
Cloud Droplet Probe (CDP)

Manual

DOC-0029, Rev 0

*Includes Documentation on
Particle-by-Particle Feature*



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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.

Laser Safety Information

The CDP contains a class IIIB laser. AVOID DIRECT EXPOSURE TO THE BEAM. Observe laser safety precautions and wear appropriate laser safety glasses. Avoid placing reflective materials in the beam that could redirect the beam, including watch bands, rings or tools.

STRICT OBSERVANCE OF THE FOLLOWING WARNING LABELS IS ADVISED.

The following label is located on the CDP:



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1.0 Product Description

1.1 Introduction

The Cloud Droplet Probe (CDP) is designed to measure cloud droplet size distribution from 2 μm to 50 μm . The CDP and an appropriate data system can also calculate various other parameters including particle concentrations, effective diameter (ED), Median Volume Diameter (MVD), and Liquid Water Content (LWC).

Droplet Measurement Technologies (DMT) has implemented state-of-the-art electronics and optics that offer flexibility to the CDP user in a variety of applications. The miniaturized and streamlined housing allows use in a variety of ground-based or airborne applications.

The Particle Analysis and Display System (PADS) offers a graphical user interface at the host computer. PADS provides control of CDP measurement parameters while simultaneously displaying real-time particle size distributions and derived parameters. All standard data interfaces are done via line drivers meeting the RS-422 electrical specification, allowing cable lengths of up to 100 meters.

Figure 1 shows the CDP. For details on specific components within the CDP housing, see Figure 3.

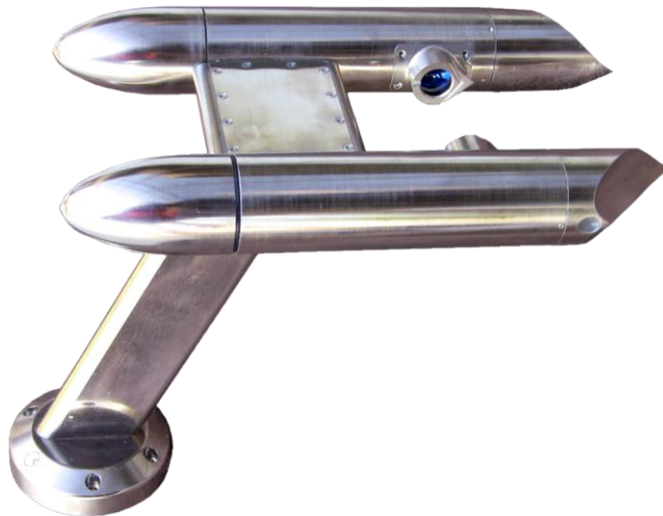


Figure 1: Cloud Droplet Probe

The CDP probe housing contains the forward-scatter optical system, which includes a laser heating circuit, photodetectors, and analog signal-conditioning. The signals are transmitted via a robust differential driver/receiver interface to the CDP Electronics Module, or CDPE. There, the signals are received and processed, particle pulses are digitized and categorized, eight different “housekeeping” parameters are tracked, and a serial data stream in either RS-422 or RS-232 standard format is sent on to the user’s data system.

1.2 CDP Specifications

Technique:	Light-scattering probe with 30 bins
Measured Particle Size Range:	2 μm – 50 μm
Typical Sample Area:	0.24 mm ²
Air Speed Range:	10 - 250 m/sec
Sampling Frequency:	Selectable, 0.04 sec to 20 sec ¹
Refractive Index:	non-absorbing, 1.33 ²
Light Collection Angles:	4° - 12°
Laser:	658 nm, up to 50 mW
Data System Interface:	RS-232 or RS-422 serial interface
Calibration:	Precision glass beads

¹ Versions of the Particle Analysis and Display System (PADS) earlier than 3.5 assume a sampling frequency of 1 sec / 1 Hz. As a result, this frequency is recommended if you are using PADS 2.7 or earlier. CDP-PBPs are also limited by the baud rate; a sampling rate of faster than 2 Hz may compromise the data.

² A refractive index of 1.33 for water is the industry standard. Contact DMT for support for measuring particles with other refractive indexes.

1.3 Electrical Specifications

Power requirements for the CDP are shown below.

System:	28VDC at 2A
Anti-Ice:	28VDC at 7A; 115VAC at 2A

1.4 Physical Specifications

Weight:	10.5 lbs / 4.8 kg
Probe Dimensions:	9.25" / 23.5 cm long, 6.0" / 15.2 cm wide, 8.5" / 21.6 cm high
Electronics Dimensions:	

1.5 Operating Limits

Temperature:	-40 to +40 °C
Altitude:	0 - 50,000 feet
Humidity:	0 - 100%

2.0 Probe Setup

For CDPs that are attached to Cloud Combination Probes, see the Probe Unpacking and Handling section in the *Cloud Imaging Probe Operator Manual, DOC-0028*.

Stand-alone CDPs arrive in a padded carrying case. The instrument should be handled carefully; holding it by the strut is best. In the event that CDPs need to be shipped back to DMT, repack the CDP in its padded carrying case. Instructions for setting up the CDP are on the inside of the front cover.

3.0 Theory of Operation

The CDP uses a laser to illuminate particles and forward-scatter their light. The detected scattered light is then used to size the particles.

The intensity of the scattered light depends upon the size, composition, and shape of the particle. For accurate sizing, the CDP must accept and size only particles that pass through a uniform power region of the laser beam. This region of the laser is called the **depth of field**. The CDP “qualifies” particles that fall within the depth of field, and the instrument only sizes these particles.

As particles pass through the laser beam, light scatters in all directions (see Figure 3). The CDP collects forward-scattered photons within a cone that is 4° to 12° from the laser beam. (Photons within the 0° to 4° range are considered part of the unobstructed laser beam and are diverted elsewhere so as not burn out the photodetectors.) The collected light is then directed onto a 50/50 optical beam splitter and finally to a pair of photodetectors. These two detectors are referred as the **sizer** and the **qualifier**. An optical mask filters the optical signal going to the qualifier, and only signals from particles that fall within the laser’s depth of field reach the qualifier in significant quantity and focus.

Both photodetectors then convert the photon pulses into electrical pulses. The pulse from the qualifier is then multiplied by two. If the resulting signal exceeds the pulse from the sizer, a DOF flag is set to true, indicating the particle is within the depth of field.

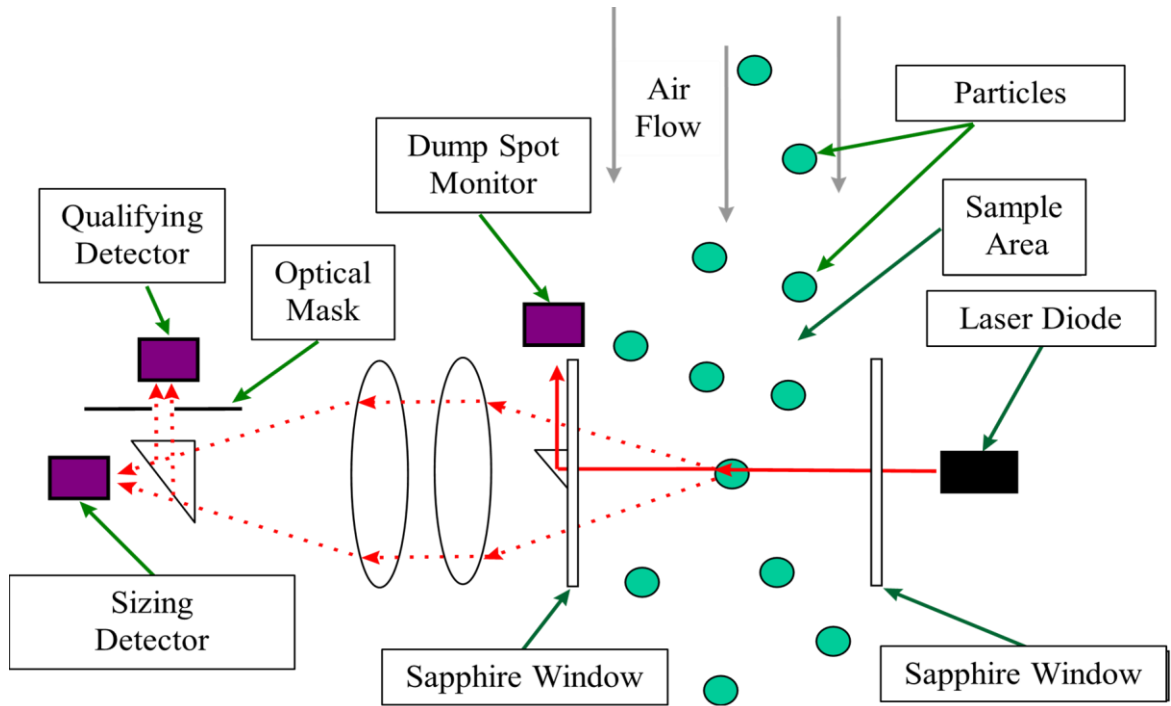


Figure 2: CDP Theory of Operation

Figure 3 shows where these components are located on the actual CDP.

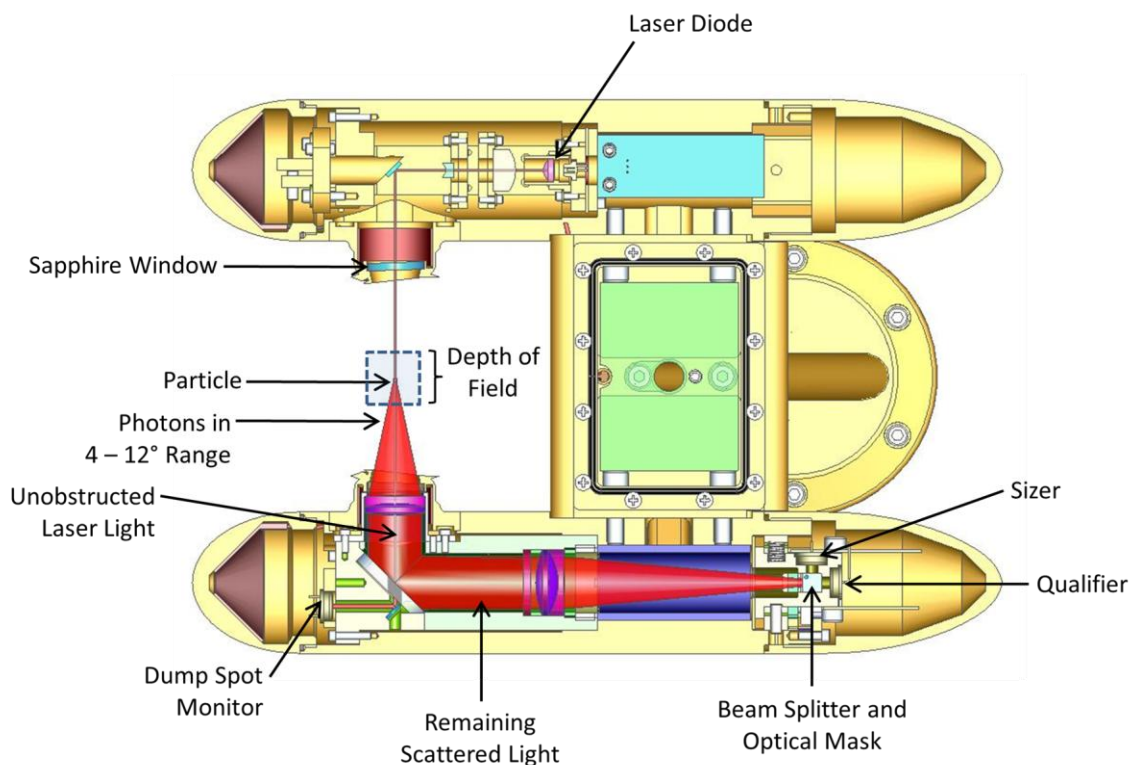


Figure 3: CDP with Important Components Labeled

Once the CDP's electronics have recorded, amplified, and evaluated the particle signal to see if the particle falls within the depth of field, the analog voltage value is digitized. The peak digital value, which corresponds to the particle's size, is then categorized into one of 30 bins. The histogram resulting from all particles sized during the sample interval is transmitted to an external computer via an RS-232 or RS-422 serial packet.

3.1 PbP Option

An option for the CDP is the inclusion of Particle-By-Particle information. This information includes inter-arrival time and the exact pulse height with 12-bit resolution for the first 256 particles every sample interval.

3.2 CDP Data Acquisition Features

The CDP provides the following data in its serial stream output:

- Classification of particle sizes in histogram form.
- Monitoring of multiple housekeeping variables, e.g. total particles, average transit time, laser current, dump spot monitor, CDP internal temperature (“Wingboard Temp” in the data packet), or particles rejected due to their transit time or DOF.
- Optional PbP data on up to 256 particles per sample interval.

For more information on the instrument’s output, see Appendix D.

The instrument also features user-programmable sample rates, number of bins, and bin thresholds. There are zero deadtime losses.

4.0 Particle Analysis and Display System (PADS)

DMT’s Particle Analysis and Display System (PADS) is a Windows-based, LabVIEW software package that is the default interface system for the CDP. It offers attractive display and analysis features, and data acquired with PADS can be stored to a file for later analysis. The program also stores all configuration information as a file header, so users can easily determine the system settings at the time of data acquisition.

PADS automatically calculates variables such as particle number concentration and volume concentration, effective diameter, and liquid water content. It creates time-series charts of user-specified variables and displays a histogram of particle counts by size.

Any computer with an available serial port, PADS software, and a PADS hardware key can act as the data acquisition device. Figure 3 shows PADS displaying data acquired with the CDP.

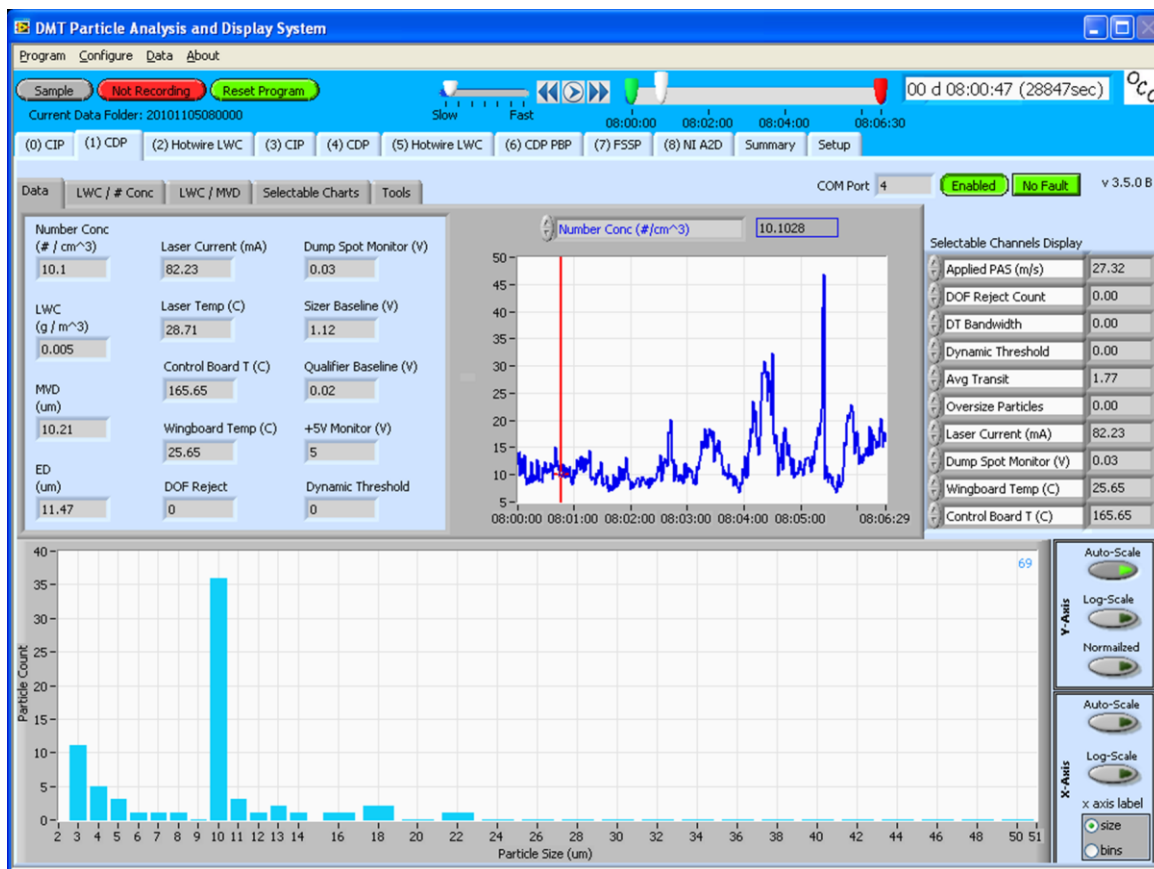


Figure 4: CDP Data, Histogram, and Particle Images

PADS is also used to configure the setup for the CDP. For instance, the program allows users to specify the time interval at which the probe relays data to the computer, the locations of threshold tables used in particle sizing, and so on. See the *PADS Operator Manual (DOC-0116)*, the *PADS CDP Module (DOC-0177)*, and/or the *PADS CDP-PBP Module (DOC-0192)* for configuration and display details.

5.0 Dynamic Threshold Feature

The CDP's dynamic threshold feature automatically adjusts the instrument's sizer and/or qualifier signals to account for drifts due to temperature changes. Instruments manufactured after mid-2010 have a dynamic threshold feature for the sizer signal. Instruments manufactured after January 2012³ have this feature for both sizer and qualifier signals.

³ CDPs with expanded dynamic thresholding will have serial numbers ending in 63 or greater.

5.1 Dynamic Threshold for Sizer Signal

The dynamic threshold feature works as follows. The instrument's sizer signal voltage is digitized with a 12-bit ADC, which yields a 0 to 4095 count. A histogram is created of all counts between 0 and 512. (Signals above 512 are assumed to be responses to particles, and thus not relevant to establishing the baseline.) The system then identifies the narrowest band that contains at least 75% of counts in the histogram. This band, referred to as the "noise band," is the system's attempt to identify a range for baseline noise when no particles are present.

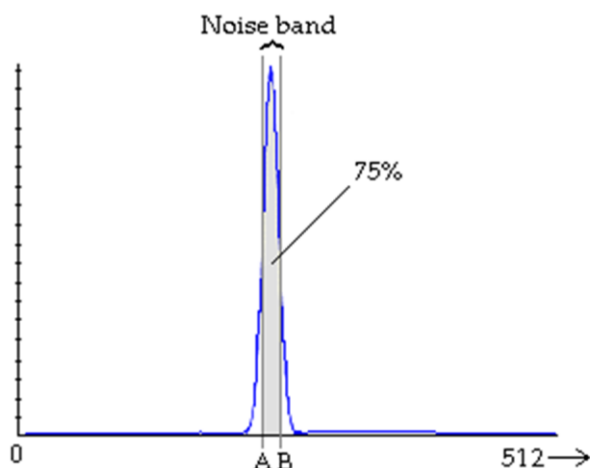


Figure 5: Identifying a Noise Band

If the noise band exceeds 20 counts (i.e., the width is too wide), or if no noise band was identified, the previous noise band is used. These qualifications are imposed in order to distinguish the noise from actual particle events. The instrument then uses the noise band to adjust the sizer baseline and identify particles. The noise band updates at a rate of 10 Hz.

CDPs with dynamic thresholding for the sizer signal have two additional channels included in their serial data output. **DT Bandwidth** is the width of the noise band—that is, $[B - A]$ in Figure 4. **Dynamic Threshold** is the upper boundary of the noise band, i.e. B in Figure 4. Both of these channels are given in digital counts.

5.2 Dynamic Threshold for Qualifier Signal

Dynamic thresholding for the qualifier signal works exactly as it does for the sizer signal, except that the qualifier signal is used to determine the noise band and the qualifier

signal is subsequently adjusted. CDPs that have dynamic thresholding for the qualifier signal have two additional channels included in their serial data output. **Qual Bandwidth** is the width of the noise band—that is, [B - A] in Figure 4. **Qual Threshold** is the upper boundary of the noise band, i.e. B in Figure 4. Both of these channels are given in digital counts.

6.0 Instrument Maintenance and Troubleshooting

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.

The Cloud Droplet Probe is environmentally sealed and is water resistant *but not waterproof*. The optical path is protected with the sapphire windows that can be seen through the wetless window ports. Water residue can cause contamination on the windows and this contamination will distort or attenuate the amount of scattered light collected from a particular particle.

To clean the sapphire windows, follow accepted optical cleaning techniques. Use white vinegar on a Q-tip to remove water spots, then use alcohol or acetone for final cleaning procedures.

6.1 Troubleshooting with Housekeeping Channels

Several of the CDP's housekeeping channels offer information that helps diagnose instrument health. These are described below. For information on how to convert the housekeeping analog-digital values returned by the CDP into the units given below, see the section on CDP Housekeeping Channels in Appendix D. If you have PADS, the program will have already performed these conversions.

Laser_Current (mA): The electrical current flowing through the instrument's laser diode. A sudden change in current could reflect a problem with the instrument. A reading of 60 - 120 mA indicates the instrument is functioning properly. If the laser current is weak and the laser begins pulsing, the laser has become overheated. A current reading of zero indicates a failure. However, a temporary drop in laser current is normal when anti-icing heaters are initially turned on. A high laser current can indicate the laser is nearing the end of its life.

Dump_Spot_Monitor (V): The amount of focused, unobstructed laser light collected in the dump spot monitor. This channel can indicate overall system health. If the monitor

reading goes down when there are no particles present, there may be a problem. (When particles are present, the laser light scatters, which reduces the focused light collected in the dump spot.) It is important to track the trend over a long period of time, for instance over several months, as this channel can change slowly. Overheated lasers or probe windows blocked by fog and/or ice could cause the laser monitor reading to go down even though no particles are present. The dump spot monitor is averaged over the timing interval.

Wingboard_Temp_(C): The temperature at the CDP's signal and power distribution board. This temperature gives an idea of the average temperature of the probe body. Wing_Board_Temp should be a few degrees higher than ambient temperature, since the board is enclosed in the instrument housing and since the anti-ice heaters warm it.

Laser_Temp (C): The temperature of the laser heat sink. The Laser_Temp reading should be relatively stable. Healthy Laser_Temp readings are 20° -30° C.

Sizer Baseline (V): The voltage output from the sizing detector, which is periodically sampled. This voltage will vary considerably based on whether particles are present at the time of the reading. When no particles are present, it ranges from .2 - .5 V.

Qualifier Baseline (V): The voltage output from the qualifier detector. This voltage, which is periodically sampled, varies considerably based on whether particles are present at the time of the reading. When no particles are present, it ranges from .2 - .5 V. Its value is typically 20-60 mV below the sizer baseline.

+5V Monitor (V): The power 5-volt reference for the CDP's control system. In PADS this voltage is divided by two, digitized, and multiplied by two to allow an effective 0 - 10 volt range. The scaled value should be 4.75 - 5.25 volts. Values outside this range may indicate a problem in the power distribution board.

Control Board Temp (C): The temperature at the digital board, which should fall between -40 and +50 °C. Values outside this range indicate a potential problem with the board.

7.0 Calibration

Calibration of the CDP is typically verified with precision glass beads. Glass beads of a known size are injected into the sample area, and the instrument sizes them. The resulting particle-size histogram should show a definite peak at a size slightly smaller than the size of the glass beads. DMT instruments are calibrated to measure water particles, and water and glass have different refractive indexes. As a result, the particle sizes measured by the instrument will be about 80% of the actual size of the glass beads. The conversion table in Appendix B provides corresponding water droplet sizes for given glass bead sizes. The water-droplet size indicates where the number of particles detected during calibration testing should peak. For instance, if 17- μm glass beads are used for testing, the particles detected by the instrument should peak at about 14 μm . See Figure 6.

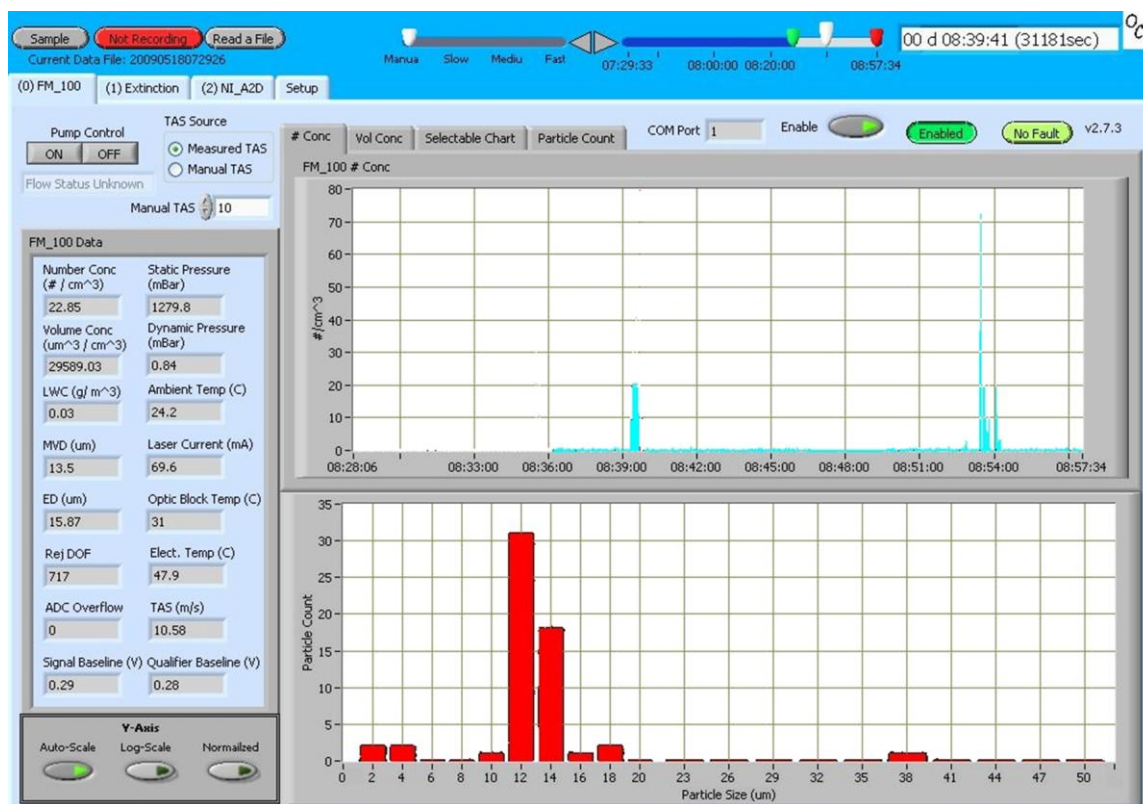


Figure 6: Display of Calibration Test Results. Note the definite peak in the 12-14 μm particle range.

7.1 Required Equipment

To calibrate an instrument with glass beads, the following equipment is needed:

- Can of compressed gas (also called a “duster”) to clean the bead dispenser and calibration device. See Figure 7 for examples of dusters. These are generally available at electronics supply stores or computer stores.
- Bottle of certified glass beads, as shown in Figure 8. These are available from DMT.
- Glass bead dispenser (DMT #AD-0164), pictured in Figure 9.
- Calibration fixture for the instrument (DMT # ASSY-0035), designed to keep the glass beads within the appropriate depth of field. See Figure 12.



Figure 7: Compressed Gas Cans or “Dusters”



Figure 8: Bottle of Glass Beads, DMT OP-0591-0020

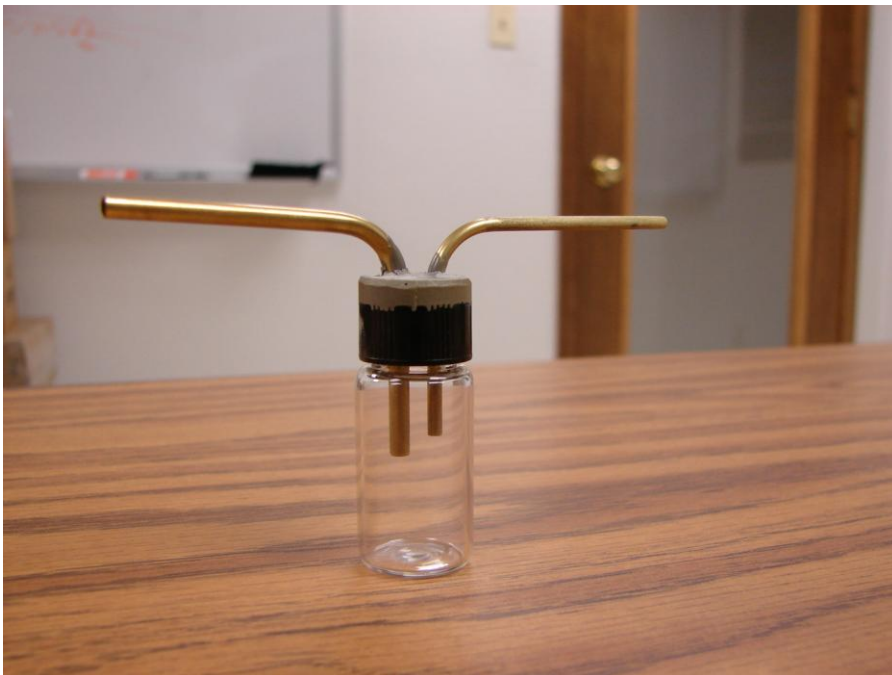


Figure 9: Glass Bead Dispenser, DMT AD-0164

7.2 Instructions

- 1.) Turn on the instrument system power and start the data acquisition system.
- 2.) Using the duster, clean the glass bead dispenser by blowing air through it (Figure 10). Make sure the bottom of the cap and tubes are cleaned as shown on the left in Figure 10. Also clean the dispenser's glass canister as shown on the right.

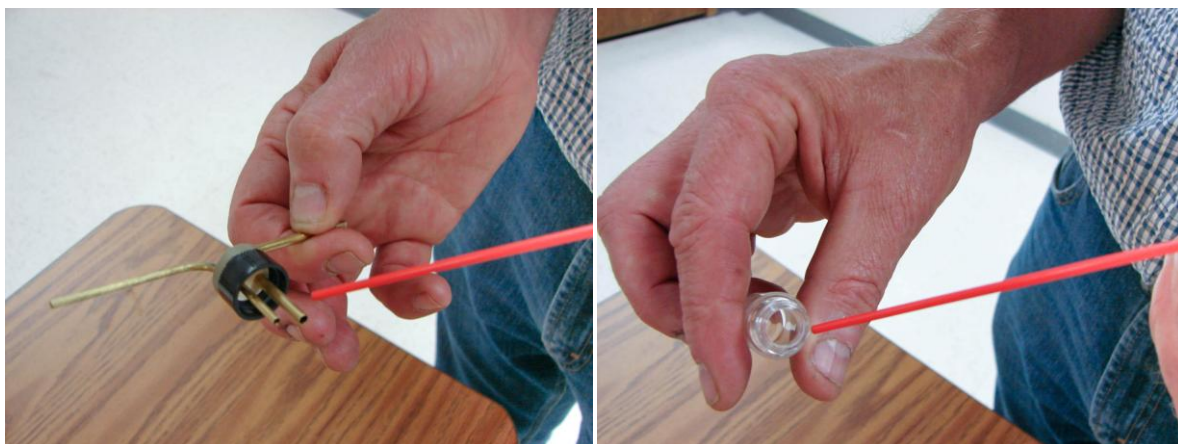


Figure 10: Cleaning the Glass Bead Dispenser

- 3.) Clean the calibration device with the duster by blowing air down the tube.

Note: Steps 2 and 3 should be performed at the start of each calibration test session and whenever a new size of glass beads is being used. Steps 2 and 3 may be bypassed for repeated tests with the same size of glass beads.

- 4.) Turn the bottle of glass beads upside down and then right side up. This will leave a thin film of beads on the lid of the bottle.
- 5.) Place the lid of the bottle over the bead dispenser. Tap the dispenser lightly against a table to dislodge the beads on the lid. (See Figure 11.) A very thin film of beads should appear in the dispenser, as shown in Figure 12.

Warning: Do not pour glass beads directly into the dispenser. Doing so will result in too many beads entering the sample space, which may compromise sizing.



Figure 11: Tapping the Bead Dispenser to Dislodge Beads

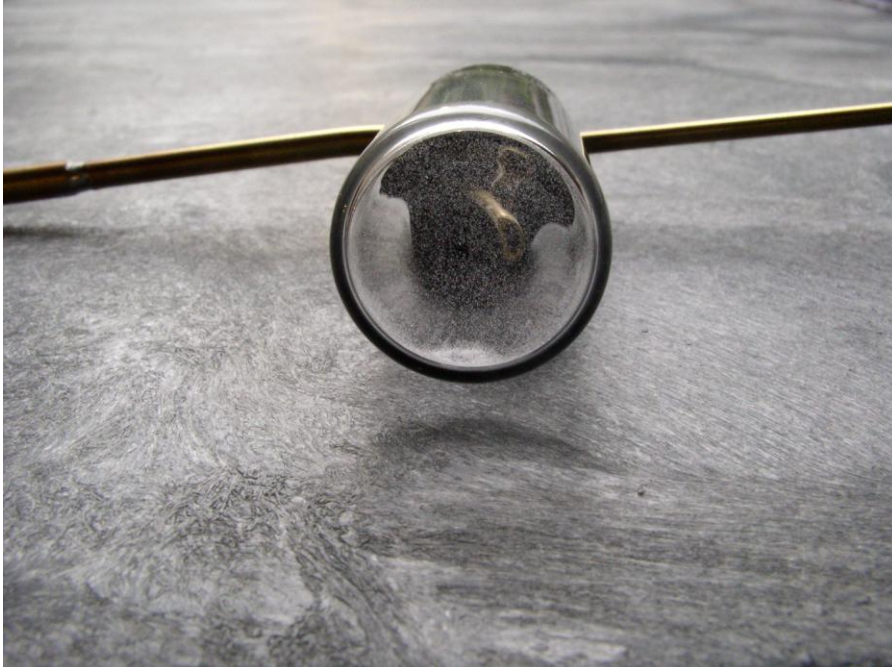


Figure 12: Dispenser with Film of Beads on Bottom

- 6.) Replace the lid on the glass bead bottle. This prevents water infiltrating the beads, which can cause clumping.
- 7.) Attach the calibration fixture to the CDP. Figure 13 shows a calibration fixture mounted on a CDP.

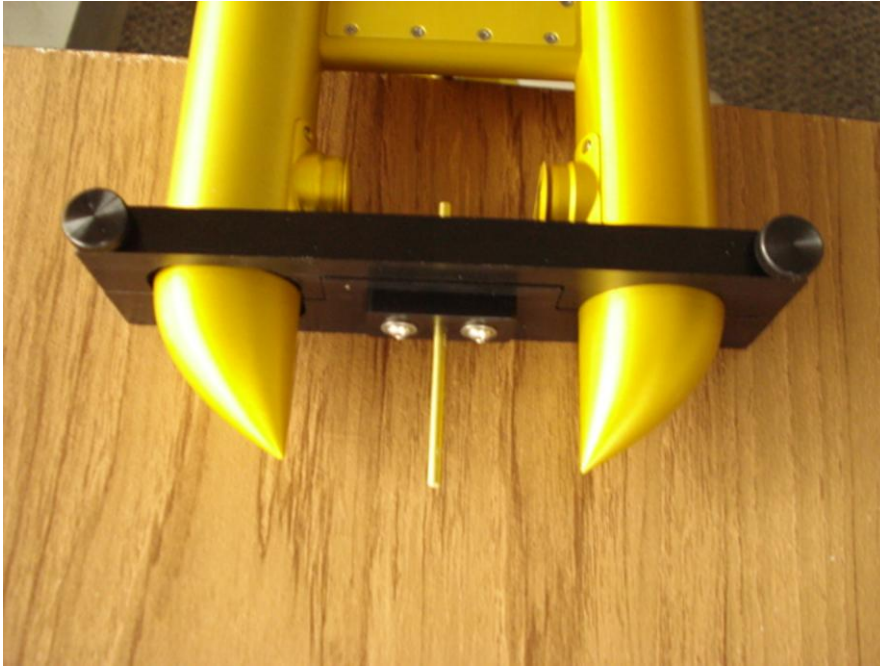


Figure 13: CDP Calibration Fixture

- 8.) Connect the tube on the calibration fixture's far end to the dispenser, and connect the dispenser to the duster. (See Figure 14.) *Gently* press the duster so glass beads are released into the instrument. A very small amount of pressure on the trigger of the duster can will suffice. The calibration should be done in a short burst about 1 second or less. There will be a delay of 1-3 seconds before the data shows on the computer screen. (See Figure 6.) The total number of particle counts, not concentration, should be 30-200. This is summed across all of the bins.

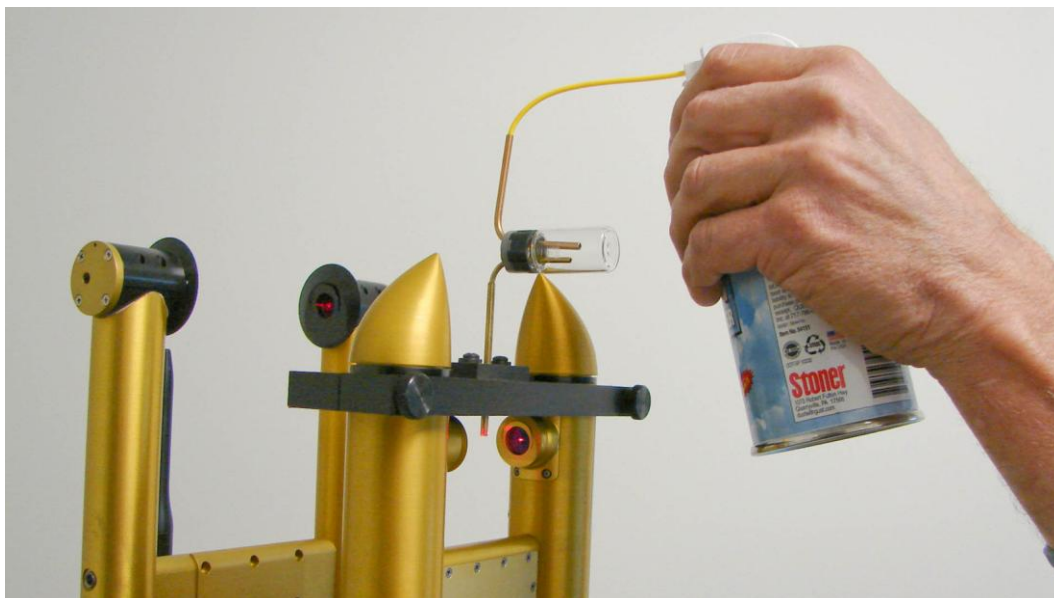


Figure 14: Releasing Glass Beads into the CDP. Note this picture is of a CDP attached to a CCP; operation is the same for stand-alone CDPs.

- 9.) Keep pressing the duster as necessary, checking the data system display to see if the instrument is detecting the glass beads. Ideally, the histogram display should peak at the water droplet size that corresponds to the size of the glass beads being testing. See Appendix B for exact glass-to-water conversion values.

Warning: Make sure to read the label on the bottle of glass beads carefully when determining bead size. Often the size listed most prominently is not the most exact size. The label on the bottle in Figure 8, for instance, lists the beads as size 20 μm , but further down the size is clarified as being $17.3 \pm 1.4 \mu\text{m}$.

- 10.) When calibration testing is complete, remove the calibration fixture from the instrument.

Figure 5 shows the typical calibration response.⁴ Histogram results will look similar for the CDP. Note that the total number of particle counts is about 50 particles, which is an acceptable concentration. The nominal size of the glass beads is 17.3 μm . In consulting Appendix B, the equivalent water size is 14.5 μm . In Figure 5, there are two predominant peaks, one at 12 μm and the other at 14 μm . The designations are the upper boundaries of bins, so the major peak is 10-12 μm and the other peak is 12-14 μm sizing. While these peaks occur at particle sizes slightly smaller than one might expect, they are acceptable given the $\pm 1.4 \mu\text{m}$ variation in glass bead size and a 12% coefficient of variation.

⁴ Note that this figure displays results for a Fog Monitor; however, the histogram for the CDP should be very similar.

Consult Appendix C for information on how to interpret results of glass-beads tests.

Appendix A: Revisions to Manual

Rev. Date	Rev. No.	Summary	Section
9/18/09	J-1	Added section on CDP-PBP response to Setup Data command, which includes two-byte code rev #.	Appendix D
2/2/10	J-2	Corrected inaccurate Example Hex Value in “Particle 2 PbP Data” row	Appendix D
3/4/10	K	<ul style="list-style-type: none"> Added laser safety information Updated CDP pictures Inserted pictures of CDP calibration device Moved sections on heaters and data communications to appendixes 	Various
6/14/10	L	<ul style="list-style-type: none"> Updated CDP Schematics 	Appendix G
9/23/10	M	<ul style="list-style-type: none"> Updated Housekeeping Channels Updated channels to include dynamic threshold channels 	5.1, 6.10, 6.10.1, 6.10.3
8/18/2011	M-1	<ul style="list-style-type: none"> Corrected size of Checksum parameter in CDP-PBP response to “SEND DATA” command 	6.12
12/12/11	M-2	<ul style="list-style-type: none"> Corrected Example Hex Values in Bin 1 and Bin 2 counts 	6.10, Table 6
3/22/12	N	<ul style="list-style-type: none"> Updated with information about dynamic threshold feature Removed schematic SCH-0072 since ABD-0072 board is no longer being used 	5.0, Appendix D; Appendix G
4/9/12	N-1	Removed instrument schematics in accordance with new policy	Appendix G
4/19/12	N-2	Added information on DMT Instrument Locator	Appendix H
6/12/12	N-3	Added recommendation for annual cleaning and calibration at DMT	6.0
		Updated description of the CDP’s response to a setup command	Appendix D
7/18/12	N-4	Changed air speed and sampling frequency ranges	1.2
8/2/12	N-5	Changed available number of bin sizes from 10, 20, 30 or 40 to only 30.	1.2, 3.0, Appendix D
8/16/12	O	Updated manual to reflect changes resulting from new ABD-0234 Board, detailed below	Throughout
		Added bytes 2 and 3 to Table 4 (CDP response to the Setup Data Command)	Appendix D

8/16/12	O	Removed note in Table 6 about older CDPs having Reject Average Transit channel	Appendix D
		Added threshold tables for CDPs with ABD-0234 boards	Appendix I

Appendix B: Glass Bead to Water Droplet Conversion

Glass Bead to Water Droplet Conversion Table 5 May, 1999

Glass Bead Calibration Size: $n=1.51$ Water Equivalent Size: $n=1.33$

Glass Bead Tolerances, and Equivalent, in Microns:

Glass Bead	Range
2.1 ± 0.5 =	1.6 to 2.6
8.1 ± 0.8 =	7.3 to 8.9
15.5 ± 1.1 =	14.4 to 16.6
19.9 ± 1.4 =	18.5 to 21.3
20.6 ± 1.4 =	19.2 to 22.0
40.0 ± 2.8 =	37.2 to 42.8

Glass	Water	Glass	Water	Glass	Water	Glass	Water
0.5	0.6	13.5	11.6	26.5	21.5	39.5	31.8
1.0	0.9	14.0	12.0	27.0	21.9	40.0	32.5
1.5	1.3	14.5	12.5	27.5	22.3	40.5	32.9
2.0	1.8	15.0	12.8	28.0	22.7	41.0	33.3
2.5	2.3	15.5	13.2	28.5	23.1	41.5	33.7
3.0	2.7	16.0	13.6	29.0	23.4	42.0	34.1
3.5	3.1	16.5	13.9	29.5	23.8	42.5	34.5
4.0	3.5	17.0	14.3	30.0	24.4	43.0	34.9
4.5	4.0	17.5	14.7	30.5	24.8	43.5	35.3
5.0	4.5	18.0	14.9	31.0	25.1	44.0	35.7
5.5	5.0	18.5	15.3	31.5	25.5	44.5	36.1
6.0	5.2	19.0	15.7	32.0	25.9	45.0	36.5
6.5	5.5	19.5	16.1	32.5	26.3	45.5	36.9
7.0	5.8	20.0	16.1	33.0	26.7	46.0	37.3
7.5	1.5	20.5	16.5	33.5	27.1	46.5	37.7
8.0	6.2	21.0	17.0	34.0	27.5	47.0	38.2
8.5	6.6	21.5	17.4	34.5	27.9	47.5	38.6
9.0	7.3	22.0	17.8	35.0	28.3	48.0	39.0
9.5	8.1	22.5	18.2	35.5	28.6	48.5	39.4
10.0	8.9	23.0	18.6	36.0	29.0	49.0	39.8
10.5	9.1	23.5	19.0	36.5	29.4	49.5	40.2
11.0	9.5	24.0	19.4	37.0	29.8	50.0	40.6
11.5	9.9	24.5	20.0	37.5	30.3		
12.0	10.3	25.0	20.4	38.0	30.7		
12.5	10.8	25.5	20.8	38.5	31.1		
13.0	11.2	26.0	21.2	39.0	31.5		

Appendix C: CDP Alignment Response

The CDP is typically calibrated with precision glass beads. Figure 15 through Figure 23 show the results of such tests as the CDP is progressively moved out of alignment.⁵ Figure 15 through Figure 17 are for 8- μm beads, Figure 18 through Figure 20 are for 20- μm beads, and Figure 21 through Figure 23 for 40- μm .

Figure 15, Figure 18, and Figure 21 show the calibration with a properly aligned CDP. The CDP response to the calibration beads gives a narrow histogram with the bead sizing falling in the proper bin (see note below). As the CDP is moved out of alignment, the width of the histogram increases, as shown in Figure 16, Figure 19, and Figure 22. With severe misalignment, as seen in Figure 17, Figure 20, and Figure 23, the width of the histogram increases even more, and for the 40- μm beads, the sizing of the beads is one bin low. In addition to the increased width of the histogram and the incorrect sizing of the beads, the misalignment will change the sample volume of the CDP, resulting in incorrect concentration measurements.

Note: Due to the fact glass beads and water droplets have different refractive indexes (see previous appendix), a correctly aligned probe will size glass beads at approximately 80% of their size.

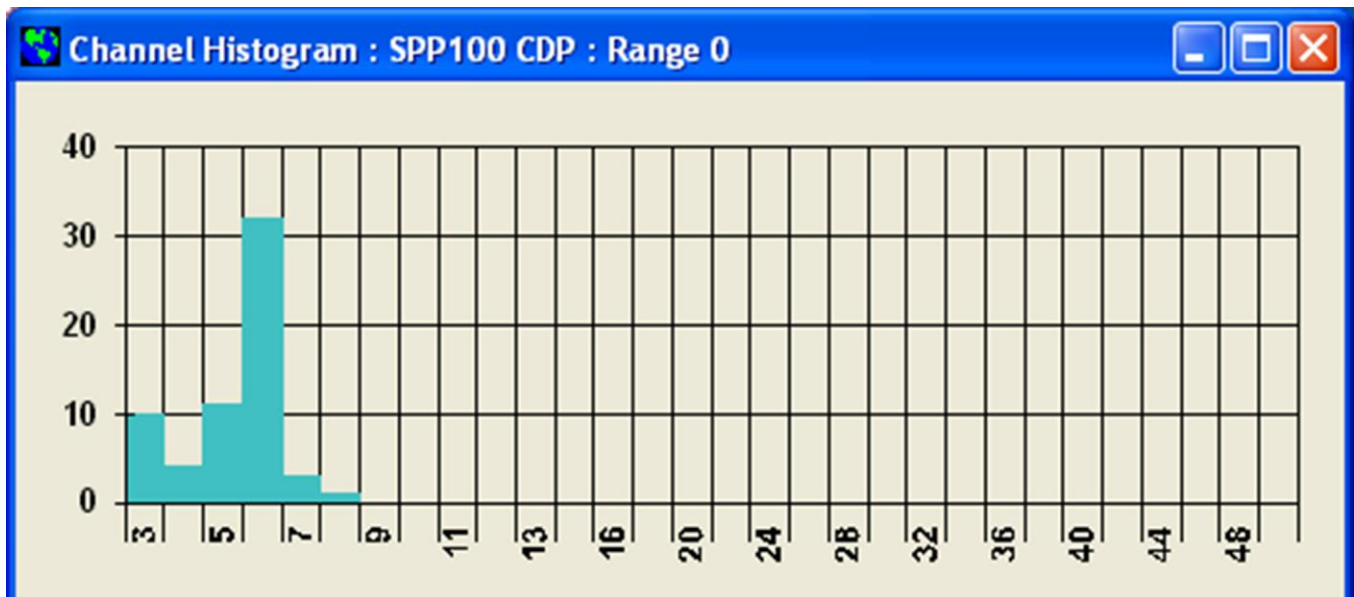


Figure 15: 8- μm glass beads CDP aligned

⁵ These histograms were generated by the PACS software program. Your display will look different if you have a different or more recent system such as the Particle Analysis and Display System (PADS). However, the shape of the histograms will stay the same.

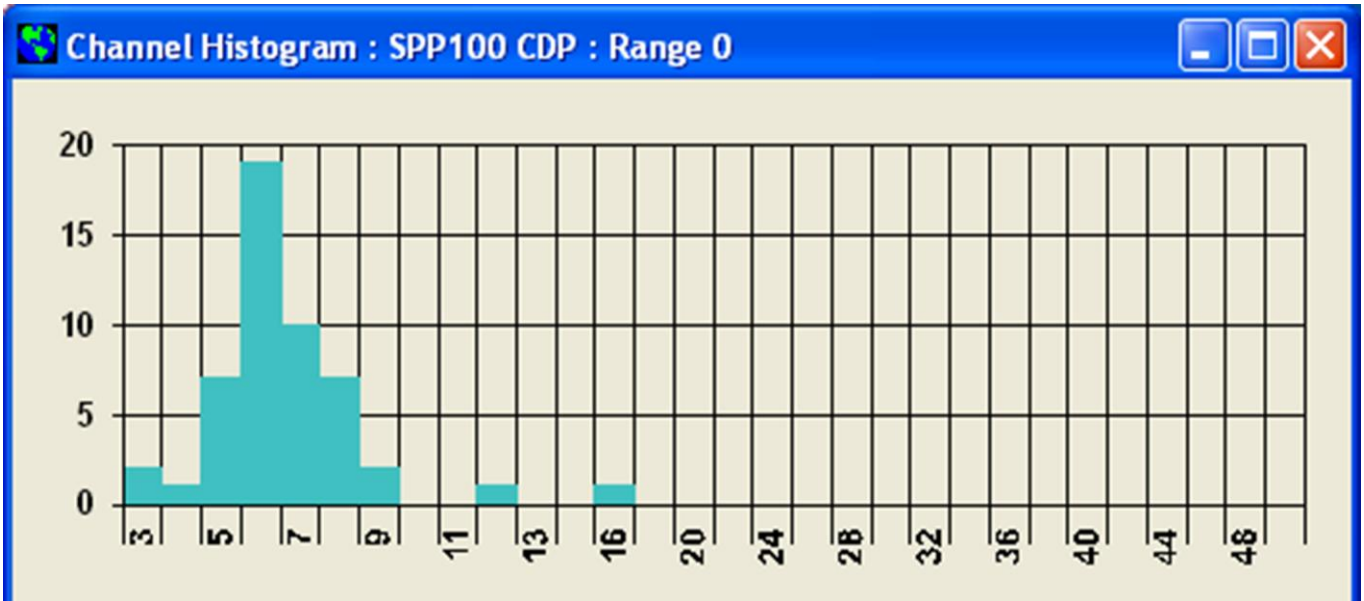


Figure 16: 8- μ m glass beads CDP moderate misalignment

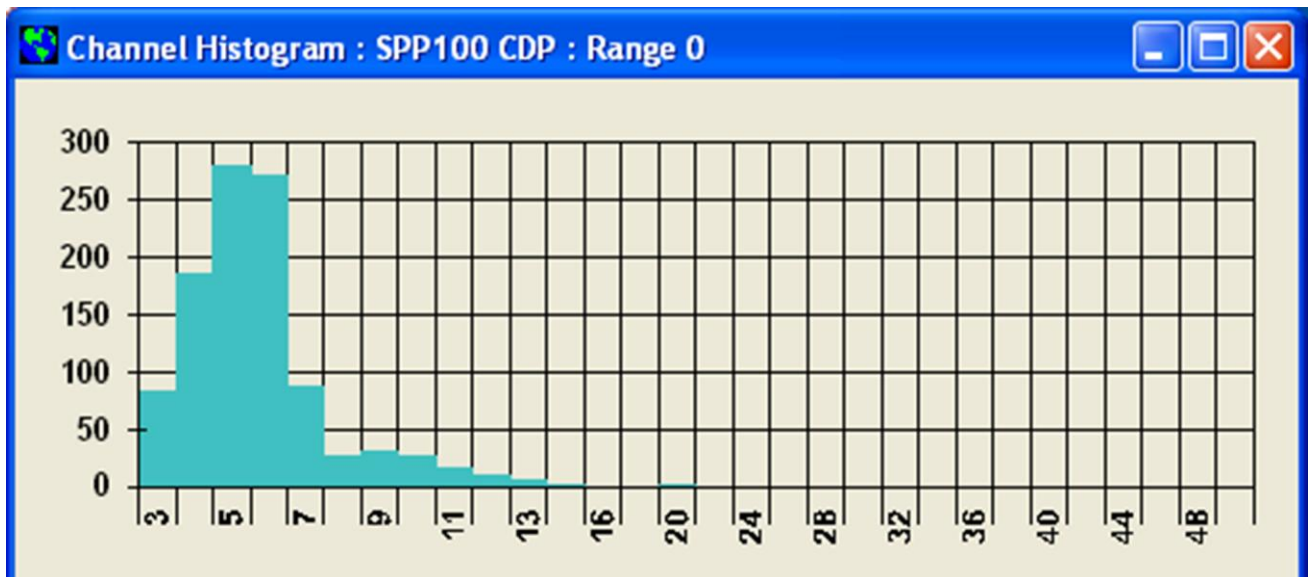


Figure 17: 8- μ m glass beads CDP severe misalignment

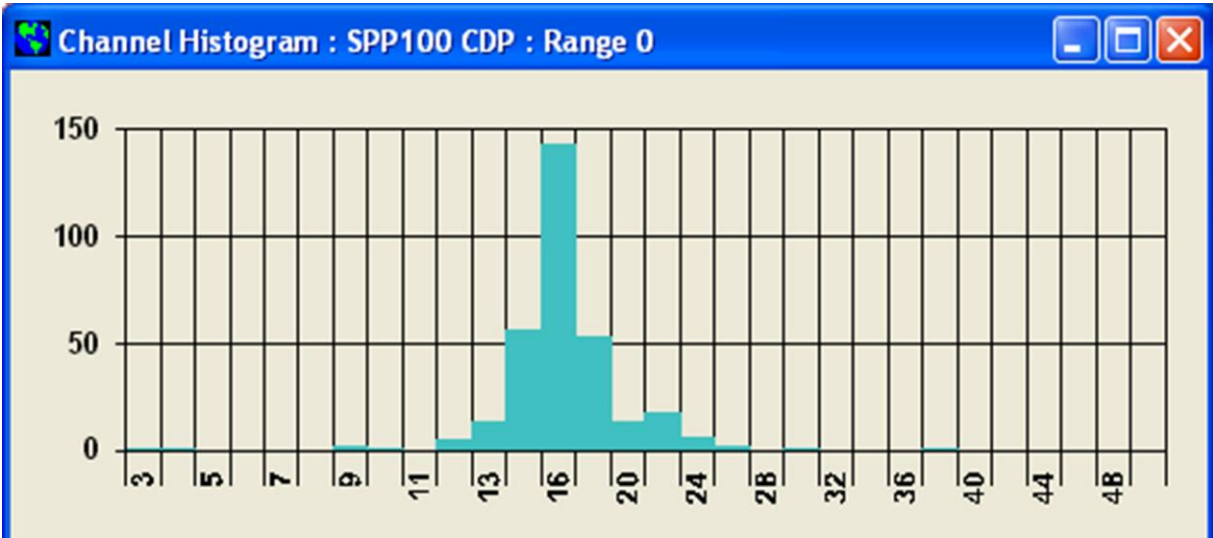


Figure 18: 20-μm glass beads CDP aligned

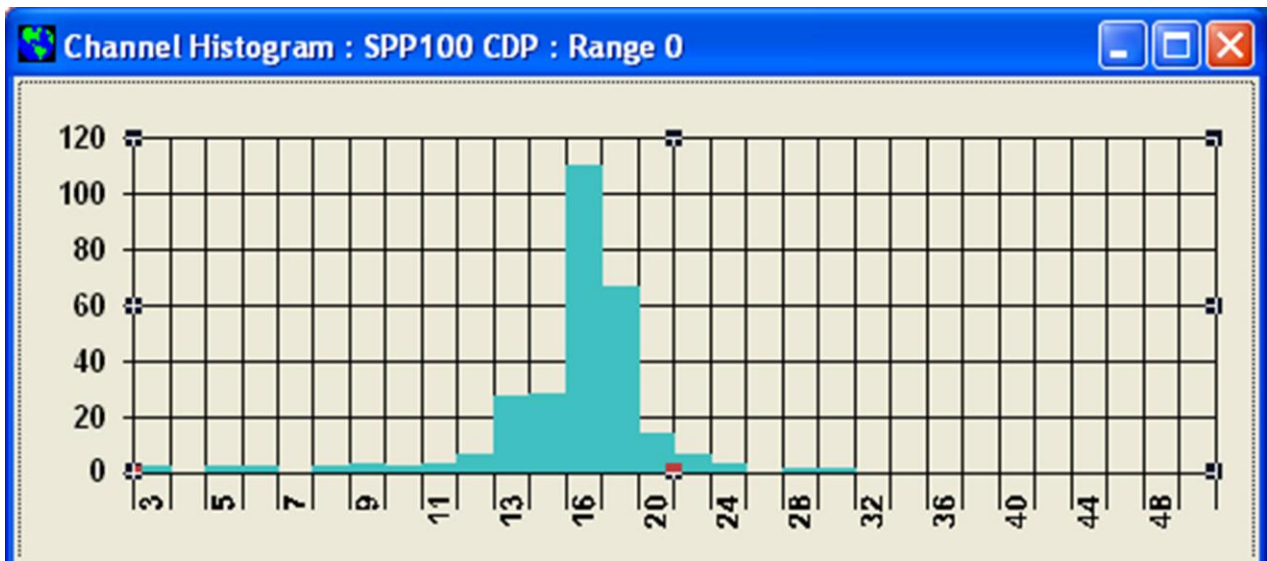


Figure 19: 20-μm glass beads CDP moderate misalignment

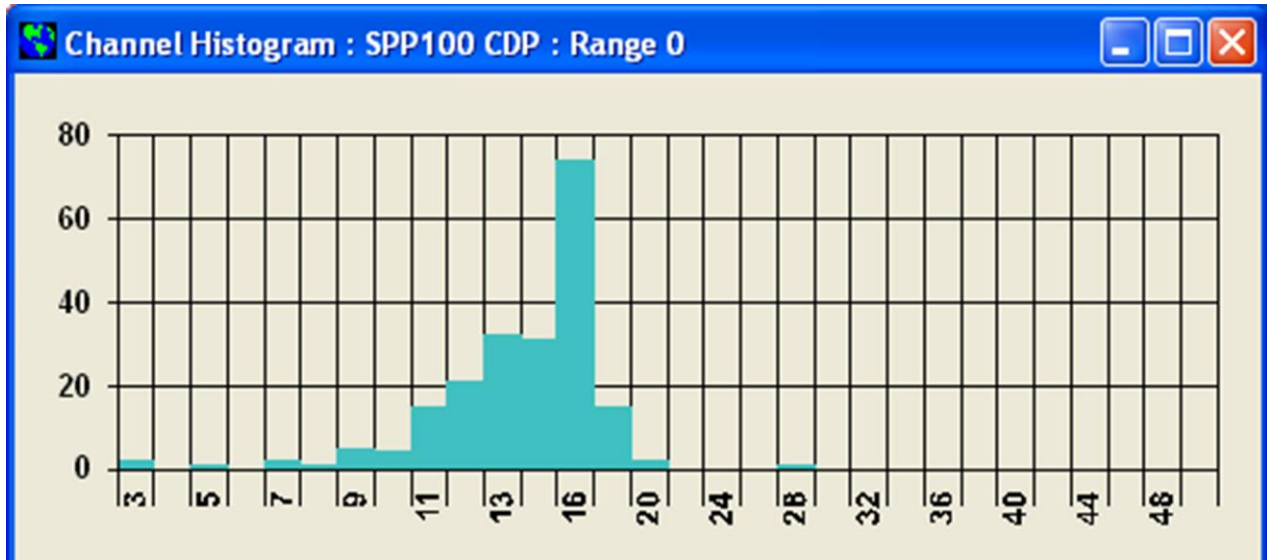


Figure 20: 20-µm glass beads CDP severe misalignment

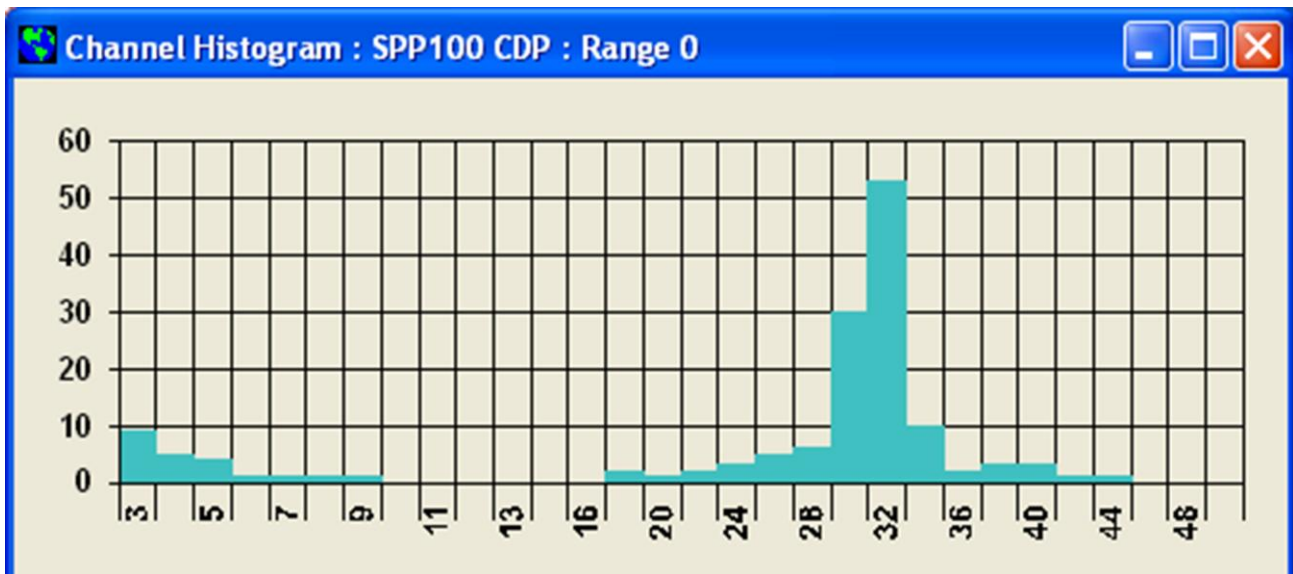


Figure 21: 40-µm glass beads CDP aligned

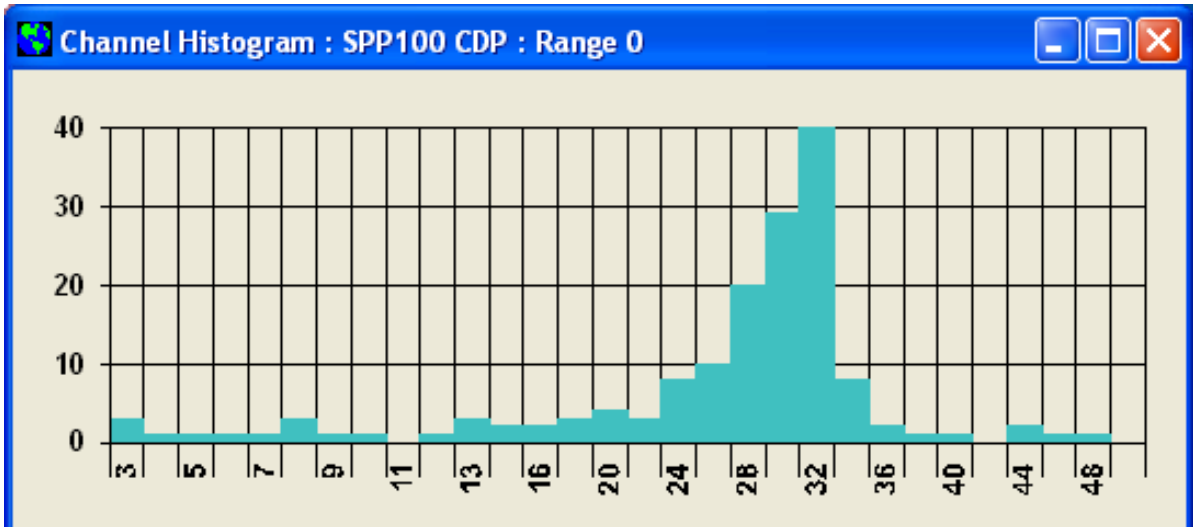


Figure 22: 40- μm glass beads CDP moderate misalignment

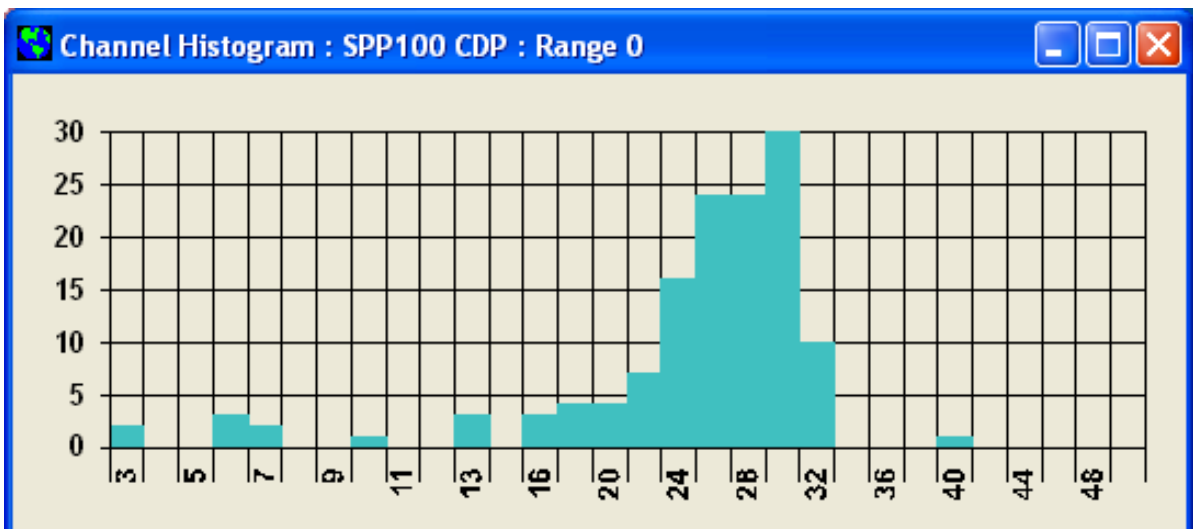


Figure 23: 40- μm glass beads CDP severe misalignment

Figure 24 shows the calibration of a CDP in good alignment with an excess concentration of calibration beads. Under these conditions, there will be coincidence of the beads in the beam and over-sizing will occur. A major peak can be seen in the 16- μm bin, where the beads are correctly sized. The large numbers of beads shown at the larger sizes are the result of coincidence. If possible, the bead counts should be kept to less than 100 in the calibration bin of the proper size for minimal coincidence. (This is more difficult with

the beads of 10 μm and below, as they tend to come out in a cloud from the bead dispenser.)

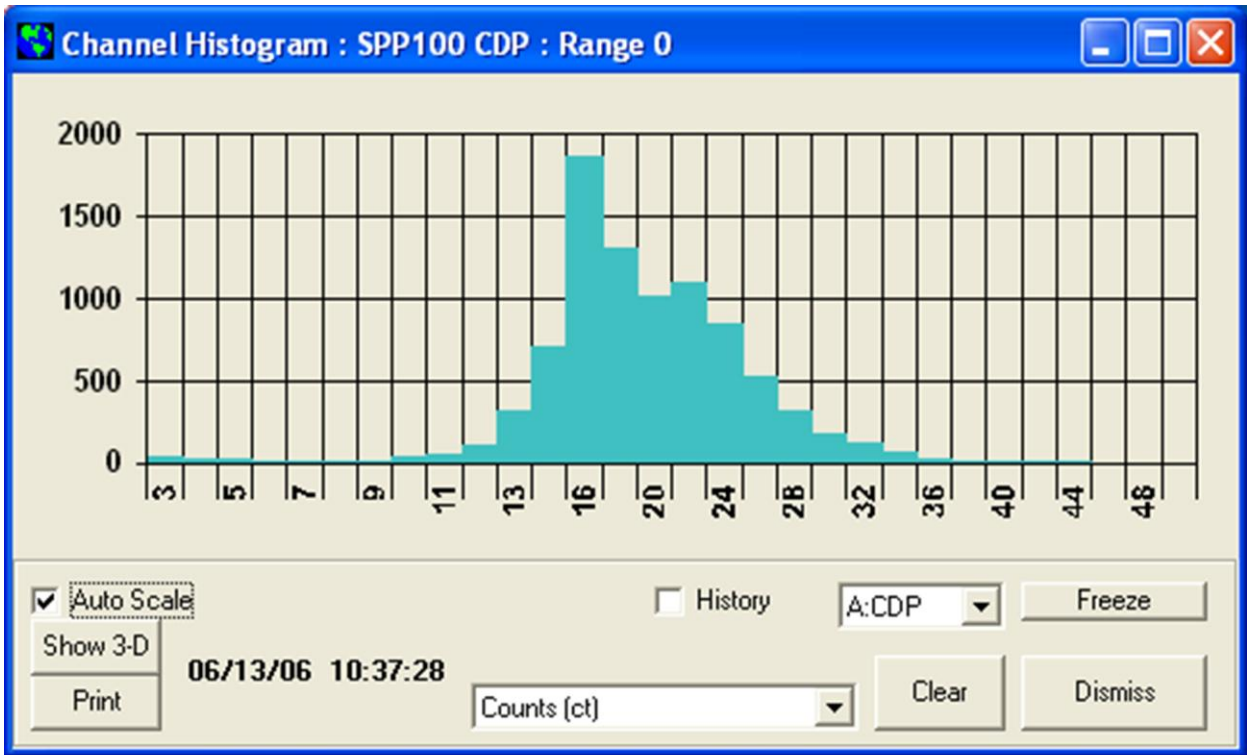


Figure 24: 20- μm glass beads calibration overload

Appendix D: Communications between the PC and CDP

Communications Parameters

Any computer capable of communications over an RS-232 or RS-422 port should be capable of communicating with the CDP. The port parameters for communications should be set as follows:

	CDP	CDP with PBP Option
Baud Rate	38.4K	57.6K
Data format	8-N-1: <ul style="list-style-type: none"> • 8-bit data bytes • No parity bit • One stop bit 	8-N-1: <ul style="list-style-type: none"> • 8-bit data bytes • No parity bit • One stop bit

Table 1: PC-CDP Communications Parameters

Since binary data are sent across the interface, it is possible that some systems will react to the non-ASCII characters that are sent as control characters. It is recommended that all communications with the CDP be programmed at a low level to avoid this problem.

The CDP and host computer send data to each other in data packets. Within these packets, data are stored in different types of structures. More information about these structures appears in Table 2.

Structure	Abbreviation	Bits	Order of Bytes								
Unsigned Character	U8	8	N/A (only one byte)								
Unsigned Integer	U16	16	<table border="1"> <tr> <td>Byte 0</td> <td>Byte 1</td> </tr> <tr> <td>Bits 7:0</td> <td>Bits 15:8</td> </tr> </table>	Byte 0	Byte 1	Bits 7:0	Bits 15:8				
Byte 0	Byte 1										
Bits 7:0	Bits 15:8										
Unsigned Long	U32	32	<table border="1"> <tr> <td>Byte 2</td> <td>Byte 3</td> <td>Byte 0</td> <td>Byte 1</td> </tr> <tr> <td>Bits 23:16</td> <td>Bits 31:24</td> <td>Bits 7:0</td> <td>Bits 15:8</td> </tr> </table>	Byte 2	Byte 3	Byte 0	Byte 1	Bits 23:16	Bits 31:24	Bits 7:0	Bits 15:8
Byte 2	Byte 3	Byte 0	Byte 1								
Bits 23:16	Bits 31:24	Bits 7:0	Bits 15:8								

Unsigned Extra Long	U48	48	Byte 4	Byte 5	Byte 2	Byte 3	Byte 0	Byte 1
			Bits 39:32	Bits 47:40	Bits 23:16	Bits 31:24	Bits 7:0	Bits 15:8

Table 2: Data Structures Used in CDP-Host Computer Communications

Initiating Communications

The host computer initiates all communications with the CDP. Since the CDP only responds with data after it has received a request for data, all of the timing for data acquisition needs to be performed in the host processor. To increase the rate data are relayed from the CDP, the host only needs to increase the rate at which it makes requests for data. After completing a data request, the CDP clears all of its summation registers and starts taking a new set of data.

Note that the first data packet of particle information the CDP sends is relatively meaningless. This is because the time interval between instrument start-up and the first data packet being sent likely differs from the standard sampling interval.

Communications Commands

There are three commands that the CDP/SPP-100 responds to:

- Setup Data Acquisition Parameters Command (command = 1)
- Send Data Command (command = 2)
- Send PbP Data Command (command=3)

These commands and the CDP's responses are discussed in detail in the following sections.

SETUP DATA Command

This command allows the host computer to transmit data acquisition parameters to the CDP. The CDP automatically comes up with default parameters at power up, but to ensure these are correct, the data system should set up the parameters each time the instrument is used. These parameters will remain in effect until power is cycled or a new Setup command is sent.

The following table displays the packet the host computer sends to the CDP probe to set up the data acquisition parameters. Full definitions of these parameters appear after the table.

Note that parameters marked “unused” must still have data sent in them in order for the CDP to read the data packet correctly. The instrument will ignore unused data, however.

Byte	Parameter Description	Data Type ⁶	Ex. Hex Value	Parameter Setting as Indicated by Hex Value in Previous Column (after bytes have been swapped, if necessary)
0	Start Byte	U8	1B	1B h = ASCII 27 = Esc Character
1	Command Number	U8	01	Setup Command
2	ADC Threshold	U16	14	0014 h = 20 counts
3			00	
4	<i>Unused</i>	U16	00	N/A
5			00	
6	Bin Count	U16	1E	001E h = 30 bins
7			00	
8	DOF Reject?	U16	01	01 h = On
9			00	
10	<i>Unused</i>	U16	00	N/A
11			00	
12	<i>Unused</i>	U16	40	N/A
13			00	
14	<i>Unused</i>	U16	00	N/A
15			00	
16	<i>Unused</i>	U16	00	N/A
17			00	
18	<i>Unused</i>	U16	00	N/A
19			00	
20	Bin 1 Upper Boundary	U16	64	0064 h = 100 counts
21			00	
22	Bin 2 Upper Boundary	U16	C8	00C8 h = 200 counts
23			00	
24	Bin 3 Upper Boundary	U16	2C	012C h = 300 counts

⁶ See section 0 for explanations of data types.

Byte	Parameter Description	Data Type ⁶	Ex. Hex Value	Parameter Setting as Indicated by Hex Value in Previous Column (after bytes have been swapped, if necessary)
25			01	
...Bins 4 – 39 ...				
98	Bin 40 Upper Boundary	U16	00	0 h = 0 counts ⁷
99			00	
100	Checksum	U16	6B	0C6B h = 3179
101			0C	

Table 3: Setup Command – Data Packet

Definition of the Declared Parameters

The possible values for the parameters the host computer sends to the CDP are explained below.

- Start Byte ASCII 27, HEX = 1B, the escape character.
- Command Number The command number: 01h = setup data; 02h = send data; 03h = send PbP data.
- ADC Threshold The minimum ADC trigger level, which can be any hex number between 0001h and FFF0 hex. This parameter sets a digital amplitude or pulse-height threshold, and it can be used to raise the bottom end of bin #1 to reduce noise. The CDP's default ADC Threshold is 20.
- Bin Count The number of size bins for the histogram. The standard value is 30 (1Eh).
- DOF Reject? An instruction to the CDP to either reject or include particles for statistical processing based on the depth of field signal. 0000h = includes particles outside the DOF, 0001h = rejects them. The CDP should always have DOF rejection turned on.
- Upper Bin Boundaries The peak count thresholds for the bins/channels. These values set the UPPER threshold of each size bin. The first value here will be the upper threshold of Bin Number 1. Thus, every ADC value read in below this value and above the ADC Threshold value will fall into Bin 1. The last bin's upper boundary, Bin 30, must be FFFF hex. The CDP uses 12-bit numbers for particle sizes, so the largest possible

⁷ This CDP is set for only 30 bins, so the upper boundaries of bins 31-40 are set to 0. See Definitions section below for more details.

value is 4095. *Note: 40 bin thresholds must be sent out.* Thus 30 valid thresholds are sent out, and the remaining 10 bins should be 0000 hex or FFFF hex.

- Checksum The 16-bit sum of all the 8-bit characters in the packet.

CDP Response to SETUP DATA Command

The CDP and CDP-PBP send a four-byte response to the **Setup Command**. The first two bytes indicate whether the received and calculated checksums match. If they do, the instrument responds with two ACK characters (ASCII character 6, HEX = 06) and then two bytes containing the firmware revision number. If the checksums do not match, the instrument responds with two NAK characters (ASCII 15, Hex = 15). The last two bytes again indicate the revision number of the instrument's code. This revision number allows for easy determination of which version of code is being used in a particular instrument.

The setup response does not include the ESC char to begin the data packet, nor does it have a CKSUM of its own at the end of the packet. This is true for the CDP and CDP-PBP.

Byte	Parameter Description	Data Type ⁸	Ex. Hex Value	Parameter Setting as Indicated by Hex Value in Previous Column
0	Response	U8	06	06 h = ACK
1		U8	06	06 h = ACK
2	Firmware Revision No.	U8	N/A	N/A
3	Firmware Revision No.	U8	N/A	N/A

Table 4: CDP Response to Setup Command – Data Packet.

SEND DATA Command

The second type of command the host computer sends to the CDP probe is the **Send Data Command**, command 2. This command instructs the probe to send back all the data it has acquired since it last relayed data to the host computer. PBP data are not included, although the command will work with a CDP-PBP probe.

The table below shows the packet that is sent to the CDP probe to request a data packet.

⁸ See Table 3 for an explanation of data types.

Byte	Parameter Description	Data Type ⁹	Ex. Hex Value	Parameter Setting as Indicated by Hex Value in Previous Column (after bytes have been swapped, if necessary)
0	Start Byte	U8	1B	1B h = ASCII 27 = Esc Character
1	Command Number	U8	02	Send Data Command
2	Checksum	U16	1D	001D h = 29
3			00	

Table 5: Send Data Command – Data Packet

Definitions for these parameters are the same as those given for the SETUP DATA command.

CDP Response to the SEND DATA Command

After the host computer sends the CDP a Send Data request, the instrument sends back a response as shown below.

Byte	Parameter Description ¹⁰	Data Type ¹¹	Comments
0	Laser Current /	U16	The first 8 channels in the data packet are analog-to-digital signals that must be converted by the data system (e.g., PADS) into meaningful numbers. The data arrive in hex format. PADS or another data system must then use a scaling algorithm specified within the program to yield results such as laser current, dump spot monitor voltage, etc.
1	Housekeeping 1		
2	Dump Spot Monitor /	U16	
3	Housekeeping 2		
4	Wingboard Temp /	U16	
5	Housekeeping 3		
6	Laser Temp /	U16	
7	Housekeeping 4		
8	Sizer Baseline /	U16	
9	Housekeeping 5		
10	Qualifier Baseline /	U16	
11	Housekeeping 6		
12	+5V Monitor /	U16	

⁹ See Table 3 for an explanation of data types.

¹⁰ Note that older CDPs may not have their eight housekeeping channels set to measure default parameters such as laser current, dump spot monitor, wingboard temp and so on.

¹¹ See Table 3 for an explanation of data types.

Byte	Parameter Description ¹⁰	Data Type ¹¹	Comments
13	Housekeeping 7		
14	Control Board T / Housekeeping 8	U16	
15			
16	Reject DOF	U32	
17			
18			
19			
20	Qual Bandwidth	U16	
21			
20	Qual Threshold	U16	
21			
24	Average Transit	U16	
25			
26	DT Bandwidth	U16	
27			
28	Dynamic Threshold	U16	
29			
30	ADC Overflow	U32	
31			
32			
33			
34	Bin 1 Counts	U32	
35			
36			
37			
38	Bin 2 Counts	U32	
39			
40			
41			
<i>...Bins 3 – 29 ...</i>			
150	Bin 30 Counts	U32	
151			
152			

Byte	Parameter Description ¹⁰	Data Type ¹¹	Comments
153			
154	Checksum	U16	
155			

Table 6: CDP Response to Send Data Command -- Data Packet

Definitions of the Send Data Response parameters

- Laser Current The electrical current flowing through the instrument's laser diode. See Table 7 for conversion equation.
- Dump Spot Monitor The amount of focused, unobstructed laser light collected in the dump spot monitor. See Table 7 for conversion equation.
- Wingboard Temp The temperature at the CDP's signal and power distribution board. See Table 7 for conversion equation.
- Laser Temp The temperature of the laser heat sink. See Table 7 for conversion equation.
- Sizer Baseline (V) The voltage from the instrument's sizing detector. See Table 7 for conversion equation.
- Qualifier Baseline (V) The voltage from the instrument's qualifier detector. See Table 7 for conversion equation.
- +5V Monitor The power 5-volt reference for the CDP's control system. See Table 7 for conversion equation.
- Control Board T (C) The temperature at the digital board. See Table 7 for conversion equation.
- Reject DOF The number of particles rejected because the signal analog pulse is less than the qualifier pulse (not in DOF).
- Reject Average Transit The number of particles rejected because they did not meet the criteria for transit time.
- Qual Bandwidth See section 5.0.
- Qual Threshold See section 5.0.
- Average Transit The average of the raw count of the particle widths in the sample interval.
- DT Bandwidth See section 5.0.
- Dynamic Threshold See section 5.0.
- ADC Overflow The number of times that the Analog-to-Digital Converter was at its maximum digitized count (4096). These particles are not processed

into the calculated parameters and only reported as “over-range particles.”

- Bin Count (Formerly called “OPCchan[]”) An array which holds the number of particles detected in each of the CDP sizing bins during the current sampling interval.
- Checksum The 16-bit sum of all the 8-bit characters in the packet.

Response Data Packet Length and Transmission Rate

The data-packet length for the CDP is 156 bytes. The packet is transmitted at 38,400 baud.

CDP Housekeeping Channels

A list of CDP housekeeping channels appears in the table below, along with the equations used to convert analog housekeeping values to meaningful digital values. (For channel definitions and ranges, see section 6.1.) The following conventions are assumed:

- “ad” is the analog-to-digital converter value sent over the serial channel in the housekeeping slots.
- All temperatures are in degrees Celsius.
- The analog-to-digital converter on the CDP has a 12-bit output and an input voltage range of 0 to 5 volts. Therefore, the solution of the input voltage, given a conversion value, (ad), is

$$V = 5(ad/4095)$$

#	Name	Equation to Convert Analog-Digital Counts to Meaningful Values
1	Laser_Current (mA)	mA = 0.061(ad)
2	Dump_Spot_Monitor (V)	Volts = 5*(ad/4095)
3	Wingboard_Temp (C)	Two Steps: 1.) $V = 5*(ad/4095)$ 2.) °C =
4	Laser_Temp (C)	$\left[\frac{\ln(5/V - 1)}{3750} + \frac{1}{298} \right]^{-1} - 273$
5	Sizer_Baseline (V)	Volts = 5*(ad/4095)

6	Qualifier_Baseline (V)	
7	+5V Monitor (V)	Volts = $5*(ad/4095)*2^{12}$
8	Control_Board_T (C)	$^{\circ}\text{C} = (0.06401*ad) - 50$

Table 7: Conversion Equations for Analog-to-Digital Housekeeping Channels

SEND PbP DATA Command

The final type of command the host computer sends to the CDP probe is the **Send PbP Data (Poll Request) Command**, command 3. This command instructs the probe to send back all the data including PbP data it has acquired since the last data transmission.

The following table shows the packet that is sent to the CDP probe to request a PbP data packet.

Byte	Parameter Description	Data Type ¹³	Ex. Hex Value	Parameter Setting as Indicated by Hex Value in Previous Column (after bytes have been swapped, if necessary)
0	Start Byte	U8	1B	1B h = ASCII 27 = Esc Character
1	Command Number	U8	03	Send PbP Data Command
2	Checksum	U16	1E	001E h = 30
3			00	

Table 8: Send PbP Data Command – Data Packet

Definitions for these parameters are the same as those given for the SETUP DATA command.

¹² This 5-volt nominal value can easily exceed the input range of the ADC, so it is divided by two to ensure it fits within the proper range. To get accurate voltage measurements, the value must be multiplied by 2 again as done in the formula.

¹³ See Table 3 for an explanation of data types

CDP Response to the SEND PbP DATA Command

The CDP responds to a SEND PbP DATA Command with a data packet identical to the one shown in Table 6 with the exception that PbP data are added. The CDP sends these data after the last Bin Count and before the Checksum.

The PbP data consists of one extra long (the header in **1st_PbP_Time**) followed by 256 unsigned longs (= one four-byte variable for each particle). However, the unsigned long data does not conform to byte boundaries. The first 12 bits are peak height, with 4095 (hex FFF) representing an oversize particle. The remaining 20 bits are the time between the first detected particle and the current particle, which is given with a resolution of 1 μ sec. If there are more than 256 particles in the sample interval, only the first 256 are reported. If there are fewer than 256 particles, these data are padded with zeros to fill 1024 bytes.

For a 30-bin CDP, then, the CDP-PbP would send a data packet with the bytes 0 - 153 looking identical to those shown in Table 6. The remainder of the data packet would continue as shown below.

Byte	Parameter Description	Data Type ¹⁴	Ex. Hex Value	Parameter Setting as Indicated by Hex Value in Previous Column (after bytes have been swapped, if necessary)
154	1st_PbP_Time	U48	00	Time of first detected particle = 0000 0050 634D hex (after swap) = 5268301 (decimal) μ sec = 5.2683 seconds
155			00	
156			50	
157			00	
158			4D	
159			63	
160	Particle 1 PbP Data	U32	00	ADC Counts = 0001 0011 0111 bin = 311 decimal Time since first detected particle = 0000 0000 0000 0000 0000 bin = 0 msec
161			00	
162			37	
163			01	
164	Particle 2 PbP Data	U32	37	ADC Counts = 0001 0011 0001 bin = 305 decimal Time since first detected particle = 0000 0110 0011 1111 0110 bin = 25.462 msec
165			06	
166			31	
167			61	

¹⁴ See for an explanation of data types.

...PbP Data for Particles 3 - 256 ...				
1184	Checksum	U16	A0	E2A0 hex = 58016
1185			E2	

Table 9: CDP-PBP Response to Send PBP Data Command – Data Packet

Response Data Packet Length and Transmission Rate

The length of the CDP's PbP data packet is 1186 bytes. This packet is transmitted at 57,600 baud. *Note that a sample rate of faster than 2 Hz may compromise data validity.*

Definitions of the SEND PbP DATA Response parameters

For all parameters other than those listed below, see the definitions for the SEND DATA response parameters.

- 1st_PbP_Time**

The time of the first particle in the PbP data. 1st_PbP_Time is given in μ s since the setup command. Byte order is 4, 5, 2, 3, 0, 1. In the event that no particles were observed during the sampling interval, this number is undefined.
- Particle-by-Particle Data**

An array that holds size and timing information about PbP particles. PbP Data is sent as 256 unsigned longs (one for each PbP particle) with byte order 2, 3, 0, 1. Once the bytes are reordered to 3, 2, 1, 0, the first 20 bits are particle time. Time is given in μ s since 1st_PbP_Time; the first particle's time in the PbP data is therefore zero. Actual particle time since setup is obtained by adding 1st_PbP_Time to the 20-bit PbP Data particle time. The remaining 12 bits of each unsigned long store the particle size. Oversize particles are represented by 4095 (hex fff). If there are more than 256 particles in the sample interval, only the first 256 are reported. If there are less than 256 particles, these data are padded with zeros to fill 1024 bytes.

Changing the Serial Interface Type

Typically DMT will already have configured the CDP for an RS-422 serial type, which is the default for the CDP. The CDP can also work with an RS-232 serial port, however. If you

change serial port types, you will need to change the CDP board wiring as described below.

The CDPE electronics box contains the power supply module, and underneath the CDP-PSB is the FPGA module. On the FPGA module, there are five jumpers used to select either RS-232 or RS-422. (See the CDP schematics). J901 through J905 are used to select the expected protocol. In the five sets of 3-pin jumpers, connect pins 1 and 2 for RS-422, and pins 2 and 3 for RS-232. Remember that RS-232 is a 3-wire serial protocol with a range of only 50 feet, while RS-422 is a 4-wire differential protocol rated for up to 1000 feet. The computer serial port must be of the same protocol as the instrument; built-in serial ports are typically RS-232.

See Appendix G for the power connections and signal connections.

Appendix E: CDP Heaters

The CDP has several standard heaters that are described below. The instrument may have additional heaters if it is part of a Cloud Combination Probe (CCP). See the CCP Manual (*DOC-0226*) for details.

Strut Heater

Location: Inside the CDP strut.
Specifications: 25 W at 28 VDC, .89 A, 31.36 ohms, DMT P/N HTR-0082.
Other: The strut heater is the same model as that used in the cross-bar heater.

Cross-Bar Heater

Location: Inside the CDP cross-bar.
Specifications: 25 W at 28 VDC, .89 A, 31.36 ohms, DMT P/N HTR-0082.

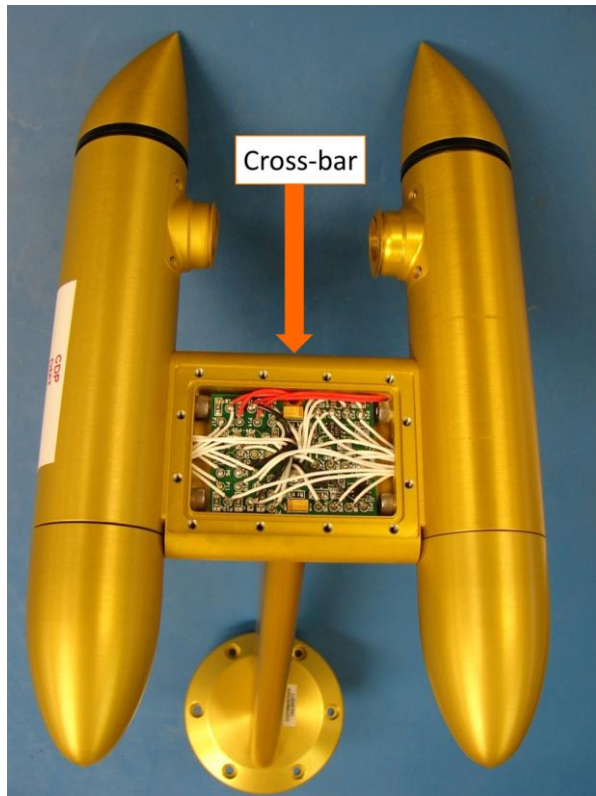


Figure 25: CDP Crossbar

Nose-Tip Heaters

Location:	One inside each tip of the CDP arms (Figure 26).
Specifications:	39 W at 28 VDC each, 1.07 A each, 26.13 ohms each.
Total power for both heaters:	78 W at 28 VDC, 2.14 A.

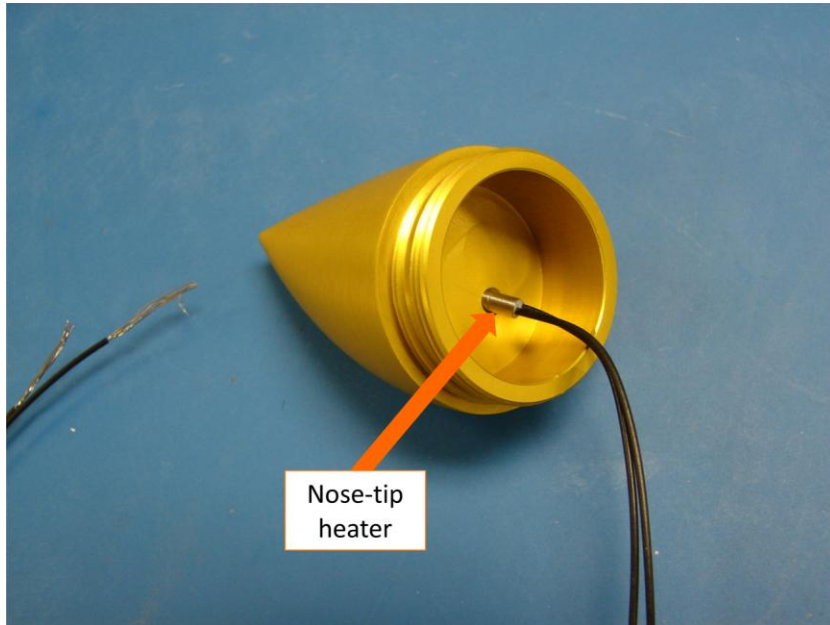


Figure 26: CDP Nose-tip Heater Being Inserted into Nose-tip.

Window Heaters

Location:	Two, one near the send-side window and one near the receive-side window.
Specifications:	Curved ribbon heater, 25 W each at 28 VDC, .89 A each, 31.36 ohms each, DMT P/N HTR-0051.
Total power for both heaters:	50 W at 28 VDC, 1.78 A

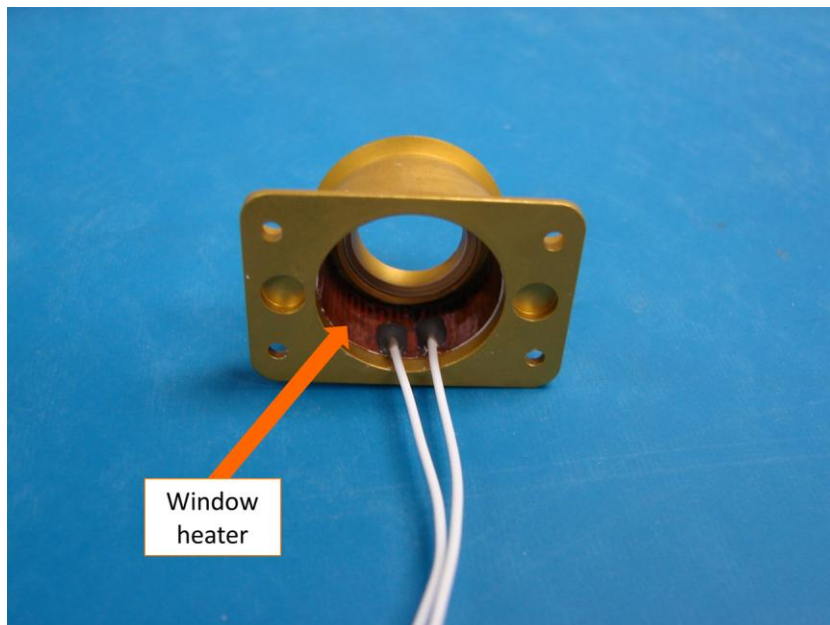


Figure 27: CDP Window Heater before Instrument Assembly

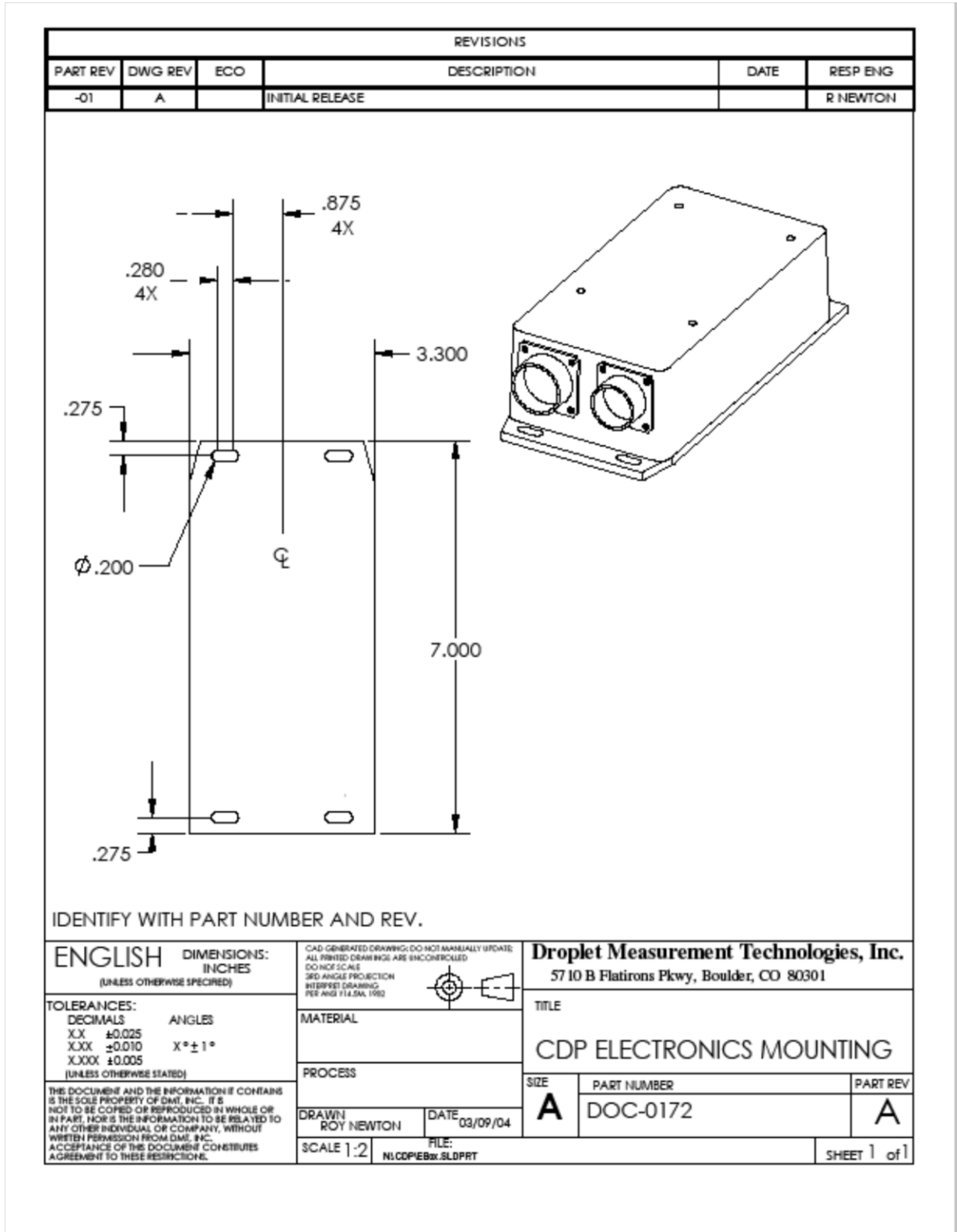
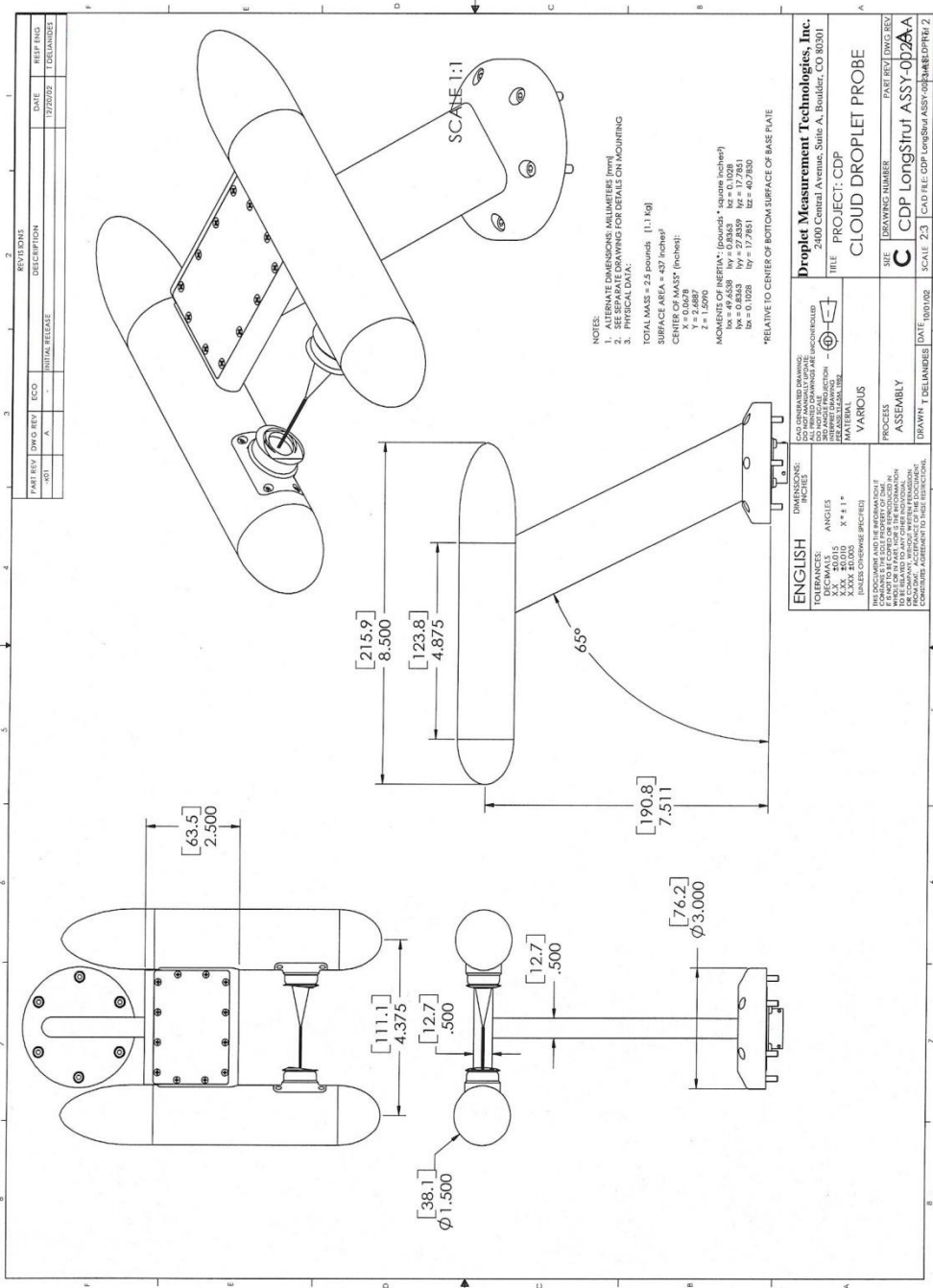


Figure 29: CDP Electronics Mounting

Appendix G: CDP Dimensional Drawing



Appendix H: 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.

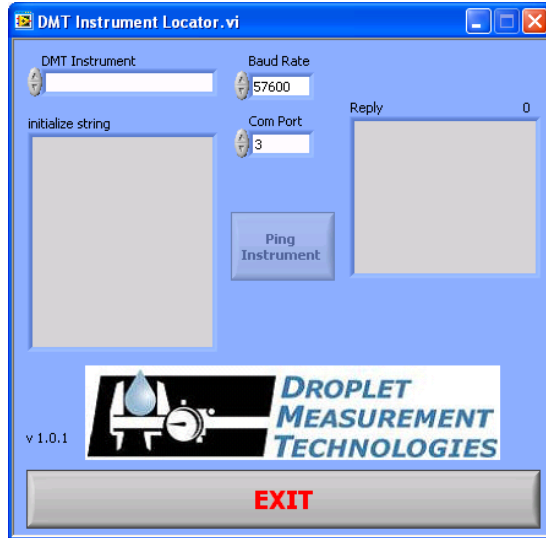


Figure 30: Instrument Locator

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 I: Threshold Table for CDPs with ABD-0234 Board

The following particle-sizing thresholds should be used for CDPs with an ABD-0234 board. If you use PADS and you have upgraded an older CDP to one with this board, make sure you also have the most recent version of the PADS software.

Bin 1 Lower Size Threshold: 2

Bin 1 Lower ADC Threshold: 60

<i>Bin #</i>	<i>Upper Bin Sizes</i>	<i>Upper ADC Thresholds</i>
1	3	91
2	4	111
3	5	159
4	6	190
5	7	215
6	8	243
7	9	254
8	10	272
9	11	301
10	12	355
11	13	382
12	14	488
13	16	636
14	18	751
15	20	846
16	22	959
17	24	1070
18	26	1297
19	28	1452
20	30	1665
21	32	1851
22	34	2016
23	36	2230
24	38	2513
25	40	2771
26	42	3003
27	44	3220
28	46	3424
29	48	3660
30	50	4095