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Precision Cleaning Systems

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Designing an Ultrasonic cleaning System

Equipment

Console Construction
The construction of the console is the first step in determining the final shape of your cleaning system. The basic materials and form of construction will determine the final cleaning results.
Materials: The basic material the console is constructed of is predicated on the end use of the console. If it is to be used in an industrial application a simple tubular steel frame and epoxy paint are sufficient. Usually a stainless steel top of 304 stainless is used for the deck and containment areas. This type of construction is sufficient for class 10,000 clean room conditions.

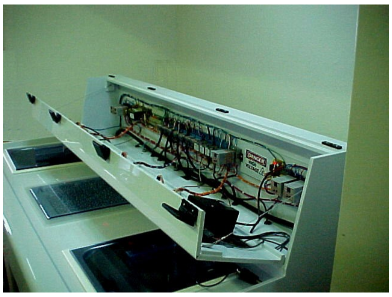
For class 1000 and class 100 clean room conditions a different method of construction is used. The console frame may be steel reinforced but the console should be fabricated out of PVC or other plastic or stainless steel that is a low particulate shedding material. Stainless steel and aluminum are also acceptable. Care should be taken to avoid ledges and steps where particles can build up. The overall design should be smooth and without sharp corners. The material surface should be easily cleaned.

In class 10 clean room conditions the console should be constructed of stainless steel [electro-polished] or anodized aluminum with built in positive pressure filtration systems within the cleaning area to prevent introduction of contaminants from the production floor.

Modularity:
Tanks
Today most ultrasonics are extremely reliable and long-lived. However there may be times when repairs are required on the tank or the electronics. Tanks and generators should be designed in a modular fashion so they may be easily removed from the system without resorting to cutting them out with a welding torch. Tanks and generators are designed removable simply by disconnecting the plumbing connections and unplugging the power cords to the heat and generators. The tanks should be removable from the top of the console. Another method is to design the console in individual modules such as detergent clean, spray rinse etc. this allows flexibility in meeting thoughput expansion needs. Modules can be added at a later date to increase production. This method is more expensive to start but in the long run is extremely flexible and adaptable for different cleaning requirements.

Below Deck Components
Modules such as filters, valves, point of use DI heaters that are located below deck in an ultrasonic console should be easily reached via front and rear removable panels or placed outside the unit.

Controls:
Controls and electronics should be located where they are easy to use. Either located in a separate electrical bay at the rear of the working deck or on the front panel below the working deck of the console. [for ultra clean systems a separate control panel is located on the outside of the machine. Care should be used in designing the layout of the control electronics. DIN rails with snap in components are a good choice. There should be an emergency stop button located in a prominent position where it is easily reachable by the operator. Controls should be large enough to work while wearing gloves and be capable of being seen by a person wearing restrictive clean room garb. The electrical bay should be locked with a key lock to prevent unauthorized access. Fuse or breaker panels should conform to good electrical standards and be located in an area not readily accessible to the operator.



Space:
In selecting are area for the console keep in mind the following considerations;
Working room: Provide enough room for working on the console and do not block the panel access. In ultra clean systems there should be access from the rear of the unit for most maintenance tasks. This avoids contaminating the working area of the unit.
Water supply: Try to avoid long runs for your water and drain connections

Power supply: Make sure that your power circuits are adequate for the Amps required by the system. Always connect a cleaning system to a ground fault circuit.

Ultrasonic Detergent Tanks
The ultrasonic detergent tanks are the primary means of removing the particulates from your parts. In a high end cleaning system they are designed to minimize the retention of particulates. A series of ultrasonic detergent tanks are used for high end cleaning. The lowest frequency tank is first, [it will remove the largest particles first.] then immersion in a spray rinse tank to flush off any remaining particles and soap. The next step is a cleaning in a higher frequency tank to remove smaller particles. Followed by another spray rinse, the finial step is the highest frequency tank to remove the smallest particles, again followed by a spray rinse. Note all tanks in a high end cleaning system should be coved and electro-polished. This will reduce the retention of particles within the tank.

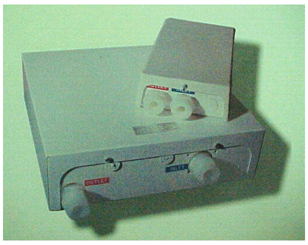
Spray Rinse Tanks
A spray rinse tank is usually made of polypropylene and is slightly larger that the ultrasonic tanks in the system. It has 2 or more spray bars with multiple nozzles in them. These can be adjusted to focus the spray of DI water on a load of parts. All wetted parts are designed to be compatible with DI water. A point of use DI water heater is used with a spray rinse tank to provide more effective rinsing.

Whenever a load of parts is removed from an ultrasonic cleaning tank the parts should be rinsed. Any loose particulates are removed and the majority of the detergent film is removed. The load of parts is now ready for the next stage of cleaning.

Dump Rinse Tank
A dump rinse tank is used much in the same way as a spray rinse tank with additional steps built in. A dump rinse has a 4 sided overflow and a large [2-3" dia] solenoid controlled drain plug in the bottom. It also has spray bars in the top of the tank to spray DI water on the parts. A Programmable Logic Control or PLC controls the tank sequence. The sequence of events is as follows;

A. Parts are placed in tank and the cycle start button is activated
B. The tank sprays water on the parts [with drain closed] until the tank overflows
C. At a preprogrammed time the drain opens and all the water is dumped from the tank immediately
D. The drain closes and the cycle is repeated as many times as programmed.

The Dump rinse is used in conjunction with the spray rinse and ultrasonic tanks in a high end cleaning system.



Point of use DI Water Heater System
A Point of use DI water heater uses ceramic heating elements to raise the temperature of DI water instantly. When the water is flowing the heater is activated by a flow switch and heats the water on demand. How hot it gets depends on the flow rate and the size of the DI point of use heater.

Ultrasonic Rinse Tank
An Ultrasonic rinse tank is a standard ultrasonic tank that has a continuous DI water inflow from a regulated source. The amount of DI water can be controlled from a valve either manually or PLC controlled . The DI water overflow a dam and caries any particulates out of the tank. The ultrasonics help keep the particulates from re depositing on the parts. The Frequency of the ultrasonic rinse tank is usually the highest in the cleaning system.

Determining Tank Size & Loading
The total surface area of the work to be cleaned, measured in square inches, should not be greater than the tank volume, measured in cubic inches., or about 230 square inches of cleaning area per gallon of tank capacity. The size of the tank should be such that when the work is loaded into the basket there is at least 1.5 inches on each side and top and at least 2 inches of liquid on the bottom free of parts.

Essential Steps in Cleaning Systems
Ideally and ultrasonic cleaning system should incorporate These essential steps in its design: three filtered ultrasonic cleaning cycles: interspersed by hot spray rinse cycles: three filtered hot countercurrent cascading ultrasonic rinses or a dump rinse and a single overflow ultrasonic rinse and a final cool spray rinse cycle. **(Figure # 5)**

Cleaning Tank Construction

The construction of the tank should be of 316L stainless steel and electro-polished for maximum shedding of contaminates. The side and bottom of the tank should be coved so that any particulate is easily flushed from the tank during cleaning. The ultrasonic tank should have sufficient heat to bring the operating temperature to 145 degrees F. An outer shell of 304 stainless steel provides insulation and protection for the heaters and the transducers. The tank should have at least one overflow to provide for re-circulation of the cleaning fluid through a filter system. This will provide a longer cleaning bath life and prevent the re depositing of particulate on the substrates.

Power Requirements

The average Watts per gallon of ultrasonics should be between 70 to 100 Watts. This is the average rating and can be adjusted dependent on the cleaning application. To calculate the power requirements use the following formula;
L x(in) W(in) x. (H –2") /231*100=Avg. Watts power. It is important to remember that ultrasonic companies can rate the watts of ultrasonic energy in two ways; Peak & Average. Peak watts are the start up requirement and Average Watts are the continuous operating wattage. Base all calculations on Average Watts.

Most companies will offer a power intensity control as an option. This control will lower the Wattage of the ultrasonics to any desired level on the top of the power curve. Below 50% there is not enough energy to activate the transducers. (ie: if you have a 100 watt avg. ultrasonic tank you will be able to adjust the power from 50 watts to 100 watts below 50 watts the transducers will not operate.)

The power intensity control is a good option where you will be cleaning delicate parts that may be subject to cavitation erosion or in a situation where the ultrasonics is being used in a plating operation or in other chemical processes.

Cleaning Process

Cleaning Solvents and Detergent Solutions
The importance of using clean solvents cannot be overemphasized. Exposure of substrates to dirty solvents could easily result in the deposition of soils that are more difficult to remove than the original contaminants. Solutions are the most single influential variable in ultrasonic cleaning. Properties of the specific fluid interact greatly, that is, some fluids operate quite well at ambient temperatures while others operate better at 140 to 160 degrees F. Some fluids require wetting agents [surfactants, detergents] to effectively transfer the ultrasonic energy into the solution. Water always requires a wetting agent and operates better at the higher temperatures. The choice of a detergent is dependent on the type of soils to be removed. This is one of the more important choices to make in any ultrasonic cleaning process.

The intensity with which cavitation takes place in a liquid medium varies greatly with the Colligative properties of that medium which include vapor pressure, surface tension, viscosity, and density as well as any other property that is related to the number of atoms, ions or molecules in the medium. In ultrasonic cleaning applications, the surface tension and the vapor pressure characteristics of the cleaning fluid play the most significant part in determining cavitation intensity and cleaning effectiveness. The energy required to form a cavitation bubble in a liquid is proportional to both surface tension and vapor pressure. The higher the surface tension of a liquid, the greater will be the energy that is required to produce a cavitation bubble and the greater will be the shock wave energy that is produced when the bubble collapses, In pure water whose surface tension is about 72 dynes/cm sq. , cavitation is produced only with great difficulty at ambient temperatures. It is easily produced when a surface-active agent is added to the liquid, reducing the surface tension to about 30dys/cm sq. When the vapor pressure of a liquid is low, as is the case with cold water, cavitation is difficult to produce but becomes less and less so as the temperature is increased. Every liquid has a characteristic temperature relationship in which cavitation exhibits maximum activity within a fairly narrow temperature range.

The flow characteristics or reological properties of the cleaning applications static fluid conditions are highly conducive to the formation of the standing wave pattern that characterize intense ultrasonic fields, and hence it would seem likely that cavitation intensity would be maximized under such conditions. Optimum performance is seldom achieved in static fields since continuous purification of the cleaning fluid either by overflow or by recycle filtration [filtering up to 50% of the tank volume per minute] is a prerequisite to effective cleaning. When the filtered liquid is properly introduced into the bath little or no cavitation is lost. In fact, improvement in overall surface impingement and homogeneity of cleaning can be attained with this method.

Aqueous Cleaning Solutions
Aqueous cleaners are designed to reduce the surface tension of the water and also to provide a chemical reaction with the type of soils it is designed to remove.

The chemicals in an aqueous cleaner may vary from soaps to surfactants to acids or chelating agents, builders, saponofiers, alkaline or combinations of the above. The cleaning solutions may be Ionic or non-Ionic dependent on the application.

De ionized water itself can be an effective cleaning agent in some circumstances. It is always preferable to use DI water as the major portion of the cleaning fluid as it is pure water and does not have minerals or other contaminants in it. It provides an excellent vehicle for the detergent and there no chance of depositing minerals on the substrate. This will aid in the rinsing of the detergent and will provide spot free drying.

Aqueous Cleaners/Soaps and Detergents
Aqueous cleaning works by the detergent actually bonding to the dirt (oil, grease, or particulate) and the mechanical action of the ultrasonics flushing this new compound into solution. This reaction of alkaline detergent with fatty acids is the saponification of dirt emulsifying in to solution.

A typical detergent is made up of several agents which work in combination to accomplish cleaning, Surfactants (wetting agents), reduce the surface tension of the dirt, allowing the cleaning agents to penetrate, Saponifies combine with the fatty acids and the flocculent to disburse the dirt into tiny particles, the mechanical action of the cleaning system flushes away the contaminants, one microscopic layer at a time.

Acidic type cleaners are typically used for removal of scale, rust and calcium deposits. Heavy acid cleaners are used for pickling parts as they are cleaned, since in a good ultrasonic system the parts are striped to the bare metal and all natural oxides are removed the part will oxidize rapidly after extraction unless protected either by pickling or by addition of rust inhibitors to the cleaning solution

Solvent Cleaners

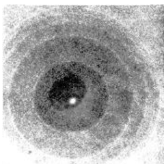
Solvent cleaners generally have a lower surface tension than water and are much denser. Solvents work on the basis of dissolving the contaminant. The extremely low surface tension of a solvent permits it to penetrate fine cracks or blind holes and dissolve oils organic and other contaminants. The solvents penetrating action as well as its chemical action remove Inorganic. Solvents can be blends, azeotropes or mixtures of both solvent and water. Solvents require special handling and design in selecting the correct ultrasonic system. In most cases since solvents are denser than water additional ultrasonic power is required to induce cavitation. Most solvents are specific in type of soil removed and care must be used in selecting the correct solvent.

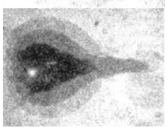
HFC solvents contain carbon, hydrogen and fluorine and are not ozone depleting. As a class hydrofluorocarbons remain the only option, which could be non-flammable because they contain fluorine.

Flammable solvents such as isopropyl, turpines and ethers are also usable in an ultrasonic system, however specific modifications must be made to any system that uses flammable solvents.

Wetting

Wetting should be accomplished not more than a few seconds following the introduction of the sonicated cleaning fluid, after which the particles will compete with the solvent or solution for adhesion to the substrate surface.





Ultrasonic cavitation promotes and accelerates both the displacements of particles from the substrate and the dispersion of these particles throughout the cleaning medium. Re deposition of the particles is restricted by the presence of solvent layers on the substrate surface and also by the fact that the displaced particles become solvated through absorption of solvent molecules or molecules of the detergent solution.

Cavitation shock waves can penetrate the solvent layers on the substrate and impinge the surface with particles, leading to the reattachment of these particles to the substrate. If this process continues, the number of particles benign displaced from the surface will eventually equal the number benign re deposited. At this point all cleaning action will cease. The only way to ensure complete removal of all contamination is to shift this equilibrium state in favor of the dispersed particles by means of continuous filtration, overflow or both.

Filtration

The amount of filtration that is required will depend on both the number of particulate present and the required degree of cleanliness. The chart illustrates the percentage of filterable particles that can theoretically be removed for a solution by continuous recycling through an absolute filter. Only 65% of the particles are removed in a single cycle and three complete cycles of the total solution volume are necessary to ensure better than 90% removal. In an ultrasonic bath the maximum flow rate that can be tolerated without loss of cavitation activity is equivalent to 50% of the liquid volume per minute, A six-minute cleaning cycle would be required to achieve 90% removal of dispersed contamination. A way to overcome this limitation is to use two consecutive, Identical tanks whose substrates have received two cleaning cycles of two minutes each. By this means, 98% cleaning can theoretically be achieved in only four minutes.

Cleaning Efficiency in % For ultrasonic tanks with and with out filtration						
Sets of Substrates	**Tank 1 No Filtration**	**Tank 1 Filtration**	**Tank 2 No Filtration**	**Tank 2 Filtration**	**Tank 3 No Filtration**	**Tank 3 Filtration**
1	78.46	89.30	92.26.	97.69	96.09	99.00
2	68.30	87.63	87.25	97.16	93.50	98.97
3	60.66	87.19	82.68	97.01	90.91	98.95
4	54.46	87.05	78.41	96.96	88.32	98.95
5	49.22	87.02	74.40	96.95	88.75	98.95
6	44.71	87.01	70.63	96.94	83.19	98.95
7	40.77	87.00	67.06	96.94	80.66	98.95
8	37.29	87.00	63.69	96.94	78.16	98.90

The need for filtration of cleaning solutions is even greater when the ultrasonic process is operated on a continuous basis to clean consecutive batches of substrates. Under such circumstances, lack of filtration would lead to rapid contamination of the tanks and to the deterioration of cleaning ability. The above chart summarizes the cleaning efficiencies that were obtained in filtered and unfiltered three tank cleaning systems. After only seven batches of substrates, the cleaning in the first unfiltered tank fell to 40%m while that in the third tank fell to 80% By contrast, cleaning in the first tank of the filtered system remained at almost 90% efficiency, while in the third tank, essentially complete cleaning was achieved. It is evident that in order for an ultrasonic cleaning system to function effectively on a continuous basis, it must have two essential elements: 1: a filtration system to remove soils as they are displaced from substrates: 2: at least two consecutive cleaning tanks in series.

Spray Rinse Tanks
Spray rinse tanks should be used after any immersion of the substrates in an ultrasonic detergent tank. The spray rinse tank will remove the majority of the detergent residue and prevent the ultrasonic rinse tank from packing up too quickly. The spray rinse will be more effective with the addition of heat. Hot DI water is a more effective cleaning agent than cold.

Ultrasonic Overflow Rinsing
Substrates must be thoroughly cleaned following each ultrasonic cycle so that all contaminated solvents or detergent solutions can be removed. In solvent systems, this is usually easiest to accomplish by means of spraying or vapor rinsing techniques. In aqueous detergent systems, spraying with pure DI water is recommended, but ultrasonic immersion rinsing is also essential to the absolute removal of particles and detergent residues. Detergent chemicals are freely soluble in water, they are not always completely removed by spraying alone, since molecular monolayers are readily absorbed and require ultrasonic cavitation forces in order to be displaced. It is recommended that substrates be sprayed with pure DI water following cleaning and then subjected to ultrasonic rinsing to remove traces of remaining detergent along with residual particulate matter. The tanks used in his process should be the same size as those of the preceding cleaning cycles, and the water should be as pure as the cleaning requirements demand. The water should, in addition, be heated to 120 to 140 deg. F in order to maximize cavitation activity.

The rate of flow in an ultrasonic rinse tank would depend on the amount of contamination that must be removed. In most cases a rate of 1- 4 gallons per minute, [with ultrasonic action] are sufficient. In some cases up to 50% of the volume of the tank per minute are required. The result of a high flow rate will reduce the visual action of the ultrasonics; however the cavitation effects are still effective in removing the particulates. There should be a manual or automatic valve to control the flow rate. It is also important to measure the effect of overflow rate on ultrasonic power. Different flow rates will affect the power and not in a linear fashion. The L-2001 ultrasonic probe will measure W/cm2 power in an ultrasonic tank with overflow

The addition of a resistivity probe in the last overflow rinse tank can be used to measure and control the level of clean the product sees. The DI water used in high end cleaning and rinsing is at a specific resistivity when it is introduced to the tank. As soon as product is immersed in the tank the resistivity of the water will drop. As the rinsing progresses, the resistivity of the water will increase. When it reaches a set point determined by observation, the parts will be clean. This is an effective and reasonably cost effective way of insuring the cleanliness of the parts.

Filtered Air Dry
Dry the parts in hot filtered air [HEPA type filter] this prevents re-deposition of particulates on the part. The dryer should be set for about a 150 to 170 degrees F depending on the configuration and load. The dryer should be designed so that the air passes through the dryer one time only and then is exhausted. This drastically decreases drying time and prevents any contamination of the part. Drying tanks should be electro-polished to prevent particle retention. Parts should then be stored in a clean atmosphere.

How may of the above steps you need depends on how clean you want your part. For high levels of cleanliness several ultrasonic clean at progressively higher frequencies are required. Several spray rinses and ultrasonic rinses are also required. It is important to remember that a good rinsing step will improve the results of any cleaning process.

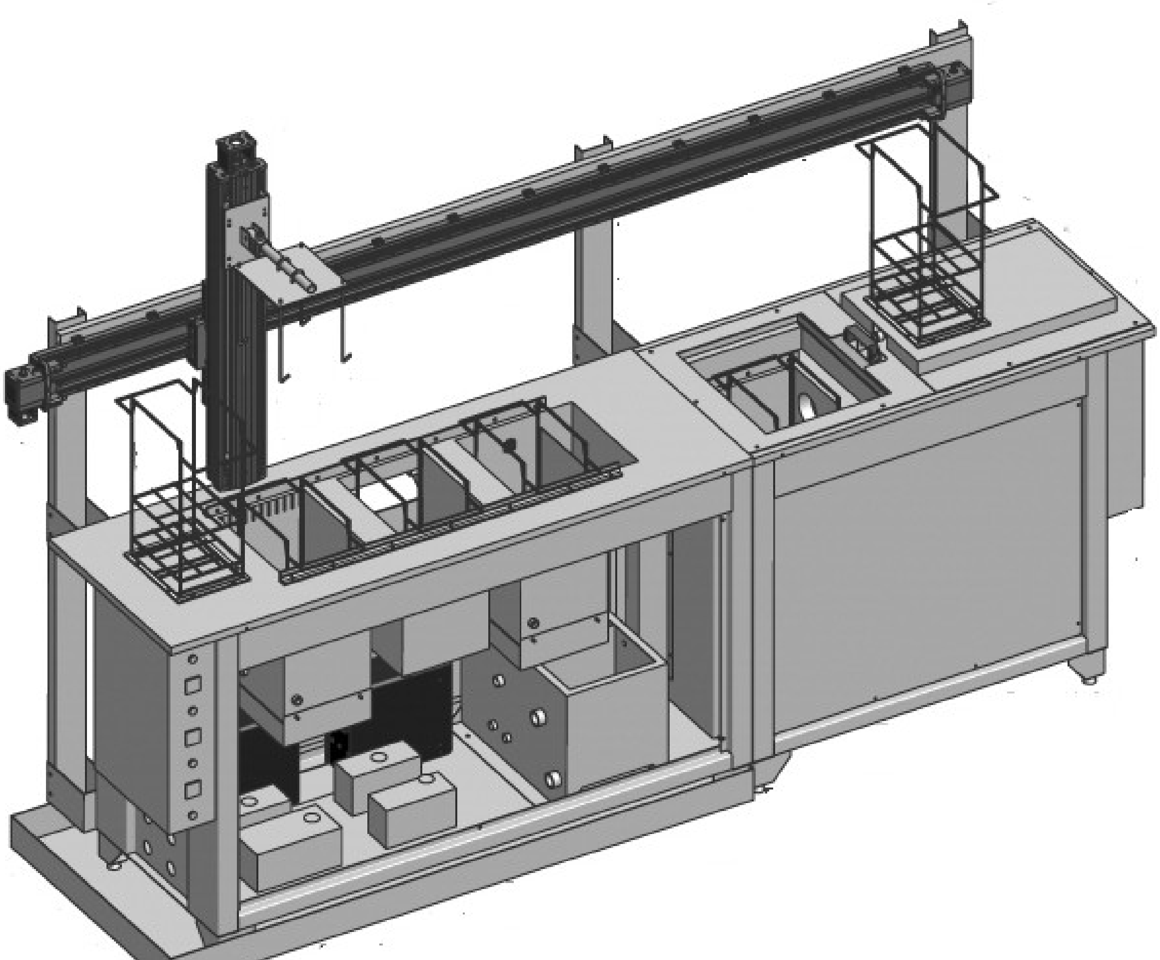
Work Baskets and Fixtures
Workbaskets or fixtures should have as little mass as possible and should be made of stainless steel or some other hard, sound transparent material, and should be of open construction so that there will be minimal interference with the free passage of both sound waves and cleaning fluids. Plastic work fixtures should be avoided whenever possible as they will deteriorate in ultrasonics and also absorb the energy. Work fixtures are an important part of the cleaning process and they should be the first item in the design process.

Work fixtures are most commonly designed with stainless steel and are sometimes coated with either Nylobond or Teflon to prevent scratching or other damage to the part.

We have developed several standard work fixtures, such as our beaker holder series that permits the cleaning and rinsing of small parts in any ultrasonic tank.

Automation:

The automation systems available for consoles consist of PLC controlled robots that can range from simple one load at a time processing robot to a multi load-processing unit. All automation today is plc controlled and can be programmed with multiple cleaning



programs. Pricing will depend on the complexity and cleanliness standards required.

General Cost of basic consoled

A four station Manual transfer console with Ultrasonic detergent clean, Spray rinse, ultrasonic overflow rinse and Hot air filtered dry station can range from 90- to 120 thousand dependent on the level of controls and the amount of options such as filter systems, DI water heaters, digital controls, size and power of the tank and other options.

Automation for a console dependent on the level of automation and program considerations can run from 35 thousand to 60 thousand

Basic rules for consoles

1 Always make sure the tank solution is clean and the bottom of the tank is free from any dirt or parts. Change the cleaning solution often.

2. Clean the inside of the tank with a mild detergent if it gets dirty. Wipe the outside case with a damp cloth and mild detergent

3. Never put any items directly on the bottom of a tank.

4. Never use a flammable solvent in an ultrasonic tank unless it is specifically designed for flammable solvents.

5. Do not place fingers or hands in an ultrasonic tank when it is running, it will cavitate the fluid in your joints and feel like you were cracking you knuckles 40,000 times a second. Prolonged exposure to ultrasonics will damage tissue.

6. Keep the cover on the tank when not in use.

7. Use only recommended chemicals in your tank.

Maintenance Schedule Ultra Clean Console

Daily:

1. Inspect and clean tank bottoms for any material or dirt.
2. Check containment deck area for any leaks
3. Replace cleaning fluid in detergent tank
4. Wipe down decks and console exterior with a rag and mild detergent solution

Weekly:

1. Check fittings under console deck for any leaks
2. Check filter flow on detergent tank Make sure flow is normal.
3. Drain all tanks and inspect drains for any debris.
4. Clean and wipe down interior of all tanks with Isopropyl alcohol.
5. Clean containment deck with a rag and mild detergent solution

Monthly:

1. Drain all tanks and fill with DI water, turn on ultrasonics for about 10 min. Drain tanks and refill. [This will help clean out drain plumbing and tank interior]
2. Replace Filter whether it needs it or not [Clean out interior of filter chamber with a mild detergent solution rinse with DI water and reassemble]
3. Check heaters by filling tank and setting the temperature to about 120 deg. F when the digital heater controller indicates it has reached temperature, Measure the liquid temperature with a thermometer if there is a difference, less than 5 degrees, set the offset on the temperature controller to compensate for the difference, if there is a lager discrepancy, the heaters may be damaged, consult factory.