# ES-642 Dust Monitor
# Operation Manual

**ES-642-9800, Rev G**

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# 1   INTRODUCTION

## 1.1  About This Manual

This document is organized with the most important information grouped together for easy reference by the user. All ES-642 owners and operators should read and understand the sections on installation, setup, and field calibrations. Other sections that provide in-depth information on subjects such as theory, diagnostics, accessories, and alternate settings provide valuable information which should be consulted as needed. An electronic version of this manual is also available.

## 1.2  Technical Service and Warranty

This manual is structured by customer feedback to provide the required information for setup, operation, testing, maintaining, and troubleshooting your ES-642. Should you still require support after consulting your printed documentation, we encourage you to contact one of our expert Technical Service representatives during normal business hours of 7:00 a.m. to 4:00 p.m. Pacific Time, Monday through Friday. In addition, technical information and service bulletins are often posted on our website. Please contact us and obtain a Return Authorization (RA) number before sending any equipment back to the factory. This allows us to track and schedule service work and to expedite customer service.

| | | | |
|---|---|---|---|
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## 1.3  About the ES-642

The Met One Instruments, Inc. model *ES-642* is a type of nephelometer which automatically measures real-time airborne $PM_{10}$, $PM_{2.5}$, $PM_1$ or TSP particulate concentration levels using the principle of forward laser light scatter.

**Laser Light Scatter System**
Sample air is drawn into the ES-642 and through the laser optical module, where the particulate in the sample air stream scatters the laser light through reflective and refractive properties. This scattered light is collected onto a photodiode detector at a near-forward angle, and the resulting electronic signal is processed to determine a continuous, real-time measurement of airborne particulate mass concentrations.

## 1.4  Laser Radiation Safety and Conformity

**The ES-642, when properly installed and operated, is considered a Class I laser product. Class I products are not considered to be hazardous.**

This system contains a diode laser operating at < 5 mW power and 670 nm wavelength. This is visible to the naked eye, and can cause damage to the eye if directly exposed. A protective optical housing fully encapsulates the laser beam and optics system within the ES-642. Do not attempt to disassemble the optical module. Failure to comply with this instruction could cause accidental exposure to laser radiation. The manufacturer certifies that this product operates in compliance with the following standards and regulations:

- **FDA / CDRH This product is tested and complies with 21 CFR, Subchapter J, of the Health and Safety Act of 1968.**

- **US 21 CFR 1040.10.**

Always power down the system whenever service or repair work is to be performed inside the instrument enclosure. Only trained technicians should attempt to repair the ES-642. Routine maintenance does not require removing the instrument from its weatherproof enclosure.

## 1.5 ES-642 Specifications

| PARAMETER | SPECIFICATION |
|---|---|
| Measurement Principles: | Particulate concentration by forward light scatter laser Nephelometer. |
| Available Cut Points: | TSP Inlet Standard. PM10, PM2.5, and PM1 sharp-cut cyclone inlets available. |
| Measurement Range: | 0 to 100 mg/m3 (0 to 100,000 µg/m$^3$) |
| Measurement Sensitivity: | .001 mg/m$^3$. |
| Nephelometer Accuracy: | ± 5% traceable standard with 0.6 µm PSL. |
| Particle Size Sensitivity: | 0.1 to 100 micron. Optimal sensitivity 0.5 to 10 micron particles. |
| Long Term Stability: | 5% with clean optics. |
| Laser Type: | Diode Laser, 5 mW, 670 nm. Visible red. |
| Display: | 2 X 16 backlit LCD.  Provides information on operation including: Power, Flow Operation, Status and Concentration. |
| Zero Calibration: | Automatic Zero Calibration every hour or as programmed from 1 to 999 minutes. |
| Flow Rate: | 2.0 liters/minute ± 0.1 lpm. Actual volumetric flow. |
| Pump Type: | Brushless Diaphragm (20,000 hour). |
| Power: | 11 – 40 VDC @ 1.5 A maximum. |
| Power Consumption: | 350 mA (no heater) 1.1 A (with heater) @ 15 VDC. |
| Analog Output: | 4-20 mA and 0 – 2, 0 – 5 or 0 - 10 VDC, selectable. |
| Digital I/O: | RS-485 full and half duplex, RS-232. |
| Alarm Output: | Normally open and normally closed relay 30 VDC @ 1A maximum. |
| Purge Filter | 0.2 micron |
| Protection Filter: | 5.0 micron. |
| Serial Communication: | ASCII and MODBUS RTU. |
| Operating Temperature: | 0 to +50°C . (Ambient Temperature Sensor Range -30 to +50°C). |
| Barometric Pressure: | 600 to 1040 mbar absolute barometric pressure sensor range. |
| Ambient Humidity Range: | 0 to 90% RH, non-condensing. |
| Humidity Control: | Automatic 10 Watt inlet heater module controlled to sample RH, with set point. |
| Approvals: | CE, ISO-9001. Designed to agree with EPA Class I and Class III FRM/FEM particulate samplers and monitors. Not an EPA-designated equivalent method. |
| Factory Service Interval: | 24 Months typical, under continuous use in normal ambient air. |
| Mounting Options: | Optional wall mount bracket.  Optional mounting tripod. |
| Unit Weight: | 2.7 kg (6 lbs) |
| Unit Dimensions: | 25.4cm high, 17.8cm wide, 10.8cm deep. (10.0" x 7.0" x 4.25"). Without inlet assembly.<br>48.3cm high, 17.8cm wide, 10.8cm deep. (19.0" x 7.0" x 4.25"). With inlet assembly. |

Specifications may be subject to change without notice.

# 2  ES-642 SETUP and STARTUP

The ES-642 is designed for rapid deployment and easy setup by a single person. This section describes the basic assembly, setup, and start-up of the instrument.

## 2.1  Standard and Optional Accessories

When unpacking a new ES-642, verify that the contents are undamaged. If the shipping cartons are damaged, notify the carrier immediately. Verify that the included accessories are correct and complete. If anything is missing, contact the technical service department at service@metone.com or (541) 471-7111. See the Accessories section at the back of this manual for more details. The normal configuration of the ES-642 is supplied with the following standard accessories:

- Weatherproof TSP inlet with debris screen.
- Multi-Signal cable PN 80959 (10 ft)
- External Power cable PN 80943 (10 ft)
- Instruction manual.  ES-642-9800
- Mounting ears

The following optional accessories may or may not also be included, depending on the order:

- Sharp Cut Cyclone for $PM_{10}$, $PM_{2.5}$ or $PM_1$ cut-points

- 82836 Mounting Bracket Kit

- 81039 Solar Shield Kit

## 2.2  Setting Up the ES-642

Set up the rest of the ES-642 hardware items and accessories as described below:

1. **Install $PM_{10}$, $PM_{2.5}$, $PM_1$ cyclones and TSP inlets:** For TSP (Total Suspended Particulate) monitoring, the included weatherproof TSP inlet is simply installed directly onto the top of the ES-642 inlet tube to keep water, insects, and debris out of the instrument. For $PM_{10}$, $PM_{2.5}$ or $PM_1$ monitoring, the optional sharp-cut cyclone of the desired cut-point must be installed onto the inlet tube, under the TSP inlet. Lubricate the o-rings if necessary. Never operate the ES-642 outdoors without at least the TSP inlet in place, as the resulting water/debris damage is not covered under warranty.



**Figure 2-1 Sharp cut cyclone attached to intake**

## 2.3  Mounting Options

### 2.3.1  Basic Unit Mounting:

The ES-642 can be mounted using the included mounting ears. The unit must be screwed or bolted to the support structure with appropriate hardware.   For normal wall or pole mounting the optional mounting bracket is recommended.
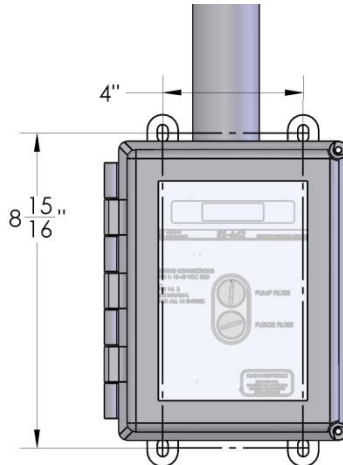


**Figure 2-2 Basic Mounting Installation**

### 2.3.2  Wall or Pole Mounting:

The ES-642 can be wall mounted using the optional mounting bracket.  This bracket can be used for both wall and pole mounting of the ES-642.  The mounting bracket must be screwed or bolted to the support structure with appropriate hardware.  When pole or tripod mounted, the V-Bolts can be used to attach the mounting bracket.   1/4-20 hardware is used to mount the ES-642 to the mounting bracket.



**Figure 2-3 Typical Wall Mounting**



**Figure 2-4 Typical Pole Mounting**

Note: Take care to ensure that there is adequate clear space around the inlet to allow unrestricted airflow into the instrument.  Mount the instrument with no large obstructions nearby whenever possible.

In some applications, an optional solar and weather shield may be required due to extreme weather conditions.  Request part number 81039.  It attaches to the mounting bracket for the ES-642.

## 2.4 Electrical Connections

The standard ES-642 has two weatherproof connectors on the bottom of the unit. These connectors provide the connections for the power supply, analog outputs, alarm outputs, and communications options. The ES-642 will turn on automatically whenever a power source is connected to the power input, there is no power switch.  The ES-642 is supplied with two 10 foot long cables (80959, 80943).  The user can cut these cables to any desired length. NOTE:  Make sure you have cut any exposed wires, which are not being used, so that they can't short together.

Because of the heater power required and to prevent any ground loops, it is recommended that a junction box be used to terminate the supplied cable.  At this point larger AWG wires can be used for longer connections, or the power source can be located in this junction box.  This will help to reduce any power lost in the heater power wires.
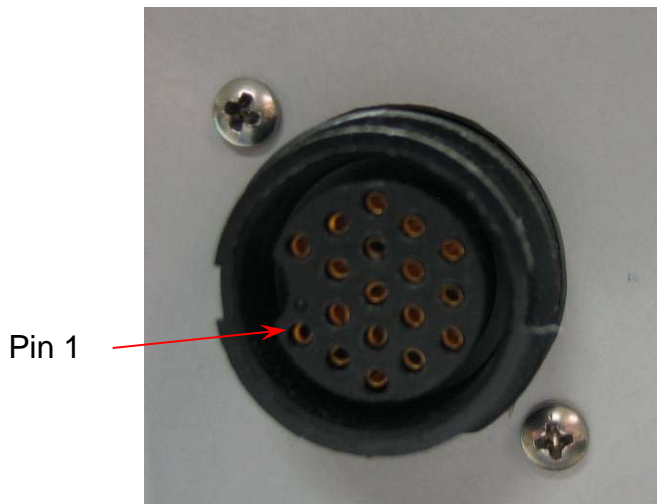


Pin 1

**Figure 2-5 Connector Layout**

| Signal | Pin Number | Color (80959) |
|---|---|---|
| Power Input 11 – 40 VDC | Pin 1 | Red |
| Ground | Pin 2 | Black |
| RS-485 TX + | Pin 3 | White |
| RS-485 TX - | Pin 4 | Green |
| RS-485 RX + | Pin 5 | Orange |
| RS-485 RX - | Pin 6 | Blue |
| RS-232 TX | Pin 7 | White/Black |
| RS-232 RX | Pin 8 | Red/Black |
| Analog Sense | Pin 9 | Green/Black |
| Analog Voltage Signal Output | Pin 10 | Orange/Black |
| 4 – 20 mA Signal Output | Pin 11 | Blue/Black |
| Relay Normally Closed Alarm Output | Pin 12 | Black/White |
| Relay Normally Open Alarm Output | Pin 13 | Red/White |
| Relay Common Alarm Output | Pin 14 | Green/White |
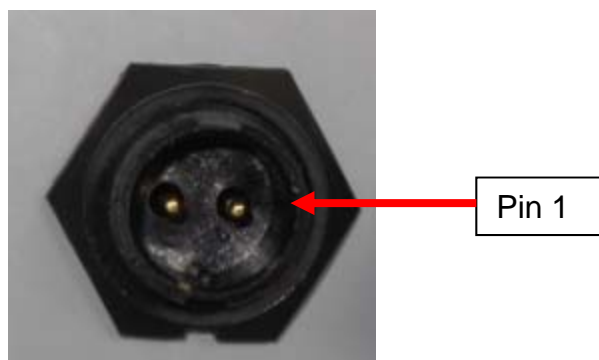
**Figure 2-6 ES-642 Power Connector**

| Signal | Pin Number | Color (80943) |
|---|---|---|
| Power Input 11 – 40 VDC | Pin 1 | Red |
| Ground | Pin 2 | Black |

### 2.4.1 Power Requirements

The ES-642 will require at least 11 VDC @ 1.5 Amp when the heater is operating.  The positive connection will be connected to pin 1 Red while the negative connection will be connected to pin 2 black.

### 2.4.2 RS-485 Connections

The RS-485 can work in Full Duplex (4 wire continuous bidirectional serial communication) or Half Duplex (2 wire command response serial communication).  To connect as a 4 wire Full Duplex connect the TX+ and TX- outputs from the computer to the TX+ (white) and TX- (green) connections of the ES-642.  Connect the RX+ and RX- inputs from the computer to the RX+ (orange) and RX- (blue) wires.  For Half Duplex jumper the TX+ connection to the RX+ connection and the TX- connection to the RX- connection.  Then connect the computer + and – connections to these pairs.

### 2.4.3 RS-232 Connections

The RS-232 can be connected to a computer using RS-232 TX (white/black) input to pin 2 of a female DB-9 connector and RS-232 RX (red/black) output to pin 3 of the DB-9 connector.  Please note you will need to share the power ground (black) with pin 5 of the DB-9 connector.

### 2.4.4 Analog Sense

The heater and pumps can draw a large amount of current from the power supply.  The ground current will have an effect on the analog output voltage.  When the heater turns on, it would make the analog output appear to change due to the voltage drop in the cable.  The analog sense wire should be connected to the ground input of the external logger monitoring the analog voltage. The power supply ground, should also be connected to the loggers input ground (see appendix F). This will compensate the analog output for any change in current from pumps and heater.

### 2.4.5 Analog Voltage Output

The analog voltage output is the proportional voltage output for the concentration.  The maximum concentration for the analog output can be set using the AR serial command and the analog

voltage range can be set with the AV command (See Appendix C for more information on serial commands). For example if the maximum concentration is set to 10,000 µg/m$^3$ and the analog output voltage range is set to 0 – 10 VDC, the output voltage would represent 0 to 10,000 µg/m$^3$ or 1 µg/m$^3$/mv. Note: See appendix F for suggested wiring.

### 2.4.6  4 to 20 mA Analog Output

The 4 to 20 mA analog output is the proportional current output for the measured concentration. The maximum concentration span value for the analog output can be set using the AR serial command (See Appendix C for more information on serial commands). For example if the maximum concentration span is set to 10,000 µg/m$^3$, the output current of 4 to 20 mA would represent 0 to 10,000 µg/m$^3$ or 1µg/m$^3$/1.6 µA. Note:  See appendix F for suggested wiring.

### 2.4.7  Concentration Relay Contact

The ES-642 has the ability to activate a relay if the concentration limit set by the SPA serial command has been exceeded (See Appendix C for more information on serial commands).

This relay has a normally open contact which closes when the relay is activated and a normally closed contact which opens when the relay is activated (Form C).  The COM connection is going to be one of the connections used while the user will decide if they want a Normally Open or Normally Closed connection.  See section 4 for more information on the alarm relay.

## *2.5  Power-Up and Starting Operation*

As soon as power is applied to the ES-642, the unit will start and display the following screens while the automatic zero process is running.

```
CONC:    0.000 mg        CONC:    0.000 mg        CONC:    0.000 mg
ZEROING                  TEMP       25.2 C        RH          42 %

CONC:    0.000 mg
BP       978 mbar
```

When the zero process has completed the unit will show the following screens:

```
CONC:    0.010 mg        CONC:    0. 010 mg       CONC:    0. 010 mg
SAMPLING                 TEMP       25.2 C        RH          42 %

CONC:    0. 010 mg       CONC:    0. 010 mg
BP       978 mbar        FLOW      2.0 lpm
```

The concentration is always displayed on the top line while the second line cycles through the various measurements.

If an error occurs, the display will change to show the fault on the second line as shown below:

```
CONC:    0. 010 mg
Flow Error!
```

## 2.5.1 Default Setup

The ES-642 is factory configured to measure continuously and perform hourly self-tests. The following table lists some of the factory default configurations which may need to be changed for your application. See Section 9 for details about the settings.

| Parameter | Setting |
|---|---|
| Update Period | 1 Second |
| Sampling Mode | Continuous |
| Auto Zero Interval | Hourly |
| Concentration Range Display | 0 - 100 mg/m3 |
| Concentration Range Analog Output | 0 - 1 mg/m3 |
| Analog Output Current Range | 4 - 20 mA |
| Analog Output Voltage Range | 0 – 10 VDC |
| K-Factor | 1.0 |
| RH Set Point | 40% |
| Baud Rate | 9600 |
| Concentration Alarm Relay Output | Off |

# 3  SITE SELECTION

Use the following criteria when deciding on a sampling location for the ES-642. Always consider the safety and security of the unit, as well as the suitability of the sampling environment.

## 3.1  Site Selection Requirements

Selection of a proper site for the ES-642 is critical for accurate measurements.

The following is a summary of general ambient particulate monitoring site requirements that will be appropriate for use with the ES-642 in many cases. Some of these criteria may not be appropriate in some applications, due to the versatile nature of the ES-642:

**Inlet Height:**

- The inlet should be located in the "breathing zone", between 2 and 15 meters above ground level. When installed on the standard tripod, the ES-642 inlet is positioned two meters above the ground or other mounting surface, when used with a cyclone.

- If the ES-642 is to be collocated with other particulate instruments, such as FRM filter-type samplers or BAM units, then the air inlet must be the same height as the inlet of the other samplers, within one meter vertically. Within one foot is preferred.

- If the ES-642 inlet is the highest point on a building, then lightning rods must be installed to prevent destruction of the unit during electrical storms.

**Inlet Radius Clearance:**

- If an ES-642 is to be collocated at a station along with BAM or FRM samplers, the inlets of each sampler must be no less than one meter apart from each other, and no more than four meters apart. Two meter inlet spacing is recommended where possible.

- If installed near a $PM_{10}$ Hi-Volume sampler, then the distance between the inlet of the ES-642 and the Hi-Vol must be no less than two meters.

- There should be at least a 270 degree arc of unrestricted airflow around the inlet. The predominant direction of concentration movement should be included in the arc.

**Artificial Particulate Sources:**

To avoid possible errors in the concentration measurements, the inlet must be located as far as possible from any artificial sources of particulate, such as blowers, vents, or air conditioners on a rooftop. Especially if any of these types of devices blow air across the inlet of the ES-642. Even sources of filtered air must not blow across the inlet.

# 4 CONCENTRATION ALARM RELAY SET POINT

The ES-642 has a relay output designed to indicate that the measurement has exceeded a set point for an average period of 1 minute.  The relay has a normally open contact and a normally closed contact.  The relay will energize when the concentration exceeds the concentration alarm set point for more than 1 minute.  The normally closed contact will open and the normally open contact will close.

**Note:** The ES-642 relay is intended for DC operation only with a 30VDC @ 1A maximum load.

## 4.1  Setting the Concentration Alarm Relay Set Point

To change the concentration alarm set point using a serial communication program you would use the SPA serial command to change the set point.

Example:

The maximum value of concentration desired is 1000 µg/m$^3$.  Type SPA 1000 <ENTER>  The concentration alarm relay set point is now 1000 µg/m$^3$.

# 5 FIELD CALIBRATIONS

The ES-642 has a system of serial commands which allow the operator to audit or calibrate the airflow control system parameters for optimal performance. These parameters are often audited monthly and calibrated quarterly during continuous operation. The exact frequency may vary depending on the harshness of the local conditions and the data validation requirements established by the sampling program administrator and your resulting standard operating procedures (SOP).

**Note:** The ES-642 temperature and pressure should always be checked before any flow calibrations are performed, since the flow calculation is dependent on these parameters.

## 5.1 Ambient Temperature Calibration

The AT screen is used for field audits or calibrations of the ambient temperature measurement of the ES-642.

```
CONC:     0. 010 mg
TEMP        25.2 C
```

Note: The ES-642 ambient temperature sensor is a thermistor bead on the bottom panel of the ES-642.   As such it is not particularly accurate compared to solar shielded or motor aspirated temperature sensors.   An accuracy of ±2 degrees C is adequate for flow control purposes.

To change the temperature calibration using a serial communication program you would collocate a reference standard near the intake head and then use the RA serial command to change the temperature calibration.

Example:

The collocated temperature sensor reads 26 degrees C and the temperature sensor on the ES-642 reads 23 degrees C.  Type RA 26 <ENTER> The temperature calibration has now been corrected to read 26 degrees C on the display.

## *5.2  Ambient Pressure Calibration*

The CALIBRATE BP screen is used for field audits or calibrations of the ambient barometric pressure measurement of the ES-642.

```
┌─────────────────────────┐
│ CONC:    0. 010 mg       │
│ BP       978 mbar        │
└─────────────────────────┘
```

The BP parameter is the current reading from the ES-642 pressure sensor. To change the BP calibration using a serial communication program you would collocate a reference standard and then use the RP serial command to change the BP calibration.

Example:

The collocated pressure sensor reads 974 mbar and the BP sensor on the ES-642 reads 978 mbar.  Type RP 974 <ENTER> The BP calibration has now been corrected to read 974 mbar on the display.

## *5.3  Sample RH Calibration*

The CALIBRATE RH screen is used for field audits or calibrations of the sample relative humidity measurement of the ES-642.

```
┌─────────────────────────┐
│ CONC:    0. 010 mg       │
│ RH          42 %         │
└─────────────────────────┘
```

**Note:** The ES-642 sample RH sensor is located inside the pulsation dampening chamber. If the ES-642 has been operating with the inlet heater running, the inside of the unit will likely be hotter than ambient temperature, resulting in sample RH readings that will be lower than an ambient standard. If the sample RH sensor is to be calibrated, make sure that the unit has equilibrated to ambient conditions first, or a large artificial positive offset could be calibrated into the sensor reading. This will result in the ES-642 over-reading the sample RH and turning the inlet heater on when the actual RH is lower. **Leave the factory default calibration in place unless necessary.** If the sensor fails, it will usually read an impossible value such as 125% or -25%.

The RH parameter is the current reading from the ES-642 humidity sensor. To change the RH calibration using a serial communication program you would collocate a reference standard and then use the RR serial command to change the RH calibration.

Example:

The collocated RH sensor reads 55% and the RH sensor on the ES-642 reads 50%.  Type RR 55 <ENTER> The RH calibration has now been corrected to read 55% on the display.

## 5.4  Flow Sensor Calibration

The CALIBRATE FLOW screen is used for field audits or calibrations of the sample flow measurement of the ES-642. Remove the TSP inlet and any cyclones from the ES-642 inlet tube, and then connect the top of the inlet tube to the outlet of your traceable flow meter using a length of appropriate flexible tubing. The ES-642 temperature and pressure status must be checked before performing any flow calibrations in order to prevent errors. The ES-642 flow rate should be maintained to within ±0.1 LPM (1.9 to 2.1 LPM) for proper cut-point performance of inlet cyclones.

```
CONC:     0. 010 mg
FLOW      2.0 lpm
```

The FLOW parameter is the current reading from the ES-642 flow sensor, in actual volumetric liters per minute. You must send the serial command CAL <ENTER> to put the ES-642 into the flow calibration mode and will automatically regulate to the set point (2.0 LPM). This may take a moment.

To change the FLOW calibration using a serial communication program you would use the value from the flow reference standard and then use the RF serial command to change the flow calibration.

Example:

The flow reference sensor reads 2.2 LPM and the flow sensor on the ES-642 reads 2.0 LPM. Type RF 2.2 <ENTER>.  The flow calibration has now been corrected and will adjust itself back to 2.0 LPM on the display.

Remember to exit the flow calibration mode by typing CAX <ENTER>

## 5.5  K Factor

The ES-642 is calibrated on latex 0.6 micron micro-spheres. These provide an extremely consistent calibration, but do not generally match the characteristics of all ambient particulate.

A K-Factor (multiplier) must be established for good accuracy and correlation to collocated instruments.  The base K-Factor multiplier is set to 1.0 at the factory.

The K-Factor is only valid at the same site and for the same particulate type. If the local particulate source changes, the K-Factor may no longer be valid.

The SK command is used to set the K Factor.

# 6   MAINTENANCE and TROUBLESHOOTING

This section provides information about routine maintenance of the ES-642, and for performing more detailed diagnostic tests if a problem is encountered. The ES-642 can generate an error message on the display if a problem is detected. Many times there is a simple solution. Persistent errors often signify a failure which will require investigation.

Only skilled and trained electro-mechanical technicians should attempt any disassembly or repairs inside the ES-642. Routine maintenance procedures do not involve removing the ES-642 assembly from the enclosure.

## *6.1  ES-642 Alarm Displays and Alarm Codes*

The ES-642 contains a comprehensive system of error and alarm codes which are used to alert the operator of any problems with the unit. These error codes may be generated during normal operation or during a self-test routine. The errors appear on the ES-642 display and in the status output if serial communications are used.

The following table describes each of the error and alarm types which can be generated by the ES-642, along with the conditions which cause the alarms. Many of these alarms indicate critical parameters which must be working correctly for machine operation.

| Alarm/Error Message | Alarm Description |
|---|---|
| FLOW FAILED | This alarm indicates that the flow system is more than 5% out of regulation. |
| ZERO FAULT | This alarm indicates a problem during the Auto Zero phase and the sensor was not stable or the zero value was too high. |
| SENSOR ERROR | This alarm indicates a failure in the laser.  This error requires the sensor to be returned for repair. |
| COUNTER FAULT | This alarm indicates the detector is not functioning correctly. |

The following are some examples of how the alarm and error records appear when shown on the main ES-642 display.

```
CONC:   0. 010 mg      CONC:    0. 010 mg      CONC:    0. 010 mg
Flow Error!            Zero Fault!             Sensor Error!
```

```
CONC:   0. 010 mg
Counter Fault!
```

Note:  The alarm indication will continue to show until the start of the next sample.

The normal ES-642 digital data array also contains an "alarm" code column to indicate if there were any alarm or error flags during that particular sample period.  See sections 9.2 and 9.3 for details and examples.

The following table defines the possible error codes that can appear in the "alarm" column of the ES-642 data output:

| Code | Error/Alarm Type |
|------|------------------|
| 0 | No alarm |
| 1 | Auto Zero Low |
| 2 | Auto Zero High |
| 3 | Auto Zero Stability |
| 10 | Laser Current Failure |
| 20 | Detector Failure |
| 40 | Flow Failure |

**Note:** If multiple errors or alarms occur in the same data period, then the alarm code stored in the data array will be the *sum of the two* individual *code numbers*. This is a rare occurrence.

## *6.2  Basic Problem and Cause/Solution Table*

The following table contains information on some of the more common ES-642 problems which may be encountered, and some steps to identify and remedy the problems. Met One welcomes customer suggestions for new items to include in this section of future manual revisions. If the solution cannot be found in the following table, then contact one of our expert service technicians for help in resolving your problem.

| Problem: | The ES-642 won't start a measurement cycle. |
|----------|---------------------------------------------|
| Cause/Solution: | • The ES-642 may not start a measurement cycle if it detects a hardware failure, such as a pressure sensor failure or a pump failure.<br>• The unit will usually display an error message on the display if it cannot start a cycle. |

| Problem: | Flow failures or low flow. |
|----------|----------------------------|
| Cause/Solution: | • Check the PUMP and PURGE filters. These must be replaced periodically.<br>• Check for insect debris or other obstructions in the small exhaust port on the bottom of the unit.<br>• Verify the AT and BP sensor function. Failed sensors can affect the flow.<br>• In some cases re-setting the sensor calibrations to Factory Default and re-calibrating can solve flow calibration difficulties.  In Hyperterminal issue the DFLT <enter> command (see 9.2 for more details).<br>• The sample pump itself will eventually wear out and need to be replaced. It should last at least a year under normal conditions. Check the other possibilities first. |

| Problem: | Optical system alarms and failures |
|---|---|
| Cause/Solution: | • The ES-642 must be periodically returned to the factory for optical system cleaning. The period will depend on your particulate levels.<br>• Check the PURGE filter and replace it as needed.<br>• The laser diode has a finite lifetime which will be reduced at high temperatures. It may eventually fail and need to be replaced at the factory.<br>• Never disassemble the MDF laser optical subassembly! |

| Problem: | The ES-642 data is not consistent with other sensors. |
|---|---|
| Cause/Solution: | • An external K-Factor (multiplier) must be established for good accuracy and correlation to collocated instruments.  The base K-Factor is assumed to be 1.<br>• The K-Factor will sometimes be very significant, such as a multiplier of 3 or 5.<br>• The ES-642 is calibrated on latex 0.6 micron micro-spheres. These provide an extremely consistent calibration, but do not generally match the characteristics of all ambient particulate.<br>• The K-Factor is only valid at the same site and for the same particulate type. If the local particulate source changes, the K-Factor may no longer be valid.<br>• Make sure the correct cyclone is used on the ES-642. The PM10, PM2.5 or PM1 cyclones look very similar. The cyclone cut point must match the cut point used on any collocated instruments.<br>• Clean the TSP inlet and any cyclones at least monthly.<br>• Check the sample RH data and RH sensor calibration. High sample RH will cause ES-642 over-reading. The sensor itself can occasionally fail.<br>• Check the ES-642 for flow calibration problems. |

## 6.3 *Suggested Periodic Maintenance Intervals*

The following table shows the Met One recommended periods for routine maintenance items. Some of these items will need to be performed more or less often depending on the exact characteristics of your location. The program administrator should review these items and establish SOPs appropriate for your application.

| Maintenance Item | Suggested Period |
|---|---|
| Flow, temperature, and pressure audits or calibration | Monthly |
| Clean sharp-cut cyclone, particle trap, and TSP inlet | Monthly |
| Check filter RH sensors | 6 Months |
| Replace PUMP filter and PURGE filter | 12 Months |
| Factory service, recalibration, and optical system cleaning | 24 Months |

## 6.4  PUMP and PURGE Filter Changes

The ES-642 PUMP FILTER and PURGE FILTER are the two filter cartridges located in the front panel of the instrument. They can be removed by unscrewing the black aluminum filter holders with a coin using the slot in the face of the holder. The expected lifetime of the two filters is greater than one year, but in heavy particulate areas they may need to be replaced more often.

The 5 micron PUMP filter keeps any large particles from entering the flow sensor or sample pump. The 0.2 micron PURGE filter cleans the recirculated purge air which is used to keep the optics clean during normal operation and the zero self-test.



**Figure 6-1 Pump Filter and Purge Filter Replacement**

## 6.5  TSP Inlet and Cyclone Cleaning

A TSP inlet must be installed on the inlet of the ES-642. In addition to the TSP inlet, sharp-cut cyclones may be used to remove particles greater than the rated cut-point. These inlets need to be periodically cleaned. The time interval between cleanings varies depending on the local particulate levels. Met One recommends cleaning the cyclone particle trap at least once a month. The TSP inlet and cyclone body should be disassembled and cleaned every three months during continuous use.

Clean the cyclone particle trap by unscrewing the knurled cap from the cyclone body, then wipe it out with a cloth or blow it clean with compressed air. Check the o-rings and lubricate if necessary. Full cleaning of the cyclone requires unscrewing the three socket-head hex screws to access the conical chamber inside. All of the inside surfaces must be cleaned. Isopropyl alcohol and cotton-tipped applicators work well.

The TSP inlet can be disassembled for cleaning by removing the three screws in the cap. Soap and water often work best for cleaning the TSP inlet and debris screen. Do not over-tighten the screws during reassembly or the plastic threads will strip out.

## 6.6  Factory Service Interval
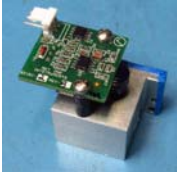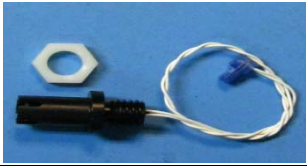
The ES-642 needs to be periodically returned to the factory for service and recalibration. The recommended period is typically two years during continuous use. However, some users establish their own interval depending on the harshness of the sampling conditions, particulate levels, and data scrutiny. High concentration operation will often require more frequent factory service.

Factory service primarily consists of optical system cleaning, laser/detector checks, and recalibration. As-found calibration checks can also be requested. Contact the Met One technical service department to schedule ES-642 service. A Return Authorization (RA) number must be obtained before the unit is returned.

# 7  ACCESSORIES and PARTS

## 7.1  Consumables, Replacement Parts, and Accessories

The following parts are available from Met One for maintenance, replacement, service, and upgrades. If unsure about a part you need, please contact the technical service department. Some of these parts may require technical skills or special instructions before use or installation.

| Description | Part Number | Graphic |
|---|---|---|
| **Flow System Components** | | |
| Sample Pump Module Assembly | **80949** |  |
| Flow Sensor, ES-642 (older ES-642's) | **9049-3** |  |
| Flow Sensor, Differential Pressure | **82258** |  |
| Ambient Temperature Thermistor and Harness | **81410** |  |
| RH Sensor | **9278-1** |  |
| Purge Filter Holder, Black Aluminum | **8912** |  |
| Pump Filter Holder, Black Aluminum | **8913** | |
| Purge Air Filter, 0.2 micron | **580302** | |
| Pump Filter, 5.0 micron | **580345** | |
| O-Ring, For Purge and Pump Filter Holders | **720063** | |
| PM2.5 Sharp Cut Cyclone, 2 LPM | **SCC 112** |  |
| PM10 Sharp Cut Cyclone, 2 LPM | **SCC 110** | |
| PM1 Sharp Cut Cyclone, 2 LPM | **SCC 111** | |
| TSP Sampling Inlet<br>Harsh environment, with insect screen and rain cap | **9441** | |

| | | |
|---|---|---|
| ES-642 I/O Board | **80950-1** |  |
| LCD Display, ES-642, 2x16 Character | **80830-1** |  |
| MDF Engine Assembly, Frequency to Voltage | **80868-3** |  |
| External Cable, ES-642 | **80959** |  |
| External Power Cable, ES-642 | **80943** |  |
| ES-642 Factory Service and Recalibration | | Call Met One |
| Kit, Mounting Bracket | **82836** | |
| Kit, Solar Shield | **81039** | |
| CometTM Software CD | **80248** | |

# 8 APPENDIX A - ES-642 MEASUREMENT METHOD

The Met One Instruments, Inc model ES-642 is a type of nephelometer which automatically measures and reports real-time airborne $PM_{10}$, $PM_{2.5}$, $PM_1$ or TSP particulate concentration levels using the principle of forward laser light scatter. This section describes the measurement systems.

## 8.1 Forward Laser Light Scatter Nephelometer System

Sample air is drawn into the ES-642 by an internal diaphragm pump. The flow rate is controlled based on actual conditions for accurate cut-points through sharp-cut cyclones.

This sample air is drawn through the MD laser optical module or "laser engine", where an internal visible laser diode beam is collimated and directed through the sample air stream. The particulate in the sample air stream scatters the laser light through reflective and refractive properties. This scattered light is collected onto a silicon photodiode detector at a near-forward angle, and the resulting electronic signal is processed to determine a continuous, real-time measurement of airborne particulate mass.

The forward light scatter method allows for a more accurate total mass estimate compared to right-angle light scatter, which is better suited for counting and sizing individual particles. Met One also manufactures a complete line of right angle particle counters.
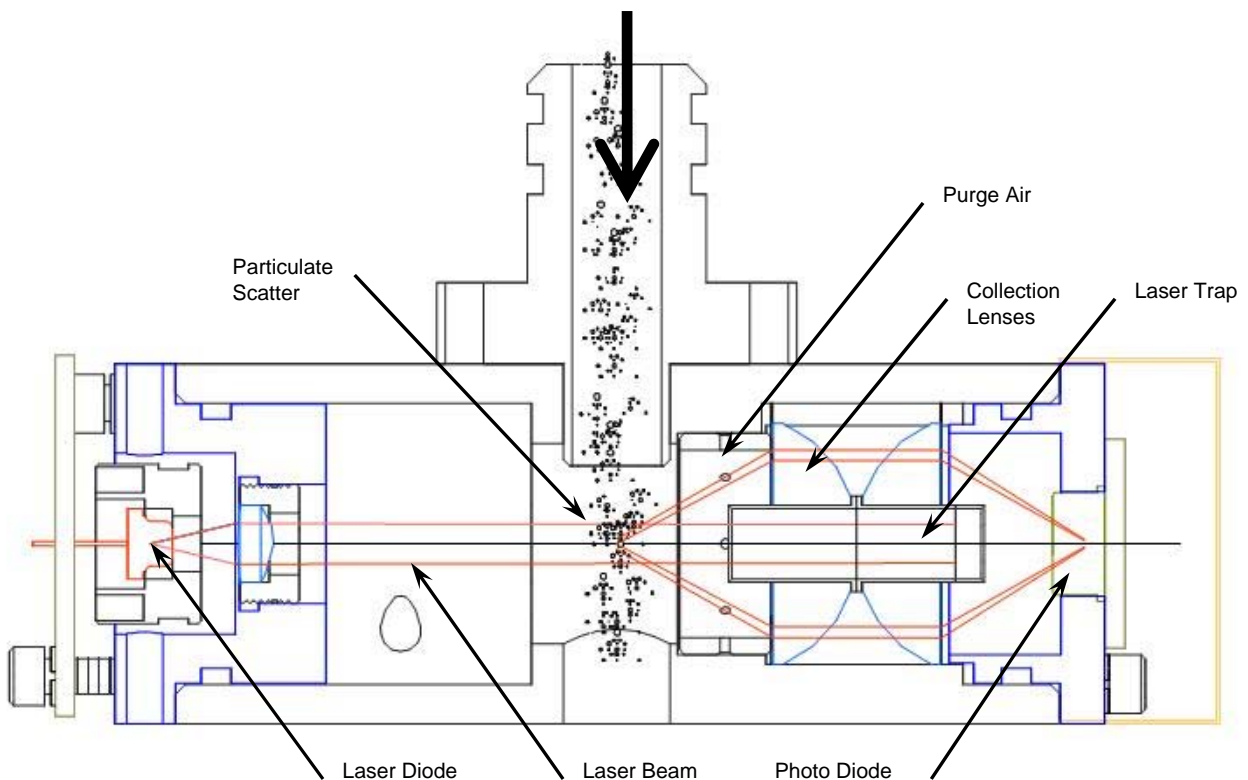


**Figure 8-1 MDF Forward Light Scatter Laser Optical Engine**

Forty detector measurements are made and averaged into an updated concentration value each second. The 1-second values are also displayed on the LCD and available on the analog output.



**Figure 8-2 MDF Clean Air and Particulate Scatter Conditions in the MD Engine**

## Sample RH Control for Light Scatter Mass

The relative humidity (RH) of the sample air has an influence upon the measurement of particulate mass by nephelometers. At RH values greater than about 50% this effect begins to increase due to particle aggregation and particle size increases as water is absorbed. The ES-642 mitigates this through a heated inlet tube that uses an internal sample RH sensor. The RH of the incoming air is measured and the inlet heater is turned on whenever the user-set set-point is exceeded (typically 50% RH). See section 5.3.

A study in *Atmospheric Environment* showed that RH can drastically affect the concentration measurement as shown in the graph in Figure 8-3 from volume 34, pp 4829-4838, 2000. The following article references also contain related information:

*Volume 35, Issue 30, Oct 2001:*
*-Aerosol Light Scattering Measurements as a Function of Relative Humidity. (Malm, Day).*
*-Diurnal and Seasonal Patterns in Light Scattering, Extinction, and Relative Humidity. (Malm, Gebhart, Copeland).*
*Volume 35, Issue 16, June 2001:*
*-Estimates of Aerosol Species Scattering Characteristics as a Function of Relative Humidity. (Malm, Day).*
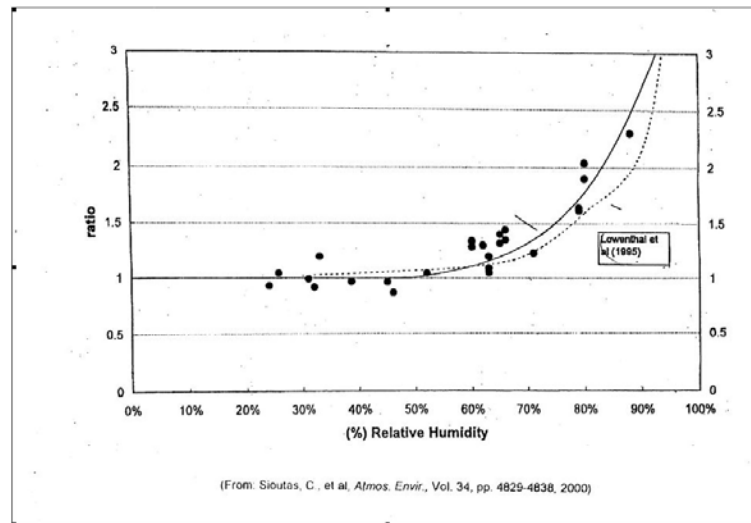


**Figure 8-3 The Effects of RH on Sample Concentration**

## 8.2  Automatic Zero Self-Tests for the Optical System

To assure stable concentration data, the ES-642 performs optical system zero self-tests at a rate that is controlled by the sample period. See section 9.7.

A separate zero air pump activates and circulates clean air through the optical system. The ES-642 filters the air through a 0.2-micron pore size, 99.99% efficient filter element before it enters the sensor. This is the PURGE FILTER located in the front panel of the instrument. The ES-642 zeros itself based on this clean air condition.

## 8.3  The Airflow Control System Diagram and Description

The flow control system is an integral component of the ES-642. A complete description is included to assist the user in understanding the ES-642 flow system:

1. Ambient air is drawn in through the TSP inlet and the $PM_{10}$, $PM_{2.5}$ or $PM_1$ cyclone (if used) at 2.0 lpm. This flow rate is used because the cut-point of the cyclones is dependent on the velocity of the particles and is only accurate at the rated flow rate.

2. The sample air goes through the vertical inlet tube, which is heated, if necessary, to keep the sample air humidity below 50% RH to prevent measurement errors caused by moisture.

3. The sample air stream immediately enters the laser optical module where it passes through the laser beam and the particulate is measured.

4. The pump filter removes particles larger than 5 microns to protect the flow sensor and pump. The air stream then passes through the flow meter which measures the mass flow rate of the sample air as an analog electronic signal which is sent to the CPU where the ambient temperature and pressure are used to calculate the actual flow.

5. Down-stream of the flow meter, a pulsation chamber is used to reduce the pressure pulsations caused by the diaphragm pump, which would otherwise appear as noise in the flow sensor signal. There is nothing inside the pulsation chamber.

6. The air is drawn into the vacuum side of the main sample pump. This is a brushless diaphragm pump which is pulse-width modulated (PWM) by the CPU to control the flow rate.

7. Most of the sample air exhausts through the pump to the exhaust hole on the bottom of the ES-642. A small amount (about 10%) of the pump exhaust is recirculated through a simple purge adjust valve (a screw installed in one of the ports). This purge adjust is factory-set to control the ratio of the purge air, and should not be tampered with.

8. The purge air passes through the purge filter which removes any remaining particles larger than 0.2 microns in size. The purge air enters the laser optical module in a ring around the detector lenses, and through a port in front of the laser focus lens. The clean air circulating past the lenses greatly reduces the amount of dirty sample air which would otherwise contact and contaminate the optics.

9. During the zero portion of the automatic periodic self-test cycle, the main sample pump is turned off and the purge pump is turned on. The air is filtered by the purge filter and circulated through the laser module at a higher flow rate. The air in the laser module is 100% filtered during this process, and no scattered light should enter the detector. The ES-642 takes a zero

reading and establishes a new signal baseline. A check valve prevents air from back-flowing through the purge pump during normal sampling.

Inlet

Purge

MD

Pump
Filter

Purge
Filter

Flow

Sample

Pulsatio

Purge

Check

Sampl

Purge

Exhaust
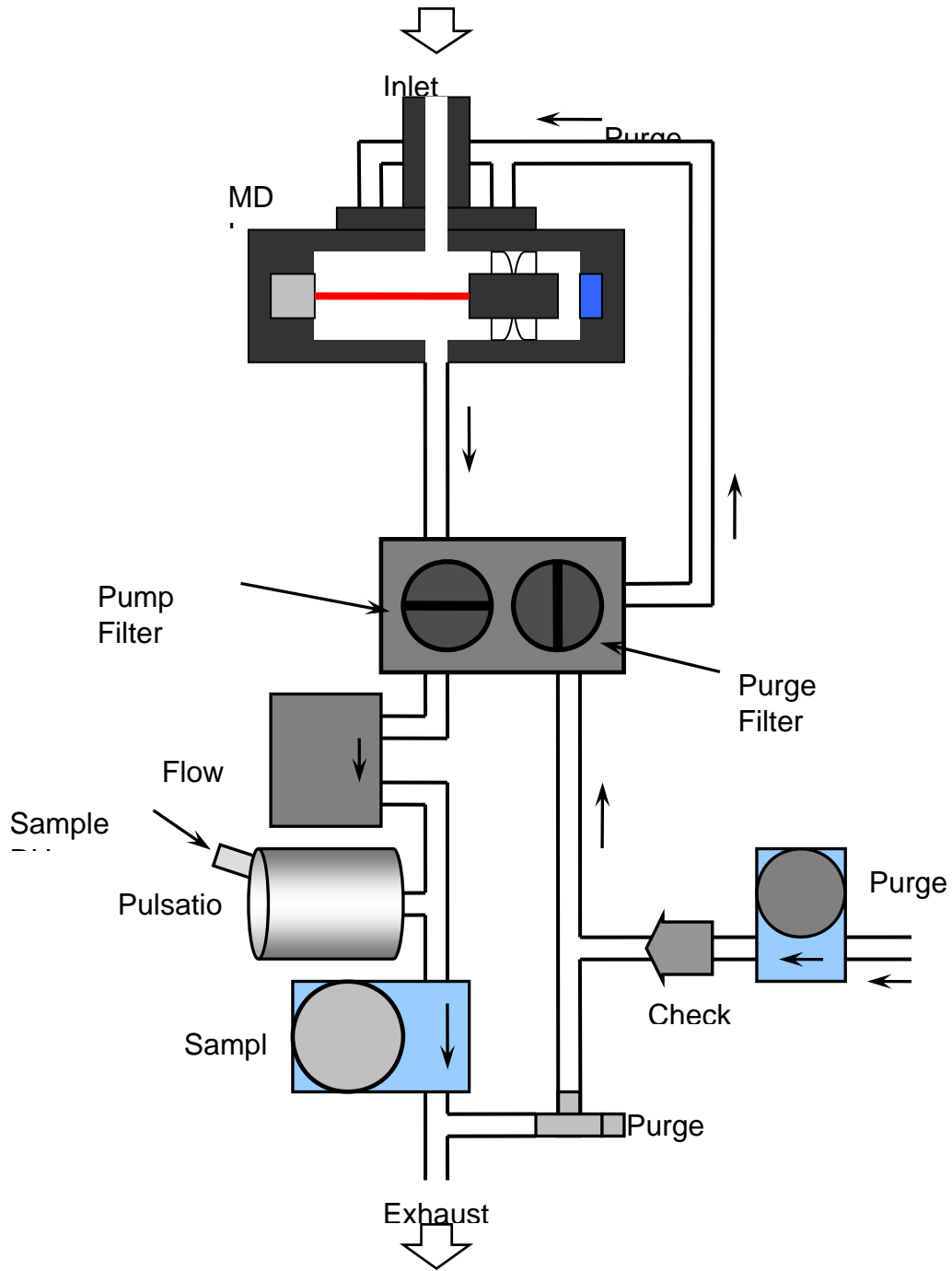
**Figure 8-4 ES-642 Flow System Diagram - Simplified for Clarity**

# 9 APPENDIX B - COMMUNICATION

## 9.1 Comet Software

The ES-642 is supplied with a CD containing a free copy of the Comet™ program, which is a simple Windows-based communications terminal program developed by Met One Instruments. Comet allows the user to connect to the ES-642 and read/set various parameters (K factor, Concentration Alarm, Analog Output Range and DAC Output Range), and log real time data.

The Comet CD also contains a very comprehensive pdf user's manual for the program. Install the program onto the computer that you will be using and review the manual for more details. The "ES-642" help section under "Plugins" provides specific information for the ES-642.

## 9.2 Serial Communication

| Command | Description |
|---------|-------------|
| ?,H | Displays the help menu. |
| AR | Enters the Analog Output Range in µg/m$^3$. |
| AV | Enters the DAC Voltage. 0=2V, 1=5.0V, 2= 10V. Range selection must be 2 for the 4 – 20 mA output to be correct. |
| CAL | Enters Calibration Mode. Regulates flow to 2.0 lpm |
| CAX | Exits Calibration Mode. |
| DFLT | Clears sensor calibrations to defaults (Flow, Ambient Temp, BP, RH and Case Temp) |
| MA | MODBUS Address. 1 - 247 |
| ME | Request Measurement. |
| NW | Network Mode. 0=Off, 1=On |
| OP | Report Operation Status. |
| RA | Reference Ambient Temperature for Calibration. |
| RF | Reference Flow for Calibration. |
| RP | Reference BP for Calibration. |
| RR | Reference RH for Calibration. |
| RV | Returns the current software revision. |
| SID | Sets / Reads the Unit ID. |
| SK | Sets / Reads the Unit K Factor. |
| ST | Sets / Reads the Sample Time in seconds. |
| S | Manually Start/Stop a measurement. 1=Start, 0=Stop |
| SPA | Sets / Reads Concentration Alarm Setpoint |
| SPR | Sets / Reads the RH Set Point for the Inlet Heater Control. |

The unit provides a serial command set for accessing settings. Commands are one or more characters in length and require a carriage return. Commands which need additional information prompt for the appropriate information.

Commands can be entered in either Upper or Lower Case.

Optionally, a command integrity checksum can be added. If used, a "*" delimiter character will be added to the end of the command string followed by the decimal checksum of all characters in the command line up to but not including the "*" character. If the command integrity checksum is supplied, the response string will also include an integrity checksum. The command will be ignored if an incorrect checksum is given. For ease in human operation, the special checksum string "*//" (without quotation marks) will resolve as a correct checksum without the need to calculate it.

In general, issuing a command by itself will respond with the current value of the setting. Issuing a command with a value will change the setting to the new value. For example, to read the current analog output range, type AR <ENTER> and the current full scale setting for the analog output range will be returned.

To set the analog output range, type AR 1000 <ENTER> and the output range would then be set to a full scale reading of 1000 µg/m$^3$.

All serial commands work in this fashion.

## 9.3 Computer Mode

The unit is designed to primarily be connected to a computer or data logger. This is the default mode called Computer Mode.

In Computer Mode, the unit will ignore all incoming serial characters until an <Esc> (ASCII 27) character is received. A command can then be entered. No characters will echo out the serial port while entering commands in Computer Model. All commands are executed using the <ENTER> key.

Each time the <Esc> key is pressed, the unit will reset to Computer Mode and start the command over.

When in Computer Mode, commands should use the command integrity checksum. The <Esc> character is Not included in the checksum.

## 9.4 User Mode

User Mode is intended for direct user interaction. In User Mode, all incoming characters are echoed back to the user.

The user can wake the unit into User Mode by sending three <CR> (Enter Key) characters within 3 seconds. The prompt character '*' will be displayed when the unit is in Terminal Mode.

Once in User Mode, the unit will continue to respond to serial commands until User Mode is exited. This can be done by issuing the Q or X command or pressing the <Esc> key. The unit will also revert back to Computer Mode if no serial traffic is seen for two minutes.

All commands are accessible in either User or Computer Mode and behave the same except for the echo behavior of incoming characters.

## 9.5  Output Formats

The unit supports two output formats for the data. The record formats are MetRecord and Legacy. The MetRecord format provides some additional output fields that the original Legacy format did not. The default is MetRecord. The Legacy format is provided for backward compatibility with older units as necessary.

The RL command will list the available Record Formats. The RT command can be used to view and set the Record Format Type.

## 9.6  MetRecord Format

The output of the Measurement command is both Comma delimited and fixed length to facilitate data parsing as well as importing into spreadsheets / databases. All fields are padded with leading and trailing zeros as necessary. Fields which can go negative will be preceded with either a + or – character.

Once the flow has settled, the measurements will be output once per second until the measurement cycle is completed.

The format is as follows.

mmm.mmm,f.f,+ttt.t,rrr,bbbb.b,ss,*ccccc

Where mmm.mmm is the measurement in milligrams per cubic meter. The Field f.f is the Flow rate. The field ttt.t is the Temperature in degrees C.

The field rrr is the Relative Humidity. Note: this is not an Ambient RH measurement but is taken inside the instrument after the Inlet Heater. This is the measurement that controls the Inlet Heater.

The ss field is the Status field. See below.

The ccccc field is a 5 character checksum field with leading zeros as necessary. This is the 16 bit sum of all the characters from the start of the output string up to but not including the '*' delimiter character. This value is in Decimal.

## 9.7  Legacy Format

The Legacy Format is preceded by the characters ME and indicates a Measurement follows. Once the flow has settled, the measurements will be output once per second until the measurement cycle is completed.

The output of the Measurement command is both Comma delimited and fixed length to facilitate data parsing as well as importing into spreadsheets / databases. The format is as follows.

ME, iiiiiiii, mmm.mmm, ss,*cccc<CR><LF>

Where iiiiiiii is an 8 character Unit Identifier. This can be from 1 to 8 characters alpha numeric and will be padded by ASCII Space characters at the end of the string.

The field mmm.mmm is the measurement in milligrams per cubic meter. The field will be padded with leading and trailing zeros as necessary.

The field ss is the Status field. This is a numeric field where 00 indicates no errors and a non-zero value will indicate various error conditions. (See Below).

The cccc field is the checksum and is a three character checksum which is the Decimal sum of all characters from the start of the string up to but not including the "*" delimiter character.

## 9.8  Status Field

The Status Field is a two character Hexadecimal representation of the status and error flags.

Bits 0-3 of the Status Field are reserved for the Sensor Calibration Status Code. These codes are mutually exclusive and are stored as a status code number.

| Value | Status | Description |
|-------|--------|-------------|
| 0 | OK | Zero Calibration good. No errors |
| 1 | Low | Zero Reading Too Low |
| 2 | High | Zero Reading Too High |
| 3 | Stability | Stability error. Too Many Retries |

Bits 4-15 are reserved for single bit error flags which allow for multiple error conditions to be represented concurrently.

| Bit | Decimal Value | Hex Value | Description |
|-----|---------------|-----------|-------------|
| 0-3 | | | Calibration Status. See codes above |
| 4 | 16 | 0x10 | IOP Alarm (Laser). |
| 5 | 32 | 0x20 | Counter Error (Sensor) |
| 6 | 64 | 0x40 | Flow Regulation |

## 9.9  Example output

Following is an example of the serial output in MetRecord format.

000.002,2.0,+27.3,044,0974.0,00,*01543

The CSV header for this format is as follows:

Conc(mg/m3),Flow(lpm),Temp(C),RH(%),BP(mbar),Status

Legacy Format is as follows

    ME, 01    , 000.002, 00,*1139

    Command, Station ID, Concentration, Status, Check Sum followed by <CR><LF>

## 9.10 Basic Command Summary

The following is a summary of the basic commands.

| Command | Description |
|---------|-------------|
| ?,H | Displays the help menu to assist users. |
| CAL | Enters Calibration Mode. |
| CAX | Exits Calibration Mode. |
| DFLT | Sets Sensor Calibration offsets to zero (factory calibration) |
| ID | Sets / Reads the Unit ID. |
| OI | Output Interval. |
| Q | Exit User Mode. |
| RA | Reference Ambient Temperature for Calibration. |
| RF | Reference Flow for Calibration. |
| RP | Reference BP for Calibration. |
| RR | Reference RH for Calibration. |
| RV | Returns the current software revision. |
| ST | Sets / Reads the Sample Time in seconds. |
| S | Manually Start/Stop a measurement. |
| SPR | Sets / Reads the RH Set Point for the Inlet Heater Control. |

## 9.11 Report Model and Firmware Version [RV]

| Command | Response | Description |
|---------|----------|-------------|
| RV<CR> | | This command reports the model, part number and firmware version. |
| RV<CR> | ES-642, 80708, R1.1.0 <CR><LF> | |

## 9.12 Set Unit ID [ID x]

The SID command is the same and is also supported for backward compatibility.

| Command | Response | Description |
|---------|----------|-------------|
| ID x<CR> | | This command will Set or Get the Unit ID string. This can be anywhere from 1 to 8 characters |
| ID 001<CR> | ID 001<CR><LF> | Set Station ID. |
| | | Issuing the command without a parameter will respond with the current setting value. |
| ID<CR> | ID 01<CR><LF> | Station ID "01". |

## 9.13 Set Sample Time [ST x]

| Command | Response | Description |
|---|---|---|
| ST x<CR> | | This command will Set or Get the Sample Time in Seconds. This sets the actual measurement time excluding the Zero Calibration, Flow settling and Purge times.<br><br>When the sample is finished, the unit will restart with a new Auto Zero. The default time is 3600 seconds (1 Hour)<br><br>A Sample Time of 0 will run indefinitely and can only be stopped by issuing a manual Stop Command from the serial port. The unit will not perform a new Zero cycle unless manually re-started. |
| | | Issuing the command without a parameter will respond with the current setting value. |
| ST<CR> | ST 3600<CR><LF> | Sample Time is set to 3600 Seconds (1 Hour). |

## 9.14 Set Operation Control [S x]

| Command | Response | Description |
|---|---|---|
| S x<CR> | | This command will start or stop a sample event. Issuing a start command while the unit is sampling will restart the sample event. |
| S 1<CR> | | Start the sample event. |
| S 0<CR> | | Stop the sample event. |

Issuing a Stop command will have different results depending on the Operation Mode the unit is in when the command was issued.

If the Operation Mode is the Zero Calibration cycle, the unit will stop immediately.

If the Operation Mode is Sampling, the unit will proceed directly to the Purge Cycle then stop.

If the Operation Mode is Purging, the unit will continue with the Purge cycle to its completion before stopping.

## 9.15 Exit User Mode [Q,X]

| Command | Response | Description |
|---|---|---|
| Q<CR> | | This command will start or stop a sample event. Issuing a start command while the unit is sampling will restart the sample event. |
| Q<CR> | Exit User Mode | User Mode Exited. Returned to Computer Mode |
| X<CR> | Exit User Mode | |

The Q command and X command both exit User Mode and return the unit to Computer Mode.

## 9.16 Enter Calibration Mode [CAL]

| Command | Response | Description |
|---|---|---|
| CAL<CR> | | This command will enter Calibration Mode. |

Under normal circumstances, there should be no need to adjust the factory calibration of the internal sensors.

The CAL command is provided to audit the performance of the internal sensors and adjust them as necessary.

Entry to Calibration Mode is signaled by an OM, Test message. The pump will start and the flow controller will control the flow rate to 2.0 lpm. Once in Calibration Mode, the unit will output internal sensor values once per second. An example output follows.

F: 2.003 AT: 22.5  BP:  979.1  RH:  39  CT: 26.2

The sensors monitored are:

Flow in lpm.

Ambient Temperature (AT) in Deg C.

Barometric Pressure (BP) in mbar.

RH in percent.

Case Temperature (CT) in Deg C.

The AT and BP values are used to calculate Volumetric Flow and should be adjusted before the Flow if necessary.

## 9.17 Exit Calibration Mode [CAX]

| Command | Response | Description |
|---|---|---|
| CAX<CR> | | This command will exit Calibration Mode. |

## 9.18 Default Sensor Calibrations [DFLT]

| Command | Response | Description |
|---|---|---|
| DFLT<CR> | Default Cal | Clears sensor calibrations to defaults (Flow, Ambient Temp, BP, RH and Case Temp) |

### 9.19 Reference AT [RA]

| Command | Response | Description |
|---|---|---|
| RA x<CR> | | This command will enter the Reference AT value for Calibration. X = Reference Temperature in Deg C. |
| RA 24.0<CR> | AT Cal 24.0 | Set the Reference temperature to 24C. |

This command is used to calibrate the Ambient Temperature reading and is entered in Calibration Mode. The unit will calculate the correct offset to apply based on the current AT reading when the RA command was entered.

### 9.20 Reference Flow [RF]

| Command | Response | Description |
|---|---|---|
| RF x<CR> | | This command will enter the Reference Flow value for Calibration. X = Flow Rate in lpm. |
| RF 2.07<CR> | Flow Cal 2.070 | Set the Reference Flow to 2.07lpm. |
| | Not in Cal Mode! | This warning will appear if not in Cal Mode when the command was entered. |

This command is used to calibrate the Flow sensor and is entered in Calibration Mode. The unit will calculate the correct offset to apply based on the current Flow reading when the RF command was entered.

If the unit is not in Calibration Mode when this command is entered, a warning will be issued and the calibration will not take place.

Allow sufficient time for the flow to settle and stabilize before entering a flow value.

### 9.21 Reference Pressure [RP]

| Command | Response | Description |
|---|---|---|
| RP x<CR> | | This command will enter the Reference BP value for Calibration. X = BP in mbar. |
| RP 981.1<CR> | BP Cal 981.1 | Set the Reference Flow to 981.1mbar. |

This command is used to calibrate the BP sensor and is entered in Calibration Mode. The unit will calculate the correct offset to apply based on the current BP reading when the RP command was entered.

### 9.22 Reference Humidity [RR]

| Command | Response | Description |
|---|---|---|
| RR x<CR> | | This command will enter the Reference RH value for Calibration.<br>X = RH in percent. |
| RR 35<CR> | RH Cal 35 | Set the Reference RH to 35. |

This command is used to calibrate the RH sensor and is entered in Calibration Mode. The unit will calculate the correct offset to apply based on the current RH reading when the RR command was entered.

### 9.23 RH Set Point [SPR]

| Command | Response | Description |
|---|---|---|
| SPR x<CR> | | This command will enter the RH Set Point for the Inlet Heater Control.<br>X = RH in percent. |
| SPR<CR> | SPR 0.0 | RH Set Point at 0, (disabled). |
| SPR 50<CR> | SPR 50.0 | Set the Reference RH Set Point to 50%. |

The Inlet Heater control is a simple On/Off style controller. If the RH goes over the Set Point, the heater turns on and when it drops below, the heater turns off. This command allows the setting to be changed.

A Set Point of 0 or 100% can be used to disable the Inlet Heater Control altogether.

### 9.24 Output Interval [OI]

| Command | Response | Description |
|---|---|---|
| OI x<CR> | | This command will set the Output Interval for measurements when the instrument is running.<br>X = Is the interval in Seconds. |
| OI<CR> | OI 0 | Output Interval 0, (disabled). |
| OI 1<CR> | OI 1 | Set the Output Interval to 1 second |

The unit normally outputs its measurement once per second when it is in operation. This output can be disabled by setting the Output Interval to 0. This allows for a computer or data logger to Poll for the data instead.

While it is possible to set the Output Interval for longer than 1 second, it should be noted that no averaging will take place. The output will be the instantaneous 1 second reading at the interval period.

### 9.25 Advanced Command Summary

The following is a summary of the advanced commands. These consist of the more rarely used settings or commands that are primarily intended for direct computer or data logger interaction rather than user interaction.

| Command | Description |
|---|---|
| DS | Field Descriptors |
| DSCRC | Field Descriptor CRC Signature |
| MA | Modbus Address. |
| ME | Request Measurement (Legacy Format). |
| NW | Network Mode. |
| OP | Display Operation. |
| QH | Query Header |
| RL | List Record Formats. |
| RT | Set Record Format Type. |
| RQ | Request Measurement (MetRecord Format). |
| SK | Set K-Factor multiplier |
| UN | Set / Read Units |

### 9.26 Modbus Address [MA]

| Command | Response | Description |
|---|---|---|
| MA a<CR> | | This command will set the Modbus Address. a = Is the Modbus Address from 1 to 247 |
| MA<CR> | MA 1 | Modbus Address is set to 1 |
| MA 3<CR> | MA 3 | Set the Modbus Address to 3 |

### 9.27 Measurement Request [ME]

| Command | Response | Description |
|---|---|---|
| ME<CR> | | Request the Measurement in Legacy output format. |

This command will respond with the current measurement result in Legacy output format regardless of the current Record Type setting. This command is generally used by a computer or data logger system to Poll for data and is usually used with the Output Interval set to 0.

### 9.28 Request Query [RQ]

| Command | Response | Description |
|---|---|---|
| RQ<CR> | | Request the Measurement in MetRecord output format. |

This command will respond with the current measurement result in MetRecord output format regardless of the current Record Type setting. This command is generally used by a computer or data logger system to Poll for data and is usually used with the Output Interval set to 0.

### 9.29 Set K-Factor Multiplier [SK]

| Command | Response | Description |
|---|---|---|
| SK k<CR> | | This command will set the K-Factor multiplier.<br>k = Is the K-Factor multiplier |
| SK<CR> | SK 1.000 | See the current setting |
| SK 2.6<CR> | SK 2.600 | Set the K-Factor multiplier to 2.6 |

### 9.30 Network Mode [NW]

| Command | Response | Description |
|---|---|---|
| NW x<CR> | | This command is used to Enter or Exit Network Mode.<br>x = 1 to Enter Network Mode<br>x = 0 to Exit Network Mode |
| <Esc>A 01 NW 0*// | NW 0 | Take the unit with the ID of "01" out of Network Mode |

This command is used to Enter or Exit Network Mode. The unit will also automatically enter Network Mode if it detects network messages addressed to this unit or any other unit on the network.

Note, to exit Network Mode, you will need to use the proper network address as shown in the example above. It the unit is the only device on the network, the Global address of 0 can be used.

### 9.31 Operation Mode [OP]

| Command | Response | Description |
|---|---|---|
| OP<CR> | | This command is used to display the current Operation Mode.<br>0 = Stopped, 1 = Zeroing, 3 = Sampling, 4 = Purging |
| OP | OP, 3, SAMPLING | The unit is currently Sampling. |

This command is primarily intended to be used by another computer controlling the unit

### 9.32 Query Header [QH]

| Command | Response | Description |
|---|---|---|
| QH<CR> | | Display the CSV column header for the MetRecord format output |
| QH | Conc(mg/m3),Flow(lpm),AT(C),RH(%),BP(mbar),Status | |

This command is intended to be used by a computer accessing the instrument to retrieve the CSV record header for the MetRecord format data.

### 9.33 List Record Formats [RL]

| Command | Response | Description |
|---------|----------|-------------|
| RL<CR> | | List Available Record Type formats |
| RL | RL 1-MetRecord 2-Legacy | |

### 9.34 Record Type [RT]

| Command | Response | Description |
|---------|----------|-------------|
| RT f<CR> | | Sets or views the current Record Type. Refer to the RL command for available formats. |
| RT | RT 1-MetRecord | Unit is currently set to the MetRecord output format. |
| RT 2 | RT 2-Legacy | Set the unit to Legacy output format. |

Starting with Revision 1.1.0 of the firmware, the default behavior of the instrument is to follow the MetRecord protocol. In order to maintain backward compatibility with installations which were programmed for the earlier systems, this command allows the user to set the unit to output data in the old format.

### 9.35 Descriptor Table Retrieval [DS]

The Descriptor Table Retrieval commands are used by a computer or data logger to discover the number of data fields and their parameters to automatically setup the data logging process.

### 9.36 DS 0 – Query Abbreviated Descriptor Information

| Command | Description |
|---------|-------------|
| DS 0 | This command returns the general header information |

| Response | Description |
|----------|-------------|
| DS n,id,r | The response indicates the general header information<br>n        – Number of field descriptor lines available.<br>id        – Location ID<br>r        – Reserved for future use. 0 is the default. |

| Example |
|---------|
| DS 0<cr> |
| DS 5,01,0 |

### 9.37 DS c – Specific Channel Descriptor Information

| Command | Description |
|---|---|
| DS c | This command returns the specific channel descriptor information<br>c – Channel number. |

| Response |
|---|
| DS c,FieldName,MeasureType,units,prec,math,max,min |

| Parameter | Description |
|---|---|
| c | Field Number – 1 based. |
| FieldName | Field Name string in printable ASCII. |
| MeasureType | Measurement Type string in printable ASCII. |
| Units | Engineering Units in printable ASCII. |
| prec | Display decimal precision. |
| math | Math type field. Vector (V), Scalar (S), Total (T), Minimum (MIN), Maximum (MAX), Standard Deviation (STD). |
| max | Maximum measurement value. |
| min | Minimum measurement value. |

| Example |
|---|
| DS 1<cr><br>DS 1,Conc,CONC,mg/m3,3,S,100.000,0.000 |

### 9.38 Request Units [UN]

| Command | Description |
|---|---|
| UN c | Request the list of available channel / field units.<br>c – Desired channel/field 1 based |

| Response | Description |
|---|---|
| UN c 1-a,... | Returns the available units for the channel/field specified.<br>c – Specified field number<br>1-a – Unit enumerator and name.<br>... – More enumerators and names as the field requires |

| Example |
|---|
| UN 1<cr><br>UN 1 1-mg/m3 |

# 10 APPENDIX C - NETWORK MODE

The following extension is used for networking the unit in a multi-drop RS-485 network.

The unit is not in Network Mode on power up. Any Network command will automatically place the unit in Network Mode until the unit is powered off or taken out of Network Mode with the NW command.

Once in Network Mode, all command input echo is turned off and all automatic serial output is suppressed. The only output from the unit is in response to a network poll command with the correct identifier for this instrument.

## 10.1 Identification Command Prefix

When in Network Mode, the unit will only respond when correctly addressed. The network address is the Unit ID setting. This is set with the SID command. NOTE: This ID string is a 9 character Alpha String. The Identifier string must match exactly including upper/lower case and leading zeros in the case of numeric identifiers. The Default ID is "01" (no quotes)

The Identification Prefix takes the following form:

<Esc>A<sp>id<sp>cmd …*cs<cr>

Receipt of an Identification command will cause the unit to recognize that it is in a network and disable command echo and real time output.

| Command Component | Description |
|---|---|
| <Esc> | ASCII escape character (0x1B hex, 27 decimal) |
| A | ASCII character 'A' (0x41 hex, 65 decimal) |
| <sp> | ASCII space character (0x20 hex, 32 decimal) |
| id | 1 to 9 alphanumeric ASCII characters 0 – 9 (0x30 – 0x39 hex, 48 – 57 decimal) and A-F upper and lower case. An address of 0 will function as a "Global Address" |
| <sp> | ASCII space character (0x20 hex, 32 decimal) |
| cmd | Normal serial command with 0 or more additional parameters. |
| * | ASCII '*' character (0x2A hex, 42 decimal). Checksum Delimiter |
| cs | Checksum described above. |
| <cr> | ASCII carriage return character (0x0D hex, 13 decimal) |

After the Identification Prefix, any standard terminal command can be used with the exception of the Calibration Commands which require the unit to not be in Network Mode.

The two ASCII Space characters above are mandatory.

The Command Integrity Checksum is also mandatory or the network command will be ignored as will any other command not addressed to this specific unit. The checksum will be a 16 bit sum of all the characters After the <Esc> Character, up to but Not Including the "*" delimiter character. The number will be printed in Decimal format.

# 11 APPENDIX D - MODBUS

## 11.1 Modbus 3X Registers

| MODBUS Name | | Addr | Type | Points | Description |
|---|---|---|---|---|---|
| MB_123456 | = | 0 | float | 2 | Known value for easier Byte Order configuration |
| MB_Op_State | = | 2 | Int | 1 | Purge, Sample, Zero etc |
| MB_Time_Remain | = | 3 | Int | 1 | When used with modes above which have set times in each state |
| MB_Revision | = | 4 | char | 16 | 31 Char + Zero Terminator word aligned to 32 bytes |
| | | | | | |
| MB_Conc | = | 100 | float | 2 | Concentration in uG/M3 |
| MB_AT | = | 102 | float | 2 | Temperature in C |
| MB_RH | = | 104 | float | 2 | Relative humidity % |
| MB_BP | = | 106 | float | 2 | Barometric pressure mbar |
| MB_IOP | = | 110 | float | 2 | Laser current mA |
| MB_Flow | = | 112 | float | 2 | Flow rate lpm |
| | | | | | |
| | | | | | |
| MB_Alarm_Flags | = | 200 | word | 1 | 16 Bit Alarm Flags |
| MB_Alarm_Code | = | 201 | word | 1 | Alarm Code of first alarm in the queue, 0 if none left to read in |
| MB_Alarm_P1 | = | 202 | dword | 2 | Long Parameter for reason  (Alarm Dependent) |
| MB_Alarm_P2 | = | 204 | float | 2 | Float Parameter for reason ( Alarm Dependent ) |

## 11.2 4X Registers

| MODBUS Name | | Addr | Type | Points | Description |
|---|---|---|---|---|---|
| MB_Byte_Order | = | 0 | Int | 1 | 1 thru 4 |
| MB_OP_Mode | = | 1 | Int | 1 | |
| MB_Out_Mode | = | 2 | int | 1 | Settings Based |
| MB_Cmd | = | 3 | Int | 1 | 1=Run, 2=Stop, 3=Zero, 4=Span, 5=Sample, 6=Purge, 7=Cal Low, 8=Cal High, 9=Cal Exit |
| MB_ModBus_Addr | = | 4 | Int | 1 | 1 to 247 |
| MB_Baud | = | 5 | int | 1 | Baud Rate Enumerator value (reserved, not implemented) |
| MB_Unit_ID | = | 10 | char[10] | 5 | 8 Char + Zero Terminator (word aligned to 10 bytes) |
| MB_Name | = | 15 | char[18] | 9 | 16 Char + Zero Terminator (word aligned to 18 bytes) |
| MB_DAC_V | = | 24 | Int | 1 | DAC Full Scale Voltage 0=2V, 1=5V, 2= 10V |
| MB_DAC_Range | = | 25 | Float | 2 | DAC Range in µg. |
| | | | | | |
| MB_Nxt_Alarm | = | 50 | Int | 1 | Any value written here pops the next alarm message off the queue and puts it in the Alarm 3X read area |
| | | | | | |
| MB_AT_Reference | = | 100 | float | 2 | Triggers an Offset calculation and settings change |
| MB_RH_Reference | = | 102 | float | 2 | |
| MB_BP_Reference | = | 104 | float | 2 | |
| MB_T_Internal_Ref | = | 106 | float | 2 | |
| MB_Flow_Low_Ref | = | 108 | float | 2 | Sets Low X1,Y1 and triggers an M & B calculation |
| | | | | | |
| MB_Sample_Time | = | 202 | dword | 2 | Sampling Time in Seconds |
| MB_RH_Setpoint | = | 209 | float | 2 | |
| MB_Relay_SP | = | 214 | float | 2 | Concentration Alarm Relay Set Point |
| MB_K_Factor | = | 218 | float | 2 | K-Factor Mulitpier |

# 12 APPENDIX E – WIRING ANALOG OUTPUT.

Long cable length can cause a voltage drop in the ground from the power source to the ES-642 electronics. This can cause 100's of millivolts of error in the analog output, as seen at the end of the cable. To correct for this DC offset, the ES-642 comes with an analog sense wire which measures the difference in ground potential from the logger to the ES-642. You should always use this remote analog sense wire, so the error can be removed. This wire should be connected at the ground side of the loggers input. The power ground of the ES-642 should also be connected to the power ground side of the logger as well. (see the following wiring examples):

## 12.1 Single supply (logger and sensor)
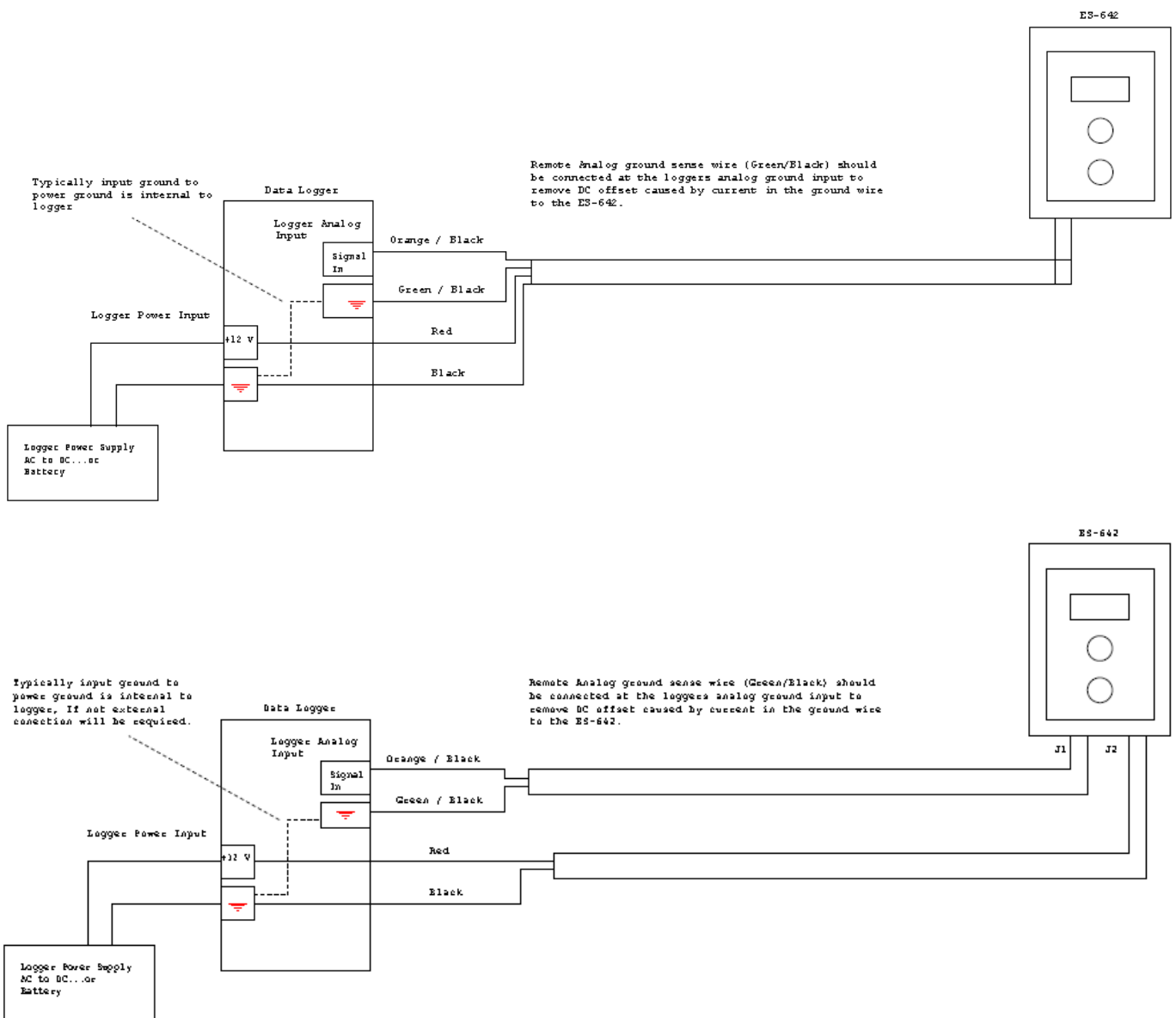
## 12.2 Separate supplies, logger and sensor.

Note: All three grounds should be
connected to the loggers power ground
input. Typically the logger provides
an internal connection to the input
ground and external connection can be
omitted.

ES-642

Typically not required

Data Logger

Logger Analog
Input

Remote Analog ground sense wire (Green/Black) should
be connected at the loggers analog ground input to
remove DC offset caused by current in the ground wire
to the ES-642.

Signal
In

Orange / Black

Green / Black

Logger Power Input

+12 V

Logger Power Supply
AC to DC...or Battery

Black

Red

Logger power ground and ES-642
power ground should be
connected

- voltage        + voltage

ES-642 Power Supply

Note: All three grounds should be
connected to the loggers power ground
input. Typically the logger provides
an internal connection to the input
ground and external connection can be
omitted.

ES-642

Typically not
required, most loggers
already connect analog
ground to power ground
internally.

Data Logger

Logger Analog
Input

Remote Analog ground sense wire (Green/Black) should
be connected at the loggers analog ground input to
remove DC offset caused by current in the ground wire
to the ES-642.

Signal
In

Orange / Black

J1      J2

Green / Black

MOI#80959 Cable

Logger Power Input

Black

+12 V

MOI#80943 Cable

Logger Power Supply
AC to DC...or
Battery

Black

Red

Logger power ground and ES-642
power ground should be
connected

- voltage        + voltage

ES-642 Power Supply

## 12.3 Using the 4-20 ma output option.

External Resistor Selection

| Value (ohms) | voltage seen at logger input |
|---|---|
| 25 | 100 mv to 500 mv |
| 50 | 200 mv to 1000 mv |
| 100 | 0.4 V to 2.00 V |
| 200 | 0.8 V to 4.00 V |
| 250 | 1.00 V to 5.00 V |

Note: The ES-642 must be set for a 0-10 V analog output for the 4-20 ma to work corectly. This is done by issuing a 'AV 2' command on the digital communication.
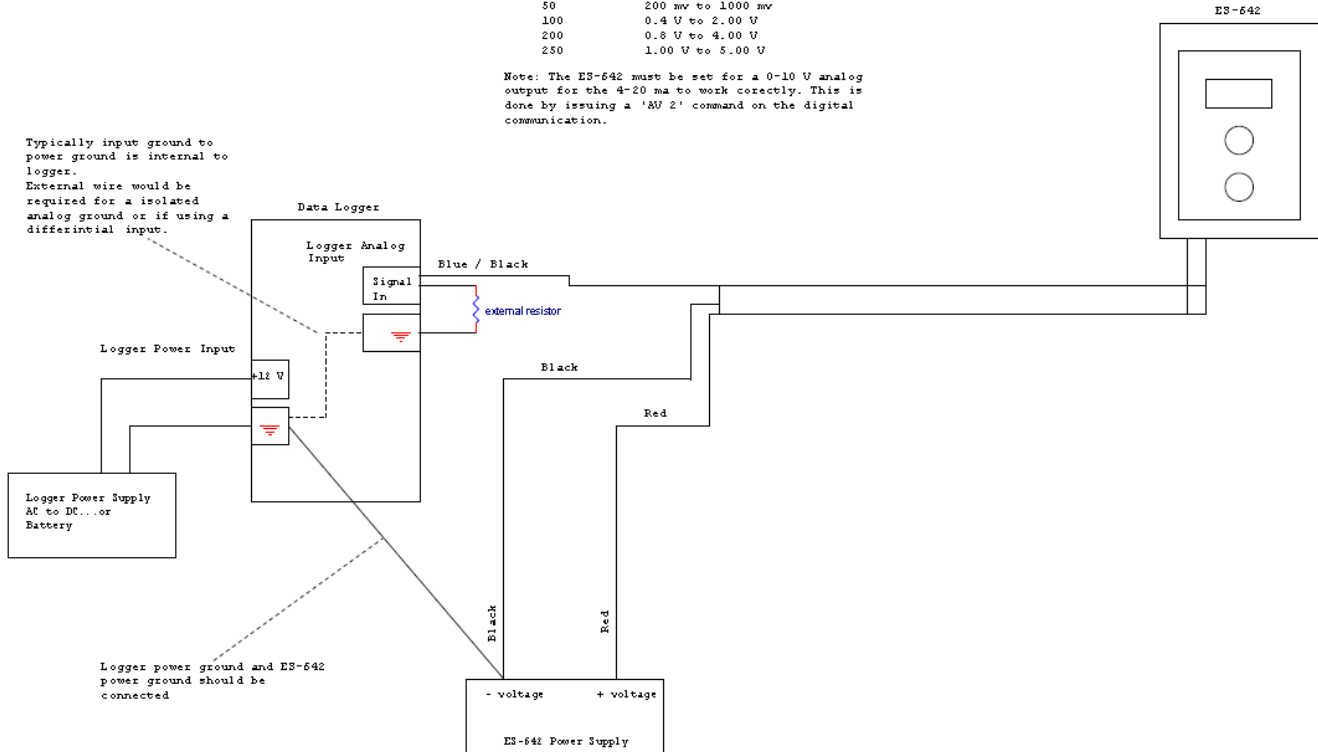
ES-642

Typically input ground to power ground is internal to logger.
External wire would be required for a isolated analog ground or if using a differintial input.

Data Logger

Logger Analog Input

Signal In
Blue / Black

external resistor

Logger Power Input
+12 V

Logger Power Supply AC to DC...or Battery

Black

Red

Black     Red

Logger power ground and ES-642 power ground should be connected

- voltage     + voltage

ES-642 Power Supply

---

External Resistor Selection

| Value (ohms) | voltage seen at logger input |
|---|---|
| 25 | 100 mv to 500 mv |
| 50 | 200 mv to 1000 mv |
| 100 | 0.4 V to 2.00 V |
| 200 | 0.8 V to 4.00 V |
| 250 | 1.00 V to 5.00 V |

Note: The ES-642 must be set for a 0-10 V analog output for the 4-20 ma to work corectly. This is done by issuing a 'AV 2' command on the digital communication.

ES-642

Typically input ground to power ground is internal to logger.
External wire would be required for a isolated analog ground or if using a differintial input.

Data Logger

Logger Analog Input

Signal In
Blue / Black

external resistor
Black

MOI# 80959 Cable

J1     J2

Logger Power Input
+12 V

Logger Power Supply AC to DC...or Battery

Black

Red

MOI#80943 Cable

Black     Red

Optional ground path, Logger power ground and ES-642 power ground should be connected externally if analog input is isolated.

- voltage     + voltage

ES-642 Power Supply