

Model DR-4000

Instruction Manual

DataRAM 4

Part Number 100334-00

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1.0 GENERAL DESCRIPTION

The DataRAM 4 (for Data-logging Real-time Aerosol Monitor 4), model DR-4000 is a technologically advanced instrument (**embodies U.S. Patent No. 6,055,052**) designed to measure the concentration of airborne particulate matter (liquid or solid), as well as mean particle size, air temperature and humidity, providing direct and continuous readout as well as electronic recording of the information.

The DataRAM 4 is the result of many years of field experience acquired with thousands of units of its well known predecessors, the model RAM-1 and its successor, the DataRAM, and embodies many technological advances made possible by the latest electronic hardware and software.

The DataRAM 4 is a high sensitivity, two-wavelength nephelometric (i.e. photometric) monitor whose light scattering sensing configuration has been optimized for the measurement of the fine particle fraction of airborne dust, smoke, fumes and mists in ambient, atmospheric, industrial, research, and indoor environments.

The DataRAM 4 is a compact, rugged and totally self-contained instrument designed for portable, as well as unattended fixed-point operation. It is powered by its internal rechargeable battery, or by an AC power supply/charger (included as standard accessory).

In addition, the instrument automatically checks its own optical background during the zeroing sequence and indicates any significant deviations requiring maintenance.

The DataRAM 4 covers a wide measurement range: from 0.0001 mg/m³ (0.1 µg/m³) to 400 mg/m³, a 4 million-fold span, corresponding to very clean air up to extremely high particle levels.

In addition to the auto-ranging real-time concentration readout, the DataRAM 4 offers the user a wide range of information by scrolling its four-line LCD screen. This information includes: median particle diameter, scattering coefficient, Ångström coefficient, visual range, run start time and date, time averaged concentration, elapsed run time, maximum with time of occurrence, air temperature and relative humidity, etc. Operating parameters and diagnostic information screens can also be displayed.

Furthermore, the DataRAM 4 features complete, large capacity internal data logging capabilities with data retrieval on screen or through an externally connected computer. The stored information (up to 50,000 data points) includes individual point averages, particle size, temperature and humidity with time information as well as overall average and maximum concentration, and tag numbers.

Selectable alarm levels with built-in audible signal as well as switched and signal outputs, RS-232 and RS-485 communications ports, and a programmable analog (voltage and current) concentration output are all part of this versatile instrument.

A custom software package is provided with the DataRAM 4 for communications to and from a PC.

2.0 SPECIFICATIONS

Concentration measurement range (auto-ranging)¹:

0.0001 to 400 mg/m³

Precision/repeatability (2-sigma)^{2,3}:

± 1% of reading or ± 0.001 mg/m³, whichever is greater (1-second averaging)

± 0.3% of reading or ± 0.0003 mg/m³, whichever is greater (10-second averaging)

Accuracy¹:

± 2% of reading ± precision

Resolution:

0.1% of reading or 0.0001 mg/m³, whichever is greater

Scattering coefficient range:

10⁻⁷ to 0.4 m⁻¹ (resolution: 3 significant digits, max.)

Visual range:

0.01 to 337 km (@ λ = 550 nm) (resolution: 3 significant digits, max.)

Ångström coefficient measurement range:

0.0 to 4.0

Particle sizing range (log-normal, σ_g = 2.0, m = 1.50):

0.04 to 4.0 μm

Temperature measurement range:

-15 to 60 C° (accuracy: 0.5 C°)

Relative humidity measurement range:

0 to 100% (accuracy: 2%, non-condensing, @ 25 C°)

Sampling flow rate range⁴:

1.0 to 3.0 liters/minute (accuracy²: 0.05 liters/minute; adjustability: 0.1 liters/minute)

Measurement/display integration time range⁴:

1 to 60 seconds (selectable in 1-second steps)

Measurement/display update frequency:

1/second

HEPA filter cartridge replacement frequency (typical):

< 1 per 5 years (@ < 1 mg/m³)

Alarm level adjustment range⁴:

Selectable over entire measurement range for any of the selected measurement units (concentration, scattering coefficient or visual range)

Data logging averaging periods⁴:

1 second to 24 hours (selectable in 1-second increments)

Data logging memory capacity:

50,000 data points in up to 99 tags (data groups)

Programmable zeroing periods⁴:

1 to 168 hours (selectable in 1-hour increments; if enabled, logging period must be > 10 minutes)

Elapsed time readout range:

1 second to 100,000 hours (over 11 years), in seconds, minutes and hours

Digital communications:

RS232/RS485: full duplex, 9600 baud, software controlled, device filtered

Computer requirements:

IBM-compatible PC, 486 or higher (Pentium I or higher, preferred); Windows™95 or higher; 8 MB memory or more

Analog outputs:

0 to 5 V and 4 to 20 mA, with selectable full scale ranges between 0.1 and 400 mg/m³

Power:

- Internal battery: rechargeable sealed lead-acid, 7.2 Ah, 6 V, 20-hour run time between charges (typical)
- AC line: universal voltage charger/power supply (included), 100 – 250 V, 50 – 60 HZ (CE marked)

Alarm outputs:

- Alarm switch: 0 to +30 VDC (off, open), 2.5 A (on, closed)
- Alarm signal: 0 V (off), 5 V (on) (1 mA maximum load current)
- Audio alarm (back panel): > 60 dB @ 1 m

Operating environment:

-10 to 50 C° (14° to 122° F), 10 to 95% RH, noncondensing

Storage environment:

-20 to 70 C° (-4° to 158° F)

Dimensions (maximum external, including handle and inlet fitting):

166 mm (6.54 in) H x 226 mm (8.90 in) W x 327 mm (12.87 in) D

Weight:

5.5 kg (12 lbs)

¹ Referred to gravimetric reference calibration (NIST traceable) with SAE

Fine test dust (mmd = 2 to 3 μm , $\sigma_g = 2.5$, as aerosolized)

² At 25 °C

³ For single wavelength concentration sensing

⁴ User selectable

3.0 USER GUIDELINES

3.1 Handling Instructions

The DataRAM 4 is a sophisticated optical/electronic instrument and should be handled accordingly. Although the DataRAM 4 is very rugged, it should not be subjected to excessive shock, vibration, temperature or humidity. As a practical guideline, the DataRAM 4 should be handled with the same care as a portable CD player. **The DataRAM 4 must be protected from all forms of precipitation.**

If the DataRAM 4 has been exposed to low temperatures (e.g. in the trunk of a car during winter) for more than a few minutes, care should be taken to allow the instrument to return to near room temperature before operating it indoors. This is advisable because water vapor may condense on the interior surfaces of the DataRAM 4 causing temporary malfunction or erroneous readings. Once the instrument warms up to near room temperature, such condensation will have evaporated. If the DataRAM 4 becomes wet (e.g. due to exposure to water sprays, rain, etc.), allow the unit to dry thoroughly before operating it.

Whenever the DataRAM 4 is shipped, care should be taken in placing it in its carrying case and repackaging it with the original cardboard box with the factory provided padding.

3.2 Safety Instructions

- ***Read and understand all instructions in this manual.***
- ***Do not attempt to disassemble the instrument. If maintenance is required, return unit to the factory for qualified service.***
- ***The DataRAM 4 should be operated only from the type of power sources described in this manual.***
- ***Shut off DataRAM 4 and any external devices (e.g. PC) before connecting or disconnecting them.***
- ***Shut off DataRAM 4 before plugging in or disconnecting the AC power supply.***
- ***Never operate the DataRAM 4 without one of its internal filters in place.***
- ***If the internal battery of the DataRAM 4 has been allowed to discharge completely, recharge the battery for at least 30 minutes before operating the DataRAM 4.***
- ***During battery charging the DataRAM 4 should not rest on its front (i.e., bottom up).***
- ***To change position (angle) of the carrying/support handle, the large buttons on both sides of the handle must be pushed in at the same time to release handle lock. Do not attempt to rotate handle without releasing its lock.***

3.3 Orientation During Operation

The DataRAM 4 can be operated and/or charged in any of three orientations or attitudes:

- Horizontally (front panel vertical), resting on its 4 bottom rubber pads.
- Tilted with front panel up, resting on 2 rear rubber pads and locked down handle.
- Vertical (front panel horizontal, upwards) resting on 4 rear rubber pads.

3.4 Air Sampling Guidelines

Caution: The DataRAM 4 is not designed to sample highly corrosive aerosols or solvent fumes

3.4.1 Area Monitoring

For typical area monitoring applications, the DataRAM 4 should be placed and operated centrally within the area to be monitored, away from localized air currents due to fans, blowers, ventilation intakes/exhausts, etc. This is to ensure representative sampling within the area to be assessed.

3.4.2 Ambient Air Monitoring

For ambient (extramural) sampling/monitoring the following procedures and precautions should be applied:

- The sampling inlet should be away and above any obstructions whose wake may affect sampling representativeness. Typically, the inlet should be about 1 m (or more) above ground or any major surface (e.g., roof).
- Under typical horizontally directed and variable wind conditions, the use of the Omnidirectional Inlet, model DR-OSI, is required, otherwise particles with equivalent (inertial) diameters larger than about 1 μm may not be sampled representatively.
- At ambient relative humidity above 65% to 70% airborne particles are likely to grow by accretion of water. If only the solid portion of the particulates is to be measured, the use of the Temperature Conditioning Heater, model DR-TCH should be considered, especially when monitoring under fog or water mist conditions. On the other hand, the user should be aware that such heating of the sample stream might result in the evaporation of some volatile and semi-volatile particles of interest.
- The DataRAM 4 is not weatherproof. To operate the DataRAM 4 outdoors, provisions must be made to protect it from environmental extremes such temperatures beyond its specified range, and from any form of precipitation. A small shelter or roof may be required, with a modicum of heating during the winter.

3.4.3 Extractive Sampling

Two general types of extractive sampling occur: a) from a chamber/vessel/room, and b) from a duct or stack. In the first case the air to be monitored is generally nearly stagnant or gently stirred (by means of a fan or blower). The second case almost invariably involves a directed flowing stream at typical speeds of 3 to 30 m/s (600 to 6,000 ft/min).

To sample either from an enclosure (assuming the DataRAM 4 is to be located externally to that enclosure), or a duct/stack, a length of tubing can be used to which the following guidelines should be applied:

- Minimize tubing length, especially horizontally running lengths.
- Minimize the number bends and angle of change in direction.
- Minimize tubing inner diameter thus maximizing transport velocity (a practical lower limit of about 2 mm, or 0.08 in. ID is indicated for reasons of excessive pressure drop).
- If possible, changes in inner diameter (at unions, couplings, etc.) should be incremental in the direction of flow, i.e., the inner diameter should only increase in the direction of flow.
- Use non-electrostatic tubing. Best is electrically grounded metal or conductive plastic (black) tubing, Tygon™ is acceptable, and Teflon™ is not to be used.

For tubing lengths of up to 2 m (6 ft.), 6 mm ID (1/4 in. ID) plastic tubing with wall thickness of 1/16 in. is a practical size which can be stretched over the DataRAM 4 inlet stem.

For enclosure monitoring, the sampling inlet should be at some distance from the inner wall of the enclosure in order to ensure sampling representativeness. Typically, a minimum of 20 or 30 cm (1 ft.) is advisable. If a particle precollector is required (e.g., a cyclone) it should be used as the inlet to the tubing, within the enclosure to be monitored. If there is any pressure difference between the interior of the enclosure and the location of the DataRAM 4, its exhaust port (on rear panel) must be connected by tubing to the enclosure, i.e., the air stream extracted from the enclosure must be returned to it after passing through the DataRAM 4.

For duct/stack monitoring, a probe should be used whose inlet faces the direction of the airflow. If particles in the stream are larger than about 1 μm , sampling should be under isokinetic conditions, i.e., the velocity of the air entering the sampling inlet should equal the air velocity in the duct/stack at that point. This can be achieved using the Isokinetic Sampling Kit model RAM-ISN which, in combination with the DataRAM 4 covers the range of about 3 to 30 m/s (600 to 6000 ft./min). As in the case of enclosure monitoring, it is advisable to return the DataRAM 4 exhaust air stream to the duct/stack in order to ensure proper internal flow conditions within the instrument.

3.5 Environmental Constraints and Certifications

The DataRAM is designed to be reasonably dust and splash resistant, however, it is not weatherproof. To operate the unit outdoors provisions should be made to protect it from environmental extremes outside its specified range, and ***from any exposure to precipitation.***

The DataRAM 4 is certified for compliance with the electromagnetic radiation limits for a Class A digital device, pursuant to part 15 of the FCC Rules. The unit also complies and is marked with the CE (European Community) approval for both immunity to electromagnetic radiation and absence of excessive emission interference.

4.0 ACCESSORIES

4.1 Standard Accessories

The DataRAM 4 is provided to the user with the following standard accessories:

- Soft-shell carrying case (model RAM-2-184-1))
- Digital communications cable (model DR-DOC)
- Communications software disk (model DR4-COM)
- Universal AC power supply/charger (model RAM-2-183-1)
- Standard filter cartridge (installed)(model MSA-95302)
- Analytical Filter Holder (model RAM-2-182-1)
- Instruction manual

4.2 Optional Accessories

The following optional accessories are available from Thermo Fisher Scientific for use with the DataRAM 4:

- Omnidirectional Sampling Inlet (model DR-OSI)
- Temperature Conditioning Heater (model DR-TCH)
- In-line Impactor Head (10 and 2.5 μm) (model DR-PM10/2.5)
- Impaction Nozzle for 1 μm (model DR-PM1N)
- Ambient Sampling Inlet Set (consists of DR-OSI, DR-TCH and DR-PM10/2.5)
- Isokinetic Sampling Set (model RAM-ISN)
- Sampling Dilution Unit (model DR-SDU)
- Respirable Cyclone Precollector (model DR-RCP10)
- Solar Power Supply (model DR-SOL)
- External DC cable assembly (model DR-DCS)
- Analog signal output cable (model DR-ANC)

5.0 INSTRUMENT LAYOUT

The user should become familiar with the location and function of all externally accessible controls, connectors and other features of the DataRAM 4. Refer to Figures 1 through 3.

All user related functions are externally accessible. Qualified Thermo Fisher Scientific personnel should perform all repair and maintenance. Please contact the factory if any problem should arise. Do not attempt to disassemble the DataRAM 4, except as described in Section 12.0 (Maintenance), otherwise voiding of instrument warranty will result.

5.1 Front Panel

Refer to Figure 1 for location of controls and display.

The front panel contains the 10 touch switches (keys) and the LCD screen required for the operation of the DataRAM 4.

The touch switches provide tactile ("popping") feedback when properly actuated.

The ON/OFF key serves only to turn on the unit (while it is in the off state), and to turn it off (when it is operating). In the latter case, the DataRAM 4 switches automatically to its internal purge mode for about one minute, and then shuts itself off.

The EXIT and ENTER keys serve to execute specific commands that may be indicated on the screen, and the NEXT key generally serves to scroll the displayed information, e.g. to review the operating parameters that have been programmed, diagnostic values, etc.

The four-line, 20-character per line LCD indicates either measured values of concentration (instantaneous and time averaged on the same screen), elapsed run time, and maximum values, operating and logging parameters, diagnostics, command prompting or other messages.

The LCD screen is backlighted whenever the DataRAM 4 is powered by its AC charger/power supply. When operating from the internal battery, the screen backlighting is disabled in order to save battery charge.

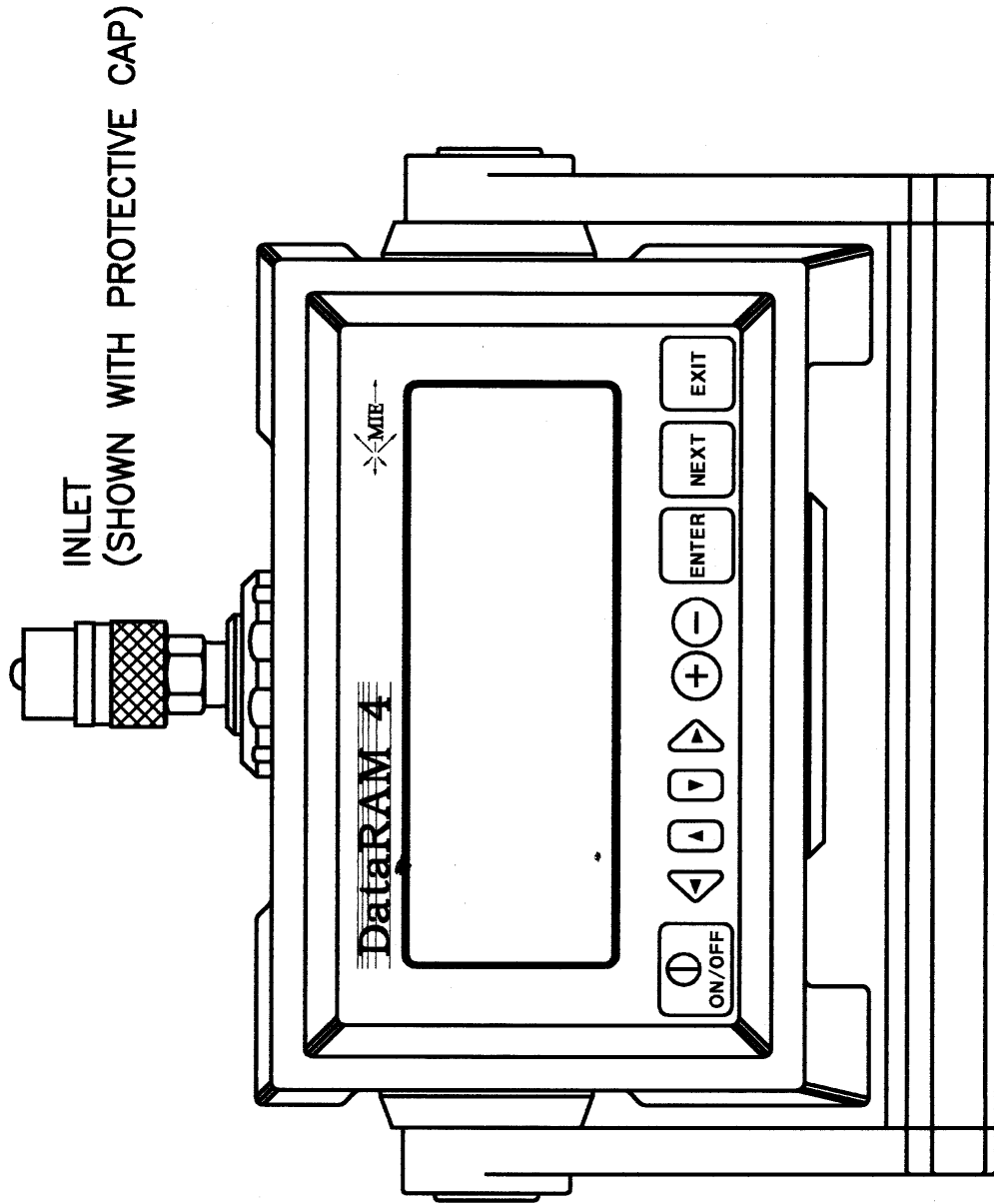


FIGURE 1. FRONT-PANEL VIEW OF DataRAM

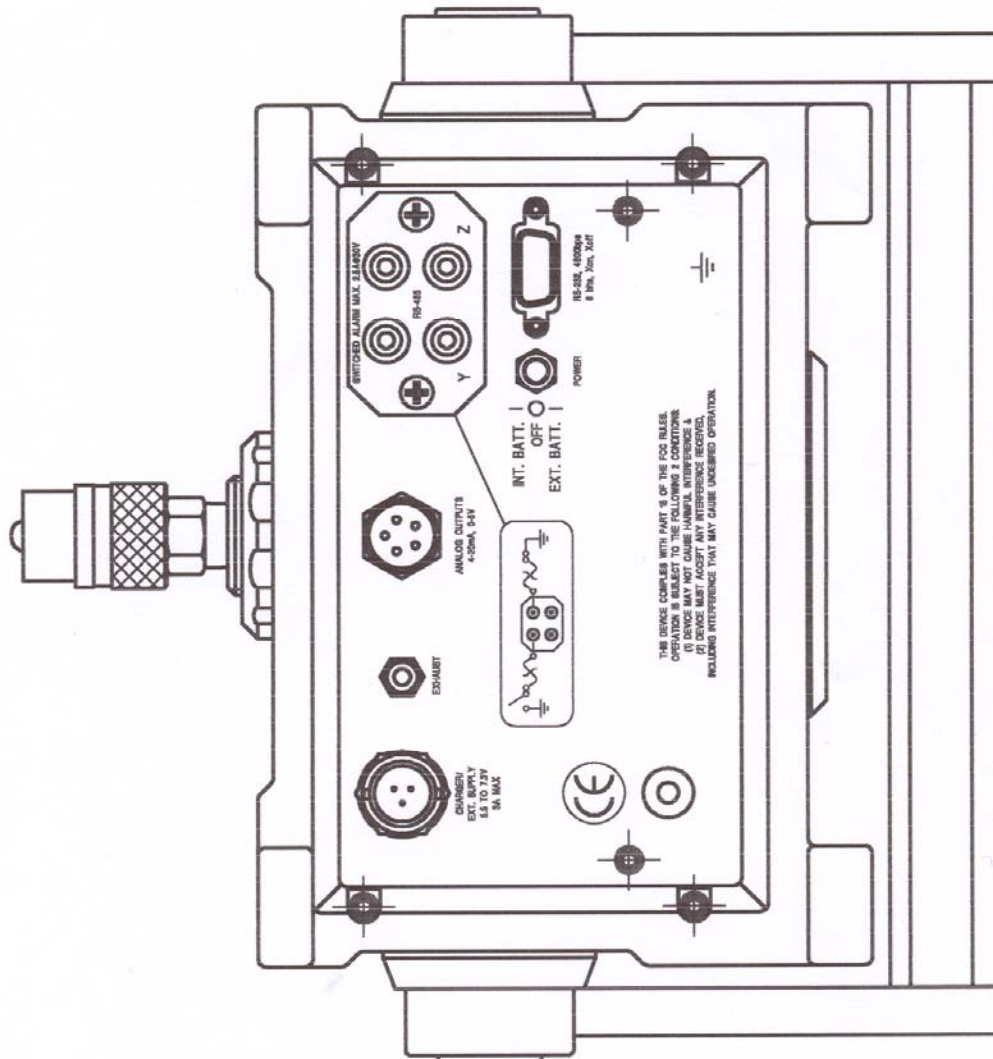


FIGURE 2. BACK-PANEL VIEW OF DataRAM

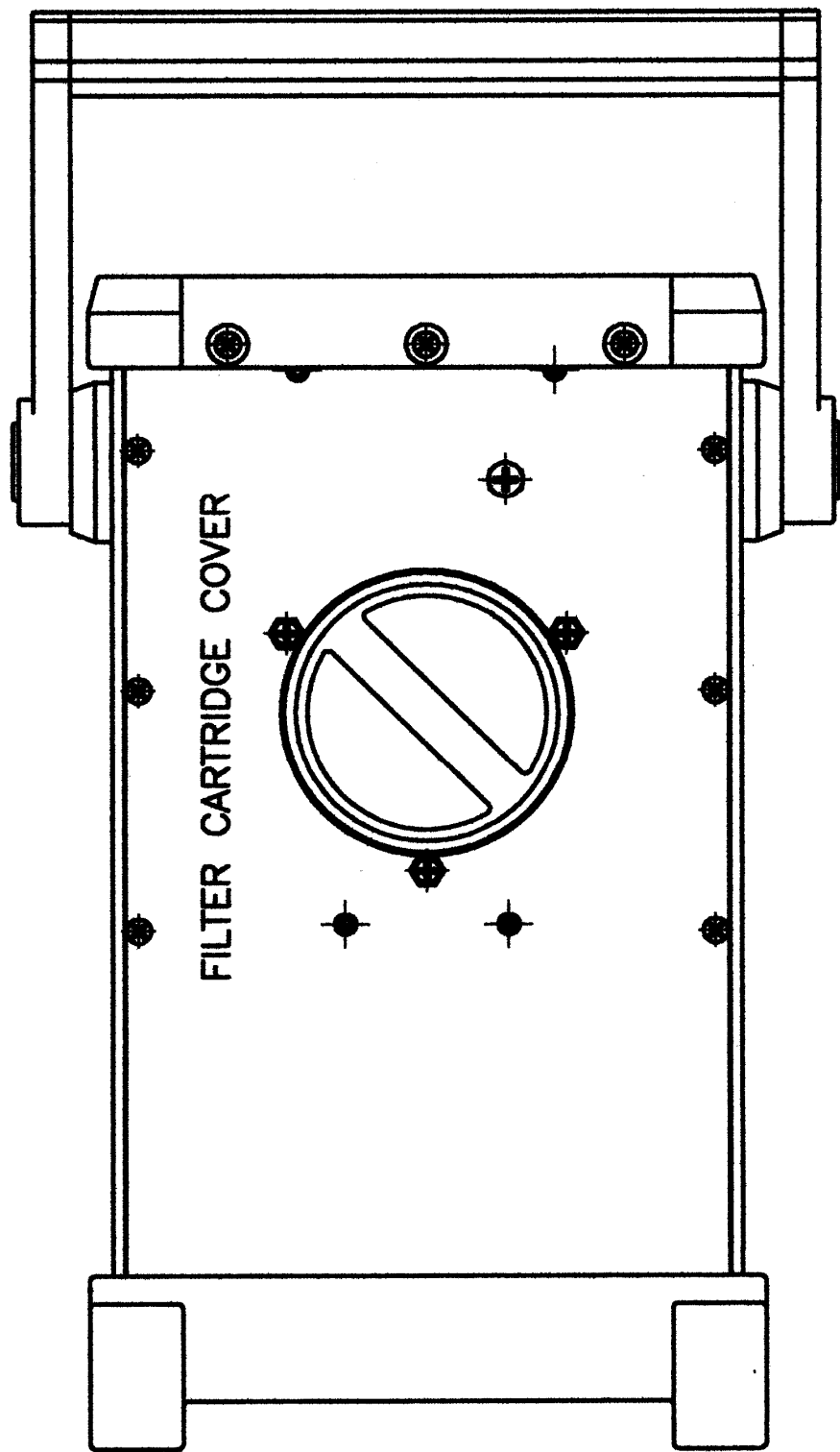


FIGURE 3. BOTTOM VIEW OF DataRAM

5.2 Rear Panel

Refer to Figure 2 for the location of items on the back panel of the DataRAM 4.

All components on the back panel are either labeled to indicate their respective functions, or are self-explanatory. Viewing the back panel from the rear of the DataRAM 4, the user should identify and become familiar with the following items:

- The **CHARGER/EXT. SUPPLY** 3-pin male receptacle. The AC power supply/charger provided with the DataRAM should be connected here whenever the internal battery is to be recharged and/or when running continuously from the AC line. Any other DC source (e.g., solar power supply, external battery, etc.) to be used to power the DataRAM would be connected at this location.
- **Inlet cap storage pod.** Directly below the charger/power supply connector is a gray plastic pod provided for storage of the metal inlet cap whenever the DataRAM 4 is in operation. The cap is snapped onto, or removed from the pod by pulling the knurled sealing ring away from the opening of the cap.
- The **CE** marking above the pod signifies that the DataRAM 4 has been certified to satisfy all requirements that are implied in that marking (please consult with Thermo Fisher Scientific about any questions on the CE certification).
- To the right of the charger/ext. supply receptacle is the **EXHAUST** fitting. This is the point where the sampled air exhausts from the DataRAM 4. This exhaust airflow is particle-free as it has passed through the internal filter of the DataRAM 4.
- To the right of the exhaust fitting is the **ANALOG OUTPUTS** signal connector. Both 4 to 20 mA and 0 to 5 V outputs are available at that connector. In addition, this connector also provides a **VOLTAGE ALARM** output (0 to 5 V).
- At the upper right hand of the back panel is a 4-post connector. The upper two binding posts provide a **SWITCHED ALARM** output activated whenever the measured concentration exceeds a user set level (same as the voltage alarm output). The lower two posts are for **RS-485** communications.
- Below the 4-post connector is a standard 9-pin male connector for **RS-232** communications.
- Directly to the left of the RS-232 connector is a 3-position switch provided for **POWER** selection and shut off. To actuate this locking switch, pull its small handle outwards while moving it up or down. In the mid position (handle horizontal), the DataRAM 4 is shut off from any source of power, internal or external. This position should be used for transport, or when the DataRAM 4 is not to be used for an extended period of time. ***The upward position is for normal operation, and should be used whether the DataRAM 4 is powered from its internal battery, being charged or when powered from its AC power supply.*** The downward position is only to be used when an external DC source is applied (e.g., external battery, etc.).
- In the lower right hand corner is a chassis ground post to which a grounding connection may be made for fixed-point uses.

5.3 Bottom Base

Refer to Figure 3 for the location of items on the bottom surface of the DataRAM 4.

A large threaded plastic cover that seals the internal filter holder (either the large capacity HEPA metal cartridge, or the analytical plastic filter holder) can be accessed on the DataRAM 4 bottom panel. See Sections 6.3 and 12.4 for filter replacement procedures.

5.4 Carrying Handle

The swivel-type carrying handle can be locked at any of several angles, 30° apart. To unlock, press inwards the large buttons on both hinges, while rotating the handle. Allow these buttons to lock (by springing outwards) at any desired angle. At a 90° downward position the handle will provide an upward tilted position for the DataRAM 4, facilitating access and viewing of the front panel. ***Under no conditions should the handle be rotated without unlocking the hinges on both sides. Otherwise, the internal mechanism of the handle lock will be damaged.***

5.5 Sampling Inlet

The sampling inlet of the DataRAM 4 is located on the upper face of the instrument. This inlet is a quick-connect ¼-inch stem compatible with all inlet accessories available. When the DataRAM 4 is not in use, the inlet should be closed by means of the metal stem cap provided with the instrument. During DataRAM 4 operation this cap should be stored on its pod on the back panel. This stem cap serves to prevent accidental entry of objects, debris, or other form of contamination into the sensing stage of the DataRAM 4, as well as to protect the inlet stem from any surface damage. Figure 1 shows the inlet covered with the stem cap.

To remove the stem cap from the inlet, slide spring-loaded knurled sleeve backwards, and pull cap away from inlet. To insert cap, slide spring-loaded sleeve back, push cap down on inlet stem until it bottoms, and release knurled sleeve. The same procedure applies when removing cap from or inserting it onto the storage pod on the back panel of the DataRAM 4.

Do not loosen the large notched aluminum nut that secures the inlet stem to the DataRAM 4 case.

6.0 PREPARATION FOR OPERATION

6.1 Battery Charging and Operation

The internal rechargeable battery of the DataRAM 4 is a sealed lead-acid gel-cell type with very long lifetime. Under normal circumstances, the battery will provide reliable operation for several years.

When shipped from the factory, The DataRAM 4 internal battery has been fully charged allowing immediate operation of the instrument as received by the user.

Always recharge the battery after use and before storing the instrument for any length of time. The battery of a stored instrument must be recharged at least every three months.

If the DataRAM 4 has not been used for more than one month, it is advisable to recharge its battery to full capacity before operating.

A fully discharged battery requires at least **12 hours of charging**, using the supplied charger, in order to attain full capacity.

A new and fully charged battery, at temperatures above 15°C (60°F), approx., is expected to provide at least 20 hours of continuous operation.

During battery charging the DataRAM 4 can be placed in any of its operating positions, **but not resting on its front (upside down position)**.

If, while operating the DataRAM 4 from its internal battery, the battery charge were to be nearly depleted such that its voltage drops below an acceptable level, the DataRAM 4 will automatically switch to internal air purging and then shut itself off.

The DataRAM 4 can be operated continuously and for an indefinite time using its universal charger/power supply. This charger/power supply accepts any line voltage between 100 and 240 VAC, 50 to 60 Hz, without requiring any adjustments. When using this charger/power supply, its connector should be plugged into and fastened to the corresponding receptacle on the rear panel of the DataRAM 4 (see Section 5.2).

6.2 Inlet Uncapping

Before starting a measurement run, the protective stem cap must be removed from the inlet and stored on the pod on the back panel (see Section 5.2). *The DataRAM 4 should never be in its run mode (pump operating) with the cap covering the inlet.*

6.3 Filter Cartridge Installation

Ensure that one of the two types of filter cartridges has been installed in the filter chamber accessible from the bottom panel of the DataRAM 4 (see Figure 3). The DataRAM 4 is shipped from the factory with the large capacity HEPA (High Efficiency Particulate Air) filter cartridge in place. See Section 12.4.1 for procedures to replace this cartridge or to install the analytic filter holder (Section 12.4.2). ***Except when gravimetric measurements or chemical analysis of the filter collection are to be performed, only the HEPA filter cartridge should be installed in the DataRAM 4.***

In order to gain access to the filter chamber, the large threaded plastic cap covering the filter chamber must be rotated counterclockwise (as viewed from the bottom). Do not leave this chamber open for any extended period of time, otherwise dust may settle on the internal optical surfaces. Hand tighten the plastic cap firmly after filter cassette replacement, to ensure a proper seal. ***At no time should the DataRAM 4 be running without a filter in place, otherwise serious damage to internal components may result.***

6.4 Power Selector Switch

When the DataRAM 4 is received from the factory, the 3-position power selector switch will typically be in its OFF position (mid-position). **To enable operation with either its internal battery or with the charger/power supply provided with the DataRAM 4, this switch must be placed in its INT. BATT. position (handle upward).** Refer to section 5.2 on how to operate this locking-type switch.

6.5 External Electrical Connections

Plugging in or unplugging any external equipment (e.g., computer, modem, alarm circuitry, etc.) should be made only while both the DataRAM 4 and the external equipment are shut off, in order to prevent damage or interference due to transient electrical effects.

6.6 External DC Power Operation

If an external DC source of power is used, for example if AC power is not available and continuous operation over more than 20 hours is required, an external battery or other DC source (e.g., solar power) can be used.

If an external battery is used, its specifications are:

- Voltage: 6.0 to 9.0 VDC
- Instantaneous current capability: 3 A
- Continuous average current requirement: 300 mA
- To calculate the required ampere-hour capacity:
Ampere-hours = 0.3 x hours of operation

To connect external DC source to DataRAM 4, place 3-position **POWER** switch in its OFF position. Use special cable assembly, Thermo Scientific model DR-DCS. Insert its 3-pin connector into the **CHARGER/EXT. SUPPLY** receptacle on the rear panel of the DataRAM 4 (See Section 5.2 and Figure 2). Connect positive (+) side of external battery to the lead marked (+), and the negative side (-) to the lead marked (-). Once the connections have been completed, place the **POWER** switch in its downward position (EXT. BATT.). Again, before disconnecting external battery, return **POWER** switch to its OFF position.

7.0 OPERATING MODES

The DataRAM 4 has several different operating modes which will be described in what follows. The specific commands and displays within each of these operating modes will be explained in detail in Section 9.0

7.1 Set-Up Mode

The DataRAM 4 enters the Start-Up Mode as soon as the instrument is switched on. The user then has the choice to:

- a) Wait before proceeding;
- b) Zero the instrument and check its readiness;
- c) Review or export previously logged data;
- d) Edit data logging parameters; or
- e) Edit operating/measurement parameters

All parameter and status changes must be performed while in the set-up mode. Once the DataRAM 4 is in the run (measurement) mode no changes can be made in the parameters or status of the instrument.

While the DataRAM 4 is in the set-up mode the internal pump is not activated, except while zeroing.

7.2 Run/Data Logging Mode

The Run Mode is the measurement/logging mode. The user can operate the DataRAM 4 in this mode either with or without data logging. For example, the instrument may be used first as a survey monitor without logging, for walk-through assessment of an industrial plant, before deciding where to set up the unit for continuous monitoring and logging. While in the run mode, the user will be able to view all current measurement values, operating parameters, diagnostic status, as well as any logged values up to that moment.

While the DataRAM 4 is in the run mode the internal pump is always activated.

8.0 KEY SWITCHES AND SCREEN CURSOR FUNCTIONS

Refer to Figure 1 showing the location of the front panel keys.

8.1 ON/OFF Key

The only function of the **ON/OFF** key is to switch the DataRAM 4 on or off depending on whether the instrument is shut off or operating, respectively. When keying **ON** (while instrument is off) the screen will display an identification screen and then the MAIN MENU (see Section 9.1).

When keying **OFF** the screen will request confirmation by keying **ENTER**. If the DataRAM 4 is in the run mode, this will then terminate the run and initiate the automatic internal purging sequence with particle free air for about 1 minute, at the end of which the DataRAM 4 will shut itself off. If the DataRAM 4 is not in the run mode, keying **OFF** and then **ENTER** will also initiate the automatic purging sequence followed by automatic shut off. In either case, keying **EXIT** instead of **ENTER** after keying **OFF** cancels the termination command (the DataRAM 4 continues the run). Regardless of whether the DataRAM 4 was in the run mode or any other mode when shutting the unit off, all previously stored data remains in memory.

8.2 Screen Cursor, Arrow and +/- Keys

The cursor on the display screen is a blinking black rectangle marking a specific function, status or parameter value that can be selected or modified. When the cursor marks a > on the screen that specific function can be enabled by keying **ENTER**.

To move the cursor from one line to the other on the screen use the \vee or \wedge keys.

When the cursor marks the first letter of a status, that status can be toggled (changed) by keying **+** or **-**.

When the cursor marks a digit of a parameter, the value of that digit can be incremented by keying **+** or decreased by keying **-**. To move the cursor to the next significant digit, either the **<** or the **>** keys should be used.

8.3 ENTER, NEXT and EXIT Keys

The **ENTER** key serves to implement or activate a specific function indicated by the screen cursor, or when the screen display presents ENTER as a command selection.

The **NEXT** key is used principally to go from one screen to the next either in the set-up or in the run/logging mode.

The **EXIT** key is provided to initiate the run termination sequence, or to return to the basic run screen (Run 1 screen) while the DataRAM 4 is in the run mode, to interrupt zeroing, or to return to a previous screen.

9.0 START-UP PREPARATION

Please ensure that the rear panel power switch is in the upward position (see Section 6.4).

9.1 The MENU Screens

Note: Bold, underlined symbols of the screens printed in this manual will denote blinking cursor location (e.g., ≥).

Press **ON** key. The following screen appears for about 5 seconds:

MIE	DataRAM 4
VER	35
S/N	D376
DEV#	1

The first line identifies the type of instrument, the second indicates the installed firmware version, the third is the serial number of the instrument, and the fourth line indicates an instrument identification number for serial communication purposes. Then the display automatically changes to the following screen:

MAIN MENU	
<u>≥</u>	START RUN
>	ZERO/INITIALIZE
>	VIEW/TRANSFER DATA

At this point, there are the following options:

- Keying **ENTER** starts a measurement run.
- Keying ∇ moves cursor to the next line (ZERO/INITIALIZE)
- Keying **NEXT** selects the next MENU screen:

EDIT MENU	
<u>≥</u>	LOGGING PARAMETERS
>	SETUP PARAMETERS

Keying **NEXT** from the EDIT MENU returns the screen to the initial MAIN MENU screen.

9.2 ZERO/INITIALIZE Operation

Before initiating a measurement run it is advisable to perform the automatic zeroing and internal check out sequences, to ensure optimal operation.

- From the MAIN MENU select ZERO/INITIALIZE by moving the cursor to that line.
- Key **ENTER**

The pump starts up and the following screen appears initially:

ZEROING/INITIALIZING
COUNTDOWN: 194 sec
MEMORY LEFT: 100%
BATT. CHARGE 412 mA

NOTE: Specific numbers used in his manual are given only as examples; values actually displayed may differ.

The time indicated on the second line is the countdown time required to complete the automatic zeroing/initializing sequence. The MEMORY LEFT indication is the unused percentage of the total logging memory. The BATT CHARGE reading is the charging current when the DataRAM 4 is connected to the a.c. line through its charger/power supply. If the charger is not used, that line on the screen will indicate BATTERY LEFT, i.e., the percentage of charge still available from the battery.

A few seconds after the above display appears, the screen will go to:

ZEROING/INITIALIZING
COUNTDOWN: 186 sec
SOURCE 1: NORMAL
SOURCE 2: NORMAL

And finally to the following screen, indicating that the zeroing/initializing sequence has been completed:

ZEROING/INITIALIZING
READY!: 0 sec
SOURCE 1: NORMAL
SOURCE 2: NORMAL

If the second line of the above screen indicates BACKGROUND HIGH instead of READY!, it is probable that the lenses in the sensing chamber require cleaning. Please refer to Section 12.2 for such cleaning procedures.

If the READY! message is displayed, return to the MAIN MENU by keying **EXIT**.

9.3 Selecting Logging Parameters

To select the data logging parameters, key **NEXT** from the MAIN MENU and the EDIT MENU is displayed. The flashing cursor appears on the LOGGING PARAMETERS line. Key **ENTER** to activate that function. The following screen appears:

```
LOG DATA:  DISABLED
LOG PERIOD:  00:00:05
TAG #:      13
AUTO START: DISABLED
```

In order to activate (enable) the data logging function for the next measurement run, key **+** or **-** and the first line will display ENABLED (either of these two keys can be used to toggle between DISABLED and ENABLED).

Key **v** and the following screen is displayed:

```
LOG DATA:  ENABLED
LOG PERIOD:  00:00:05
TAG #:      13
AUTO START: DISABLED
```

The cursor in this line indicates that logging period can be selected (to any period between 1 second to 24 hours). The value of the flashing digit can be changed up or down by keying **+** or **-**, respectively. To change from one significant digit to another, key either **>** or **<**.

To select another tag number (the one displayed automatically is always the next one available, e.g., in this case, 12 tags would have been used already, and tag # 13 is the next one available), key **v** and the cursor will be on one of the tag # digits. Change/select as desired, or leave unchanged.

The last line of the logging parameters allows for programming a specific start time and date for logging the data (the DataRAM 4 must be operating in the run mode to effect such delayed logging). If the automatic start is disabled (as shown in the above screen) and logging has been enabled, then the logging of data starts as soon as a measurement run is initiated (see Section 9.6). If the user desires to start the logging at a later time (or date), the cursor should be moved to the last line and use either the **+** or **-** keys to enable the logging auto start function (toggling between enabling and disabling is accomplished by these same keys). If this function is enabled, the following screen is displayed:

```
LOG DATA:  ENABLED
LOG PERIOD:  00:00:05
TAG #:      13
AUTO:      16:25 JAN 17
```

As usual, the desired time and date for the automatic start of logging can be selected as described previously.

To return to the EDIT MENU screen, key **EXIT**.

9.4 Selecting Set-Up Parameters

To select operating parameters, set time and date, etc., key \vee to select SETUP PARAMETERS on the EDIT MENU. Key **ENTER** and the first of 4 set up parameters screen is displayed:

```
DISPLAY AVG:  10 SEC
CAL FACTOR:   1.00
UNITS:        (MASS) ug/m3
SIZE CORRECT: DISABL
```

As described before, the numerical values are changed by using the **+** and **-** keys, selecting significant digits by using the **>** and **<** keys, and selecting lines by using the \vee and \wedge keys. Toggling or scrolling the units of the third line, or enabling/disabling the relative humidity correction algorithm of the fourth line are performed using the **+** and **-** keys.

The **display averaging time** (first line) determines the smoothing of the displayed measurement values. This time can be selected between 1 and 60 seconds. Short averaging times provide faster response but noisier (more fluctuating) data. Conversely, long averaging times slow down time response but provide smoother (less fluctuating) data.

The **calibration factor** (second line) is the multiplier of the calibration slope programmed at the factory. A factor of 1.00 indicates that the calibration slope is identical to that programmed at the factory. This factor can be changed to agree with a user calibration (see Section 13.2).

The **measurement parameters (units)** can be selected on the third line. The selection alternatives are: mass concentration in $\mu\text{g}/\text{m}^3$, scattering coefficient in $(\text{Mm})^{-1}$, or visual range in kilometers.

The **particle size correction** refers to the computation of the mass concentration. When this function is enabled, the measured mass concentration automatically takes into account the volume median particle diameter determined in real time from the ratio of the scattering irradiances at the two wavelengths of illumination of the DataRAM 4. When this function is disabled, the monitor behaves as a single wavelength (880 nm) nephelometer with its characteristic size dependence (similar to that of the DataRAM, model DR-2000).

The second set up screen can be displayed by keying **NEXT**:

RH CORRECT: <u>D</u> ISABL TEMPERATURE UNITS: C FLOW RATE: 2.00 LPM

The first line of this screen refers to the **relative humidity correction**. When this function is enabled, the particle growth effect due to a high humidity environment is corrected for. This means that the computed mass concentration is based on the original dry environment particle population. This correction only applies when mass concentration units have been selected, but not when scattering coefficient or visual range has been selected.

The indicated **temperature units** can be selected between degrees Celsius (°C) and degrees Fahrenheit (°F).

The air sampling **flow rate** of the DataRAM 4 can be adjusted over the range of 1.00 to 3.00 liters per minute (LPM). The nominal operating flow rate is 2.00 LPM. Whatever the selected flow rate, it will be maintained at a constant volumetric rate during the measurement run regardless of any changes in the system flow resistance, up to a maximum pump load.

Key **NEXT** to view the following screen:

ANLG OUT: <u>4</u> .00 mg/m ³
SERIAL MODE: RS-232
DEVICE #: 124

The first line refers to the full-scale concentration of the **analog output** signal (0 to 5 V and 4 to 20 mA) available at the back panel of the DataRAM 4. The full-scale concentration ranges that can be selected (if mass concentration units are selected) are: 0.1, 0.4, 1, 4, 10, 40, 100 and 400 mg/m³. If scattering coefficient units are selected, the ranges are: 10, 100, 1,000, 10,000 and 100,000 (Mm)⁻¹. If visual range has been selected the full scale range is fixed at 500 km.

The **serial mode** of digital communication can be selected on the second line between RS-232 and RS-485.

The last line is an **identification number** that the user can select to label this particular DataRAM 4 for future reference. This number will accompany the logged data information.

The next set up screen can be displayed by keying **NEXT**:

16:49:11	10 May 2000
TIME	16:48:55
DATE	10 May 2000
TO SET PRESS => ENTER	

This screen is used to set the **time and date**, should these require resetting. The first line indicates the time presently registered by the DataRAM 4. The second is the time editing line. To set the time accurately, select a time (on the second line) that is slightly ahead of the actual time (e.g., by 30 seconds) and select the seconds as a multiple of 10. In the U.S., it is convenient to dial 1-900-410-8463 (U.S. Naval Observatory time information), and at the instant when the time announced equals the time preset on the second line of the above screen, key **ENTER**, as instructed on the last line.

To display the next set up screen, key **NEXT**:

ALARM	ENABLED
LEVEL (ug/m3)	1000
AUTO ZERO	ENABLED
INTERVAL	48 hrs

The first line of the above screen allows enabling or disabling of the alarm function. When the flashing marker is on that first line it is possible to toggle between those two conditions by keying either **+** or **-**. The alarm level in the units of micrograms per cubic meter can be selected on the second line.

The third line of the above screen allows enabling or disabling of the automatic zeroing function whereby the DataRAM 4 automatically purges itself with particle-free air, and registers and then subtracts its optical background from all subsequent measurements. The fourth line allows for the selection of the time interval in hours (in one-hour steps up to 200 hours) between consecutive automatic zeroings.

To return to the MAIN MENU screen, key **EXIT**.

9.5 Review or Transfer Stored Data

To access stored data either for viewing on the DataRAM 4 screen or for transfer to a PC or other external device, select the VIEW/TRANSFER DATA line on the MAIN MENU, and then key **ENTER**. The following screen appears:

```
TAG # 12
> VIEW LOGGED DATA
> TRANSFER TEXT FILE
> DELETE LOGGED DATA
```

The above screen provides a selection of commands with respect to the last logged run (e.g., tag # 12). To select the contents of another tag, select the appropriate number, using the **+ - > <** key strokes, as described previously.

To review the data logged for a selected tag #, key **v** to select the VIEW LOGGED DATA line, then key **ENTER** and the following screen appears:

```
TAG # 12      43 POINTS
START  11:23 09 May 00
END    11:27 09 May 00
LOG PERIOD  00:00:06
```

The above screen is the first of two available **tag summary** screens. The first line identifies the tag # and the number of data points logged during that run. The second line provides the run start time and date. The third line indicates the end time and date for that run. The fourth line indicates the logging period use during that run. For the above example, 43 data points of 6 seconds each were logged between 11:23 and 11:27 on May 9, 2000.

Keying **NEXT** displays the second tag summary screen:

```
TAG # 12      43 POINTS
AVG SCATR    0.00 1/Mm
MAX 207.33 11:23 09 May
AVG. DIA:    0.653 um
```

The first line of the above screen repeats the information of the first tag summary screen. The second line indicates the average measured value for that run. This average is given in whatever units were selected originally on the first set-up screen (Section 9.4). The third line indicates the maximum registered instantaneous value in the same selected units, and the time and date when this maximum occurred. The

last line indicates the average volume median particle diameter in micrometers for that run.

In order to review the individual **data points** within a tag, key **NEXT** and the following screen is displayed:

```
TAG # 12    POINT #  1
11:23:20 09 May 2000
171.46 1/Mm    D = 0.40
um
TEMP = 28.0C    RH = 40%
```

The first line indicates the tag # and the point # within that run, the second line is the time and date of that point, the third line indicates the average measured value and the average volume median particle diameter for that logging period, and the last line indicates the corresponding temperature and relative humidity values.

Keying **+** advances the point # scrolling the screens through all data points within the selected tag # or run.

Keying **NEXT** returns the screen to the first tag summary table then, keying **EXIT** returns to the VIEW/TRANSFER DATA screen (i.e., the first screen of this section).

In order to delete (erase) logged data, select the DELETE LOGGED DATA line from the VIEW/TRANSFER DATA screen, and key **ENTER**. The following screen appears:

```
DELETE LOGGED DATA
TAG # 01
≥ DELETE TAG DATA
> DELETE ALL DATA
```

Select either DELETE TAG DATA or DELETE ALL DATA, as preferred. In the first case, only the data in the selected tag # are erased from memory, whereas in the second case all stored data are erased. After the appropriate selection of the data to be deleted, key **ENTER**, and the following screen is displayed (as an example it is assumed that only the data of tag #1 are to be erased):

```
DELETING LOGGED DATA
TAG # 01
ENTER TO CONFIRM
EXIT TO CANCEL
```

To confirm the deletion command, key **ENTER**, or to rescind the deletion command, key **EXIT**. If **ENTER** is keyed, the following screen is displayed:

TAG # 01 HAS BEEN DELETED PRESS ANY KEY

After confirmation that the data have been deleted, pressing any key (e.g., **EXIT** or **NEXT**) reverts the display to the DELETE LOGGED DATA screen if not all the data have been erased. Otherwise, the VIEW/TRANSFER DATA screen appears.

9.6 Run Start

From the MAIN MENU (see Section 9.1), select START RUN. When ready to initiate the run, key **ENTER**, and one of the following types of screen appears (depending on which measurement units were selected in the set-up procedure described in Section 9.4):

16:08:09	10 May 2000
CONC:	5.7 ug/m3
TWA:	11.0 ug/m3
RUN TIME:	00000:02:25

or:

16:08:09	10 May 2000
SCATR:	10.33 1/Mm
TWA:	6.83 1/Mm
RUN TIME:	00000:02:25

or:

16:08:09	10 May 2000
RANGE:	17.6 km
TWA:	15.2 km
RUN TIME:	00000:02:25

It should be remembered that the measurement units can only be selected in the set-up mode and not during a run.

The first line of the above run measurement screen shows the real time (24-hour format) and date. The second line displays the real-time (instantaneous) measurement value (mass concentration, or scattering coefficient, or range, depending on the selected units) updated every second. The third line displays the time-weighted average measurement value (TWA) from run start, in whatever units were selected. The last line shows the elapsed run time in hours, minutes and seconds.

In order to view the other run parameters and diagnostic information, key **NEXT** and the following screen appears if the charger/power supply is **not** connected and the DataRAM 4 is being powered by its internal battery.

MEMORY LEFT	87%
BATT. LEFT	76%
FLOW RATE	1.99 LPM
TEMP= 25.3C	RH= 59%

If the DataRAM 4 is being powered by its charger/power supply, this screen will automatically display the charging current:

MEMORY LEFT	87%
BATT. CHARGE	326 mA
FLOW RATE	1.99 LPM
TEMP= 25.3C	RH= 59%

Key **NEXT** again and the following screen appears:

FLOW:	NORMAL
SOURCE 1:	NORMAL
SOURCE 2:	NORMAL
DETECTOR:	NORMAL

If any of the above functions or components is not operating correctly, the corresponding message will change from NORMAL to FAULT.

Key **NEXT** again and the following screen will be displayed:

```
SCATR PARAMETERS
PAR SCAT RATIO  0.5133
ANGSTROM COEF:  2.336
PARTIC. DIA:    0.454 um
```

The above screen shows the scattering parameters and the computed volume median particle diameter in micrometers. The SCA RATIO value is the ratio of the scattering irradiances detected at the two internal source wavelengths, i.e., at 880 nm and at 660 nm, respectively. If mass measurement units are selected (see Section 9.4), the second line of the above screen will display PAR SCAT RATIO which means that the indicated ratio is that due to particle scattering alone. If scattering coefficient or visual range units have been selected (see Section 9.4), that second line will read TOT SCAT RATIO, i.e., the ratio due to particle plus air scattering. The Ångström coefficient is the exponent that defines the wavelength-dependence of the scattering irradiance. This coefficient varies between 4 for pure Rayleigh scattering (molecular scattering), and 0 for wavelength-independent geometric scattering.

9.7 Run Termination

To terminate a run key **EXIT**. The following screen will then appear:

```
TERMINATE RUN ?
TERMINATE:  => ENTER
CANCEL:     =>  EXIT
```

To confirm the run termination, key **ENTER**. To continue the current run, key **EXIT**. If **ENTER** is keyed, the DataRAM 4 performs a purging operation for about 1 minute, and then displaying the initial MAIN MENU screen from which a new run can then be started. A new run can be started during the 1-minute purging cycle, thus interrupting that cycle. Alternatively, if during this purging period (following run termination) the **OFF** key is pressed, the purging operation will continue while the following screen will appear indicating the countdown time in seconds for the completion of the purging cycle. At the end of that period the DataRAM shuts off automatically.

```
TURN POWER OFF ?
          PURGING:  39
POWER OFF:  => ENTER
CANCEL:     =>  EXIT
```

If **EXIT** is keyed while the above screen is displayed, the MAIN MENU screen will appear and remain after the purging has been completed. If the **OFF** key is then pressed the DataRAM 4 will shut off without further purging since the instrument had already purged itself.

9.8 Resetting and Defaults

The DataRAM 4 memory can be reset through commands entered on its keypad, as follows:

- Starting with the DataRAM 4 shut off, press the EXIT and ENTER keys at the same time, and while holding down those two keys, press ON;
- The screen will then indicate DataRAM 4 SELF-TEST followed in rapid succession by several diagnostic screens, ending with TESTING COMPLETE;
- Shut off unit. When turned on again, the DataRAM 4 memory will have been reset.

Resetting, as described above, accomplishes the following:

- Erases all stored (logged) data from memory;
- Resets all parameters and operating conditions to their default values and conditions (see below); and
- Cancels the zero correction offset.

The **default** values and operating conditions of the DataRAM 4 are:

- Logging period (LOG PERIOD): 60 seconds
- Logging status: disabled (LOG DATA: DISABLED)
- Alarm level (LEVEL): 1 mg/m³
- Alarm status: disabled (ALARM: DISABLED)
- Analog output full scale: 1 mg/m³
- Measurement units (UNITS): MASS
- Calibration factor (CAL FACTOR): 1.00
- Real-time display averaging time (DISPLAY AVG): 10 seconds
- Flow rate: 2 liters/minute
- Temperature units: C
- Particle size correction ((SIZE CORRECT): disabled (DISABL)
- Humidity correction (RH CORRECT): disabled (DISABL)
- Auto zero: disabled (DISABL)
- Serial port output format (SERIAL MODE): RS-232
- Data output mode (DATA OUT): continuous

When turning on the DataRAM 4 after resetting the instrument, it will automatically go to the zeroing mode. The DataRAM 4 will not measure (operate in the run mode) unless an initial zeroing operation has been completed.

10.0 ANALOG SIGNAL OUTPUT

10.1 Analog Output Description

The DataRAM 4 incorporates the capability to provide both a voltage and a current signal output directly proportional to the sensed concentration of airborne particulates. Both these analog signal outputs are concurrently available. These outputs are provided, principally, for fixed-point applications with hard-wired installations.

The particulate concentration range corresponding to the output voltage and current ranges (0 to 5 V and 4 to 20 mA) can be user selected on the DataRAM 4 screen (see Section 9.4) or via a PC using the communications software package included with the instrument. The most sensitive range available is 0 to 0.100 mg/m³ (0 to 100 µg/m³), and the least sensitive range is 0 to 400 mg/m³. For example, if the user selects the analog output range of 0 to 0.400 mg/m³ then the analog output signal levels, at a concentration of 0.200 mg/m³, would be 2.5 V and 12 mA.

This concentration range is independent of the digital display, data logging and real-time digital output range which are controlled automatically (auto-ranging).

10.2 Analog Output Connection

For the 0 – 5 V output signal, the externally connected load must have an impedance of more than 200 kilo-ohms. For the 4 – 20 mA output signal, the externally connected load must have an impedance of less than 300 ohms.

Since both voltage and current outputs are present at the same time, both can be used concurrently, if so required.

The accuracy of the analog output signals is better than 1% of the reading with respect to the digital reading.

The 4 to 20 mA current output is available between pins # 1 and 4 of the 5-pin ANALOG OUTPUTS connector on the back panel (see Section 5.2). The 0 to 5 V analog voltage output is available between pins # 2 and 4 of that connector. Pin # 4 is common ground.

11.0 ALARM

11.1 Alarm Description and Operation

There are two alarm outputs available on the back panel of the DataRAM 4: a switching alarm and a voltage alarm. The switching alarm output is capable of sinking a current of up to 2.5 amperes to ground. The voltage alarm output goes from 0 to 5 volts when the alarm is triggered. Whenever the alarm is triggered, the on-board sound will be activated.

The alarm function can be enabled/disabled and the alarm level (trigger threshold) can be selected by the user through the DataRAM 4 keyboard (see Section 9.4).

The alarm is triggered whenever the selected alarm level is exceeded. When the displayed concentration falls below that level the alarm condition stops. While the alarm is on, the user can disable it momentarily by pressing any key on the DataRAM 4. If the concentration continues to exceed the set alarm level after 10 seconds, the alarm condition will be reactivated.

11.2 Alarm Output Connection

There are two alarm outputs on the DataRAM 4:

- a) **Switching alarm.** This alarm is available between the two upper terminals of the 4-terminal block on the upper right side of the back panel. The right-most terminal is ground and the left terminal is normally open. When the alarm level is exceeded, this latter terminal becomes grounded. A maximum load current of 2.5 A is allowed.
- b) **Voltage alarm.** This alarm signal is available between pins # 3 and 4 on the ANALOG OUTPUTS connector in the upper middle of the back panel. This output consists of a voltage that steps from 0 to 5 V whenever the alarm is triggered. The minimum external load impedance for this output is 10 kilo-ohms.

12.0 MAINTENANCE

12.1 General Guidelines

The DataRAM 4 is designed to be repaired at the factory. No user serviceable components are inside the metal enclosure of the DataRAM 4 with exception of the filter cartridge or the analytic filter holder. Access to the internal components of the unit by others than authorized personnel voids warranty.

Unless a MALFUNCTION message is displayed, or other operational problems occur, the DataRAM 4 should be returned to the factory once every two years for routine check out, test, cleaning and calibration check.

12.2 Battery Charging and Cycling

If the DataRAM 4 is to be operated without its charger/power supply, i.e., deriving power from its internal battery, this battery should be fully charged before initiating a run. The DataRAM 4 charger/power supply can be connected continuously to the instrument whether the DataRAM 4 is on or off. If the charger/power supply is not connected, the internal battery will discharge very slowly depending on storage temperature. Low storage temperature reduces battery capacity. High storage temperatures, however, reduce battery life which is of the order of 8 years at 20°C (68°F), and only 2 years at 40°C (104°F).

In general, the user should maintain the battery charge as high as possible in order to extend its charge/discharge cycling capacity (this characteristic differs from that of nickel-cadmium batteries).

12.3 Instrument Storage

If the DataRAM 4 is to be stored for an extended period of time (i.e., 3 months or more), place the 3-position switch on the back panel in its OFF position (mid-position), in order to minimize gradual battery discharge. This will have no effect on data retention or internal clock function. It is recommended, however, that the battery be recharged every 3 months in order to prolong battery life (see Section 6.1).

During storage always snap on quick-connect cap over the instrument inlet to protect the sensing optics from gradual dust contamination. Store DataRAM 4 in a dry environment.

12.4 Filter Replacement

To replace either of two types of filters used with DataRAM 4, place the instrument on its back rubber feet (front panel facing upward). On the bottom surface of the DataRAM, locate the large threaded plastic filter cover and holding the cross bar, rotate this cover counterclockwise. Remove cover and the filter holder within the open cavity.

12.4.1 HEPA Filter Cartridge Replacement

The DataRAM 4 is shipped from the factory with the HEPA filter cartridge installed. This cartridge can be identified by its metallic cover. Remove this cartridge as indicated in Section 12.4, above. Clean the internal black rubber gasket against which the cartridge is normally compressed. Install new HEPA-type cartridge (part no. MSA-95302) by inserting its wider ridged end first. Reposition threaded plastic cover engaging threads carefully; rotate cover clockwise, hand tightening firmly. Properly dispose of used cartridge to prevent inadvertent re-use.

12.4.2 Analytic Filter Installation/Replacement

In order to install or replace the analytical filter holder, proceed as follows. Remove the HEPA cartridge normally in place, as described in Section 12.4.1. Remove (separate) the inlet cover (with the blue plug) of the Millipore plastic filter holder from the rest of that holder assembly containing the white membrane filter. Insert firmly the gray plastic adapter annulus into the open face of the filter holder assembly, as shown in Figure 4. Remove the red plastic plug from the exhaust nipple of the filter holder assembly. Ensure that all three components of the holder assembly are fully compressed to preclude any leakage. Insert the assembly into the filter cavity of the DataRAM 4 with the gray plastic adapter annulus bearing against the internal black gasket (adapter annulus inserted first). Reposition threaded plastic cover and hand-tighten carefully and firmly. Set aside HEPA cartridge for future use.

In order to remove and/or to replace the membrane filter within its holder, remove the gray plastic adapter annulus and separate (pry apart) the two transparent plastic rings that compress the membrane filter. Make sure to remove and replace only the membrane filter (using tweezers), leaving the white backing disc in the holder. A new membrane filter should then be placed over that backing and the sealing ring should then be inserted to trap and compress the filter and backing discs. For storage, the inlet cap with the blue plug should be inserted as well as the red plug on the back of the filter holder.

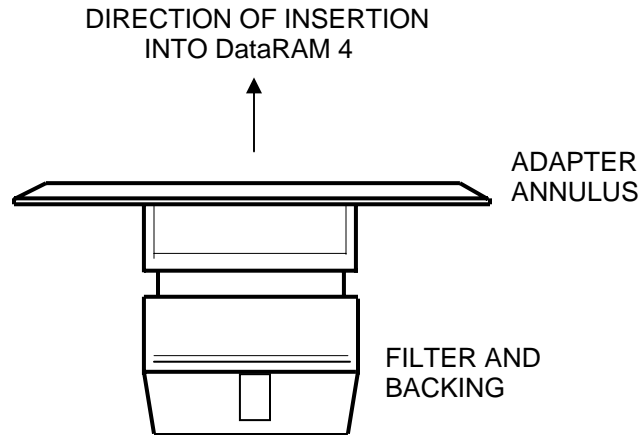


Figure 4. Analytical filter holder with adapter annulus inserted

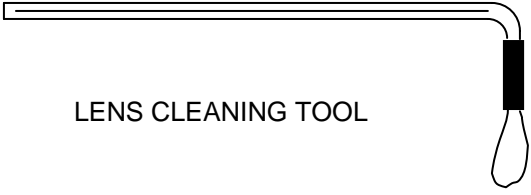
12.5 Cleaning of Optical Sensing Chamber

Although the DataRAM 4 incorporates filtered air shielding of the critical optical sensing surfaces, continued sampling of airborne particles at high concentrations may result in gradual build-up of contamination on those interior surfaces of the sensing chamber components. This may cause an excessively high optical background level. If this background level does becomes excessive, the DataRAM 4 will alert the user at the completion of the zeroing sequence, as indicated in Section 9.2 by the display of a BACKGROUND HIGH message. If this message is presented, the DataRAM 4 can continue to be operated providing accurate measurements. However, it is then advisable to clean the front surfaces of the optical lenses within the sensing chamber at the first convenient opportunity, as described below. The tools required for this cleaning are: an intense concentrated light source (e.g., flash light) to view the inside of the sensing chamber, denatured alcohol, a soft lint-free cloth, and the special cleaning tool provided with the DataRAM 4 consisting of a cut-off cotton swab inserted in a plastic sleeve and held by a right-angle Allen wrench (see Fig. 5).

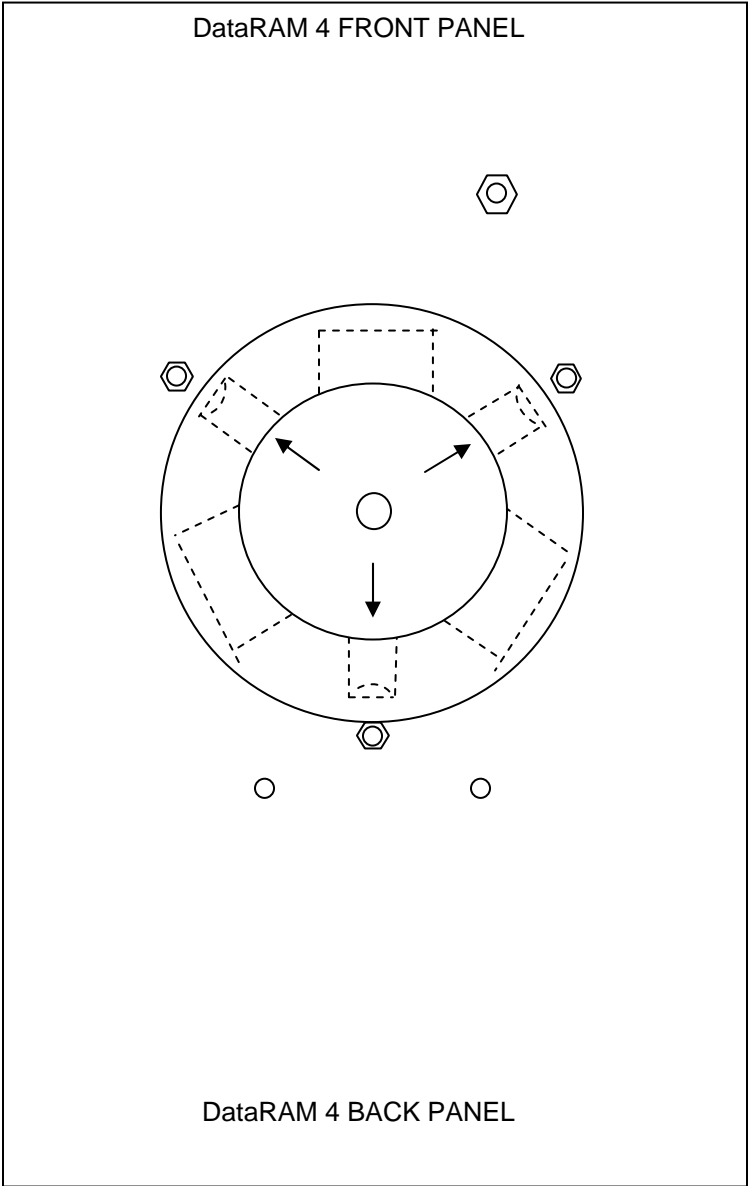
Proceed as follows to clean the lens surfaces within the sensing chamber:

- ***Make sure to shut off power completely before proceeding with cleaning***
- Install the stainless steel cover on the inlet of the DataRAM 4 to protect this fitting.
- Place the DataRAM 4 upside down on a table, resting the instrument on the inlet cover and the rear protective bumper.
- Unscrew the gray plastic cover of the filter cavity on the bottom surface of the DataRAM 4.
- Remove the filter cartridge from its cavity.
- Carefully clean the black soft filter-sealing gasket within the filter cavity by wiping it with the lint-free soft cloth. Use alcohol if necessary.

- Shine the concentrated light source into the sensing chamber located about 3 cm (1¼ in.) beyond the soft-sealing gasket in the filter cavity.
- Using the layout of the Figure 5 as a guide, locate the three smaller side cavities inside the sensing chamber, identified by the arrows on that figure. These three cavities contain the lenses of the two sources and the common detector of the DataRAM 4. The frontal surfaces of these lenses are likely to require cleaning if the instrument indicates BACKGROUND HIGH.
- Wet the cotton swab of the lens-cleaning tool with alcohol (e.g., methanol, ethanol, or rubbing alcohol).
- Holding the cleaning tool by its long handle, insert this tool into the sensing chamber without touching the walls of this chamber.
- Direct the cotton swab tip towards the opening of one of the three smaller cavities as indicated by the arrows of Figure 5, and insert the cotton tip into this cavity as far as it will go. Gently wipe that internal surface touched by the swab tip by a rotating motion. Carefully withdraw the swab tip from the cavity.
- Repeat previous cleaning step for the other two small cavities as indicated by the arrows of Figure 5.
- Carefully remove the cleaning tool from the sensing chamber. Allow the alcohol to dry leaving the filter cavity open for about 15 minutes.
- Re-insert the filter cartridge into its cavity and close it with its gray plastic cover, hand-tightening it firmly. Remove the inlet cap and store on its pod on the back panel.
- Place the DataRAM 4 right side up and key **ON**. Proceed to check its optical background by running the ZERO/INITIALIZE check as described in Section 9.2. The message READY! should appear at the end of this check indicating that the lens contamination has been eliminated. Should the message BACKGROUND HIGH persist after completion of the above-described lens cleaning procedure, please contact the factory.



LENS CLEANING TOOL



DataRAM 4 FRONT PANEL

DataRAM 4 BACK PANEL

Figure. 5. Lens cleaning tool and bottom view of open filter cavity showing location of sensor chamber lens cavities (arrows).

13.0 CALIBRATION

13.1 Factory Calibration

For mass concentration measurements, each DataRAM 4 is factory calibrated against a set of reference monitors that, in turn, are periodically calibrated against a gravimetric standard traceable to the National Institute of Standards and Testing (NIST).

The primary factory reference method consists of generating a dust aerosol by means of a fluidized bed generator, and injecting continuously the dust into a mixing chamber from which samples are extracted concurrently by two reference filter collectors and by two master real-time monitors that are used for the routine calibration of every DataRAM 4.

The primary dust concentration reference value is obtained from the weight increase of the two filters due to the dust collected over a measured period of time, at a constant and known flow rate. The two master real-time monitors are then adjusted to agree with the reference mass concentration value (obtained from averaging the measurements of the two gravimetric filters) to within $\pm 1\%$.

Three primary, NIST traceable, measurements are involved in the determination of the reference mass concentration: the weight increment from the dust collected on the filter, the sampling flow rate, and the sampling time. Additional conditions that must be met are: a) suspended dust concentration uniformity at all sampling inlets of the mixing chamber; b) identical sample transport configurations leading to reference and instrument under calibration; and c) essentially 100% collection efficiency of filters used for gravimetric reference for the particle size range of the test dust.

The test dust used for the factory calibration of the DataRAM 4 is SAE Fine (ISO Fine) supplied by Powder Technology, Inc. It has the following physical characteristics (as dispersed into the mixing chamber):

- Mass median aerodynamic particle diameter: 2 to 3 μm
- Geometric standard deviation of lognormal size distribution: 2.5
- Bulk density: 2.60 to 2.65 g/cm^3
- Refractive index: 1.54

In addition to the mass calibration described above, the DataRAM 4 is factory calibrated using a gas with known scattering coefficient in order to adjust the relative scattering irradiance at the two source wavelengths.

13.2 Field Gravimetric Calibration

If desired, the DataRAM 4 can be calibrated gravimetrically for a particular aerosol (dust, smoke, mist, etc.) under field conditions (actual conditions of use). To effect such calibration in the particle environment of interest, proceed as indicated below:

- Weigh and load into the analytical filter holder a fresh membrane filter (see Section 12.4.2).
- Start measurement run.

The duration of this comparison run should be sufficient to collect a mass of at least 1 mg on the reference filter (in order to permit accurate weighing of the collected mass by means of an analytical balance). The time-weighted average (TWA) reading of the DataRAM 4 can be used to estimate the required sampling time to collect the above-mentioned mass on the filter. To estimate the required sampling time (RUN TIME as measured on the DataRAM 4) in minutes, read the TWA value (see Section 9.6) after a RUN TIME of one minute or more, and apply the following relationship:

$$\text{RUN TIME} \geq 500/\text{TWA}$$

For example, if $\text{TWA} = 2.5 \text{ mg/m}^3$, then $\text{RUN TIME} \geq 200$ minutes (approximately 3 hours). If the TWA value changes significantly as the run proceeds, recalculate the required RUN TIME accordingly.

At the end of the run record TWA (in mg/m^3), RUN TIME (in minutes), and the flow rate Q (in liters per minute) used to sample the air. Weigh the filter on an analytical balance and obtain Δm , the mass increment due to the collected particles. Calculate the average gravimetric concentration C, as follows:

$$C = 1000 \Delta m / [(\text{RUN TIME}) \times Q]$$

Compare the recorded value of TWA and the calculated value C, and calculate the calibration factor to be programmed into the DataRAM 4 (see Section 9.0) as follows:

$$\text{CAL FACTOR} = C / \text{TWA}$$

For example, if C was found to be 3.2 mg/m^3 , and TWA had been determined to be 2.5 mg/m^3 , the CAL FACTOR equals 1.28. Select this value on the DataRAM 4 screen (or on the PC), as described in Section . This completes the gravimetric calibration of the DataRAM 4 for a specific aerosol.

14.0 COMMUNICATIONS WITH COMPUTER

14.1 Computer Hardware and Software Requirements

The computer requirements to install and run the software provided with the DataRAM 4 (DR4-COM) are the following:

- IBM-PC compatible
- Pentium I or higher processor
- Minimum operating system: Windows 95™ or better
- 32 MB of RAM
- 8 MB hard disk drive
- 3.5" floppy drive
- VGA or higher resolution monitor

The custom hardware and software provided with DataRAM 4 as standard accessories:

- Digital communications cable (model DR-DOC))
- Software floppy disk (3.5", model DR4-COM)

14.2 Software Installation Procedure

To install the provided software (DR4-COM) in the computer, proceed as follows:

- Insert the 3.5" disk labeled DR4-COM into the computer;
- Select **Start** and then **Run** on the computer screen;
- Type in on the **Command Line: a: install** (or **b: install**, as required);
- The computer displayed install shield then serves to guide the rest of the installation.

14.3 Communication Between DataRAM 4 and Computer

To effect the communication between the DataRAM 4 (via the DR4-COM software installed in the computer as described in the preceding section) and the PC proceed as follows:

- Connect the DataRAM 4 to one of the computer's serial ports using the DR-DOC cable provided. This cable has a 9-pin female connector for the computer port.
- Key **ON** the DataRAM 4. Select the ZERO/INITIALIZE line on the MAIN MENU screen and key **NEXT** to display the EDIT MENU screen. Then select the SETUP PARAMETERS line and key **ENTER**. Key **NEXT** repeatedly until SERIAL MODE appears. Select RS-232 if this has not been selected already.
- On the computer, double click on the **DR4-COM** icon. A multi-tabbed notebook display should appear on the computer screen. From the Menu Bar, select **Settings** and **Select Serial Port**. Select the port to which the DR-DOC cable

has been connected. From the multi-tabbed notebook displayed on the computer screen select the tab with the desired option. The options are:

- ♣ **Main:** This page allows the user to Device Filter and to operate the DataRAM 4 through the serial port;
- ♣ **Logged data:** This page allows the user to download, tabulate, print data, or transfer to a CSV file the data stored in the DataRAM 4. This page also serves to display real-time numerical data when the computer is connected to the DataRAM 4 in the Run Mode of the instrument;
- ♣ **Graph data:** This page enables the downloading and graphing of stored data to the computer screen and to a printer. In the Run Mode, this page displays the real-time data in graphic format;
- ♣ **Configure instrument:** This screen allows the user to edit the operating/logging parameters. Click on the item to be edited and select or type in the new value. To review the parameter values currently programmed into the DataRAM 4, click on **Get configuration**. After editing the parameters, click on **Set configuration** to input the newly selected values into the DataRAM 4.
- ♣ **Communication settings:** A DR4000 purchased after September 1, 2006 (Firmware version 105) will have a faster baud rate of 38400 bps. Prior to September 1, 2006 (Firmware version 104) will have a baud rate of 9600 bps. **Note:** DR4Com Software (version 3.0.4.0) does have the ability to auto-detect the instrument's baud rate. Manual change may be accomplished by going to **Settings / Baud Rate** and choosing **9600** or **38400**.

Most operations with the DR4-COM software program are self-evidently labeled, including fly-over dialog boxes. In addition, instructions may be found in the On-line Help files by selecting **H**elp and then **C**ontents.

The following operating/logging parameters of the DataRAM 4 can be selected (edited) via the computer:

- Current date (year, month and day of the month)
- Current time (hour, minute and second)
- Display averaging time (1 to 60 seconds, in 1-second increments)
- Calibration factor (0.01 to 9.99, in 0.01 increments)
- Analog output full scale concentration (0.1, 0.4, 1, 4, 10, 40, 100, or 400 mg/m³)
- Analog output status (enabled or disabled)
- Alarm level (0.001 to 409.5 mg/m³, in 1-μg/m³ increments)
- Alarm status (enabled or disabled)
- Particle size correction (enabled or disabled)
- Humidity correction (enabled or disabled)

The serial number of the DataRAM 4 is transferred automatically to the PC and displayed on the screen.

The year is to be entered as a two-digit number. Leap years are treated correctly until the end of the 21st century.

14.4 Real-Time RS-232 Output

During the RUN mode the DataRAM 4 can communicate real-time concentration data through its serial port via the DR4-COM software package. This software application decodes the data and displays it on the computer screen in both graphical and tabulated form.

In order to use this output with some other application, the following information will enable the user to decipher the encoded output signal. The communication settings for the digital output of the DataRAM 4 are:

- Baud rate: 9,600/38400 Version 105 or later
- Data bits: 8
- Stop bits: 1
- Parity: none
- Flow control: Xon/Xoff

14.5 Serial Communications Protocols of the DataRAM 4

The DataRAM 4 has two serial ports. These are RS-485 or RS-232. Only one can be active at a time. The active port is selected via the setup screen of the DataRAM 4 (see Section 9.4).

The RS-232 port is for direct connection of a single DataRAM 4 to a PC's comport as described in Sections 14.1 through 14.4.

The RS-485 port is intended for connecting the DataRAM 4 to a "2-wire" network of DataRAM 4's. If there is more than one DataRAM 4 on the network each unit will need to have a unique device number. A PC can be attached to the network with a RS-232/RS-485 interface. The PC will be the master and the DataRAM 4s are all slaves. The interface needs to be set as DCE and support the T-RTS/R-~RTS protocol. (The interface transmitter is turned on with RTS from the computer). The RS-485 runs at 9600/38400 baud.

The communications protocol is the same for both RS-485 and RS-232. It is a TTY type protocol. (i.e., not encoded; communication to a DataRAM 4 is performed with a simple terminal program.) The master PC sends a single line command terminated with a <cr>. A slave DataRAM 4 answers the command with possibly many lines, ending with the signal character of ">". The master times out after 2 seconds if there is no response from a slave.

The command format follows this general pattern:

<addr> <command> <parameter(s)> <cr>

<addr> is a numeric DataRAM 4 address, 1-125. Only the device named in the address is allowed to respond. This address is required for a network setup. If there is only one device on the network or if RS-232 is being used, then the **addr** can be either blank or "0". Then that device will answer, whatever its number.

<command> is a one keyword command. The commands recognized are listed in Appendix A. Mostly these pertain to setup variables in the DataRAM 4.

<parameters> depend on the command.

The response format will generally repeat the address and command and then follow with the DataRAM 4's current settings.

For example:

- ♣ The master PC sends: 27 backlight<cr>
- ♣ DataRAM 4 #27 responds: 27 backlight enabled<cr>> (note the following ">")
- ♣ The master PC sends: 27 backlight off<cr>
- ♣ DataRAM 4 #27 responds: 27 backlight disabled<cr>>

APPENDIX A

LIST OF REMOTE DIGITAL COMMANDS

Informational commands(Read only):

battery reports charge/discharge status: (battery charging 350 mA, or
battery discharging 65 pct)

display get screen display (also: disp, d)
DataRAM returns:
This is a technical display:
V 5 21 "1st line of display" (20 chars long)
V 5 22 "2nd line ..
V 5 23 "3rd line ..
V 5 24 "4th line ..
V 5 25 (row of cursor) (col of cursor) (is cursor on?) (state number)

memory get the percent of log memory available

output if running, get current readings(also out, o):
e.g.: output 75.2 64.5 25.1 50. 0.435
for *data, TWA, temperature, RH, and particle-diameter*

temp get current temperature (in tempunits selected) and humidity
(e.g.: temp 25.3 C 45: *temperature in degrees C, 45% RH*)

tags get list of tags with data

Set/Get commands (Read or Write)

alarm enable/disable, get/set value (mass in $\mu\text{g}/\text{m}^3$, scat in 1/Mm, range in km;

e.g.: alarm enabled 2000)

analogout get/set ANALOG_OUT range

For Mass concentration units:

0 for "0.10 mg/m3"
1 for "0.40 mg/m3"
2 for "1.00 mg/m3"
3 for "4.00 mg/m3"
4 for "10.0 mg/m3"
5 for " 40 mg/m3"
6 for " 100 mg/m3"
7 for " 400 mg/m3"
8 for "1000 mg/m3"

For Scattering units:

0 for " 10/Mm "
1 for " 100/Mm "
2 for "1000/Mm "
3 for "10000/Mm "
4 for "100000/Mm"

For Visual range units:

0 for " 500 km"

autostart Get/set auto start enable and date/time (e.g. enabled *hh mm dd mm*,
for hours, minutes, day, month)
autozero Enable/disable, value (e.g.: autozero enabled 1,
auto zero every hour)
calfactor Get/set CAL_FACTOR (e.g.: calfactor 1.0)
backlight Enable or disable the display backlight (e.g.: BACKLIGHT ENABLED)
date Set/get Dataram date [e.g.: date 31 12 2001 (day, month, year)]
displayavg Get/set the display averaging time in 1 to 60 seconds
(e.g. displayavg 10)
flowrate Get/set flowrate (e.g.: set flowrate to 2 LPM: flowrate 2.0)
logperiod Get/set log period in format hh mm ss (seconds, minutes, hours: 24
hours max)
rhcorrect Enable/disable Humidity correction (e.g.: rhcorrect enabled)
sizecorrect Enable/disable size correction (e.g. sizecorrect enabled)
tag Set the tag number and enable(if empty)/disable logging
tempunits Get/set Temperature units in Celsius or Farenheit (e.g.: tempunits
F)
time Set/get Dataram time [e.g.: time 23 59 59 (hours, minutes,
seconds)]
units Get/set UNITS:
0 for "(MASS) ug/m³",
1 for "(SCATR) /Mm " and
2 for "(RANGE) km "

Operational commands:

key Send key (ie, button) pushes (enter, next, right, left...) to the DataRAM
onoff(1), exit(2), next(3), enter(4), plus(5), minus(6), up(7), down(8),
right(9), left(10)
The DataRAM will return: KEY and the numeric version of the key
requested or 0 if the key is not recognized.
Note: 'display' is useful in conjunction with the 'key' command.
tagdump Transfer the tag data of the currently selected tag (see tag)

APPENDIX B

PRINCIPLE OF OPERATION OF THE DataRAM 4

General Description

The DataRAM 4 is a two-wavelength nephelometer (light scattering photometer) with active air sampling (i.e., using an internal pump). The patented optical system (US Patent No. 6,055,052) incorporates two sources of illumination (light emitting diodes). One of these emits at a peak wavelength of 660 nanometers (red) and the other at 880 nanometers (near infrared). The light beams from these two sources is collimated by means of corresponding lens systems such that these beams illuminate the same axial portion of the air flow duct. Figure 1B depicts the sensing configuration of the DataRAM 4.

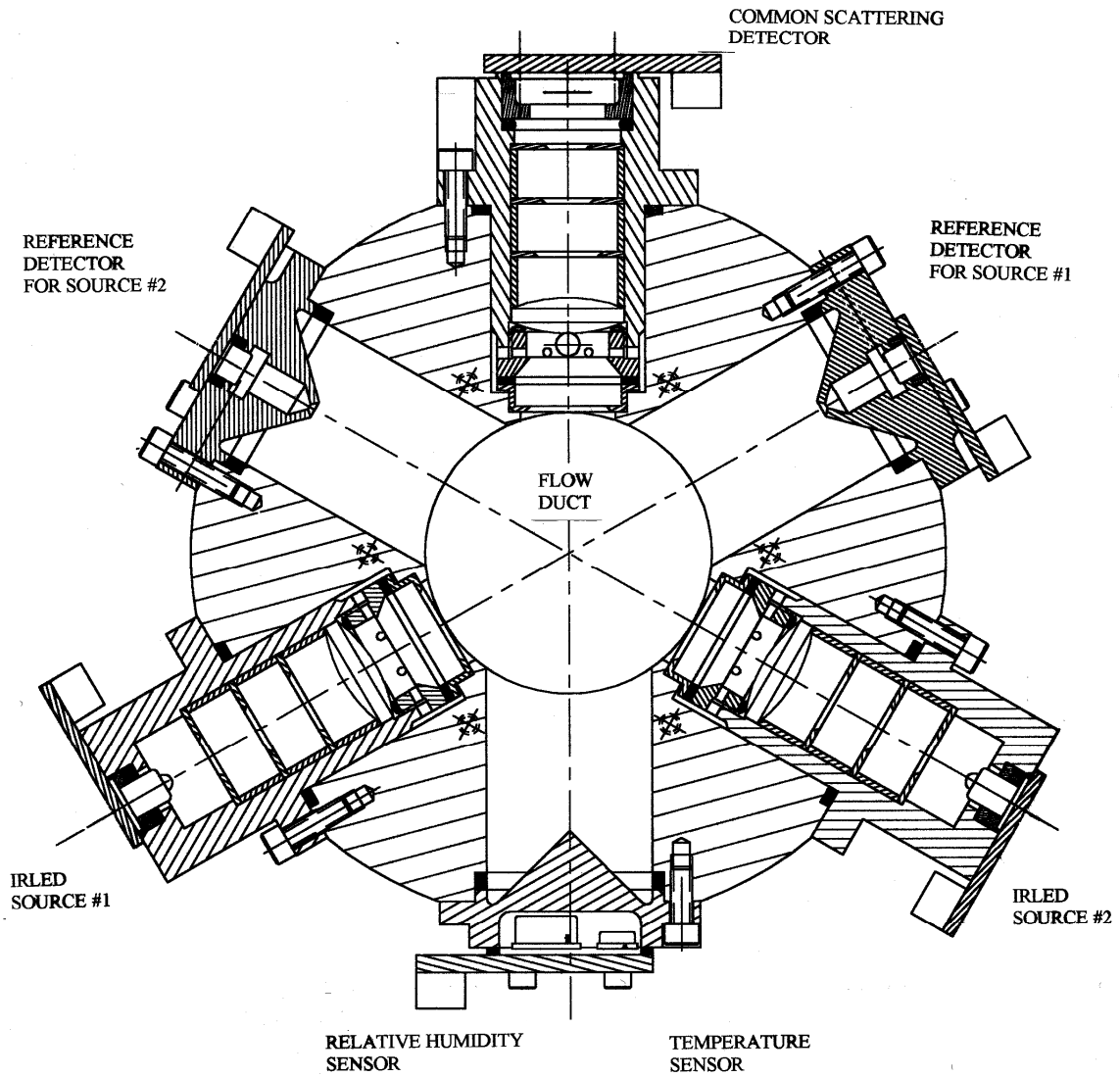
The axes of the two source beams are angularly symmetrical with respect to the axis of a common detector (silicon-hybrid preamplifier type) that senses the light scattered by particles passing through the illumination beams. The two sources are alternatively activated at a frequency of 27 pulses per second, i.e., only one source is turned on at a time. The detector output signal is gated in synchronism with the alternating source pulses, providing two signal channels, one for each wavelength.

The scattering angle for both source-detector combinations is centered on $60^\circ (\pm 18^\circ)$ with respect to the forward direction of the two beams.

Figure 1B

DataRAM 4 Two-Wavelength Portable Nephelometer

Optical Sensing Configuration



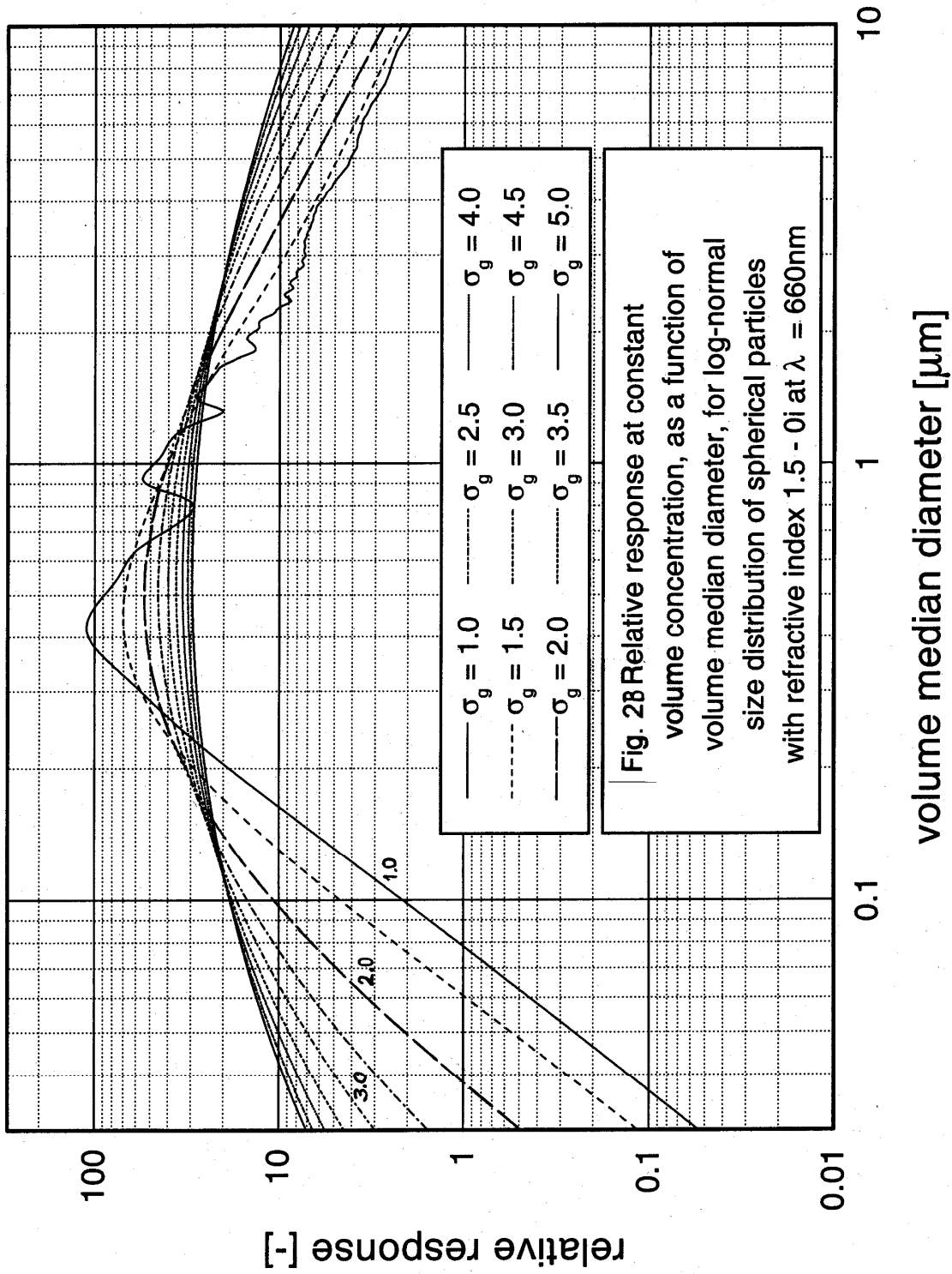
After these two beams traverse the sensing region within the flow duct, they enter their respective light traps at the end of which there are corresponding reference detectors that sense the intensity of each of the illumination beams. Feedback circuits ensure that the light output of both sources remains constant.

The Effect of Particle Size

The magnitude of the detected light scatter at either of the two wavelengths is directly proportional to the amount of particles passing through the sensing region of the DataRAM 4, defined as the volume of intersection between the illumination beams and the field of view of the common scattering detector. This response linearity, however, assumes that the optical properties of the particle population remain constant, i.e., that particle size and shape distributions, and effective particle refractive index do not change appreciably*. In practice however, and especially for the fine particle fraction (PM_{2.5}) in ambient environments, particle size can vary appreciably over time and from site to site due to particulate emission and climatic changes. The effect of particle size changes on the scattering signal depends on the ratio of that size to the wavelength used to generate that scatter, and also on the breadth of the size distribution.

Figure 2B shows the relative scattering signal (at the 660 nm wavelength) as a function of the volume median particle diameter for several different geometric standard deviations (σ_g , a measure of the spread of particle sizes) for single-mode log-normally distributed particle populations, for an effective particle refractive index of 1.50 (a typical value for ambient environments). This graph represents the response (output) of the DataRAM 4 assuming constant particle volume concentration (constant mass concentration for a given particle density) as a function of the median size of the particle population being measured. Under most practical situations, this population will not be monodisperse (geometric standard deviation of 1.0) but will be polydisperse, i.e., will have a range of sizes with a single or a multi-mode log-normal distribution. The fine particle fraction of ambient environments (PM_{2.5}) can usually be modeled by a single-mode log normal distribution with a geometric standard deviation of 2.0 and a refractive index of approximately 1.50 (for low relative humidity conditions). The response of the DataRAM 4 to that population of particles is represented by the curve labeled 2.0 of Figure 2B.

* Additional conditions that must be satisfied for response linearity are those of independent and single scattering, both of which are fulfilled over the operating range of the DataRAM 4.



For an idealized mass monitor, the response curves of Figure 2B would be reduced to a single horizontal line, implying that the measurement of mass concentration is independent of particle size. The inherent behavior of light scattering (as modeled by the rigorous Lorenz-Mie theory for spherical particles*), however, precludes such size independence. Alternatively, based on that size dependence and by measuring the ratio of the responses at two different wavelengths it is possible to determine the particle size and, consequently, to correct the mass measurement accordingly. This capability has been incorporated in the DataRAM 4 and is intended to be applied to fine particle monitoring, in combination with an inertial coarse-particle precollector (e.g., impactor). This precollector removes the particle population (typically larger than an aerodynamic diameter of 2.5 μm) whose size exceeds that of the fine particle fraction.

When the particle size correction algorithm is enabled (the user has the option to disable it), the DataRAM 4 computes the mass concentration as follows:

- a) The scattering signal detected at the wavelength of 880 nm (after subtraction of the zero particle concentration offset) is cross correlated with the corresponding signal detected at 660 nm, and a combined signal is generated;
- b) The ratio of the signals at 880 nm and at 660 nm is computed;
- c) Based on the ratio determined in step b), the volume median particle diameter is determined (from a stored look-up table derived from Lorenz-Mie calculations based on the DataRAM 4 optical geometry and spectral sensing characteristics) for a particle refractive index of 1.50 and a log-normal size distribution with a σ_g of 2.0**;
- d) The particle size determined in step c) is then used to obtain the particle volume (i.e., mass) correction factor (also stored as a look-up table); and
- e) The above determined particle volume correction factor is applied to the combined signal generated in step a) in order to compute the mass concentration.

The equivalence between particle volume and mass used within the DataRAM 4 is based on the calibration dust (SAE Fine) density of about 2.6 g/cm^3 which is representative of a wide range of particle materials in the environment. The user, however, can select a different particle density scaling factor on the DataRAM 4 (i.e., the CAL FACTOR).

The DataRAM 4 performs the above discussed particle size computation in real time on condition that the sensed mass concentration exceeds 0.005 mg/m^3 (5 $\mu\text{g}/\text{m}^3$). If the concentration falls below that threshold, the DataRAM 4 performs this computation and the size correction of the mass measurement based on the last size determination that had been performed when the above concentration threshold was exceeded.

* Field investigations indicate that the fine particulate fraction consists predominantly of spherical particles

** For custom applications involving different refractive indexes and/or particle size distributions, please consult Thermo Fisher Scientific

Scattering Coefficient, Visual Range and Ångström Coefficient

The fact that the DataRAM 4 incorporates the capability to measure the wavelength dependence of the scattering of light by airborne particles allows the determination of the atmospheric visibility effects of that population. These effects are customarily referred to a standard wavelength of 550 nm, the approximate center of the photopic response of the human eye as well as the peak of the solar irradiance spectrum.*

The **scattering coefficient** is the primary parameter sensed by the light scattering system of a nephelometer such as the DataRAM 4. This coefficient is a logarithmic exponent that represents the degree of light attenuation due to scattering, per unit path length, expressed in the units of inverse length (e.g., inverse megameters, abbreviated as Mm^{-1}). By measuring the scattering coefficient at two different wavelengths it is possible to establish the wavelength dependence of that coefficient and, consequently, calculate the scattering coefficient at the reference wavelength of 550 nm. This calculation is performed within the DataRAM 4 and this information can be displayed/logged as measurement parameter in lieu of the mass concentration data.

Based on the value of the measured scattering coefficient the DataRAM 4 then computes what is called the **visual range** defined as the distance, under daylight conditions, at which the apparent contrast between a specified target (usually a black surface) and its background (horizon sky) becomes just equal to the threshold contrast of the average observer. This dependence of the visual range on the scattering coefficient assumes that light absorption by the particle population under scrutiny is negligible compared to scattering. Although this assumption is not always satisfied, for a majority of cases it constitutes an acceptable approximation. The empirical relationship between the scattering coefficient sensed by the DataRAM 4 and the visual range is given by the Koschmieder equation. The visual range (in the units of kilometers) can also be displayed/logged as measurement parameter in lieu of either the mass concentration or of the scattering coefficient.

Finally, and based on the ratio of the detected irradiances at the two operating wavelengths, the DataRAM 4 is programmed to compute the **Ångström coefficient**. This coefficient is a dimensionless exponent that expresses the functional relationship between the atmospheric scattering coefficient and the wavelength of light, and is dependent on the size distribution of the fine particle fraction. Theoretically, the Ångström coefficient varies over the range of 0 to 4. The limit value of 4 is for scattering by particles whose size is much smaller than the wavelength of visible light (Rayleigh or molecular scattering regime). The limit of 0 is for particles larger than the wavelength of the illuminating light (geometric regime). This coefficient can also be displayed on the DataRAM 4 screen, as a secondary parameter.

* The near matching between these two peaks is generally attributed to an evolutionary selection process

The Effect of Ambient Humidity

Fine airborne particles tend to accrete liquid water whenever the relative ambient humidity is high. Therefore, particles grow in size as humidity increases. This growth has been found to be generally negligible up to relative humidity (RH) levels of about 50%. At higher levels, especially over 70% this growth becomes very significant to the point that the majority of the mass of the fine particulate matter is constituted of water.

Figure 3B shows the relationship between the concentration measured by a nephelometer (model DR-2000, DataRAM) and a collocated gravimetric sampler. The curve is an interpolation of experimentally obtained field data. This curve shows that below a RH of 50% the two devices agree whereas above that point the nephelometer indicates a higher value which is the result of the humidity induced particle growth mentioned above.

For atmospheric visibility measurements this high-humidity particle growth effect must be included since the purpose of such measurements is to assess the actual visual effects of airborne particles. For fine particle mass concentration determinations, however, the accreted water interferes with the measurement of interest, i.e., monitoring the mass of the original core particles. Gravimetric methods require sample conditioning (post sampling drying) to eliminate the water accreted by the collected particulate matter sample. Continuous mass monitors such as those based on beta attenuation or on mechanical resonance have heretofore relied on sample heating to enhance water evaporation. This latter approach, however, not only reduces the amount of interfering water but also causes partial evaporation of semi-volatile particle components of interest, thus introducing a measurement error. Other methods, such as diffusion drying can be applied without affecting the measurement of semi-volatiles, but are inconvenient in their application to continuous unattended ambient monitoring.

In the case of the DataRAM 4, the user has the option to activate an automatic humidity correction that is based on the experimentally obtained curve of Figure 3B. When the humidity correction process is enabled (by keystroke selection), the DataRAM 4 applies a correction factor to the measured mass concentration that depends on the relative humidity measured within the optical sensing chamber. For example, if the sensed humidity were to be 80%, the DataRAM 4 without correction would over-read by a factor of 1.8 with respect to a gravimetric sampler. If the automatic humidity correction is enabled, the optically sensed concentration will be internally multiplied by $1/1.8$, or 0.56, in order to compensate for the humidity induced particle growth. This correction is valid for most fine particle measurements, but should not be applied to measurements of larger particle sizes. This correction takes into account the change (decrease) in the refractive index of the grown particles due to the predominance of water (with its lower index).

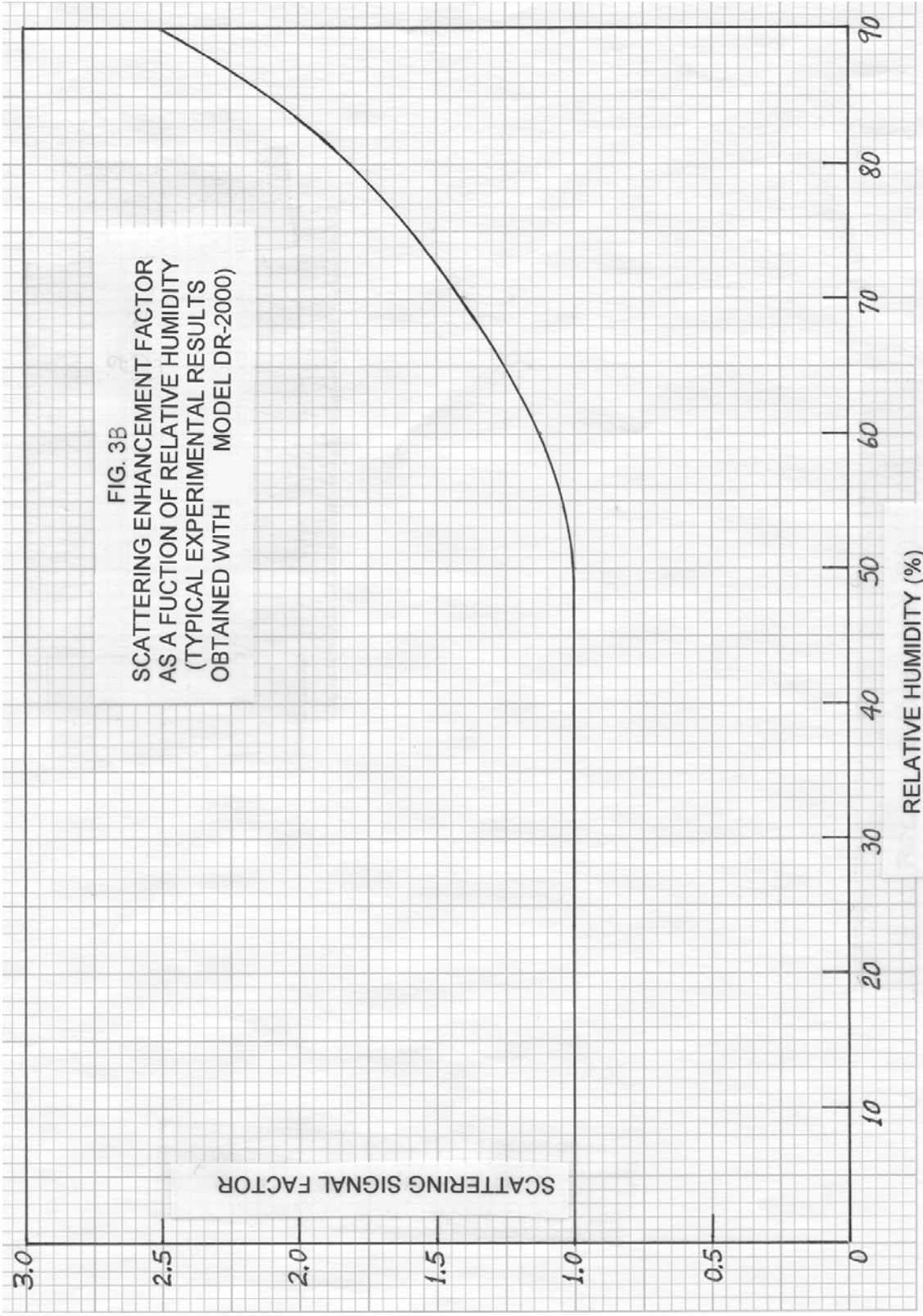


FIG. 3B
 SCATTERING ENHANCEMENT FACTOR
 AS A FUNCTION OF RELATIVE HUMIDITY
 (TYPICAL EXPERIMENTAL RESULTS
 OBTAINED WITH MODEL DR-2000)

SCATTERING SIGNAL FACTOR

RELATIVE HUMIDITY (%)

The particle size determination, based on the ratio of signals at the two DataRAM 4 wavelengths (discussed above) is not significantly affected by the change in refractive index associated with the particle uptake of liquid water. In the PM_{2.5} range, a change of particle refractive index from the typical dry value of about 1.50 to that of pure water (1.33) causes a sizing error ranging from 0% for 0.1 µm particles to 7% for 2.5 µm particles. The actual sizing error is likely to be smaller since the refractive index of water-accreted ambient particles generally exceeds 1.40.

It is of interest to note that if the DataRAM 4 is used in conjunction with an in-line sample stream heater (e.g., model DR-TCH), and the resultant measurements are compared with the humidity corrected measurements mentioned above (without the heater), it is possible to assess the loss of particle mass due to evaporation of semi-volatile particles. Alternatively, if there were no difference between measurements obtained with and without the inlet heater, it would indicate that there is no humidity induced particle growth and thus, the humidity correction should not be enabled.

SERVICE LOCATIONS

For additional assistance, service is available from exclusive distributors worldwide. Contact one of the phone numbers below for product support and technical information or visit us on the web at www.thermo.com/aqi.

1-866-282-0430 Toll Free
1-508-520-0430 International

APPENDIX C

LIST OF DR-4000 Fault/Failure Error Codes

ERROR CODE	DESCRIPTION	POSSIBLE CAUSE (IF ERROR PERSISTS)	ACTION TO CORRECT
0000	No Fault/Failure		
0001	Source 1 Fault/Failure	Damaged connector or obstruction in Optics chamber.	Remove filter cap and check for obstructions in the optical path.
0010	Source 2 Fault/Failure	Damaged connector or obstruction in Optics chamber.	Remove filter cap and check for obstructions in the optical path.
0100	Detector Fault/Failure	Damaged connector or obstruction in Optics chamber.	Remove filter cap and check for obstructions in the optical path.
1000	Pump Fault/Failure	Filter is clogged or pump is worn / defective. Sampling contaminated air without a filter or with a clogged filter will shorten the life of the pump.	Use the HEPA filter whenever the sample filter is not required. To see if the HEPA filter is clogged, try to run the pump will run (less than a minute) without the HEPA filter.

Please note the four-bit code indicates whether or not one of four monitored signal voltages was out of specification during a logged run. Because of signal noise, eventually all four error bits will become set ("1111") if the equipment is operated for extended periods without performing a periodic zero cycle.

During a run, the DR-4000 switches to the DIAGNOSTICS display whenever an error is detected. This is not necessarily an indication of instrument failure unless the error(s) persists. Persistent faults displayed in the 'DIAGNOSTICS' display for longer than 4 seconds indicate that an instrument may require service.

