Miniature Diffusion Size Classifier

Instruction Manual Rev 1.1, July 15, 2010

Quick Start Guide

Read these instructions before operating the instrument!

Your miniDiSC is a simple and robust instrument. It measures tiny currents (Femtoampères), and measuring such extremely low currents is challenging.

1. Never operate the instrument at condensing conditions; e.g. do not measure exhaust gas directly.
2. To avoid premature aging of the instrument, do not expose it to extremely high aerosol concentrations such as undiluted cigarette smoke (it can't measure such high concentrations anyway)
3. Have your instrument recalibrated once per year. If you use it 24/7, consider recalibrating it more often
4. There are no user-serviceable parts inside the miniDiSC, and some very sensitive parts. Do not open your miniDiSC, as you may damage it. Warranty is voided if the case is opened.
5. MiniDiSC measures nanoparticles. If you use it to measure microparticles (>~1µm) you will get wrong readings. Use the impactor when measuring in environments where you suspect a large number of microparticles to be present. For microparticles, good optical particle counters are available from other companies.
6. At low signal levels, compensate the zero offsets before your measurement, and check the zero levels with a particle filter - or measure over long periods of time to use the offset correction feature in the data analysis tools (offsets are measured once every hour)

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Overview

The Miniature Diffusion Size Classifier (MiniDiSC) is a compact, battery-powered instrument which measures the number and average size of nanoparticles (<~0.5 micron) in air. It stores its measurements to a memory card (SD-card), which you can remove and read in your PC.

MiniDiSC charges the aerosol in a unipolar diffusion charger. The charged aerosol passes through a diffusion stage consisting of stainless steel grids. In the diffusion stage, particles are deposited by diffusion. The resulting electrical current is measured with a sensitive electrometer. The remaining particles are collected in a second stage, the filter stage, and again, the current is measured. Small particles have a larger diffusion coefficient, and therefore are more likely to be collected in the diffusion stage, while larger particles are more likely to end up in the filter stage. The diffusion stage is designed to have 50% penetration at a particle diameter of 40nm. By comparing the currents in the filter and the diffusion stage, the average particle size can be determined. The total current and the particle size are then combined to compute the number of particles.

Compared to standard instruments like CPC or SMPS, miniDiSC is different in the following respects:

- miniDiSC is less accurate than a CPC or an SMPS (errors of up to 30% can occur)

- 👎 miniDiSC is less sensitive than a CPC and typically has a lower detection limit of 500 particles/ccm. The detection limit can be improved by averaging data over longer periods of time.

- 👍 miniDiSC offers the same high time resolution as a CPC (1 second), much faster than the SMPS (60 seconds)
- 👍 miniDiSC gives average size information and not only particle number count like the CPC
- 👍 miniDiSC is very portable and needs neither operating liquids nor radioactive sources.

The miniDiSC is therefore quite different than CPC/SMPS systems, which are well suited for accurate laboratory measurements, while miniDiSC is well suited for field measurements with lower accuracy requirements.

Unpacking the Instrument

Use the information in the following packing list to determine if your delivery is complete:

- Miniature Diffusion Size Classifier
- Protective Neoprene sleeve for the miniDiSC
- Power supply
- Manual
- CD with software
- SD-Card (in the miniDiSC)
- Particle Filter
- Impactor (on the miniDiSC) and tube fitting as alternative inlet

If anything is missing or appears to be damaged, contact FHNW at martin.fierz@fhnw.ch.

Controls, Indicators and Connections

All controls are located on the front panel of MiniDiSC; connections are on the left side, and the aerosol inlet at the bottom of the instrument. Please refer to the image above for a description of the controls. The items are

1: Power Button (Press to power on; press long (2s) - until beep sounds - to power off)
2: Menu Button
3: Recording Button (Press to record, press long (2s) - until beep sounds - to stop recording)
4: Left and right arrow buttons to select options in menus
5: Display
6: Status Area
7: Fuel Gauge

On the left side of the instrument you will find the power connection, USB connection and the slot for the SD card. Note that the SD card is inserted "upside down" (with the contacts visible).

Aerosol Inlet

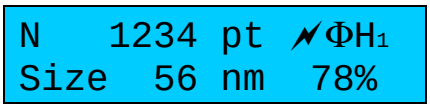
The aerosol inlet is located at the bottom of the instrument. The standard aerosol inlet has a 6mm barb for tubing connection and contains a coarse wire mesh to keep coarse dirt and small insects out of the instrument.
Alternatively, use the ~0.8 µm-cutoff impactor if you suspect high levels of coarse particles to be present.

The impactor has to be cleaned regularly after use; open it by removing the cap, and wipe the smooth surface below the thread to screw the cap into the impactor housing. From time to time, the 6 impactor nozzles in the housing should be cleaned; the easiest way to do this is to use an ultrasonic bath.

LCD screen

The LCD screen has 3 main menu screens and 8 auxiliary screens. Pressing the Menu button on the front panel for 3 seconds moves into advanced mode, from which pressing the menu button cycles through the auxiliary screens. Press the menu button again for 3 seconds to switch back to the standard main screen. The screens are:

Main Screen

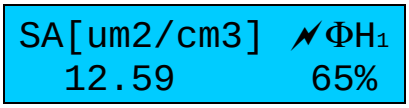


In the main screen, the current particle number concentration and the average particle size are displayed, as calculated from the stage signals. Note that the relative accuracy of these numbers depends on the concentration level. In the right upper corner 4 status symbols are visible or invisible depending on the status of the miniDiSC: a lightning bolt for high voltage, a Φ for flow, a H for heating and a blinking circle when recording. When miniDiSC is not recording data, it displays the number 1 in the recording status position. This number corresponds to the averaging time in seconds used by the miniDiSC when recording. On the lower right, the remaining battery charge is displayed. This is only an approximate value. Pressing the right arrow button (►) will lead you to the raw data screen, Pressing the left arrow button (◄) will lead you to the surface area screen.

Raw Data Screen

The raw data screen displays the measured currents in fA on the electrometer stages; the upper value is the diffusion stage, the lower value the filter stage. These values are offset-corrected, i.e. not the real measured values, but rather (measured value – offset). The offset is 0 initially (after startup of the instrument), but can (**and should**) be compensated for at any time (see below).
Use this screen to diagnose electrometer-related problems, such as excessive noise or offset problems.
Press the left arrow button to go back to the main screen

Surface Area Screen



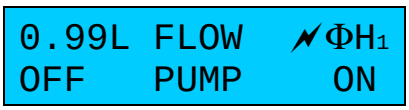
The surface area screen displays a quantity that can be described as "alveolar lung-deposited surface area" (A-LDSA). The reasoning behind this measurement is the following: According to the ICRP model, the deposition probability of particles in the lung (both for the alveolar and the tracheobronchial region) is roughly proportional to d^{-1} for particles smaller than about 250 nm, where d is the particle diameter. The surface area of compact (non-fractal) particles scales with d^2. Regarding air quality, we should be interested in what really ends up in the human body (and not so much what effectively is in the air). To calculate the surface area of the particles that are deposited in the lung, we have to multiply the available surface area in the air with the deposition fraction, i.e. $d^2 * d^{-1} = d^1$. By coincidence, the diffusion charging process employed in the miniDiSC imparts a charge on the particles that is roughly proportional to their diameter, i.e. the total current measured on the two miniDiSC stages is approximately proportional to d^1, and thus also approximately proportional to the LDSA. During the calibration process, a calibration constant is determined by which the A-LDSA is computed from the total current signal. The tracheobronchial lung-deposited surface area (TB-LDSA) is approximately 5 times lower than the A-LDSA.
Note that for larger particles, the relation between LDSA and total current is no longer linear - the deposition probability increases again for larger particles up to a maximum at a bit more than a micron. The LDSA computed from the total current is thus a lower bound for the effective LDSA; if few larger particles are present, it is a very good measure of LDSA.
Press the right arrow button to go back to the main screen

The next screens are only available in the advanced display mode

Charger Screen

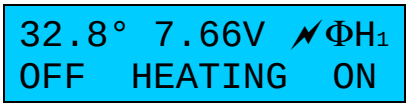
The charger screen informs you of the status of the corona charger that is used to impart a positive charge on the aerosol. It displays the high voltage applied to the corona wire, and the charging current measured. By pressing the left or right arrow buttons located below the off and on display, you can turn the charger off or on. When the charger is turned off, the miniDiSC operates as an aerosol electrometer if you add up the two stage currents.

Flow Screen



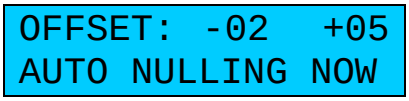
The flow screen informs you of the status of pump. The flow is displayed on the upper left hand side. Note that 1.0L corresponds to the factory-calibrated flow of 1 liter per minute, but that other flows displayed are not accurate. By pressing the left or right arrow buttons located below the off and on display, you can turn the pump off or on.

Heating Screen



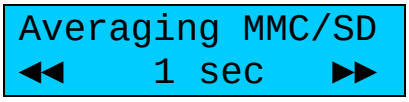
The heating screen informs you of the status of the heating that is used to control the temperature of the sensor parts. It displays the measured temperature in °C, and the operating voltage of the device. By pressing the left or right arrow buttons located below the off and on display, you can turn the heating off or on.

Offset compensation Screen



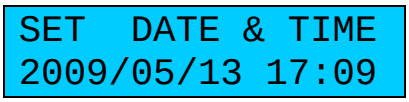
The electrometers have zero offsets, i.e. even if no current is flowing, their reading is not zero. These offsets must be measured and compensated for. Before measuring with your miniDiSC, you should always compensate the offsets. The offsets can be compensated with two different methods: AUTO (press the left arrow button) turns off the pump, waits for 10 seconds, and then measures the offsets. During this time, miniDiSC indicates that it is measuring the offsets by displaying "Please wait 15s" and counts down until it reaches zero. When it is done measuring the offsets it turns the pump back on. The NOW method simply uses the currently measured values (displayed in the top line) as zero offsets. Use this method if you are certain that you are in fact measuring the zero offset, e.g. because you have an absolute filter at the inlet of the instrument, or because you have turned the pump off. We recommend the AUTO method. We also recommend that you place the instrument on a stable non-vibrating table during the offset compensation.

MMC averaging Screen

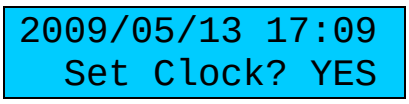


This screen is currently not used.

Date/Time Screen



You can set the internal clock of the instrument in this screen. When the screen appears, the year will be blinking for a few seconds. During this time you can change the year by pressing the left or right arrows. If you do nothing for a couple of seconds, the year stops blinking and the month indicator starts blinking, and you can change the month with the arrow keys. This procedure continues until every value is set. Then the following screen appears:



By pressing the right arrow key located below the YES you will save the adjusted date and time. Press the menu button to discard the changes

Miscellaneous Screen

In this menu you can turn the backlight of the display on or off. Additionally, it displays an approximate value of the remaining battery charge.

Statistics Screen

In this screen, the accumulated charge on the diffusion stage is displayed. This gives an indication when the instrument should be serviced.

Using the Memory Card

MiniDiSC can save its measurements to an SD card. To start recording, press the red record button. The miniDiSC will indicate that it is recording by blinking a recording symbol in the upper right corner of its display. The data file looks as follows:

```
nw PERSONAL AEROSOL MONITOR Data written with SW-Ver 3.20
Filename: 0713Q34T.TXT
Averaging Period: 1 sec
Date and Time: 2010.07.13 16:34:58
CalData: G3_025      4.03   30.31   -6.07    1.18    1.1519199.24    0.53
 NaCl 2010_06_29
    4.03          30.31          -6.07           1.18           1.15       19199.24
0.53
Offsets:     0.12         4.22
Sampled:     1886 pC  C:      27     W:      30
```

Time	Diffusion	Filter	Temp	Idiff	Ucor	Flow	Batt	Status
0	9.52	26.67	30.2	9.90	3.52	1.00	8.21	8B
1	9.66	26.33	30.2	9.91	3.52	1.00	8.22	8B
2	9.36	26.47	30.2	9.89	3.52	1.00	8.21	8B
3	9.45	26.62	30.2	9.83	3.52	1.00	8.22	8B
4	9.34	26.77	30.2	9.84	3.52	1.00	8.21	8B
5	8.92	26.27	30.2	9.89	3.52	1.00	8.21	8B
6	9.74	26.19	30.2	9.90	3.52	1.00	8.22	8B
7	9.23	26.71	30.2	9.90	3.52	1.00	8.21	8B
8	9.33	26.47	30.2	9.88	3.52	1.00	8.21	8B
9	9.48	26.29	30.2	9.90	3.52	1.00	8.21	8B
10	9.45	26.08	30.2	9.90	3.52	1.00	8.21	8B
11	9.66	26.80	30.2	9.90	3.52	1.00	8.21	8B
12	9.70	26.86	30.2	9.94	3.52	1.00	8.21	8B
13	9.34	26.40	30.2	9.89	3.52	1.00	8.21	8B
14	9.50	26.20	30.2	9.89	3.52	1.00	8.21	8B
15	9.74	26.99	30.2	9.90	3.52	1.00	8.21	8B
16	9.72	26.66	30.2	9.90	3.52	1.00	8.21	8B

The file header contains information on the firmware version, the filename, the averaging period, the start date and time, calibration data and zero offsets. After the header, the data follow in a tab-delimited format. The columns are time (in seconds), Diffusion stage signal (in fA), filter stage signal (in fA), temperature (in °C), charging current (in nA), high voltage (in kV), flow (in lpm) and battery voltage (in V) respectively.
Tab-delimited text files can easily be imported into all common data processing programs. We strongly recommend that you use the miniDiSC offline software program or the Excel Add-in (see separate manuals for these tools).

Checking the Instrument

After unpacking the instrument, you should check whether the instrument is working properly. To do this, turn on the instrument and use the LCD to verify the proper operation. The LCD screen displays particle number and size, and you can now verify the proper operation of the instrument.

When you turn on the instrument, it will warm up for 5 minutes. After this interval, it will automatically measure the zero offsets and start its pump.
When it is cold, the 5-minute warmup interval will not be enough, and you should let the instrument warm up longer to reach a stable temperature, and then compensate the zero offsets manually.
Check that the instrument is producing sensible results. Typical indoor aerosol concentrations are a few 1000 pt/ccm and typical indoor aerosol has an average diameter of 50-100nm. Press the mode button once to switch to the raw data screen. You will see the current on each of the stages (a few fA). These currents should be reasonably stable.
Go to the pump screen, and turn the pump off and on – you will hear whether this is working. When the pump is turned off, go to the raw data screen, and verify that all stage signals are very close to 0fA, i.e. that their absolute values are all smaller than 2fA. To verify proper functioning of the pump and that the instrument is sealing, plug the inlet with a finger for a second or two - the pump should increase its speed audibly. If this is the case, the instrument should be working properly.

Measuring with MiniDiSC

Basic operation

MiniDiSC is a simple instrument which gives average particle size and particle number information with a time resolution of about 1 second. It is not a precision instrument: Compared to CPC and SMPS measurements, deviations of up to 30% can occur; in particular, if you have an aerosol with a very wide size distribution, the errors will be even larger. In such cases, MiniDiSC will overestimate the particle diameter and underestimate the particle number. For typical urban aerosol, the errors are usually <~30%.

When making a measurement with MiniDiSC, you should proceed as follows:

- Turn on MiniDiSC about 15 minutes before the measurement. The stages are heated, and the temperature change causes the electrometer offsets to drift slightly (by a few fA). Therefore, you should only start measuring after the instrument has warmed up, and calibrate the zero offsets before you start the measurement. The instrument has a 5-minute warm-up time

and measures the zero offsets after this interval, and compensates for them. Nevertheless, it is good practice to leave the instrument running a bit longer, and to check the zero offsets before a measurement.

- When you start the measurement, and also after you finish, connect a particle filter to the aerosol inlet to verify that the zero offsets are corrected for properly, i.e. that the stage signals are indeed very close to 0 (at most about 2fA off).

Make sure that you avoid condensing conditions inside the instrument at all times. The operation of the electrometers depends on excellent insulation, which is no longer guaranteed if the insulators are humid.

Automatic Offset Measurement

All electrometer-based instruments are subject to electrometer noise and electrometer offset. The noise of an electrometer can be measured by supplying it with a stable (zero) signal, e.g. by turning off the pump in the miniDiSC, or by connecting a HEPA filter to the instrument inlet. Data can then be recorded at one-second intervals; the standard deviation of this time series is the electrometer noise. For the miniDiSC, this noise is typically about 0.2 fA. Note that the noise depends on the averaging time and gets smaller with longer averaging intervals.

The electrometer offset drifts with temperature, and can also drift if the insulator is dirty or humid. To verify proper instrument operation and to compensate for small drifts, miniDiSC automatically turns off its pump once an hour for one minute and continues recording data. MiniDiSC does not use this data immediately (having a file with multiple different zero offsets seems like a bad idea to us); instead, the offline miniDiSC software / Excel add-in detects the intervals where the pump was turned off and uses the values recorded there to correct zero offset drifts.

Troubleshooting

Problem	Solution
High voltage in charger not present, although it is turned on.	The charger is regulated to produce a constant diffusion current at the electrode opposite of the corona wire. If the charger is exposed to too much coarse dirt, small conductive dirt particles can produce a short circuit between the electrode and the charger housing. In this case, miniDiSC will measure a large diffusion current through the short circuit, and regulate the Corona voltage to 0V. The firmware detects this error and report "dirt on counterelectrode" The charger is not user-serviceable. Please contact FHNW for service.
Noise levels too high	If you run the instrument with a particle filter at the inlet, and measure the RMS noise of the electrometers, this noise should be <~0.5fA (To compute this number, save 1-second data to the memory card for 10 minutes and then calculate the standard deviation of the sample). If this noise is larger, then something is not working properly. Most often, electrometer noise is the result of contaminated insulators. You can try to run miniDiSC with filtered and dried air for several hours to remove a water film on the insulators, which can form at high RH conditions.
Zero offsets too far away from 0	Large / unstable zero offsets are also a sign for contaminated insulators. Again, run miniDiSC for several hours with filtered and dried air and see whether this solves the problem. If the problem persists, contact FHNW for support.
Readings differ clearly from other instruments (such as CPC / SMPS)	If the number and concentration readings of miniDiSC are inconsistent with standard instruments such as CPC or SMPS, return the instrument to FHNW for a recalibration. In this context, “inconsistent” means that the readings of miniDiSC are more than 50% different than those of a CPC or an SMPS.

Known Issues

This section lists all known issues with miniDiSC.

- Due to the measurement principle of miniDiSC, the instrument can produce wrong results if the incoming aerosol is highly positively charged: if particles carry a higher positive charge than that which they would get in the miniDiSC charger, the current in the electrometer stages will be higher than expected, and miniDiSC will report a higher concentration than what is really there.
- Very small particles (<20nm) are affected by the electric field in the ion trap. The miniDiSC calibration curve neglects this loss of particles. For particles <20nm, miniDiSC will in general underestimate the particle number (this is similar to the lower size limit cutoff seen in CPCs). Particles smaller than about 6 nm cannot be detected by the instrument.
- The instrument is calibrated for a size distribution with a given shape (lognormal with a geometric standard deviation of 1.9). For narrower size distributions, miniDiSC will overestimate the particle diameter and underestimate particle number. For broader size distributions, miniDiSC will underestimate particle diameter and overestimate particle number.

Appendix A: Specifications

Particle size:	10…300nm
Particle concentration:	Detectable particle concentrations depend on particle size and averaging time. Typical values are given below. 20nm: 2E3….1E6 pt/ccm 100nm: 5E2…5E5 pt/ccm
Accuracy:	±30% in size and number typical; ±5E2/ccm absolute in number.
Flow rate:	1.0 L/min +- 0.1 L/min
Operating conditions:	Pressure 600…1100 mbar Temperature 10…30°C
Time resolution:	1 second
Dimensions:	12 x 8 x 4.5 cm
Weight:	0.7 kg
Power requirements:	The AC/DC power adapter is compatible with the any 100-120 volt or 200-240 volt 50/60 Hz AC wall outlet.
Battery lifetime:	8 hours typical; varies with ambient temperature.
Pump:	The pump (G6/01-K-LCL) will only reach the set point flow for low underpressures. You should not exceed 20mbar underpressure.