
Meteorological Particle Spectrometer

Operator Manual

DOC-0072 Revision H



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Warranty

The seller warrants that the equipment supplied will be free from defects in material and workmanship for a period of one year from the confirmed date of purchase of the original buyer. Service procedures and repairs are warranted for 90 days. The equipment owner will pay for shipping to DMT, while DMT covers the return shipping expense.

Consumable components, such as tubing, filters, pump diaphragms, and Nafion humidifiers and dehumidifiers are not covered by this warranty.

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1.0 Product Description

1.1 Introduction

The Meteorological Particle Spectrometer (MPS) is designed to directly measure precipitation shapes, sizes and fall velocities. In post processing, rainfall rates and statistical data on the intensity of the rainfall can be derived. The image data can be analyzed to determine if the precipitation is in the form of droplets or frozen precipitation. The Particle Analysis and Display System (PADS), a graphical user interface operating on a host computer, provides control of measurement parameters. PADS simultaneously displays real-time particle-size distributions. All standard data interfaces are done via line drivers meeting the RS-422 electrical specification, allowing cable lengths of up to 100 meters. The MPS is designed to be mounted on a single post and orient the direction of the sampling volume with the prevailing wind via the self-contained wind vane. The MPS uses all solid-state electronics, and requires minimum warm-up time.



Figure 1: Meteorological Particle Spectrometer

1.2 MPS Specifications

Technique:	Optical array imaging (64 element: 62 sizing elements, end diodes reject)
Size Range:	50 μm – 3.1 mm (50 μm resolution) 25 μm – 1.55 mm (25 μm resolution) (special-order option)
Sample Area:	20 cm x 3.1 mm or special order 20cm x 6.2 mm
Number of Size Bins:	62
Sampling Frequency:	1-0.1 Hz
Laser Wavelength:	685
Data System Interface:	<i>Histogram data, housekeeping data, and instrument control:</i> RS-422 (standard) or RS-232 port ¹ , 57,600 baud <i>Image data:</i> RS-422 port at 460,000 baud (standard), or high-speed serial port
Operating Temp:	-40 to +40 degrees C
Altitude:	15,000 feet
Humidity:	0 to 100%
Power Requirements	2 A @ 115 VAC, other voltages optional
Weight:	48 pounds (21.8 Kg)

2.0 Instrument Setup

The system consists of a particle sensor, a computer and a calibration verification tool. The sensor is shipped and stored in a reusable prefabricated shipping case. The computer and calibration verification tool are shipped in a cardboard box.

¹ Switching to an RS-232 port requires jumpering and the removal of board termination resistors. The RS-232 is not recommended, as it is more susceptible to noise than an RS-422 connection.

2.1 Connecting Components

Please carefully open the instrument shipping boxes, take out the components, and place them on a sturdy surface.

Follow these following steps to set up the system:

- Connect the MPS power cable to a power source
- Turn on MPS power (push power switch up; the light will be on)
- Insert MPS PADS software (labeled “MPS PADS”) USB key into a USB 2.0 port on the laptop computer
- Connect the two RS-422 cables to the MPS and to USB 2.0 ports on the laptop
- Connect the laptop to a power source
- Turn on the laptop
- If the computer displays “Found New Hardware,” follow the install wizard on the screen (optional step)

2.2 Basic Health Check

Follow the following steps to perform a basic health check of the system:

- Double-click on the “PADS” icon on the computer desktop to open the PADS program.



- Click on the MPS instrument tab.
- Click on the “Sample” button. The button is originally gray. Upon clicking, it will turn green, and the label will change to “Sampling.”
- Click on the “MPS Diagnostics” tab.
- Check Diode Voltages. The value for “Diode Voltage” 1, 32, and 64 should be close to 2.5 V, respectively. The instrument will work as long as the value is between 1-3 V. If the value is significantly below 1 V, the instrument will not work properly and needs to be serviced.
- Check temperatures. DSP Board Temp. and Internal Temp. should be close to ambient temp. The Window Temp is thermostatically controlled. It should be close to approximately 25 °C.

When the diode voltages and temperatures are within normal ranges, the MPS is in good working condition.

2.3 Calibration Verification

The MPS is carefully calibrated in the factory. It is possible, however, that the optics of the instrument can become misaligned during transit. The user is advised to perform an on-site calibration verification using the provided spinning disk to ensure that the instrument is in good operating condition. See DOC-0012, the Spinning Disk Manual, for instructions on mounting and aligning the spinning disk and interpreting results.

2.4 Mounting Considerations

The MPS should be mounted on a pedestal a minimum of 1 m above the surface. The mounting location should have no trees or overhead obstructions in the vicinity that would interfere with the falling precipitation. The specifications for the pedestal mount are given in Appendix G and an example mount is shown in Figure 1.

3.0 Theory of Operation

The light from a laser diode is shaped into an elliptical beam to illuminate the volume where the drops are detected. The light and the shadow of a drop in the beam are then imaged onto a 64-element photo-diode array. This image has been magnified so that a 50 micron drop will shadow one element and a 3200 micron drop would shadow the whole array. The state of all 64 elements is sampled at a rate set by a digital clock signal. The state of the array at each clock interval is known as a slice. The first slice that contains a shadowed element starts the processor storing the data in each slice. Subsequently when a slice contains no shadowed elements, the image of the drop is complete. If an end element is shadowed it is not possible to know how large the drop is, so that particle is rejected for sizing. When an image is complete the processor stores in a buffer a time stamp, the data with a header that contains the number of slices, and the maximum number of elements shadowed. The particle size is also stored as statistical data. The image data are sent asynchronously to the host processor when the buffer is full. The statistical data are sent synchronously to the host when requested. The host can then display and store the data.

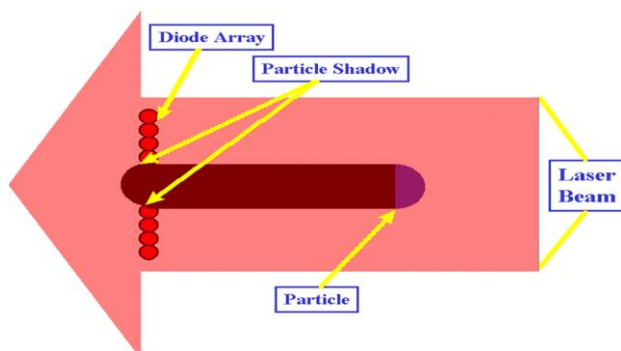


Figure 2: Particle Imaging with the MPS (Vertical View across Horizontal Optical Path)

3.1 Environmental

The optical heads of the MPS are heated to prevent the window becoming coated with fog or frozen precipitation. These are thermostatically controlled at 25 °C. There is a series resistor in line with the heater. If additional heating is needed, this resistor can be changed or bypassed. The body of the MPS contains two fans. One fan operates continually circulating air over the electronics. The other fan is designed to circulate outside air with the inlet on the bottom of the leading edge of the MPS. This air is exhausted out through the ring aperture at the outside of the turntable. A filter is supplied on the air inlet and can be replaced from the outside of the MPS. The fan that circulates external air is thermostatically controlled and will start when the internal temperature reaches 25 °C.

3.2 Calibration

Calibration of the MPS is accomplished with a spinning disk calibrator that simulates particles passing through the beam or by dropping size-calibrated glass beads across the sampling beam. See the *Spinning Disk Calibrator Operator Manual*, DOC-0012, for details.

The MPS can also be calibrated with precision glass beads, which can be poured through the optical path. For proper shape of the images using this calibration technique the airspeed should be set to 1 m/sec.

4.0 Computer System and Software

4.1 Computer

The MPS is supplied complete with a laptop computer system with a Windows-based operating system and pre-installed PADS data collection software. The MPS requires two data lines to the host computer. An RS-422 or RS-232 line transmits the histogram and housekeeping data, while an RS-422 line or high-speed serial port is used for transferring the particle images to the computer. It is strongly recommended that an RS-422 line be employed for the housekeeping and histogram data, as it has much better noise immunity than RS-232.

Note: If the computer attached to the MPS is displaying information chaotically, turn off both the instrument and the computer. Then turn the computer back on and allow it to boot before turning the instrument on again. This should resolve the display issues. The computer must be allowed to boot up before power is applied to the instrument.

4.2 Introduction

The Particle Analysis and Display System (PADS) is a software package that interfaces with all the instruments produced by Droplet Measurement Technologies (DMT) and other leading instruments used in the atmospheric sciences. The program is designed using National Instruments' LabVIEW software, which facilitates instrument connectivity while providing powerful graphical displays. PADS uses a tab-based structure to display information about individual instruments and the overall program. The system will sample real-time information from the instruments and record the data to files. During playback mode, it will also read files for graphical analysis. The output data files are in comma-delimited format, so that the data can be imported into spreadsheet programs for additional analysis. The program is configurable to use any combination of instruments and has the ability to sample at various speeds.

5.0 Theory of Calculations in the MPS

5.1 Rain Rate Calculation

The rain rate is defined as the height of a column of water that forms over a unit area during a given period of time. The convention is to use dimensions of mm/hr. When a size spectrum of precipitation is being measured, the rain rate is calculated as:

$$\text{Rain Rate} = \sum_{i=1}^n A \cdot c_i \cdot vt_i \cdot d_i^3 \cdot \frac{\pi}{6}$$

where

A = $3.6 \cdot 10^{-6}$, a scale factor to convert units to mm/hour

c_i = particle concentration of bin i in particles/cm³

vt_i = mean calculated particle fall velocity in m/sec of particles in bin i

d_i = mean diameter in μm of bin i particles

n = the total number of sizing bins for the instrument

Note on Scaling Factor:

The scaling factor of 3.6×10^{-6} is computed as follows. The rain rate should be in mm/hour, whereas the units in the equation are as follows:

$$\#/\text{cm}^3 * \text{m}/\text{sec} * \mu\text{m}^3$$

Thus, we need the scaling factors in the square brackets below in order to convert all distances to mm and to convert seconds to hours:

$$\#/\text{cm}^3 * [10^{-3} \text{ cm}^3/\text{mm}^3] * \text{m}/\text{sec} * [10^3 \text{ mm}/\text{m} * 3600 \text{ sec}/\text{hour}] * \mu\text{m}^3 * [10^{-9} \text{ mm}^3/\mu\text{m}^3]$$

These scaling factors then reduce to 3.6×10^{-6} .

Note on Sample Volume:

The sample volume used to calculate the particle concentration varies with particle size.

5.2 Uncertainties

If the particles are rain or drizzle drops, and they fall in still air, the rain rate can be determined with only a small degree of uncertainty since the fall velocity is a drop's terminal velocity (see next section), a quantity that has been well defined by laboratory measurements. A density term need not be included, as the terminal velocity is assumed to be that of a particle with the density of water (1 g/cm^3). Turbulent air will add an extra vertical motion component, either positive or negative, to the drop's fall velocity. This is a source of uncertainty if the vertical wind or drop velocity is not directly measured. In the MPS the drop velocity is measured, as discussed below.

Additional uncertainties arise with frozen precipitation hydrometeors such as snow, graupel, sleet or hail. In these cases, the particles can be aspherical with variable density. The drag force is sensitive to particle shape and the gravitational force depends on density. For this reason, the terminal velocity is difficult to predict. The liquid water content also depends upon the shape and density. Hence, with no *a priori* knowledge of the particle characteristics, estimated precipitation rate uncertainties can exceed 100%. These uncertainties are discussed in greater detail in the following sections, accompanied by some techniques that can be used to minimize them.

5.3 Fall Velocity Determination

The fall velocities of drizzle and precipitation particles depend upon their terminal velocities and the vertical air velocity. The terminal velocity is the steady state velocity attained by an object when the gravitational force is balanced by the air drag force. For water drops, this velocity has been measured in the laboratory and analytical expressions have been derived that accurately predict the relationship between terminal velocity, drop diameter, ambient temperature, and pressure. The terminal velocities of other types of precipitation particles, such as hail, graupel, snow pellets, sleet, or snowflakes, are much less predictable since neither the gravitational or drag force can be well defined, due to the diverse masses and shapes that these particles have.

The MPS determines the fall velocity of each particle directly by measuring the particle residence time, t , over the diode array. The width of the particle, derived from the maximum number of diodes shadowed across the array, provides an estimate of the particle size, d . The particle velocity, V , is then d/t .

The residence time is measured by counting the number of cycles of a 2 MHz clock that occur while the particle shadow is on the array. This particle count is encoded in an 11-bit word that is stored with each particle image in the image buffer. The digitization uncertainty is approximately $\pm 25 \text{ } \mu\text{m}$ (one-half the probe resolution). The residence time accuracy is $\pm 0.25 \text{ } \mu\text{s}$. From this we can estimate the uncertainty as a function of particle size and terminal velocity using propagation of errors. Figure 3 shows how the error in estimating terminal velocity decreases rapidly as particle size increases. This is because

the digitization error dominates the terminal velocity error and decreases with increasing size.

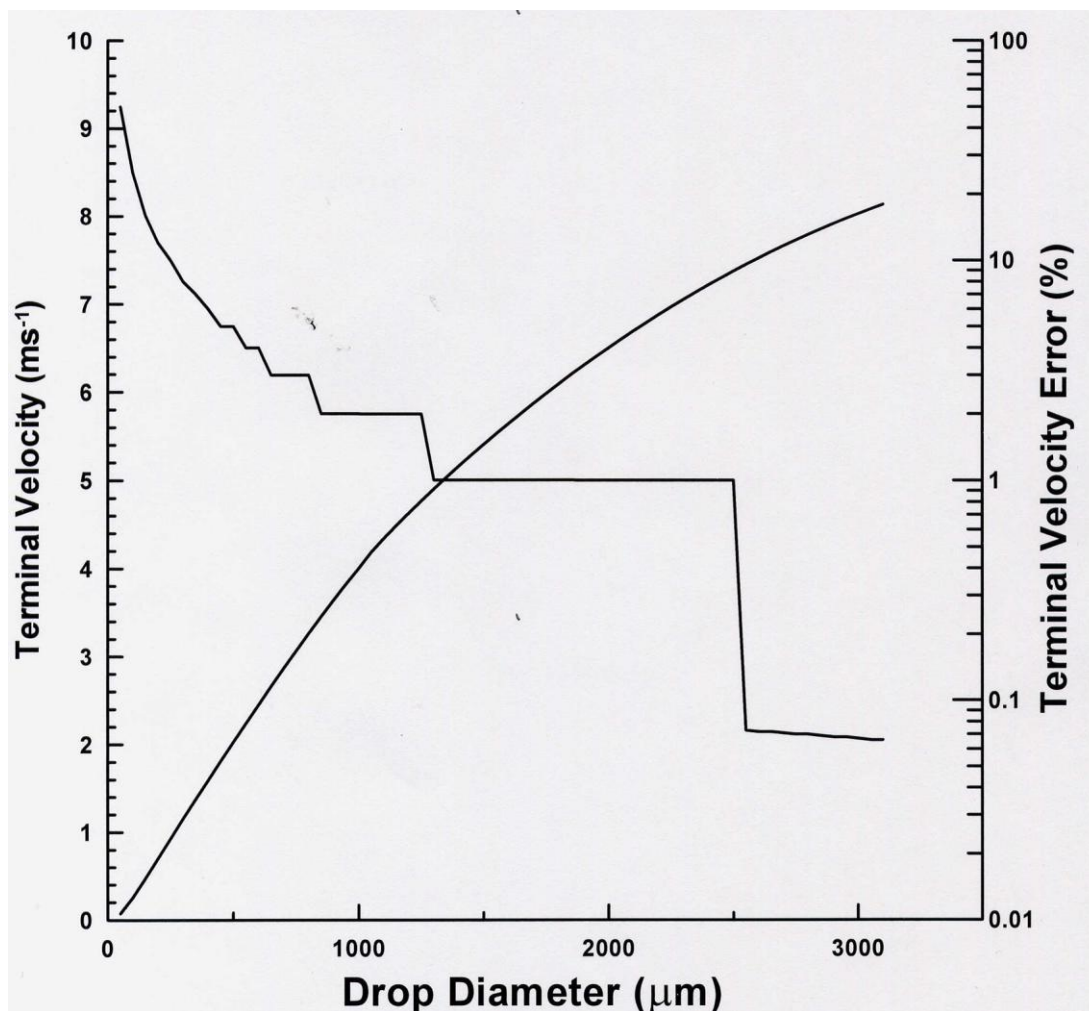


Figure 3: Terminal Velocity Error as a Function of Terminal Velocity and Drop Diameter

5.4 Reflectivity

The reflectivity, Z , is a parameter that is used to relate the amount of microwave energy returned to a radar from an ensemble of particles and is defined as

$$Z = \sum_{i=1}^N c_i D_i^6$$

where the unit of Z is $\text{mm}^6 \text{m}^3$.

One of the powerful uses of radar is to estimate the rainfall amounts from the direct measurement of reflectivity. The MPS measurements are one of the mechanisms for

deriving a relationship between rain rate and radar reflectivity. As shown in the following figure, a power-law relationship of the form $Z = aRR^b$ describes the relationship very well.

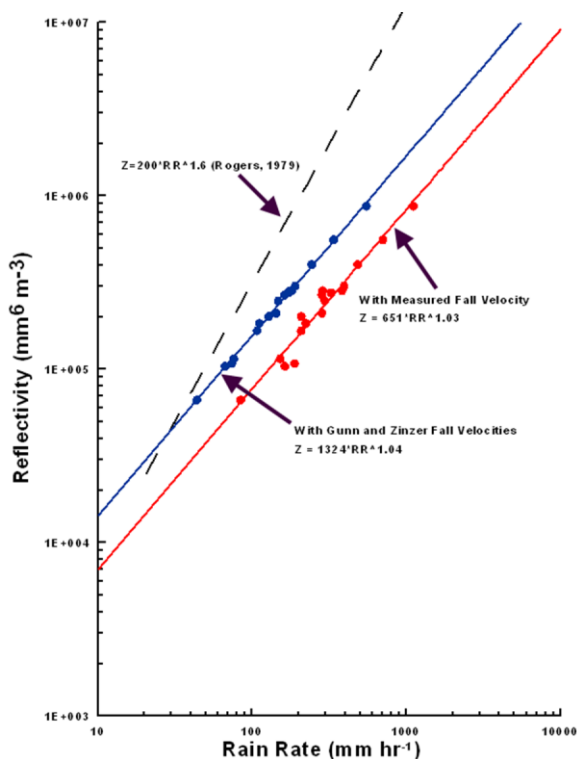


Figure 4: Rain Rate vs. Radar Reflectivity

This figure, which uses the ground-based measurements from the MPS, also illustrates two other very important features. First, as discussed previously, the rain rate can be calculated from the droplet spectra and terminal velocities derived from laboratory results (Gunn and Kinser, 1949; Beard, 1977) or measured directly. The colored, filled circles and the least squared fits show how the resulting rain rates differ depending which particle velocity is used. The exponent of the Z-R relationship is identical but the coefficients differ by a factor of two. This implies that the rain rate, if predicted from the reflectivity, would be underestimated by a factor of two if the Z-R relationship using the Gunn and Kinser terminal velocities instead of those directly measured.

The second feature drawn on the graph is a Z-R power-law relationship that is often assumed by radar meteorologist when estimating rainfall from reflectivity. The coefficient and exponent are quite different and, in comparison with the Z-R relationship derived from the MPS using the measured terminal velocities, the derived rainfall rate would be substantially smaller.

The uncertainty in Z is quite large because of the sixth power relationship to particle diameter. Ignoring at the moment the considerable error in determining D for non-spherical particles, for uncertainties in number concentration, c, and diameter, D, of 20%

for water droplets, the subsequent, root-sum-squared error in determining Z is approximately $\pm 53\%$. This error increased to more than 200% when the uncertainty in diameter is larger than 20%. In addition, for non-spherical particles, the equation for Z is no longer applicable and needs to be replaced with a more complex formulation that takes into account particle shape and the associated change in dielectric constant.

5.5 Interarrival Time Information

The time of arrival of each particle is recorded with each of the particle images stored in the particle image buffer. This time is calculated with a resolution of 125 ns. The arrival time provides a valuable research tool for looking at how precipitation is distributed in time with respect to precipitation rates and the measured versus expected distributions in time. For example, rain burst events can be distinguished from constant rainfall. Another event that might be detected would be drop break-up occurring due to hydrodynamic instabilities caused by turbulence. Both of these events, important in the interpretation and comparison with satellite or radar measurements, would be seen as non-Poissonian distributions in time, diverging from uniformly random spatial distributions.

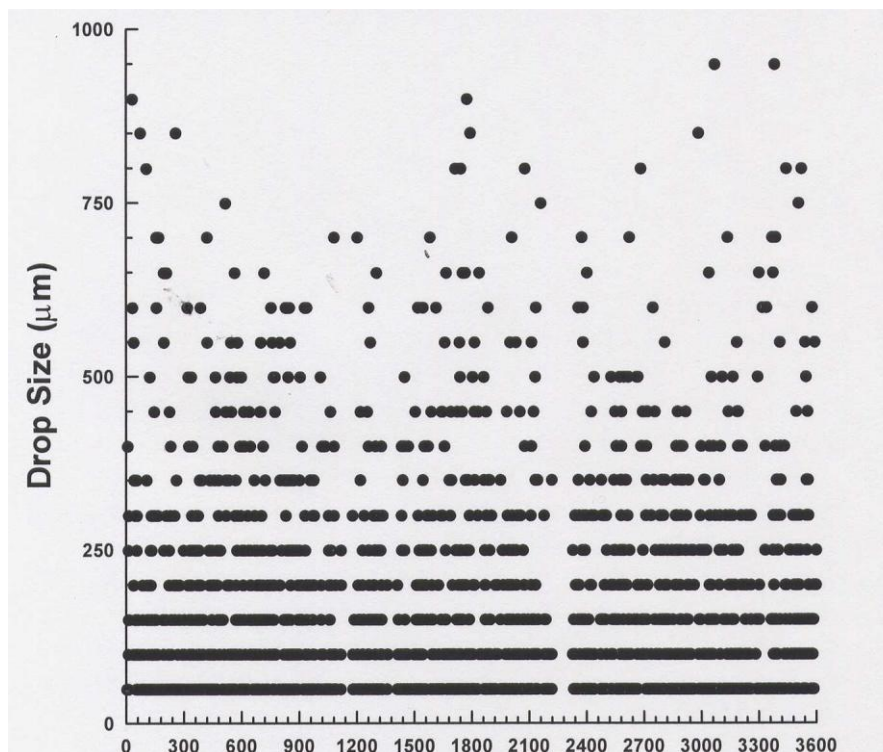


Figure 5: Simulated Raindrop Distribution for a One-Hour Period

Figure 5 illustrates a useful method for examining rainfall events, where the individual sizes of precipitation drops are plotted as a function of time. These are simulations of

what the MPS would be expected to measure if the size distribution of raindrops followed a Marshall-Palmer probability distribution, i.e.

$$N(D) = N_0 e^{-\Lambda D}$$

$$\Lambda = 4.1RR^{-1}$$

Where $N(D)$ is the concentration of particles of size D , in units of $m^{-3}mm^{-1}$, N_0 is a constant, 8×10^3 , and RR is the rain rate in $mm\ hr^{-1}$ ($= 50\ mm\ hr^{-1}$ in Fig. 7).

Another way to examine and evaluate the uniformity of the rain rate is to look at frequency distributions of drop arrival times. The arrival rate of drops with size, D_j , and concentration of C_j is given by

$$R = C_j V_j A$$

Where V_j is the fall velocity of the drop with this size, and A is the sample area of the MPS. The probability of a drop arriving within a time period, $t=t_0$, after a previous drop of the same size is just

$$P(t = t_0) = Re^{-Rt_0}$$

The measured frequency distribution can then be tested statistically against the predicted distribution. Figure 6 illustrates some simulated frequency distributions using the same parameters for the Marshall Palmer distribution in the previous example.

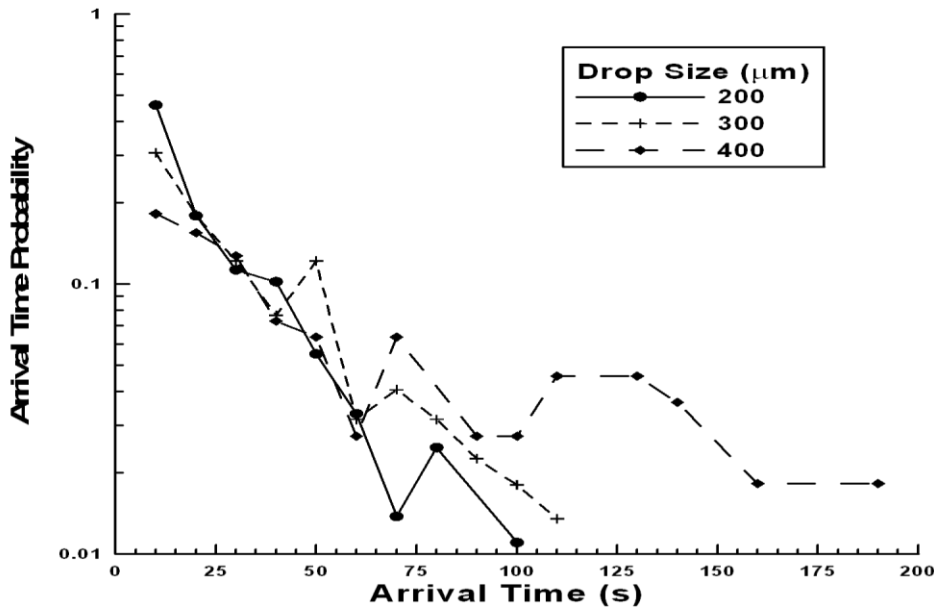


Figure 6: Probability of Drop Arrival Time as a Function of Drop Size

5.6 Selection of Clock Timing

As discussed in an earlier section, the MPS calculates size spectra at a synchronous rate of one spectrum each second and sends these 64 channels of information (in addition to the housekeeping) to the data system. The individual particle images are stored in a separate buffer that is transmitted asynchronously to the data system after it is filled. The particle size that is used to create the size spectra is determined from the maximum width of an image. This width is partially dependent upon the rate at which the diode array is sampled, a rate that is set by the air speed clock. The air speed clock is a manual setting that the user selects from PADS, the data system software. Ideally, the clock rate should be set to a rate such that the diode array is sampled each time the images moves past the array a distance equal to one array width. In this way the image will remain symmetric with respect to the length and width. The particle velocity through the array is variable since the terminal velocity varies with size. As it is impossible to change the clock rate dynamically to adjust to each particle's fall speed, the clock rate should be set to some optimal value. Figure 7 shows the effects of clock rate on how particles are sampled and stored.

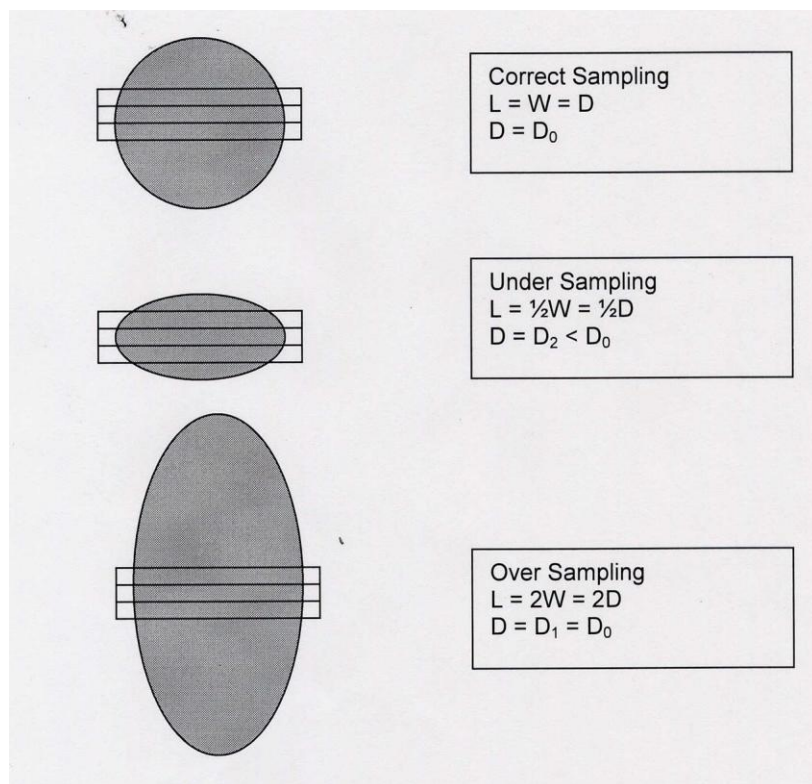


Figure 7: Effect of Sampling Clock Rate on Particle Aspect Ratios

In Figure 7, the rectangular boxes represent the diode array. Multiple boxes illustrate multiple slice samples of an image as the image moves across the array. In the case of

sampling correctly the length, L , and width, W , of a symmetric object will be undistorted and the image will accurately reflect the shape of the actual particle. If the clock is set faster with respect to the fall velocity of the particle, the length of the sampled image will be longer than the width *in the real-time displayed images*. The derived size, however, will still be accurate since the width is correct and the sampling is fast enough to capture the details of the image. In the case of undersampling, the image is again distorted with the length now less than the width. Depending on the degree of undersampling, the measured width can be less than the actual width.

From this discussion it would appear that the obvious choice is to set the clock fast enough to sample correctly the particle with the highest expected fall velocity. The disadvantage of this approach is that the smaller particles with substantially slower fall velocity will be oversampled by factors of 10-100. This creates copious quantities of image data since the image buffers will be filled with the smaller particles with a large quantity of extra data slices. Undersampling runs the risk of introducing unacceptable uncertainties in the measurement of the particle size.

This problem has been simulated by modeling the operation of the MPS and calculating the number of slices that would be produced for drops of different sizes falling at their terminal velocities but sampled at different rate. Figure 8 illustrates how the slice count is a function of particle size and clock rate. Figure 9 shows the error as a function of clock rate and drop size.

From these figures can be seen that a clock rate of 50 kHz maintains the total number of slices that are stored in an image buffer to less than 20/particle and the size error is on the order of 1% or less. The true air speed clock is set by the user in terms of air speed in ms^{-1} , and not in terms of frequency. To convert frequency to air speed, multiply the desired frequency by the size resolution of the MPS. If the resolution is 50 μm , and the desired frequency is 50 kHz, then the air speed clock would be set to 25 ms^{-1} .

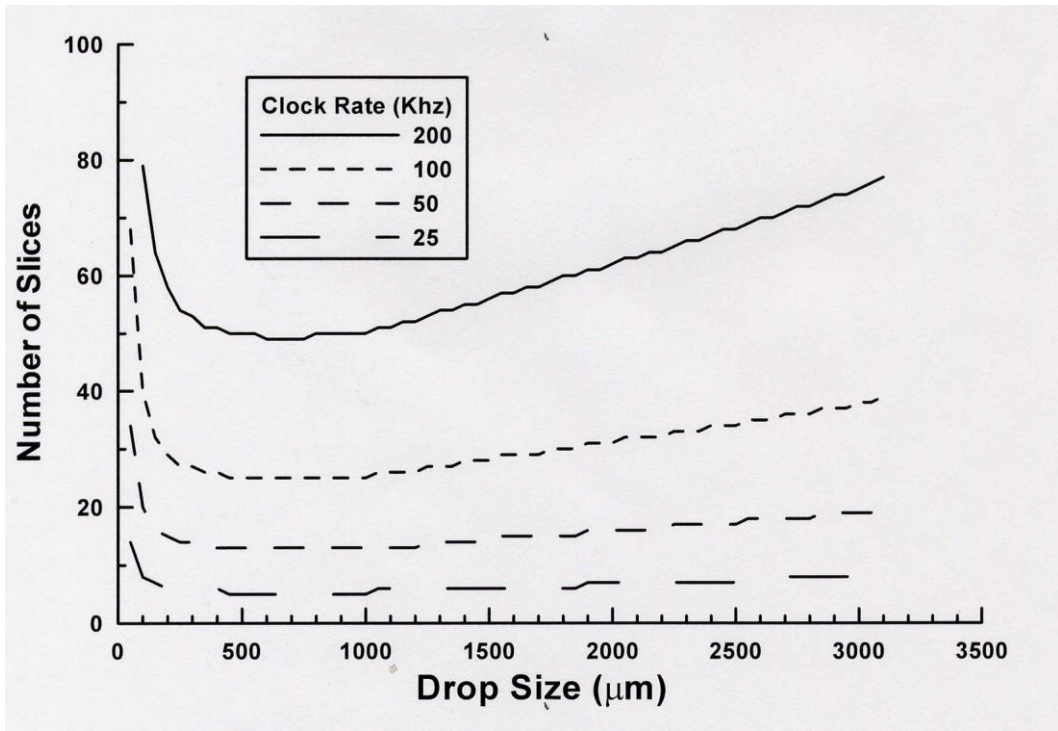


Figure 8: MPS Clock Rate, Drop Size, and Number of Slices Generated

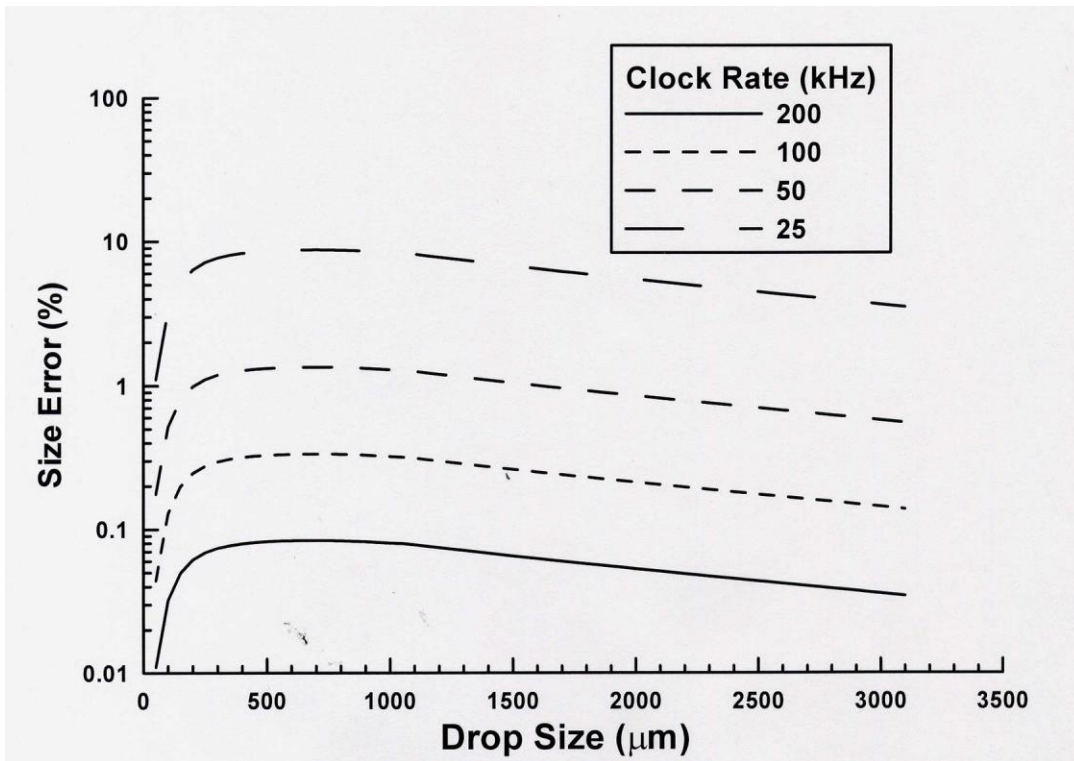


Figure 9: Error as a Function of Clock Rate and Drop Size

6.0 Electronic Trouble Shooting And Repair

The MPS electronics are modular in design, which will allow for in-field trouble-shooting and repair. There are four printed circuit boards (PCB's) that implement the MPS: Back Plane, Power Mod(ule), DSP Mod(ule) and the Diode Array. Schematics for each are shipped with the probe.

6.1 Power Distribution

Power distribution is routed through the power/auxiliary board located in the base of the MPS. There are four LEDs on this board that show the status of the +/- 15 and +/- 5 V power supplies. If any of these LEDs are not lit, there is a basic power problem in the MPS.

The back plane routes all the signals, including power, between the diode array and DSP boards, so it and the power module should be checked first in case of problems to ensure proper mating of connectors and existence of required voltage levels.

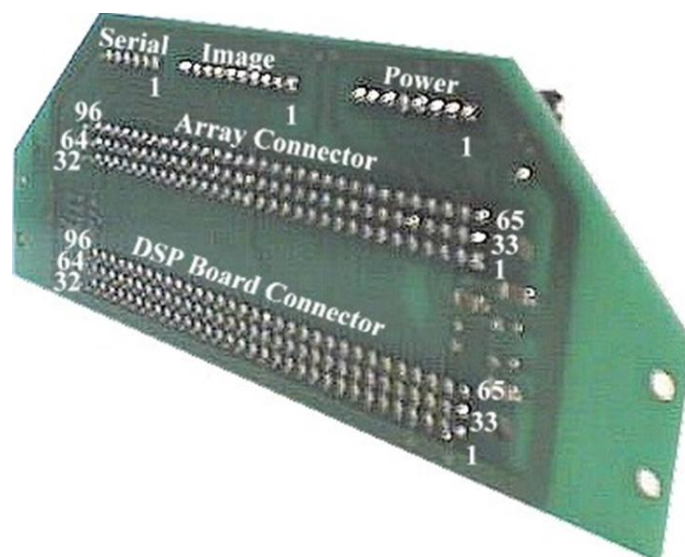


Figure 10: MPS Back Plane Board

Figure 10 shows the back plane board with the pins numbered to help in finding specific pins. Note that the two 96-pin connectors have pin one on the lower right-hand corner, and the AMP connectors on the top also have their pin ones on the right.

To verify proper operation check for the following with the probe on:

- Check for +5 Volts on pin one of both the DSP Board and Array connectors (ground is on pin 4 of the DSP Board connector, and 5 of the Array connector).
- Check for -5 Volts on pin two of the Array connector.

- Check for +15 Volts on pin two of the DSP Board and pin three of the Array connectors.
- Check for -15 Volts on pin 34 of the DSP Board connector.
- If any of the voltage levels is bad, check the power connector for the correct levels (+5V on pin 1, ground on 2, -5V on 3, 15V on 5, -15V on 7).

If any problems exist only at the back plane board, check that all the boards are mated tightly with their respective connectors.

6.2 Probe Communications Problems

If the probe fails to communicate with PADS, and the power has been checked, look to see that LED1, on the bottom of the DSP board, is lit. If it is unlit, the DSP board is not working. Contact DMT for assistance. If it is working, there are other things to look for.

If the clear to send signal is at an improper level on the image connector, the probe will stop communicating with the host computer (PADS); in such a case, PADS will generate a probe error. If this occurs, disconnect the image connector at the host computer (with the computer and the probe turned off). Power up, start PADS and attempt to communicate with the probe. The clear to send signals are pulled to the correct value when there is nothing connected to them, so if the probe communications resumes through this test, there is most likely a problem with the host computer's high-speed serial interface card, or with PADS calling the card's driver.

If the previous test does not cause communications to resume, there may be a problem with chip U31 or U16: the RS422 and RS232 interface chips, respectively. Assuming RS422 is used, check for signals, using an oscilloscope, on U31 pin 2 when the Start Sampling command is given in PADS. If there is no signal generated, check that there is a signal at pin 8. If these two conditions are true, then the part has failed and needs replaced. If there is a signal at pin 2, watch pin 3, then execute the Start Sampling command in PADS. If there is no signal here (but there was on 2), then the chip is okay—something is wrong with the system. If there is a signal on pin 3, watch pin 5. If, after executing Start Sampling again, there is no signal here, the chip needs replaced. If there is a signal on 5, but no communications with PADS, there is a problem with cables or connectors. Check the Serial connection on the back plane PCB, the computer connection

If the RS422 chip has failed, replace it with a MAX3490 ESA from Maxim¹. If this is not a possibility, try running the probe in RS232 mode. To do this, switch jumpers J6, J7, J8, J9 and J10 to RS232 on the DSP board (requires removal and installation of board), then, using DMT's RS422 to RS232 adapter on the computer side cable connection, plug into the standard serial port on the computer, switching the instrument's port number in the "Probe Setup", "DMT Probe X", "Settings" window.

¹ See Appendix A for vendor information.

6.3 Image and Data Problems

If the computer attached to the MPS is displaying information chaotically, turn off both the instrument and the computer. Then turn the computer back on and allow it to boot before turning the instrument on again. This should resolve the display issues. The computer must always be allowed to boot up before power is applied to the instrument.

If the probe is producing no images, and/or the size histogram is empty, or the images consistently have one diode that is always dark, there may be a failure on the diode array board. A discussion of the array board and how it processes the diode array signals will help in diagnosing failures on this board. Refer to the Diode Array schematic, and turn to the page labeled Diode Array Amplifiers - 1, 3, 5, 7. The amplifier chain at the bottom of the page will be discussed.

On the array board, there are 64 analog signal-processing circuits (the PCB is a high density 12 layer board, with multiple ground and power planes). The input marker labeled IN-D is the input from a reverse biased photodiode. When a particle is shadowed, the photodiode produces a current that flows through R155, the 10K Ω resistor, generating a positive voltage swing on pin 14 of U16 on the order of 1 mV. Amplifier U17D inverts and amplifies this signal, producing a negative swing at its output, viewable at the TP7 test point (this is diode seven's output). Normally, the signal at TP7, with the laser incident on the array, is between 2 and 3.5 Volts. When the diode is fully shadowed, the voltage drops to approximately 100 mV. Amplifier U18D DC couples this signal and divides it by $\frac{1}{2}$. Thus comparator U61C will switch from high to low at its output, pin 8—labeled Diode-D, when shadowing of the laser drops the voltage at TP7 to $\frac{1}{2}$ its full laser incidence voltage. Note that as the laser is shadowed, the charge stored on capacitor C32 begins to bleed off, and the Output of U18D will begin to decay.

Looking now at the NAND/NOR page of the schematic, note that all 64 of the comparator outputs are ANDed, then ORed together, so that if any one comparator goes low, the - PARTICLE signal goes low. The digital electronics on the DSP board watches this signal to determine when there is a particle, and begins storing image data. If the signal stays low for more than 100 sample clocks, the electronics stops storing the image until this signal again goes high. *Therefore, if any one-signal chain fails such that its comparator output is stuck low, the MPS will stop measuring particles.* Note that the DOF comparators perform the same function, but require the DC test point outputs to drop to $\frac{1}{3}$ their nominal voltage before triggering; the digital electronics only use this signal to determine whether the particle should be rejected (if the user selects this option in the “Probe Setup”, “DMT Probe X”, “Settings”, “Particle TAB”) based on depth of field. It does not affect particle image acquisition.

The last thing in the circuit to note, going back to the amplifier chain, is R129: a potentiometer. This adjusts the DC voltage of TP7. When there is no light on the diode array, all test points are set to approximately 200 mV.

If the problem occurring is a diode that is always light in the images, the voltage at the test point is probably stuck high. Monitor the test point and block the laser from hitting the diode array. If the test point voltage doesn't drop, there is a problem with one of the first two stage amplifiers. It is possible that the potentiometer has a problem, but more likely, one of the two operational amplifiers has failed. The first one is an OPA4650U-ND from BurrBrown¹; the second is an AD8004AR-14 from Analog Devices¹. If the test point voltage is okay, then the 3rd stage Op Amp or the comparator has failed. If so, replace the OP Amp with a LT1356CS from Linear Technologies¹, and the comparator with a MAX908CSD from Maxim¹.

If the problem occurring is no images, and/or no sizing histogram data, then a test point has probably failed at a low voltage. First check the -Particle signal: pin 30 on the Array Connector of the back plane board (see Figure 10). If it is high when the laser is not blocked, but goes low if the laser is blocked briefly, then the diode array board is not the problem. If the test shows the array board is not working, check the diode test points with full laser incidence on the diode array. If the voltage is well below 2V at any of them, something is wrong. Try replacing the first and second stage amplifiers. If these signals are okay, continue down the signal chain until an incorrect signal is found.

7.0 Maintenance

7.1 Optical Cleaning

There is little maintenance required to keep the MPS operational. The one problem that can arise, and affect the data, is the cleanliness of the optical windows. The rain and splash guards prevent most droplets from reaching the optical windows, located in each arm tip, but those droplets that do reach the windows will evaporate and leave a contamination layer on the window.

The laser diode voltages 1, 32 and 64 should be checked weekly. Significant drops in these voltages indicate the optics may need to be cleaned. A weekly visual check of the windows is also recommended. When the instrument is on and the windows are clean, only a faint red spot will be visible where the laser beam passes through the center of the window. Dirt on the window will scatter laser light, causing the spot to be much brighter. Note that these two weekly checks should increase in frequency if the instrument is operating in severe conditions. Such conditions include when the instrument is operating in a sandy area, in an area with a high concentration of industrial soot, or in an area within five miles of the ocean.

¹. See Appendix A for vendor information.

To clean the windows, turn off the MPS and gently wipe the center of the window with a cotton swab moistened with a suitable solvent. The choice of solvent depends on the particular contamination. Since the contaminant is usually unknown, we recommend starting with a commercial glass cleaner such as Windex followed with isopropanol. If this does not work, a solution of ammonia or acetic acid followed by isopropanol can be tried. Acetone works well for oily substances. If the window is very dirty and the swab just brings more dirt from the edges to the center, the window cover, held by four screws, can be removed and then the window itself removed and completely cleaned by the above technique (see Figure 11).

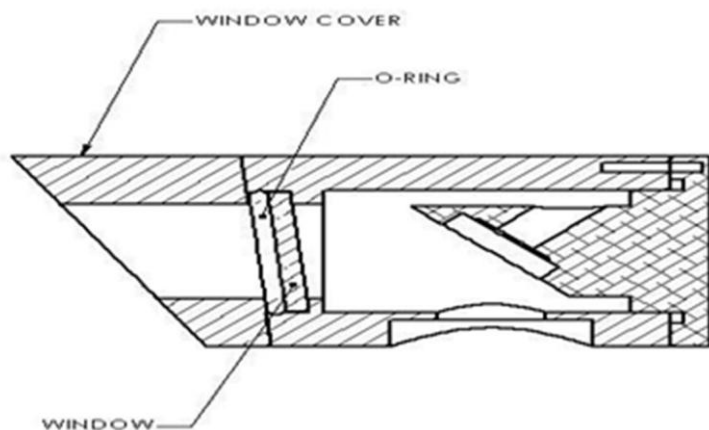


Figure 11: MPS Window Components

7.2 Optics Alignment

Diode voltages significantly below 1 V usually indicate that the laser optics are out of alignment. When this happens, it is recommended that the unit be shipped to DMT or a DMT-certified service center to have the instrument serviced because optics alignment has to be performed by a skilled optics expert.

Appendix C: DMT Instrument Locator—Operator Guide

Purpose

The Droplet Measurement Technologies (DMT) Instrument Locator tests whether a DMT instrument is responsive to an initialization command. This can be useful in determining if an instrument is powered on and has functional communications lines, or in verifying the serial port number that each instrument is connected to. Beyond this, the software does not ensure that the instrument is functioning properly.

This document describes version 1.0.1 of the Instrument Locator. This version of the program supports the following DMT instruments:

- APSD
- BCP
- CAS and CAS-DPOL
- CDP and CDP-PBP
- CIP and CIP-GS
- CPSD
- FM-100
- FSSP
- MPS
- PCASP-100X
- PCASP-X2
- PIP

Installation

The DMT Instrument Locator is on a USB stick included in a sealed plastic bag. To install the software, follow the instructions on the small card also included in the bag.

Operation

1. To open the Instrument Locator, navigate to `C:\Program Files\PADS 3` and double-click on `DMT Instrument Locator.exe`. You will see the window in Figure 1.

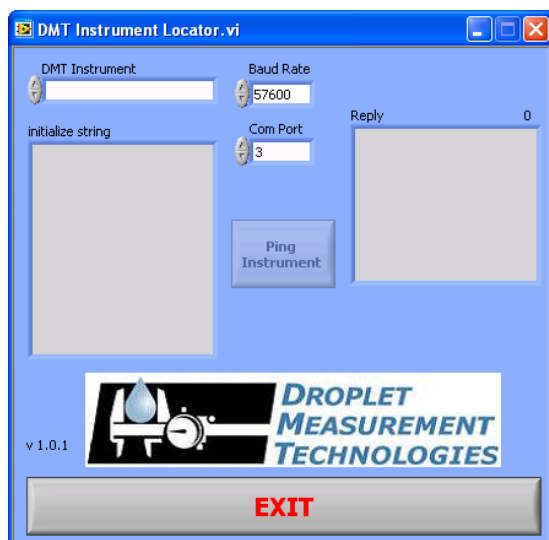


Figure 12: Instrument Locator

2. Click on the **DMT Instrument** field to bring up a list of available instruments. (Grayed-out instruments have not yet been tested with the Instrument Locator.) Select your instrument from the list. The **Baud Rate** will auto-populate, though in some special cases you may need to adjust the baud rate for your specific instrument.
3. Select the COM port for the instrument you want to test.
4. Click on **Ping Instrument**.
5. The Instrument Locator will display the initialization string sent to the instrument and the instrument's reply. All instruments reply with "0606" when sent a valid initialization command. If there is no reply, the Instrument Locator will indicate this with a **No Reply** indicator. The Instrument Locator also displays a possible reason for the communication failure in the **Reply** box.
6. To quit the Instrument Locator, click on **Exit**.

Note: Several DMT instruments—the CDP, CDP-PbP, BCP, FSSP, and FM-100—all respond to the same initialization string. The instrument locator simply sends this string to the instrument. The program has no way of knowing if the instrument connected to the COM port is actually of the correct type. Thus, if you have multiple instruments in your system, it is important to specify the correct COM port for the instrument you wish to test.

Appendix D: Revisions to Manual

Rev. Date	Rev No.	Summary	Section
9-30-09	C-2	Updated Signal and Wiring Diagram	Appendix
2-5-10	C-3	Added warning to boot computer before probe	4, 6
7-8-10	D	Deleted old calibration section, which has been replaced by spinning disk manual	3.2
		Omitted packing list	Appendices
11-10-10	E	Added instructions on diagnosing optics problems and severe conditions maintenance	7.1
11-29-10	F	Added information on new size-range option Updated data system specifications Updated set-up instructions to reflect replacement of desktop computer with laptop	1.2, 2.1
6-6-11	G	Corrected voltage output on TP7 when diode is fully shadowed	6.3
4-23-12	H	Removed Schematics	Appendix B
		Added information about DMT Instrument Locator	Appendix C