CLEANING TECHNOLOGIES GROUP
9 North Main Street/PO Box 220/Jamestown, NY 14702-0220
Phone: 800.766.6606 Website: www.ctgclean.com

Understanding Ultrasonic Power Requirements Based on Tank Size and Other Factors

The amount of ultrasonic energy in cleaning tanks is often the key to the success of an aqueous or solvent cleaning process. As a result, Blackstone-NEY Ultrasonics is frequently asked to recommend appropriate ultrasonic power levels for tanks ranging from a few gallons up to several thousand gallons in volume.

Ultrasonic energy is usually specified in watts per gallon. Very simply, the total ultrasonic power delivered to the tank is divided by the number of gallons of liquid the tank contains to arrive at this number. It would be very simple if the appropriate power level for every application was, say, 20 watts per gallon. All the designer would have to do is calculate the volume of liquid in the tank in gallons and multiply by 20 to establish the required ultrasonic power. In practice it isn't that simple. Many factors must be considered in determining what amount of ultrasonic power will be appropriate for a specific application in a specific setting. The purpose of this paper is to help raise the awareness of variables that can affect ultrasonic power requirements based on the application and several other (not so obvious) factors.

System design includes determination of the appropriate ultrasonic power density but also the number of transducers to be used and their placement in the cleaning tank for maximum cleaning effectiveness.

Considerations for Ultrasonic Power Requirements

The Tank Volume and Shape

- Volume - Cubic measure or gallons
- Shape - Length, Width and Depth
- Internal features - Heaters, Agitators, Linings, Submersible Pumps, etc.
- Cleaning zone - Parts placement and racking

The Characteristics of the Parts Being Cleaned

- Size - Physical dimensions
- Weight - Weight/Density
- Number of parts per load or per unit of time - Parts per rack or basket, parts per hour
- Complexity of Cleaning - Holes, blind holes, internal surfaces, hems, etc.
- Ratio of part surface area to part size – A solid cube, for example, has less surface area per unit of volume than does a typical heat exchanger which is purposely designed to have a very large surface area relative to its mass to provide maximum heat transfer.

The Contaminant Being Removed

- Removal difficulty - Light oil vs. buffing compound, for example
- Thickness of buildup - Holes plugged solid vs. surface coat, for example
- Solubility of the contaminant and its ability to absorb ultrasound – a thin coating of light oil vs. a thick coating of heavy grease, for example.

Process Parameter Requirements

- Typical cleaning time required
- Temperature limitations (if any)
- Chemical and concentration

Determination of the Ultrasonic Power Required

Watts per gallon of cleaning solution is a good starting point for the determination of the total ultrasonic power required for a ultrasonic cleaning system. The volume of a tank in gallons can be calculated by first multiplying the length of the tank (in feet) by the width of the tank (in feet) by the depth of the tank (in feet). *Note - if inches are used, the number of cubic feet must be divided by 1,728 to convert the volume from cubic inches to cubic feet.* The volume of the tank in gallons of liquid is then found by multiplying the number of cubic feet by 7.5.

The number of watts per gallon required in a cleaning system diminishes as the size of the tank is increased. Small ultrasonic cleaners with a capacity of one or two pints may be powered with the equivalent of up to several hundred watts per gallon of ultrasonic power while a system with several thousand gallons of cleaning solution may be equally effective with as little as 5 watts per gallon.

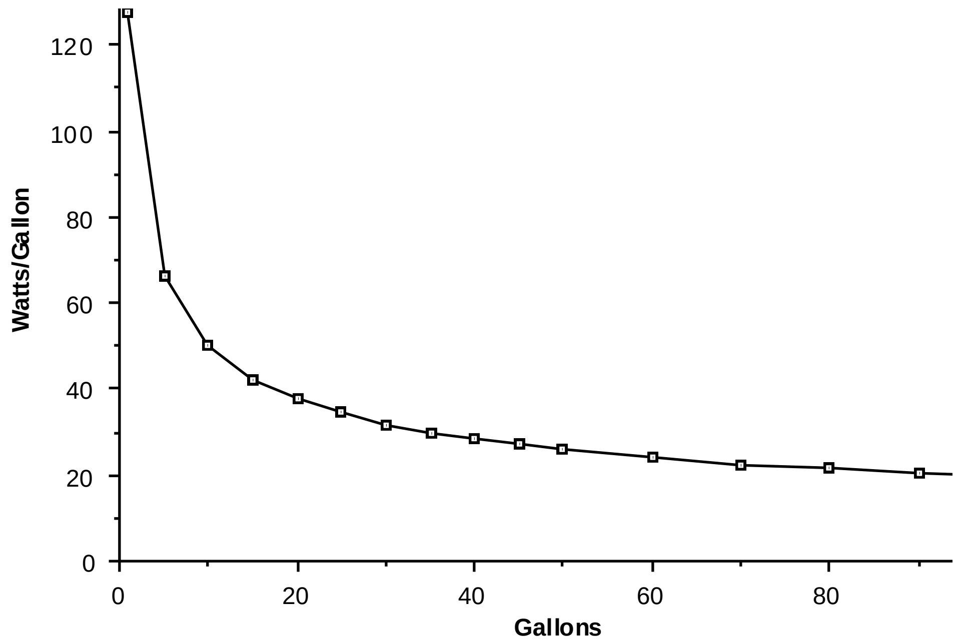
This phenomenon can be attributed to several factors.-

- As tank size is increased from that of a typical table-top laboratory unit to that of an industrial tank with a capacity of up to hundreds of gallons or more, less energy is absorbed into the tank walls. This is because that as the tank size increases, the walls present proportionately less surface area compared to overall tank volume than those in a smaller tank.

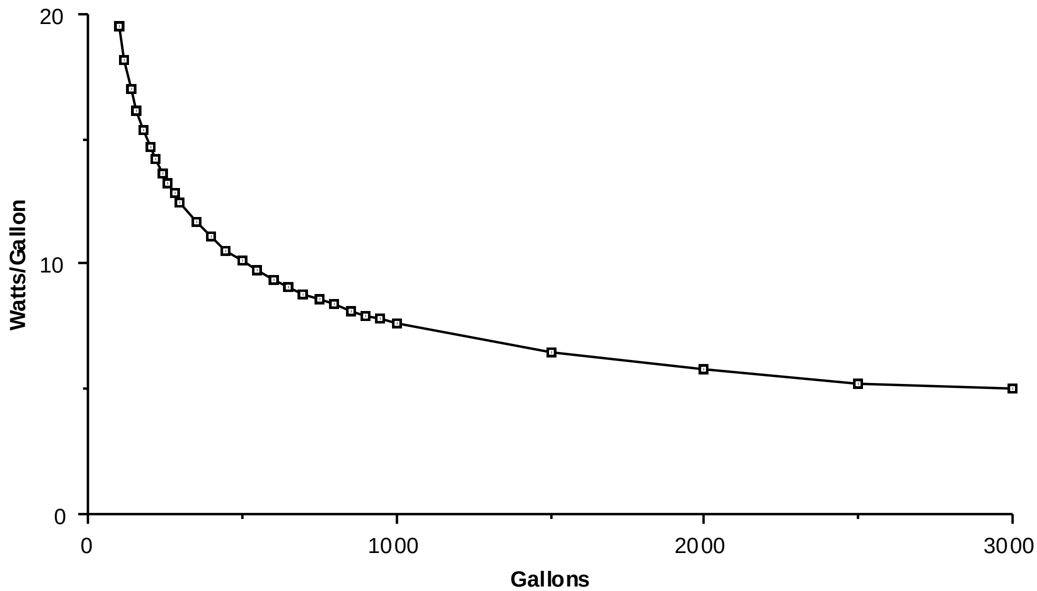
- In a large tank, ultrasonic energy travels unimpeded through the volume of liquid for greater distances and is reflected by large flat surfaces including the sides and bottom of the tank as well as the liquid/air interface at the top. In a small tank, frequent and inefficient reflection may lead to rapid dissipation of energy due to dampening effects and destructive interference. The longer the sound wave lasts, the more useful cavitation bubbles it creates.

- In small tanks, the loading factor (ratio of the volume or surface area of the parts being cleaned to the volume of the tank) is generally higher than in larger tanks. This necessitates higher watt density in smaller tanks. Similar loading factors are not achieved in typical large cleaning systems.

Taking the above into account, the following figure has been developed as a guideline for the number of watts per gallon required for tanks up to 100 gallons. The numbers are based on watts to the transducer(s) at an ultrasonic frequency of between 25 and 104 kHz. The chart assumes a cleaning operation requiring average ultrasonic power and average tank loading.



This curve was generated by taking a number of known successful installations and fitting a curve to the data. As tank capacity is extended further, the number of watts per gallon required continues to decrease at a diminishing rate.



Over 3000 gallons, a minimum of 5 watts per gallon is recommended.

Other Considerations

It was stated earlier that the measure of watts per gallon in a cleaning tank, although it is a good starting point for determining the ultrasonic power required, is not sufficient without considering a number of other factors.

Tank Geometry and Transducer Distribution -

The geometry of a cleaning tank can be such that even with the number of transducers required to give the recommended number of watts per gallon, the entire volume of the tank will not have uniform ultrasonic intensity. The ultrasonic transducers must be properly arranged to provide uniform ultrasonic density. One example might be a very narrow, long tank. Assume a tank one foot wide by one foot deep by 10 feet long. A sufficient number of transducers to provide the recommended power for the entire tank could easily be grouped in a 5 foot long section at one end of the tank. That, however, would leave the remaining 5 foot length of the tank underpowered or completely void of ultrasonic activity. Distributing the required number of transducers spaced over the entire length of the tank will provide an even distribution of ultrasonic energy.

Tank Design and Construction -

Tanks with complex interior surfaces or linings require added power. These features tend to absorb and scatter ultrasonic energy and prevent effective reflection of the available ultrasonic energy. In some instances, the addition of a special reflecting surface on the wall opposite the ultrasonic transducers is used to enhance the reflection of ultrasonic energy.

Tank Loading Factor -

The greater the load in a tank, the more power will be required. A system used to clean small parts such as kitchen utensils (forks, spatulas, etc.) hung 200 per rack will require less ultrasonic power than the same size system used to clean racks of 20 or 30 zinc die castings weighing 10 pounds each. The key factors here are the weight of the parts and the number being cleaned at one time. A heavily loaded tank may require up to several times the power of one with a lower loading factor.

The Parts Being Cleaned -

Nature of the parts being cleaned can have a great bearing on the amount of power required in a cleaning system. Simple parts with relatively little surface area are easiest to clean. As complexity grows, effective cleaning requires a higher ultrasonic intensity. Blind holes and internal cavities provide the first level of complexity and may require an increase in power over the level required for the simplest of parts. As the ratio of surface area to volume increases, cleaning becomes much more difficult. A typical heat exchanger including fins is representative of such a part configuration and may require up to several times more power than the simplest parts.

So What Does All This Mean?

1) Watts per gallon data developed by applications trials conducted in small, laboratory type ultrasonic cleaning tanks can not be used as a base for the design of a larger cleaning system to do the same task. Laboratory cleaning trials can be useful to define process (Time, Temperature, Chemistry, etc.) but do not accurately indicate the ultrasonic watts per gallon requirement in a larger tank.
2) The fact that a given ultrasonic cleaning system is effective in cleaning one part under a certain set of parameters does not necessarily indicate that it will be equally as effective in cleaning another (sometimes even apparently similar) part.
3) The notion that watts per gallon requirements are the same in both smaller and larger tanks has resulted in many projects being rejected based on the price of providing extremely high ultrasonic power density levels in large industrial cleaning tanks.

In Summary –

With due respect for the abilities of the process engineers who are experts at developing cleaning processes for their own individualized needs and their own industries, the design and specification of ultrasonic cleaning tanks should be done in collaboration with a reputable manufacturer of ultrasonic equipment. As difficult as it is to admit, the application of ultrasonic energy to cleaning processes is still more in the realm of Art than Science. Experience is the best teacher.