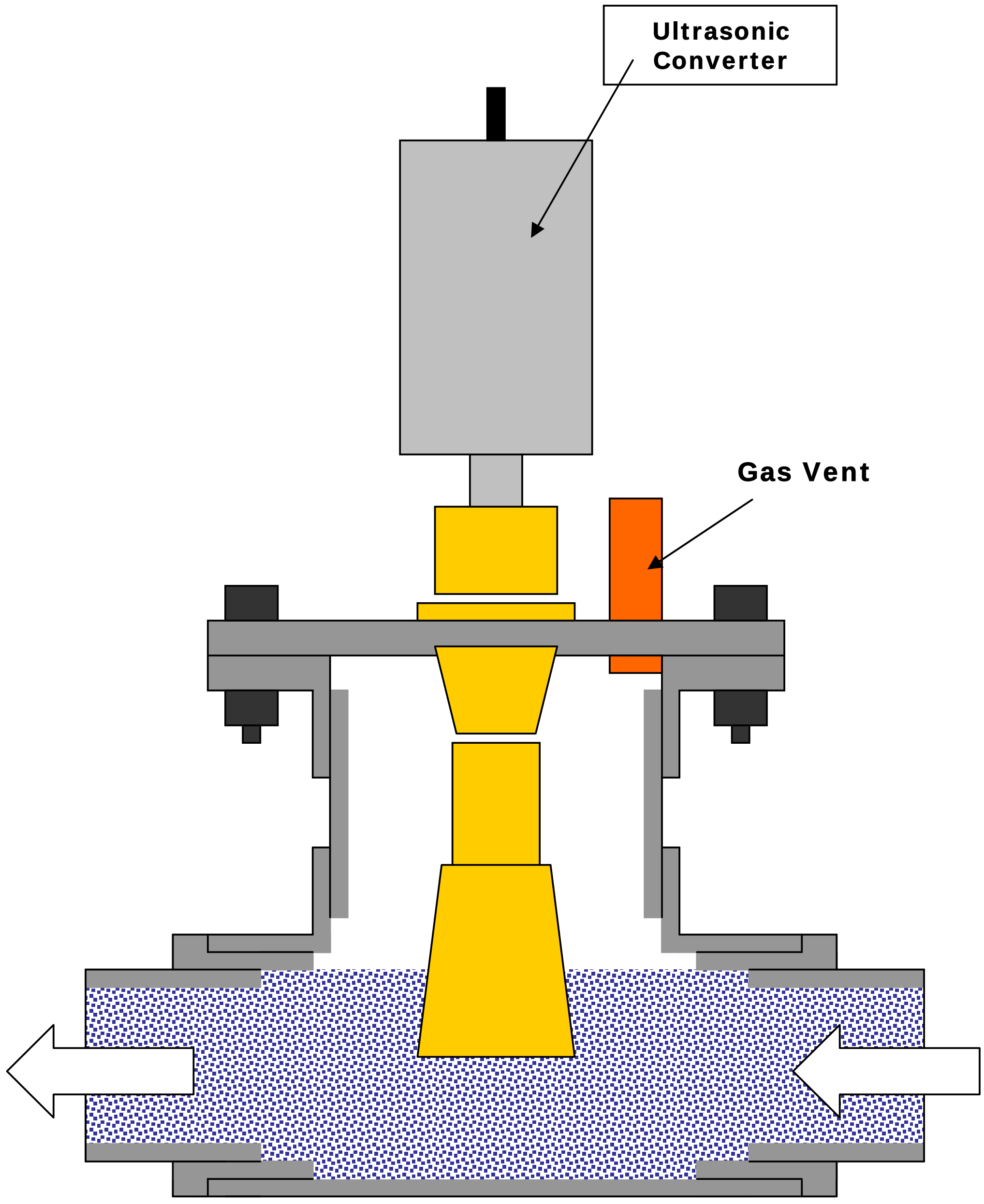


(2 + 8) Submersible box & MMM Tube

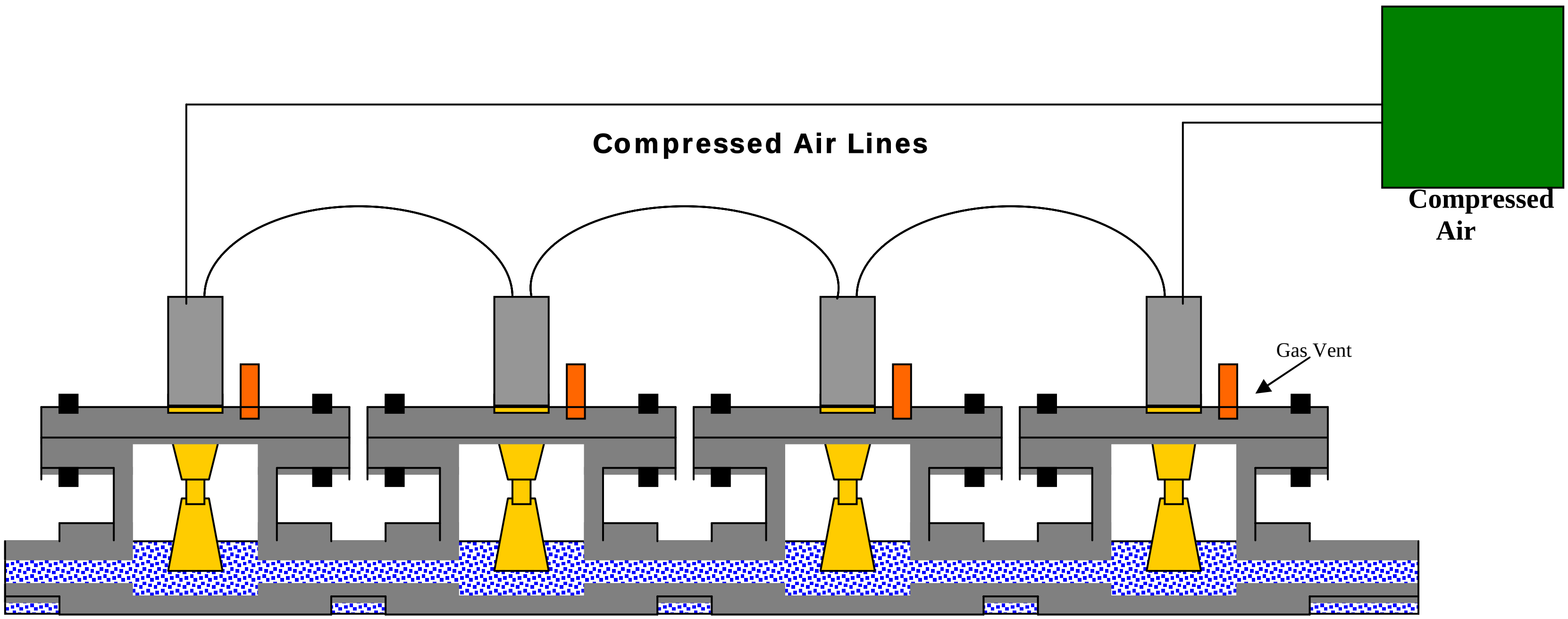
Group B): High Intensity, Single-Frequency Probe Systems: HSPD



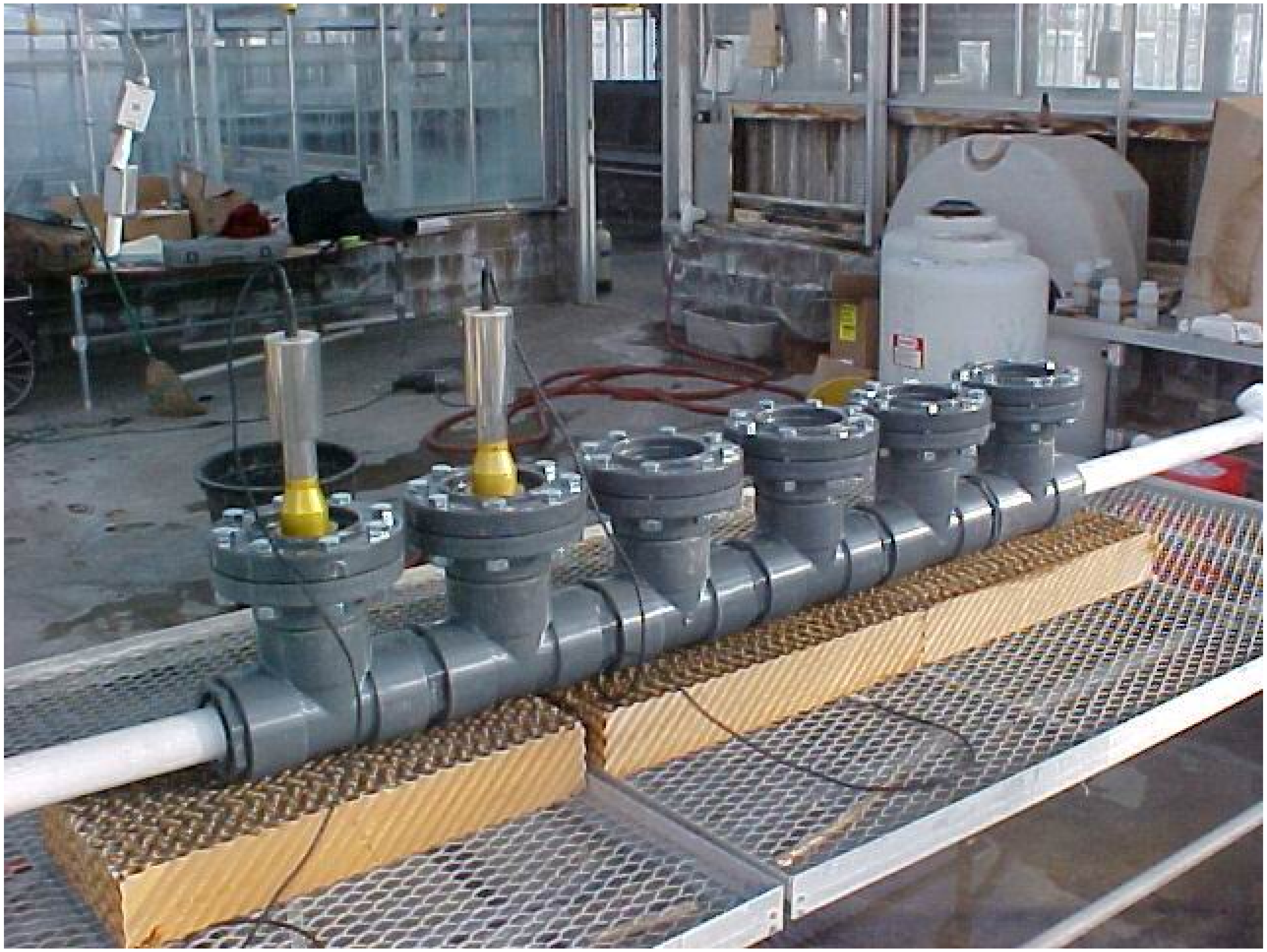
Sonication Chamber
Utilizing Fixed Booster Mounting Flange



Multiple Converters Sonication Chamber



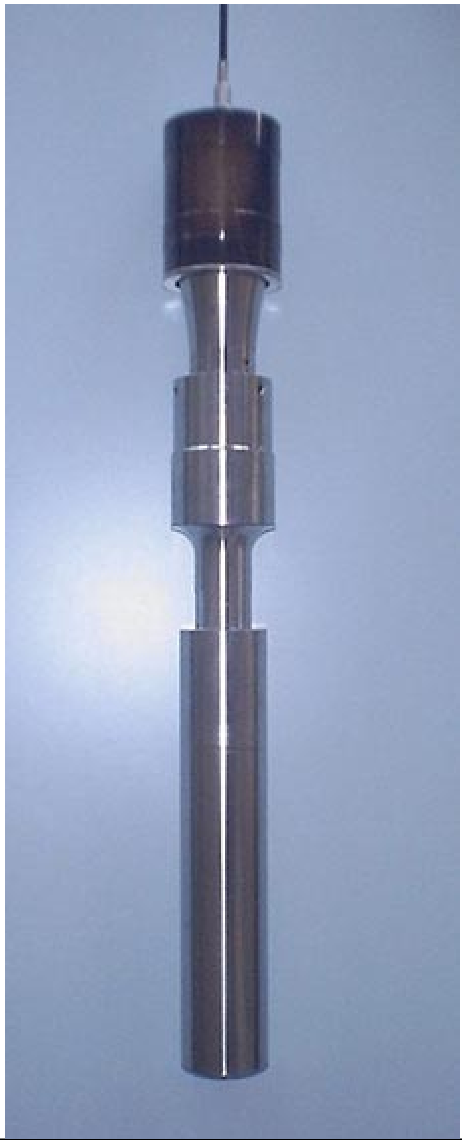
Multiple Converters Sonication Chamber Examples



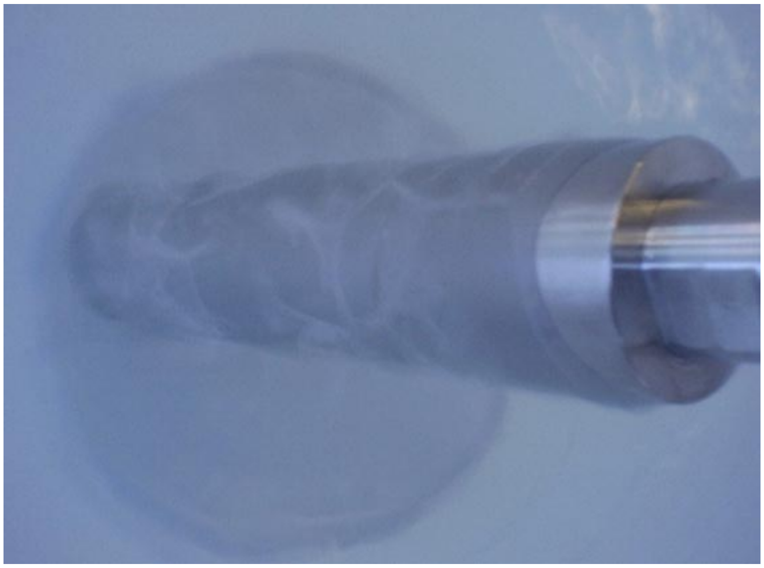
Waste water treatment

Waste water treatment

High Power Fixed-Frequency Piston-Probe



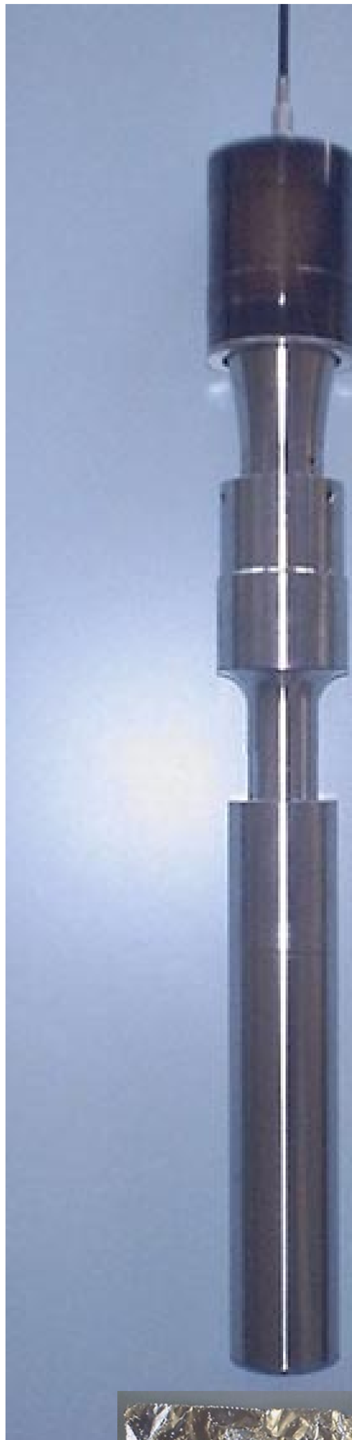
- 20 kHz Fixed frequency
- 2,000 watts max
- Booster Ratio 1:2.0
- Full-wave Probe (titanium)
    - Diameter = 50mm
    - Length = 250 mm
- Very high axial energy produces strong cavitation and acoustic power for mixing, homogenization, flock & particle breakdown.
- New probe design also provides high radial energy for strong cavitation along the probe length.



Power Draw Test : In Water		
Probe Submerged	50% Amplitude	100% Amplitude
Full submerge:	1,000 W	1,500 W
½ Submerge:	600 W	1,000 W
½ Submerge:	600 W	1,000 W
¼ Submerge:	300 W	600 W

What to order (minimal order): Converter, Booster, Probe, and Power Supply

20 kHz Fixed frequency
2,000 watts max
Booster Ratio 1:2.5
Fullwave Probe (titanium)
Diameter = 50mm
Length = 250 mm



Power Draw Test: **In Water**

Amplitude at:	50%	100%
Full submerge:	1,000 W	1,500 W
¾ submerge:	1,000 W	1,500 W
½ Submerge:	1,000 W	1,500 W
¼ Submerge:	1,000 W	1,500 W

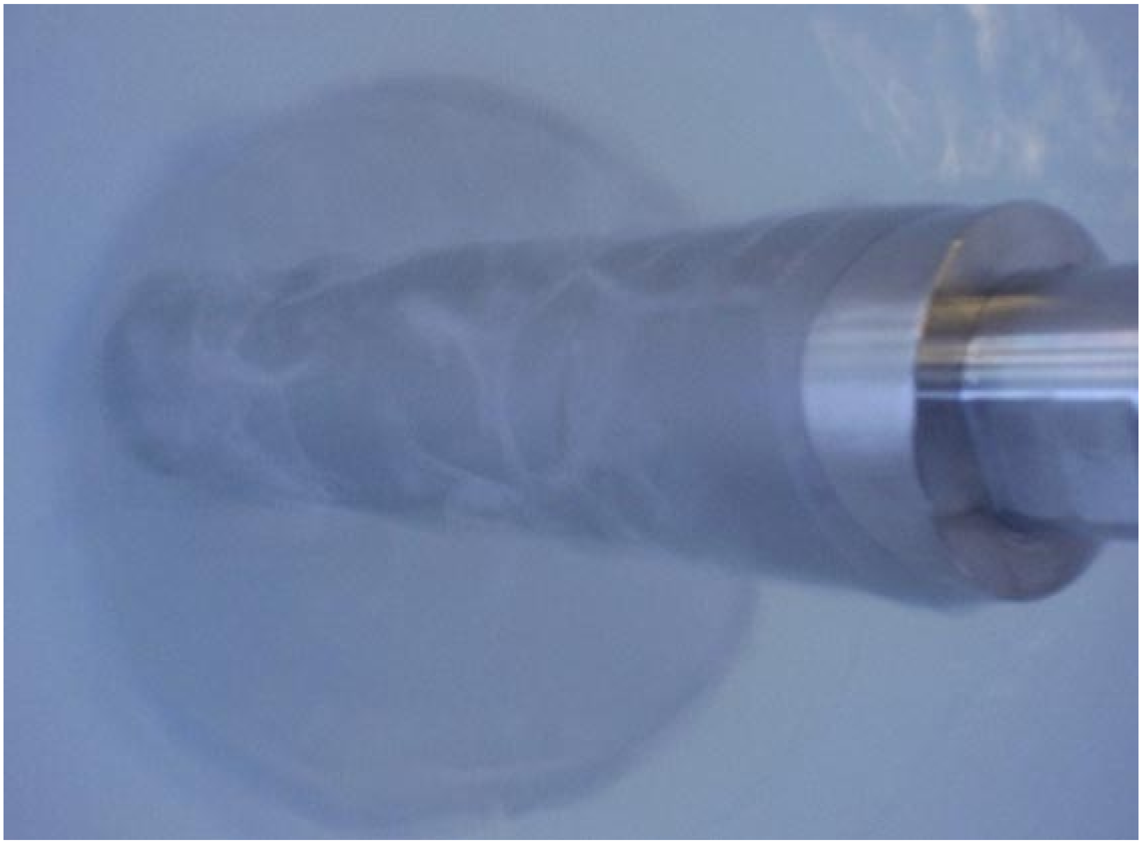
Notes:
Good probe radial cavitation shown on sides by aluminum perforation test for 30 seconds.

Good probe radial cavitation shown on bottom by aluminum perforation test for 30 seconds.

Notes:

Good probe radial cavitation shown by visual inspection and by feel with hand submersion.

Piston Probe Operating in Water



We took a standard fixed frequency generator and converter and tested with a high gain booster (ratio 1:2.5) and a full wave length titanium probe. The probe is about 250 mm (10 inches) in length and 50mm (2 inches) in diameter. Because of the larger diameter we are able to see excellent radial ultrasonic effects in addition to the axial effects on the probe tip.

As is normally done with ultrasonic baths to test for cavitation we did a quick foil test to see if cavitation would penetrate. The results were very good for a 30 second test. This was a slightly thicker foil than normally used so we feel good about the results.

We also see clearly the cavitation areas streaming of the side of the probe. When you immerse your hand in the water you can feel strong cavitation.

This option allows you some good flexibility:

1.) You can submerse the probe directly into the treated liquid from an inch up to 9 inches. (You must not submerse above the probe top, this will cause a system overload)
2.) We can deliver from low to very high concentrations of power with this system (300 to 1,500 watts). If your liquid load is much denser than water you will draw even more power.

3.) You can also change the booster to lower the amplitude (1:2.0 or 1:1.5) or remove the booster to test lower power and amplitude results.

4.) We can also discuss optional probe diameters after you have tested in your liquid media. Smaller probes are possible but they will tend to give more axial and less radial energy. Larger probes become difficult to manage with an unknown liquid density so we need to be careful about larger probes. They may in fact require a special factory set-up that is different from what the 50 mm probe requires.

Piston Sonicator, liquid processing performance: 2000 watt power supply

Amplitude / Power	**Booster**	Probe Percent Sub-merged	Circular Probe **25 mm diameter** 120 mm length **Power Output**	Circular Probe **38 mm diameter** 125 mm length **Power Output**	Circular Probe **50 mm diameter** 125 mm length **Power Output**
100 %	Titanium **1:2.5**	50 %	200 W	640 W	900 W
100 %	Titanium **1:2.5**	90 %	300 W	780 W	1200 W

SONIC-digital Acoustic Stack

Transducer (2,000 W)

Best mounting Point

Booster (1:2.5)

Probe (50 mm)

<u>High Surface Power Density Piston-Probe Systems</u> are also available for ultrasonic cleaning applications where it is desirable to deliver extreme or high ultrasonic power to a focused area. Probes may be designed to deliver maximum acoustic power to the tip face where amplitudes are greatest or we can offer probes providing a combination of radial energy along the sides of the probe in addition to high axial power at the end tip face. Probe tip surface power density can be in the range of 10 w/cm2 to hundreds of w/cm2. This high power ultrasonic energy from the probe tip gives the added benefit of strong acoustic streaming that is directed outward in a straight tight pattern. Advantages in cleaning applications include:

- Intense acoustical pressure at the probe tip generates a combination of ultrasonic cavitation plus strong mixing and streaming liquid currents.
- The strong acoustic streaming energy helps to break apart large flocks and surface contaminants allowing the combined cavitation to further act on smaller particles and exposed surfaces.

Strong acoustic streaming allows cleaning of problematic parts with very small holes or cavities. Gas bubbles trapped in small holes prevent entry of cleaning solution and hinder cleaning. Normal ultrasonic baths that rely only on cavitation may not drive air bubbles from small and long holes. Strong acoustic streaming acts to drive the air bubbles from the void allowing the cleaning solution to enter.

Ultrasonic Power Supplies for above-described single-probe systems are well optimized to deliver very high ultrasonic energy into a liquid load, being fully protected against all accidental and over-loading situations.

Known restrictions related to single-probe systems:

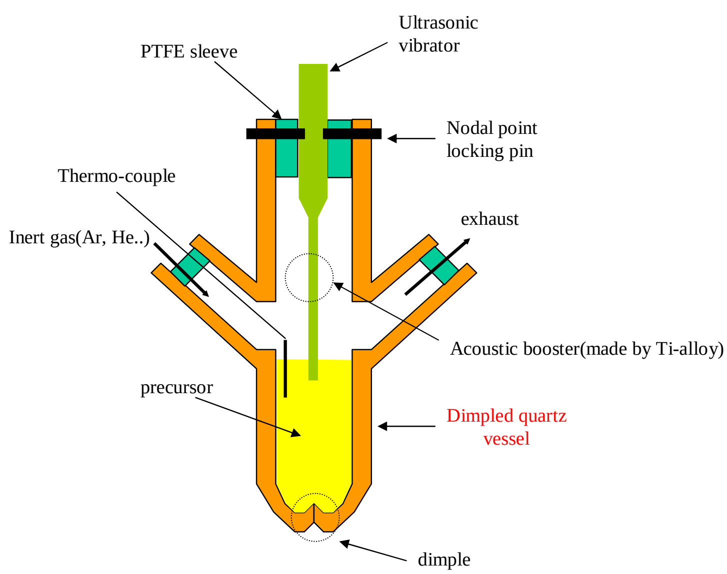
1. **Operating liquid temperature. Necessary to have forced cooling**
2. **Complexity regarding mounting, fixation, sealing**
3. **Sonotrode front-emitting surface-erosion caused by Intensive Cavitation and Sonication**

(After 3 months of operation: 1000 watts, 20 kHz)

Possible applications of single-frequency, high intensity probe systems are:

1. Mixing and Homogenization of liquids
2. Cleaning and surface processing applications (deep holes cleaning)
3. Degassing (or gases injection if sonotrode is differently mounted)
4. Nano particles technologies
5. Accelerated diffusion, filtration
6. Extractions
7. Sonochemistry
8. Accelerated Polymerization (and in some cases de-polymerization)
9. Waste waters treatment
10. Liquids atomizing
11. Surfaces plating, metallization, coating
12. Welding…

Single Probe (single-frequency) Ultrasonic Reactor

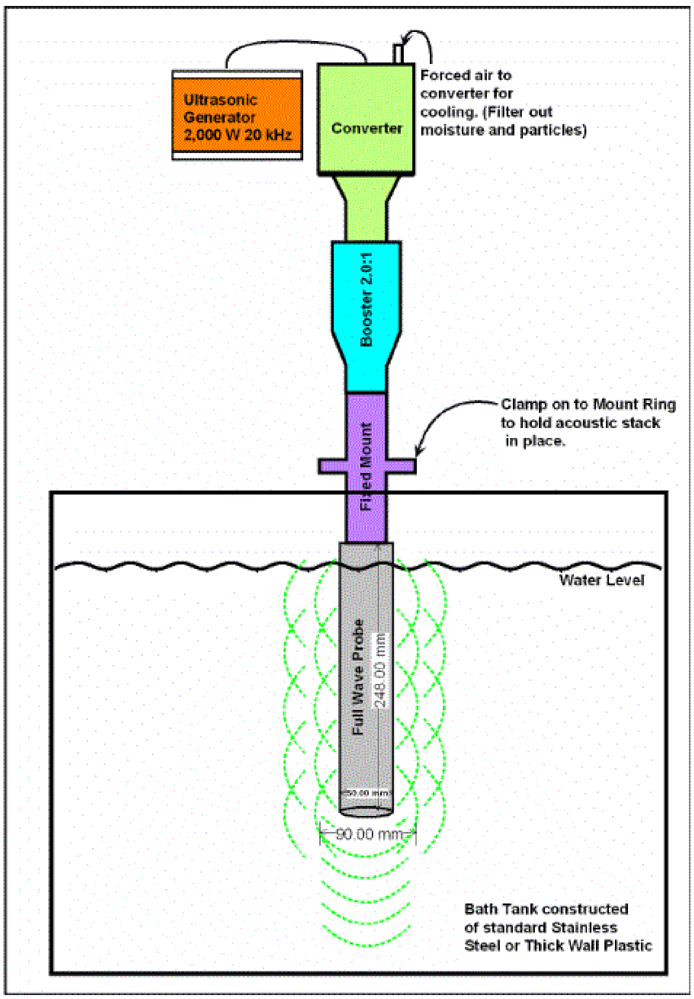


Nano-particles production

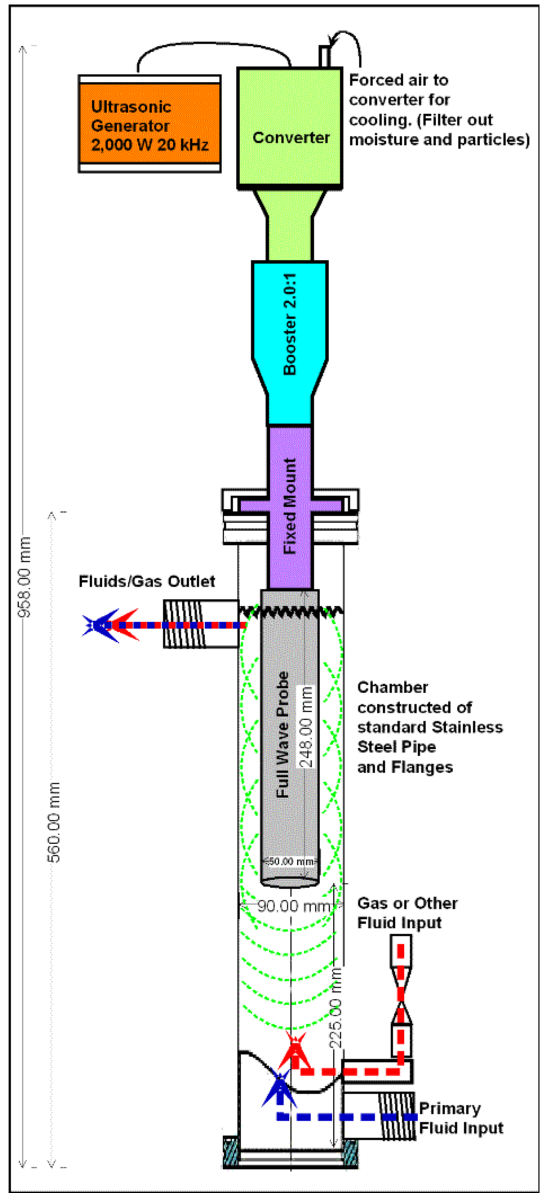
For creating nanoparticles it is necessary to apply 2 kind of ultrasonic reactors: First reactor is very high intensity piston or single-probe type, fixed frequency ultrasonic mixer (usually 20 kHz, type B, HSPD). Such reactor is making first mixing, homogenization and particles braking towards much smaller particles (micrometers sizes). Then, such liquid mixture should be treated inside of the second reactor (type A, HVPD) that is generating lot of cavitation, and cavitation is eventually generating nano particles.

High Power Fixed-Frequency Piston-Probe ULTRASONIC REACTORS

Ultrasonic Liquid Processing, Sonochemistry, and Extractions



Option A:
Ultrasonic Bath with Fixed Frequency Piston Probe



Option B:
Flow-Thru Chamber with Fixed Frequency Piston Probe

SONOREACTORS Group B: HSPD

Applications of Flow Through or Static Cylindrical Reactor Systems: For organic or inorganic material processing:

- **Disruption and Cell Lysing** - will break open biological tissues and cells to extract enzymes and DNA, **prepare vaccines**. This technology provides a method for **ultrasonically lysing cells and spores** in a liquid flowing continuously or intermittently through a cylindrical reactor.
- **Transdermal Drug Delivery** (no more needles).
- **Bioengineering and genetic research** (extracting cells' fluids).
- **Activation of seeds:** almost 100% successful germination and healthier plants.
- **Filtering**
- **Sterilization**
- **Extractions**
- **Food products treatment**
- **Sonochemistry**
- **Electroplating & Electrochemistry processes optimization**
- **Reaction Acceleration** - cavitation accelerates chemical and physical reactions.
- **Cracking in petrochemical technologies**
- **Fine Particle Dispersion** - e.g. **nanoparticles processing**
- **Liquid food processing.**
- **Homogenization** - making uniform mixtures of liquids or liquid suspensions.
- **Emulsification** - processing foods, pharmaceuticals, and cosmetics.
- **Dissolution** - dissolving solids in solvents.
- **Degassing** - removing gases from solutions without heat or vacuum.
- **Inline pipe cleaning**, removes scale or build/up without disassembly (also nuclear industry…).
- Cylindrical **360° internally radiating** chamber.
- Internal or external **liquid atomizing or powder making** sonotrode.
- **Powders production in liquid phase** by precipitation (minimizing the particle sizes including surface treatment).
- **Quenching optimization**: uniform and immediate vapor and bubbles layer removal.

3-Clamp-On Reactor

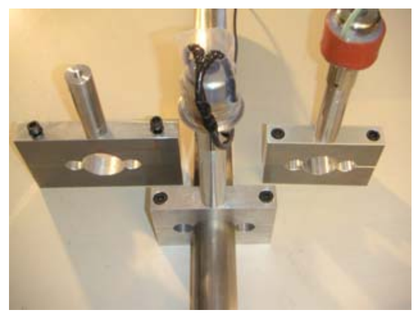
Clamp-On Ceramic tube for Liquid Metals Treatment

A new method of continuous or intermittent inline ultrasonic processing for any liquid material or food that requires ultrasonic treatment. Single or multiple transducers are connected to custom clamps designed to fit nearly any size tube or pipe constructed of aluminum, stainless steel, or titanium. Our unique MMM technology offers a highly efficient transfer of ultrasonic energy to the metal pipe or tube. The pipe / tube becomes a radiating element allowing internal or external material treatment.

These assemblies will turn nearly any suitable pipe or tube into a highly efficient ultrasonic reactor. Longer pipe sections may be driven with multiple clamps powered by one or more MMM generators.

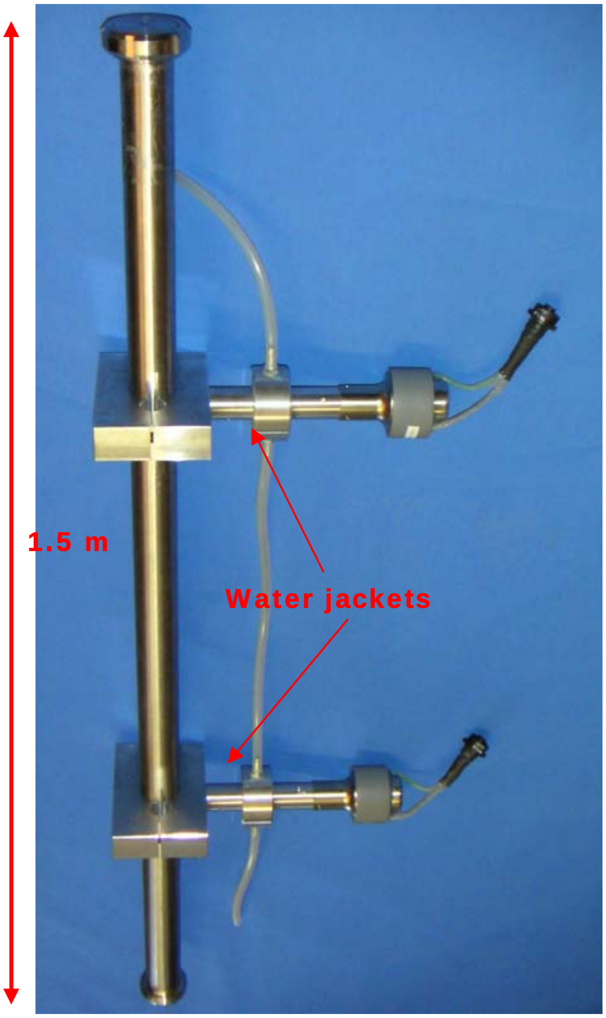
Key Features:

- MMM technology will drive most **any pipe thickness** (e.g. 1mm to 30mm) at high power.
- May be designed for most **any diameter** pipe or tube (e.g. 25mm to 150 mm).
- Flexible system designs for **any length** of pipe.
- **Flow through design** allows easy adaptation to lab and industrial systems.
- Long wave guides options allow for very **high temperature applications**.
- Wide ranging power options offer:
  - Low power non-cavitation treatment
  - High power strong cavitation treatment
  - 0 to 100% power control
  - Advanced modulation techniques to modify and improve acoustic effects.
  - Standard systems from 300 watts to 2,000 watts. Custom systems to 120,000 watts.
- Simplified tube design without seams or joints allows **easy internal cleaning and sterilization**.



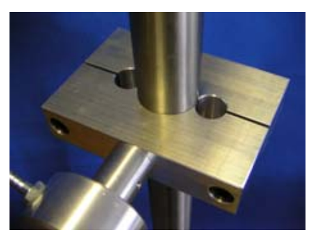
Multi-parameters PC-controlled (fully overload-protected)

Solving problems with air bubbles in liquid food products using MMM, Clamp-On Ultrasonic technology



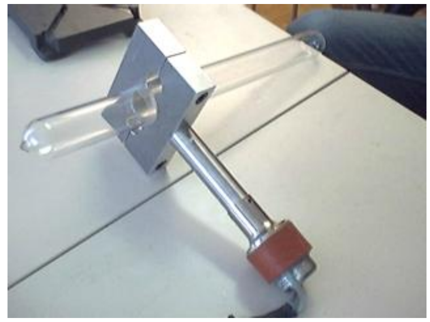
Fruit and vegetable processing plants.
Degassing products that have small air bubbles in the mixture.
Milk degassing, blending and homogenizing.
Wines degassing, homogenizing and aging.
Heat exchange optimizing by removing gas bubbles.
Filters de-blinding.

Pipes cleaning in NPP
(Nuclear Power Plants)
Removing builds-up
High temperatures...
High radioactivity zones
Any size, length, shape



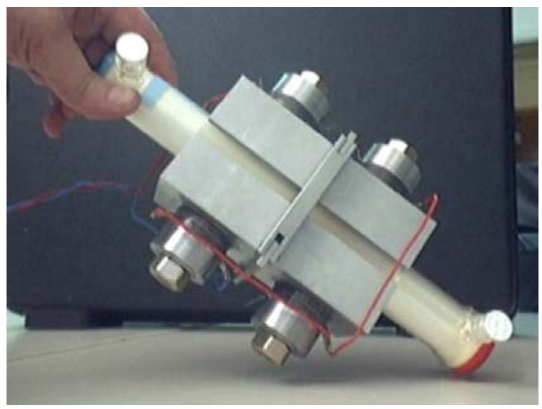
Special Clamp Systems

- Glass, Quartz, or Plastic Tube Chambers:
    - Using special interface materials and clamp designs we can apply ultrasonic energy directly to a glass tube for treatment of liquid materials or chemicals.
    - Alternatively glass tubes may be submersed into water filled stainless steel pipe system for indirect 360° ultrasonic treatment.



Custom System Designs and Consulting:

- MPI provides consulting services and custom reactor designs.
- High amplitude probe flow cells
- Unrestricted flow-through cylindrical systems



Flow-Trough Cylindrical Reactors; -Important Comments:

This system uses a new ultrasonic generator technology that allows us to make reactors from cylindrical pipes and tubes. As you will see the size can be customized for any length and diameter of reactor. The amount of power delivered to such systems is a function of the mechanical load (pipe size and liquid contained). For example the cylindrical reactor shown on the application note (50 mm diameter x 600 mm length) is driven by three clamp/transducers and we recommend a 600 watt limit. We could deliver a 1200 watt generator for this system but over-driving with too much power will lead to mechanical damage to the reactor and excessive heating to the mechanical components. A larger reactor would of course take more power. The key benefit to this cylindrical reactor system is the possibility to make batch or inline flow-through production. The system also offers a unique capability for applications requiring use of glass or quartz tubes for a controlled sterile reaction vessel in lab testing or batch production. By closing one end of the cylindrical reactor it may be mounted in a vertical position and filled with water. A glass tube may then be inserted through the top opening. In this way ultrasonic power is delivered 360° around and to the entire length of the tube. This technique will give a more homogeneous application of ultrasonic power to the liquid and improve reaction time.

We can also offer a high power ultrasonic probe system (sonicator) for conventional ultrasonic mixing, homogenizing, and cell disruption. See our web-server page with products overview: http://mastersonic.com/documents/mmm_products_overview.pdf for this alternative system. This is a conventional system and has limitations. In general terms a brief comparison of the two systems can be summarized as follows:

Cylindrical Reactor - this system offers more even homogeneous application of ultrasonic energy, a simple in-line flow-through option, high temperature possibilities, high pressure possibilities, batch option, a sterile glass or quartz tube option, and finer control of applied power that can give good acoustic energy with little or no cavitation or at high power will give both strong acoustic energy and high cavitation. Due to the extra machining and in one example three converters the cost is much higher for this system but it offers new possibilities for bio research and production.

Probe System – this equipment gives very high focused energy to the probe tip that allows strong acoustic streaming and mixing with strong cavitation on an area around the probe tip. Simple system but little control of cross-contamination, limited control of power distribution and only moderate control of power output.

Which is best for you depends on what you wish to achieve. If you wish to make cell lysing then the cylindrical reactor is offering the most flexibility and control.

Clamp-On ultrasonic reactor -is the MMM resonating stainless steel tube (open on both ends, which can also be closed on both ends). Clients of MPI are using such tubular reactors for processing non-aggressive, "ordinary industrial liquids" directly (inside of the tube). In case/s of ultrasonic processing of aggressive liquids, and/or biologically or pharmaceutically sensitive liquids, the best is to create coaxial tubular reactor-system for indirect ultrasonic treatment, as for example: to fill water in the 3-Clamp-On tube, and pass another glass or plastic tube inside, coaxially. Water would serve as an acoustic coupling medium for passing ultrasonic vibrations to the internal tube with sensitive, aggressive or biological material. External water shell could be connected to a thermo-regulating system in order to keep constant operating temperature during sonication. Usually, the client would need to solve design details regarding watertight fixation around both stainless-tube ends in order to keep water inside of the tube and to have easy passage of internal tube which will be sonicated. The liquid which should be ultrasonically treated (internal plastic tube content) can have certain flow rate in order to process large quantities, or static in case of processing laboratory samples.

Water coupling layer could have content of certain sterilizing chemistry in order to maintain the perfectly clean and safe environment.

Internal tube should be made of some acoustically transparent material (to pass maximum of ultrasonic energy to the internal liquid content). The best materials regarding acoustic transparency are different plastic foils (high density PVC, PVDF, PTFE…). MPI clients are also using Pyrex glass tubes (but glass is not as acoustically-transparent as some plastic foils).

Clamp-On reactor can be delivered with end flanges or in any other similar configuration (as you can see on the MPI web sites).

During 10 minutes or shorter it would be possible to sonicate easily much more than 20 liters (just by making a closed liquid flow). If converters (and all other metal parts) are not unusually heating during certain liquid processing, this can also be a continuous operating regime. If you notice some increased

heating (between 20°C and 50°C, for instance), the best would be to reduce the power or to apply much more efficient cooling on the transducers.

Most of sonochemical reactions are happening within first 10 minutes of processing, and 90% of them in less than 3 minutes of processing. It is not necessary to insist on long time liquid processing, since this will mostly increase the liquid temperature... Also after reaching certain ultrasonic power level, by increasing of ultrasonic power you will only increase mechanical failure risks, losses, resulting in reactor heating... Expecting miraculous and too ambitious results is also not recommendable strategy, since MMM generator and transducers could be overloaded without really producing expected ultrasonic effects. The problem is related to ultrasonic-power liquid loading (creating of gas layer between ultrasonic reactor tube and liquid, which is attenuating ultrasonic energy transfer). Also mobility of liquid molecules is increasing until certain temperature and than, if temperature is still increasing, mobility of molecules starts decreasing, meaning that you should always find and keep optimal operating temperature (to have highest level of ultrasonic processing). Please see the explanations here:

http://mastersonic.com/documents/mmm_basics/general_info/summary_mmm/understanding%20mmm_selection%20&%20loading.pdf

Polluted Liquids Decontamination

For treating different polluted fluids (for instance water with sand, mixed with oil, slurry, other chemical pollutants, poisons etc.) the first step is to make certain level of fluid homogenization (if shows necessary), usually by applying mechanical rotating mixers. If this is not enough, after mechanical mixing we can apply very high intensity, single-probe sonicator, for getting much more homogeneous liquid. For proper and efficient ultrasonic processing, content of solids in liquid should not be higher than 15%. Than, such homogenized fluid should pass trough a tubular ultrasonic reactor for last phase of ultrasonic processing.

For neutralizing poisons, microbiological items and other contaminants it is necessary to involve an additional chemistry in the same process. For instance, by mixing polluted liquid (which is already homogenized, mechanically and ultrasonically, in the initial phase) with ozone and hydrogen peroxide, and applying ultrasonic agitation in the same time, such treatment (if properly made) is eliminating, neutralizing or oxidizing all pollutants and killing all micro species inside. By applying ultrasonic agitation, mixture of water, ozone and hydrogen-peroxide is becoming the super oxidant and performing total decontamination.

MPI is producing very efficient apparatus for inline (immediate) ultrasonic injection of ozone in water, which is injecting much more ozone in water than any other presently known method of water ozonation. With ultrasonic ozone injection it is possible to get super or over-saturated ozone levels in water.

Later on, polluted liquid, well homogenized with ozone and hydrogen peroxide, should pass trough a tubular Clamp-on ultrasonic reactor to enable oxidants to react and finalize the process. What is going out (as a final product) is well decontaminated liquid with clean (and neutral) solid content.

Other strategically important applications

Nano-particles production, creating vaccines, nuclear decontamination, biodiesel production, hydrogen production, producing chemical and biological agents, recycling precious and rare metals, accelerated electrochemistry, difficult extractions...

High Power Converters for single probe systems

BOOSTERS AND SONOTRODES

Krell Engineering : Industrial Resonators

Industrial resonators deliver high energy density in order to substantially affect the materials with which they are in contact. Common uses include welding of plastics and nonferrous metals, cleaning, abrasive machining of hard materials, cutting, enhancement of chemical reactions (Sonochemistry), liquid processing, defoaming, and atomization. Usual frequencies are between 15 kHz and 40 kHz, although frequencies can range as low as 10 kHz and as high as 100 kHz.

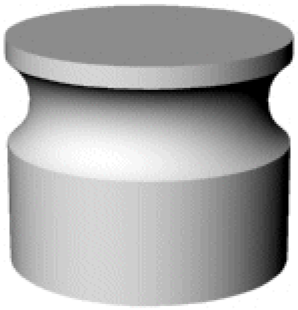
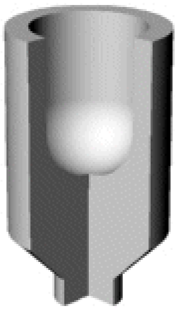
Krell Engineering can design many variations of the resonators shown below. (Note: not all resonators are shown to the same scale.)

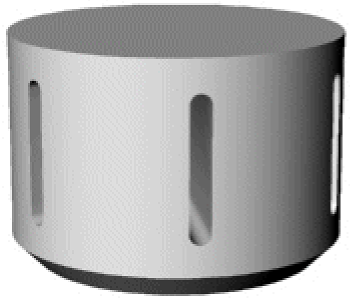
A typical industrial ultrasonic stack consists of a horn, booster, and transducer (converter).

<table>
<tr>
<td rowspan="3">
Ultrasonic stack</td>
<td>The horn contacts the load and delivers power to the load. The horn's shape depends on the shape of the load and the required gain. Horns are typically made of titanium, aluminum, and steel. Horns are also called sonotrodes. Small diameter horns are sometimes called probes.</td>
</tr>
<tr>
<td>The booster adjusts the vibrational output from the transducer and transfers the ultrasonic energy to the horn. The booster also generally provides a method for mounting the ultrasonic stack to a support structure.</td>
</tr>
<tr>
<td>The transducer (converter) converts electricity into high frequency mechanical vibration. The active elements are usually piezoelectric ceramics although magnetostrictive materials are also used. Transducers are also called converters.</td>
</tr>
</table>

Horns

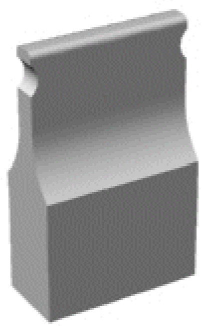
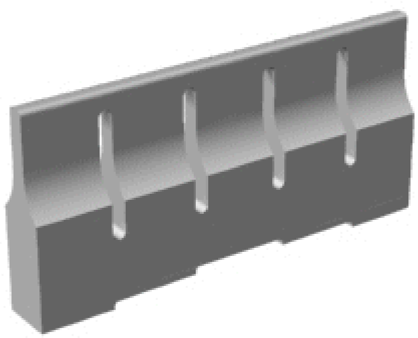
Cylindrical horns

Type	Typical shape	Description
Simple		Solid horns with a simple geometry (stepped, exponential, or catenoidal). May have a replaceable tip. Can have high gain. Used for plastic spot welding and inserting and liquid processing.
Spool		Solid horn with a spool shape and large diameter (up to 1/2 wavelength). Has good amplitude uniformity across the face (generally >= 90%) and relatively low stress. Face must be flat or have only minor relief. Low gain. Used for plastic welding of circular parts and liquid processing.
Bell	 3/4 section	Unslotted horn with a cavity that extends to the node. Maximum diameter is generally <= 0.4 * wavelength. Moderate gain. May have considerable radial face amplitude. Used for plastic welding of circular parts and liquid processing.

Slotted		Large diameter horn with radial or cross-slots. Diameter usually >= 0.4 * wavelength. May have a face cavity. Low gain. Used for plastic welding of circular parts.

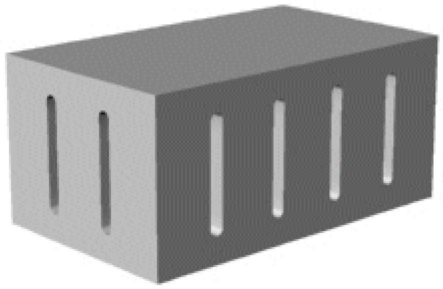
Bar horns

A bar horn has a rectangular output face and is either unslotted or has slots in one direction only. The horn thickness is generally <= 0.35 * wavelength.

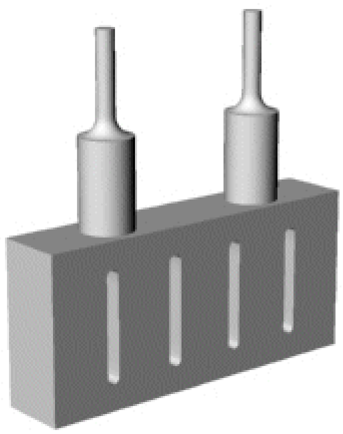
Type	Typical shape	Description
Unslotted		Horn width is generally <= 0.4 * wavelength. Moderate gain. Used for plunge and scan welding and for some liquid processing applications (e.g., ultrasonic soldering).
Slotted		Horn width is generally >= 0.4 * wavelength. Special design techniques give optimum face amplitude uniformity. Moderate gain. Used for plunge and scan welding.

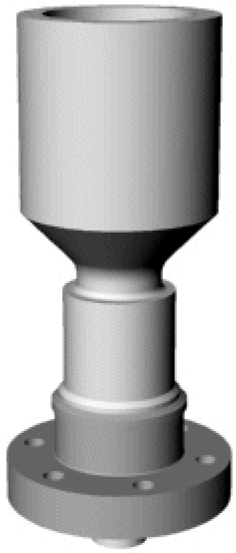
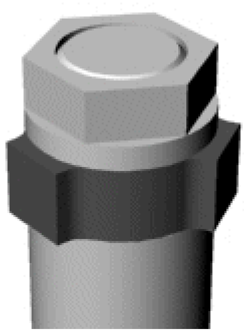
Block horns

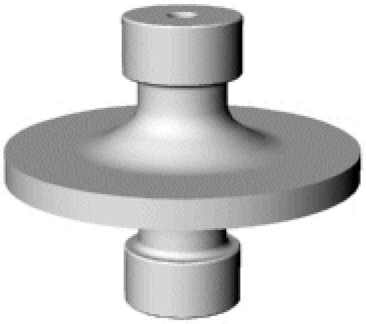
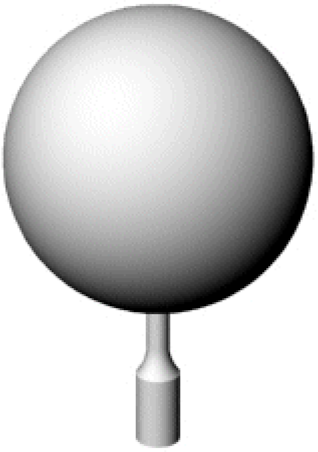
A block horn has a rectangular output face and has slots in two perpendicular directions.

Type	Typical shape	Description
Block		Width and thickness are generally >= 0.4 * wavelength. Low gain. Used for plastic welding of large, flat, rectangular parts.

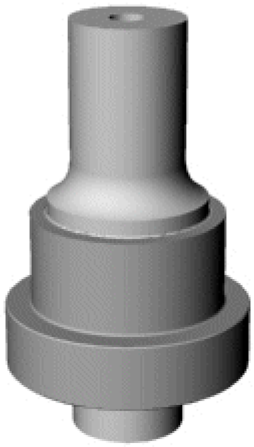
Special horns

Composite		High gain tip horns are driven by a common mother horn. Used for spot welding of plastics and for liquid processing.
Contoured		A horn that has a complex, often irregular shape machined into its face. Used for plastic welding.

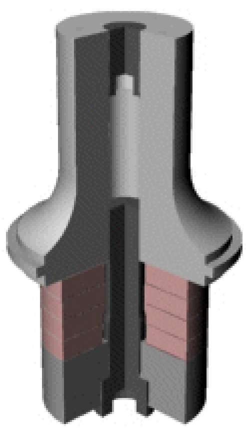
Full-wave bell		This bell horn has an integral booster and is designed for liquid processing. The rigid mount flange provides a hermetic seal against the wall of the pressure vessel.
Metal welding	  Tip and nut details	Metal welding horns have a replaceable annular tip (typically tool steel) that is secured by a nut. The tip has multiple welding lobes.

Radial disk		The resonator is driven axially but the disk vibrates radially. Designed for use with a rigid mount booster. Used for rotary seam welding of plastics.
Flexure disk		The flexure disk is driven axially at its center but vibrates in bending with circular nodes. The amplitude decreases from the center to the edge. Compared to conventional horns, the disk has a large surface area with low mass. With the proper contour, the disk can produce a very narrow, intense acoustic beam. Used primarily for airborne ultrasound (drying, defoaming, agglomeration, etc.).
Radial sphere		The resonator is driven axially but the sphere vibrates with a uniform radial motion. The sphere's diameter is approximately twice the axial half-wavelength (about 250 mm at 20 kHz). Used for atomization and cavitation.

Boosters

Type	Typical shape	Description
O-ring		The mounting ring is isolated from the booster body by O-rings.
Rigid mount		Because the rigid mount booster is constructed only of metal (no compliant elastomers), it has excellent axial and lateral stiffness. For additional stiffness a second mounting ring can be incorporated into a full-wave design. Used with heavy loads or where precise positioning is required and for rotating applications (e.g., seam welding; see radial disk). Also used where a hermetic seal at the mounting ring is required (e.g., for mounting through the wall of a pressure vessel); for an example, see the full-wave bell horn.

Transducers (converters)

Type	Typical shape	Description
Transducer	 3/4 section	Typical transducer with four piezoelectric ceramics, center-bolt design. The housing and electrode leads are not shown.

Also see resonator design by finite element analysis.