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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

The SP2-D is a Class 1 Laser Product. **STRICT OBSERVANCE OF THE FOLLOWING WARNING LABELS IS ADVISED.**

The following label appears on the back panel of the SP2:

**Class 1 Laser Product**
Complies with 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice no. 50, dated June 24, 2007

The following laser safety label is located on the exterior of the laser frame:

**CAUTION**
CLASS 4 INVISIBLE LASER RADIATION
WHEN OPEN AND INTERLOCKS
DEFEATED
AVOID EYE OR SKIN EXPOSURE TO
DIRECT OR SCATTERED RADIATION

The following laser safety label appears next to the interlock switches:

**INTERLOCK**
Laser Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Pump Laser</th>
<th>Main Laser</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>808 nm</td>
<td>1064 nm</td>
</tr>
<tr>
<td>Maximum power</td>
<td>4 W</td>
<td>.4 W</td>
</tr>
</tbody>
</table>

Additional Instrument Labels:

The following identification label appears on the back panel of the SP2:

![Identification Label]

The following label appears on the back panel of the instrument:

![Warning Label]

Warning: If not properly grounded, the instrument can cause an electrical shock.

Use a three-conductor cord and a plug appropriate for the location in which the instrument will be used. Connect the plug to a properly grounded receptacle.

CAUTION: Use of control or adjustments or performance of procedures other than specified in this manual may result in hazardous radiation exposure.
# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Introduction</td>
<td>7</td>
</tr>
<tr>
<td>1.1 Specifications</td>
<td>7</td>
</tr>
<tr>
<td>1.2 Electrical Specifications</td>
<td>9</td>
</tr>
<tr>
<td>1.3 Physical Specifications</td>
<td>9</td>
</tr>
<tr>
<td>1.4 Operating Limits</td>
<td>9</td>
</tr>
<tr>
<td>2.0 Theory of Operation</td>
<td>10</td>
</tr>
<tr>
<td>2.1 Laser Characteristics</td>
<td>11</td>
</tr>
<tr>
<td>2.2 Optical Detectors</td>
<td>13</td>
</tr>
<tr>
<td>2.3 Control Board Inputs</td>
<td>14</td>
</tr>
<tr>
<td>3.0 Unpacking and Setup</td>
<td>14</td>
</tr>
<tr>
<td>3.1 Unpacking</td>
<td>14</td>
</tr>
<tr>
<td>3.2 Set Up</td>
<td>14</td>
</tr>
<tr>
<td>3.3 Turning On the System</td>
<td>16</td>
</tr>
<tr>
<td>3.4 Turning Off the System</td>
<td>21</td>
</tr>
<tr>
<td>4.0 Flow System</td>
<td>22</td>
</tr>
<tr>
<td>5.0 Typical Operating Parameters</td>
<td>23</td>
</tr>
<tr>
<td>6.0 Laser Safety Interlocks</td>
<td>23</td>
</tr>
<tr>
<td>7.0 Routine Maintenance</td>
<td>25</td>
</tr>
<tr>
<td>7.1 SP2-D: Procedure to Calibrate the Laminar Flow Element</td>
<td>26</td>
</tr>
<tr>
<td>7.2 Procedure for Alignment of the YAG Laser</td>
<td>26</td>
</tr>
<tr>
<td>7.3 Cleaning the Laser Optics</td>
<td>26</td>
</tr>
<tr>
<td>8.0 Calibrating the Instrument with Aerosol Black Carbon</td>
<td>27</td>
</tr>
<tr>
<td>8.1 Required Equipment</td>
<td>27</td>
</tr>
<tr>
<td>8.2 Calibration Procedure</td>
<td>27</td>
</tr>
<tr>
<td>9.0 Troubleshooting</td>
<td>28</td>
</tr>
<tr>
<td>Appendix A: Revisions to Manual</td>
<td>29</td>
</tr>
<tr>
<td>Appendix B: SP2 YAG Pump Laser Storage and Handling Instructions</td>
<td>30</td>
</tr>
<tr>
<td>Storing the SP2 YAG Pump Laser</td>
<td>30</td>
</tr>
<tr>
<td>Handling the SP2 YAG Laser</td>
<td>31</td>
</tr>
<tr>
<td>Appendix C: Configuring and Testing the SP2’s Four Analog Input Channels</td>
<td>33</td>
</tr>
<tr>
<td>Configuration</td>
<td>33</td>
</tr>
<tr>
<td>Testing the Input Voltages</td>
<td>34</td>
</tr>
</tbody>
</table>
Appendix D: Plumbing Diagram ................................................................. 35
Appendix E: SP2-D System Schematic ...................................................... 36

Figures

Figure 1: Front View of the SP2 Analyzer ..................................................... 10
Figure 2: Rear View of the SP2 Analyzer Chassis ........................................ 11
Figure 3: Schematic Diagram of the YAG Laser in the SP2 ......................... 12
Figure 4: SP2 Optical Diagram ................................................................. 13
Figure 5: Connecting SP2 and SP2 Pump Exhaust Valves .......................... 14
Figure 6: Connecting SP2 Purge Valve to Drierite Cartridge ....................... 15
Figure 7: Connecting SP2 Pump Purge Port to Drierite Cartridge ............... 15
Figure 8: Connecting the SP2 Purge Valve to the SP2 Pump Purge Port ....... 16
Figure 9: Verifying the Config File on the Config Tab ............................... 17
Figure 10: Loading a New Configuration File ........................................... 18
Figure 11: Sample Pump Power Switch ..................................................... 19
Figure 12: Sample Flow Stabilizing ......................................................... 19
Figure 13: Turning on the Laser from the Control Tab ............................... 20
Figure 14: Verifying Particle Response .................................................... 21
Figure 15: Turning the Laser Off .............................................................. 22
Figure 16: SP2 Key in the Locked (left) and Unlocked (right) Positions ....... 24
Figure 17: Laser Interlocks (Circled in Lower Left and Upper Right of SP2) 24
Figure 18: Interlock Jumper ................................................................. 25
Figure 19: Schematic Diagram for SP2 Calibration with DMA .................. 28
Figure 20: SP2 Pump Laser in Protective Box ......................................... 31
Figure 21: Shorting Plug Detached (left) and Attached (right) to Power Connector ................................................................. 31
Figure 22: Protective Cap and SMA Fiber Connector (above); Cap Attached to Connector (below) ................................................................. 32
Figure 23: Configuring Analog Input (AI) Channels in the SP2-D ............... 34
Figure 24: Control Tab Display of Newly Added AI Channels ..................... 35
1.0 Introduction

The SP2 directly measures the black carbon, known as soot, in individual aerosol particles. Its high sensitivity, fast response, and specificity to elemental carbon make it the premier instrument for the following tasks:

- Characterizing pollution sources
- Characterizing soot in snow, ice or water
- Calibrating Aethalometers
- Documenting thin, atmospheric layers of contamination

This manual describes revision D of the instrument.

1.1 Specifications

<table>
<thead>
<tr>
<th>Measured Parameters</th>
<th>Single-particle laser incandescence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single-particle light scattering</td>
</tr>
<tr>
<td>Auxiliary Parameters</td>
<td>Temperature</td>
</tr>
<tr>
<td></td>
<td>Pressure</td>
</tr>
<tr>
<td>Derived Parameters</td>
<td>• BC mass distribution as function of particle diameter</td>
</tr>
<tr>
<td></td>
<td>• Particle number distribution as a function of particle size</td>
</tr>
<tr>
<td>Maximum Data Acquisition Rate</td>
<td>• 25,000 particles/second</td>
</tr>
<tr>
<td></td>
<td>• 0 – 12,500 particles/cm³ at standard flow rate of 120 volumetric cm³/minute (Concentrations can basically increase until particles become coincident)</td>
</tr>
<tr>
<td>Particle Size Range</td>
<td>• Scattering signal: 200 – 400 nm diameter (this range encompasses the accumulation mode of most particles, i.e. range where most mass is found)</td>
</tr>
<tr>
<td></td>
<td>• Incandescent signal: depends on particle density, but 70 – 500 nm mass-equivalent diameter assuming a black carbon density of 1.8 g/cm³</td>
</tr>
<tr>
<td>Aerosol Medium</td>
<td>Air, 0 - 40 ºC (32 - 104°F)</td>
</tr>
<tr>
<td>Lasers</td>
<td>• Nd:YAG Laser: 1064 nm, 3 MW/cm² intracavity circulating power</td>
</tr>
<tr>
<td></td>
<td>• Pump Laser: 808 nm, 4 W</td>
</tr>
<tr>
<td></td>
<td>The pump laser can be controlled either through the SP2 software or through the touch-screen on</td>
</tr>
</tbody>
</table>
**Sample Flow** | 30 – 180 volumetric cm³/minute (typically 120)
---|---
**Flow Control** | Electronic flow control with a laminar flow element (LFE) and a solenoid valve
**Pump** | Two single-head diaphragm pumps contained in a box
**Minimum Black Carbon Detection Limit** | • 10 ng/m³
• 0.3 fg/particle
**Routine Maintenance** | Weekly:
• Refreshing or replacing the desiccant in the drying cartridge on the purge line
• Conducting PSL size check to monitor laser power
*Monthly and around field campaigns:*
• Conducting zero check with high-efficiency filtered air sample
*Annually (more frequently for high-BC environments):*
• Checking calibration of the laminar flow element on the sample inlet

**Recommended Service** | Annual cleaning and calibration at DMT service facility
**Front Panel Display** | System power switch, 1/8 in. Swagelok® sample inlet, 2 USB 2.0 ports, laser ON/OFF indicator light
**Rear Panel Connections** | Keyboard port, mouse port, VGA and HDMI monitor ports, 2 Ethernet ports, 2 RS-232 communications ports, 4 USB 2.0 ports, 4 analog inputs, ¼ in. Swagelok® purge line, ¼ in. Swagelok® exhaust line, SATA hard drive connection, exhaust vents, system and pump power connections
**Computer System** | On-board Intel®Core™ i7 CPU 8 GB RAM
750 GB hard drive for data storage
NI PCI-6133 DAQ interface card
NI PCI-6259 housekeeping data card
User interface via standard keyboard, mouse, and 19” monitor (included)
**Software** | • SP2 Executable program written in LabVIEW
• PAPI program written in Igor
**Data Storage Capacity** | Depends on number of particles; at a concentration of 1,000 #/cm³ and a standard flow rate of 120 volumetric cm³/minute, the SP2 computer has the capacity to store 56 hours of continuous data
**Communications Output** | Gigabyte Ethernet interfaced through an Intel® PC82573V PCIe GbE controller
1.2 Electrical Specifications

<table>
<thead>
<tr>
<th>Voltage:</th>
<th>SP2: Universal Voltage (100-240 VAC, 50/60 Hz)</th>
</tr>
</thead>
</table>
| Power Consumption: | - 300 W for instrument  
| | - 30 W for pump |

1.3 Physical Specifications

| Weight: | 26.1 kg for SP2 alone  
| | 3.4 kg for pump  
| | 3 kg for monitor |
| Dimensions: | SP2: 48 cm W x 61 cm L x 26 cm H  
| | Pump: 20 cm W x 25 cm L x 10 cm H  
| | Monitor: 37 cm W x 22 cm L x 39 cm H |
| Shipping Container: | Durable Atlas Case Corporation ATA Transit Case that conforms to the Air Transport Association’s Specification 300 Category 1 standards |
| Other: | Suitable for airborne mounting in the aircraft cabin |

1.4 Operating Limits

| Temperature: | 0 to +40 °C (32 – 104 °F) |
| Altitude: | 0-40,000 ft |
| Humidity: | 0 - 100% (non-condensing) |
2.0 Theory of Operation

The Single Particle Soot Photometer (SP2) utilizes the high optical power available intra-cavity from an Nd:YAG laser. Light-absorbing particles, mainly black or elemental carbon in atmospheric measurements, absorb energy and are heated to the point of incandescence. The energy emitted in this incandescence is measured, and a quantitative determination of the black carbon mass of the particle is made. This mass measurement is independent of the particle mixing state, and hence the SP2 is a reliable measure of the black carbon mass concentration. Since the SP2 detects single particles, the SP2 can also measure the black carbon number concentration.

All particles scatter light, regardless of whether or not they absorb light. A scattering detector is included in the SP2, which detects single particle scattering at 1064 nm, and the scattering signal can be used to indicate the black carbon mixing state at the single-particle level. The scattering detector can also be used to detect non-BC-containing aerosol number and mass concentrations.

The SP2 measures the light scattering and/or incandescence of each particle. The full scattering and/or incandescence response of each particle is completely digitized for detailed analysis.

Figure 1: Front View of the SP2 Analyzer

1 Basic details on the theory of this technique are given by Stephens et al. (2003). Details on the SP2 and application to atmospheric measurements are given by Schwarz et al. (2006). Additional work on the theory of the measurements has been published by Moteki and Kondo (2006).
### 2.1 Laser Characteristics

The heart of the SP2 is the Nd:YAG laser. This will be referred to in the following discussion simply as the YAG laser. Figure 3 gives a schematic diagram of the laser and the main optical components. The laser cavity consists of a gain medium, the YAG crystal (in the center of Figure 3), and the output coupler on the right. The particles from the aerosol jet interact with the laser beam at the center of the cavity. The optical surfaces on both of these components are coated to have a reflectivity of 99.97% or better at the 1064-nm wavelength of the YAG laser. In a standard laser, the power that escapes through one of the laser mirrors is used as the laser source; in the SP2 application, the goal is to contain and use the power within the cavity between the mirrors (open-cavity...
laser) and utilize it directly. The power in the cavity is approximately 3 MW per cm$^2$ of circulating laser power. The YAG laser operates continuously and is not pulsed. The power that is available external to the cavity, the pump laser, is approximately 50-100 mW. This power is monitored by the YAG power monitor and is displayed on the data system in relative numbers. The entire laser radiation is contained, and therefore the system qualifies as a Class 1 laser.

The mode aperture on the cavity side of the gain medium is used to minimize pump light in the cavity and also helps confine the laser beam to the TEM$_{00}$ mode.

The gain medium is optically pumped with a diode laser at 808 nm (not shown) and the optical energy is coupled via a fiber. Two mode-match lenses focus the energy from the fiber onto the gain medium.

The laser beam is Gaussian in shape, nominally 230 microns width at 90% power level.

Figure 4 details the YAG laser, the optical configuration of the SP2, and the optical detectors. The YAG laser is central to the system, with the four detectors being seen as in the plane of the page. The aerosol jet is perpendicular to the plane of the page and sends the particles across the laser beam.

AVS resonator layout

Figure 3: Schematic Diagram of the YAG Laser in the SP2
2.2 Optical Detectors

Four optical detectors are used. One detector is optically filtered to pass only the 1064 nm radiation. This will measure the scattering signal from all particles, both those that scatter light only, and those that absorb light and both scatter and incandesce. This detector is identified as Channel 0 in the data.

Two photomultiplier tube (PMT) detectors measure the incandescence signal in the visible region. These channels are optically filtered to pass broadband light, nominally from 400-650 nm and narrow-band light, nominally from 610-650 nm. These are identified as channels 1 and 2 in the data, respectively. The ratio of the signals from these two detectors allows the color temperature of the incandescing particles to be calculated, providing assurance that the particle measured is elemental carbon.

A fourth detector allows measurement of the leading edge of the scattering signal. This can be used to analyze the amount of coating or mixing state of the incandescing particle. Details on this analysis are given by Gao et al. (2007). This is Channel 3 in the data.
2.3 Control Board Inputs

The SP2 control board inside the chassis has three inputs for sampling external voltages and recording the data in the housekeeping file. These inputs are J13, J14, and J15, corresponding to Aux Input 0, Aux Input 1, and Aux Input 2, respectively. Pin 1 of the connector is the signal input and pin 2 is the return. These inputs have buffer amplifiers so that low-level signals can be connected to the inputs.

3.0 Unpacking and Setup

3.1 Unpacking

The SP2 will be shipped in two cartons. One is a case specially designed to fit and protect the analyzer chassis. This case should be saved and used to return the analyzer to DMT if service is needed. The other carton will contain the sample pump, keyboard, monitor, cables and other accessories. Check both cartons for damage immediately upon receipt, and notify the carrier and DMT if damage is noted. After unpacking, remove the cover from the analyzer chassis to look for components shaken loose in transit.

3.2 Set Up

To set up the SP2, follow the instructions below. Note: Users who have the SP2 with an Auto Sampler and Nebulizer should consult DOC-0318, the Set-up and Operation Manual for the SP2 with Auto Sampler for this procedure.

1.) Using Poly tubing with ¼” Swageloks (included), connect the exhaust port on the SP2 to the exhaust in-flow port on the SP2 pump.

Figure 5: Connecting SP2 and SP2 Pump Exhaust Valves
2.) If you want to connect a Drierite cartridge to the system, follow the steps below. (Both the Drierite and Nafion dryer are used to dry sheath and purge flow air in humid conditions.)
   a. Connect the Poly tubes exiting the SP2 purge port to the Drierite cartridge (Figure 6).

   ![Figure 6: Connecting SP2 Purge Valve to Drierite Cartridge](image)

   b. Connect the Drierite cartridge to the out-flow purge port on the SP2 pump (Figure 7). The out-flow purge port is on the left side of the pump.

   ![Figure 7: Connecting SP2 Pump Purge Port to Drierite Cartridge](image)

   c. Plug in the power supplies for the SP2 and SP2 pump. The set-up is now complete; you do not need to follow the steps below.

3. If you want to connect the SP2 directly to the pump without a Drierite cartridge, connect the SP2 purge valve to the SP2 Pump purge port. See Figure 8.
Figure 8: Connecting the SP2 Purge Valve to the SP2 Pump Purge Port

4. Plug in the SP2 pump power connector to the back of the SP2 instrument.

5. Plug in the SP2 power supply. See warning below.

**Warning:** If not properly grounded, the instrument can cause an electrical shock. Use a three-conductor cord and a plug appropriate for the location in which the instrument will be used. Connect the plug to a properly grounded receptacle.

### 3.3 Turning On the System

To turn on the SP2, follow the instructions below. *Note:* Users who have the SP2 with an Auto Sampler and Nebulizer should consult **DOC-0318**, the *Set-up and Operation Manual for the SP2 with Auto Sampler* for this procedure.

1.) Turn on the SP2 Computer using the **Computer** switch on the SP2.

2.) Turn on the SP2 using the **System Power** switch on the SP2.\(^2\)

3.) Start the SP2 software by double-clicking on the SP2 icon on desktop.

4.) In the software, go to **Config** tab and **Program** sub-tab.

---

\(^2\) The **SYSTEM POWER** switch controls the power to the SP2 analyzer electronics, and is the master switch for the SAMPLE PUMP power. If **SYSTEM POWER** is off, the PUMP cannot be powered. The **COMPUTER** switch is independent of the other two switches, and turns only the computer on and off.
5.) Check to ensure **Config File Being Viewed** is set to the correct config file. See Figure 9 for the location of this parameter. The name of the config file may vary depending on your instrument. If the correct file is loaded, skip to step 10.

![Image of SP2 Config Tab](image)

**Figure 9: Verifying the Config File on the Config Tab**

6.) If a different file is listed, press the **Load a File** button (Figure 10). Navigate to the directory `C:\DMT\SP2 Support`. **Select the correct file** and click on **OK**.
7.) Click on the Control tab in the SP2 software. Move the Sample Pump Power Switch to ON (Figure 11). You will hear noise as the pump starts up.
8.) Go to the SP2 tab on software. Wait until the flow has stabilized. Sample Flow LFE should be approximately 120 vccm (Figure 12).
9.) Click on the **Control** tab in the SP2 software (Figure 13). Move the Laser Power Switch to ON.

![Figure 13: Turning on the Laser from the Control Tab](image)

10.) Go to the SP2 tab in the software and verify the particle response (Figure 14).
11.) Proceed with sampling and data recording. For details, see DOC-0092, the SP2 Software Manual.

3.4 Turning Off the System

To turn off the SP2, follow the instructions below. Note: Users who have the SP2 with an Auto Sampler and Nebulizer should consult DOC-0318, the Set-up and Operation Manual for the SP2 with Auto Sampler for this procedure.

1.) On the SP2 software’s Control tab, set the Laser Power Switch to Off (Figure 15). WARNING: Laser Power must be turned off before the pump is turned off.
2.) Turn off the **Sample Pump** switch on the SP2.

3.) Shut down the SP2 software by selecting **File > Exit**.

4.) Turn off the SP2 using the **System Power** switch on the SP2.

5.) Turn off the SP2 Computer using the **Computer** switch on the SP2.

### 4.0 Flow System

The SP2 requires both a source of vacuum, and of low-pressure (approximately 10 psi) dry compressed air for operation. The instrument is supplied with a boxed diaphragm pump which provides both functions. Appendix D, the SP2 Plumbing Diagram, provides details about the SP2-D flow.

The sample flow is measured by a Laminar Flow Element immediately ahead of the sample jet. The sample jet uses a sheath of filtered air to narrow the aerosol stream just before the laser beam. An additional stream of filtered purge air is injected on either end of the laser frame to minimize the chance of aerosol particles contaminating the laser optics.

The flows of sheath air for the jet and purge air for the optics are regulated by flow controllers. The flow controllers are mass flow controllers, but in the software the mass flow is converted to volume flow and they are regulated as volume flow controllers. The data-acquisition card for the housekeeping channels has only two digital-to-analog control lines. One of the lines controls the sheath flow, and the other goes to the exhaust flow regulation, which is fed information from the sample flow measurement. Since the amount of purge flow air is not critical, the purge flow controller is slaved to the sheath flow controller. In normal operation, the voltage provided to the purge flow controller is
60% of that to the sheath flow. The purge flow controller has half the range of the sheath flow controller, so the net purge flow is 30% of the sheath flow.

The exhaust control system contains dual valves in parallel. A manually-controlled needle valve is in parallel with an electronically-controlled proportional solenoid valve. This valve is computer-controlled with the signal input from the laminar flow element on the inlet. The solenoid valve in the dual-valve system is used to provide finer flow control. The normal sample flow rate for the SP2 is 120 cc/min. The full range of sample flow has not been examined, but it has been run successfully from 60-180 cc/min.

The parameter Exhaust Valve Set is the voltage that is applied to the proportional valve by the computer. This has a range of 0-5V, and it is recommended that this be set at about 2V +/- 1V in normal operation. To set this voltage, set the desired sample flow, and read the Exhaust Valve Set voltage. If the voltage is higher than desired, the valve is opening farther than planned, and the needle valve is closed too far, so open the needle valve 1/8-turn or less and allow the system to stabilize. This will take a minute or more. Continue adjusting the needle valve until the desired valve set voltage is reached.

### 5.0 Typical Operating Parameters

For typical operating values for the SP2 housekeeping channels, see the SP2 Software Manual (DOC-0092).

### 6.0 Laser Safety Interlocks

The SP2 features a number of interlocks, which are described below. These interlocks all operate in a series.

- **SP2 Key** (Figure 16). This must be in the locked position for the laser to turn on.

- **Cabinet laser interlock switches** (Figure 17). For the laser to turn on, these switches must both be engaged, i.e. pressed down.

- **Interlock jumper** (Figure 18). This jumper must be plugged in for the laser to turn on. The jumper is designed to connect the SP2 to a laser-room door interlock system. If you are interested in using this feature, contact DMT for assistance.

- **The Laser Power Digital Output Switch**. This switch is located on the SP2 software’s Control tab. For the laser to turn on, this switch must be set to On. In addition, the
controller channels Laser Temp SP (C) and Pump Laser Current SP must be set to non-zero values.

Figure 16: SP2 Key in the Locked (left) and Unlocked (right) Positions

Figure 17: Laser Interlocks (Circled in Lower Left and Upper Right of SP2)
Caution: If the laser turns off because an interlock switch was disengaged, the laser will automatically turn on again when the interlock is re-engaged. Note that this result differs from that found with Rev. C of the SP2. In that version of the instrument, if an interlock switch becomes disengaged, the laser does not automatically turn on when the interlock is engaged again. Rather, the user must first turn laser power off and then on again in the software.

7.0 Routine Maintenance

The only routine maintenance that the SP2 requires is to periodically refresh or replace the desiccant in the drying cartridge on the purge line. If the desiccant becomes saturated and the SP2 is operated in a very humid environment, condensation could build up in the purge line and possibly contaminate the flow controllers, which can cause them to fail.

An occasional particle zero check is also recommended; this is done by placing a HEPA or other high-efficiency filter on the SP2 inlet. After a few minutes, the instrument should record an occasional particle, but effectively the particle concentration measurement should be zero. If not, contact DMT for support.
If the SP2 is operated in a highly particle-laden environment, it may be necessary to check the calibration of the laminar flow element (LFE) on the sample inlet.

### 7.1 SP2-D: Procedure to Calibrate the Laminar Flow Element

1. Disconnect the proportional valve by unplugging the control board’s J16 connector.
2. Connect a DVM to TPL22 (Ashcroft) and to the ground test point, TPL17 (GND).
3. Connect a bubble flow meter or volume-displacement flow meter to the sample inlet line on the SP2.
4. Start the SP2 data system, software, analyzer chassis power and sample pump—DO NOT START THE YAG LASER!
5. Take a series of readings with the bubble flow meter, over the range of 30-200 cc/min nominally. For each of these readings, record the voltage shown on the DVM (for best accuracy, average together 3-5 readings at each setting). Change the flow by manually adjusting the needle valve, which is in parallel with the proportional valve.
6. With this data, make a linear regression, with the flow rate on the Y-axis and the voltage on the X-axis. This should be very linear, with a slope of about 90 (+/-20) and an intercept close to zero (+/-5).
7. In the SP2 software, click on the **Config** tab and the **Analog In** sub-tab. (This may require a password.) In the **AI Channels** table, find the **Offset** and **Linear** parameters for **Sample Flow**. These should read -1.1819 and 110.3629, respectively. Insert the value for intercept in the **Offset** field and the value for slope in the **Linear** field.
8. Shut down the SP2 sample pump, data software, and the analyzer chassis.
9. Reconnect the proportional valve cable at J16.

### 7.2 Procedure for Alignment of the YAG Laser

For complete instructions on aligning the laser, see DMT **DOC-0229: SP2 Laser Alignment Manual**.

### 7.3 Cleaning the Laser Optics

The optics used in the SP2 have reflectivity of 99.97% or better, and it is very difficult to clean them without damaging or further contaminating the optics. If the laser power drops and it cannot be recovered by a minor alignment, and other parameters such as the pump laser power are verified, it is worth trying to clean the optics to recover laser
power. Most likely the contamination will be on the surface of the coupler and this should be cleaned first. A full alignment system will be required to replace the coupler and get the YAG laser operational. It is also recommended that a replacement coupler be available; if the unit cannot be cleaned, it will need to be replaced. A separate manual, DOC-0229, gives information about optical cleaning and alignment of the YAG laser.

8.0 Calibrating the Instrument with Aerosol Black Carbon

The recommended material for the SP2 calibration is Aquadag. This is an aqueous suspension of colloidal graphite, with particle size less than 0.5 micron. At this time there are no known mono-dispersed black carbon particles available for calibration of the SP2.

8.1 Required Equipment

Aerosol generator and an aerosol classifier that will provide particles in the 50-500 nm size range.

8.2 Calibration Procedure

To calibrate the instrument, follow the steps listed below. Figure 19 shows the typical setup for the SP2 calibration using a DMA.

1. Start the SP2 and the DMA. Take approximately 10 data points, with nominal particle size between 80 nm to 500 nm. Generally two data files are taken at each setting.

2. Shut off the DMA and the SP2.

3. Process the data files and analyze the histograms generated for each of the particle sizes. Depending on the DMA used, several peaks with particles of charge 1, 2, 3, and on up can be seen. To avoid confusion, it is recommended that the first data analysis be conducted with mid-range size particles, as the charge 1 aerosols will be seen clearly.

4. Calculate the particle mass for the each of the particle sizes and plot particle mass vs. maximum peak height. This should be a polynomial function. The
parameters of this function will form the calibration of the SP2. See the Probe Analysis Package for Igor (PAPI) Manual (DOC-0232) or contact DMT for details.

![Figure 19: Schematic Diagram for SP2 Calibration with DMA](image)

### 9.0 Troubleshooting

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible Cause</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>After a few minutes of running, the actual sample flow does not match the set sample flow.</td>
<td>Exhaust bypass valve set incorrectly. No purge or sheath flows.</td>
<td>If the sample flow is significantly off (several hundred ccm), the problems is possibly in the sheath and purge flows. Check the sheath and purge flow readings compared to the sheath and purge flow set points. If these are low, the sample flow will not regulate and be high. Check the operation of the pressure side of the sample pump. Cracked pump diaphragm, kinked, plugged, or disconnected purge line. Check the Exhaust Valve Set voltage. If this is zero and the flow is high, the needle valve is too far open and must be closed to bring the proportional valve into regulation. If the Exhaust Valve Set voltage is 5V and the flow is low, the needle valve is closed too far and needs to be opened. See the flow system section of the manual for setting of these valves.</td>
</tr>
</tbody>
</table>
Large burst of high-concentration aerosol particles have contaminated the instrument and the laser power has dropped significantly.

Rapid overpressurization of the chamber.

IMMEDIATELY turn off the laser. If possible, put a filter on the front of the instrument, and allow to purge for 30-60 minutes. After this time turn the laser on, and observe the laser power. If it is nearly to the level before the contamination, allow the SP2 to operate. If not, purge for additional time. Contact DMT if the laser power does not recover.

The instrument has been started, but no particles are seen on the display.

Laser off or no sample flow.

Check that the laser has not shut off. Check that the sample flow is positive. Check the laser interlocks are engaged (i.e., depressed).

Sample pump does not start when the PUMP switch is turned on.

Pump head pressure not bled down.

If the pump has just been turned off, the head pressure in the purge side may be too high to allow the pump to start. Otherwise check the pump fuse on the back of the analyzer chassis.

Sample flow oscillates more than +/- 1 ccm.

Pressure fluctuations in the inlet line. A 0.5 in water pressure transducer is used on the LFE in the inlet and the unit is very sensitive to pressure noise.

Check if pressure fluctuations are present in the inlet. At the startup, it can take several minutes for the flow to stabilize. Also, if there are pressure perturbations in the inlet, it can take a minute or more for the pressure to stabilize.

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**Appendix A: Revisions to Manual**

<table>
<thead>
<tr>
<th>Rev. Date</th>
<th>Rev No.</th>
<th>Summary</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1-10</td>
<td>B</td>
<td>Added instrument specifications</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Omitted section on Laser Alignment (this section replaced by separate Laser Alignment Manual)</td>
<td>6.0</td>
</tr>
<tr>
<td>4-16-10</td>
<td>C</td>
<td>Updated Laser Safety information</td>
<td>Front matter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Updated Theory of Operation</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Omitted Software section</td>
<td>5.0</td>
</tr>
<tr>
<td>6-7-10</td>
<td>D</td>
<td>Added Laser Handing instructions</td>
<td>Appendix B</td>
</tr>
<tr>
<td>7-27-10</td>
<td>E</td>
<td>Revised specs</td>
<td>1.1-1.4</td>
</tr>
<tr>
<td>7-1-11</td>
<td>E-1</td>
<td>Revised specs</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Appendix B: SP2 YAG Pump Laser Storage and Handling Instructions

Storing the SP2 YAG Pump Laser

For SP2 YAG pump lasers purchased separately from the SP2 instrument, the laser is provided with a special protective box (Fig. 1). Keep the laser in this box until it is needed.
Handling the SP2 YAG Laser

When handling all SP2 YAG pump lasers:

1. The power connector is provided with a plug that shorts the input and guards against damage due to static electric discharge. Keep this plug in place until the laser is to be immediately connected to the power supply. Attach this shorting connector to any laser that is removed from the power supply (Fig. 2).
2. Keep the protective cap on the SMA fiber connector end unless the fiber end is being cleaned or being attached to the YAG laser assembly. Immediately cap the end of any laser fiber that is removed from the YAG laser. Typically the fiber caps are a small plastic blue cap (Fig. 2), but others can be used.

![Figure 22: Protective Cap and SMA Fiber Connector (above); Cap Attached to Connector (below)](image)

3. The minimum bend radius of the fiber is 6 cm. Bending the fiber at a smaller radius can break the glass fiber inside the sheath. If the fiber is broken, the laser will need to be returned to Droplet Measurement for repair. The following diagram is a 6 cm radius.
4. When handling the pump laser outside of the box, support the fiber and do not let it hang down, where it can catch on components and bend to the point of breaking.

Appendix C: Configuring and Testing the SP2’s Four Analog Input Channels

Configuration

A new feature of the SP2-D is that four analog input channels are available on the instrument’s rear panel. To set up these channels, follow the steps below.

1. Click on Config > Analog In.
2. Scroll down the right-hand table to the first undefined line.
3. Click on the first blank of that line and enter the channel name (e.g., “Back AI 1” in the screen below.)
Figure 23: Configuring Analog Input (AI) Channels in the SP2-D

4. Click in the second blank field (the Scaling column) to reveal a drop-down list.
5. Select None (Volts).
6. Highlight the number in the Device column and change it to “2.”
7. Change the Chan column’s number to “24.”
8. In the Range column, define the range as desired.
9. Repeat steps 3 - 8 to enter information for any other desired analog input channels. In step 7, increment the channel number by one for each new channel. (Thus analog input 2 would be number 25, analog input 3 would be 26, and so on.)
10. Click the Save Changes button in the upper-right
11. Click the green Restart Program button.

The analog input channels are now configured.

Testing the Input Voltages

To view and test the input voltages from the analog-input channels, follow the steps below.

1. Click on the Control tab.
2. Scroll down the far-right table until you can see the four entries that were defined during the Configuration step.

![Figure 24: Control Tab Display of Newly Added AI Channels](image)

3. Apply a known voltage (within the ±10V limits) to one or more of the Analog Input jacks.
4. Observe the displayed voltage in the table. In Figure 24, approximately 3V has been applied to the Back AI 1 input.
5. Confirm that all four inputs respond as expected.

**Appendix D: Plumbing Diagram**

The SP-2 Plumbing Diagram can be found on the following page.
Appendix E: SP2-D System Schematic

System schematics can be found on the following pages.
TO INTERFACE BOARD

TO CONTROL BOARD

SEE PAGE 10 FOR DETAIL

SEE PAGE 13 FOR DETAIL

HIGH SPEED M SERIES MULTIFUNCTION DAQ TO CONTROL BOARD

I/O CONNECTOR

P0 COMP - 0209

P7 P7

PCOrange-0309

CON 0

AI 0 - 15

CON 1

AI 16 - 31

ABD - 0236

SP2-D INTERFACE BOARD

ABD - 0235

SP2-D INTERFACE BOARD

Page 8 of 15

NI6259
STATUS LIM PUMP LASER
GND

DIG 5 TO NI CARD
DIG 4 TO NI CARD

SET PUMP LASER TEC
SET PUMP LASER CUR
ANALOG 4 TO NI CARD

MON PUMP LASER
ANALOG 2 TO NI CARD
ANALOG 5 TO NI CARD

THERM CRYSTAL BUF
ANALOG BNC TO NI CARD

THERM PUMP LAS BUF
ANALOG BNC 1 TO NI CARD

DIG 3 TO NI CARD
DIG 2 TO NI CARD
DIG 1 TO NI CARD

DIG 6 FROM NI CARD
DIG 5 FROM NI CARD

OTEMP GND

MON LIM PUMP LASER
ANALOG 3 TO NI CARD

MON PWR PUMP LASER
ANALOG 1 TO NI CARD
ANALOG BNC 4 TO NI CARD

HS THERM BUFF
ANALOG BNC 2 TO NI CARD

GND

GND 5, GND 6 POR

DIG 4 FROM NI CARD

GND

GND

COM 1-16 - COM 20-13

HIGH SPEED M SERIES MULTIFUNCTION DAQ

NI 6259