User's Guide for the Miniature Portable In-Situ Wind ERosion Lab (PI-SWERL)

Version: 1.3a

Updated: January 11, 2011

PI-SWERL

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Las Vegas, Nevada, U.S.A.

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User's Guide Version 1.3a
January 11, 2011

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1. Introduction

1.1. What's new in the User's Guide version 1.3a?

This User's Guide represents a moderate modification of version 1.2 to accommodate the use of a different PM_{10} nephelometer than prior versions of the miniature PI-SWERL and to document minor, mostly cosmetic changes in the SWERLView control software. In earlier versions of the miniature PI-SWERL, the DustTrak 8520 (TSI Inc.) nephelometer was the primary means for measuring suspended dust particles. The manufacturer ceased making this model and replaced it with the 8530 family of nephelometers. The model 8530[1] DustTrak, used in the present version of the miniature PI-SWERL, is designed to tolerate high dust concentrations. In addition to a substantially different physical appearance and form factor, the 8530 differs from the earlier 8520 in that it uses Ethernet communications protocol instead of RS-232, has an LCD touch-screen user interface, and allows for simultaneous collection of the sample air stream onto filter media. This latter feature is useful for comparing the dust concentrations inferred from the light scattering properties of dust particles to the mass of those particles.

The main differences between the current version of the SWERLView test control software (1.1) and earlier versions are that this version: 1) is compatible with the DustTrak 8530 nephelometer, 2) eliminates differentiation between Step and Ramp test specifications (can still do both), 3) uses an enhanced color scheme to facilitate user interaction, 4) includes an upgrade to the OGS peak detection algorithm, 5) writes the dust monitor Serial Number to the "info" file, and 5) incorporates other, minor cosmetic differences.

1.2. Overview of the PI-SWERL

The Portable In-Situ Wind ERosion Lab (PI-SWERL) is a highly portable device that is used to measure the potential for soil wind erosion and dust suspension. It can be operated by one individual, with a typical test completed in minutes. Direct comparison of PI-SWERL measurements with the University of Guelph, straight-line field wind tunnel at seventeen sites in the Mojave Desert (Etyemezian et al., 2007; Sweeney et al., 2008) showed good correspondence between the two measurement methods.

The miniature PI-SWERL is a smaller version of an earlier design described by Etyemezian et al. (2007). It is a cylindrical chamber (D = 30 cm, H = 20 cm) that has an open end which is placed over the soil surface to be tested. Soft foam along the circumference of the open end forms a seal with the test surface. The PI-SWERL measurement cycle can consist of a series of steps of increasing simulated wind speed (Step Test) or of a gradual increase in simulated wind speed (Ramp Test). Ventilation of the PI-SWERL chamber is accomplished by a DC blower (AMETEK, Mini-Jammer) and monitored by a mass flow meter (Honeywell, Model AWM720P1). Filtered air that is introduced by the blower, mixes with the air in the chamber and the flow is exhausted

[1] As of January, 2011, TSI replaced the model 8530 DustTrak with model 8531, but retained the original 8530 model designation. The new 8530 has all of the capabilities that 8531 had, most notably, the higher concentration limit (400 mg/m^3). In the context of this guide, model 8531 and 8530 are interchangeable.

through a port (diameter = 5.0 cm) at the top of the chamber. A clean air flow rate of 100 Liters per minute corresponding to about 14 air changes per minute has been found to provide a satisfactory degree of ventilation while avoiding the undesirable suspension of dust by inlet blower air.

Once the measurement cycle is initiated, one-second concentrations of PM_{10} (particles with diameter less than 10 micrometers) are measured by a nephelometer-style dust monitor (TSI, DustTrak Model 8530). Although the DustTrak does not provide a true mass based measurement, it is used in conjunction with the PI-SWERL because it is very portable, has a fast response (1 second), and can measure concentrations over four orders of magnitude (~0.001 to 400 mg/m3).

Dust suspension within the PI-SWERL chamber is induced by a rotating, flat annular ring. The annular ring (inner diameter = 16 cm, outer diameter = 25 cm) is coupled through a metal shaft to a 24-volt DC motor that is fastened to the top of the PI-SWERL chamber. When in motion, through the formation of a velocity gradient, the rotation of the ring results in shear stress being generated at the soil surface. In concept, this is similar to Couette flow where one infinite plate moves parallel to another resulting in shear flow without the presence of a pressure gradient in the principal direction of the flow. Within the PI-SWERL, the flow is three-dimensional and turbulent; symmetry is axial rather than planar. This design is based on the principal that windblown sediment transport and dust emission are driven by wind that is tangential to the soil surface and is often parameterized as a friction velocity (u*) or shear stress (e.g. Bagnold, 1941; Chepil and Milne, 1939; Gillette, 1978). For straight-line wind tunnels, some substantial fetch is required prior to achieving an approximate steady boundary layer (Gillette, 1978) and surface shear stress. Practically, this requires that a straight-line tunnel have a length of at least a few meters. By employing a rotating, flat annular blade, the PI-SWERL design is aimed at ensuring that the average flow over the soil surface is at steady state and symmetrical about the axis of rotation.

A typical PI-SWERL measurement begins with the operation of the clean air blower, flushing out any PM_{10} dust in the chamber. After flushing with clean air, a computer directs the motor to spin the annular blade to achieve a target rate of rotation specified in revolutions per minute (RPM). The target RPM may be held for some period (Step) or varied continuously to achieve a specified rate of change (Ramp).

The vertical dust flux is calculated based on the measured air flow rate, dust concentration, and the effective area of influence from the annular blade. The shear stress distribution at varying RPM has been measured with Irwin sensors mounted onto a smooth plywood surface onto which the PI-SWERL had been placed and operated (Irwin, 1981). Results indicate that shear stress increases with RPM and is concentrated in an area underneath the annular blade in a "region of influence". This region is taken as the Effective Area (A_{eff}) of shear stress application and is equal to 0.026 m^2 for the miniature PI-SWERL (Figure 1-1 and Figure 1-2).

There are several ways to estimate dust emissions from a soil surface. For example, in conjunction with the data for a Step test shown in Figure 1-3 either Non-cumulative or Cumulative emissions may be used to estimate the dust emission potential from the test data. Non-cumulative PM_{10} emissions E_i at a specific step level i can be calculated according to

$$E_i = \frac{\sum_{begin,i}^{end,i} (C \times F)}{(t_{end,i} - t_{begin,i})}$$

where the summation occurs over every one-second measurement of clean air flow and PM_{10} concentration during level *i* which begins at $t_{begin,i}$ and ends at $t_{end,i}$ and where *t* is measured in integer seconds. Cumulative emissions $E_{i,cum}$ at level *i* account for all emissions that would have occurred if the PI-SWERL blade was immediately spun to the RPM setting of level *i* instead of in a step-wise manner. Cumulative emissions are calculated as

$$E_{i,cum} = \frac{\sum_{begin,1}^{end,i} C \times F}{t_{end,i} - t_{begin,i}} = \sum_{1}^{i} E_i \ .$$

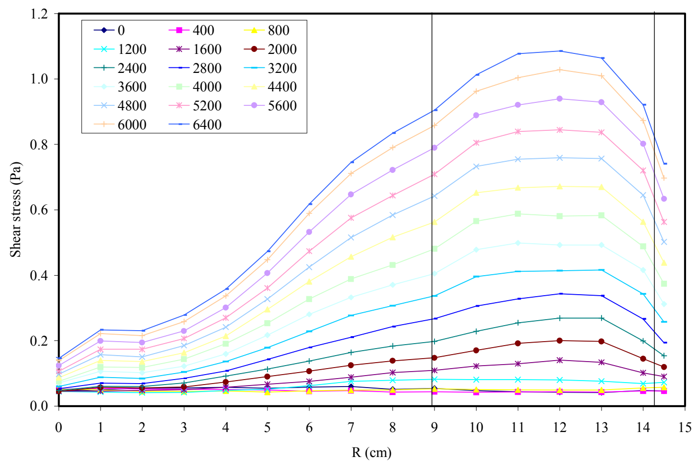


Figure 1-1. Surface shear stress distributions at varying RPM as measured by Irwin sensor. Test surface: smooth plywood. Vertical lines represent "region of influence" underneath the annular blade corresponding to an effective area, A_{eff} of 0.026 m^2.

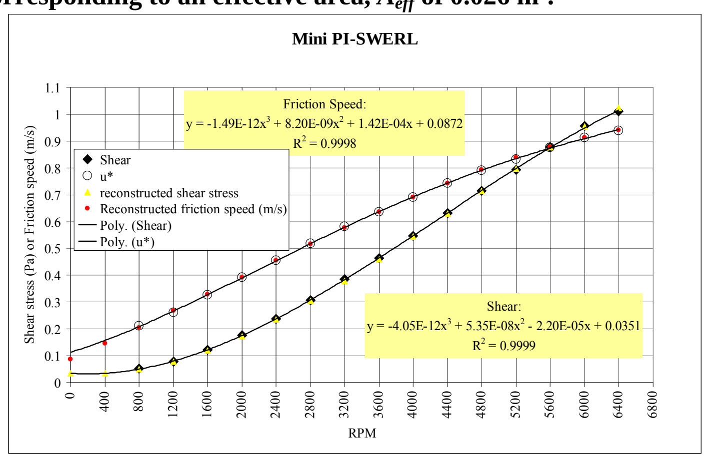


Figure 1-2. Average shear stress and/or friction velocity (u_*) underneath area of influence shown in Figure 1-1.

A recent addition is an optical gate sensor (OGS) within the PI-SWERL chamber for estimating the horizontal sand sediment transport flux. The sensor, consisting of an LED photodiode (~ 1mm beam aperture) and a photoreceiver that are separated by 10 mm, is polled and processed at 2 kHz. An algorithm has been developed that utilizes the high sampling rate to detect individual grains that move through the sensing volume. Tests on constructed soil plots indicate that the information from the sensor provides a consistent measure of sand movement, which can be used as a quantitative (but uncalibrated) metric for horizontal flux. However, The OGS sensors have not been fully characterized at the time of writing of this Guide and are included in the PI-SWERL to allow the User to utilize the data as they see fit. There are four OGS sensors inside the PI-SWERL chamber, two that are 1 cm above the base ring and two that are elevated within the chamber.

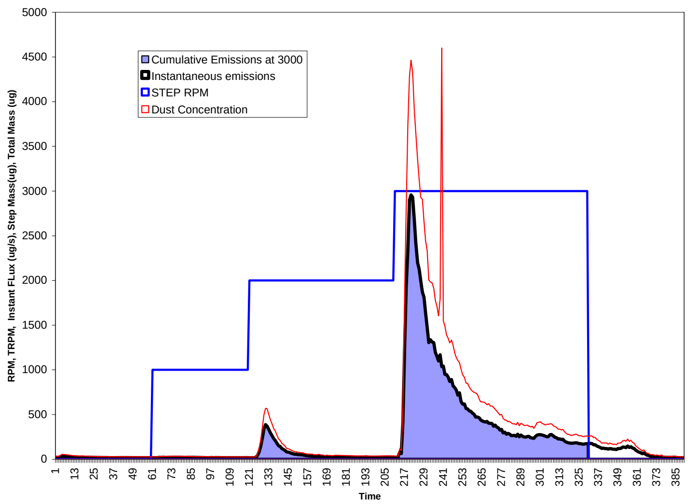


Figure 1-3. Example PI-SWERL Step measurement. Cumulative emissions include all emissions up to the last Step divided by the duration of the last Step.

1.3. *How to Use this Guide*

This guide to the Miniature PI-SWERL serves as an instruction manual for operating the instrument as well as a tutorial for examining the data that the PI-SWERL produces. It is suggested that the User reads or skims the entire Guide to become familiar with the location of different types of information. Some information (for example examination of data quality covered in Chapter 3) would also be helpful in determining if the instrument is operating properly (covered in Chapter 2).

1.4. *What This Guide Covers*

This Guide covers the details of operating the miniature PI-SWERL. It aims to provide an overview of the PI-SWERL principal of operation, assembly and disassembly for field measurements, procedures for operation, care and maintenance procedures and requirements, addressing some commonly encountered problems with PI-SWERL operation, and description of the resultant data files.

Chapter 2 is organized to allow the unfamiliar user to assemble the PI-SWERL field cart for the first time, prepare the instrument for use, and conduct a measurement. The Chapter also provides instructions on completing subsequent measurements.

Chapter 3 is a guide to understanding the data files that are generated during a PI-SWERL measurement. The Chapter covers the format of the data files, the units used in the data files and summary reports, and the data generated by the optical gate sensors.

Maintenance and care of the PI-SWERL are discussed in Chapter 4. Some forms of maintenance are suggested after each day of use of the PI-SWERL (or more frequently in some cases) while other forms are required less frequently. Proper maintenance is an important part of ensuring that the measurements completed using the PI-SWERL are of a high quality.

Common types of problems encountered during PI-SWERL operation are enumerated along with possible causes of those problems in Chapter 5: Troubleshooting guide.

1.5. What this Guide Does Not Cover

The PI-SWERL, at the time of writing of this version of the User's Guide, is a research-grade instrument. Specific protocols for how to interpret the data generated by the measurement, what level of replication is required for adequate site characterization, and how PI-SWERL measurements relate to real World wind erosion events are not established at this time. It is worth pointing out that these types of protocols have yet to be established for any form of field wind tunnel, partly because using traditional field wind tunnels is resource-intensive and robust datasets that can be used to guide data interpretation are generally absent from the scientific literature.

The PI-SWERL, owing to the ability to employ it economically in field measurements, may eventually yield the large datasets that are needed for establishing standard methods for data interpretation. However, at this time, the specific protocols for measurements and data interpretation are left to the judgment of the User.

REFERENCES

Bagnold, R.A. (1941). The Physics of Blown Sand and Desert Dunes. London: Methuen.

Chepil, W.S. and Milne, R.A. (1939). Comparative study of soil drifting in the field and in a wind tunnel. *Scientific Agriculture*, 249-257.

Etyemezian, V., Nikolich, G., Ahonen, S., Pitchford, M., Sweeney, M., Purcell, R., Gillies, J.A. and Kuhns, H. (2007). The Portable In-Situ Wind ERosion Laboratory (PI-SWERL): A new method to measure PM10 windblown dust properties and potential for emissions. *Atmospheric Environment* 41, 3789-3796.

Gillette, D.A. (1978). A wind tunnel simulation of the erosion of soil: effect of soil texture, sandblasting, wind speed, and soil consolidation on dust production. *Atmospheric Environment* 12, 1735-1744.

Irwin, H.P. (1981) A simple omnidirectional sensor for wind tunnel studies of pedestrian level winds. *Journal of Wind Engineering and Industrial Aerodynamics* 7 (3): 219-239.

Sweeney, M., Etyemezian, V., Macpherson, T., Nickling, W.G., Gillies, J.A., Nikolich, G. and McDonald, E. (2008). Comparison of PI-SWERL with dust emission measurements from a single-line field wind tunnel. *Journal of Geophysical Research*, doi:10.1029/2007JF000830.

2. Conducting field measurements

<u>WARNING:</u>

DURING OPERATION, PORTIONS OF THIS DEVICE MAY BE MOVING AT VERY HIGH SPEEDS. IMPROPER USE OF THIS DEVICE MAY RESULT IN DAMAGE TO INSTRUMENT OR BODILY HARM TO PERSONS IN THE VICINITY OF OPERATION. NEVER PLACE HANDS OR OBJECTS UNDERNEATH THE INSTRUMENT WHILE ANNULAR BLADE IS IN MOTION OR WHILE PI-SWERL IS CONNECTED TO THE CONTROL BOX. NEVER OPERATE THIS INSTRUMENT ON A SURFACE WITH LOOSE DEBRIS THAT MAY BE DISLODGED INTO THE PATH OF THE ANNULAR BLADE.

<u>WARNING:</u>

THE BATTERIES USED WITH THIS INSTRUMENT HAVE AN ELECTRICAL POTENTIAL OF 24 VOLTS. IMPROPER USE MAY RESULT IN ARCING, DAMAGE TO BATTERIES, DAMAGE TO INSTRUMENT, OR ELECTROCUTION. NEVER USE THIS INSTRUMENT NEAR WATER OR ON A WET SURFACE. VISUALLY INSPECT CONNECTOR PINS FOR DAMAGE PRIOR TO CONNECTING/DISCONNECTING BATTERIES FROM INSTRUMENT AND/OR CHARGING STATION. DAMAGED PINS MAY RESULT IN ARCING, INSTRUMENT DAMAGE, OR INJURY.

2.1. Setup

The goal of the following set of instructions is to demonstrate how the PI-SWERL field cart can be assembled and how all of the miniature PI-SWERL components can be attached to the field cart in preparation for conducting field measurements.

A system of load-bearing and clip-in straps is used to attach the control box to the field cart, secure the computer panel in place, and secure the cover unto the control box. The clip-in connectors have been color-coded so that it is clear which male/female pairs are intended to be mated.

All electrical connections utilize multi-pin twist-lock connectors. These connectors can be attached to their respective receptacles in one orientation only. The proper orientation can be achieved by placing the connector over the receptacle loosely and rotating the connector until it depresses into position. Once the connector is properly seated, the outer ring on the connector is twisted (clockwise) to lock the connector in place. To disconnect, simply rotate the outer ring on the connector counterclockwise until the twist-lock is disengaged. Then pull the connector out of its receptacle. If the connector is not easily pulling out of the receptacle, try twisting the outer ring counter-clockwise again.

The PI-SWERL unit rests on a docking plate that sits atop the field cart. It is held in place by a toggle latch.

Figure 2-1 Miniature PI-SWERL Measurement System. Left - fully assembled, right - principal components.

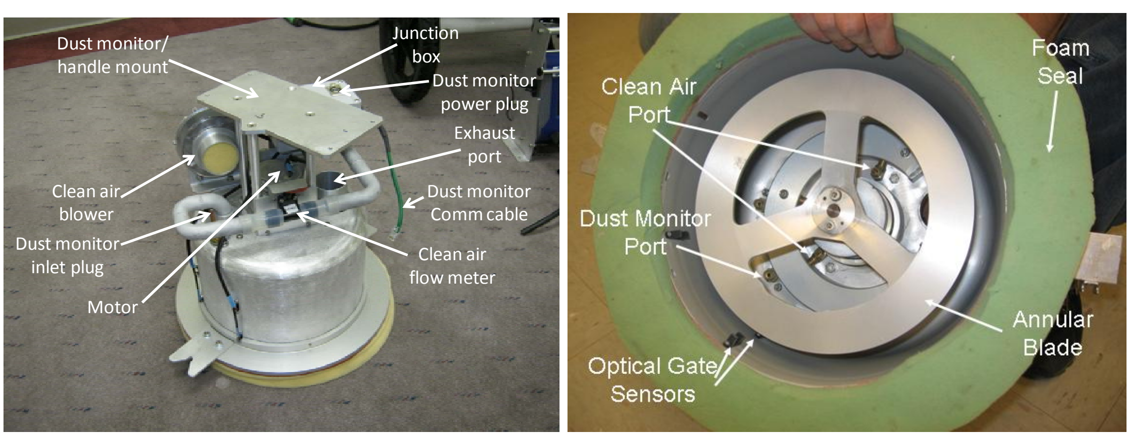
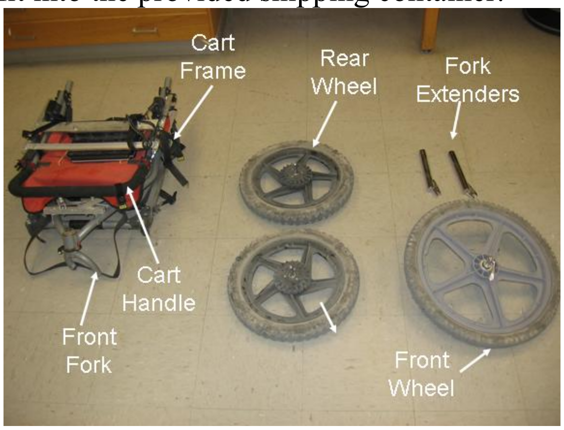


Figure 2-2. Components of PI-SWERL Instrument. Left - Top View, right- Bottom View.

2.1.1. Assembling the field cart

The field cart is used to transport all of the miniature PI-SWERL components between different measurement locations. It folds and unfolds for easy storage and long-distance transportation. The field cart has two wheels in the back and a front fork that supports a single swiveling wheel. The front fork can be disassembled to allow the field cart to fit into the provided shipping container.



Assuming that the field cart is being removed from the shipping container (i.e. totally disassembled), it can be assembled as follows:

1. Open the frame of the cart by pulling the rear axle apart from the front fork mount.

2. Slip the shaft of one of the black-rimmed wheels into the axle and lock the shaft in place by depressing the shaft lock towards the axle.

3. Repeat 2 with the other black-rimmed wheel on the other side of the cart.

4. Add the fork extenders to the front fork mount by slipping them over the fork mount. When in place, the indented sides of the front fork wheel mounts should be directed toward the wheel.

5. Align the holes on the fork extenders and fork mount and place cotter pins through holes ensuring that safety latch is deployed.
6. Install the gray wheel on the front fork and secure the tension fastener. The tension fastener works similarly to those used on bicycle wheels.

7. Pull the cart handle away from the cart body until it locks into place with a click.
8. Release the straps that are holding the computer panel in place so that the panel lowers toward the cart body.
9. Attach the clip-in straps on the left side of the computer panel to the clip-in strap on the cart body.
10. Repeat step 8 for the right side.

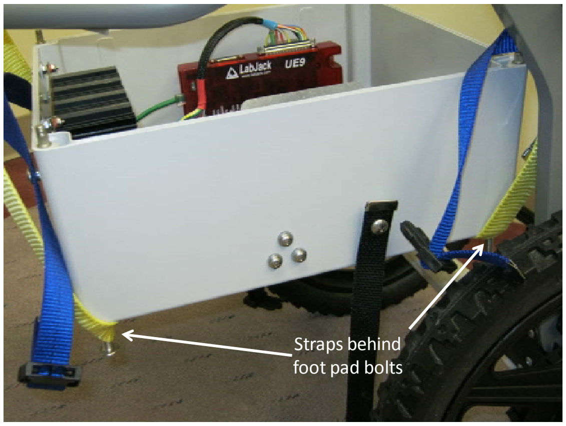
NOTE: The cart comes with a foot brake that locks the rear wheels and keeps them from rotating. The foot brake can be deployed by pushing it down towards the cart body. It can be released by pulling up away from the cart body until in clicks.

2.1.2. Mounting the control box

The control box is held in place by two weight-bearing straps, each running from one side of the cart to the other. Additional clip-in straps are used to stabilize the control box and keep it from swaying excessively during cart movement.

To install the control box:

1. Ensure that the battery pack is NOT inside the control box. This makes the box lighter and easier to maneuver.
2. Lift the front end of the control box and place the cross-strap that straddles the front of the cart underneath the control box, ensuring that the strap gets hooked behind both bolts underneath the front end of the control box.



3. Lift the back end of the control box and place the cross-strap that straddles the back of the cart underneath the control box, ensuring that the strap gets hooked behind both bolts underneath the back end of the control box. The control box should now be entirely suspended above ground.
4. Connect the clip-in strap on the front right side of the control box to the corresponding clip-in strap on the right side of the cart (attached to the cart about 15 inches above the rear axle).
5. Repeat step 4 for the left side.
6. Place the control box cover in place so that the clip-in straps on the cover are towards the rear of the cart.

7. Connect the clip-in strap that is attached to either side of the control box (about midway) over the cover so that the cover is being held in place by the strap.
8. Attach the right clip-in strap on the top cover of the control box to the corresponding clip-in straps on the field cart.
9. Repeat step 7 for the left side.

2.1.3. Installing and uninstalling the battery pack

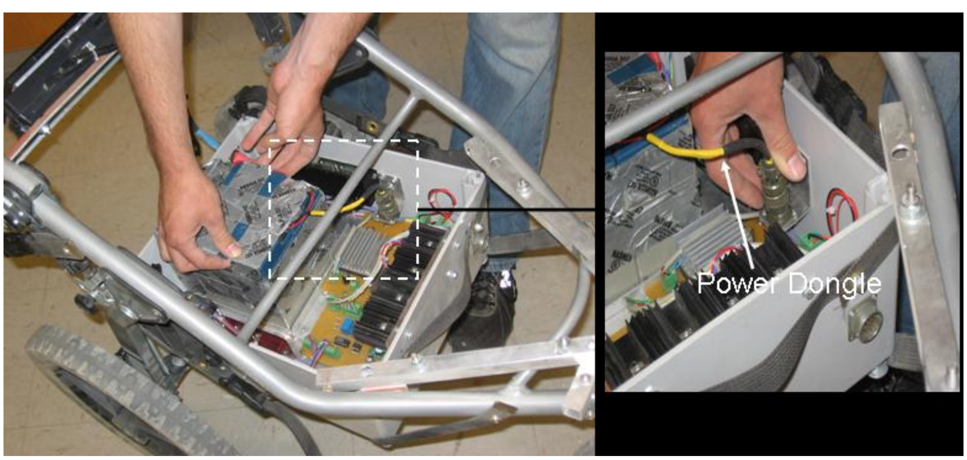
<u>WARNING:</u>

THE BATTERIES USED WITH THIS INSTRUMENT HAVE AN ELECTRICAL POTENTIAL OF 24 VOLTS. IMPROPER USE MAY RESULT IN ARCING, DAMAGE TO BATTERIES, DAMAGE TO INSTRUMENT, OR ELECTROCUTION. NEVER USE THIS INSTRUMENT NEAR WATER OR ON A WET SURFACE. VISUALLY INSPECT CONNECTOR PINS FOR DAMAGE PRIOR TO CONNECTING/DISCONNECTING BATTERIES FROM INSTRUMENT AND/OR CHARGING STATION. DAMAGED PINS MAY RESULT IN ARCING, INSTRUMENT DAMAGE, OR INJURY.

The PI-SWERL battery pack is the primary source of power for the entire instrument. It is designed to be replaced in the field with a minimum of interruption of measurements.

To install a new battery pack (assumes depleted battery pack has been removed):

1. Ensure that the computer has been properly switched off and that the main control box power switch is in the OFF position.
2. Undo both clip-in straps that attach the top cover of the control box to the cart.
3. Undo the strap that goes over the top of the control box and keeps the cover in place.
4. Lift the cover slightly and slide it out towards the rear of the cart carefully past the docking plate. You may need to undo the straps that secure the computer panel in place and lift the computer panel slightly.
5. Lift the battery pack by the indentations in the battery case body at the top of the pack (along the long sides) and place the pack into the cutout in the control box. The indentations should be aligned with the long side of the control box and the power dongle should be facing the front of the cart. Ensure that the battery pack is sitting snugly in the cutout channel.



6. Attach the twist lock connector on the battery dongle to the receptacle in the control box. Once the connector has been oriented correctly, press the connector onto the receptacle and twist the outer ring to lock it in place.
7. Replace the control box cover and reattach the cover strap and the side-stabilizing clip-in straps.

NOTE: To prevent battery discharge, always ensure that the main power switch on the control box is in the Off position when the PI-SWERL is not being used.

2.1.3.1. Uninstalling the battery pack

1. Ensure that the computer has been properly switched off and that the main control box power switch is in the OFF position.
2. Undo the clip-in straps that secure the cover to the cart and that hold the cover in place.
3. Remove the control box cover.
4. Twist the outer ring of the battery dongle connector counter-clockwise until the locking mechanism is disengaged.
5. Pull the connector out of the receptacle (This should not require much force. If it does, you may need to twist the outer ring until the lock disengages).
6. Using the indentations on either side of the battery pack (along the long sides at the top), pull the battery pack out of the control box.

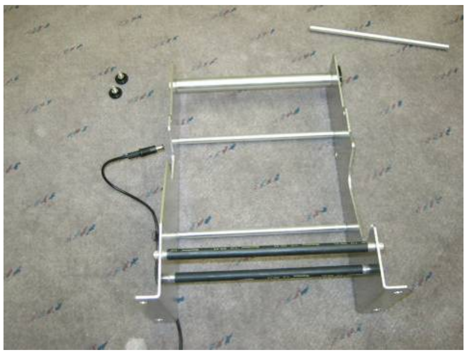
2.1.4. Attaching the Dust Monitor to the PI-SWERL

The dust monitor (DustTrak, TSI Model 8530) is the primary means that the PI-SWERL utilizes to measure the amount of dust that is emitted from a surface at varying amounts of applied shear stress. It is important that the dust monitor is maintained properly in accordance with the manufacturer's recommendations. The User should carefully read the manual for the DustTrak instrument that is provided by TSI Inc. Minimal good practice is to clean and re-zero the dust monitor at the beginning of a field day.

DUST-QUANT LLC HIGHLY RECOMMENDS THAT THE RECHARGEABLE BATTERY PROVIDED BY TSI FOR USE WITH THE DUSTTRAK NOT BE INSTALLED WHEN THE DUSTTRAK IS USED IN CONJUNCTION WITH THE PI-SWERL. THE PI-SWERL UNIT IS DESIGNED TO PROVIDE POWER TO THE DUSTTRAK THROUGH THE PI-SWERL BATTERY LOCATED INSIDE THE CONTROL BOX. CONNECTING THE PI-SWERL BATTERY WITH THE DUSTTRAK BATTERY COULD DAMAGE ONE OR BOTH BATTERIES IRREPARABLY.

The dust monitor fits into a cradle space within the detachable PI-SWERL handle. To attach the dust monitor to the PI-SWERL body:

1. Place the dust monitor inside the cradle space within the detachable handle. This is accomplished by removing the two thumbscrews that hold one of the cross bars in place, removing the cross bar, and inserting the dust monitor as shown. Replace the cross bar and thumbscrews. Use care when replacing the thumbscrews as the cross bar is made of aluminum and the threaded ends could be damaged if thumbscrews are not set properly. The dust monitor should now be securely attached inside the PI-SWERL handle.



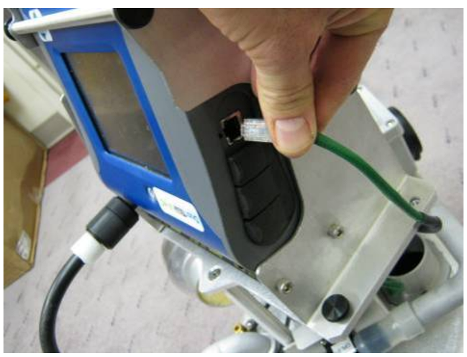
2. Insert the power connector that is attached to the PI-SWERL handle into the plug on the dust monitor (see below).

3. Slip the manufacturer-provided PM_{10} (or other size if preferred) sampling head onto the dust monitor. Care and maintenance of the PM_{10} sampling head should be completed in accordance with the manfucaturer's instructions (See TSI manual). Slip the white-tipped end of the sample line onto the PM_{10} sampling head.

4. Attach the PI-SWERL handle to the PI-SWERL using the four black-headed thumbscrews. Use care when fastening thumbscrews as the handle mount is made of aluminum and the threaded holes may be stripped if thumbscrews are improperly set. The dust monitor should be upside down with the LCD screen facing away from the junction box on the PI-SWERL.

5. Attach the sample line from the dust monitor to the copper nipple on the PI-SWERL.

6. Attach the CAT-5 connector from the PI-SWERL to the dust monitor. Attach the metallic end of the power connector to the junction box on the PI-SWERL (press to click in place).



7. The dust monitor will usually power on by itself when the power is switched on at the control box (see below).

There are several important procedures that relate to the preparation of the PM_{10} sampling head (e.g., placing a few drops of lubricant on impactor), zero-checking the dust monitor, and using an inline filter in conjunction with the dust monitor that are not covered in this Guide. The manual supplied by TSI Inc should be consulted for the correct operation and maintenance of the dust monitor.

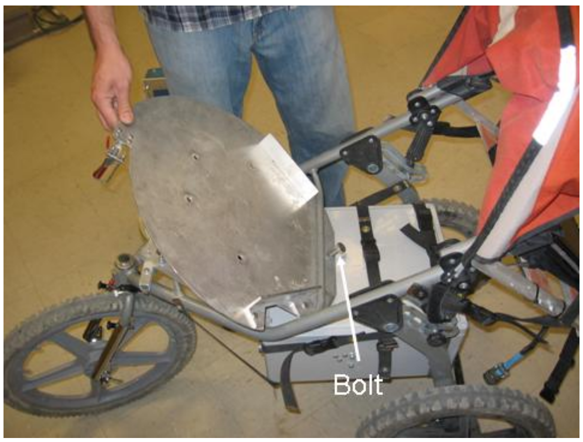
NOTE: The communications setting on the dust monitor should not be changed from the values set by Dust-Quant LLC. IP address should be: 192.168.002.020, Sub Net Mask should be: 255.255.255.000, and the Gateway should be 192.168.002.001. The PI-SWERL uses Ethernet protocol to communicate with the dust monitor and NOT USB protocol.

2.1.5. Mounting the PI-SWERL

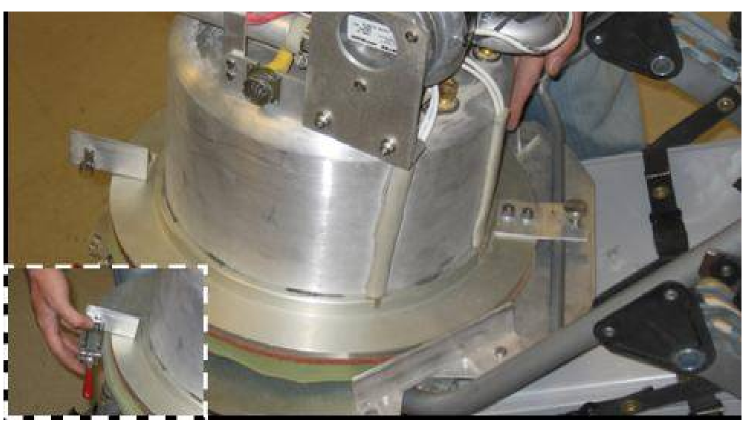
During field measurement activities, the PI-SWERL can be transported short distances using the field cart. The PI-SWERL body can be placed and secured unto the field cart using the docking plate.

To mount the PI-SWERL body unto the field cart:

1. Tilting the aluminum docking plate, pass the bolt on the plate underneath the support cross-bar on the field cart. The head of the bolt should be on the top side of the docking plate.



2. Straighten the plate so that the four bolts on the field cart support structures go through the four holes in the docking plate.
3. Use the four thumb screws to secure the docking plate to the field cart.
4. Lift the PI-SWERL off the ground and tilt slightly so that the V-notch slides underneath the head of the bolt on the docking plate.



5. Rest the PI-SWERL on the docking plates so that the V-notch is underneath the head of the bolt on the docking plate and the lateral guides on the plate are against the PI-SWERL body.
6. Secure the PI-SWERL body unto the docking plate by latching the toggle clamp at the front of the plate.

2.1.6. Completing the connections

To complete all the electrical connections:

1. Connect the cable bundle from the computer panel to the back of the control box.
2. Connect the 3-meter control cable between the PI-SWERL receptacle and the receptacle on the side of the control box.

NOTE: The connectors that go between the PI-SWERL and the control box are similar to the connector that goes between the control box and the computer panel.

2.1.7. Disassembling the PI-SWERL field cart for long-distance transport or storage

In general, disassembling the PI-SWERL field cart follows the reverse procedure as the assembly. The steps for disassembly are:

1. Disconnect the control cable between the PI-SWERL and the control box at both ends.
2. Disconnect the cable that attaches between the computer panel and the control box.
3. Remove the PI-SWERL from the docking plate.
4. If desired, disconnect the CAT-5 connector from the Dust monitor, the plug-in power connector at the top of the junction box, and the inlet line that connects the PI-SWERL to the Dust monitor and then remove the four thumbscrews that secure the handle to the PI-SWERL body.
5. Remove the four thumbscrews holding the docking plate in place on the field cart.
6. Remove the docking plate by slightly tilting the front of the plate upwards and sliding the plate out.
7. Remove the cover to the control box by disconnecting the clip-in connectors that hold the cover in place and the clip-in connectors that are attached between the cover of the control box and the cart.
8. Disconnect and remove the battery pack.
9. Lift the back of the control box slightly and release the strap from underneath the bolts. Rest the back of the control box on the ground.
10. Lift the front of the control box slightly and release the strap from underneath the bolts.
11. Replace the control box cover and fasten the clip-in strap across the top of the control box.
12. Release the clip-in straps that tension the computer panel against the cart.
13. Lift the computer panel towards the handle and fasten the adjustable straps against the handle.
14. Depress the red levers on the cart to fold the handle toward the cart body.
15. Remove the front wheel by releasing the tension fastener.
16. Remove the cotter pins from the fork extenders and slide off the fork extenders.

17. Push the two black knobs above the rear axle in towards the center of the cart. This allows the rear wheels and axle to fold in towards the front of the cart.
18. Remove the rear wheels by releasing the tension fasteners and sliding the wheels out of their sockets.

2.2. *Conducting a PI-SWERL measurement*

2.2.1. Preparing the instrument for the first test at a site or after replacing the battery pack.

The following procedures should be used before the PI-SWERL is used for the first time on a given day or before the first test immediately after replacing the battery pack.

Turn the PI-SWERL components on in the following order:

1. Toggle the master power switch on the control box. A red LED on the switch will light up to indicate that the power is on.
2. Turn the computer on by toggling the power switch located underneath the display (between the power and serial connectors) A green LED indicator at the top of the screen will turn on and the computer will begin booting. This may take 30 seconds or so and the User could complete the next step while waiting for the main Windows screen to appear.
3. If properly connected, the dust monitor will power up as soon as the master power on the control box is switched on. The dust monitor will go through a brief boot up phase before going into standby mode, where the pump does not run. If the dust monitor does not start on its own, then try manually turning it on using the push switch on the dust monitor front panel.

2.2.2. Placement of the PI-SWERL test chamber

<u>WARNING:</u>

DURING OPERATION, PORTIONS OF THIS DEVICE MAY BE MOVING AT VERY HIGH SPEEDS. IMPROPER USE OF THIS DEVICE MAY RESULT IN DAMAGE TO INSTRUMENT OR BODILY HARM TO PERSONS IN THE VICINITY OF OPERATION. NEVER PLACE HANDS OR OBJECTS UNDERNEATH THE INSTRUMENT WHILE ANNULAR BLADE IS IN MOTION OR WHILE PI-SWERL IS CONNECTED TO THE CONTROL BOX. NEVER OPERATE THIS INSTRUMENT ON A SURFACE WITH LOOSE DEBRIS THAT MAY BE DISLODGED INTO THE PATH OF THE ANNULAR BLADE.

The quality of measurements conducted by the Mini-PI-SWERL strongly depends on the proper placement of the instrument. For this reason, it is important to be mindful of the area where a measurement will be conducted. Specifically, avoid disturbing the area unintentionally by walking on it or rolling the field cart over the test surface.

From a safety standpoint, it is important to inspect the candidate measurement location prior to placing the PI-SWERL chamber over the surface. The Mini-PI-SWERL should never be used on a wet surface since this may lead to an electrical hazard. In any case, wet surfaces do not emit dust and aside from the safety concern, using the PI-SWERL on wet soil surfaces is likely to deposit mud onto the instrument and adversely affect the quality of subsequent measurements.

It is also important to ensure that the candidate measurement location does not contain large rocks or sticks that may become dislodged during the operation of the PI-SWERL and come into contact with the rotating annular ring. The annular ring may be rotating at a very high rate and impact of the blade with a rock while in motion could pose a serious safety risk. Note that small pebbles on the order of a few millimeters up to a centimeter in diameter generally do not pose a safety hazard.

Vegetation is often a consideration when conducting a Mini-PI-SWERL measurement. The clearance between the PI-SWERL annular blade and the test surface ranges from 5 cm to 10 cm depending on variability of the surface. Grasses, shrubs, and other vegetative debris that are at about this height will interfere with measurements. For very sparse vegetation, a pair of sharp grass clippers can be used to carefully trim the vegetation close to the soil surface. Here again, it is important that the soil is not disturbed during this procedure. It is also important to keep in mind that vegetation offers the soil surface protection against wind erosion and that removing the vegetation renders the soil more vulnerable to shear stress.

Surface roughness, up to a point, is easily accommodated by the foam seal at the base of the Mini-PI-SWERL. Generally, if the foam seal is resting on the soil surface all along the perimeter of the PI-SWERL base, then the surface roughness can be accommodated by the instrument. If some portion of the foam seal is elevated above the soil surface, then the measurement is likely to be somewhat compromised as a result.

With these considerations in mind, place the PI-SWERL unto the measurement location as follows:

1. Unfasten the toggle clamp on the PI-SWERL docking plate and undo the latch.
2. Tilt the Mini-PI-SWERL slightly so that it is elevated above the docking plate at the front of the field cart.
3. Slide the PI-SWERL off the docking plate.
4. Hold the PI-SWERL above the desired measurement location and slowly lower the instrument unto the ground. Try to use only vertical motion to avoid disturbing the test surface during placement.
5. Once the PI-SWERL is on the ground, inspect the perimeter of the PI-SWERL to ensure that the foam seal is in contact with the soil surface at all points.

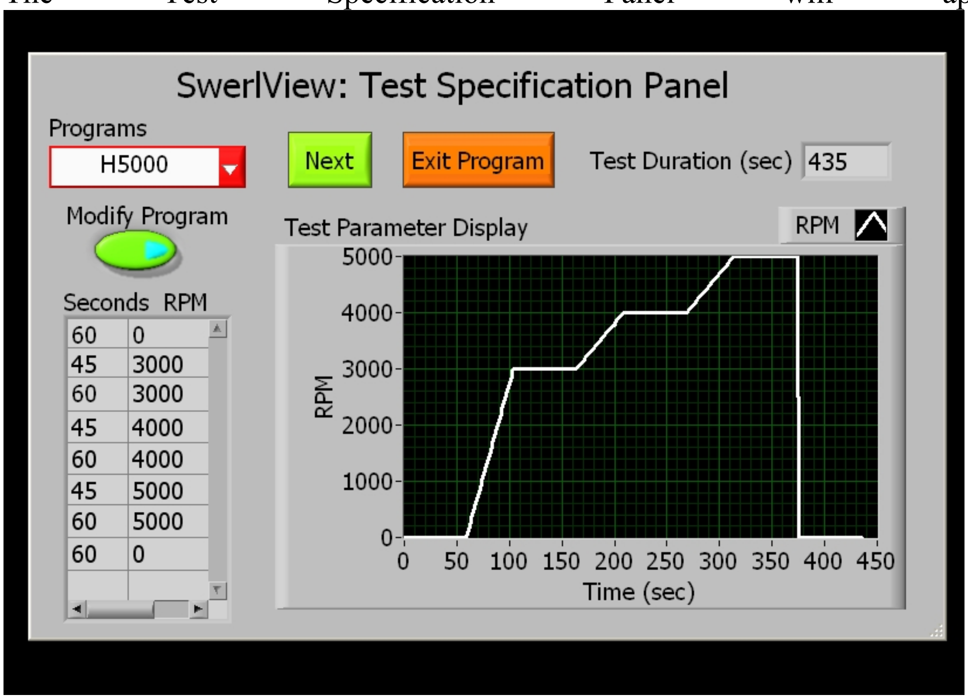
2.2.3. Programming a Test Cycle

Prior to conducting a measurement, the user has to make several decisions that affect the way that the PI-SWERL program will control the instrument during the measurement. First, the user must decide if they will be conducting a “Ramp”, “Step”, or “hybrid” test. The Ramp and Step tests were introduced in Chapter 1. In summary, during a Ramp test, the PI-SWERL target RPM increases linearly over a period of time. The result is a gradual increase in the RPM (and shear stress). For Step tests, the target RPM follows a sequence of steps where the RPM is held at a constant value for a specified period of time before it is increased to the next target RPM value where it is held for another specified period of time. The Hybrid test uses a combination of both ramps and steps to obtain the two different types of information during a single measurement.

All three types of tests are specified in a similar manner within the SwerlView control software.

2.2.3.1. Software Setup

1. Check the date and time on the computer.
2. If this is the first test of the day, you will need to launch the SwerlView control software. To launch the control software, double click on the SwerlView icon on the desktop. The main panel may take several moments to load as the software initializes libraries and communications ports for use.
3. The Test Specification Panel will appear.



4. The Test Specification Panel contains several pieces of information. The *Programs* drop down box indicates the name of the test to be conducted ("H5000" in the example above).

   Underneath the *Program* drop down box, there is a table with two columns labeled "Seconds" and "RPM". This table shows the entries in the "H5000" test. The first row (60 seconds, 0 RPM) represents a 60 second clean air flush. The annular ring in the PI-SWERL will not rotate while the PI-SWERL chamber is being flushed at with clean air provided by the blower. This is usually desirable because dust can be suspended inside the PI-SWERL chamber when placing the PI-SWERL on the test surface. Once the clean air flush is completed, the next row (45 second, 3000 RPM) will be executed. The instruction can be translated roughly as "Go from 0 RPM to 3000 RPM linearly over a 45-second interval" where 0 RPM was the previous target RPM, 3000 RPM is the new target RPM. This results in an increase in the RPM at a rate of

3000/45 = 66.67 RPM per second. The next row (60 seconds, 3000 RPM) instructs the PI-SWERL to "Go from 3000 RPM to 3000 RPM linearly over a 60-second interval". Since the previous target RPM and the new target RPM are the same (3000), this instruction will be interpreted as "hold 3000 RPM for 60 seconds." The next instruction (45 seconds, 4000 RPM) is translated as "Go from 3000 RPM to 4000 RPM linearly over 45 seconds", and so on. The final instruction (60 seconds, 0 RPM) is interpreted differently. It is interpreted as "shut off power to the motor and flush for 60 seconds." Note that if the final instruction had a target RPM other than zero (e.g., 1 or any other integer), then the PI-SWERL RPM would linearly decrease to that target value from 5000 RPM over the time period specified. The value zero signals SwerlView that the user wishes the power to the main motor to be cut off abruptly.

Note that the PI-SWERL motor does not have a brake so that abrupt reductions in RPM are not achievable even if they are programmed into the software.

The graph at the right side of the window above illustrates the effect that the Program will have on the PI-SWERL RPM. The *Test Duration* box shows the duration of the entire test (435 seconds).

5. Several pre-programmed tests are provided with the PI-SWERL software. If you click on the *Programs* drop-down menu the list of already programmed tests will be displayed. When a test is selected, the table and the graph to the right of the *Programs* drop-down menu are updated to reflect the test's parameters.

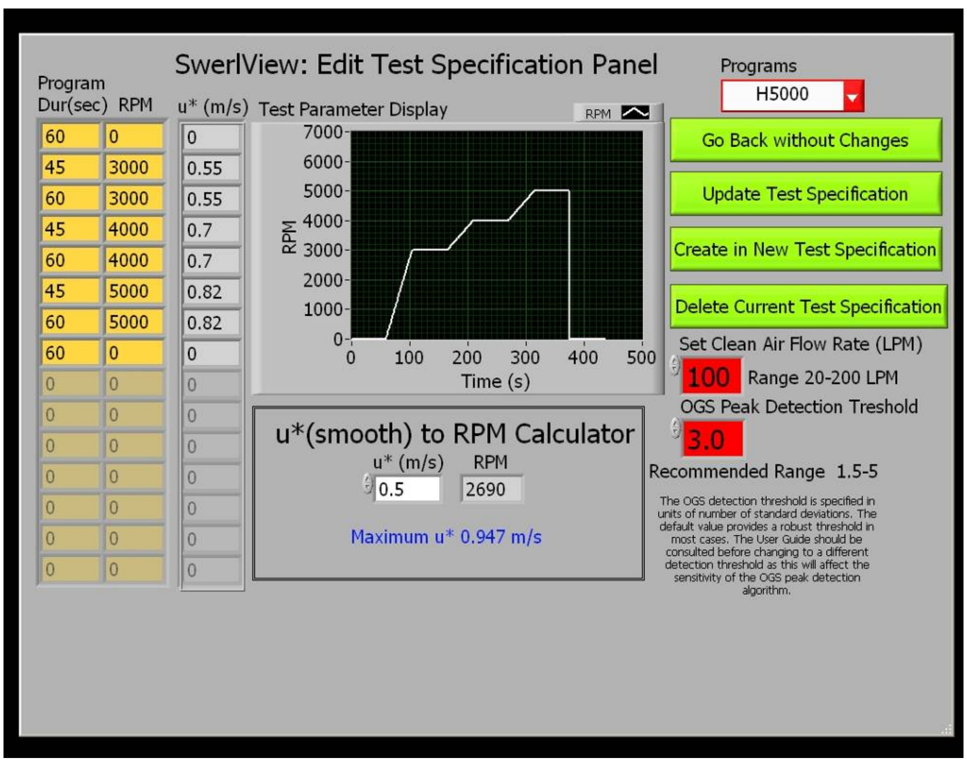
   The user may modify a specific pre-programmed test or create a new test. <u>To modify an existing test specification</u>, select the test from the *Programs* drop-down menu, then click the *Modify* button. This will open the Edit Test Specification Panel (see example below for H5000). In general, for minor changes to a test specification, it may be desirable to modify an existing test specification. For example, if you wanted to change the third entry so that the PI-SWERL would go only hold 3000 RPM for 30 seconds (instead of 60 seconds as shown below), then you would click into the appropriate box, change "60" to "30" and then click *Update Test Specification*.

   <u>To create a new test specification,</u> click the *Modify* button (it doesn't matter which program is selected in the *Program* drop-down menu). When the Edit Test Specification Panel opens. Enter the new parameters. As you enter in new values for RPM, the figure to the right will update the test specification graph and the column to the right (gray) will display approximate corresponding values of friction velocity (u_*). These values are estimated from a polynomial fit to the shear-stress/friction velocity versus RPM data shown in Figure 1-2. They apply to the shear stress as measured underneath the *Effective Area* of the annular blade (See Figure 1-1) over a smooth surface. In the middle of the window, towards the bottom, a calculator utility is also available to estimate the

RPM that would be required to achieve a desired friction velocity (again based on measurements reported in Figure 1-1 and Figure 1-2). The calculator also uses a polynomial fit to estimate the RPM needed to achieve a specific shear stress. Because of uncertainties in curve-fitting, when an RPM value calculated using the calculator utility is entered into the Test Specification table, the friction velocity value displayed to the right of the Test Specification table may be slightly different than the one entered into the calculator utility.

To create a new Test Specification click *Create as New Test Specification*. You will be prompted for a new name for the test specification. This will add the new test specification to those available in the *Programs* drop-down menu.

You can also use the Edit Test Specification Panel to delete tests that are no longer in use. If you don't wish to create a new test or modify an existing test, you can exit the test specification window by clicking *Go Back Without Changes.*

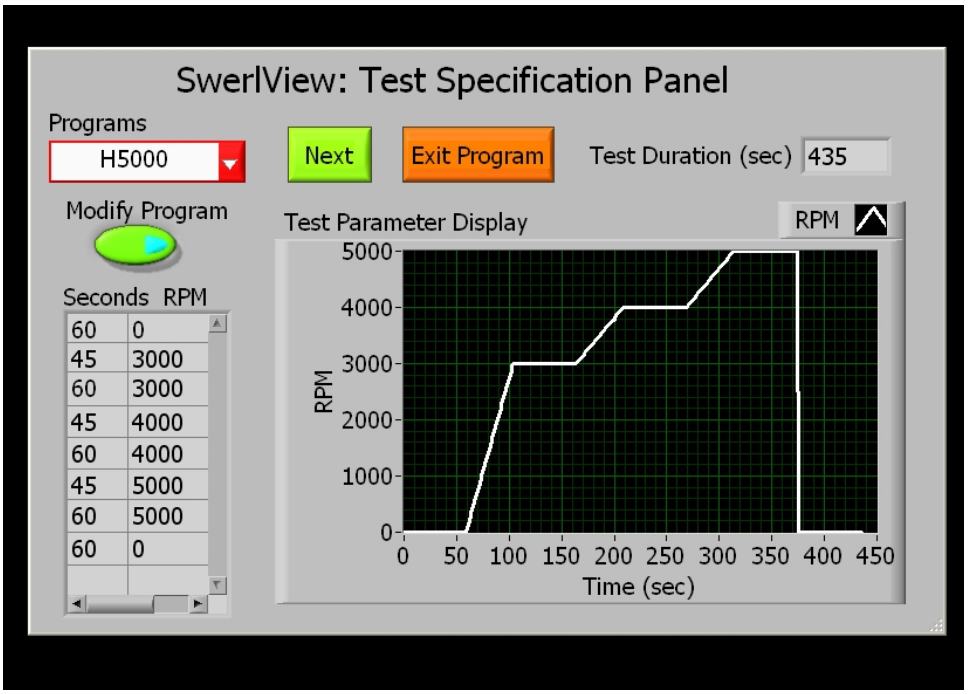


NOTE: **There are two boxes that are highlighted in red that may also be altered as part of the test specification. The first is the clean air flow rate. This corresponds to the volumetric flow rate of clean air introduced into the PI-SWERL chamber by the blower. The second is an OGS sensitivity parameter. The default value of "3" corresponds to the number of noise signal standard deviations added to the OGS base signal that must be overcome for a signal peak to be considered valid. Higher values render the**

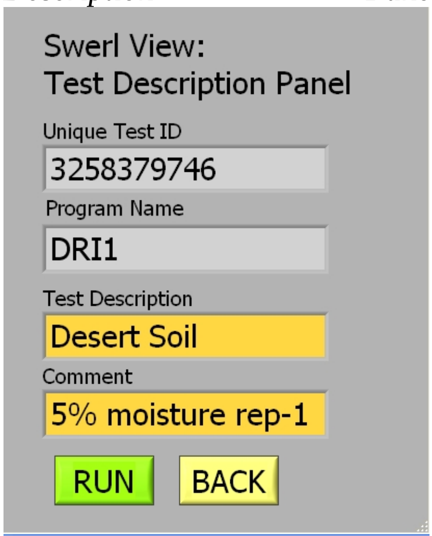
OGS sensors less sensitive (increased likelihood of missing sand grain motion), while lower values render them more sensitive (higher possibility of false positive). In general, the default values for the clean air flow rate and the OGS Peak Detection Threshold should only be changed by experienced users.

2.2.4. Conducting a Measurement

Once the PI-SWERL has been properly placed on the measurement location and the appropriate test specification has been selected, the software will be displaying the Test Specification Panel and the instrument is essentially ready to begin a measurement.



1. Click "Next" in the *Test Specification Panel*. This will bring up the *Test Description Panel* shown below.



   There are four Text boxes in this window. The top two are provided by the software and the bottom two are for the user. The *Unique Test ID* is an integer that uniquely identifies the test being conducted. As explained in a later section, the *Test ID* appears in every row of the 1-second Data file as well as in the test Summary files. It cannot be changed by the user. The *Test ID* always increases between one test and the next. However, it does not increment by a fixed amount. It is tied to the number of seconds that have passed since a fixed date. The *Program Name* box displays the name of the test specification that will be used for the measurement. The *Test Description* box can be filled in by the User. It is written to the test summary file and is a convenient way of labeling your measurements. It can be used to specify the site name, the replicate number at a site, etc. Similarly, the *Comment* text box can be filled in with information that helps document the test.

2. Once the *Test Description Panel* has been filled in as desired, click on the *Run* button to start the measurement. Clicking on "Back" will return you to the *Test Specification Panel*.

WARNING:

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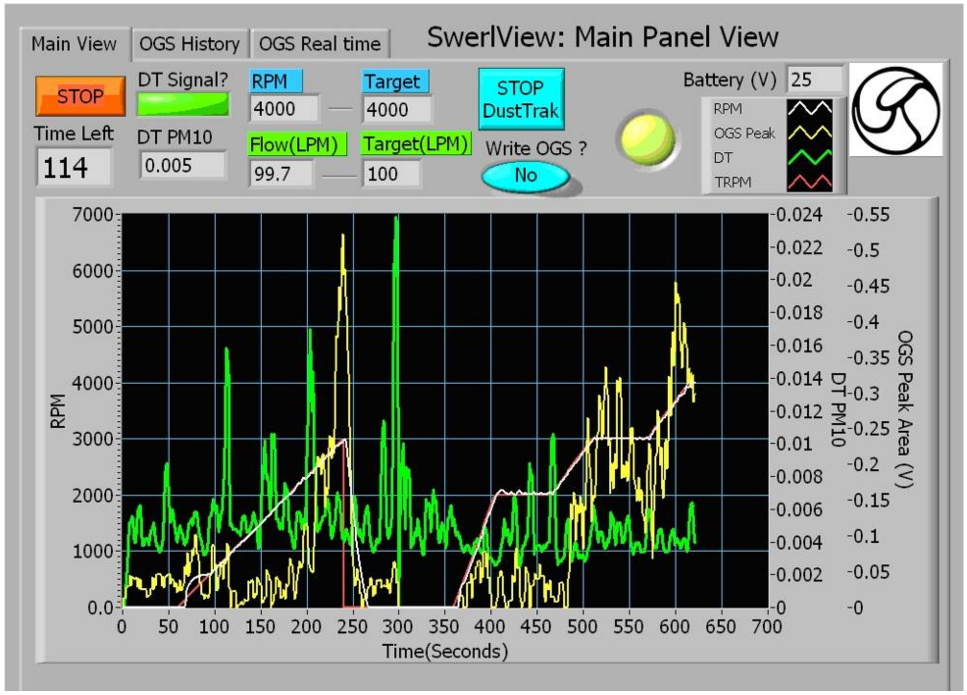
NEVER OPERATE THIS INSTRUMENT ON A SURFACE WITH LOOSE DEBRIS THAT MAY BE DISLODGED INTO THE PATH OF THE ANNULAR BLADE.

If no error messages are displayed, at this point, the SwerlView control software automatically executes the program and writes the data files. The dust monitor pump and clean air blower will start and the software will switch to *Main Panel* View. **If the dust monitor is not connected, SwerlView will report an error and allow the user to turn on or connect the dust monitor. If this error is dismissed, SwerlView will continue running the test without any input from the dust monitor.** The user should check on the progress of the test periodically to determine if it is proceeding smoothly. The figure below shows the *Main Panel View* after one full ramp test has been completed and one hybrid test is in progress.

From left to right the top two rows display the following information/function: the *Stop* button is used to terminate the measurement before the entire test can be completed and write the data files up to the point of termination. Pressing this button will stop the motor, blower, and data collection within a few seconds. A *Time left* text box informs the user how many seconds remain before the measurement is completed. To the right of the *Stop* button is the *DT Signal?* indicator, which is green when the dust monitor is connected and communicating with SwerlView properly and is red otherwise. The *DT* PM_{10} box displays in real-time what the dust monitor is measuring. The *RPM* box displays the actual motor RPM and the *Flow (LPM)* box displays the actual clean air flow rate. The *Target* and *Target (LPM)* boxes display respectively the target values of RPM and clean air flow prescribed in the test specification.

The *Stop DustTrak* switch turns the pump off on the DustTrak. This can be used when the dust concentrations exceed the DustTrak's measurement range and useful data are not being collected. Using this feature allows the user to minimize unnecessary exposure of the DustTrak to damaging levels of dust. Note that once the DustTrak has been turned off in this manner, SwerlView will not communicate with it again until the test is over and a new test has started. A "-2" will be written to the data file to indicate that the DustTrak was switched off by the User.



A *Write OGS?* Switch can be used to toggle file writing of the raw OGS data. In general, this switch should be left in the "Off" position since OGS data are collected at high frequency and the associated files tend to be quite large. Data from the optical gate sensors are discussed in Chapter 3.

Finally, a round indicator blinks (yellow/blue) when SwerlView is running a test and the *Battery (V)* box displays the battery voltage.

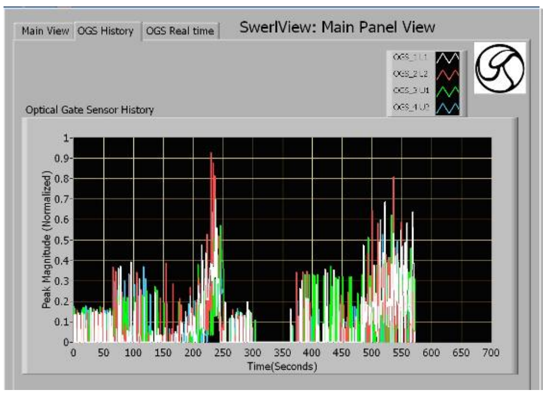
Of course the main feature of the *Main Panel View* is a graph that displays the values of the target and actual RPMs (left y-axis), the dust monitor reading (mg/m^3, right y-axis labeled DT PM_{10}), and the 1-second averaged optical gate sensor data (OGS, Far right y-axis). Note that the right y-axes scale automatically with the values being reported and that this scale can change over the course of a test to accommodate varying ranges in dust concentration and OGS signal activity.

3. Once SwerlView has executed the entire test, a window will appear asking if the User wishes to conduct another measurement or Exit the SwerlView software. **The dust monitor pump will not stop in between tests.** If the dust monitor has been turned off by the User (with *Stop DustTrak* switch), then the dust monitor will restart when the next test is started. Upon exiting SwerlView, the dust monitor pump is turned off, and the dust monitor is placed in standby mode. To completely power the dust monitor off, the User must initiate shut down procedures through the dust monitor's LCD display.

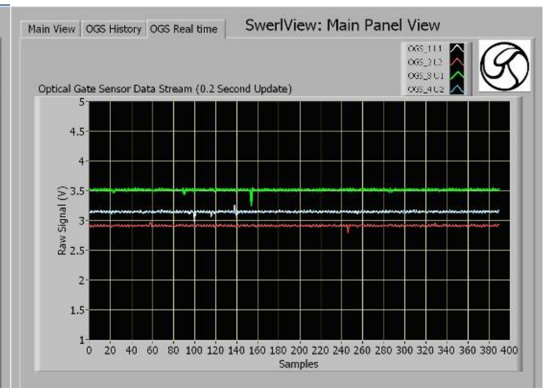
2.2.4.1. Tabs available in the SwerlView *Main Panel View* window.

There are three (3) tabs available in the *Main Panel View* window: “Main View”, “OGS History”, and “OGS Real Time”. When you first start a measurement, by default, SwerlView will display the “Main View” tab that was described above.

The “Main View” tab contains most of the information that is needed by the User while conducting a measurement and has already been discussed. The “OGS History” tab shows a time trace of the data from the OGS sensors. It is useful for determining whether OGS data from a specific test appear to be different from prior tests (magnitude, counts, etc) or if an OGS sensor is malfunctioning. The “OGS Real Time” tab shows the OGS data closer to real-time so that the User can observe the frequency of OGS sensor triggers and the consistency of triggers. As mentioned, most Users will prefer viewing the “Main View” tab the majority of the time.



a. OGS History tab



b. OGS Real Time tab

2.2.4.2. When should a User Stop a Measurement before the test cycle is completed?

Safety is always a good reason to stop a PI-SWERL measurement before the test cycle is completed. If for any reason, conditions during a test become unsafe, press the *STOP* button on the SwerlView Main View tab. Alternatively, if the test must be stopped immediately for safety reasons, turn the power off to the control box and PI-SWERL motor using the switch on the control box.

There are some other reasons when it makes sense to stop a test before it is completed. In general, the only loss incurred by stopping a test is a few minutes of time. The following is a list of potential reasons why it may be more efficient to stop a test than to wait for the test cycle to complete:

A. The test location is compromised or the foam seal exhibits a leak
B. One of the critical onboard instruments appears to be not functioning. This may include:
    a. The clean air flow sensor or clean air blower
    b. The PI-SWERL motor or RPM gauge
    c. The DustTrak Monitor
C. The Dust Monitor is out of Range: A common problem on very dusty surfaces is that the amount of dust generated at a high RPM may exceed the upper limit of the dust monitor. The dust monitor upper limit is specified as

400 mg/m^3 by the manufacturer. Prolonged use at extremely high dust concentrations compromises the accuracy of the dust monitor and may lead to unnecessarily frequent recalibration of the dust monitor. A good rule of thumb is if the dust concentration exceeds about 300 mg/m^3 for 15 seconds or more, it may be a good idea to turn off the dust monitor or terminate the test. Here are a few options that can be exercised in the event that dust concentrations are at very high values for certain field conditions:

a. Try running the PI-SWERL at lower RPM values. You might consider how important the higher values of RPM are for your application and whether the potential for damaging the dust monitor is warranted.
b. Once dust concentrations reach an upper threshold (say 300 mg/m^3 for 15 seconds), completely stop the test using the *STOP* button in the SwerlView Main Panel View.
c. Once dust concentrations reach an upper threshold, do NOT stop the entire measurement. Instead, simply use the *Stop DustTrak* switch in the Main Panel View. This technique has the advantage that you collect as much data with the DustTrak as is possible before having to power the instrument off. Furthermore, as the measurement cycle continues, the DustTrak is not operating, but the OGSs inside the PI-SWERL chamber are. The OGSs have a much higher upper limit than the DustTrak. Thus, when post-processing the test data, you may be able to correlate the optical gate sensor data with DustTrak data from periods when the DustTrak was operating. This correlation could then be used to extrapolate dust concentrations even after the DustTrak has been turned off.

2.2.5. Cleaning the PI-SWERL between measurements

During operation of the PI-SWERL, dust is suspended from a test surface. Most of the suspended dust is exhausted out of the PI-SWERL chamber. However, some amount of dust will inevitably deposit on the inside surfaces of the PI-SWERL. If not accounted for or cleaned, then this "carry-over" dust may affect the quality of the next measurement. There are three ways that the PI-SWERL can be cleaned in between measurement locations. Which of these three is most appropriate depends on how dusty the soil test surface is and how much variability is expected between consecutive measurements. the worst-case combination of these two factors can be achieved if a very dusty measurement location is tested first and then a relatively stable surface is tested in a subsequent measurement without cleaning in between these two measurements. In this case, the dust deposited on the inside of the PI-SWERL chamber during the first test at an emissive site will be partially liberated during the second test on the relatively stable surface. This would result in the stable surface appearing more emissive than it actually is.

With this in mind, a good rule of thumb is to try to schedule the measurements so that the measurements at the beginning of a field day are at relatively stable sites while those later in the day are at the dustier sites. Noting that it is not always possible to accommodate such a schedule, the following three techniques can be used individually or in some combination to minimize carry-over from one measurement location to the next:

A. Run a “Cleaning” cycle: Place the PI-SWERL over a solid, relatively clean surface – a piece of flat wood or aluminum works well. Program a PI-SWERL test where the RPM is held at a relatively high value for a period of several minutes. For example, if you have been running tests that reach a peak RPM of 4000, you could program a Cleaning cycle where the RPM is held at 5000 for a period of 2-3 minutes. Run the cleaning cycle and observe the measured dust concentrations. If dust concentrations decrease to an acceptable value, then the PI-SWERL is clean enough for use at the next measurement site. If the dust concentrations continue to be unacceptably high, either repeat the cleaning cycle or try a different cleaning technique.

B. Blow out the deposited dust: Using a compressed air can (refillable air can is more economical than single-use products), blow compressed air on the inside surface of the PI-SWERL and along the exhaust port. Using a jet nozzle usually frees the surfaces of any deposited dust particles. Try to avoid blowing air directly into the clean air ports as this may cause dust to deposit on the clean air flow meter and result in a malfunction.

C. Wipe down the inside surfaces with soapy water: This is generally not convenient to do and should be avoided if possible. However, if necessary (for example if inside of chamber gets muddy), start by disconnecting the PI-SWERL from the control box to avoid electrocution. With a soapy rag, wipe down the inside surfaces of the PI-SWERL until they are clean. Be sure that the PI-SWERL is dry before reconnecting the instrument to the control box.

2.2.6. Checking the battery charge between measurements

Lead-acid batteries discharge at varying rates depending on environmental conditions and intensity of use. In addition to the voltage display on the SwerlView *Main View Panel*, the SwerlView program keeps track of battery performance and provides a prompt when the battery pack is close to needing replacement. Signs of a battery that need replacement include:

A. Appears that the PI-SWERL is struggling to maintain/meet target RPM values

B. Convergence to target RPM is slow compared to when battery pack is fresh

C. SWERLView program suggests that the battery packs be replaced.

Though it varies widely depending on use levels, a battery pack can usually be used for 2- 5 hours of measurements or from 15 – 25 measurements (assuming ~10 minutes per measurement).

In any case, if the battery pack requires replacement between tests exit the SwerlView program and follow the procedures outlined in Section 2.1.3.

2.2.7. Cleaning the dust monitor between measurements

Occasionally, very high dust concentrations during a measurement may result in the dust monitor itself getting dirty. Dust deposited on the inside of the monitor and along the inlet lines may result in a “reservoir” of dust that carries over into the next measurement. This is often expressed as dust concentrations that do not seem to decrease to values less than 0.1 mg/m^3 even after the PI-SWERL has been cleaned. It might be necessary to clean and re-zero the dust monitor and adjust the flow in such cases before proceeding to the next measurement (See TSI DustTrak manual for instructions).

2.2.8. Moving to a different site

To move to a different measurement location:

1. Make sure that any tests that were running are completed and the PI-SWERL annular blade has come to a stop.
2. Lift the PI-SWERL instrument off the ground and tilt it slightly so that the V-notched bracket slides underneath the bolt on the back of the docking station.
3. Secure the front latch.
4. Ensure that the cable that runs between the PI-SWERL and the control box is out of the way of the wheels of the cart.
5. Go to your next measurement location, unload the PI-SWERL, and begin your next measurement.

For short periods of time (10 minutes) and distances between measurement locations, it is not necessary to power down the PI-SWERL or computer if using the field cart to transport the instrument. If transporting in a different vehicle, such as a truck, it is best to power down the computer and control box and remove the PI-SWERL instrument from the docking plate for transport. If using a pick-up truck, it is good practice to transport the PI-SWERL instrument in the cab of the vehicle. The field cart (with control box mounted) can be transported in the bed of the truck if strapped securely.

3. Data files

While the SwerlView software is useful for entering test parameters and monitoring the progress of a test, data from PI-SWERL measurements require a significant amount of post-processing to ensure adequate data quality and to extract useful information. Several different types of data files are written to the computer hard drive during a measurement. All data files are written in tab-delimited ASCII, allowing for easy import into spreadsheet and/or database software. It is assumed that the User is experienced with using such software packages for performing calculations, graphing results, and extracting data. Therefore, this Chapter focuses on explaining the different data files that are written during a PI-SWERL measurement and the contents of those data files. Some guidance on determining the quality of the data is provided as part of the discussion

3.1. Where are the files located?

The most frequently used data files are located in the "c:/Swirlerdata" directory on the PI-SWERL computer. When the first test is completed on any given day, the SwerlView software creates a new subdirectory within the "c:/Swirlerdata" directory. For example, after the first measurement on April 7, 2008, the SwerlView software will create the subdirectory "20080407" so that all the main PI-SWERL data files associated with measurements conducted on April 7, 2008 will be located in the "c:/Swirlerdata/20080407" subdirectory.

If the *Write OGS* option is enabled during the measurements, a file will also be written to the "c:/Swirlerdata/SwirlerSalt/" subdirectory. In general the raw optical gate data files are very large in size and somewhat cumbersome to handle. This is because the raw data from the optical gate sensors is collected at 2 kHz so that the number of entries to the raw data file during an 8-minute PI-SWERL measurement approaches 1 million for each optical gate sensor (approximately 200 MB in disc space). Many commercially available spreadsheet programs are unable to handle this many number of rows. For this reason, if there is no known use for the raw optical gate data, it is suggested that the User instructs the SwerlView software not to write the raw optical gate data (This is the default setting within SWERLView).

3.2. Understanding the data files

There are two main types of data files that are written during PI-SWERL measurements: The "Info" file and the "Data" file. For a given day of testing, one "Info" file will be created by the SwerlView software. This file is small and is simply appended to each time a new measurement is completed. In contrast, a separate "Data" file is written for each measurement that is completed. Note that in earlier versions of SWERLView, a "summary" file was also created to summarize the test results. This feature has been removed from the new version of SWERLView.

3.2.1. The "Info" File

At the time of the first measurement on any given day, the SwerlView software creates an "Info" file. Each line in the Info file provides descriptors for a particular measurement. Thus, at the completion of each subsequent measurement, the "Info" file is appended with the descriptors for that measurement. For example, the "Info" file for measurements conducted on April 7, 2008 is found in the "c:/Swirlerdata/20080407/" subdirectory and is labeled "Info_20080407.txt". As with all PI-SWERL data files, the Info file is in tab-separated ASCII format.

The Info file field headings and a description of the field contents are provided in the Table below. Note that the *TestID* field is an integer identifier that is unique to each measurement cycle and can be used to tie a specific entry in the "Info" file with entries in the "Data" files. The last four fields in each "Info" file entry (starting with *Lat(dec.deg)*) are derived from the GPS unit that is attached to the PI-SWERL instrument. At the start of each measurement, the SwerlView software begins to collect coordinate information provided by the GPS at a rate of once every 2 seconds. At the end of the measurement cycle, all the coordinates collected over the course of the measurement are averaged. This results in reasonably accurate GPS coordinates for each test location depending on the quality of the GPS signal. In general, the coordinates provided in the "Info" file are useful for approximately locating where a test was conducted (within 3 – 15 m depending on GPS signal quality) but cannot be used for pin-pointing a test location.

Table 3-1. Info File Content Description

Field Heading	Description of Field Contents
TestID	10-digit integer that is unique for each measurement conducted. The number represents the seconds that have passed since midnight on January 1, 1904. The number always increases between successive measurements. This number is one reason why the computer clock should be properly set.
TestName	This is the name of the test specification program used when the measurement was conducted.
TestComment1	Text from the *Test Description* Text Box in the SwerlView Software
TestComment2	Text from the *Comment* Text Box in the SwerlView Software
TargetFlowRate (LPM)	The target flow rate for the clean air blower as set in the test specification
OGSThreshold	The threshold value set in the test specification for detecting a peak from the OGS signal. This value corresponds to the number of standard deviations of the baseline signal that a peak signal must exceed in order to be counted as a peak. The default setting is 3
DustTrak_SN	The 10-digit serial number of the DustTrak nephelometer used during the measurement
Lat(dec.deg)	Latitude of measurement location in decimal degrees
Lon(dec.deg)	Longitude of measurements location in decimal degrees
Elevation(m)	Elevation of measurement location in meters above sea level
PointAvg	The number of GPS data points that were averaged to obtain the Latitude, Longitude, and Elevation of the measurement location. This field can also be used to estimate test duration quickly. Just multiply by two to obtain the number of seconds that a test ran for.

Table 3-2. Example “Info” File.

TestID	TestName	TestComment1	TestComment2	TargetFlowRate(LPM)	OGSThreshold	DustTrak_SN	Lat(dec.deg)	Lon(dec.deg)	Elevation(m)	PointAvg
3298373698	R3000	mug m113 5	1	100.0	3.00	8531103601	32.79762646	-114.3350051	101.2103704	135
3298374016	S2500	mug m113 5	2	100.0	3.00	8531103601	32.79761051	-114.3349529	96.68512821	195
3298374480	S2500	mug m113 5	3	100.0	3.00	8531103601	32.79760889	-114.3349467	100.2666667	3
3298374532	S2500	mug m113 5	3	100.0	3.00	8531103601	32.79759807	-114.3349449	103.0553846	195
3298374930	S3000	mug m113 5	4	100.0	3.00	8531103601	32.79759009	-114.3349575	100.2825641	195
3298375574	R3000	mug fmtv 5	1	100.0	3.00	8531103601	32.79746566	-114.3350363	92.4375	136
3298375869	S3000	mug fmtv 5	2	100.0	3.00	8531103601	32.79744848	-114.3350579	99.83179487	195
3298376303	S3000	mug fmtv 5	3	100.0	3.00	8531103601	32.79745008	-114.3350421	100.7	195
3298376741	S3000	mug fmtv 5	4	100.0	3.00	8531103601	32.79744738	-114.3350106	106.9035897	195

3.2.2. “Data” Files

At the beginning of each measurement, the SwerlView software creates a new “Data” file that contains all of the PI-SWERL information that is pertinent to the actual measurement. The file is named “Data_YYYYMMDDhhmmss.txt” with “YYYY” representing the year, “MM” the month, “DD” the day of the month, “hh” the hour of the day in military time (0-24), “mm” the minute of the hour, and “ss” the seconds. For example, a measurement started on April 7, 2008 at 3:45:21 PM would result in a data file named “Data_20080407154521.txt”. This file naming convention is useful for cross-referencing measurement data with field notes, ensuring that data files have unique names, and quickly determining the order of measurements completed on a given day. The SwerlView software uses the computer clock to determine the date and time of file writing so it is important that the computer clock is set correctly at the time of measurement.

The “Data” file is appended once a second as the measurement progresses so that if the measurement is stopped at any point, all of the data collected up to that point are recorded in the “Data” file.

The “Data” file contains several fundamental quantities as well as several quantities that are derived from the fundamental measurements. In addition, the “Data” file has been structured so that the User can group and/or manipulate data in a spreadsheet or database program in a variety of different ways.

The “Data” file is in tab-separated ASCII format and is easily imported into a number of commercially available spreadsheet or database programs.

Table 3-3 below shows the field headings and descriptions that are written to the Data file. Note that a number of fields are only useful for examining the “Step” portions of a PI-SWERL measurement. These are: *TRPM*, *RPM_Norm*, *StepMass(ug)*, and *StepDur(s)*. Because during “Ramp” portions of a measurement, the rate of revolution of the annular blade is constantly changing, these four fields are not meaningful and can be ignored.

In the next several sections, we examine the results from example tests. In most cases, figures and information presented were created using real PI-SWERL “Data” files imported into a spreadsheet program. In some cases, the underlying data were artificially altered for demonstration purposes.

Table 3-3. Field Headings and Field Descriptions for "Data" files. Highlighted Rows represent derived quantities

Field Heading	Description of Field Contents
Datetime	The Date and Time associated with the 1-second entry in "YYYY/MM/DD hh:mm:ss" format. Note that in some spreadsheet programs, this field must be formatted properly for the date and time to be displayed completely.
TestID	10-digit integer that is unique for each measurement conducted. The number represents the number of seconds that have passed since midnight on January 1, 1904. The number always increases between successive measurements. This number does not change within a given Data file and is used to cross-reference Data files with entries in the Info file
RPM	Actual revolutions per minute (RPM) of the annular blade/motor. A PID algorithm uses this value to adjust the power provided to the PI-SWERL motor in order to achieve the programmed ramp rate or step value.
TRPM	Target RPM. For tests which include a step (flat RPM over time) , this is the specified value of the RPM that the PI-SWERL attempts to maintain for a prescribed period of time. For ramping from one RPM to another, this value changes continuously over the course of the measurement. Note that this field is also useful for grouping data (e.g. examining average dust concentrations at a specific constant RPM – as during step measurements.)
RPM_Norm	Ratio of actual RPM of the annular blade to the Target RPM. A value near unity indicates that the target RPM has been attained. Note that RPM_Norm is set to 0 when TRPM is 0.
Flow(LPM)	The measured Clean Air Flow rate in units of liters per minute (lpm). The target clean air flow rate is set to 100 lpm by default. A PID algorithm uses the measured value to adjust power to the clean air blower.
DT_PM10(mg/m3)	Dust concentration as measured by the dust monitor (TSI, Model 8530) in units of mg/m^3. **This field has a value of -1 if the SWERLView software and the DustTrak lose communication at any point during the measurement**. This field has a value of -2 if the User turns off the DustTrak through the SWERLView "Stop DustTrak" switch. These negative values are intended to alert the User that DustTrak data are not available.
InstantFlux(ug/s)	The rate at which dust is being emitted from the test surface in units of micrograms per second. Note that dividing this number by the PI-SWERL "effective" area (0.026 m2) gives a dust emission rate per unit area of surface.
StepMass(ug)	The mass of dust (in micrograms) that has been suspended since the start of a specific TRPM value. This is essentially a summation of the InstantFlux over every second since a new target RPM has been set. This quantity is reported for ramp portions of a measurements, but is only meaningful for step portions of the test.
TotalMass(ug)	The total mass of dust (in micrograms) that has been suspended since the beginning of the measurement. This is essentially a summation of the InstantFlux over every second since the beginning of the measurement.
TestDur(sec)	The number of seconds that have elapsed since the beginning of the measurement.
StepDur(sec)	The number of seconds that have elapsed since the start of a new TRPM value. Note: This field is only useful for step portions of a test.
OGS_L1_Count	The number of peaks at optical gate sensor 1 (bottom of PI-SWERL chamber) detected over one second.
OGS_L1_PeakArea(V)	Total area underneath detected peaks from optical gate sensor 1 (bottom of PI-SWERL chamber.
OGS_L2_Count	The number of peaks at optical gate sensor 2 (bottom of PI-SWERL chamber) detected over one second.
OGS_L2_PeakArea(V)	Total area underneath detected peaks from optical gate sensor 2 (bottom of PI-SWERL chamber.
OGS_L3_Count	The number of peaks at optical gate sensor 3 (bottom of PI-SWERL chamber) detected over one second.
OGS_L3_PeakArea(V)	Total area underneath detected peaks from optical gate sensor 3 (bottom of PI-SWERL chamber.
OGS_L4_Count	The number of peaks at optical gate sensor 4 (bottom of PI-SWERL chamber) detected over one second.
OGS_L4_PeakArea(V)	Total area underneath detected peaks from optical gate sensor 4 (bottom of PI-SWERL chamber.
DTdatavalidty	This field is not used

3.2.2.1. Examining data from a test where the RPM is held constant for a period of time (Step test)

A rather informative and convenient graph can be created by plotting the *Datetime* field on the x-axis versus the *RPM*, *TRPM*, *Flow(lpm)*, and *DT_PM10(mg/m3)*. Figure 3-1 shows a relatively clean PI-SWERL test composed of three distinct steps. A few key points to keep in mind when examining a time series plot for a step portion of a test are:

1. Does the measured RPM converge reasonably well to the Target RPM?
2. Is the clean air flow rate relatively constant (set at 100 lpm by default)?
3. Are the measured dust concentrations well behaved?

Let us examine each of these questions one by one.

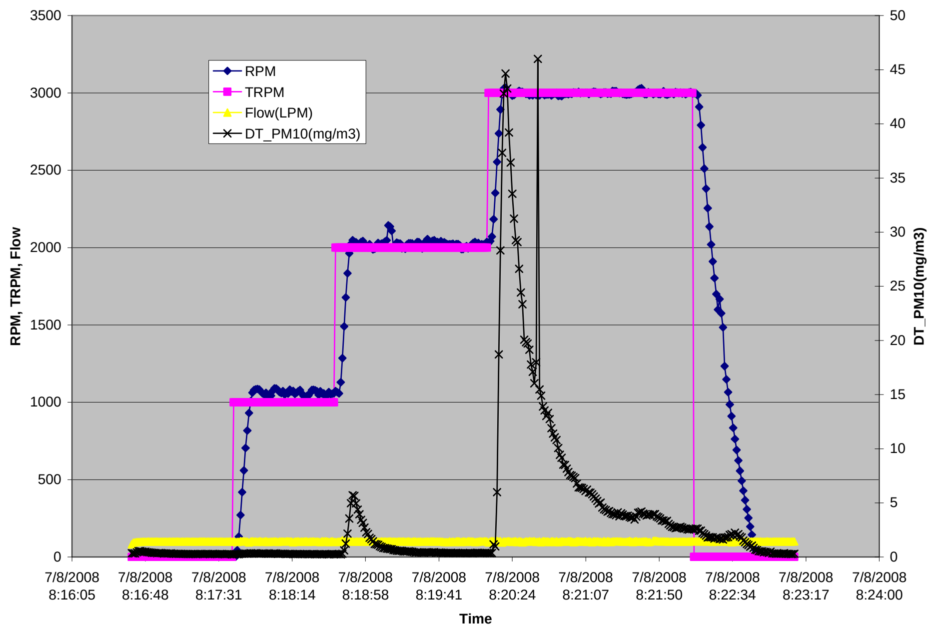


Figure 3-1. Example test consisting of 3 distinct steps. RPM, Target RPM, and Clean air flow plotted against time using Left y-axis. DustTrak PM_{10} concentration plotted against time using right y-axis.

3.2.2.1.a. Does the measured RPM converge reasonably well to the Target Value?

In the test depicted in Figure 3-1, there are 5 different regions during the test: a Clean air flush for 60 seconds (*TRPM* = 0), 60 seconds at 1000 RPM, 90 seconds at 2000 RPM, 120 seconds at 3000 RPM, and 60 seconds of clean air flush (*TRPM*=0). For the clean air flush at the beginning of the test, the PI-SWERL annular blade starts off at rest. The Target RPM is 0 (i.e. no rotation) so the annular blade does not begin rotating. The measured and Target RPM are in good agreement for this region of the test. When the Target RPM jumps to 1000, the SwerlView software attempts to quickly bring the actual RPM of the annular blade to the Target value. Within less than 10 seconds, the Target value is achieved. The software is optimized to avoid overshooting the Target value. However, the 1000 RPM target is in fact slightly overshot by SwerlView. This is a common occurrence at relatively low RPM. The reason is that the annular blade is not experiencing very much friction at these low rotation speeds. Thus, a small amount of power can easily result in an overshoot of the Target RPM value. Nevertheless, a quick examination of the *RPM_Norm* field reveals that the overshoot is within 10% of the Target RPM and is probably acceptable.

Moving on to the third region (*TRPM* = 2000), overall, the measured RPM does not significantly overshoot or undershoot the target value. A small kink halfway through the third region is within 10% of the Target value. Convergence through the fourth region is also acceptable. At the start of the fifth region, the Target RPM is set to 0. However, since the annular blade is rotating at 3000 RPM, it takes some time before it is slowed down by friction. The slow taper at the end of a test is normal. Overall, the test shown in Figure 3-1 exhibits good convergence at every step portion.

What does poor convergence look like? In general, there are three types of convergence problems that are frequently encountered. They are Excessive Undulation, Chronic Undershoot/Slow Convergence, and Chronic Overshoot. They are illustrated in Figure 3-2. There are several possible reasons for each of these convergence problems. In most instances, the cause is a discharged battery pack. In rare cases, the PID algorithm may need to be adjusted to account for changes in the PI-SWERL mechanical properties over time or to suit your specific application. Contact DUST-QUANT LLC for inquiries into PID parameter adjustment.

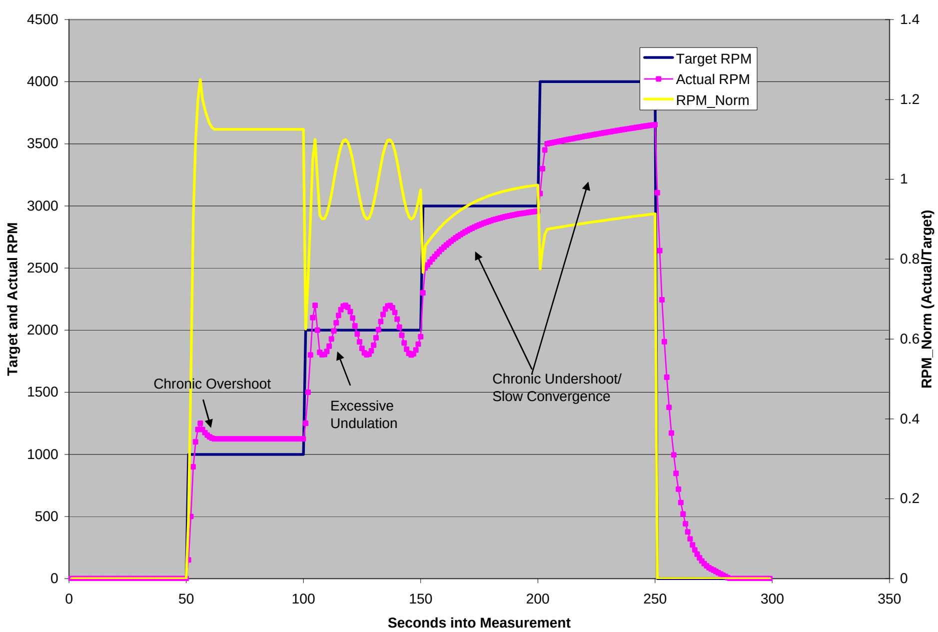


Figure 3-2. Examples of Poor RPM convergence for a test with four step portions.

Chronic Overshoot: An example of overshoot was provided earlier in Figure 3-1. This problem can occur at low values of Target RPM because there is no friction load on the spinning annular blade. Consequently, a small amount of power can result in an overshoot of the Target RPM. If overshoot is causing a problem , it may be possible to refine the PID parameters for a specific application. Contact the manufacturer for suggestions.

Excessive Undulation: This problem is usually caused by a battery pack that cannot source enough power to maintain a steady Target RPM.

Chronic Undershoot/Slow Convergence: This problem is also a symptom of a battery pack that cannot provide the power needed to achieve the Target value.

3.2.2.1.b. Is the Clean Air Flow Rate Relatively Constant?

Similar to the motor that powers the PI-SWERL annular blade, a PID algorithm is used to maintain the Clean air flow rate at a set value. The default set value of 100 lpm is adequate for most applications. A mass flow meter is used to meter the flow rate of air provided by the clean air blower. The reading from this flow meter is reported in the PI-SWERL "Data" file on a 1-second basis. Generally, all that is needed to check the clean air flow rate is a quick glance at a time series such as the one shown in Figure 3-1. If the flow rate appears to be nearly constant at 100 lpm, then the clean air flow was operating adequately. In practice, small (10%) perturbations in the clean air flow rate do not adversely affect the PI-SWERL measurement.

3.2.2.1.c. Are the measured dust concentrations well behaved?

Returning to Figure 3-1, the time series trace of the dust concentrations as measured by the TSI DustTrak 8530 monitor are plotted in black against the right-hand y-axis. There are several things to note about the dust concentration values. First, compared to the maximum dust concentrations over the course of the test, concentrations are very low at the beginning of the measurement during the clean air flush and even during the 1000 RPM step. This is a good indication that for the purposes of the measurement shown, the PI-SWERL chamber was relatively clean at the beginning of the measurement and no appreciable amounts of dust carry-over from previous measurements had occurred. It is also a good indication that the dust monitor is working properly since we expect low amounts of dust at low rotation speeds of the annular blade.

Second, overall, the time series of dust concentrations exhibits a continuous curve with few sudden changes in dust concentrations. Sharp increases can be seen at the point where the target RPM switches from 1000 to 2000 and again when the target switches from 2000 to 3000. However, these are normal and expected responses to the increase in the rotation speed of the annular blade. There is an isolated peak in dust concentration about 30 seconds into the 4000 RPM step. Such isolated peaks are not necessarily an indication of a problem with the measurement. The peak may be a result of a relatively large soil particle making it past the DustTrak inlet into the sensing chamber or else a puff of dust associated with some material that had deposited within the inlet line and suddenly dislodged into the DustTrak monitor. The peak is almost certainly not a result of dust emissions at the soil test surface. Emissions from the test surface appear smoother on time series graphs because such emissions are first dispersed within the PI-SWERL chamber, mixed in with the existing air in the chamber, and vented relatively gradually through the exhaust port.

In any case, the isolated peak during the 4000 RPM step is not of concern because it is not part of a pattern of such peaks and it is of the same order of magnitude as the dust concentrations measured during the step. In practice, this means that the isolated peak will not have much of an impact on the average, sum, or overall magnitude of the dust emissions over the entire step.

What would problematic dust monitor data look like? Figure 3-3 illustrates several different types of problems that can occur from time to time. They are: Elevated Baseline, Flat Response, Excessive Spurious Peaks, and Excessive Dropped Data.

NOTE: It is fairly common, especially at the beginning of a field measurement day that the user forgets to connect the DustTrak inlet to the PI-SWERL chamber. This is easily identified because the dust monitor does not appear to respond to any changes in PI-SWERL RPM.

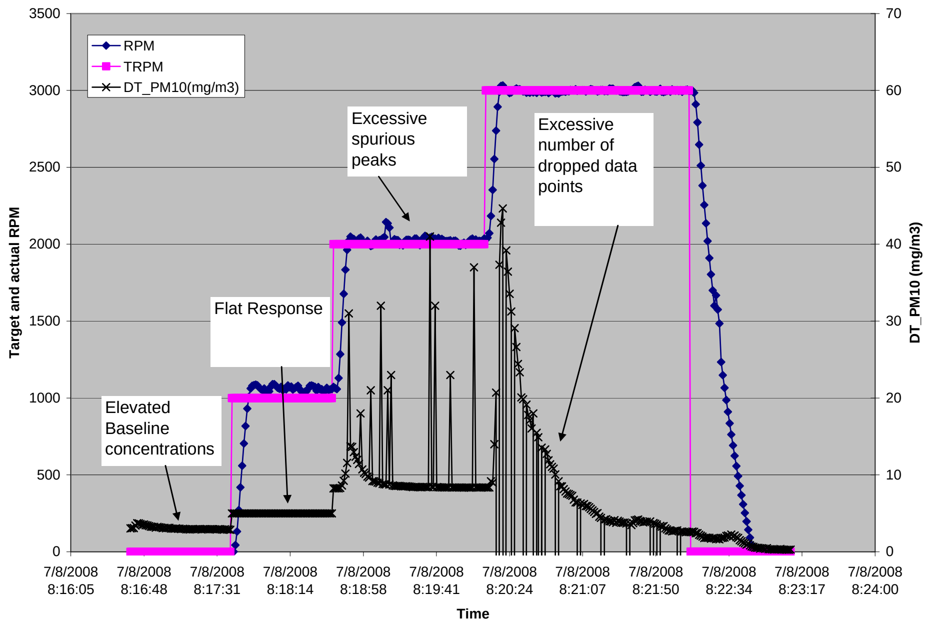


Figure 3-3. Example of poor dust monitor data quality

Elevated Baseline Concentrations: There are several possible causes of this problem:

1. The baseline reading on the DustTrak dust monitor may have drifted over the course of use so that the monitor is reading higher values than it should be. This is easily checked by placing a zero filter directly on the inlet of the dust monitor. If the dust reading with the filter in place is higher than 0.01 mg/m^3, then the dust monitor requires re-zeroing (See TSI DustTrak manual for instructions on re-zeroing).
2. The PI-SWERL chamber may have carried over a substantial amount of dust from a previous measurement. When the clean air blower begins to circulate air through the chamber, some of this dust is resuspended and measured by the dust monitor. This can be rectified by cleaning the PI-SWERL in between measurements as described in Section 2.2.5.
3. Sometimes, the placement of the PI-SWERL on a dusty surface may result in small amounts of dust being suspended from the test surface. If this is the case, then the dust concentration usually begins to fall after the clean air blower (first flushing cycle) first comes on. In such cases, the apparent elevated baseline does not pose a measurement problem.

4. In rare cases, the clean air flow may be causing the soil surface to suspend dust. This usually happens only at sites where the surface is extremely susceptible to wind erosion. There are means to reduce the clean air flow rate, but in general it is not helpful to do so. The reason is that a lower clean air flow means that the ventilation rate of the PI-SWERL chamber is decreased compared to a higher clean air flow. Thus, on very dusty surfaces, the upper limit of the dust monitor is likely to be reached very quickly and lowering the clean air flow rate only exacerbates this problem.

Flat Response: When the value being reported by the dust monitor is completely flat (i.e., exhibits no variability) there may be a communication problem or the dust monitor may be behaving erratically.

1. Dust monitor may need re-zeroing or cleaning. It is possible that some stray material may be lodged in the dust monitor sensing chamber and interfering with the dust measurement. Try cleaning the dust monitor (See TSI DustTrak Manual).
2. Communications between the dust monitor and the PI-SWERL computer may be compromised. In the field, this can be checked by observing the LCD display on the dust monitor. If the dust concentration shown on the LCD display does not change once a second, then the problem is with the dust monitor (See the TSI DustTrak manual).

Excessive Spurious Peaks: short, high peaks in dust concentration are usually a result of a dust monitor that needs to be cleaned and re-zeroed. It is also possible that some dust has deposited along the inlet lines to the dust monitor and may be intermittently suspended into the monitor, resulting in spurious peaks.

Excessive Dropped Data: When SwerlView cannot communicate with the DustTrak monitor at a given second during the measurement, it writes a value of -1 (-2 if the User turns off the DustTrak through SWERLView) to the Data file for that second. A few dropped data points are not detrimental to the measurement, but it is preferable that they are avoided altogether. Excessive dropped data points such as the case shown in Figure 3-3 require remedy before further measurements are made. In the field, try shutting down the computer, control box, and DustTrak and restarting the entire system. If you have a spare DustTrak, you could also try swapping it in to determine if the problem is specific to the unit being used.

3.2.2.1.d. Derived Quantities in a Data File

The fundamental quantities or fields in a Data file are the Date and time (*Datetime*), the unique Test integer identifier (*TestID*), the measured RPM (*RPM*), the Target RPM (*TRPM*), the clean air flow (*Flow(LPM)*), the dust monitor concentration (*DT_PM10(mg/m3)*), the Optical Gate Sensor pulse counts (*OGS_Count_1*, *OGS_Count_2*, *OGS_Count_3*, and *OGS_Count_4*), and the Optical Gate Sensor pulse areas (*OGS_PeakArea_1(V)*, *OGS_PeakArea_2(V)*, *OGS_PeakArea_3(V)*, and *OGS_PeakArea_4(V)*). Pulse counts and pulse areas from the Optical Gate Sensors will be discussed in a separate subsequent section.

Also included in the Data file are quantities that are derived from the fundamental quantities.

NOTE: Derived quantities are calculated from one or more of the fundamental measured quantities. Therefore, if there are errors associated with the fundamental quantities, those errors will be propagated into the derived quantities. Always ensure that the underlying fundamental quantities meet data quality criteria before using derived quantities for calculations, reports, etc.

The six derived quantities are the normalized RPM (*RPM_Norm*), Instantaneous mass emission rate (*InstantFlux(ug/s)*), the Step-totaled dust mass (*StepMass(ug)*), the Test-totaled dust mass (*TotalMass(ug)*), the time elapsed into the Test (*TestDur(sec)*), and the time elapsed into the Step (*StepDur(sec)*). These quantities are helpful for performing various calculations and displaying the data in a rapid manner.

The final field in the Data file is *DTValidity*. This is a flag field that is equal to 0 if the DustTrak monitor is communicating properly with the SwerlView software and set to -1 or -2 when the monitor is not communicating properly or has been turned off.

***Normalized RPM (RPM_Norm)*:** The normalized RPM is simply the measured RPM divided by the Target RPM value (*RPM/TRPM*). It is helpful for examining how quickly the measured RPM converges on the target value and whether deviations from the Target RPM value are significant. When the measured and target RPMs are equal, *RPM_Norm* is equal to unity. When the measured RPM is higher than the Target value (e.g. by 7%), then *RPM_Norm* is larger than unity (e.g. 1.07).

Elapsed Test Time (*TestDur(sec)*) and Elapsed Step Time (*StepDur(sec)*): The elapsed Test time (*TestDur(sec)*) is simply the number of seconds that have elapsed since the Test began. Likewise the elapsed step time (*StepDur(sec)*) is the number of seconds that have passed since a new step portion of the test was started. For portions of the test where the target RPM is changing over time (i.e., ramp portions), the *StepDur(sec)* value is not very helpful. An example of the relationship between *TestDur(sec)* and *StepDur(sec)* is shown in Figure 3-4.

Instantaneous mass flux (*InstantFlux(ug/s)*), Step-totaled dust mass (*StepMass(ug)*), and Test-totaled dust mass (*TotalMass(ug)*): The Instantaneous mass emission rate is the amount of dust that is being exhausted out of the PI-SWERL in a given second. It is calculated by multiplying the dust concentration by the clean air flow rate with adjustments for units so that the reported value is in units of micrograms of PM_{10} per second (µg/s). The Instantaneous mass emission rate is calculated as follows:

$$InstantFlux(\mu\text{g/s}) = DTPM10(\text{mg/m3}) \times Flow(\text{LPM}) \times \frac{1\,\text{m}^3}{1000\,\text{liter}} \times \frac{1\,\text{min}}{60\,\text{sec}} \times \frac{1000\,\mu\text{g}}{1\,\text{mg}}$$

NOTE that to obtain a "per area" emission rate or a surface emission flux, the Instantaneous mass emission rate must be divided by an effective area. Based on the analysis of the shear stress distribution at the soil surface that results from the rotation of the PI-SWERL annular blade (See Chapter 1) one reasonable choice for an effective area (A_{eff}) is 0.026 m^2.

The Step-totaled dust mass and the Test-totaled dust mass are simply the cumulative amount of dust that has been exhausted out of the PI-SWERL chamber at a specific time after a new Target RPM has started or at a specific time since a test started, respectively. They are calculated as follows:

$$\mathrm{StepMass}(\mu g)_{i,ti} = \mathrm{StepMass}(\mu g)_{i,ti-1} + \mathrm{InstantFlux}(ug/s)_{i,ti} \times 1\,\mathrm{sec};$$
$$\mathrm{StepMass}(\mu g)_{i,0} = 0 \quad ,$$

where *ti* is the number of seconds since the beginning of Step *i*.

$$\mathrm{TotalMass}(\mu g)_{t} = \mathrm{TotalMass}(\mu g)_{t\text{-}1} + \mathrm{InstantFlux}(ug/s)_{t} \times 1\,\mathrm{sec};$$
$$\mathrm{TotalMass}(\mu g)_{0} = 0$$

where t is the number of seconds since the beginning of the Test.

These three quantities are shown in an example in Figure 3-5.

NOTE that to obtain an average emission rate over a Step or Test, the StepMass(ug) or TotalMass(ug) must be divided by an effective area as well as an effective averaging period (s). Based on the analysis of the shear stress distribution at the soil surface that results from the rotation of the PI-SWERL annular blade (See Chapter 1) one reasonable choice for an effective area (A_{eff}) is 0.026 m^2. A number of choices are possible for an Effective time period (T_{eff}). The choice of T_{eff} depends on the underlying assumptions about how the soil surface behaves.

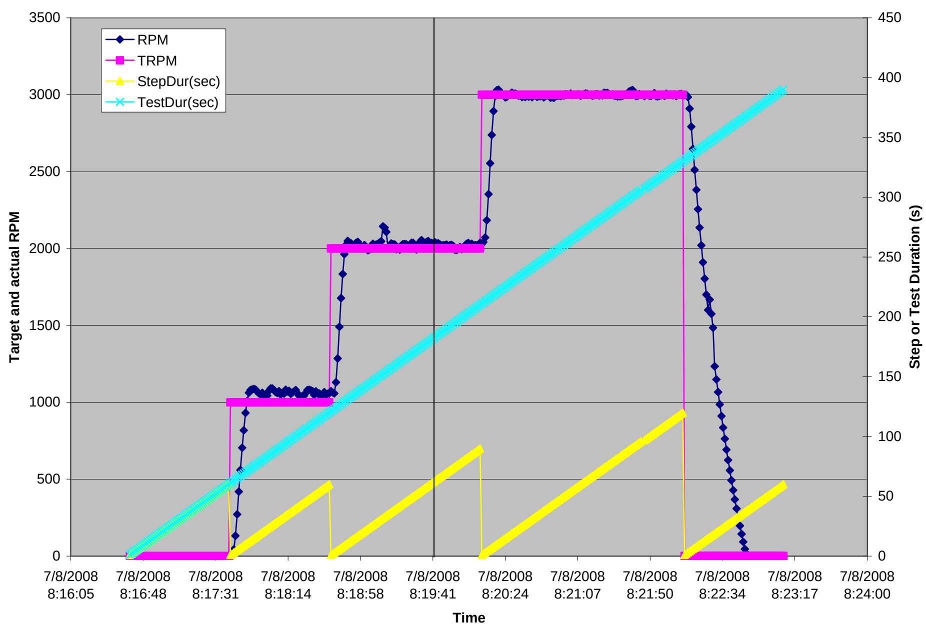


Figure 3-4. **Elapsed Test Time (*TestDur(sec)*) and Elapsed Step Time (*StepDur(sec)*). For example, the values of *TestDur(sec) and StepDur(sec)* at 8:19:41 are respectively 182 seconds and 62 seconds.**

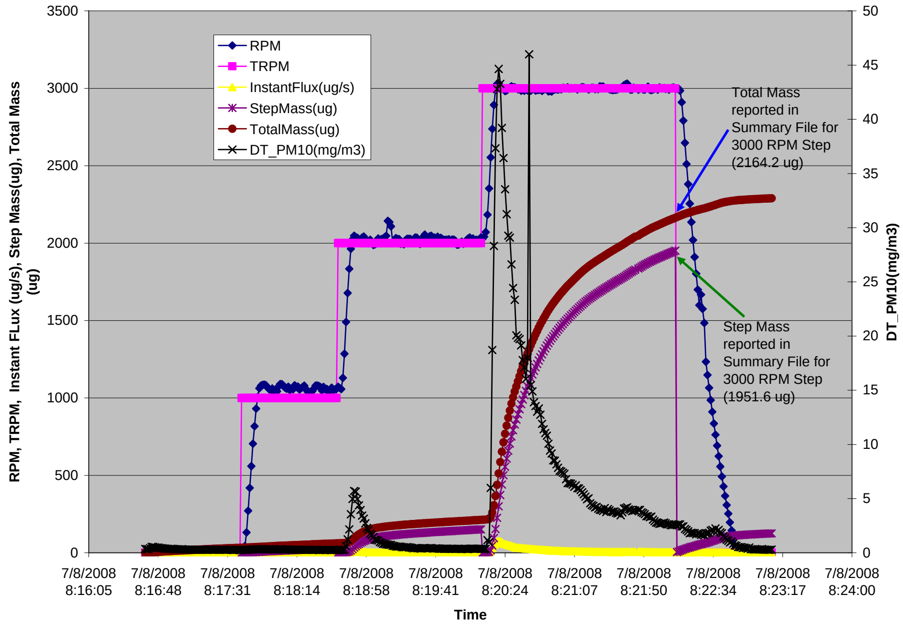


Figure 3-5. Comparison of DT_PM10(mg/m3), InstantFlux(ug/s), StepMass(ug), and TotalMass (ug). Blue arrow and green arrow show TotalMass and StepMass values reported in Summary file for 3000 RPM Step.

3.2.2.1.e. What happens to derived Quantities when the Dust Monitor is not working?

When the *DT_PM10(mg/m3)* field contains a -1 or -2 value (indicating communication between the DustTrak monitor and SwerlView was interrupted), the *InstantFlux(ug/s))* is given the value 0 by SwerlView. This is because a flux cannot be calculated for any 1-second measurements where a PM_{10} value is not available. Consequently, neither the *StepMass(ug)* or the *TotalMass(ug)* are incremented until the next valid dust monitor measurement becomes available.

3.2.2.2. Examining data from a test where the rPM varies continuously over a portion of the test (Ramp test)

One important difference between portions of a test that have invariant RPM (steps) and portions that have varying RPM (ramps) is that the *StepMass(ug)* and *StepDur(s)* fields in the Data file are NOT meaningful for the ramp portions.

3.2.2.2.a. Does the measured RPM converge reasonably well to the test specification for the Ramp?

Unlike a step portion, in the ramp portion of a test, the RPM are constantly varied to achieve a specific rate of change. The *TRPM* field in the Data file represents the value of the RPM that would meet the prescribed Ramp specification. Thus, if the *RPM* curve reasonably follows the *TRPM* curve, as it does in the example shown in Figure 3-6, then convergence is considered adequate. Some of the symptoms of poor convergence for ramp portions of a test are the same as those for step portions. Referring to Figure 3-2, these include Excessive Undulation, Chronic Overshoot, and Chronic Undershoot. These signs are frequently symptoms of a battery pack that should be replaced. Excessive Undulation could also be a result of a very shallow ramp specification (i.e. RPM does not change fast enough over time).

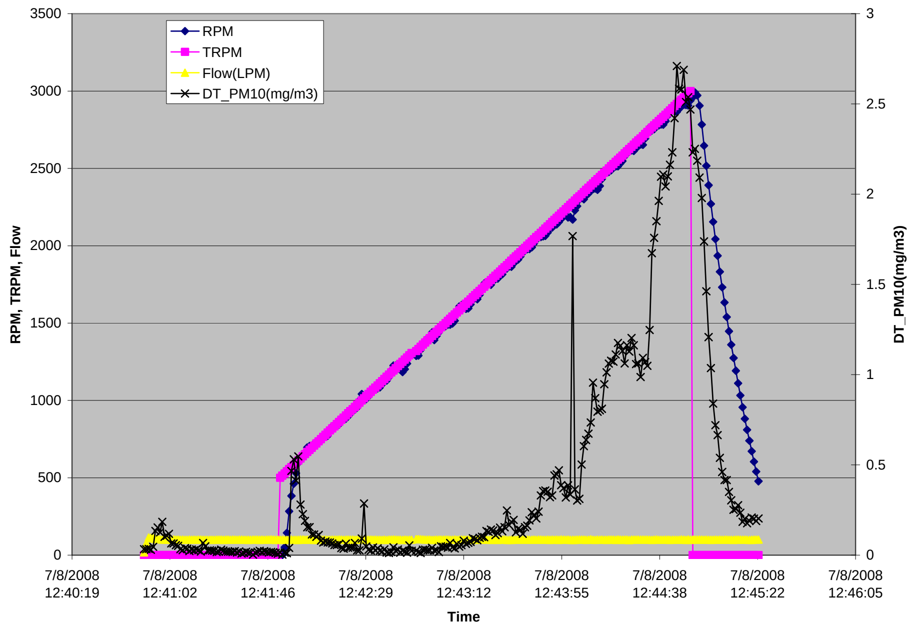


Figure 3-6. Example Gragh generated from a Test Data file consisting of one long ramp from 500 to 3000 RPM.

3.2.2.3. Optical Gate Sensor Parameters in the "Data" file

The four Optical Gate Sensors (OGS) used in the PI-SWERL are considered research instruments at the time of writing of this manual. Their behavior, meaning of the measurement, sensitivity, and response are not well known at this time. Experience with these sensors so far indicates that they are able to detect the motion of sand grains and that they seem to correlate well with data from the dust monitor. However, the data processing techniques used with these sensors are rudimentary and the measurements reported in the Data files should be used with the understanding that the OGS provide an indication of sand movement and an indication of dust concentrations when mounted near the PI-SWERL base ring or higher up within the PI-SWERL chamber, respectively. They have been provided with the PI-SWERL in anticipation that future research will inform of better ways to quantify the data that these instruments provide. Thus, we provide a brief overview of how data from these instruments are currently reported in the Data file. However, we caution that OGS data should be independently inspected by the User to ensure that they adequately meet their data quality criteria. In other words, the data are provided "as is" as a courtesy to the User.

Note: One potential application of the OGS data is discussed in Section 2.2.4.2.

The principal of operation of the Optical Gate Sensors is fairly straightforward. An LED shoots light onto a photoreceiver. When the light beam is blocked partially, the photoreceiver records a loss in light transmission. An example of the inverted raw data is shown in Figure 3-7. OGS sensors are sampled at a rate of 2 kHz so that the raw data files from these sensors can be rather large. This is one reason that the User should consider whether they really need or are likely to use the raw files from the OGS. If not, SwerlView should be instructed not to write those files (See Section 2.2.4).

The SwerlView software provides a one-second summary of the 2000 data points collected every second and writes the information to the PI-SWERL Data file. The two pieces of information that are written for each OGS are the number of peaks detected over the 1-second interval (*OGS_L1_Count*, *OGS_L2_Count*, *OGS_L3_Count*, and *OGS_L4_Count*), and the Optical Gate Sensor pulse areas (*OGS_L1_PeakArea(V)*, *OGS_L2_PeakArea(V)*, *OGS_L3_PeakArea(V)*, and *OGS_L4_PeakArea(V)*). The former are unitless, while the latter formally have units of volts. In earlier version of SWERLView, a simple filter was applied to the OGS signals to trigger the detection of a "peak". If a change in voltage greater than 50 mV was detected, then that change was assumed to be due to the existence of a peak.

In this version of SWELRView, a more sophisticated peak detection algorithm has been implemented. For every 0.5 seconds, SWERLView examines the signal from the OGS sensor and identifies the baseline and baseline noise levels through the inference of a standard deviation. Briefly, the standard deviation is inferred from examining portions of the 0.5 second time series that are clearly not associated with the passage of a detectable particle. A "peak" is detected by SWERLView when the signal deviates from the baseline by three standard deviations. The User has the option of changing this sensitivity level during the test specification (See section 2.2.3.1.)

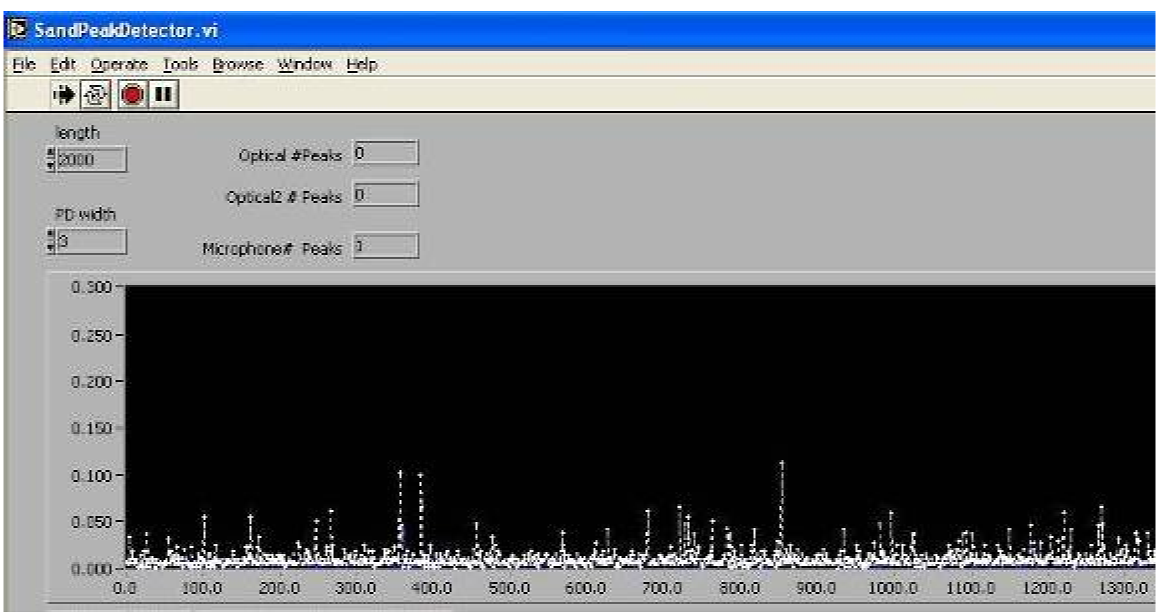


Figure 3-7. Example of time series of 2Khz data from Optical Gate Sensor. X-axis is milliseconds, y-axis is inverted voltage signal.

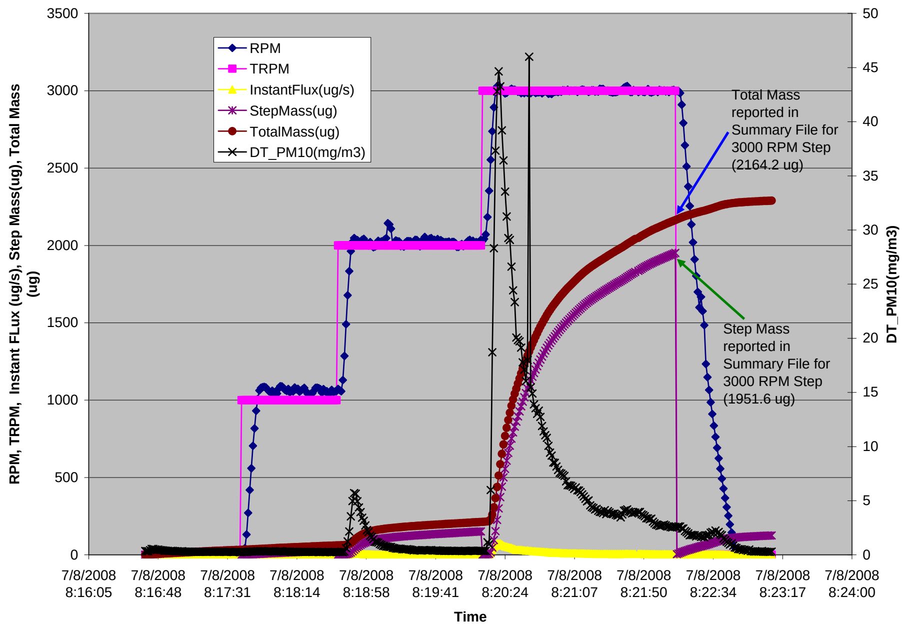


Figure 3-8. Illustration of StepMass(ug) and TotalMass(ug) calculation.

TestID	RPM	StepDur(s)	Battery (V)	Current (A)	FlowRate(LPM)	PM10(mg/m3)	StepFlux (ug/s)	TestFlux(ug/s)	StepMass(ug)	TestMass(ug)
3298374016	0	60	25.52	0.774	99.4	0.211	0.35	0.35	21.0	21.0
3298374016	1000	60	25.25	1.543	100.0	0.229	0.38	0.73	22.8	43.8
3298374016	2000	90	25.17	1.838	100.0	1.173	1.96	2.44	176.1	220.0
3298374016	2500	120	25.12	1.990	100.0	2.879	4.80	6.63	576.2	796.2
3298374532	0	60	25.48	0.771	99.4	0.225	0.37	0.37	22.3	22.3
3298374532	1000	60	25.22	1.552	100.0	0.241	0.40	0.77	24.1	46.5
3298374532	2000	90	25.13	1.849	100.0	1.033	1.72	2.23	154.5	201.0
3298374532	2500	120	25.09	1.918	100.0	3.657	6.08	7.76	730.2	931.2
3298374930	0	60	25.42	0.774	99.4	0.324	0.54	0.54	32.2	32.2
3298374930	1000	60	25.17	1.536	100.0	0.288	0.48	1.02	28.8	61.0
3298374930	2000	90	25.13	1.774	100.0	1.009	1.68	2.36	151.6	212.6
3298374930	3000	120	24.99	2.096	100.1	9.756	16.26	18.03	1951.6	2164.2
3298375869	0	60	25.33	0.765	99.4	0.317	0.53	0.53	31.7	31.7
3298375869	1000	60	25.07	1.565	100.0	0.329	0.55	1.08	32.9	64.6
3298375869	2000	90	24.99	1.804	100.0	0.919	1.53	2.25	138.1	202.7
3298375869	3000	120	24.89	2.104	100.1	5.682	9.49	11.17	1138.2	1341.0
3298376303	0	60	25.27	0.758	99.3	0.343	0.57	0.57	34.1	34.1
3298376303	1000	60	25.01	1.565	100.0	0.345	0.58	1.14	34.5	68.6
3298376303	2000	90	25.00	1.693	100.1	0.514	0.86	1.62	77.2	145.8
3298376303	3000	120	24.84	2.106	99.9	2.147	3.58	4.79	429.3	575.2

4. Instrument Maintenance and Care

The PI-SWERL is a fairly rugged field instrument. The Table Below summarizes the different types of maintenance activities and the suggested frequency. The highlighted items are required as part of the normal operation of the PI-SWERL instruments (i.e. to be conducted daily or more frequently). The entries in the Table are intended to serve as guidelines. Field and use conditions vary widely and ultimately the User is expected to judge when a specific activity should be conducted.

NOTE: The Miniature PI-SWERL, field cart, control box, or any other portion of the PI-SWERL measurement system have been designed for use in dry environments only. DUST-QUANT LLC will not be responsible for damages incurred as a result of exposure to excessive moisture and such damage is not covered by any warrantee offered by DUST-QUANT LLC.

Activity	Frequency	Additional Details
1. Re-zeroing Dust Monitor and flow adjustment.	Minimum once per day of field use - preferably at the beginning of the day.	If the dust monitor is exposed to very dusty surfaces, it may be necessary to conduct this operation every several tests. Refer to the TSI DustTrak manual for instructions for re-zeroing and adjusting the flow on the 8530 nephelometer
2. Cleaning Dust Monitor	Minimum every 2 full days of field use.	If the dust monitor is exposed to very dusty surfaces, it may be necessary to conduct this operation several times a day. Refer to the TSI DustTrak manual for instructions for cleaning the 8530 nephelometer
3. Cleaning PI-SWERL chamber and measurement surfaces	Once per day of field use-preferably at the end of the day.	Detailed instructions and suggestion for frequency of PI-SWERL chamber cleaning are provided in Section 2.2.5.
4. Charging used battery packs	Once per day – at end of field day.	Experience has shown that the battery packs used in the PI-SWERL have a longer life if they are charged immediately after being used. Instructions for battery pack care are provided in 4.3.
5. Dust monitor periodic collocation	As needed.	If you have more than one dust monitor, it is a good idea to collocate your monitors so that they are sampling the same air for a period of several hours. The TSI DustTrak manual explains how you can use the internal datalogger on the DustTrak monitors to log the measurements and download the data to a computer. You can then use third party software to determine the relative error of the dust monitors.
6. Dust Monitor Factory re-calibration	As needed. Manufacturer recommends every 6 months	If dust monitor provides erratic data and/or collocation of dust monitors does not yield acceptable relative errors, your monitor may require re-calibration at the TSI factory. The re-calibration service is expensive, so be sure that your dust monitor has been properly cleaned and maintained.
7. Other dust monitor service	As needed.	Filters, batteries, and other components of your dust monitor require maintenance from time to time. Check the TSI DustTrak manual for specific service suggestions.
8. Foam Seal re-attachment	As needed.	With use, the open-cell foam that seals the PI-SWERL to the soil surface may deteriorate or separate from the closed-cell foam attached to the PI-SWERL base ring. See Section 4.4 for instructions on Foam Seal replacement.

4.1. Keeping your PI-SWERL clean

Cleaning of the PI-SWERL chamber and measurement surfaces should be conducted as part of normal operation of the instrument and is described in detail in section 2.2.5. This section addresses cleaning that should be conducted as part of long-term instrument maintenance.

It is impossible to avoid dust deposition on the components of the PI-SWERL instrument. There are three general areas where dust can accumulate over prolonged use and should be removed from time to time. First, dust and sand are likely to accumulate in the control box. To clean the control box, remove the lid and any battery packs that may be installed. Using a handheld vacuum or a vacuum attachment, remove the sand and dust that have accumulated in the control box by vacuuming only in the indentation for the battery pack. Avoid vacuuming any other portions of the control box as this may damage the electronic components. If necessary, agitate the control box a few times to dislodge sand and dust and reapply the vacuum in the indentation for the battery pack. Vacuum the inside of the control box lid.

Second, small particles of sand and dust may accumulate on the electrical connectors. Using a handheld vacuum or suitable attachment, clean out the male and female sides of all plugs. These include the 2 male plugs on the 3-meter cable, the female plug on the PI-SWERL instrument, the two female plugs on the control box, the male plug on the inside of the control box (for battery pack), the female plugs on the battery packs, and the male plug that goes to the computer panel.

Third, sand and dust may attach to portions of the field cart. This can be cleaned with a hand brush or handheld vacuum.

4.2. Dust Monitor

The dust monitor is a TSI DustTrak Model 8530 nephelometer. It is a separate instrument that is independently sold by TSI Inc, which is solely responsible for any Warrantees, content of User's Manual, product defects, and recalls. It is used in conjunction with the PI-SWERL instrument because it has a large measurement range (nominally 0.001 -400 mg/m^3), is rugged compared to other commercially available particle monitors, and supports real-time serial communication.

In addition to the re-zeroing and cleaning that are required as part of daily PI-SWERL operation, your DustTrak monitor may require additional service (See TSI manual for suggested service schedule). DUST-QUANT LLC suggests that if you have more than one dust monitor, you perform periodic collocation of your monitors to determine of the monitors inter-compare sufficiently well for your application. Such collocation testing may help uncover problems with your dust monitor(s) that would require factory calibration and service (TSI suggested service schedule notwithstanding).

4.2.1. Periodic collocation

If you have more than one dust monitor, it is a good idea to periodically collocate your monitors and run them side by side. This helps determine if the monitors are measuring similar values for PM_{10}. To collocate your monitors, first ensure that you have performed a re-zero, cleaned the DustTrak, set the internal clock, and adjusted the flow on all monitors according to TSI's instructions. Second, place the monitors close to each other in an area where the air is likely to be well mixed such as a countertop in a large room or the roof of a building. Third, follow the TSI Manual instructions for using the onboard datalogger to log measurements every 1-second. A minimum time for a collocation test is about 30 minutes. Fourth, download the data from the onboard dataloggers (using TSI TrakPRo Software) and import the data into a spreadsheet program. Examine the time series graphs for the instruments to see if peaks and periods of relatively low particle concentration coincide. Examine the average value for the entire period of collocation. If significant differences are noticed between your dust monitors (outside the range of inter-instrument precision specified by TSI), then one of your monitors might need re-calibration.

4.2.2. Periodic calibration and service

It is a good idea to periodically re-calibrate and service your DustTrak monitors. If field use is heavy, such service may be required more frequently than suggested by TSI Inc. Contact TSI directly to schedule factory calibration and Service.

4.3. Battery Care

The PI-SWERL battery pack consists of two Power-Sonic PSH-12180FR sealed lead-acid batteries. The batteries are connected to a power dongle that can be used to both supply power to the PI-SWERL control box and for battery charging. The dongle is configured so that the two lead-acid batteries are connected in series when powering the control box and provide 24 V of DC power. When connected to the supplied battery pack chargers, the two lead-acid batteries are charged in parallel at 12 V.

NOTE: Battery Packs should only be serviced by a qualified Technician.

NOTE: Never connect your battery pack to a charger other than the one supplied by DUST-QUANT LLC.

NOTE: To prevent battery discharge, always ensure that the main power switch on the control box is in the Off position when the PI-SWERL is not being uses.

As part of your miniature PI-SWERL system, two 12 V battery chargers have been provided to allow simultaneous charging of two battery packs at the end of a field day. To charge a battery pack, connect the discharged pack to the charger using the twist-lock connection on the battery dongle. Plug the charger into a wall outlet. For a full charge, a minimum of 8 hours of charging time is required. When charging is complete, unplug the charger from the wall outlet and then disconnect the battery pack dongle.

Experience has shown that the battery packs used in the PI-SWERL have a longer life if they are charged immediately after being used in the field.

4.4. Foam Seal

There are two foam seals at the base ring of your PI-SWERL instrument. The first (orange) foam seal is a durable silicon, closed cell foam that protects the base ring from scratching and wear. The second type of foam is an open-cell foam that is thick (4 cm) and very compressible. This open-cell foam serves as a seal between the PI-SWERL chamber and the soil test surface. Over the course of use, the open-cell foam may deteriorate, fall off, or lose elasticity. Replacing this foam is relatively easy. You can request a replacement foam ring from DUST-QUANT LLC (a spare is provided with your new unit) but there is nothing special about the open-cell foam used. It can be found in department stores or fabric supply stores. To replace the open-cell foam, remove the old foam ring (NOT the orange silicon foam) and clean the silicon foam gently with a putty knife or scraper. Measure and cut out fresh open-cell foam to the correct ring size. Apply glue (Most adhesives work well enough for this purpose) and attach the new foam piece.

5. Troubleshooting

Message: “Battery needs to be replaced”
Explanation: This message will appear at the end of a SwerlView test when the battery pack voltage starts to get low. Try to replace the battery as soon as possible after this message first appears. This message usually appears after a few hours of operation (3-5 hours depending on the intensity of use) and indicates that the battery has been mostly discharged. Remember that the computer and other electronics all use the battery pack as their power source. So, even if you do not run the PI-SWERL but leave the main switch on (red LED indicator stays bright), the battery pack will discharge over a period of 8-10 hours. In general, battery capacity will depend on the battery age, operating temperature (at low temperatures battery capacity is reduced - at 0 deg C a fully charged battery has only 50% of the capacity that it has at 20 deg C). Try to charge the batteries after each field use and recharge them every 4-6 months if in storage to maximize battery pack life.

Error: “Loss of DustTrak Data”
Solution: When the DustTrak communicates properly with the SwerlView software the DustTrak indicator in the Main Panel is green and the PM_{10} numeric indicator displays the DustTrak concentration on the screen. When there is a loss of communication the DustTrak indicator flashes red. In this case the PM_{10} numeric indicator will show -999.999 to indicate that no valid data are being collected from the DustTrak. The problem might be due to one of the following: The User forgot to turn the DustTrak instrument on. To correct this, turn the instrument on and make sure that the instrument goes into data sample mode. If the DustTrak displays error number 5 or 6 after being turned on, the User can press the “Sample” button to clear the service error (consult the TSI DustTrak manual for more information of this). If the DustTrak is in sample mode and running and you still do not receive the data (indicator in Main Panel still red), make sure that the DustTrak communication and power cables are connected at the PI-SWERL.

If the DustTrak is running, and is connected to the PI-SWERL and the indicator still flashes red periodically, try stopping SwerlView, and turning everything off correctly. This includes turning off the DustTrak, shutting down the computer, and powering off the control box (in that order). Wait 20-30 seconds with everything off and restart all the equipment by turning the power on at the control box, booting the computer, and turning the DustTrak on. Once the computer has booted, launch SwerlView and try running a measurement to see if the problem has been resolved.