ULTRASONIC ENERGY METER

OPERATION MANUAL

SAFETY PRECAUTIONS

ELECTRICAL

The cavitation energy meter contains a 7.2 volts rechargeable Nickel-Cadmium battery. Always use extreme caution when recharging. Battery pack is shipped charged. Charge will occur in 12 - 14 hours at 150 mA. The pack is rated at 1,700 mA-hr. Charging the battery at faster rates without special chargers can cause overcharging resulting in the violent venting of chemicals and the release of toxic materials from the battery pack causing personal injury and/or property damage.

Special precautions should be taken not to short circuit the positive male prong to the case.

INSTRUMENT CASE

The electronic case is not waterproof. It should not be immersed in water. If water enters the case it should be sent back to ppb for maintenance. Do not attempt to open and dry because it will probably have to be replaced. There are no user serviceable components inside the case. Tamper proof screws are used to secure the cover to the case. Send the complete instrument to an authorized ppb service center for maintenance or repair.

CONNECTORS

The probe should be connected on the 3-pin male receptacle located on top of the meter above the LCD display. The RS-232 cable should be connected on the 4-pin male receptacle located on the left side of the meter next to the battery charger receptacle. Do not force the plugs into the receptacles and caution should be taken not to try to force these plugs into the wrong male receptacles.

To disconnect the probe or the RS-232 cable from the meter it is necessary to depress the latch located on the side of each plug before and during removal.

Notes:

1. Keep battery charging while not in use.
2. The calibration screw is located on the top of the meter under the probe receptacle.
3. After turning **ON** the meter, Wait 3 to 5 seconds before use to allow built-up energy to discharge.
4. Please review the Calibration (appendix C) and Operational (appendix D) procedures prior to first use.

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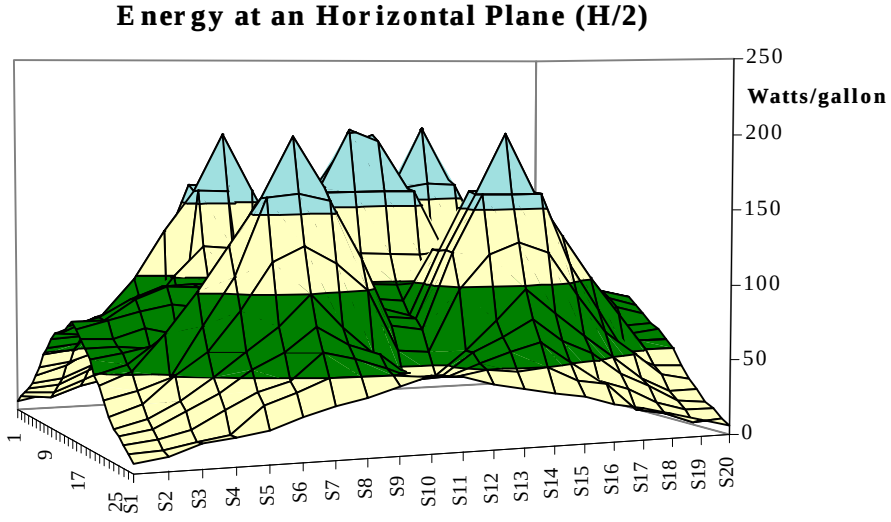
1. Introduction

The ultrasonic cavitation meter (pb-500) is an instrument used to measure the energy density (w/in^2) of cavitation in liquids. It is not a sound meter or hydrophone. The main difference is that it measures cavitation or the collapse of water bubbles as they implode on a surface, in addition to the sound waves produced by a pressure transducer.

The Ultrasonic meter is simple and easy to use, yet it contains sophisticated electronics and options for data storage, retrieval and analysis. The instrument is user friendly so we encourage the operation of the keypad functions to familiarize yourself with the instrument.

The meter measures the instantaneous energy at a point and in a given direction. This is done twice per second and the display is updated accordingly. The probe is designed with the lens surface at 45° from the rod to be able to be pointed perpendicular as well as parallel to the bottom of the tank to obtain relevant data. In "auto mode" the unit will gather statistical parameters such as average, standard deviation, minimum and maximum. This feature allows the establishment of several strategies to characterize a tank. Some strategies include:

1. Energy variations at a given point as a function of time.
2. Map geographically a tank by 'walking' the probe at a given depth under the surface of the tank.
3. Map a vertical line along the center of the tank to establish the decay of energy as the probe is further from the ultrasonic transducers.
4. Average energy comparisons from tank to tank or over the life of a tank and transducers.



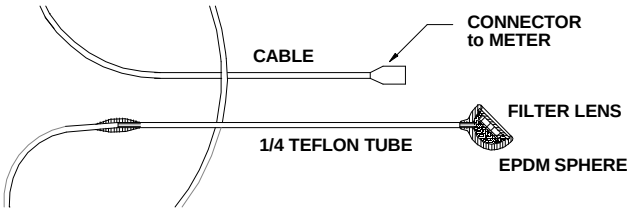
2. Description

The Ultrasonic Energy Meter is a precise instrument for measuring the energy density at a point in time and space in a given direction. Real time computation and display of average energy allows for fast tank and ultrasonic characterization.

The instrument consists of a sensing probe, an electronic case, a battery charger, and an RS-232 cable.

2.1 Probe

The probe is a 20-inch long Teflon coated stainless steel tube with an EPDM half-sphere in one end and a cable on the other. The black half sphere is made of elastic material to isolate a filter lens mounted on it from the holding rod.



Cavitation generated by the sound pressure waves is produced in the form of bubbles that grow and implode with micro-streaming water jets hitting the filter surface. The sensor mounted behind the lens detects these impacts and the signal is sent via the cable to the electronic case.

A 3-pin connector allows for quick connection of the probe to the electronic case.

2.2 Electronic Case

The electronic case is an aluminum box 3.75” wide by 2” thick by 7.6” tall. Inside the box there are a PC board, a rechargeable battery, and the microprocessor mounted on a socket.

The battery is 7.2 volts with a capacity of 1,700 mA-hr. The meter consumes between 25 and 40 mA while operating and about 2 mA while off or dormant. This should allow the meter to operate between 40 and 850 hours between charges, depending on the time of use. If the battery losses all of its charge, then the display will wake up with the date of the last software version as soon as the charger is plugged in.

On the front, it contains a keypad with 13 membrane switches and a 2.7” by 0.9” LCD display. The figure on the next page shows the front face of the electronic case.

On the left side of the case there are 2 receptacles, one for the battery charger and the other for RS-232 communications. The battery charger receptacle is a single center pin socket with 0.1” total diameter.

The RS-232 receptacle is a 4-pin male socket keyed vertically that contains *transmit*, *receive*, *neutral* and *ground* connections.

The sensing probe is connected to a receptacle located on the top case towards the right side of it.

2.3 Battery Charger

The battery charger is a universal AC/DC adapter with 110 volts input and it could have a switch-selectable DC volt output. If this is the case, the switch is to be placed at the 7.2 VDC level.

The charger has a current capacity of 150 mA to charge 90% of the battery capacity in 12-14 hours. Overnight charging will assure largest battery life. Under normal use, the battery will last about 5 years or over 1000 charges.

In locations where the voltage is 220 VAC, there is available an optional 220/110 voltage converter rated at 50 watts. Another option is to use any locally supplied 7.2 VDC battery charger with a positive center pin.

2.4 RS-232 Cable

A 6 ft. long RS-232 cable is used to allow for connecting the meter to a serial port of a computer. The cable has a standard 25-pin serial female plug on one end and a 4-pin mini-connector on the other. The 25-pin serial connector has wires connected on pins 2, 3, and 7 for ground. 2 and 3 are for transmit and receive. If the computer has a 9-pin receptacle, then a standard 9 to 25 pin serial adapter can be used. The adapter will connect pin 5 to ground, so no alterations are necessary. The RS-232 cable should not be used in conjunction with the battery charger.

Communications are done at a baud rate of 9,600. No parity check, 8 data bits with 1 stop bit are used. Any communications program or software can be used. These include ppbcom (included, please review the README file on the disk for installation instructions), “Hyper Terminal” from Microsoft windows, Tera Term, ProComm Plus, Wincom, Bitcom, and many others. The data transfer will occur if the PRN switch is depressed momentarily. The data will consist of a title line and a line of data for each location up to 100 lines. The data logged is about 40 characters wide. The format is standard ascii and can be imported directly from Excel or Lotus.

The table below shows a sample of data as it is dumped to the PC.

Loc	Date	Time	Durat	Ave	Std	Min	Max	kHz
1	12/01/98	10:12	1:22	45	4	39	50	41.2
2	12/01/98	10:15	1:12	43	4	40	48	40.5
3	12/01/98	10:18	1:39	43	6	37	52	41.5
4	12/01/98	10:22	2:57	42	4	41	49	41.8
5	12/01/98	10:26	1:21	44	5	38	50	40.7

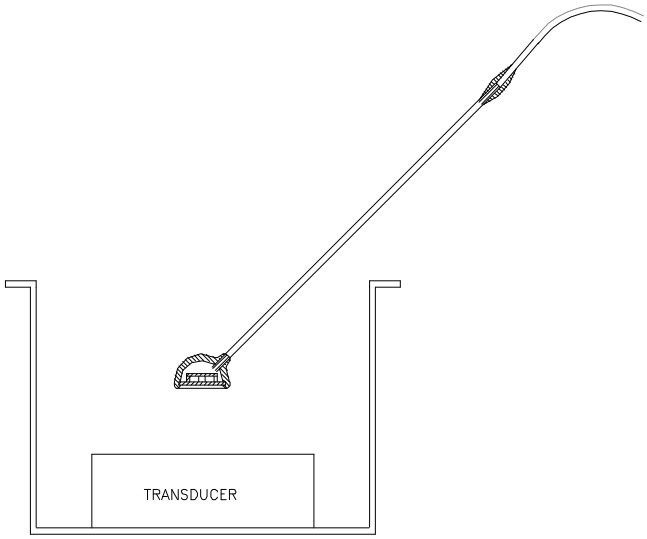
The data can be imported using standard Arial or terminal font with letter size at 10 or 12 points. This will avoid proportional spacing and preserve column width. The average shown above can be obtained at a single location or by walking the probe along and across the tank.

2.5 Software

The software is embedded in the EEPROM part of a Motorola microprocessor. This processor is a 68HC805C4 and operates at 2 MHz. The software source code is written in assembly language. It consists of 7 routines. These are main, clock, display, lcd, math, printer and eeprom. Their functions are what their names suggest.

Some features that the software includes are: Auto shut-off after 5 minutes of non-operation, time and date tracking, self calibration, continuous memory, statistical calculations, and fast sensor tracking.

The source code is available with justification and changes are to be shared with ppb. It is the property of ppb and is considered an infringement to reproduce it.



3. Operation

The operation of the meter is quite simple. There is no risk of damage by trying the different keypad functions. A brief description of the main keypad functions follows.

3.1 Nomenclature

START: Starts display of energy (E) from the probe and computation of statistics if AUTO option is chosen.
STOP: Stops display of energy from the probe and goes back to display time after writing into memory the information if in AUTO mode.
TIME: Real time using 24 hour clock.
ΔT: Duration from START to STOP displayed on small digits on top.
DATE: Date using standard calendar.
location #: Memory location.
X: Instant value for energy at a point in watts per gallon.
Xmax: Maximum value of E from START to STOP.
Xmin: Minimum value of E from START to STOP.
Xbar: Mean value of E from START to STOP.
S.D. Standard deviation of E from START to STOP.
MODE: = SNGL or = AUTO depending on running selection.

3.2 Single Keys

ON/OFF Sleep or wake-up mode. Instrument always wakes up displaying INSTANT (normal display) and in SNGL mode. If START is depressed, then energy will be displayed until STOP is depressed. If STOP is depressed, then data might be recorded if in AUTO mode.

KHZ Displays frequency while the instrument is measuring. If the tank operates at a very low energy level the frequency display will be 0.

PRN Checks for a serial connection, then it dumps the data stored. This can also be accomplished by sending the letter '**p**' from the RS-232 port.

DATE Displays date for 5 seconds and then goes back to normal display as described in ON/OFF.

TIME Displays time (24 hr clock) for 3 seconds. It is inactive if already displaying time.

SNGL Displays measurements without logging them to memory. All statistical parameters, as well as frequency are measured, computed, and displayed if the appropriate switch is pressed. No recording of data occurs, unless STO push-button is depressed.

AUTO: Makes operational the computation of statistical parameters from START to STOP. Records data into memory when STOP is depressed. Memory is treated in a sequential mode up to 100 memory locations. Each location contains a full data set.

MAX/MIN: Displays Xmax the first time that it is depressed. This is very useful to look for peaks in the tank. The next time it is depressed it displays Xmin. This is used to look for areas of low activity.

S.D.: Displays S.D. in the same units of E.

Xbar: Displays Xbar (E average, on the left) or X (E instant, on the right) like a flip/flop each time that it is pressed. The average is displayed at the left of the LCD, while the instant value is displayed at the right hand side of the LCD.

Note: The energy displayed always defaults to the instant energy (on the left) when you hit START.

START/STOP It is like a flip/flop. When depressed for the first time, it changes the display to counting and display energy as well as starts displaying and counting ΔT. If depressed again, then it stops counting and the final statistics are displayed. If it is operating in AUTO mode, then it records: Location, date, time, Xmax, Xbar, Xmin, S.D., ΔT. In this case it displays memory location for 3 seconds before displaying average again. Sending the letters '**c**' for counting and 's' for stop through the RS-232 serial port can also accomplish this.

STO: Depressing STO does not interfere with the work in progress. After displaying the memory location (location) for 1 seconds, it resumes operation.
Sending the letter '**m**' through the RS-232 serial port can accomplish this.

RCL: It allows the display of saved information. It is inactive if the unit is 'counting'. RCL only operates when in STOP mode. If depressed while in STOP mode, it displays the value of location and the small digits on top of the LCD display Δt. You may view the **Xbar**, **S.D.**, **MAX/MIN** values at each location. Please note that **kHz** and instant energy cannot be recalled, and the most recent instant energy measure will always be displayed. **KHz** (frequency) is stored into memory, and can be viewed only if downloaded to a PC.

3.3 Double Keys

All double keys are ignored except for the ones described below. It can be seen that only KHZ and STO are used as first double keys. If the user depresses the KHZ or the STO keys while no other key is depressed, then he has to depress within one second the other key described below to activate the operation. If the user depresses an invalid key then this is ignored.

KHZ/ DATE Allows setting the date with STO as 'up' key and RCL as 'down' key. The KHZ key is used to scroll from year to month to day and out of this mode.

KHZ/ TIME Allows setting the time. STO is 'up'. RCL is 'down'. The KHZ key is used to scroll from hours to minutes to seconds and out of time set at zero seconds.

STO/RCL: Allows to erase memory and start logging at location 1 again. Sending the Letter '**e**' through the RS-232 serial port can accomplish this.

3.4 Display

The icon	Counting	is displayed while in START mode (running). During this activity the frequency can be displayed by depressing the KHZ key.
The icon	SNGL	is displayed while in SNGL mode (default on wakeup).
The icon	AUTO	is displayed while in AUTO mode.

On the top-left of the LCD there are 4 digits arranged as 2 pairs of the form: XX XX. We use the two pairs of digits to display the sample duration ΔT in minutes and seconds while in START (or running) mode. In STOP mode we display the duration ΔT of the last sample.

4. Service Information

There are no serviceable parts inside the probe or the meter. The probe will probably get destroyed if opened. The meter is closed with tamper proof screws to prevent access to delicate parts inside it. If service is required please contact ppb, your distributor or a ppb service center. Units can be sent on a loan basis while a meter is being serviced.

The meter black paint is a polyurethane baked enamel about 4 mils thick. To clean use water-damped cloth and no solvents. The front panel is Mylar. Do not use scrubbing friction that might scratch the surface of the plastic front panel.

4.1 Certification

Certification is a decree that the energy readings will be linear. This implies that the change in energy readings will be proportional to the change in energy available in the tank. We recommend that the meter and probe be sent out for certification about once a year. There is not sufficient history to know if this is really necessary, but for companies operating under ISO-9000, it might be necessary to have those records. A “calibration certificate” is provided only if requested at time of purchase or requested at calibration time.

4.2 Battery

The battery life is rated at over 1000 re-charges. This should take about 5 years to occur if the unit is used continuously and recharged every other day. While running, the meter consumes between 25 and 40 mA and the battery capacity is 1700 mA-hr. If the battery life decreases substantially, then it might be necessary to exchange it for a new one.

Battery exchange should be done at the factory, although the battery is commercially available in most places. The battery is rated at its nominal 7.2 volts DC. It is a package composed of eight or six 1.2 VDC standard AA Nickel-Cadmium batteries. These batteries are connected in series.

The meter is able to operate with the re-charger providing power even if the battery is not operational. The re-charger needs to be 7.2 VDC. The center prong is positive, and the surrounding socket is negative or ground. Severe damage can occur if shorted or charged with reverse polarity. There are no current limiting devices installed that would prevent the battery from heating and failing if shorted. All regular precautions and procedures recommended by rechargeable battery manufacturers should be followed.

4.3 Probe

The probe is a sealed unit that cannot be repaired. If necessary they can be sent to the factory for exchange for new ones at a discounted price. The standard probe for ultrasonic applications is the pb-208.

- The electric cable jacket is made out of gray PVC and can be cleaned with a water-damped cloth.

- The tube is Teflon coated 316 stainless steel so it is quite resistant to chemicals, although it may bend.

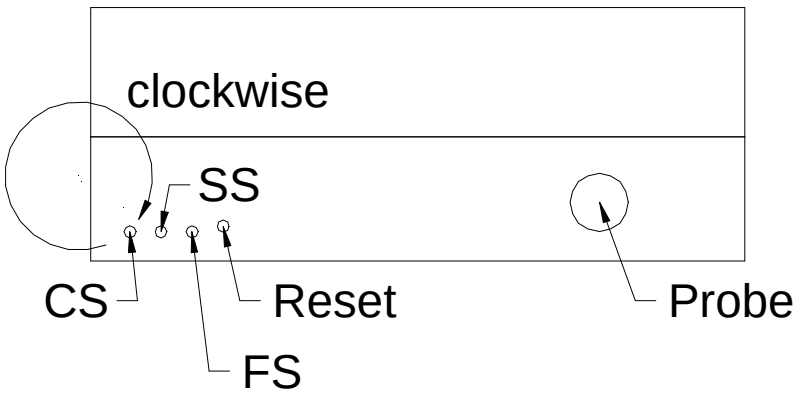
- The ball material is EPDM, and can be cleaned with detergent and water. This material is good for most ultrasonic cleaning applications. For a complete list of chemical resistivity, please visit **www.megasonics.com/chemical.html**.

- The lens is a thick quartz Crystal. It is “scratch” resistant, although caution should be taken not to crack it or scratch it. It can be cleaned with rubbing alcohol and a clean dry wipe.

The electric connector at the end of the probe’s electric cord has a small latch that needs to be depressed to remove the female plug from the receptacle installed at the meter.

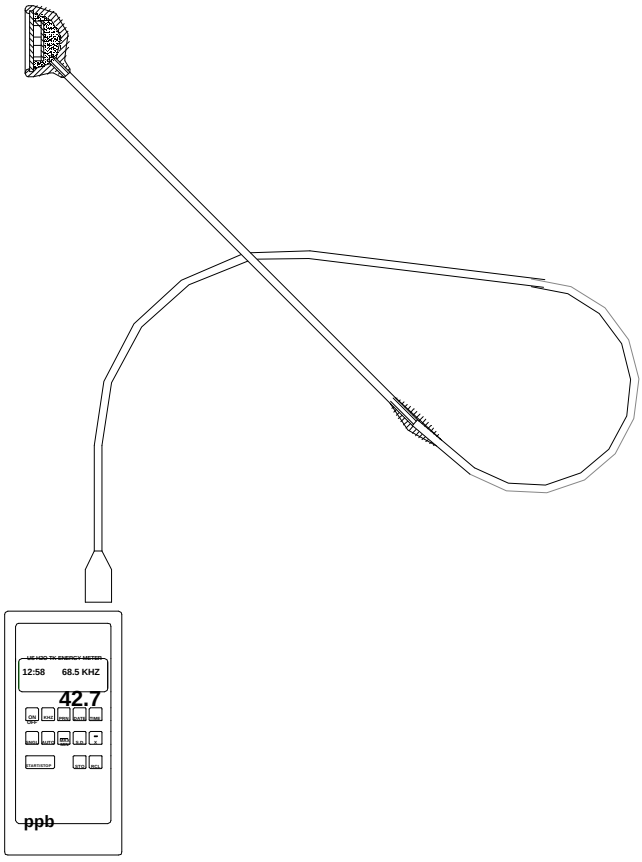
4.3 Processor

The processor needs to be reset if the meter is able to turn on, but no longer displays energy. To reset the unit, turn off the meter and push the "Reset" button for 10 seconds.



Appendix A. Specifications

Sensing Range	0 to 250 w/in^2 (w/gal)
Frequency Range	0 to 500 kHz
Data Display	w/in^2 (w/gal)
Display	Custom LCD
Memory	100 sets: loc., date, time, avg., σ, max, min, Δt
Output	Computer or serial printer interface (9600, 8, 1, n, p)
Input	Standard 7.2-volt battery Charge
Probe Materials	EPDM half-ball, Teflon coated 316 s.s. rod, Quartz lens filter, PVC electric cable
Fluid Temperature	1^o to 80^o C (33^o - 160^o F)
Fluid Resistivity	0 to 18 MΩ
Fluid pH	Compatibility with probe
Other Liquids	Only compatibility with materials is required
Case Materials	Aluminum with Polyurethane baked enamel black paint
Power	One 7.2-volt sealed Ni-Cad rechargeable battery
Weight	2 lb. Complete
Dimensions:	
Case:	4” Wx 8”L x 2” H
Probe:	24” L x 2.3” ϕ



Appendix B. Product Limited Warranty

The cavitation meter is warranted to the original purchaser to be free from defects in materials and workmanship under normal installation, use and service for a period of one (1) year from the date of shipment as shown by the shipping package or invoice.

The obligation of ppb under this warranty shall be limited to the repair or replacement (at our option), during the warranty period of any part which proves defective in materials or workmanship under normal use and service, provided the product is returned to ppb (address below) or to one of our authorized service centers transportation charges prepaid. Products returned to us or to an authorized service center.

This one (1) year warranty is in lieu of all other expressed warranties, obligations, or liabilities. Any implied warranties, obligations, or liabilities, including but not limited to the implied warranties of fitness for a particular purpose, shall be limited in duration to the one (1) year duration of this written limited warranty. Local state laws will apply.

In no event shall we be liable for any special, incidental or consequential damages for breach of this or other warranty, expressed or implied whatsoever.

This warranty gives you specific legal rights.

Company information:

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236 Stanford S Center
PMB 236
Palo Alto, CA 94304
Phone: (650) 851-4387
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Appendix C. Calibration Procedure

The unit is shipped calibrated to read cavitation energy in Watts per square inch (W/in^2). An NIST Traceable calibration certificate can be provided for an additional charge. The unit is calibrated and the certificate provided by an independent testing laboratory. Please contact us for additional information.

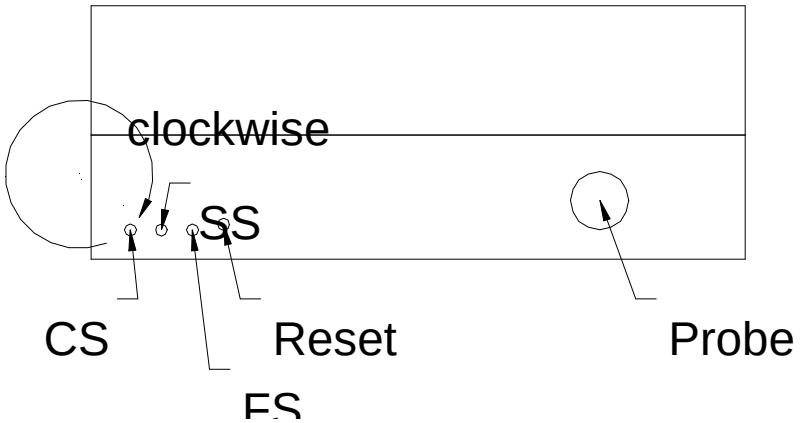
An alternative to the W/in^2 output, the meter might be calibrated to an alternative reference, such as the W/gal of your system, or an arbitrary baseline. WARNING, you will lose the calibration to W/in^2 when you adjust the calibration screw.

To proceed with a user calibration of the meter in W/gal, it is necessary to use an ultrasonic tank for which both the volume of water in the tank and the total watts coming from the ultrasonic generator are known. Using this information it is necessary to calculate the average energy density in the tank when the water is close to ambient (below 25 deg. centigrade), and the Ultrasonic generators are in operation. Please note that the Watts used are those going to the transducers, and do not necessarily reflect the percentage of energy transmitted into the system.

$$E\ (\text{Watts/Gallon}) = \frac{\textbf{Power (watts)}}{\textbf{Volume (gallons)}}$$

The meter can be calibrated by measuring the average energy throughout the entire tank, and scaling the energy reading in an iterative fashion until the average energy displayed coincides with the watts/gallon of the tank.

In some cases, people have preferred to set their own baseline, such as 100 W/gal at an average measure in the tank. They can then use that baseline when comparing energy readings within a tank, or comparing energy from tank to tank.



Ultrasonic cavitation energy meters have a **calibration screw (CS)** located on the top of the meter behind the receptacle for the ultrasonic probe. The location of the screw is shown on the drawing on the previous page. The **SS** and **FS** screws are disabled on the pb-500 meter. The procedure to calibrate the energy with this adjustment is as follows:

1. Turn the meter **OFF**.
2. Plug the sensor probe to the meter and keep it out of the tank (without energy).
3. Turn the meter **ON**.
4. Wait for the capacitors to discharge (approximately 3-5 seconds). You can check by pressing **START**. If the number is not **0**, then you need to wait some more. This is only needed when you turn on the meter. Place the probe in the middle of the tank, and make sure the ultrasonic tank is running.
5. Turn **CS** clockwise all the way (this is a 15 or 25 turn pot). The buttons on the meter should be facing forward towards you, with the probe receptacle at the top.
6. If you hit **START**, The instant energy reading (number on the right) should read 255 (in reality it is over 255).
6. Turn **CS** counterclockwise until the energy being displayed is approximately 60 W/gal. You need to have the meter displaying instant energy (on the right). You will see the number start to go down after a number of turns. If the number being displayed is 0, then you went to far. You will have to turn **CS** clockwise to increase the energy reading.
7. Measure the average energy of the entire tank by “walking” the probe for two minutes parallel to the tank bottom in a systematic fashion at the following 3 depths: 1” below the surface, mid-depth, and 1” above the tank bottom.
8. Adjust **CS** until the average energy measured coincides with the watts/gallon of the tank.

Appendix D. Operational Procedure

1. Turn the meter **OFF**.

2. Plug the sensor probe to the meter and keep it out of the tank.

3. Turn the meter **ON**. Wait for the capacitors to discharge (approximately 5 seconds). You can check by pressing **START**. If the number is not **0**, then you need to wait some more. This is only needed when you turn on the meter. Place the probe in the tank, and make sure he Ultrasonic tank is running.

4. Hold the probe in a set location and hit **START** (the meter is now counting). The reading that is displayed (on the right) is the instant energy from the moment you hit start, and will stop counting when you hit **STOP**. This number will fluctuate up and down because of the cavitation energy present. While the meter is still counting, you can hit **Xbar** to see the average energy reading (now on the left). You can hit **Xbar** again to return to the instant energy reading.

5. While the meter is counting and the instant energy is not 0, you can hit **KHZ** to see the frequency of the ultrasonic energy at that specific location, displayed in kHz. Hit **Xbar** to return to the instant energy readings. The frequency accuracy may be improved by angling the probe lens from the transducer and stirring the fluid in the tank. This is only necessary for low frequencies.

6. If you do not move the probe from the moment you hit **START** to when you hit **STOP**, you will have an average energy reading (**Xbar**) for that location during that period of time. You can also hit **MAX** to see the maximum energy in that period of time, **MIN** to see the minimum energy, and **S.D.** to see the standard deviation.

7. If the meter is in **AUTO** mode, once you hit **STOP**, all the data is stored in a memory location. If you are in **SINGLE** mode, you can hit **STO** to store the data (if desired).

8. If you would like to get an average reading within the tank, simply place the probe in the tank and press **START** and begin "walking" the prove across the tank in a systematic fashion and at various depths. If you do so for 90 seconds, the readings will begin to converge on an average for that tank. Press **STOP** before removing the probe from the tank.