associates
tm

Precision Cleaning Systems

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Calibration and Certification procedures for Ultrasonic Tank Systems

Basic requirements for Certification of an ultrasonic Tank and process

The need for certification of ultrasonic cleaning systems is becoming more important in all critical cleaning fields. The most important question is how much power and at what frequency is it applied to the product being cleaned. Most ultrasonic manufactures rate the ultrasonic tanks on the output of the generator e.g. a 500 watt generator outputs a maximum of 500 watts to the transducers on an ultrasonic tank. This information has very little to do with the actual power generated within the cleaning liquid. Factors such as power loss due to electrical to mechanical conversion, liquid density, temperature, chemical detergents, tank construction, transducer placement, filtration, and work holders have significant effects on actual power within an ultrasonic tank. The design of the generator and the amount of controls such as power intensity, sweep frequency, full and half wave power also have an effect on power expression that cannot be determined by any instrument that does not measure power within the liquid. All ultrasonic generators simply have watt meters that measure only generator output and not even the efficiency of that signal. There is also the amount of reflected power in high frequency power transmission that can drastically affect the power within the tank. An unbalanced generator can waste a significant amount of power in reflected power, decreasing actual cleaning efficiency.

To certify a process or tank the following is necessary;

1. Calibrate the instruments used to a basic easily repeatable outside standard using well known scientific principles.
2. Measure power used in W/cm2 [the only recognized power measurement standard] at the wall, [power that the entire system draws, generator, fan, and other circuitry], Forward and reverse power [Power output of the generator and the reflected power back to the generator], and actual power in the tank liquid. [Power generated at frequency in the liquid].
3. The measurement of power in the liquid of the tank is dependent on several factors and can be measured in several conditions. A static or base measurement is when the tank has a known amount of pure DI water at a specific temperature, no re-circulation and no product in the tank. This gives a base line Power to work from.
4. Power measurements are then made with a product in the tank, with work holders, chemistry and any filtration or overflow re circulation of the liquid. The measurements can be made over the entire cleaning process or at intervals.
5. The requirements are as follows; [Empty tank with DI Water only]
   A. Wall Watts: The power of the entire system measured at the wall.
   B. Generator Output: The forward and reflected power of the generator and its output frequency.[Power forward/reverse]
   C. Tank Power: The power measured in areas of the tank, both static and in actual process
   D. Frequency: The actual frequency of the power applied to the liquid and all the secondary frequencies generated in the tank and their relative power.[spectrum analysis]
   E. The effect of power intensity control [is there an even increase in power as the control is advanced?] Sweep frequency control, [does power increase or decrease as the sweep rate of frequency is changed?] Full or half wave power setting, [mostly used for degassing and not production cleaning] [Power increase in stages using transient recorder]
   F. Repeat measurements of tank power with the work product and work holder in the tankwith the correct detergent mix and any other process steps such as filtration on a detergent tank and overflow rates on ultrasonic rinse tanks. Measure resistivity drop in the rinse tank.

Once these measurements are made and the records retained the cleaning system is “certified’. The cleaning system can then be checked on a periodic basis to make sure the system has not drifted or changed. Continuous monitoring of the system can be accomplished by using the WM-2008 watt meter to measure frequency, forward and reflected power output of the generator of up to 4 systems simultaneously. The L-2001 probe can then be used with the hand held meter for quick checks within the tank liquid.

The last element in a completely traceable system is a method of monitoring the actual cleaning effect of the process. In most cases this can be a accomplished by measuring the resistivity of the rinse tank. The last process in any cleaning application should be an overflow rinse in DI water in an ultrasonic tank at an elevated [170 kHz] frequency. The resistivity of the water into the tank is measured [note: if you start out with 18 Meg ohm water, by the time it is introduced into the rinse tank it will have dropped in resistivity] without product in the tank. A base number is established. The product is then introduced to the tank and rinsing under ultrasonics continues for a preset time. After the ultrasonics is finished another resistivity measurement is taken with the meter while the overflow is still active. When the resistivity reaches a high enough level the overflow is automatically turned off and the product is considered clean. [note: the resistivity will never reach as high as an empty tank reading but will increase significantly as the product is rinsed] The Resistivity Rinse Controller [R-100] will then shut off the overflow and the product is clean.

1. **Basic Transducer Check for a Langevin Transducer Ultrasonic Tank**
   Nano-farad measurement of a typical array of twelve transducers = 1.85 to 2.1 per transducer X12 = 22.2 to 25,2 Nano- farads total at 23/25C with a 24 liter water loaded tank. This can be measured with meters in the $50.00 range or the more sophisticated B&K, Exatech and Agilent meters. This is typical of a 500 watt 40/68/170 generator tank circuit. If measurements are outside of this range there is either a short or broken transducer in the ultrasonic tank.

2. **Checking power in an Ultrasonic Tank via Heat rise method** is straightforward. An LF or RF generator can be attached to an antenna or a tank. Heat rise, over a defined time, with a set amount of fluid with a fixed density is the determinative value in watts that directly and accurately correlates to power in your ultrasonic tank. As an example 500 wall watts to the generator will generally show between 380/420 generator watts and power measured in the tank itself will be 280-340 watts. All ultrasonic tank and generator systems will absorb watts in the generator circuit and in the conversion and transmission of the power to the fluid in the tank. The common fluid used is DI Water at 18 meg-ohms. [Note: if other fluids are used compensation must be used to obtain accurate measurements]
3. **The following are Typical results for determining watts in an ultrasonic tank**
   Note all test are made as follows
   A. **Standard ultrasonic tank with known volume of water.**
   B. **Water in Tank is 17-18 meg Ohm DI**
   C. **No recirculation in tank**
   D. **Generator set a full power [if power intensity control is present] [degas tank for 15 min before test]**

   The chart below shows Watts / Avg. of a 500 Watt Ultrasonic tank with power intensity control where the power has been decreased for each of the 3 measurements [power measured at supply point] and also shows the Watts / Avg. expressed in the tank at the reduced power levels.

Ambient T/C	Start T/C	End T/C	Mass /H2o	Elapsed Time	Watts Avg.	Wall Watts
22 C	25 C	27 C	24 Kg	600 sec [10 min]	335	500
22 C	25 C	26 C	24 Kg	600 Sec [10 min]	167.5	300
22 C	25 C	25.5 C	24 Kg	600 sec [10 min]	83.5	200

1cc = 1 g [@ 4deg C]
L x W x D of water in tank in centimeters / 1000 = Kg
1 cal raises 1 gram of water 1 deg C [specific heat of water]
1 cal = .00163 Watts
1 cal = 4.19 Joules
Note: All calculations reference pure [De Ionized] water

Watt Calculations:

1. Final temperature of tank liquid – Initial temperature of tank liquid = Temperature Rise [T_f]-[T_I]= [T_r]
2. Grams of water [G_w] x T_r = Calories of heat added to water by ultrasonic energy [C_{us}]
3. Work [Joules] is calculated by multiplying Calories by 4.19 Joules [1 calorie =4.19 Joules
4. Power is defined as work over time and is expressed in Watts. Joules /ultrasonic energy divided by time of test in seconds [T] = Watts of ultrasonic energy required to raise temperature of liquid =W/A

T_f-T_i=T_r xG_w=C_{us} x 4.19J_{us} = Tj_{us}/T = Watts of Ultrasonic Energy expended in working liquid over the test period.

Or more simply

Temperature rise x # of Calories required to raise water to new temperature x 4.19 divided by the time of the test in seconds = Watts / Avg. of the ultrasonics

Note: the method described above is valid for a static tank factors such as different solvents, detergent or overflows will dramatically affect the amount of ultrasonic power in a tank. The initial calibrations should be made using a standard setup. Future measurements of tank power then can be made using the L-2000 or the L-2001 with complete accuracy.

In addition to the base line certification of an ultrasonic tank in static mode [DI Water Only] Cleaning Process certification can be made by repeating the same test with product in the tank. Using the L-2001 probe with the product in the tank will yield a record of the tanks performance with product. The following factors will affect the amount of energy in the tank.

1. Temperature of the water: As the temperature increases the efficiency of power expression in the tank increases. This increase may be up to 50 to 60 Watts.

2. Addition of detergents: The addition of detergents to the water will change the viscosity of the cleaning solution. This will increase the amount of cavitation in the tank due to the lower energy requirements to form cavitation vacuoles.

3. Filtration of the tank liquid: When and how often the tank has its liquid pumped though a filter will cause a disturbance in the tank liquid and ingress air into the cleaning solution. The ultrasonics must then use some of the energy to 'degas' this solution before the full effect of the ultrasonics is again applied to the cleaning process. The speed of the liquid movement will also affect the ultrasonic action

4. Work holder Design: The design and material of the work holder has an enormous effect on cleaning. Some types of plastics will absorb ultrasonic energy faster than the water. [a simple test is to measure the temperature of the water and the temperature of the plastic, run the tank for a set time and re-measure the temperature difference between the plastic and the water. The plastic will temperature will be higher than the water showing it has absorbed more energy than the water.] Stainless steel open work holders are the best choice, plastic of any type should be avoided.

5. Product type and placement in the tank: Some product will tend to absorb energy more than others. Some product will reflect ultrasonic energy and dependent on placement will cause localized increases in watt density. Placement within the work holder ant placement in the tank will affect the ability of the ultrasonics to reach all areas of the product. At the edges of the ultrasonic tank power will drop due to the placement of the transducers and the stiffing of the diaphragm of the tank bottom.

6. Insertion and removal of product: The speed of insertion and withdrawal of the product can cause ingression of air to the cleaning fluid requiring more time for the tank to recover to full operating power. Care should be taken to determine the best insertion and pullout speeds for the product.

The use of the L-2001 ultrasonic probe will measure all of the above changes and allow the process engineer to optimize the cleaning process.

1 .TM associates standard Meter and Ultrasonic Probe: [L-2000]

A. Originally tm associates supplied meters with complete certification to National and International Units [i.e. volt / ampere / ohm / Hertz] this certification would only apply to these units.

B. The probe and meter measures dB/m a measure of relative sound pressure difference. The certification does not apply to dB/m [this is not a recognized international measurement] even though dB/ is widely recognized and used daily it is not an international recognized unit but as the sound pressure measurement developed by Bell Labs.[this measurement can be translated into "Watts" [Joules /Second] by setting the correct impedance of the meter for any given frequency. By combining the decibel unit with a suffix to create an absolute unit of electric power [i.e. it can be combined with milliwatt suffix to produce the 'dB/m] Zero dB/m is the power level corresponding to a power of one milliwatt and 1 dB/m is one decibel greater [about 1.259 m/W

C. tm associates probe assemblies are linearized and a ratio of 1: 1000 is used and therefore at an impedance and frequency dB/m is equivalent to watt per cm2. We correlate and calibrate the probe to an absolute recognize "known" and do this over a fixed period of time. The known is the joule and the fixed period of time is seconds and therefore the calibration is to "Watts" when measuring temperature change.

This is the same procedure used to calibrate tanks using the Temperature change method. It is the same method used for RF calibration and is directly traceable to Joule's original determinations.

The absolute measurement is temperature, and we measure the rise in temperature from the monitored power input from the wall [supply] and the generator circuit [ultrasonic power supply] while measuring the temperature range in the bath of DI water [24 liters]

We prequalify the temperature probes [2 K types, Stainless Steel attached to a B&K 715[NIST calibrated] meter using salt and Ice to verify true "0" degrees C. Then measure over a period of time on a high resolution oscilloscope [self calibrating signal, square wave] set to transient record in milliseconds measurement mode. We match the transient impedance based on frequency to the "heat change based on frequency to the "heat change" watts calculation and then match that to dB/m on the meter and oscilloscope.

We have therefore applied basic heat units and directly applied them to electronic amplitude data at frequency and set our numbers accordingly after five repetitions.

The same procedures are used on our L-2001 ultrasonic probe with self calibrating Oscilloscope software

Water Density Chart

Temp (°C)	**Density** pure water (g/cm^3)	**Density** pure water (kg/m^3)	**Density** tap water (g/cm^3)	**Density** pure water lb/cu.ft	**Specific Gravity** 4°C reference	**Specific Gravity** 60°F reference
0 (solid)	0.9150	915.0	-	-	0.915	-
0 (liquid)	0.9999	999.9	0.99987	62.42	0.999	1.002
4	1.0000	1000	0.99999	62.42	1.000	1.001
20	0.9982	998.2	0.99823	62.28	0.998	0.999
40	0.9922	992.2	0.99225	61.92	0.992	0.993
60	0.9832	983.2	0.98389	61.39	0.983	0.985
80	0.9718	971.8	0.97487	60.65	0.972	0.973
100 (gas)	0.0006				-	-

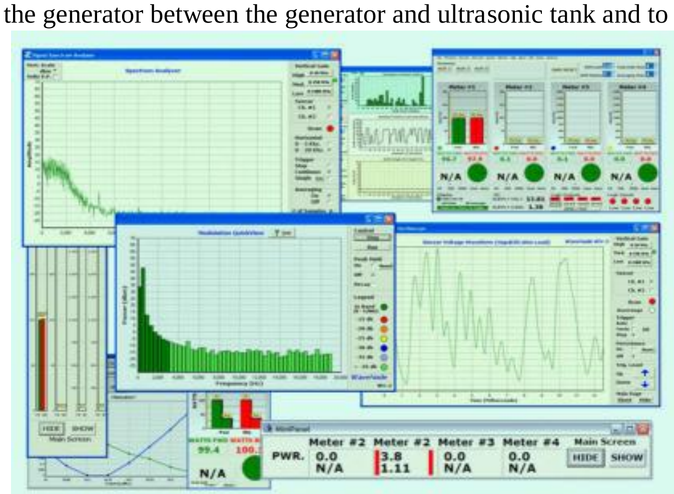
***** This is for average, clean drinking water. It will vary from area to area.

Ultrasonic / Mega Sonic Watt Meter
Model WM 2008

Digital Meter: Displays Peak, Average, Reflected Watts
Calibrate and certify generator output
Monitor up to 4 Generators performance
Automatically control over and under Power
BNC Connector for Oscilloscope Output
Voltage/Amp Ports for Scope display
30 to 15 M Hz Range with sensor
Up to 2000 Watts power
Remote Control Via software
Save Data for Analysis

The Watt Meter allows the calibration and certification of either ultrasonic or mega sonic generators to NIST standards. More companies are requiring calibration and certification of a production processes. The Watt Meter will provide this certification as well as preventing the loss of product though improper cleaning.

The Watt Meter and controller consist of a digital meter with up to four independent sensors for up to four generators. The Digital Watt Meter is connected to the computer via a USB cable. The computer software allows the complete monitoring of each generators output. Each sensor module is connected to the generator between the generator and ultrasonic tank and to the watt meter. Up to four sensors can be used with each watt meter. The sensor displays the Peak, Average, and Reflected power in Watts both on the digital meter and on your computer. The display is a bar graph with over power level control that can be set to alarm or shut down on over power indication. Each sensor has two ports for connection to a dual channel oscilloscope for monitoring phase and signal [volts & Amps]. The generators can be easily calibrated by using the watt meter alone or in combination with an oscilloscope.



An output port on the Watt Meter Sends a signal to a relay that can be used to either sound an alarm or turn off any generator that exhibits a high or low power output. The Watt Meter software has a number of screens that display the peak and average power output of the generator. The data can be saved and used with other programs such as a spread sheet or math CAD software. Calibration is achieved by reducing the reflected power in the generator output to its lowest level. Most generators have a tuning circuit for this operation.

The TM associates Watt meter offers a NIST Calibrated instrument that allows up to four different ultrasonic or mega sonic tanks to be calibrated and monitored at an exceedingly reasonable cost. A digital computer dual channel scope is available as an option.

L-2001-4 Ultrasonic Probe

- **Includes quartz probe [½" dia.]**
- **Includes interface Electronics for computer**
- **Includes Software for your computer**
- **Attaches to printer port**
- **Display Wave form on oscilloscope**
- **Display Frequency on Spectrogram**
- **Display Power Level in RMS, Peak to Peak & Db/watts per Gallon**
- **Record all Displays as Files**
- **Transient Recorder for tracking Process**
- **Lap Top computer compatible**
- **Map power levels in tank**
- **Check effect of baskets on work load**
- **Check transducers for operation**
- **Check effects of filtration on ultrasonic power**
- **Check power intensity levels between tanks**

Screen Shot of L-2001 Ultrasonic Probe Software

tm L-2001 Ultrasonic Power Meter.

The tm associates ultrasonic Probe consists of a sensor that is immersed in the liquid of the ultrasonic tank. The sensor senses the energy of the actual cavitation collapse generated by your ultrasonic tank. This energy is translated into a voltage that changes and fluctuates with the amount of energy generated. The voltage is then amplified and displayed a portable computer screen with our L 2001 probe system software. The Model 2001 Ultrasonic probe consist of a sensitive Probe, and an interface box that plugs into the parallel printer port of any computer including a portable or lap top type and the software to display the readings from the probe. It is completely self-powered and no batteries are required.

The L-2001 Software displays the following Information:

A. Wave form; The ultrasonic wave form is displayed on an on screen oscilloscope
B. Frequency; The frequency [Major and secondary] are displayed along with relative power on the Spectrogram screen. A set of cursors may be placed on the screen and a small box will show the relative frequency and strength of that frequency.
C. Power; The voltage meter screen has three windows that will show the RMS of the ultrasonic power, The peak to peak power, and the power expressed in dB/m Watts. All three of the readings are displayed at the same time.
D. Transient Recorder; The transient recorder will allow you to make a continuous record of the power in the tank over a long period of time.
E. The oscilloscope, spectrogram, and power meter readings may be saved as files and recalled and played for later analysis.
F. You may display the oscilloscope, spectrogram and voltage meter all at the same time. The transient recorder operates separately.
G. Information on power levels may be imported to a spreadsheet for graphic analysis.
H. Screen shots may be saved as Jpeg files and all files and screen shots can be annotated with on screen comments.
I. All data files may be recalled and placed in comparison mode for comparison to new readings

Hand Held Digital Meter

Tanks vary widely with frequency and the amount of power per gallon of solution in a tank. The digital meter compensates for a low power to volume ratio or a high frequency vs. low frequency tanks. [Lower frequency will tend to concentrate energy in a band or level with in the liquid. A higher frequency will distribute the power evenly throughout the tank.] The digital meter has an input for impedance at frequency. It will read power in Watts's dB/m or RMS Voltage.

A ¼"" diameter quartz probe is included for measuring the power in close quarters around work fixtures. The probe is a .5" dia. sensor for making cavatation measurements over the frequency range of 20 kHz to 400 kHz. It has a high sensitivity relative to its size and is Quartz. It measures the cavitation in a constrained spot. This is a realistic picture of what your part sees as its cleaned. Special probes are available on a custom basis.

A Lap top computer with CD, Hard Disk, and Floppy Disk Parallel printer port with the software pre installed is available as an option. The computer has a full range of forms, instruction manuals and articles on ultrasonic cleaning. It is pre set up with directory files to help you organize your ultrasonic cleaning systems performance files.

MODEL L-2001-3 KIT INCLUDES;

- Software for Desk Top or Lap Top Computer
- Windows 98, NT, 2000, XP pro compatible
- Interface for parallel or USB port
- ½" dia. Quartz or Titanium Probe
- Instruction Manual

OPTIONAL ACCESSORIES

- Lap Top with CD, Hard Disk Floppy Disk drives. Includes software installed, Instruction Manual on line, Ultrasonic process information
- Digital Hand Held Meter

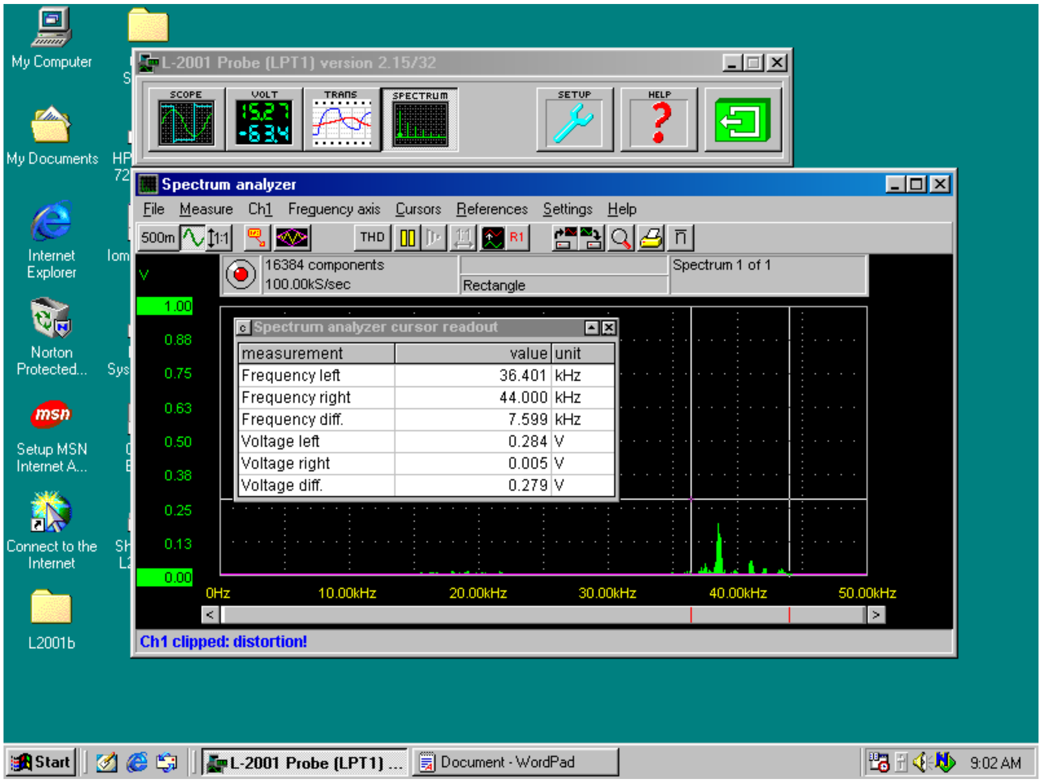
Spectrum Analyzer

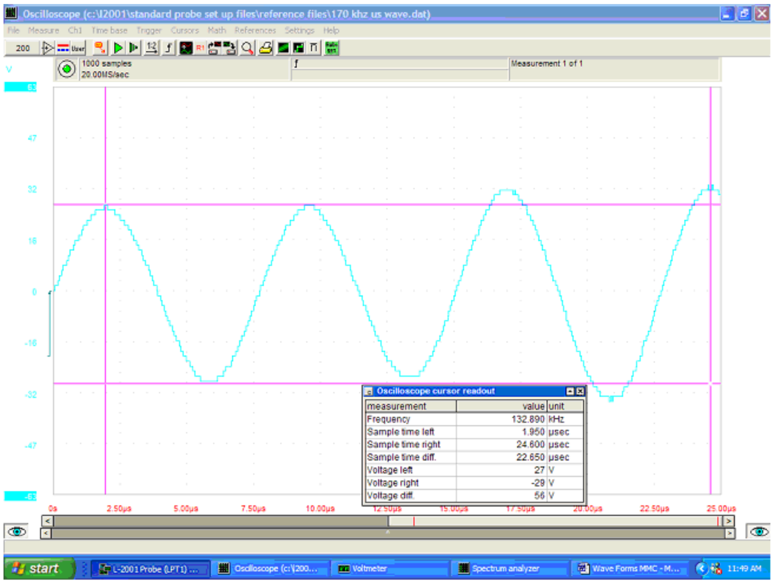
Screen shot of spectrum analyzer showing a 40 kHz 500 watt / avg. Ultrasonic tank at full power.

The frequency of this tank is 40 kHz [large spike on screen] It also generates frequencies from 36.4 to 44 kHz at a lower power.

The scale to the left of the screen shows the relative % of power that is in that particular area of the tank.

Cursors can be set to display the power and frequency envelope.





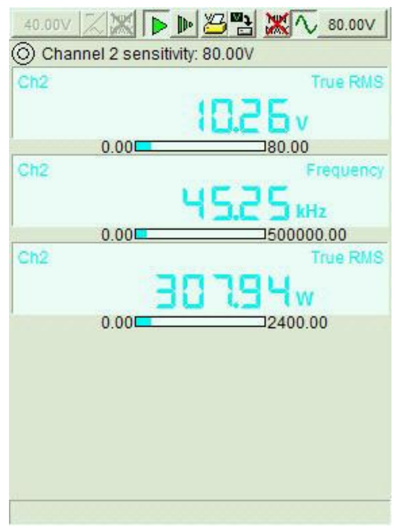
Oscilloscope Screen Shot

The screen shows the ultrasonic power of a 40kHz waveform and allows analysis of the wave.

The scale on the left is voltage of the wave in a particular spot in the tank.

The bottom scale is m/s. any portion of the wave can be expanded or recorded for later playback.

Sampling rate can also be changed.



Volt Meter Screen Shot

The voltmeter shows The RMS on Channel 1 The Frequency on channel 2 and the wattage of the ultrasonic power on channel 3.

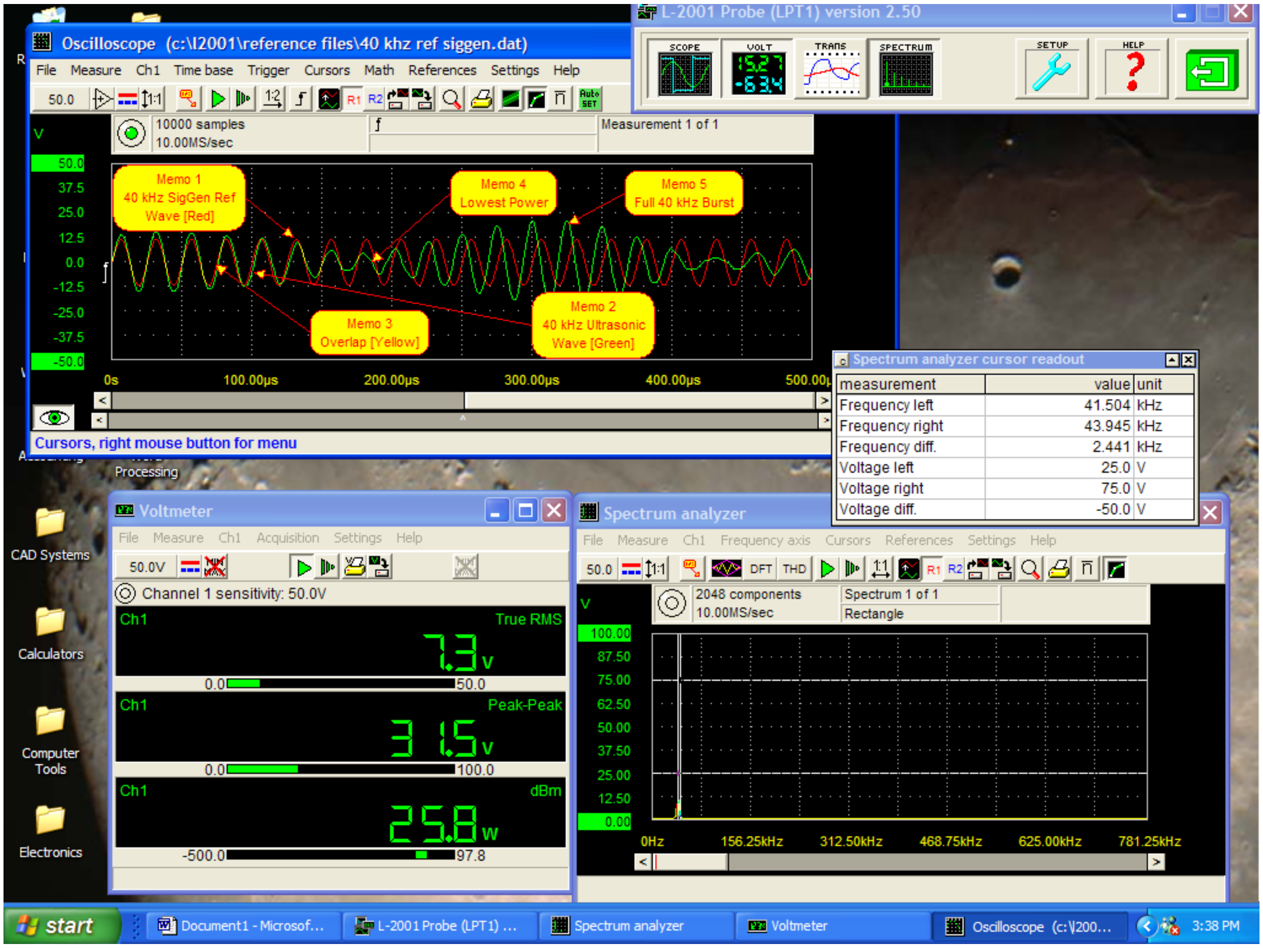
All channels are configurable and can be set to a number of parameters. The volt meter can also be configured to read resistively and temperature of the water

Transient Recorder Screen Shot

The transient recorder shows an ultrasonic tank where during the cycle of operation the power intensity has been increased over time

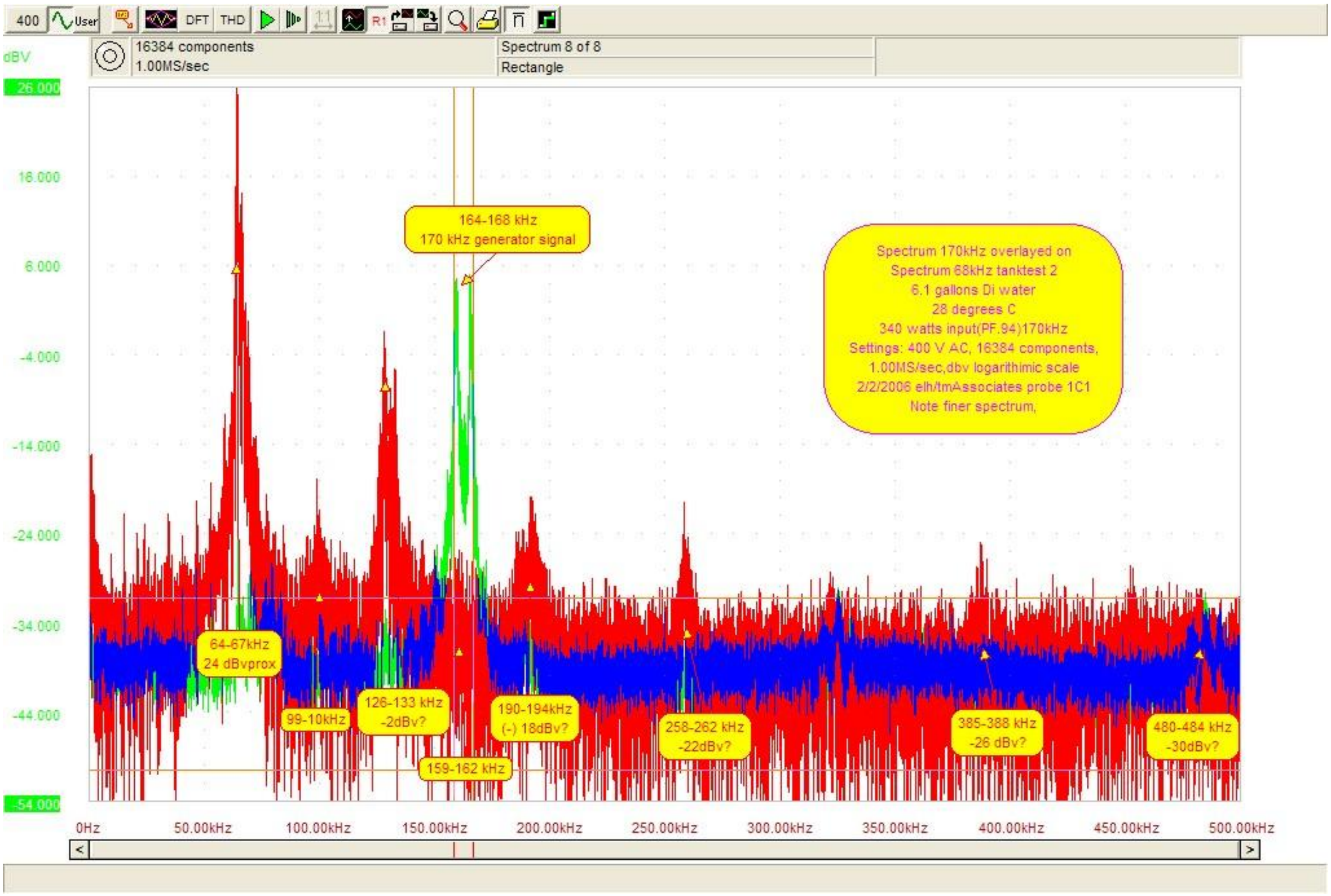
This allows you to keep track of exactly what power level your ultrasonic tank is set for.

All recordings can be saved for further comparison.



Screen Shot of probe measuring 40 kHz ultrasonic waves against a signal generator 40 kHz reference waves. The Volt Meter is measuring the True RMS, Peak to Peak and dB/m Watts of the signal. The Spectrum analyzer is showing the range of the major frequency. [40 kHz]

The screen shot is annotated with notes by the annotation button. A snapshot of the ultrasonics may be taken, saved to file and compared at a later date.



Comparison DFT Spectrum of 170 vs. 68 kHz screen shot.

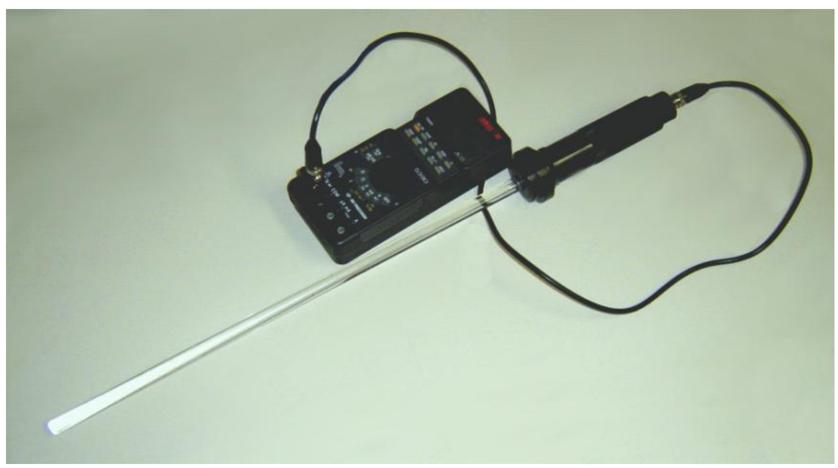
Probes:

Quartz Probe with Digital hand held meter for quick power measurements

Probes are available in either quartz or Titanium and in 9” or 18” lengths.

Custom length and shape probes are available on request.

Software / Hardware Packages: up grade:
4 channel 50 MHz scope with software



Digital Hand Held Meter with Probe

1 mega Hertz Mega Sonic wave showing increasing power steps using power intensity control on generator showing relationship of wall watts to liquid load. Note ratio is consistent

170 kHz ultrasonic wave showing increasing power steps using power intensity control on generator showing relationship of wall watts to liquid load. Note ratio is consistent

The above 2 illustrations show the difference between ultrasonic and mega sonic waves expressed in tanks with DI water as the liquid. The mega sonic wave is very even as it is stepped up in power. The ultrasonic wave is somewhat more ragged. This is the difference in propagation between the two forms of expression. Note that in both forms the probe has maintained a consistent ratio between steps