CuraTerrae

Meteorological Particle Spectrometer (MPS-2)

Operator Manual

DOC-0405 RevA

DROPLET MEASUREMENT TECHNOLOGIES

2400 Trade Centre Avenue
Longmont, CO 80503 USA

Trademark Information

All Droplet Measurement Technologies, LLC. (DMT) product names and the Droplet Measurement Technologies, LLC. logo are trademarks of Droplet Measurement Technologies, LLC.

All other brands and product names are trademarks or registered trademarks of their respective owners.

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 warrantied 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.

CONTENTS

List of Figures

Warning

The Meteorological Particle Spectrometer contains a 685 nm wavelength laser capable of producing 50 mw of power. Use eye protection when working around the exposed beam.

1.0 Product Description

1.1 Introduction

The Meteorological Particle Spectrometer (MPS-2) 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-2 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-2 uses all solid-state electronics, and requires minimum warm-up time.

Figure 1: Meteorological Particle Spectrometer

1.2 MPS-2 Specifications

Technique:	Optical array imaging (64 element: 62 sizing elements, end diodes reject)
Size Range:	50 µm – 3.1 mm (50 µm resolution, standard resolution) 25 µm – 1.55 mm (25 µm resolution, special-order option) 100 µm – 6.2 mm (100 µm resolution, special-order option)
Sample Area:	Refer to "Data Analysis User's Guide, CH-2", Doc-0223
Arm Width:	200 mm
Number of Size Bins:	62 bins. Particles imaged on element 1 or 64 are end-diode-rejected
Sampling Frequency:	1-0.1 Hz
Laser:	660nm, <30mW
Data System Interface:	1-D histogram data, housekeeping data, and instrument control: RS-422 at 57,600 baud 2-D image data: RS-422 at 460,800 baud
Operating Temp:	-40 to +40 degrees C
Altitude:	0 to 3 Km (15Kft)
Humidity:	0 to 100%
Power Requirements	Universal AC Input (115/230VAC), 50-60Hz. 300W
Weight:	21.8 Kg (48 lbs)

2.0 Instrument Setup

The system consists of a particle sensor, a laptop computer, serial-to-USB adaptors, and a calibration verification tool (spinning glass disk with opaque dots). The sensor is shipped and stored in a reusable prefabricated shipping case. The computer and calibration verification tool are shipped in a cardboard box.

2.1 Connecting Components

Please carefully open the instrument shipping boxes, take out the components, and place them on a sturdy surface. Attach the vane to the main unit as shown in the diagram in Appendix D.

Next, follow these steps to set up the system:

- Connect the MPS-2 power cable to a power source.
- Turn on MPS-2 power (toggle switch up; the light will be on).
- Insert green PADS software key (labeled “PADS Key, S.N. xxx”) into a USB 2.0 port on the laptop computer.
- Connect the two SeaLevel 2106 adaptor cables (RS-422 to USB) cables to the MPS-2 Data cable connectors and to USB 2.0 ports on the laptop.
- Connect the laptop to a power source.
- Turn on the laptop.

2.2 Basic Health Check

Follow these 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-2 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-2 Diagnostics” tab.
- Check Diode Voltages. The value for “Diode Voltage” 1, 32, and 64 should be close to 2.0 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. The "Internal Temp" value should be close to ambient temp. The Window Temp is thermostatically controlled. It should be close to approximately 25 ºC.

When the diode voltages and temperatures are within normal ranges, the MPS-2 is in good working condition.

2.3 Calibration Verification

The MPS-2 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-2 should be mounted on a pedestal at a minimum of 1m above the surface. The mounting location should have no trees or overhead obstructions in the vicinity that would interfere with the falling precipitation.

During installation, support the instrument by holding its body and base plate. Lifting the instrument by the arms (that is, the optical heads) may cause damage.

3.0 Theory of Operation

The light from a laser diode is shaped into an elliptical beam to illuminate the volume where the precipitation is 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 (standard 50µ resolution) if perfectly centered. The illumination state of all 64 elements is sampled at a rate set by an internal digital clock. 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 actually is, so that particle is rejected from the sizing algorithm. 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 2-D buffer is full. The 1-D statistical data and housekeeping information is sent synchronously to the host when requested. The host can then display and store the data.

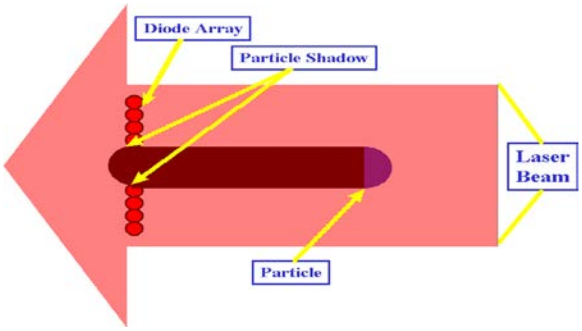


Figure 2: Particle Imaging with the MPS (Vertical View across Horizontal Optical Path)

3.1 Environmental

The optical heads of the MPS-2 are heated to prevent the window becoming coated with fog or frozen precipitation. These are thermostatically controlled at 25 ºC. The body of the MPS-2 contains two fans. One fan operates continually circulating air over the electronics. The other fan is designed to circulate outside air when the internal temperature rises above 35ºC. 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-2.

3.2 Calibration

Calibration of the MPS-2 is accomplished with a spinning disk calibrator that simulates particles passing through the beam. The glass disk has opaque dots of known diameter, the ring of dots passes through the laser beam at approximately 10m/s. This speed may vary and is related to the motor's input voltage and power supply. See the *Spinning Disk Calibrator Operator Manual*, DOC-0012, for details.

The MPS-2 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-2 is supplied with a laptop computer system. A Windows-based operating system and pre-installed PADS data collection software is included. The MPS-2 requires two serial data lines to the host computer. An RS-422 line transmits the 1-D histogram data (labeled "1-D Data") and housekeeping data, while a second RS-422 line (labeled "2-D Data") is used for transferring the 2-D particle images to the computer.

Note: If the computer attached to the MPS-2 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 PADS 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 update rates. See "Doc-0300, PADS Overview Manual", for operation details on the PADS software. See "Doc-0291, MPS-2 PADS Module", for specific details on the PMS graphical display.

5.0 Theory of Calculations in the MPS-2

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:

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

where

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

c_i = particle concentration of bin *i* in particles/cm^3

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

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

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:

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

These scaling factors then reduce to 3.6 x 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-2 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

Particle Fall Velocity can be determined in post data analysis. 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-2 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 ±25 μm (one-half the probe resolution). The residence time accuracy is ±0.25 μs. 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.

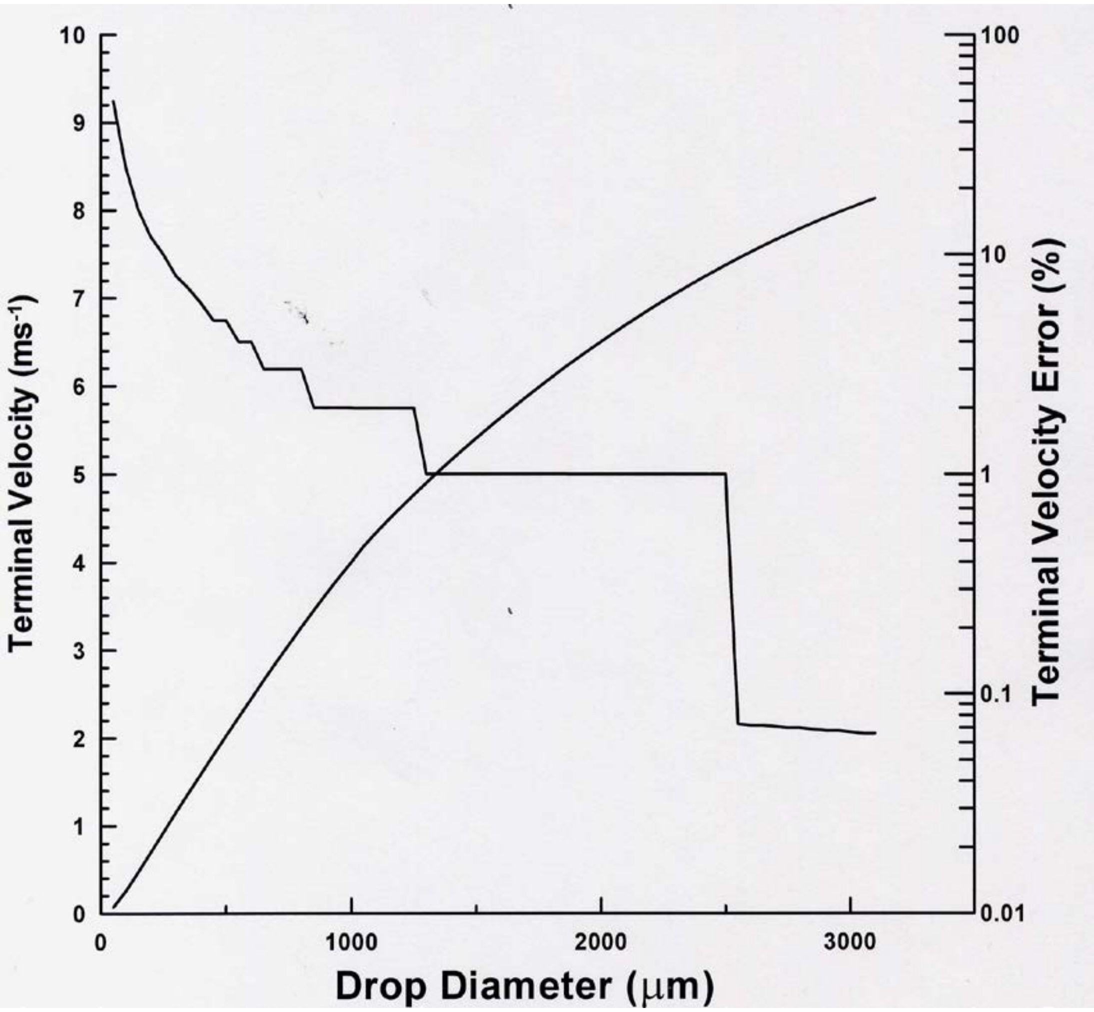


Figure 3: Terminal Velocity Error as a Function of Terminal Velocity and Drop Diameter

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 mm^6 m^3.

One of the powerful uses of radar is to estimate the rainfall amounts from the direct measurement of reflectivity. The MPS-2 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.

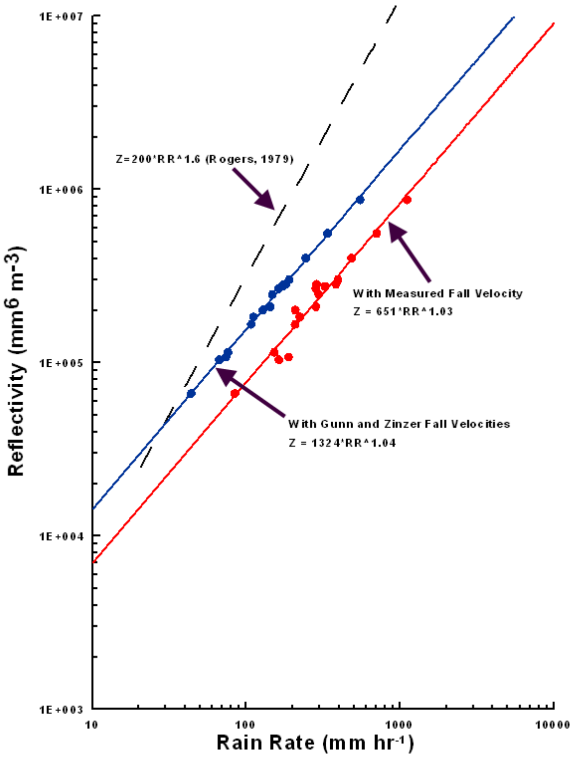


Figure 4: Rain Rate vs. Radar Reflectivity

This figure, which uses the ground-based measurements from the MPS-2, 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-2 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 ±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 Inter-Arrival 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.

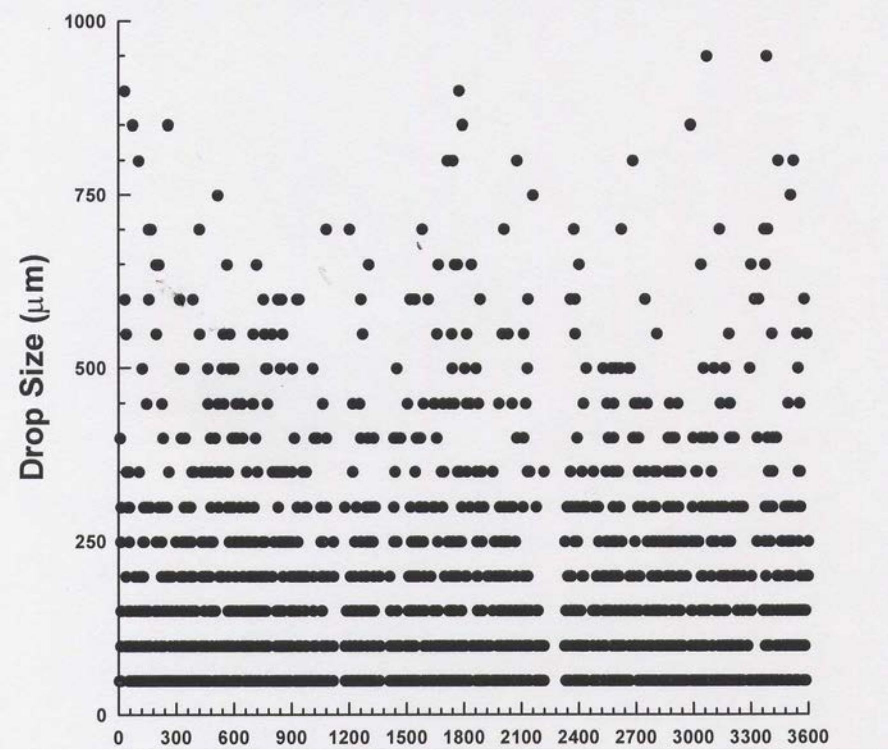


Figure 5: Simulated Raindrop Distribution for a One-Hour Period

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-2 would be expected to measure if the size distribution of raindrops followed a Marshall-Palmer probability distribution, i.e.

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

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

Where N (D) is the concentration of particles of size D, in units of $m^{-3}mm^{-1}$, N_0 is a constant, $8x10^3$, 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-2. The probability of a drop arriving within a time period, t=t0, after a previous drop of the same size is just

$$P(t = t0) = Re^{-Rt0}$$

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.

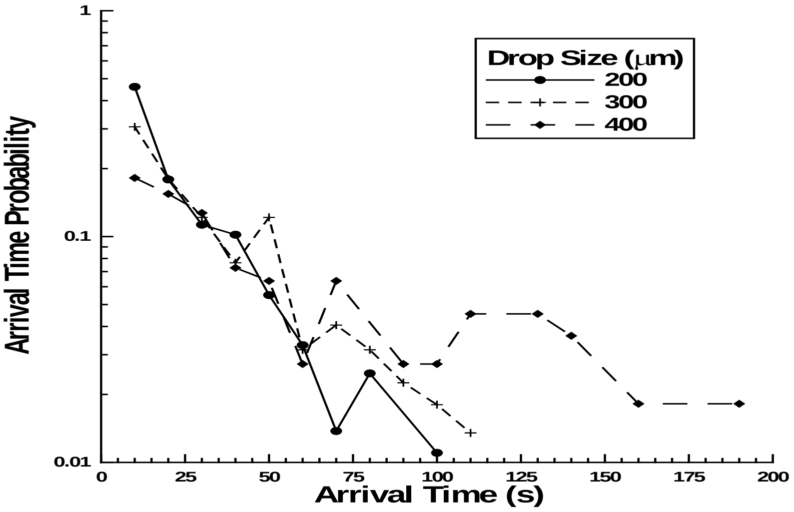


Figure 6: Probability of Drop Arrival Time as a Function of Drop Size

5.6 Selection of Clock Timing

As discussed in an earlier section, the MPS-2 calculates 1-D size spectra at a synchronous rate of one spectrum per 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 1-D 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.

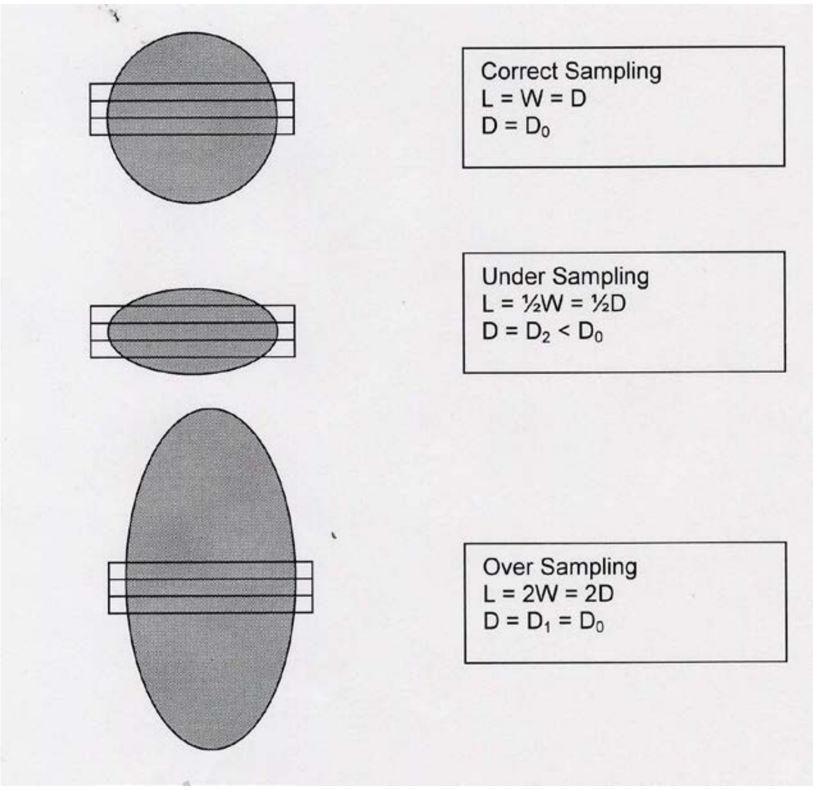


Figure 7: Effect of Sampling Clock Rate on Particle Aspect Ratios

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 under-sampling, the image is again distorted, but the length is now less than the width. Depending on the degree of under-sampling, 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. Under-sampling 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-2 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-2. If the resolution is 50 μm, and the desired frequency is 50 kHz, then the air speed clock would be set to 2.5 ms^{-1}.

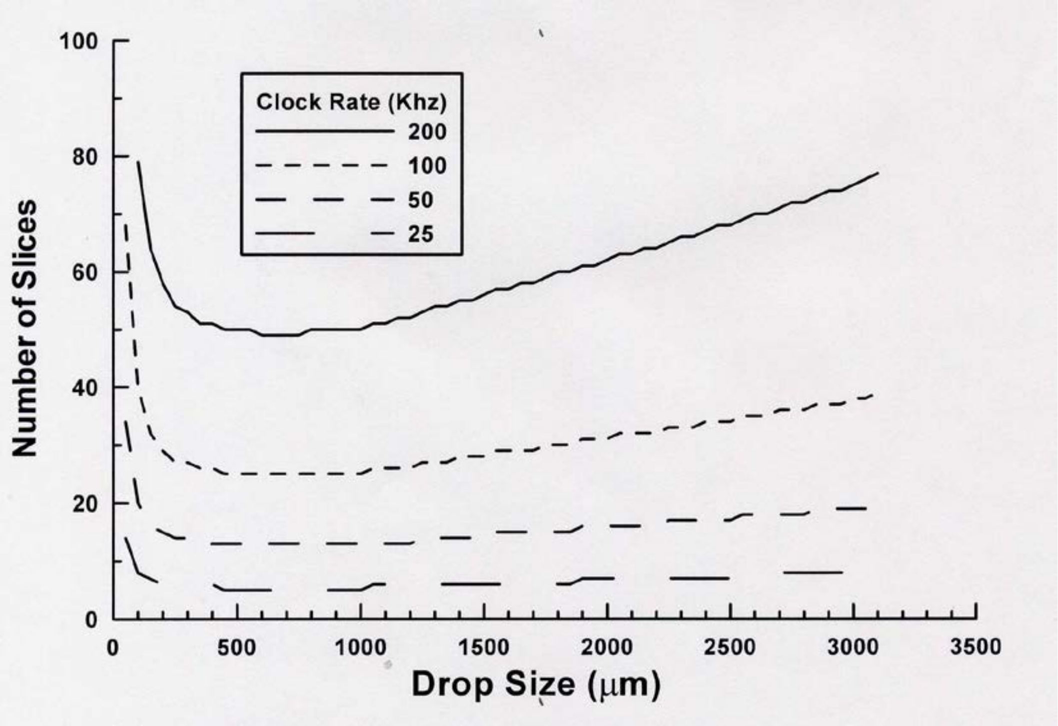


Figure 8: MPS Clock Rate, Drop Size, and Number of Slices Generated

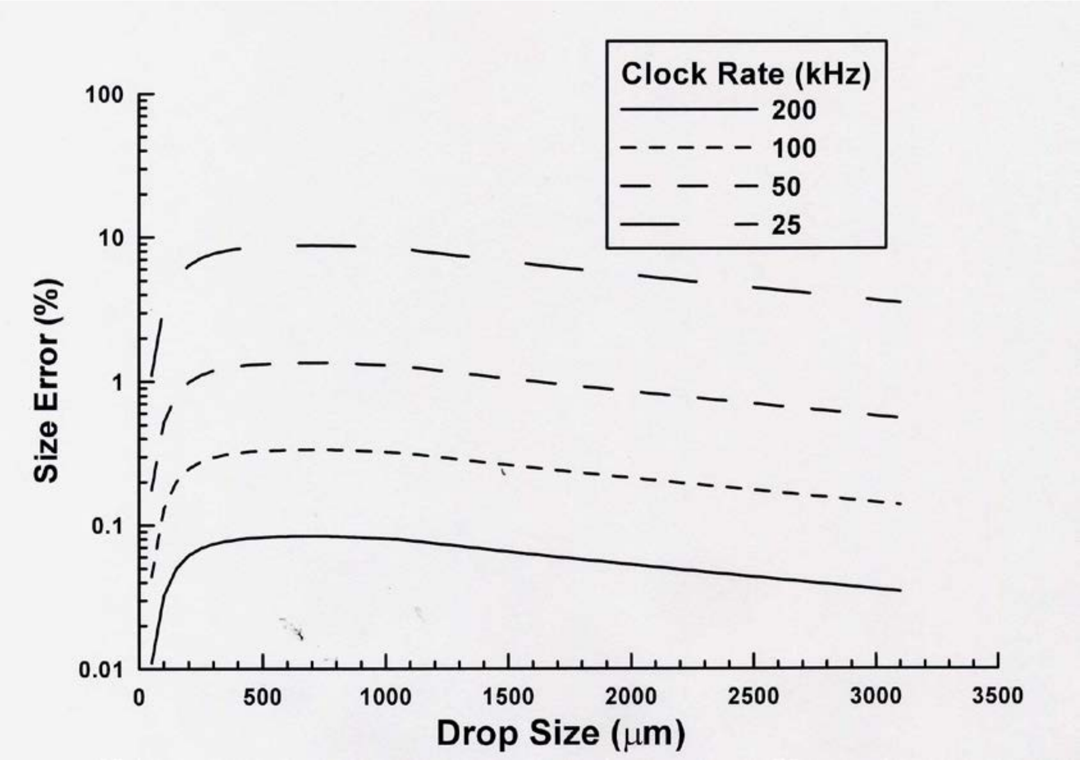


Figure 9: Error as a Function of Clock Rate and Drop Size

6.0 Electronic Trouble Shooting And Repair

The MPS-2 electronics are modular in design, which will allow for in-field trouble-shooting and repair. There are three printed circuit boards associated with the MPS-2, the Power Distribution board (ABD-0424), the Diode Array Module (ABD-0169), and the Digital Signal Processing Module (ABD-0170).

6.1 Power Distribution

The MPS-2 has an improved power system, in that an universal-input AC-DC power supply generates a source of 24VDC for system electronics and heaters. The 24VDC, on the ABD-0424 board, is converted to +/-5VDC for the diode array board and +3.3VDC for the Digital Signal Processor board. Heater and fan power distribution is routed through the ABD-0424 board located in the body of the MPS-2. There are four LEDs on this board that show the status of the 24VDC source, +/- 5VDC and + 5 VDC converters. If any of these LEDs are not lit, there is a basic power problem in the MPS-2.

Each fan and heater circuit is protected with an inline fuse, located on the ABD-0424 board. Voltage Test Points are available and clearly labeled.

Figure 10: MPS-2 power distribution board. Notice green LED's indicate good power levels.

7.0 Maintenance

DMT recommends returning your instrument to the factory for an annual cleaning and calibration. This will ensure your instrument is working properly and prolong its lifetime.

Optical Cleaning

There is little user maintenance required to keep the MPS-2 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 turned 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.

To clean the windows, turn off the MPS-2 and gently swipe the center of the window with a cotton swab moistened with a suitable solvent. Use the cotton swab for one swipe only, do not rub the windows as that can cause scratches. We recommend starting with white vinegar, as it is slightly acidic, followed by isopropanol or acetone. If the window is very dirty and the swab-cleaning 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).

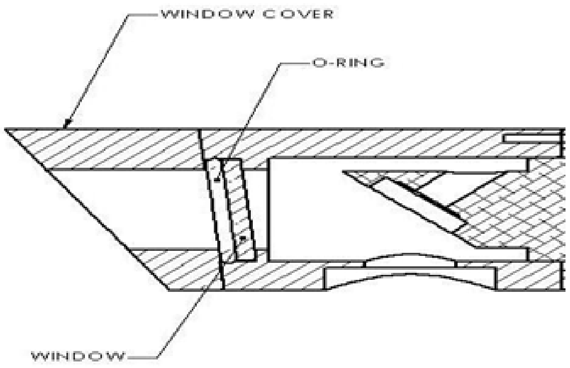


Figure 11: MPS Window Components

7.1 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.

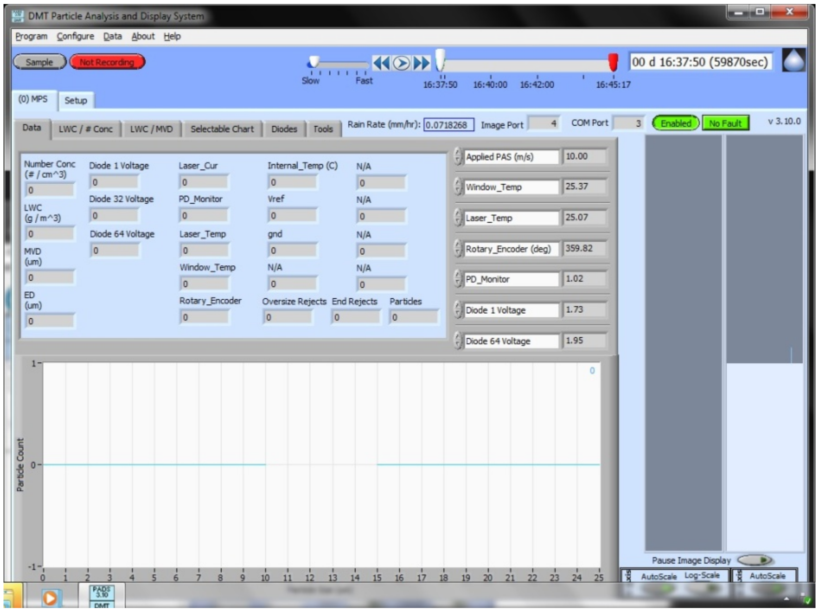
8.0 Calibration Routine: Internal Rotary Encoder

A new feature of the MPS-2 is the ability to know which direction the instrument is pointing. It should be pointing into the wind, and this new variable allows the user to determine how closely the MPS is tracking with the prevailing wind. This function can also tell the user how long it takes the MPS-2's rotation to settle into a stable position once the wind has changed direction.

The MPS-2 Rotary Encoder (RE) is an electrical device connected to the shaft of the internal slip-ring mechanism, the rotational center. The RE has a 0-5V output, corresponding to 0-360 degrees. This analog voltage is fed to the housekeeping Analog to Digital converter and requires a calibration procedure to successfully convert to rotational degrees.

Upon final installation at the research site, the MPS-2 base plate could be mounted in any random directional orientation. This calibration routine will generate an "off-set" compensation for how the base plate is fixed relative to the MPS-2 body. The following is a step-by-step instruction on how to calibrate the Rotary Encoder with PADS displaying in angular degrees.

1) From the main PADS screen (Figure 12) for the MPS-2, go to the "Configure" pull-down menu (top left)and select "Configure Instrument".



00 d 16:37:50 (59870sec)

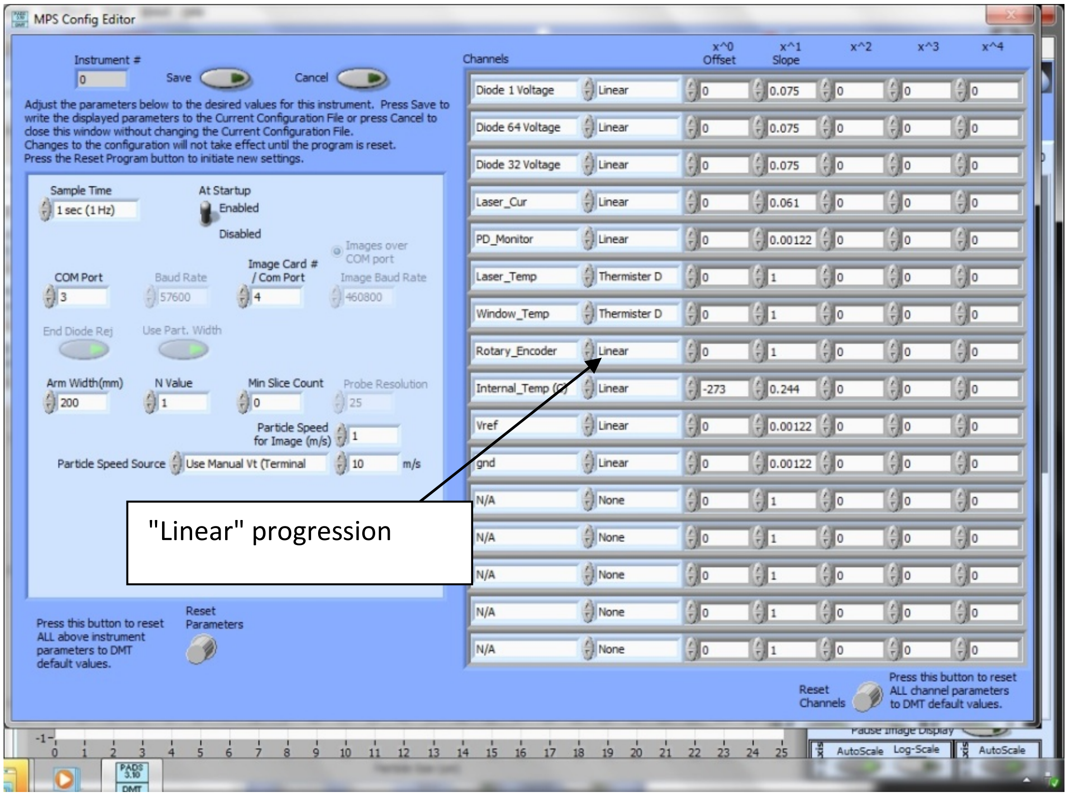
Rain Rate (mm/hr): 0.0718268
Image Port 4
COM Port 3

Number Conc (# / cm^3) 0
LWC (g / m^3) 0
MVD (um) 0
ED (um) 0
Diode 1 Voltage 0
Diode 32 Voltage 0
Diode 64 Voltage 0
Laser_Cur 0
PD_Monitor 0
Laser_Temp 0
Window_Temp 0
Rotary_Encoder 0
Internal_Temp (C) 0
Vref 0
gnd 0
N/A 0
Oversize Rejects 0
End Rejects 0
Particles 0

Applied PAS (m/s) 10.00
Window_Temp 25.37
Laser_Temp 25.07
Rotary_Encoder (deg) 359.82
PD_Monitor 1.02
Diode 1 Voltage 1.73
Diode 64 Voltage 1.95

Figure 12:Configure Instrument

2) The "MPS Config Editor" page (Figure 13) contains setup parameters and a list of calibration coefiffients pertaining to the Housekeeping parameters. Notice that the "Rotary_Encoder" row is setup with a linear progression and calibration coeficients such that the Offset is "0" and the Slope is "1". This will allow the PADS to display the Rotary Encoder in digital counts (12 bit range) on the Main page, 3rd column, bottom parameter.



Instrument # 0

Adjust the parameters below to the desired values for this instrument. Press Save to write the displayed parameters to the Current Configuration File or press Cancel to close this window without changing the Current Configuration File.
Changes to the configuration will not take effect until the program is reset.
Press the Reset Program button to initiate new settings.

Sample Time: 1 sec (1 Hz)
COM Port: 3
Baud Rate: 57600
Image Card # / Com Port: 4
Image Baud Rate: 460800
Arm Width(mm): 200
N Value: 1
Min Slice Count: 0
Probe Resolution: 25
Particle Speed for Image (m/s): 1
Particle Speed Source: Use Manual Vt (Terminal 10 m/s

Press this button to reset ALL above instrument parameters to DMT default values.

Channels		x^0 Offset	x^1 Slope	x^2	x^3	x^4
Diode 1 Voltage	Linear	0	0.075	0	0	0
Diode 64 Voltage	Linear	0	0.075	0	0	0
Diode 32 Voltage	Linear	0	0.075	0	0	0
Laser_Cur	Linear	0	0.061	0	0	0
PD_Monitor	Linear	0	0.00122	0	0	0
Laser_Temp	Thermister D	0	1	0	0	0
Window_Temp	Thermister D	0	1	0	0	0
Rotary_Encoder	Linear	0	1	0	0	0
Internal_Temp (C)	Linear	-273	0.244	0	0	0
Vref	Linear	0	0.00122	0	0	0
gnd	Linear	0	0.00122	0	0	0
N/A	None	0	1	0	0	0
N/A	None	0	1	0	0	0
N/A	None	0	1	0	0	0
N/A	None	0	1	0	0	0
N/A	None	0	1	0	0	0

Press this button to reset ALL channel parameters to DMT default values.

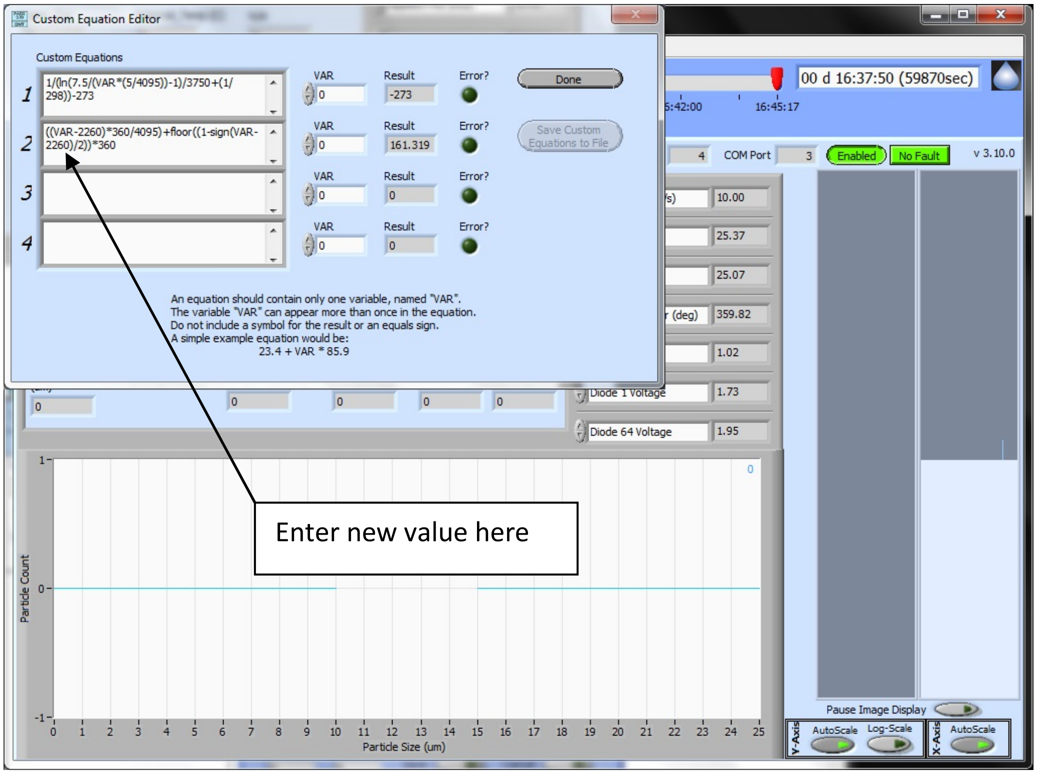
"Linear" progression

Figure 13:MPS Config editor

3) With the MPS-2 sensor-head pointing North (your choice, Magnetic North or True North) jot down the Main-Page RE value for future reference.

4) Stop Sampling and go back to the "Configure" pull down menu. Select "Edit Custom Equations".

5) In the second panel, for "Custom Equation #2" there are 2 places to make adjustments. Replace the "2260" values with the value jotted down in step-3 when pointing North.



Custom Equations

	Equation	VAR	Result	Error?
1	1/(ln(7.5/(VAR*(5/4095))-1)/3750+(1/298))-273	0	-273	●
2	((VAR-2260)*360/4095)+floor((1-sign(VAR-2260)/2))*360	0	161.319	●
3		0	0	●
4		0	0	●

An equation should contain only one variable, named "VAR".
The variable "VAR" can appear more than once in the equation.
Do not include a symbol for the result or an equals sign.
A simple example equation would be:
23.4 + VAR * 85.9

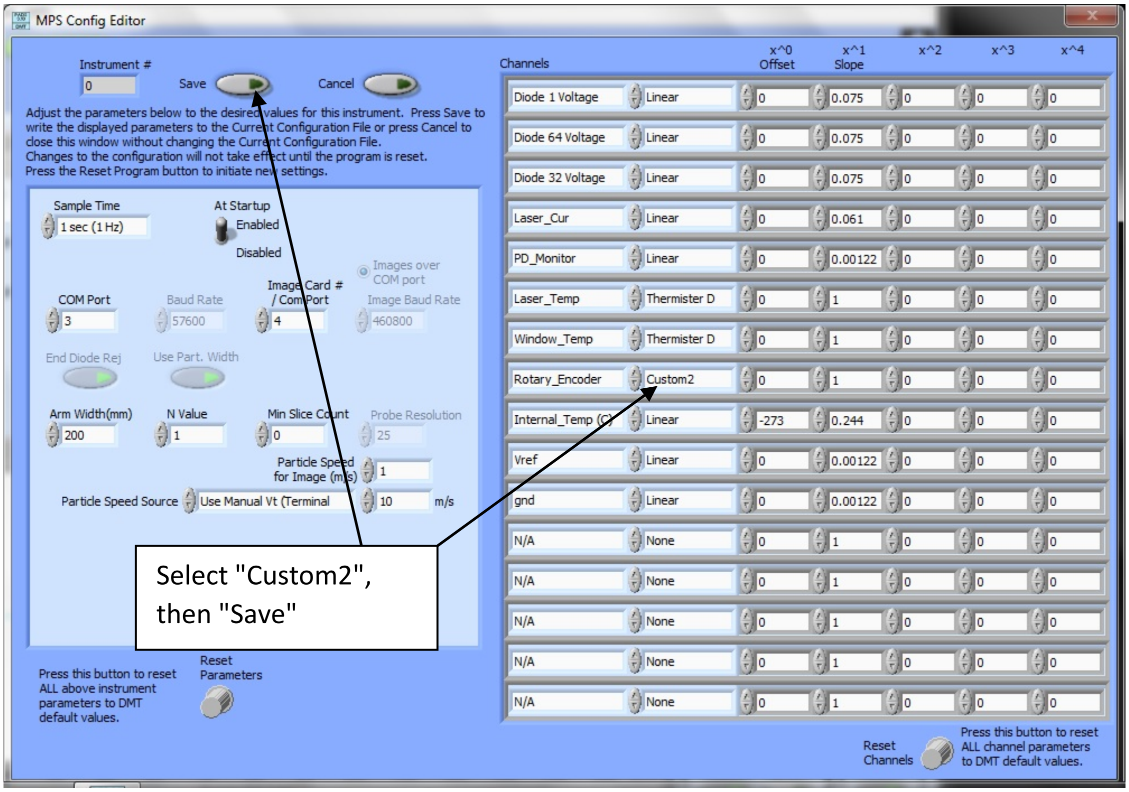
Enter new value here

Figure 14:Custom Equation Editor

When finished making these value adjustments, click the mouse curser in box #3 to close box-2. Then, click on the "Save Custom Equations to File" button. Answer "OK" to the write-over validation question. Tap on "Done" to complete the Custom Equation #2 adjustment.

6) In PADS, navigate back to the "Configure" pull down menu and select "Configure Instrument" page.

7) Change the Rotary Encoder type of formula from "Linear" to "Custom2". Tap on "Save", and then tap on the green "Reset Program" button.



Instrument # 0

Adjust the parameters below to the desired values for this instrument. Press Save to write the displayed parameters to the Current Configuration File or press Cancel to close this window without changing the Current Configuration File.
Changes to the configuration will not take effect until the program is reset.
Press the Reset Program button to initiate new settings.

Sample Time: 1 sec (1 Hz)
At Startup: Enabled / Disabled
COM Port: 3
Baud Rate: 57600
Image Card # / Com Port: 4
○ Images over COM port
Image Baud Rate: 460800
Arm Width(mm): 200
N Value: 1
Min Slice Count: 0
Probe Resolution: 25
Particle Speed for Image (m/s): 1
Particle Speed Source: Use Manual Vt (Terminal; 10 m/s

Press this button to reset ALL above instrument parameters to DMT default values.

Channels		x^0 Offset	x^1 Slope	x^2	x^3	x^4
Diode 1 Voltage	Linear	0	0.075	0	0	0
Diode 64 Voltage	Linear	0	0.075	0	0	0
Diode 32 Voltage	Linear	0	0.075	0	0	0
Laser_Cur	Linear	0	0.061	0	0	0
PD_Monitor	Linear	0	0.00122	0	0	0
Laser_Temp	Thermister D	0	1	0	0	0
Window_Temp	Thermister D	0	1	0	0	0
Rotary_Encoder	Custom2	0	1	0	0	0
Internal_Temp (C)	Linear	-273	0.244	0	0	0
Vref	Linear	0	0.00122	0	0	0
gnd	Linear	0	0.00122	0	0	0
N/A	None	0	1	0	0	0
N/A	None	0	1	0	0	0
N/A	None	0	1	0	0	0
N/A	None	0	1	0	0	0
N/A	None	0	1	0	0	0

Press this button to reset ALL channel parameters to DMT default values.

Select "Custom2", then "Save"

Figure 15:Custom 2

8) In PADS main page, tap on "Sample", and verify that the MPS-2's "Rotary Encoder" value matches the actual direction the instrument body is pointing. Rotate the instrument to the cardinal directions to validate success.

9) The Calibration is now stored in the probe's configuration file and this process will only need repeating if the instrument is moved to a new location or the mounting foot rotated for some reason.

9.0 MPS-2 Sizing Calibration Validation

The MPS-2 is supplied with a Spinning Disk calibration validation device which contains a glass disk with opaque dots of known size. Review the Spinning Disk Manual, Doc-0012, for more specific information. Below, notice how the Spinning Disk is mounted on the MPS-2 arms. Position the mechanism such that the laser beam is passing through the middle of the disk aperture. There is an adjustment screw available to facilitate this process.

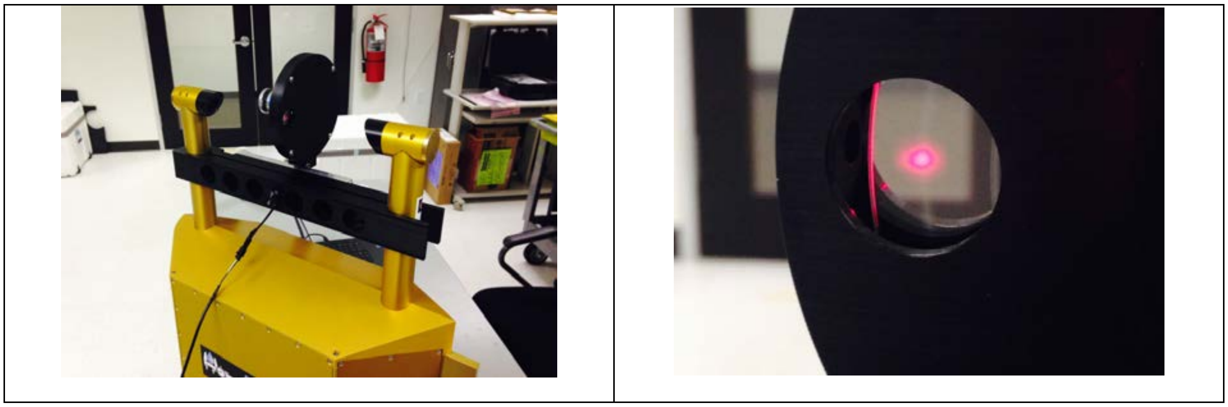
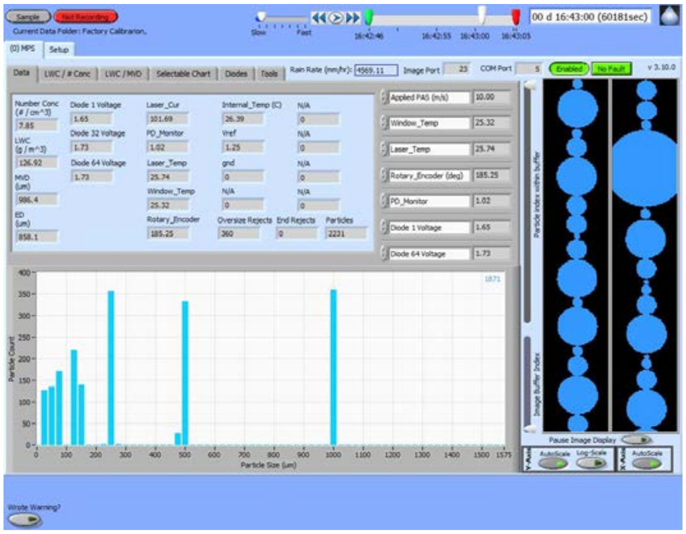


Figure 16:Positioning the Mechanism

Notice on the example below, how the 1000µm peak on the histogram is perfectly centered in the 1000µm bin. This indicates that the screw-drive adjustment is perfectly centered in the optical Depth of Field (DOF). The screw-drive moves the Spinning Disk along the length of the laser beam. Adjust this movement to minimize the 1mm dot. If the disk is not centered in the DOF along the length of the laser beam, the histogram peak will indicate a larger dot size due to optical blurring. This is a well-known sizing phenomenon that is explained in the DOC-0223, Data Analysis Guide, Ch2, contained on the supplied USB Memory stick.



Current Data Folder: Factory Calibration.

00 d 16:43:00 (60181sec)

Rain Rate (mm/hr): 4569.11

Image Port 23

COM Port 5

Number Conc (# / cm^3) 7.85

LWC (g / m^3) 126.92

MVD (um) 986.4

ED (um) 858.1

Diode 1 Voltage 1.65

Diode 32 Voltage 1.73

Diode 64 Voltage 1.73

Laser_Cur 101.69

PD_Monitor 1.02

Laser_Temp 25.74

Window_Temp 25.32

Rotary_Encoder 185.25

Internal_Temp (C) 26.39

Vref 1.25

gnd 0

N/A 0

Oversize Rejects 360

End Rejects 0

Particles 2231

N/A 0

N/A 0

N/A 0

N/A 0

Applied PAS (m/s) 10.00

Window_Temp 25.32

Laser_Temp 25.74

Rotary_Encoder (deg) 185.25

PD_Monitor 1.02

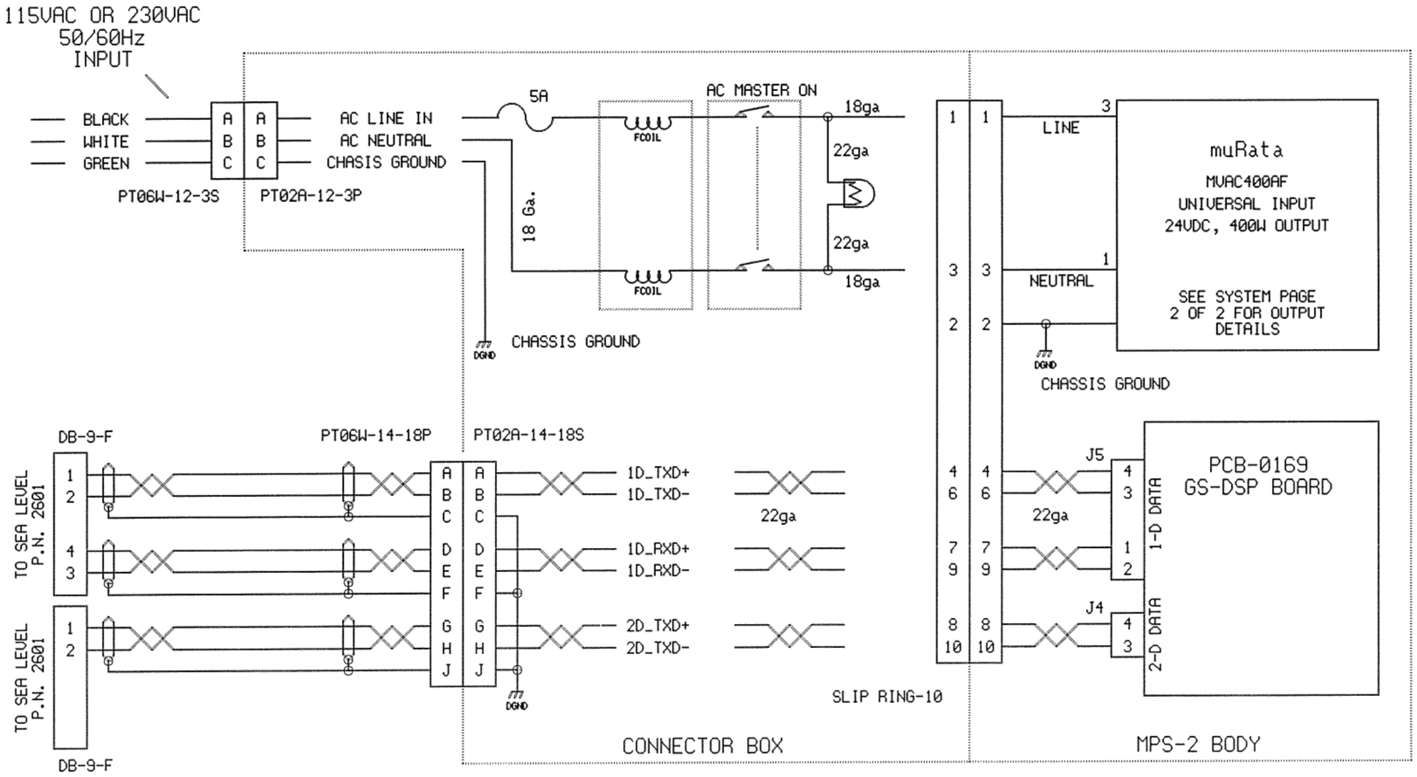
Diode 1 Voltage 1.65

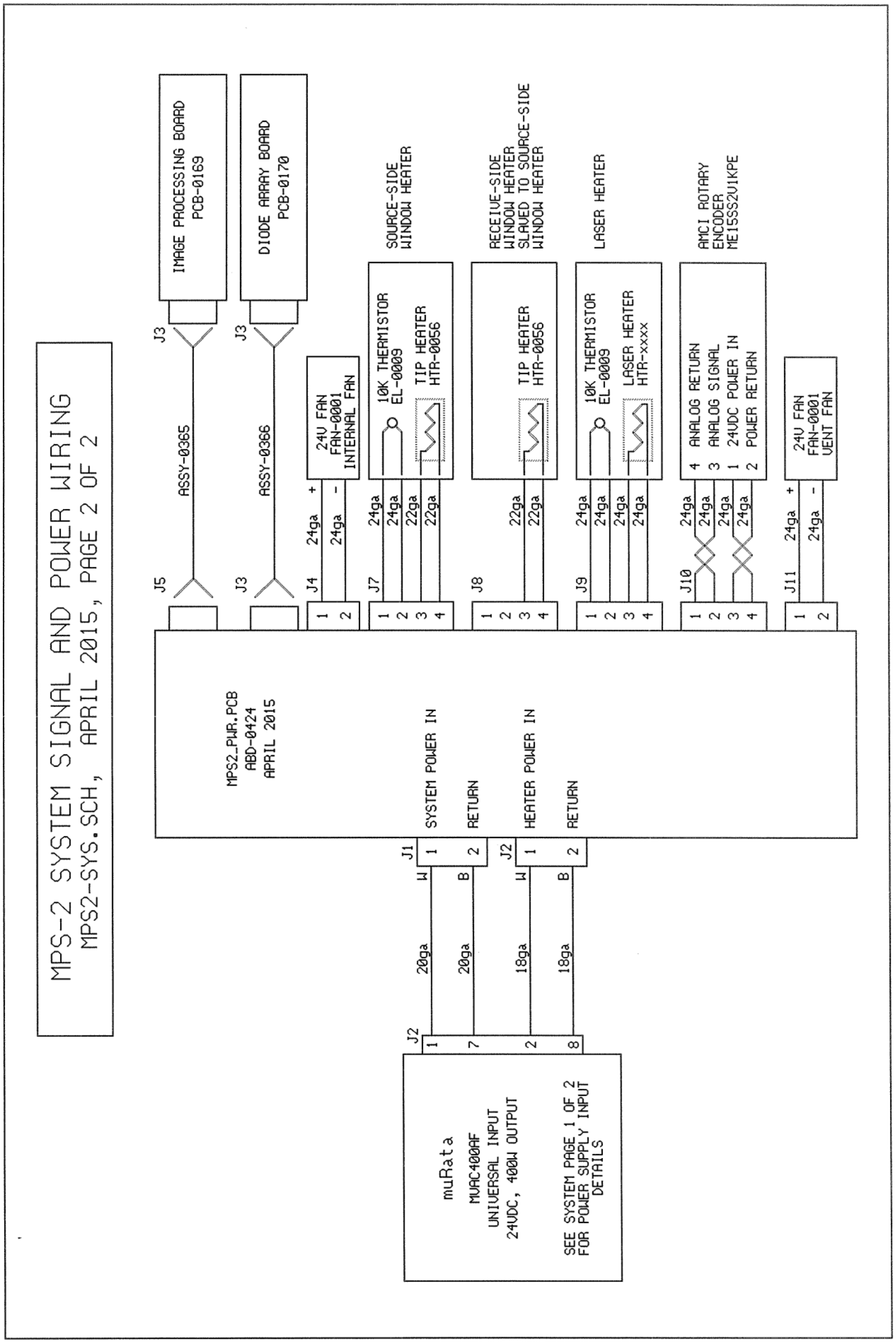
Diode 64 Voltage 1.73

Figure 17:Peak Histogram centered on the bin

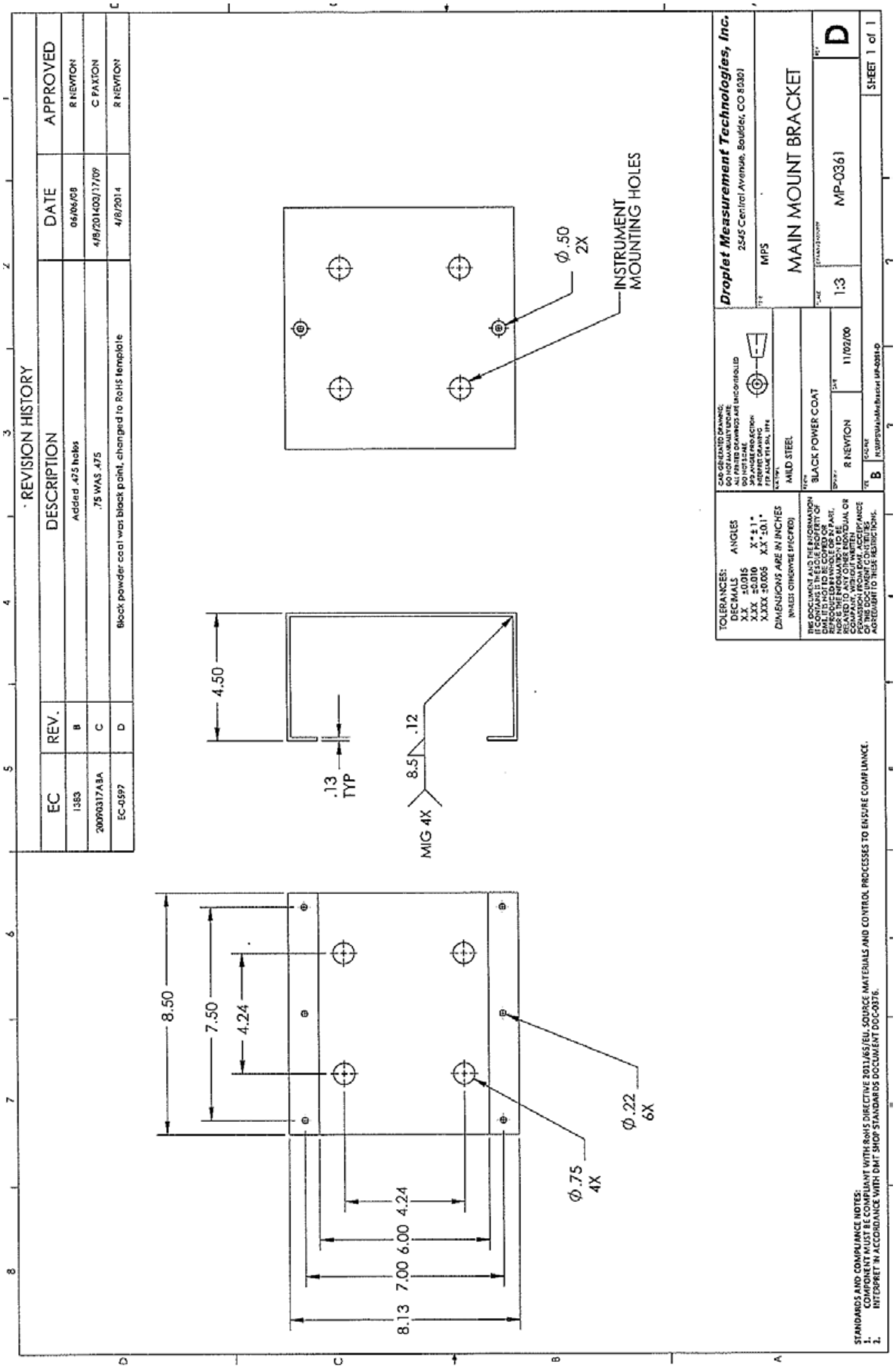
Appendix A: Wiring Diagrams

MPS-2 SYSTEM SIGNAL AND POWER WIRING
MPS2-SYS.SCH, APRIL 2015, PAGE 1 OF 2



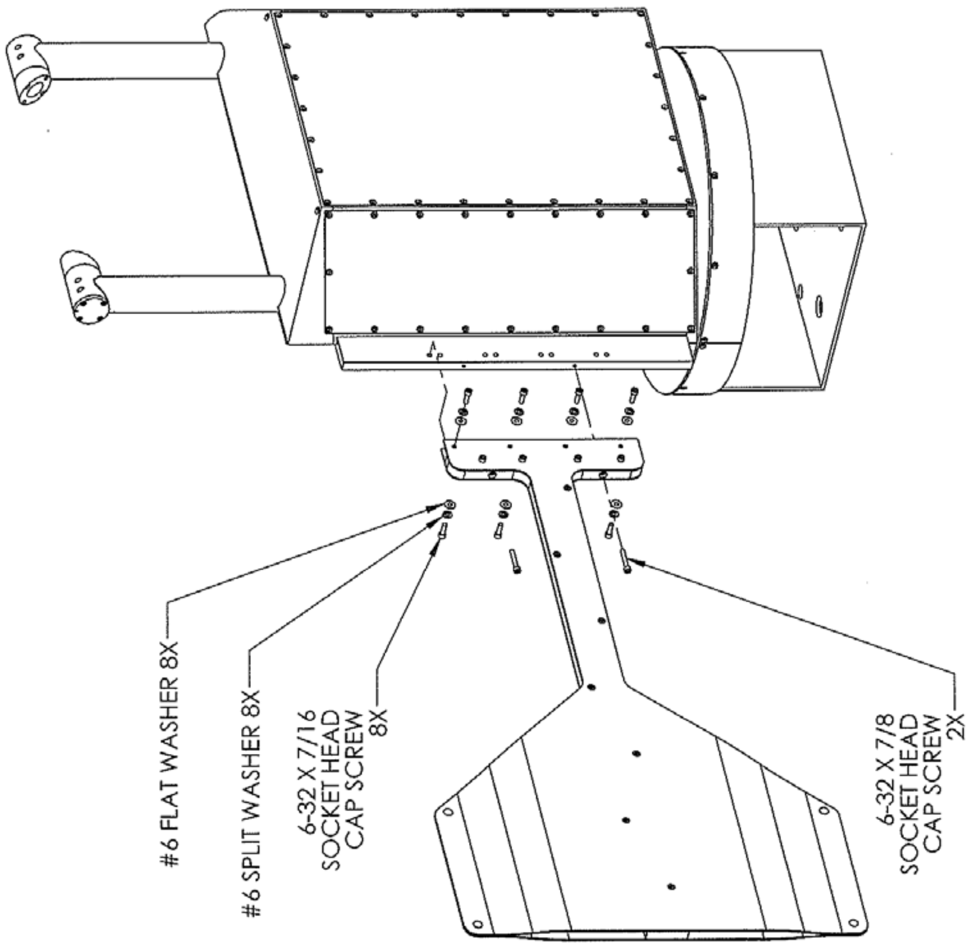

MPS-2 SYSTEM SIGNAL AND POWER WIRING
MPS2-SYS.SCH, APRIL 2015, PAGE 2 OF 2
IMAGE PROCESSING BOARD
PCB-0169
DIODE ARRAY BOARD
PCB-0170
SOURCE-SIDE
WINDOW HEATER
RECEIVE-SIDE
WINDOW HEATER
SLAVED TO SOURCE-SIDE
WINDOW HEATER
LASER HEATER
AMCI ROTARY
ENCODER
ME15S52V1KPE
J3
J3
ASSY-0365
ASSY-0366
24V FAN
FAN-0001
INTERNAL FAN
10K THERMISTOR
EL-0009
TIP HEATER
HTR-0056
TIP HEATER
HTR-0056
10K THERMISTOR
EL-0009
LASER HEATER
HTR-xxxx
4 ANALOG RETURN
3 ANALOG SIGNAL
1 24VDC POWER IN
2 POWER RETURN
24V FAN
FAN-0001
VENT FAN
24ga
22ga
J5
J3
J4
J7
J8
J9
J10
J11
MPS2_PWR.PCB
ABD-0424
APRIL 2015
SYSTEM POWER IN
RETURN
HEATER POWER IN
RETURN
J1
J2
W
B
20ga
18ga
J2
1
7
2
8
muRata
MVAC400AF
UNIVERSAL INPUT
24VDC, 400W OUTPUT
SEE SYSTEM PAGE 1 OF 2
FOR POWER SUPPLY INPUT
DETAILS

Appendix B: Base Plate Mounting Diagram



Appendix C: Attaching Vane to MPS-2

See the following page for a diagram that illustrates how to attach the MPS-2 vane to the main unit.



Appendix D: Revisions to Manual

Rev. Date	Rev No.	Summary	Section
05/06/15	A	Initial Release of MPS-2, with CIP-GS electronics and Universal Input Power capability.	all
12/6/17	A	Updates to spacing company address and others	all