

BC 1054

BLACK CARBON MONITOR

OPERATION MANUAL

REVISION K



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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 BC 1054 instrument users should read and understand the sections on installation, setup, operation, and field calibrations. Other sections with information on subjects such as diagnostics, accessories, and alternate settings should be consulted as needed. An electronic version of this manual is also available.

1.2 Technical Service

This manual is structured by customer feedback to provide the required information for setup, operation, testing, maintenance, and troubleshooting the BC 1054 analyzer. Should additional support be required after consulting the printed documentation, please 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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All BC 1054 monitors have a serial number printed on the product label on the back panel and on the calibration certificate. This number will be needed if contacting the technical service department to request information about repairs or updates for a specific monitor

1.3 About the BC 1054 – Ten Wavelength Black Carbon Monitor

The Met One Instruments, Inc. model BC 1054 MultiSpectrum Carbon Monitor is a ten-wavelength black carbon monitor, which automatically measures and records optical transmission across filter media onto which particulate matter has been deposited at ten wavelengths ranging from 370 nm to 950 nm. From this information the concentration of black carbon “BC” and particulate matter absorbing in the near-ultraviolet regions may be determined.



Figure 1-1 The BC 1054 Front Panel

In addition to these two industry standard measurements, the BC 1054 includes eight additional wavelength measurements. The additional wavelength channels allow analysis of carbon particulate at other wavelengths, as follows:

| Measurement Wavelength | BC 1054 Label | Measurement Wavelength | BC 1054 Label |
|------------------------|---------------|------------------------|---------------|
| 370 nm | BC1 | 590 nm | BC6 |
| 430 nm | BC2 | 660 nm | BC7 |
| 470 nm | BC3 | 700 nm | BC8 |
| 525 nm | BC4 | 880 nm | BC9 |
| 565 nm | BC5 | 950 nm | BC10 |

Table 1-1 BC 1054 BC Measurement Labeling

Ambient air is drawn into the instrument at a controlled flow rate, generally through a size selective PM_{2.5} or PM₁ fractionator. The sampled air is subsequently drawn through a heated inlet section and then through special glass fiber filter tape thereby trapping ambient particulate matter. Optical transmission at each of the wavelengths shown in Table 1-1 is measured through the filter tape thereby allowing BC mass concentrations to be calculated at each wavelength. The filter tape is set to advance either at predetermined frequencies (e.g., once per hour) or when sufficient particulate matter has been deposited on the tape to cause the attenuation of the selected channel to exceed user-selected values.

1.4 Safety Warnings

Optical Warnings: The BC 1054 monitor employs LED light sources ranging from the near UV (370 nm) to the near IR (950 nm). Some of them emit light that is outside the range of normal human vision, and thus could present a potential invisible ocular exposure hazard. The UV light source is a 15 mW LED, emitting at 370 nm. The infrared sources are a 100 mW near-IR LED emitting at 880 nm and a 30 mW near-IR LED emitting at 950 nm. Appropriate precautions should be employed.



A protective housing with this warning symbol fully encapsulates the light sources and optics system during normal operation. Whenever the optical module is disassembled for cleaning, the main power switch must be turned off and the power cord disconnected in order to prevent accidental exposure to UV and IR radiation.

Electrical Warnings: The BC 1054 is a 12 Volt DC powered system, and there are no hazardous live voltages located anywhere inside the instrument. It is equipped with an external desktop power supply module with a 100-240 VAC 50/60Hz input range, and a 12 VDC, 8.5 A output. The external AC pump box (115 VAC or 230 VAC model) contains hazardous voltage. Disconnect pump box power before opening the pump box to conduct maintenance. Neither the BC 1054 instrument, nor the power supply module, are weatherproof and neither should ever be exposed to precipitation or wet conditions.

Thermal Warnings: The instrument contains a 12 Volt 40-Watt internal heater, in the form of two large, gold colored power resistors and a circulation fan located inside the electronics chassis. These resistors are usually hot and should not be touched while the instrument is powered on, or within several minutes after powered off.

1.5 BC 1054 Instrument Specifications

| PARAMETER | SPECIFICATION |
|--------------------------------|---|
| Measurement Principle: | Ten Wavelength Optical Absorption. 950 nm BC10 880 nm BC9 700 nm BC8 660 nm BC7 590 nm BC6 565 nm BC5 525 nm BC4 470 nm BC3 430 nm BC2 370 nm BC1 |
| Measurement Range: | 0.01 µg/m ³ to 100 µg/m ³ BC |
| Data Display Resolution | 0.1 ng/m ³ |
| LLD: | ≤ 8 ng/m ³ at 5 LPM |
| Measurement Interval: | 1 minute |
| Sample Rate: | 2 or 5 LPM, user selectable |
| Filter Tape: | Proprietary treated glass fiber |
| Operating Temperature: | 0 to +40°C (inside shelter) |
| Inlet Heater: | 13 W (setpoints from 25 to 40 °C) |
| Ambient Temperature: | -30 to +50°C |
| Ambient Sensor: | Model BX-597A combination AT/BP/RH digital smart sensor included. |
| Sensor Input: | Support for digital Wind Speed and Wind Direction inputs |
| Internal Data Storage: | 365 days of internal data storage. |
| Data Download: | One USB Flash Drive Port, USB Serial and DB-9 RS-232 serial |
| User Interface: | Menu-driven interface with 4x20 character backlit LCD display and dynamic keypad. |
| Mounting Options: | Bench top or equipment rack mountable. A weatherproof shelter is required. |
| Unit Weight: | Approximately 40 lbs. (18 kg) |
| Unit Dimensions: | Height: 10.5" (26.7 cm) Width: 17" (43 cm) Depth: 15.8" (40 cm). |

Specifications subject to change without notice. See BC 1054 datasheet for latest published specs.

2 BC 1054 INSTRUMENT SETUP & DEPLOYMENT

The BC 1054 is designed for easy setup and simple configuration for most applications. This section describes the basic assembly, setup, and start-up of the instrument.

2.1 Accessories

See the accessories section at the back of this manual for more details about parts and accessories. The normal configuration of the BC 1054 is supplied with the following standard items and accessories:

- 510634 universal input AC to 12 VDC power supply
- 400100 US power cord (2)
- 550065 RS-232 serial communications cable
- 81947-3 span check membrane
- Model BX-597A ambient AT/BP/RH combination sensor, with serial sensor cable
- 83055 External AC pump box, 115 VAC (or 83054 for 230 VAC)
- 960025 10mm Pump tubing
- 9441 TSP inlet
- 8936-5 support tube
- 82934 grounded inlet kit (includes 960216 flexible ESD inlet tubing)
- One roll of 460211 filter tape
- Rack mount angle brackets
- Operation manual
- 80328 USB Drivers/Ethernet Configuration CD

Additionally, the following optional accessories may be included:

- SCC 112 PM_{2.5} sharp cut cyclone, 2 LPM
- SCC 111 PM₁ sharp cut cyclone, 2 LPM
- 82336 PM_{2.5} sharp cut cyclone, 5 LPM
- 82344 PM₁ sharp cut cyclone, 5 LPM
- Dilution flow system

2.2 Shelter & Mounting Options

The BC 1054 must be installed in a clean, dry, weatherproof location such as a walk-in shelter, a trailer or mobile lab, a mini outdoor shelter, or in a permanent structure.

Instrument Temperature: BC 1054 must be operated at temperatures between 0°C and 40°C.

Rack Mounting: The BC 1054 may be installed in a standard 19" equipment rack and would require six rack-units of space (6U) if done so.

Benchtop Mounting: The BC 1054 may also be installed on a table top. Make sure the mounting surface is level, and that the instrument is secured so that it won't "walk" due to vibration. Always leave adequate clearance at the back of the unit for access to the data ports, power switch, and sampling line.

2.3 Sample Inlet Configurations

The BC 1054 is designed to operate with an in-line PM_{2.5} or PM₁ fractionator through flexible tubing connected to the back of the instrument. The fractionators (sharp cut cyclones or SCC) are designed to sample at 2 or 5 LPM. There are no special installation requirements for the BC 1054 other than the monitor be no more than 20 feet away from the source of ambient air being sampled and that that source be directly accessible.

At the sample location, the SCC is coupled directly to the bottom of the 9441 TSP inlet. It is then mounted on the 8936-5 support tube. The flexible ESD sample tubing is then slipped over the barbs on the support tube. A worm-gear hose clamp (pn: 480773) is used to secure the tubing to the support tube. The other end of the sample tubing is routed to the BC 1054, grounded to a terminal on the back of the instrument, and is then installed on the rear of the monitor using a push-to-connect fitting (pn: 580399). See Figure 2-4. Note that this varies from the configuration when using the dilution system (Section 4.2)

2.4 Setting Up the BC 1054

The following section describes setting up the BC 1054 in both the standard 2 LPM and 5 LPM configurations. See section 2.5 for Dilution Flow setup. Set up the BC 1054 hardware items and accessories as described below:

1. **Connect the SCC to the TSP Inlet:** Install PM_{2.5} or PM₁ SCC onto the bottom of the TSP inlet located in the sample area.
2. **Mount the SCC to the Support Tube.** Once the TSP and SCC are coupled, the assembly should be mounted on top of the support tube.
3. **Route the Flexible ESD Tubing:** Flexible tubing (pn: 960216) should be routed from the base of the support tube in the sample location to the back of the BC 1054. It should *not* be connected to the inlet fitting at this time. See Section 2.3.
4. **Ground and Install the Flexible ESD Tubing:** Place the inlet tubing grounding assembly (see Figure 2-1) over the BC 1054 end of the sample tubing. Position the clamp between one and two inches from the end of the tubing (see Figure 2-2) and tighten it until the clamp grips firmly.

CAUTION: Do not overtighten the clamp and crush the tubing.

Insert the tubing into the ½" Push-to-Connect adapter (pn 580399) and connect to the Sample Inlet (marked "Sample" on the back of the BC 1054). Connect the green wire to the right-most terminal marked Shield on TB-1 on the back of the BC 1054 (see Figure 2-3).



Figure 2-1
Inlet Tubing Grounding Assembly



Figure 2-2
Grounding Clamp Position

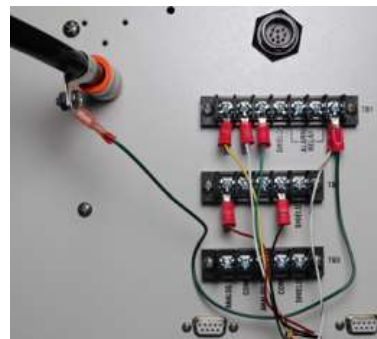


Figure 2-3
Installed Grounding Assembly

5. **Connect the BX-597A AT/BP/RH Ambient Sensor:** The BC 1054 comes with a BX-597A combination ambient temperature, barometric pressure, and relative humidity sensor. The sensor must be mounted to be able to monitor the ambient conditions of the area being sampled (see Figure 2-4).

Route the digital sensor cable (pn: 30010-25) from the corresponding connector on the bottom of the BX-597A sensor to the correct terminals on the back of the BC 1054 as shown in Table 2-1.

| BX-597A WIRE | BC 1054 TERMINAL |
|------------------|------------------|
| Red | DC PWR |
| Orange or Yellow | RS485A |
| White | RS485B |
| Black | GND TB-2 |
| Green | GND TB-1 |
| White/Brown | SHIELD TB-1 |

Table 2-1 BX-597A Sensor to BC 1054
Terminal Wiring Connections

6. **Install the AC Pump Box:** Position the pump box near the BC 1054. The best location for the vacuum pump is often on the floor under the rack or bench, but it may be located up to 20 feet away if desired. It may be preferable to locate the pump so noise is minimized if the BC 1054 is in an area where personnel are present.

Route the clear 10 mm air tubing from the pump to the back of the BC 1054, and insert it firmly into the compression fittings on both ends.

The pump box is supplied with a captive 2-conductor signal cable used by the BC 1054 to turn the pump on and off. It should be connected to the appropriate terminals on the back of the BC 1054. The red wire should be connected to the “PUMP CTRL + RED” terminal and the black one to “PUMP CTRL - BLK”.

Install the AC power connector into the fitting on the pump box. Plug the other end into the appropriate AC power source. The included US-type modular power cord (pn: 400100) can be changed to match local AC connection type, if needed.

7. **Connect the 12V power supply:** Plug the 12V, 8.5A power supply (pn: 510634) into the 4-pin power connector on the back panel of the BC 1054. The power supply has a universal AC voltage input. The included US-type modular power cord (pn: 400100) can be changed to match local AC connection type, if needed.
8. **Configure the BC 1054 Sample Settings:** Determine the appropriate settings for the sample environment and required particulate size cutoff. Configure the monitor as needed per Section 3.5.
9. **Install the filter tape:** Install a roll of filter tape (pn: 460211) as described in Section 2.6.

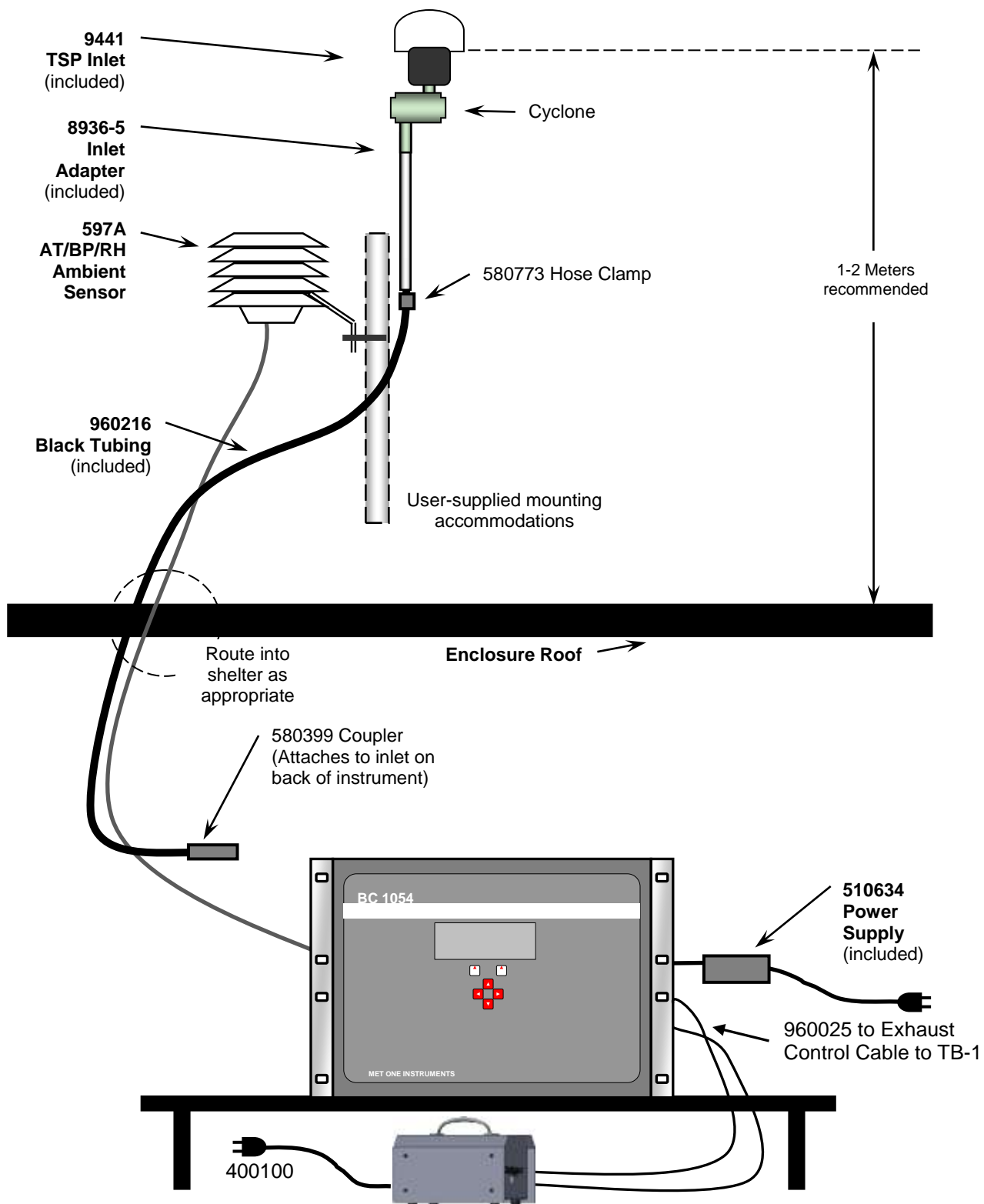


Figure 2-4 Typical BC 1054 Installation in a walk-in shelter

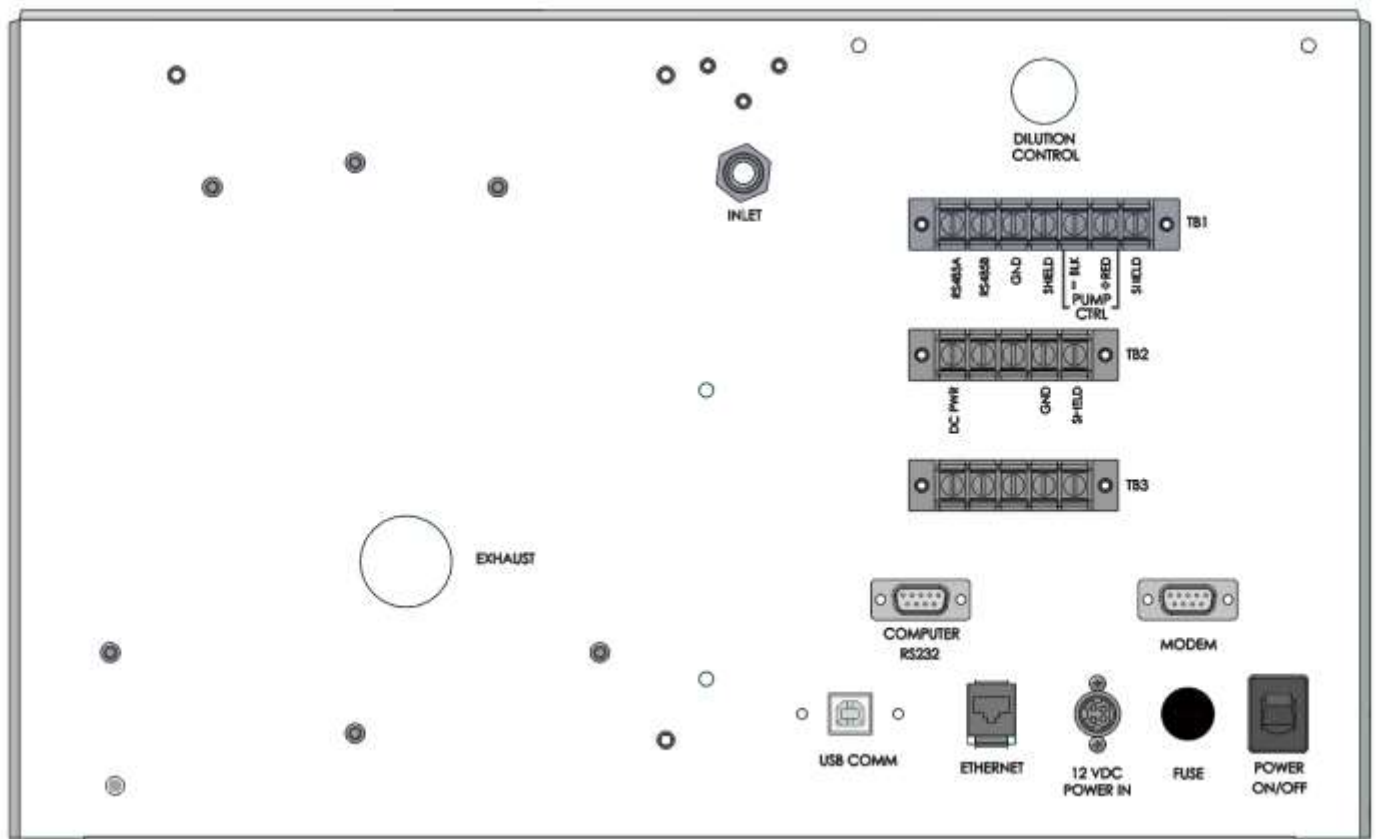


Figure 2-5 BC 1054 Rear Panel Connections

2.5 Setting Up the BC 1054 with the Dilution Flow System

The following section describes setting up the BC 1054 with the Dilution Flow System. For standard 2 LPM or 5 LPM configurations, follow the instructions in section 2.4.

Set up the BC 1054 hardware items and accessories as described below:

1. **Connect the Support Tube to the TSP Inlet:** Install the TSP Inlet on top of the support tube. The SCC will be mounted directly to the back of the BC 1054 as part of the Dilution Flow System assembly.
2. **Route the Flexible Tubing:** Flexible tubing (pn: 960216) should be routed from the base of the support tube in the sample location and connected to the inlet fitting in Dilution Flow System assembly that will be mounted on the back of the BC 1054. For now, route the tubing to the back of the BC 1054 and lay it aside.
3. **Connect the BX-597A AT/BP/RH Ambient Sensor:** The BC 1054 comes with a BX-597A combination ambient temperature, barometric pressure, and relative humidity sensor. The sensor must be mounted to be able to monitor the ambient conditions of the area being sampled (see Figure 2-4).

Route the digital sensor cable (pn: 30010-25) from the corresponding connector on the bottom of the BX-597A sensor to the correct terminals on the back of the BC 1054 as shown in Table 2-1.

4. **Mount the Dilution Flow System assembly:** Install the Dilution Flow System assembly on the back of the BC 1054.
 - a. Remove the two screws holding the cover of the assembly in place and then remove the Dilution Flow System assembly cover (see Figure 2-6).



Figure 2-6 Dilution Flow System Cover Removal



Figure 2-7 Dilution Flow System SCC Alignment

- b. Align the sharp cut cyclone with the flow inlet on the back of the monitor (Figure 2-7) and then press firmly to insert the inlet into the sharp cut cyclone. When fully inserted, the Dilution Flow System assembly will be flush with the rear housing of the BC 1054.



Figure 2-8 Dilution Flow System Mounting Screw Locations



Figure 2-9 Dilution Flow System Exhaust Adapter



Figure 2-10 Dilution Flow System Installed

- c. Align the mounting holes and install the three mounting screws (**Figure 2-8**) to secure the assembly to the main body of the monitor.
 - d. Connect the communication cable to the port in the upper right corner on the back of the BC 1054.
 - e. Insert the 82793 Exhaust Adapter tube into the exhaust (**Figure 2-9**).
 - f. Install the Dilution Flow System assembly cover and secure it in place with the two screws removed in step a. Use caution to avoid pinching the communication cable and internal tubing.
 - g. Attach the Push-to-Connect adapter to the Exhaust Adapter tube.
5. **Connect the inlet tubing.** Route the flexible inlet tubing to inlet located on the Dilution Flow System and insert it. Connect the inlet grounding strap as shown in section 2.4.
 6. **Connect the clear flexible tubing from the pump.** Route the flexible tubing from the pump to the Push-to-Connect adapter on the Exhaust Adapter tube.
 7. **Connect the two-conductor control cable from the pump.** Route the control cable from the pump to the BC 1054 back panel as shown in section 2.4.

8. **Connect the 12V power supply:** Plug the 12V, 8.5A power supply (pn: 510634) into the 4-pin power connector on the back panel of the BC 1054. The power supply has a universal AC voltage input. The included US-type modular power cord (pn: 400100) can be changed to another type if needed.
9. **Configure the BC 1054 Sample Settings:** Determine the appropriate settings for the sample environment and required particulate size cutoff. Configure the monitor as needed per Section 3.5.
10. **Install the filter tape:** Install a roll of filter tape (pn: 460211) as described in Section 2.6.

2.6 Filter Tape Loading and Filter Material Notes

The BC 1054 carbon monitor uses treated glass fiber filter tape rolls, available from Met One Instruments under stock number **460211**. It is essential that this tape be used in the BC 1054 in order to maintain proper instrument calibration and reproducibility. Since the filter tape advance frequency is typically set to depend upon filter-loading, the frequency with which the tape needs to be replaced is variable. A roll of filter tape is expected to last from 3 to 12 months, depending on the sampling conditions.

Note: The BC 1054 tape transport system runs the filter tape from left-to-right. Notice that this places the clean roll on the left side of the monitor. This is the opposite of the configuration used in the Met One Instruments BAM-series monitors.

Warning: The fiber tape is rolled with the checker pattern on the outside of the roll, and the softer side on the inside. If the new roll is installed backwards on the supply reel, then the backing material will be on top inside the measurement head, resulting in improper measurement and likely filter damage. **The instrument cannot identify this incorrect condition.**



Caution: The LEDs will be ON while the tape is being installed. Keep face and, in particular, eyes away from direct proximity of the optical head while the lightproof shields are removed.

Install the filter tape into the BC 1054 instrument as follows:

1. Turn the instrument ON. Press the STOP softkey to prevent the instrument from entering SAMPLE mode. The optical measurement head will raise automatically. To re-set the Tape Remaining Counter, enter the TEST MENU/LOAD TAPE menu (see section 6.8.1). If necessary, the optical measurement head can be manually raised and lowered from this same menu.
2. Flip down the tape load access door. Loosen the two tape reel knobs and remove the reel covers.
3. Install the new filter tape roll onto the left (supply) reel, with the tape coming off of the left side of the roll. Route the tape exactly as shown in Figure 2-11. It should go under the black idler, through the slot in the measurement head cover, under the other black idler, up over the rough encoder drum, and then down to the take-up reel on the right side. Fasten the loose end of the tape to the right edge of an empty core tube installed on the take-up reel, with cellophane tape. **Make sure that the softer side is UP** and the textured side is **DOWN**.
4. Align the filter tape and take up the slack by turning the left (supply) reel. Reinstall the reel covers and flip up the Tape Load Access Door.

5. Enter the TEST MENU/TAPE TEST screen. Press the MOVE softkey. Verify that the tape spools correctly. Advance at least one turn of filter tape over the take-up core, then exit to the main menu.

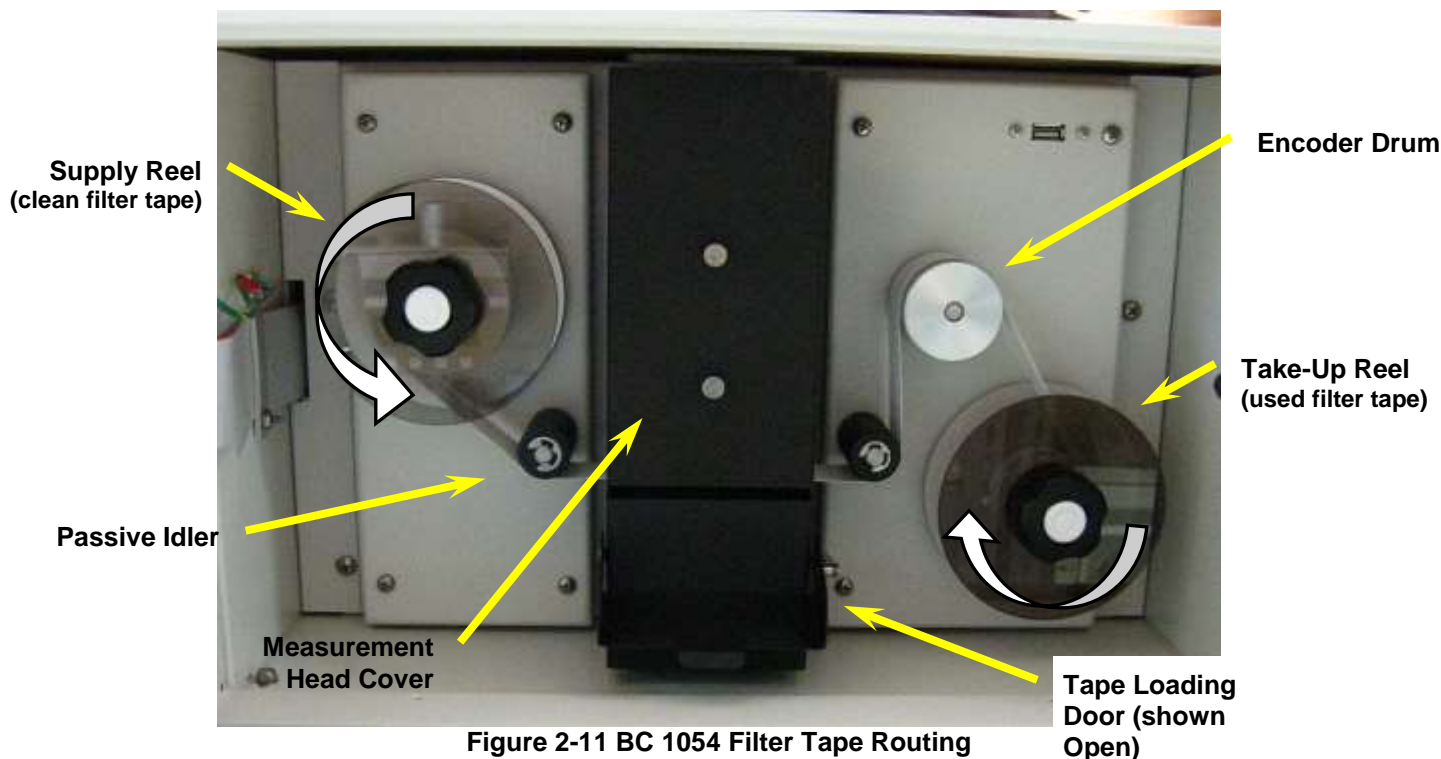


Figure 2-11 BC 1054 Filter Tape Routing

2.7 Starting and Stopping Sample Operation

When the back-panel power switch is turned on, the BC 1054 will boot up and display a splash screen identifying the instrument. After three seconds, a timer will display indicating that sampling will begin soon. The timer starts at 60 seconds and counts down in one second intervals.

2.7.1 Starting Sample Operations

The BC 1054 will automatically start sampling approximately one minute after being turned on. To start sampling immediately, press the START softkey. To temporarily cancel sampling and enter the Main Menu, press the STOP softkey. After 30 minutes of inactivity, the unit will automatically resume sampling.

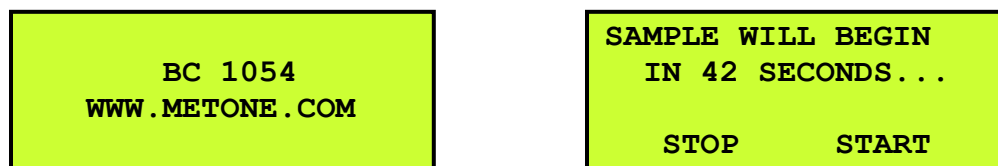


Figure 2-12 BC 1054 Start Up Screens

The unit will advance to a fresh spot of filter tape, turn on the pump, and display WAIT TOP-OF-MINUTE in the status field. Then the status field will change to SAMPLING... It will take two full minutes before BC concentrations will appear. The ▼ down arrow can be used to view the additional measurement channels, flow rate, ambient temperature, barometric pressure, relative

humidity, wind speed and wind direction (WS and WD will read zero if a digital wind speed/wind direction sensor is not installed).

| | | |
|---------------------|-------|-------|
| 2016-08-16 15:49:06 | | |
| SAMPLING... | | |
| BC9 | 115.1 | ng/m3 |
| ▼BC1 | 118.3 | ng/m3 |
| 2016-08-16 15:49:06 | | |
| ▲BC2 | 113.1 | ng/m3 |
| BC3 | 101.6 | ng/m3 |
| BC4 | 136.0 | ng/m3 |
| BC5 | 117.5 | ng/m3 |
| BC6 | 120.2 | ng/m3 |
| BC7 | 102.9 | ng/m3 |
| BC8 | 118.8 | ng/m3 |
| BC10 | 79.2 | ng/m3 |
| FLOW | 5.0 | lpm |
| AT | 20.6 | C |
| BP | 974 | mbar |
| RH | 38 | % |
| WS | 0.0 | m/s |
| WD | 0 | Deg |
| FLOW TEMP | 26.8 | C |
| BOX TEMP | 27.9 | C |
| REMAINING | 75% | |

Figure 2-13 The BC 1054 Main Sampling Screen

After powering up and starting sampling, the BC 1054 takes 3-5 hours to warm up and equilibrate before optimal measurement stability is achieved.

The BC 1054 carbon monitor is factory configured with an array of default settings that the operator may consider changing before deployment. See Section 3 for details about the user interface and the instrument settings.

2.7.2 Stopping Sample Operations

When the STOP MEASUREMENT option in the main menu is selected, the BC 1054 will ask the user to confirm if the sample should be stopped. If confirmed, the BC 1054 will continue its last sample. Once the sample has finished the BC 1054 will then move the tape to a clean spot. After moving the tape to the next clean spot, the BC 1054 will continue measuring for another 11 samples. These 11 records allow the BC 1054 to apply the correction algorithm to the previous data so that the measurement readings are reported with corrected concentrations.

3 BC 1054 USER INTERFACE, MAIN MENU, and SETUP MENU

This section describes the BC 1054 user interface system and the functions of the MAIN and SETUP menu options.

3.1 The User Interface Keypad and Display Functions

The BC 1054 user interface consists of a backlit 4x20 character liquid crystal display (LCD) and a dynamic keypad. The two white keys under the display are called “softkeys” or “hot keys”. These are dynamic keys which change in response to a menu option displayed directly above them on the bottom row of the display. The function of these keys depends on which menu is shown on the display.

The four arrow (cursor) keys are used to scroll up, down, left, and right, to navigate in the menu system, and to select items or change fields on the screen. The arrow keys are also often used to change parameters or increment/decrement values in the menu system.

The MENU key is used to enter the main menu. The ESC key is used to escape or exit out of a menu. The ENTER key enters parameters in a selected field or selects an item in a list.

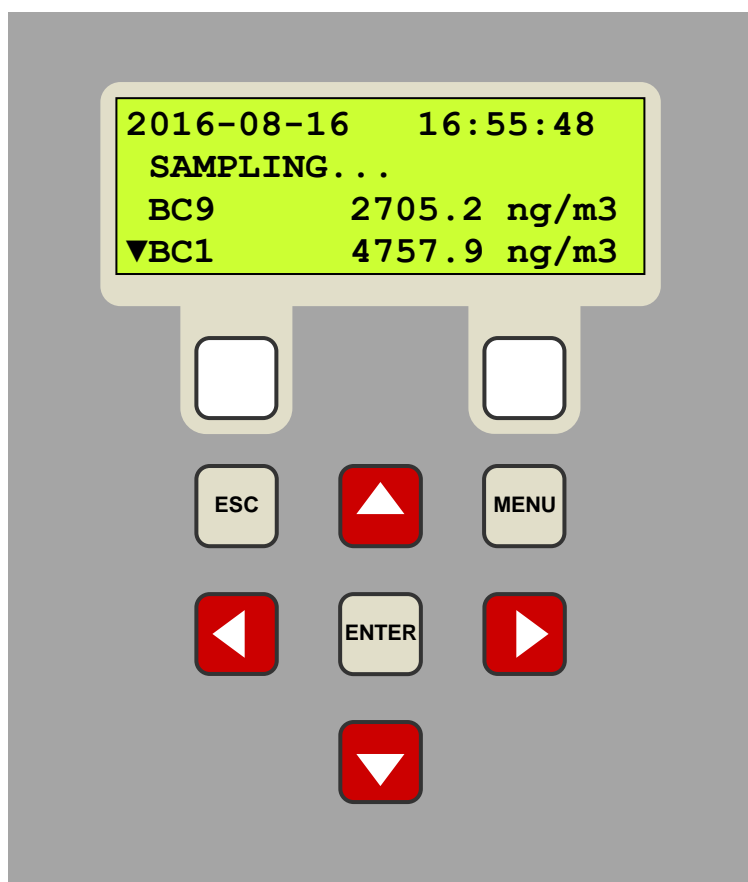


Figure 3-1 BC 1054 User Interface and Display

3.2 How to Navigate and Edit Menu Fields

Field editing in the BC 1054 is slightly different than the methods used in some of the other similar Met One Instruments products.

The flashing cursor ■ is moved to the field to be changed with the ▼▲ keys. Once the desired field is highlighted, the ENTER key must be pressed to open it for editing.

A ▼ symbol will appear next to opened fields where a pick list is available and the ▼▲ arrow keys can then be used to cycle through the available choices. Once the preferred option is highlighted, press the ENTER key again to select it and lock the field. To return to the previous menu, press ESC.

If a numeric field is opened for editing, the cursor will be positioned at the leftmost digit. Use the ◀▶ keys to move the cursor to the digit to be modified and then use the ▼▲ keys to increment/decrement the value. Once all digits have been set to the required value, press the ENTER key again lock the field. To return to the previous menu, press ESC.

Use the ESC key to cancel any edit that may be in progress. The ESC and MENU keys are used to exit the current menu and return to the previous menu level. If the Main Menu is currently selected, the monitor will exit to the Main Sampling Screen.

3.3 Using the Main Sampling Screen

The BC 1054 main sampling/operation screen is shown below in

Figure 3-2. The current date and time are always fixed at the top line of the display in this screen. The up/down arrow keys can be used to scroll to additional viewable parameters.

| | |
|----------------|---------------------|
| Default View | 2016-08-16 15:49:06 |
| | SAMPLING... |
| | BC9 2705.4 ng/m3 |
| Scroll to View | ▼BC1 4757.7 ng/m3 |
| | 2016-08-16 15:49:06 |
| | ▲BC2 113.1 ng/m3 |
| | BC3 101.6 ng/m3 |
| | BC4 136.0 ng/m3 |
| | BC5 117.5 ng/m3 |
| | BC6 120.2 ng/m3 |
| | BC7 102.9 ng/m3 |
| | BC8 118.8 ng/m3 |
| | BC10 79.2 ng/m3 |
| | FLOW 2.0 lpm |
| | DILUTION 1.0 lpm |
| | AT 20.6 C |
| | BP 974 mbar |
| | RH 38 % |
| | WS 0.0 m/s |
| | WD 0 Deg |
| | FLOW TEMP 30.6 C |
| | BOX TEMP 29.7 C |
| | REMAINING 75 % |

Figure 3-2 Main Sampling Screen Format

All ten sample concentrations are reported in units of ng/m³ and the logged concentration values update at the end of every minute.

Note: For firmware preceding version 2.2.0, the concentration values logged to the data file are **uncorrected** concentrations (**not corrected for tape loading effects**). Tape loading corrections are made using the BC Load Correction post-processing software package on data downloaded from the instrument. Version 2.2.0 and later automatically makes this correction when data is retrieved from the monitor.

The **FLOW** value is the actual sample flow rate (through the sample filter), in liters per minute. The **DILUTION** is the flow rate of the Dilution Flow System (this will only be displayed if the Dilution Flow System is detected by the BC 1054). The **AT** value is the ambient temperature, the **BP** value is the ambient barometric pressure, the **RH** value is the ambient relative humidity. The AT, BP and RH values all require that the BX-597A ambient combination sensor be connected properly and are required for instrument operation. These parameters are updated on the display once every second.

The WS value is the measured wind speed and the WD value is the measured wind direction. Both WS and WD require an optional external WS/WD sensor (part number AIO 2). Contact Met One Instruments for details.

The FLOW TEMP is the temperature of the air flow measured just after the optical measurement head whereas the BOX TEMP is the temperature of the inside of the BC 1054 enclosure.

REMAINING is an estimate, in percent of the amount of tape remaining.

3.4 The Main Menu System and Menu Descriptions

The main BC 1054 menu system can be entered at almost any time by pressing the MENU key. Use the ▲▼ arrow keys to move the flashing square cursor to the desired menu option, then press the ENTER key to enter the selected sub-menu.

The functions of the CALIBRATE menu are described in Section 5. The functions of the TEST menu are described in Section 6. The functions in the SETUP and other menu options are explained in this section and in Section 3.5.

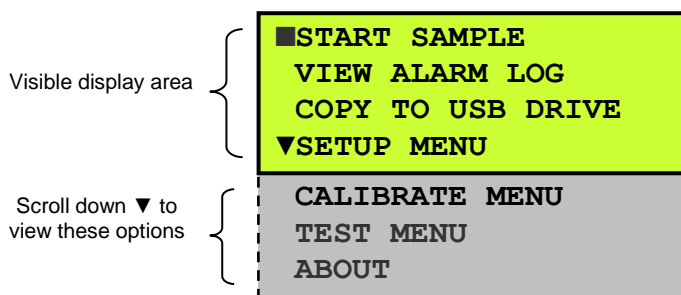
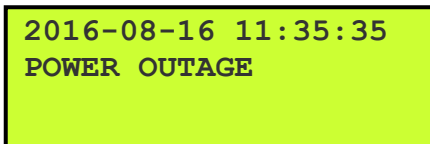


Figure 3-3 The Main BC 1054 Menu

START SAMPLE / STOP SAMPLE: This menu option is used to start or stop the sampling and measurement cycle. The unit will display a confirmation screen with the option to cancel before either action is taken. If a sample cycle is running, a password may need to be entered before the sample can be stopped. See Section 3.5.8 for details regarding the password option.

VIEW ALARM LOG: This menu allows operators to quickly view the error log entries in the BC 1054. The screen displays the type of error, and the time and date when the error occurred. Scroll through the records using the ◀▶ keys. The ◀ key cycles backward to display the previous alarm (in chronological order) while the ▶ key advances forward to the next alarm. See Section 6.1 for descriptions of the alarm types.



```
2016-08-16 11:35:35
POWER OUTAGE
```

Figure 3-4 The BC 1054 Alarm Log

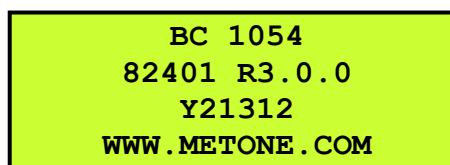
COPY TO USB DRIVE: This menu allows the user to copy BC 1054 data to a USB flash drive located inside the front door, in the upper right corner of the tape transport. See Section 0.

SETUP MENU: This is the main setup menu for the BC 1054. All user-settable operation parameters in this menu are described in Section 3.5.

CALIBRATE MENU: This is the field calibration menu for the BC 1054 temperature, pressure and flow measurements, and for setting user K Factors. The calibration audit of the optical system is also performed in this menu. The calibrations in this menu are described in Section 5.

TEST MENU: This menu is for diagnostic testing of the tape system, lamps, relays, etc. Except for the TAPE TEST and LOAD TAPE screens, these functions are rarely used and are described in Section 6.8.

ABOUT: This menu option displays the BC 1054 firmware version and revision on the second line. The BC 1054 has three separate firmware files. The third line displays the instrument serial number. Use the ▲▼ arrow keys to see the current revision of all firmware installed in the BC 1054.



```
BC 1054
82401 R3.0.0
Y21312
WWW.METONE.COM
```

Figure 3-5 The BC 1054 About Screen

3.5 The SETUP MENU

The BC 1054 setup menu contains the settings and configuration parameters used by the instrument. The factory default values may be correct for many applications but should be reviewed and altered to suit the specific needs of the local monitoring program, as needed. The settings will not be lost if the unit is unplugged or powered down.

The unit will prompt for the password in order to enter the SETUP menu, if a password has been set up by the user (see Section 3.5.8). Use the ▲ ▼ keys to select the desired sub-menu and press the ENTER key to enter. The top SETUP menu is shown below:

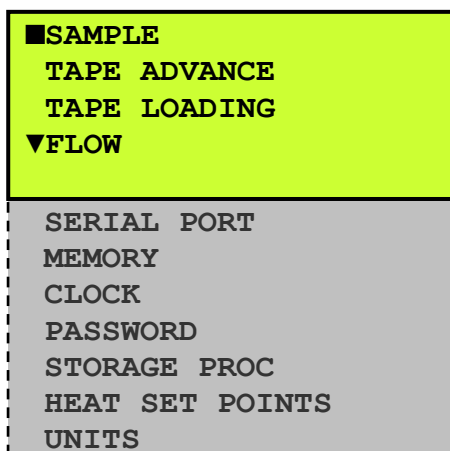


Figure 3-6 The BC 1054 Setup Menu

3.5.1 The SAMPLE Setup Screen

The SAMPLE settings screen allows users to set the Sample Rate and the Location ID of the unit. The Sample Rate is the rate at which the data is sent to the user report and the display. Setting this value to one hour will return hourly data, whereas setting it to one minute will report at a one minute sample period. The location ID is a simple ID number that will appear in the data files. It can be used as a Unit ID number in a network of multiple BC 1054 monitors. The range is 001 to 999.

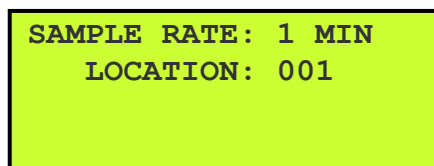


Figure 3-7 The BC 1054 Sample Screen

3.5.2 The TAPE ADVANCE Setup Screen

The TAPE ADVANCE menu contains settings that determine how and when the filter tape is advanced to a fresh spot. Some of these settings may need to be established based upon measured or likely ambient BC concentrations.

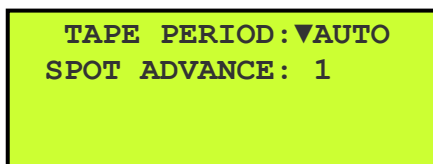


Figure 3-8 The BC 1054 Tape Advance Menu

The TAPE PERIOD setting is the time interval at which the filter tape automatically advances to a fresh spot. When set to AUTO, the unit will advance the tape spot based only on the filter loading threshold. The default operational mode is AUTO tape advance on the UV filter loading threshold. The interval can be set to 1, 2, 3, 4, 6, 8, 12, or 24 hours (independent of filter loading). With a fixed time interval, the tape will advance at the top of the respective hour demarcation. For example, if set to 6 hour tape advances, tape moves will occur at Midnight, 06:00, 12:00 and 18:00.

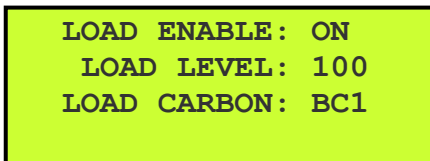
There may be additional tape advances if the loading threshold is reached before the timed tape advance time is reached. In such cases, the timed tape advance will still occur at the scheduled time interval. If frequent tape advancements due to particulate loading on the tape occur, it is recommended to use the Dilution Flow System. See section 4.2.

Note: *The BC 1054 Tape Period should be set to AUTO for normal operation. Setting the interval to anything else should be used for testing purposes only. Concentrations reported by the BC 1054 with the Tape Period **not** set to AUTO **may be inaccurate** and not acceptable by most standards.*

The SPOT ADVANCE setting is used to determine how many filter spots are advanced when the tape moves. The default setting is 1 and the resulting dirty filter spots will be closely spaced. When the setting is set to 2, the unit will leave an extra blank spot between the used spots. This setting should be left at 1 unless the local monitoring requirements mandate wider spacing.

3.5.3 The TAPE LOADING Setup Screen

The TAPE LOADING menu contains more settings that determine how and when the filter tape is advanced to a fresh spot. Some of these settings may need to be established experimentally based on the local sampling conditions.



```
LOAD ENABLE: ON
LOAD LEVEL: 100
LOAD CARBON: BC1
```

Figure 3-9 The BC 1054 Tape Loading Screen

The LOAD ENABLE setting determines if the unit will use the LOAD LEVEL setting as the threshold for advancing the filter spot based on particulate loading on the tape. This is necessary to prevent excessive tape loading and is turned ON as the factory default. If the TAPE PERIOD is set to AUTO (see Section 3.5.2) the LOAD ENABLE option will always operate as if it were ON, *even if it is configured as OFF*. It should only be configured as OFF if automatic filter advances based on loading during the selected time interval are unacceptable.

Note: care should be exercised when setting LOAD ENABLE OFF as longer tape advance settings and higher concentration environments can cause filter loading effects that make the resulting data unreliable.

The LOAD LEVEL setting is the carbon loading threshold at which the tape spot will be advanced based on filter loading (if LOAD ENABLE is set to ON). As light absorbing particulate matter accumulates on the filter spot, it eventually reaches a point beyond which the optical attenuation of the spot is greater than the optimal range for the measurement. A load level of 100 corresponds to an optical attenuation of 1. The range is 10 to 125 (%). The higher this setting is, the more attenuation will be allowed before the tape auto-advances. The default setting is 100.

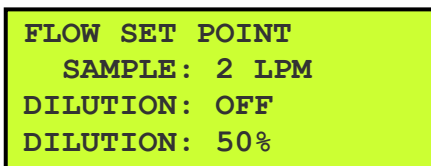
The LOAD CARBON setting determines which of the ten carbon concentrations (see Table 1-1) is used in the LOAD LEVEL calculation to determine when to advance the tape based on loading. Since shorter wavelengths have greater attenuation, using BC1 (the factory default) as the trigger will result in tape changes more often than if, for example, BC9 were used as the trigger. This may be undesirable if minimal data interruptions are required. However, using longer wavelengths (such as BC9) as the trigger will allow a sample to run to the point where the shorter wavelength attenuation becomes excessive. This can have the undesirable effect of less accurate readings for the shorter wavelength channels. More frequent tape advances will reduce the tape-loading phenomenon that results in signal discontinuities each time the tape is advanced but at the cost of losing data during the tape advancement cycles. Care should be taken to select the LOAD CARBON channel that offers the best balance of measurement accuracy with minimal data interruptions. BC1 (UV) is the factory default for triggering a tape move and will result in the best overall results across all 10 wavelength channels.

3.5.4 The FLOW Setup Screen

The FLOW setup screen is shown below. The flow rate may be set to either 2 or 5 LPM and must match the flow rate required by the attached PM_{2.5} or PM₁ cyclone. The factory default is 5 LPM but areas with heavy concentrations should consider using the lower flow rate option to reduce tape movement frequency due to filter loading (see section 3.5.3). When switching between 5 lpm and 2 lpm the flow must be re-calibrated (Section 5.3).

Extremely high concentrations should use the Dilution Flow System. If installed, the flow system is activated by turning it ON in this screen and then selecting either 50, 60, 70, or 80 percent dilution. See section 4.2 for more details.

If the dilution system is not present, the dilution enable and dilution percent are not shown.



```
FLOW SET POINT
SAMPLE: 2 LPM
DILUTION: OFF
DILUTION: 50%
```

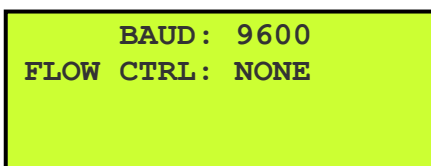
Figure 3-10 The BC 1054 Flow Setup Screen

3.5.5 The SERIAL PORT Setup Screen

The SERIAL PORT setup screen is shown below. These settings affect the configuration for the “COMPUTER RS232” and “ETHERNET” ports. The BAUD setting is the data transfer rate for the serial data output. Downloading large data files will take longer at low baud rates, so set it to the fastest rate supported by the data collection system. The value can be set to 1200, 2400, 4800, 9600, 19200, 38400, 57600, or 115200 baud. The “MODEM” port uses a fixed baud rate of 38,400.

The FLOW CTRL (flow control) setting is set to NONE for most standard RS-232 serial port applications. This setting must be set to RTS/CTS for hardware handshaking when using the Ethernet port. The baud rate and flow control settings must also be set to match in the NetBurner Ethernet card setup. See Section 7 for more information about configuring Ethernet communications and the Met One Instruments 7500 protocol.

The default settings are 9600 and NONE.



```
BAUD: 9600
FLOW CTRL: NONE
```

Figure 3-11 The BC 1054 Serial Port Setup Screen

3.5.6 The MEMORY Setup Screen – Clearing the Memory

The MEMORY screen is used to clear/erase files in the BC 1054 memory. **CAUTION: This menu function will permanently delete the selected files from the instrument memory!**

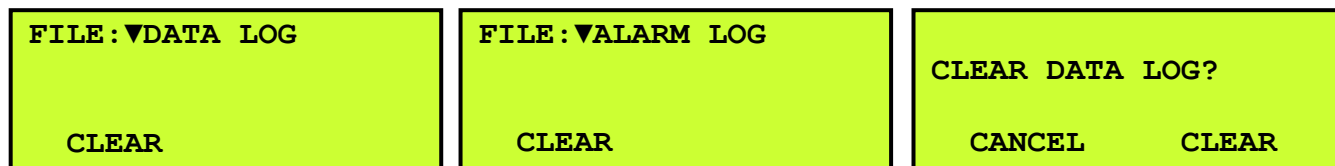


Figure 3-12 The BC 1054 Clear Memory Menus

The FILE value can be set to the DATA LOG, ALARM LOG, or ALL LOGS. Pressing the CLEAR softkey will cause the confirmation screen to appear before the selected files are cleared as shown in Figure 3-12.

3.5.7 The CLOCK Setup Screen

The CLOCK setup screen is used to change the instrument date and time and to calibrate the real-time clock. Press the ENTER key to open the fields for editing. Once open, use the arrow keys to set the desired date and time and then press the ENTER key again to lock the field. Press the SET softkey to save the changes and exit out to the SETUP menu screen.

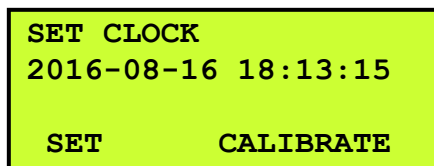


Figure 3-13 The BC 1054 Clock Setup Screen

The following rules apply to setting the clock from the front panel screen and via the serial communication port.

- Setting the clock while the instrument is sampling is allowed for adjustments less than 10 minutes.
- Adjusting the clock by more than 10 minutes requires that the instrument is NOT sampling.

If the clock is adjusted while the instrument is NOT sampling, the time is adjusted immediately.

If the clock is adjusted while the instrument is sampling, adjustments to the real-time clock are made in 5 second increments each minute until the correction is complete.

- A time correction of 1 minute would take 12 minutes to complete.
- A time correction of 10 minutes would take 120 minutes to complete.

Summary of the Real-Time Clock (RTC) Calibration process:

- Set the BC 1054 clock to a reference standard.
- Start Real-Time Clock Calibration
- After 10 to 30 days (longer is more accurate), complete clock calibration process.

To calibrate the RTC:

```
SET CLOCK
2019-06-10 13:34:10

SET          CALIBRATE
```

Enter SET CLOCK menu and calibrate RTC to a reference time standard (www.time.gov, etc).

Press the CALIBRATE softkey.

```
STATUS STOPPED

START        NEXT
```

Press the START softkey.

```
STATUS RUNNING
START 06-10 13:36:19

START        NEXT
```

Current RTC value is stored and STATUS changes to RUNNING and displays the time the calibration was started.

After 10 – 30 days, return to the clock calibration screen and press NEXT.

```
STAND 06-22 13:40:20
RTC   06-22 13:42:02
DRIFT      98.36 ppm
DRIFT          NEXT
```

Enter the STAND(ard) time 2 minutes in the future. When the setting in STAND(ard) matches the reference time standard, press DRIFT.

Press NEXT to show the RTC Calibrate Screen.

```
DRIFT      98.36 ppm
ADJUST    +0.02:49:27

CALIBRATE    EXIT
```

ADJUST is the interval when 1 second will be added to or subtracted from the RTC.

Press CALIBRATE. The Calibrate Clock Warning screen will be displayed

```
WARNING
CALIBRATE CLOCK?

YES          NO
```

Press YES to apply the RTC clock calibration. Press NO to exit with no change.

To remove an RTC calibration, Enter the SETUP > CLOCK menu.

```
SET CLOCK
2019-06-10 13:34:10

SET          CALIBRATE
```

Press the CALIBRATE softkey to enter the CALIBRATE menu.

| | |
|----------------|------|
| STATUS STOPPED | |
| START | NEXT |

Press NEXT to view the current RTC calibration.

| | |
|--------|----------------|
| DRIFT | 98.36 ppm |
| ADJUST | +0.02:49:27 |
| NEXT | 06-26 13:44:23 |
| CLEAR | EXIT |

To remove the current RTC calibration, press CLEAR.
The Remove Calibration warning screen will be displayed.

| | |
|--------------|----|
| WARNING | |
| REMOVE CLOCK | |
| CALIBRATION? | |
| YES | NO |

Press YES to remove the current RTC calibration.
Press NO to exit, keeping the current RTC calibration.

| | |
|--------|-------------|
| DRIFT | 0.00 ppm |
| ADJUST | +0.00:00:00 |
| EXIT | |

RTC calibration screen after being cleared.

3.5.8 The PASSWORD Setup Screen

The PASSWORD setup screen is used to change the 4-digit numeric password used to limit access to certain features in the menu system, including the setup menu.

The default password is **0000**. This disables the password and allows full access to all of the password-controlled functions. If the password is changed to any value between 0001 and 9999, it will subsequently be required for access to these screens.

| |
|-----------------|
| PASSWORD: ■1000 |
|-----------------|

Figure 3-14 The BC 1054 Password Setup Screen

3.5.8.1 Recovering a Lost or Forgotten Password

Should the password ever be lost or forgotten, the Met One Instruments service department can assist in password recovery. Serial communications must be established (see section 1.2) and then the RPW command must be sent. The BC 1054 will provide an encrypted response which should then be emailed to the Met One Instruments service department (see section 1.2) for decoding.

3.5.9 The STORAGE PROC Setup Screen

This screen provides a means of updating the firmware in the PC104 storage processor. Contact the Met One Instruments service department (see section 1.2) for assistance if it is necessary to perform this update.

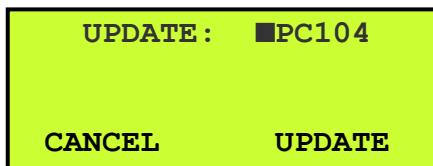


Figure 3-15 The BC 1054 Storage Proc Setup Screen

3.5.10 The HEAT SET POINTS Setup Screen

The HEAT SET POINTS screen provides a means of adjusting the set points of the internal box heater and the inlet heater.

The FLOW TEMP is the temperature of the sample air after it has passed through the inlet heater then through the optical measurement head. This temperature should be set to ~10 °C above the maximum ambient temperature in high RH conditions. The FLOW TEMP available range is between 25 °C and 40 °C. It should be noted that raising the temperature of 100% RH air 10 °C will reduce the RH saturation to approximately 60%.

The BOX TEMP is the target set point for the internal temperature of the box. The available range for this setting is between 0 and 40 °C. This is a *heat only temperature control*, so the temperature inside the box cannot be cooled below ambient temperatures. The default value for BOX TEMP is 30 °C.

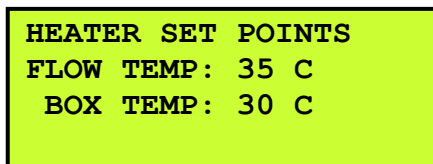


Figure 3-16 The BC 1054 Heat Set Points Setup Screen

3.5.11 The UNITS Setup Screen

The UNITS screen is used to set the display units of certain BC 1054 measurements. Setting the unit forces all reports and screens to convert and display the value in the desired units.

Currently, the only unit settable is the pressure units with the option of mbar or mmHg. Future settable units will be listed here.

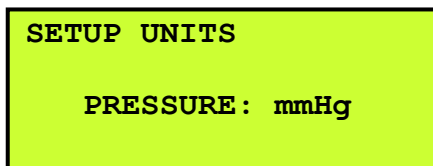


Figure 3-17 The BC 1054 UNITS Setup Screen

4 BC 1054 AIRFLOW SYSTEM

The flow control system is a critical component of the BC 1054 measurement. A complete functional description is included to assist the user in understanding this system.

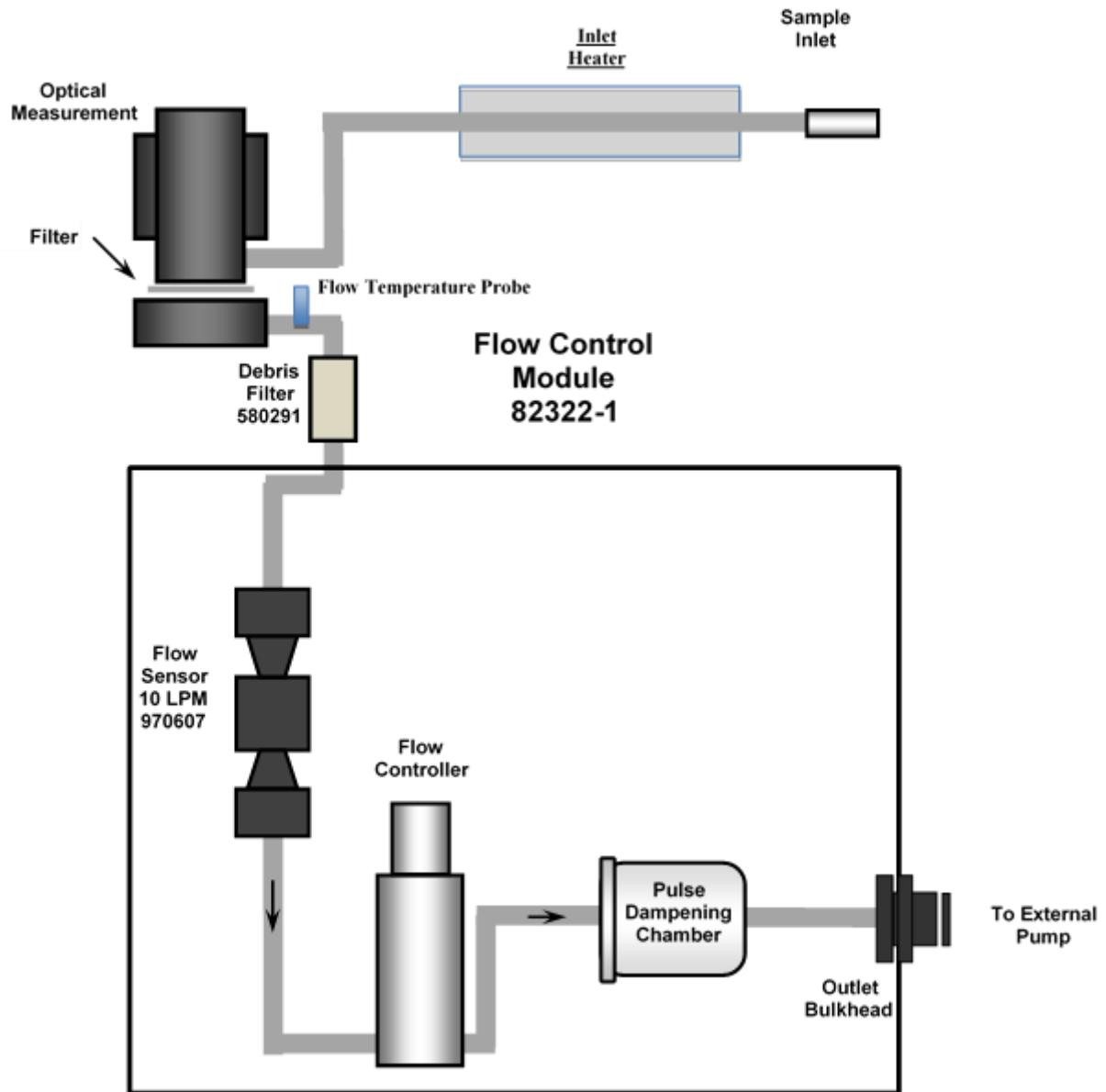


Figure 4-1 BC 1054 Flow Diagram

4.1 Airflow Control System Descriptions

The following flow control systems refer to the flow system shown in Figure 4-1.

Airflow During Normal Sampling:

1. Ambient air is drawn into the instrument at 2 or 5 LPM through a TSP inlet, then through the PM_{2.5} or PM₁ size fractionator, a stiff support tube (for mounting), and then flexible tubing before entering the back of the BC 1054.

2. The sample air is drawn through the inlet heater and into the optical measurement module and through the filter tape where ambient particulate is deposited onto a small diameter filter spot. The filter spot size is optimized for high sensitivity operation rather than for high concentration operation.
3. The sample air exits the bottom of the measurement module, passes through a small debris filter, and then flows through the mass airflow sensor where the flow rate measurement is made. The CPU converts the mass flow from the sensor into actual volumetric flow based on continuous inputs from the model BX-597A ambient temperature and pressure sensor.
4. Next, the sample air passes through the flow controller (which controls the sample flow rate), through the pulse dampening chamber and out the Exhaust bulkhead to the external pump.

Filter Spot Changes:

1. In order to change the filter tape sample spot, the unit turns off the pump and then raises the measurement head away from the filter tape. The tape take-up motor advances the filter tape to a clean spot. The measurement head is lowered to the closed position on the tape and the pump turns back on. This entire process takes less than 1-minute.
2. After the tape advances, optical carbon reports will resume after 2 minutes.

4.2 Dilution Flow System Description

In monitoring environments with extremely high concentration levels, the excessive particulate contained in the sample can result in excessive tape loading. This will result in frequent tape advances. Rapid depletion of the filter tape and potentially bad data are the most immediate detrimental side effects. Over time, there will be excessive buildup of particulate matter inside the instrument, too. This will result in additional maintenance being required and greater wear on internal components. To avoid these issues, Met One Instruments offers the Dilution Flow System.

When installed on the back of the BC 1054, a controlled portion of the clean air is mixed with the incoming sample air. Using this feature, the incoming sample concentration levels can be diluted between 50 and 80%. This means that, because the volume of air is carefully controlled, accurate measurements can be made with a mere 20% of the full particulate concentration in extreme environments.

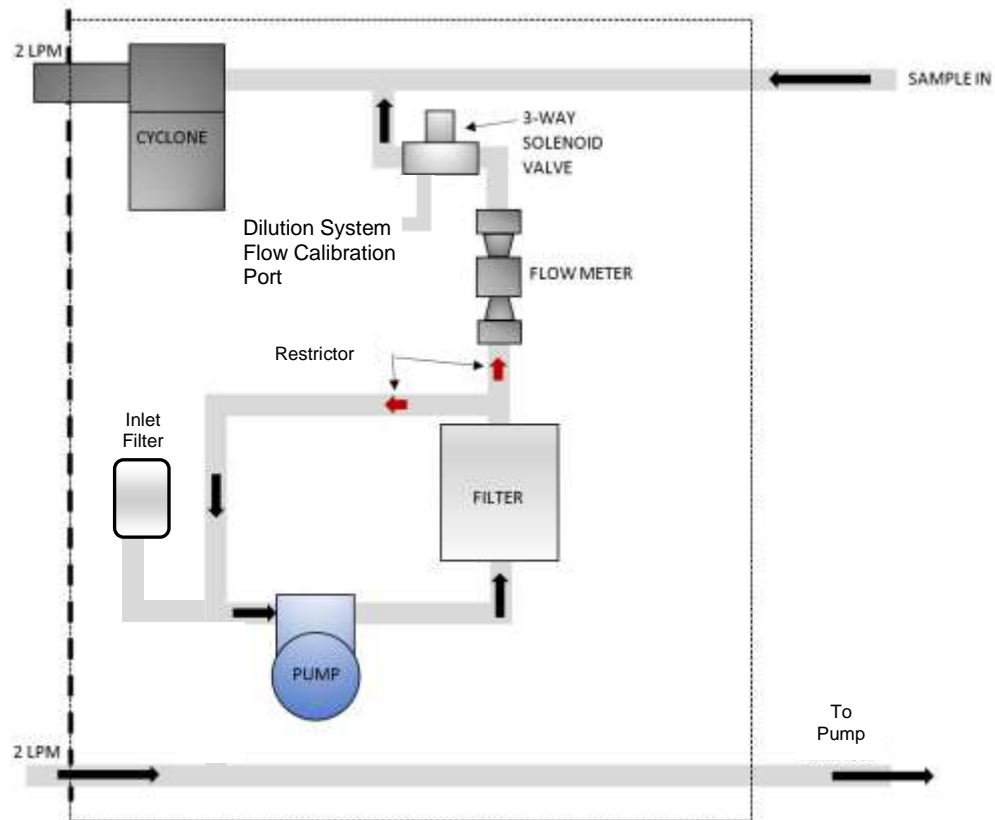


Figure 4-2 BC 1054 Dilution Flow System Diagram

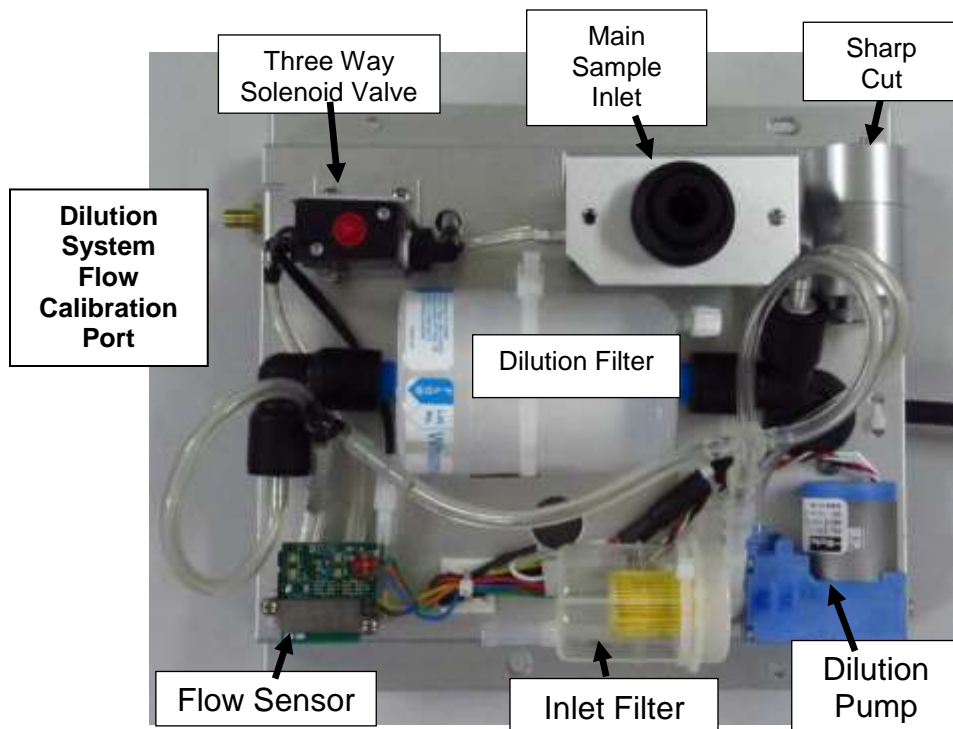


Figure 4-3 Major Components of the Dilution Flow System

Airflow During Dilution Sampling:

1. Air is drawn through the dilution pump and directed through the dilution filter to ensure the dilution air is clean.
2. It then flows through the flow meter at the target flow rate (between 1.0 and 1.6 LPM). The flow rate is controlled by adjusting the speed of the dilution pump.
3. During normal sampling, after exiting the flow meter, the three-way solenoid valve will direct the clean dilution air into the primary sample air intake path. Here it will mix with the sample air diluting the sample.
 - a. The three-way solenoid valve is closed during a leak test of the primary sample flow path (see section 6.8.4) to isolate it from the testing path. During this test, the dilution pump will not be running.
 - b. The three-way solenoid valve also provides an access point for performing flow verifications and calibrations of the dilution system (see section 5.4).

The Dilution Flow System is only useable with a 2 LPM sample flow rate. If the Dilution Flow System is engaged while the BC 1054 is configured for 5 LPM flow, sample flow rate will automatically be changed to 2 LPM.

It is important to note that sharp cut cyclone requires the proper 2 LPM flow rate to perform correctly. When using the Dilution Flow System, the inlet cyclone will not be coupled to the TSP inlet as shown in Figure 2-4, but instead is installed directly on the back of the BC 1054 (see section 4.2). This is because the sample flow will now include both the air flow from the sample inlet and the dilution air flow paths. Therefore, the 2 LPM flow rate will only be present *after* the dilution air is added to the sample air.

For example, if the dilution flow is set to the maximum value of 80%, the dilution flow rate will be 1.6 LPM. There will be a flow of clean air at 1.6 LPM being injected into the sample air flow path just before the sample air enters the SCC. The sample flow rate must be adding 0.4 LPM to the dilution flow rate in order to maintain the necessary 2.0 LPM required by the SCC. Therefore, the sample airflow *upstream of the dilution flow system outlet* is only 0.4 LPM. This is the reason the cyclone cannot be deployed in its normal location beneath the TSP inlet.

By contrast, if the dilution flow were set to 50%, both the dilution flow and the sample flow rates would be 1.0 LPM. This relationship should be considered when determining the sample inlet location and routing the sample air flow path inlet tubing. See section 3.5.4 for engaging the Dilution Flow System and setting the level of dilution.

5 CALIBRATE MENU

The BC 1054 has a system of calibration menus which allow the operator to audit or calibrate various system parameters for optimal performance. It is recommended that airflow control parameters (AT, BP, FLOW) be audited monthly and calibrated quarterly during continuous operation. The exact frequency may vary depending on local conditions and the data validation requirements established by the sampling program administrator.

Note: The BC 1054 temperature and pressure calibrations should always be checked before any flow calibrations are performed, since the flow calculation is dependent on these parameters. The model BX-597A ambient AT/BP/RH combination sensor must be fully functional and connected properly.

The CALIBRATE MENU option is located in the main BC 1054 menu. The password, if used (see Section 3.5.8), is required to enter the menu. The CALIBRATE MENU is shown below:

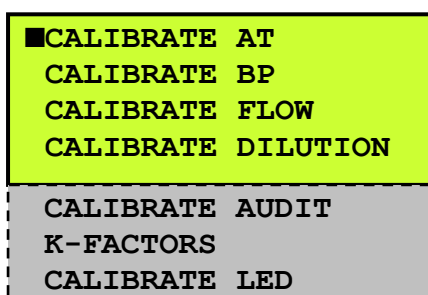


Figure 5-1 The BC 1054 Calibrate Menu

5.1 Ambient Temperature Calibration

The CALIBRATE AT screen is used for field audits or calibrations of the ambient temperature measurement of the BC 1054.

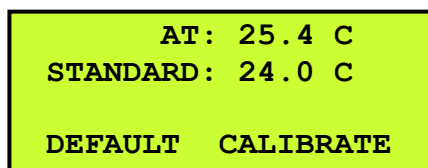


Figure 5-2 The BC 1054 AT Calibration Screen

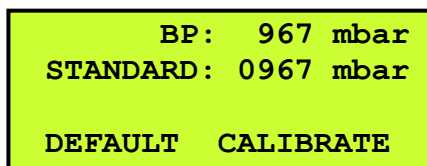
The DEFAULT softkey should be pressed to clear out all previous field calibrations and restore the factory calibration for the sensor. Use this prior to beginning the calibration process.

The AT parameter is the current reading from the BX-597A temperature sensor. The STANDARD field is where the correct value from the traceable temperature standard should be entered, if necessary. To correct the AT reading, enter the value shown on the reference sensor in the STANDARD field (see Section 3.2) and then press the CALIBRATE softkey. The AT value should change to match the STANDARD value when the CALIBRATE softkey is pressed.

To audit this parameter without making any calibration changes, enter the screen, record the AT value, and then press the ESC key to exit.

5.2 Barometric Pressure Calibration

The CALIBRATE BP screen is used for field audits or calibrations of the ambient barometric pressure measurement of the BC 1054. Note that the pressure will be calibrated using the current set units for pressure (mbar or mmHg).



BP: 967 mbar
STANDARD: 0967 mbar
DEFAULT CALIBRATE

Figure 5-3 The BC 1054 BP Calibration Screen

The DEFAULT softkey should be pressed to clear out all previous field calibrations and restore the factory calibration for the sensor. Use this prior to beginning the calibration process.

The BP parameter is the current reading from the BX-597A pressure sensor. The STANDARD field is where the correct value from the traceable pressure standard should be entered, if necessary. To correct the BP reading, enter the value shown on the reference sensor in the STANDARD field (see Section 3.2) and then press the CALIBRATE softkey. The BP value should change to match the STANDARD value when the CALIBRATE softkey is pressed.

To audit this parameter without making any calibration changes, enter the screen, record the BP value, and then press the ESC key to exit.

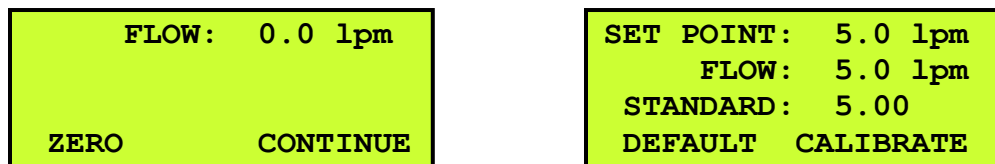
5.3 Flow Sensor Calibration

Note: The BC 1054 temperature and pressure calibrations should always be checked before any flow calibrations are performed, since the flow calculation is dependent on these parameters. The model BX-597A ambient AT/BP/RH combination sensor must be fully functional and connected properly.

The CALIBRATE FLOW screen is used for field audits or calibrations of the sample flow measurement of the BC 1054. The temperature, pressure, and leak status must be checked before performing any flow calibrations. See Sections 5.1, 0, and 6.4 for more details on these prerequisites. When switching between 5 lpm and 2 lpm the flow MUST be re-calibrated, since there is only one flow gain and offset.

Note: If the Dilution Flow System is installed, the dilution pump will remain OFF when calibrating the sample flow. See section 5.4 for calibration of the dilution flow sensor.

Flow calibrations require a traceable flow audit calibration device, and traceable standards for temperature and pressure. The BGI tetraCal and similar particulate sampler flow calibrators work well. Attach the flow meter to the BC 1054 sample inlet.



FLOW: 0.0 lpm
ZERO CONTINUE

SET POINT: 5.0 lpm
FLOW: 5.0 lpm
STANDARD: 5.00
DEFAULT CALIBRATE

Figure 5-4 The BC 1054 Flow Calibration Screens

All flow values are in Q_a actual volumetric conditions.

The screen will first display the zero flow mode with the pump OFF. The measured flow will be displayed at the top of the screen.

To access the DEFAULT menu item, enter the CALIBRATE FLOW menu. The cursor will be flashing next to the ZERO softkey. Press the ENTER key to open the ZERO field for editing. Use the arrow keys to scroll down to DEFAULT. Press ENTER again. The flow control offset and slope can now be set to factory defaults by pressing the DEFAULT softkey.

Press the ENTER key, change the DEFAULT softkey back to ZERO, and press ENTER again to return to the zero flow calibration screen. Press the ZERO softkey to zero the flow sensor. Then press CONTINUE to proceed to the main flow calibration screen and automatically turn the pump ON.

The SET POINT parameter is the target flow rate that the BC 1054 will attempt to maintain. The FLOW parameter is the current flow reading from the BC 1054 flow sensor. The instrument should automatically regulate to the SET POINT value within a few moments.

The DEFAULT softkey should be pressed to clear out all previous field calibrations and restore the factory calibration for the sensor. Use this prior to beginning the calibration process.

The STANDARD field is where the correct flow value from the traceable flow meter should be entered if the flow does not match within $\pm 5\%$ of the traceable standard. To correct the FLOW reading, enter the value shown on the reference meter in the STANDARD field (see Section 3.2) and then press the CALIBRATE softkey. The FLOW value should change to match the STANDARD value when the CALIBRATE softkey is pressed. The monitor will then attempt to regulate the FLOW value to match the SET POINT.

Audit-Only Flow Checks: To audit the flow without making any calibration changes, enter the flow calibration menu, record the zero flow value, press the CONTINUE key, allow the flow to stabilize, compare the FLOW value to the traceable standard, record the results, and then press the ESC key. No flow calibrations are changed if the ZERO and CALIBRATE softkeys are not pressed.

5.4 Dilution Flow Sensor Calibration

The CALIBRATE DILUTION screen is used for field audits or calibrations of the dilution flow measurement of the BC 1054 Dilution Flow System. The sample flow sensor should be calibrated before calibration of the dilution flow sensor. See Section 5.3 for more details.

This flow calibration requires a traceable flow audit calibration device. The standard must be able accept a pressurized flow rate. A vacuum style of flow measurement will not work for this flow. Attach the flow meter standard to the three-way solenoid valve located in the Dilution Flow System (see Figure 5-5).



Figure 5-5 Dilution Flow System Air Flow Locations

All flow values are in actual volumetric conditions. Figure 5-6 shows the various screens that will be displayed during the dilution flow rate calibration.

| | |
|--|--|
| SET POINT: 1.5 lpm DILUTION: 1.50 lpm DEFAULT CONTINUE | SET POINT: 1.0 lpm DILUTION: 1.00 lpm STANDARD: 0.98 SET CONTINUE |
| SET POINT: 1.6 lpm DILUTION: 1.60 lpm STANDARD: 1.69 CALIBRATE CONTINUE | SET POINT: 1.5 lpm DILUTION: 1.50 lpm EXIT |

Figure 5-6 The BC 1054 Dilution Flow Calibration Screens

The screen will first display the current dilution flow set point and turn on the pump. If performing a flow audit, simply allow the flow to stabilize and verify the flow rate is correct and matches the flow standard. Record the results and press ESC on the front panel to exit back to the Calibration menu. If a calibration needs to be performed, press the CONTINUE soft key to begin the calibration process.

The calibration of the dilution flow is a two-point calibration consisting of the minimum (1.0 LPM) and the maximum (1.6 LPM) flow rates. After pressing CONTINUE, the low flow set point test will be displayed and the pump will be adjusted to the 1.0 LPM flow rate.

The SET POINT parameter is the target flow rate that is trying to be maintained. The DILUTION parameter is the current flow reading from the dilution flow sensor. The instrument should automatically regulate to the SET POINT value within a few moments.

The STANDARD field is where the correct flow value from the traceable flow meter should be entered if the flow does not match within $\pm 5\%$ of the traceable standard. To correct the DILUTION reading, enter the value shown on the reference meter in the STANDARD field (see Section 3.2) and then press the SET key to temporarily store the new set point details. Press CONTINUE to advance to the high flow set point.

The instrument should automatically regulate to the SET POINT value within 30 seconds. Repeat the comparison and adjustment inputs made during the low flow test.

If any changes were input to the STANDARD field in either the low or high flow test screens, press the CALIBRATE softkey. The DILUTION value should change to match the STANDARD value. The monitor will then attempt to regulate the FLOW value to match the SET POINT. Press the CONTINUE softkey to advance to the final audit screen. The current dilution flow rate and measured flow will be displayed again. Verify they match and also match the standard and then press the EXIT softkey to return to the Calibrate menu.

If difficulty is encountered during the calibration process, the default key can be used. If the flow cannot be calibrated accurately after several attempts, press the DEFAULT key to clear out all previous field calibrations and restore the factory calibration for the sensor. Once reset, perform the Dilution Flow System flow calibration process again.

Audit-Only Flow Checks: To audit the flow without making any calibration changes, enter the flow calibration menu and allow the flow to stabilize. Verify the flow rate is correct and matches the flow standard. Record the results and press ESC on the front panel to exit back to the Calibration menu.

5.5 The CALIBRATE AUDIT Menu – Performing Optical Span Tests

The CALIBRATE AUDIT menu is used to perform the optical span calibration verification test on the instrument using a neutral density filter. This will introduce a known and consistent amount of optical attenuation into the measurement system. The 81947-3 Neutral Density Span Check Filter tool will be needed to perform this test.

Note: No changes to the instrument calibration are made with this process. This is a span check only.

Press the MENU key on the front panel display. Highlight the CALIBRATE MENU item and press the ENTER key on the keypad. Scroll to the CALIBRATE AUDIT option and press the ENTER key again.

When entering the CALIBRATE AUDIT menu, the measurement head should be in the UP position. If it is not, or if the state is unknown, press the MOVE button (see Figure 5-7) to raise the head and advance the tape one position.

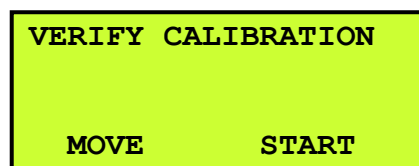


Figure 5-7 Entering the CALIBRATE AUDIT Menu

Flip down the tape slot access door on the measurement module cover as shown in Figure 5-8.



Figure 5-8 Opening the Tape Slot Access Door

Loosen the tape by manually operating the tape supply reel. Pull the tape forward through the slot far enough to be able to lay the tape beneath the cover as shown in Figure 5-9. Care should be exercised to avoid breaking or damaging the tape.



Figure 5-9 Loosening the Tape for Cover Removal

Loosen the two thumb screws on the measurement head module, remove the cover, and then re-install the tape as normal. See Figure 5-10.

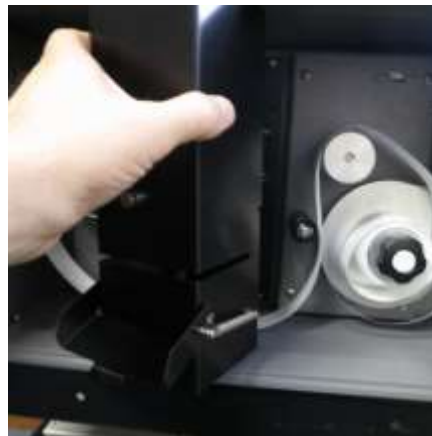


Figure 5-10 Removing the Measurement Head Cover

Press the MOVE option (see Figure 5-7) to properly tension the tape and advance it to a clean spot. *The tape must be moved if a dirty spot is currently under the nozzle.*

When the START key is pressed, the START ZERO screen will be displayed as shown in Figure 5-11. Press CONTINUE to begin the zero test.

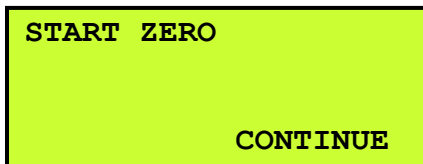


Figure 5-11 The Zero Test Start Screen

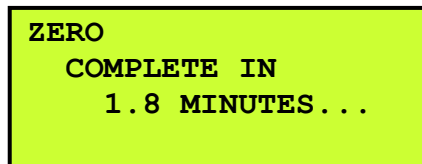


Figure 5-12 The Zero Test in Progress Screen

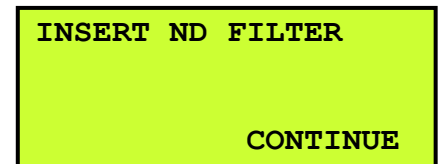


Figure 5-13 The Span Check Start Screen

The measurement head will lower onto the tape and the display will show the completion time remaining (see Figure 5-12) for the blank filter portion of the test. At the end of the ZERO portion of the test, the measurement head will raise and the display will show INSERT ND FILTER as shown in Figure 5-13.

CAUTION: *Be very careful not to move the tape as this will affect the measurement! Closing the door during the measurement will increase repeatability.*

Insert the Span Check Membrane neutral density filter above the tape. The alignment tabs will insert into notches on the mounting plate and the filter will press squarely against it when properly inserted. See Figure 5-14.



Figure 5-14 Inserting the Neutral Density Span Membrane

Press CONTINUE and the measurement head will lower and begin the span check. The display will show the completion time remaining for the ND filter test as shown in Figure 5-15.

**ND FILTER
COMPLETE IN
1.6 MINUTES...**

Figure 5-15 The Span Test in Progress Screen

At the end of the test, the calibration results will be displayed (see Figure 5-16). The values should be within $\pm 5\%$ of the values indicated on the label inside the Span Check Membrane holder mounted on the inside of the door of the BC 1054. Use the ▲ and ▼ keys to view values for all 10 channels. Record the results and then press the CONTINUE button.

| CALIBRATION RESULTS | |
|---------------------|-----------|
| BC1 | 1010.9 ng |
| BC2 | 1130.1 ng |
| CONTINUE | |
| BC3 | 1225.5 ng |
| BC4 | 1368.1 ng |
| BC5 | 1405.0 ng |
| BC6 | 1455.3 ng |
| BC7 | 1584.6 ng |
| BC8 | 1654.7 ng |
| BC9 | 1924.1 ng |
| BC10 | 2044.5 ng |
| CONTINUE | |

Figure 5-16 The Calibration Results Screen

The measurement head will raise and the display will indicate when it is safe to remove the ND filter as shown in Figure 5-17.

Remove the filter and then press the EXIT button to return to the CALIBRATE menu.

REMOVE FILTER

EXIT

Figure 5-17 The Calibration Audit Exit Screen

Should the values fail to be within $\pm 5\%$, the most likely reason is inadvertent tape movement during the test. The test should be run again with particular attention paid to maintaining the tape stationary. If the test still fails, contact the Met One Instruments, Inc. service department for assistance. See section 1.2 for contact details.

Loosen the tape supply wheel and lay the tape across the bottom of the enclosure to allow room to reinstall the measurement head cover. Reinstall the cover, open the access door (if necessary) and reload the tape per the instructions provided in section 2.6 of this manual.

5.6 K Factor Calibration

Each BC 1054 monitor leaves the factory with a calibration certificate containing the K-factors used to adjust the referenced BC 1054 monitor to a factory standard. In certain sampling situations, it may be desirable to adjust the output readings of one or more channels to more closely match a reference instrument under local conditions. The K-FACTORS screen in the CALIBRATE MENU may be used to do this.

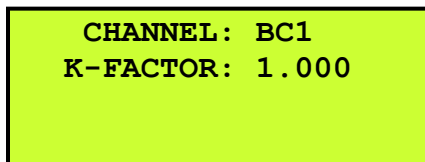


Figure 5-18 The BC 1054 K-Factors Screen

To select a given wavelength channel, highlight the CHANNEL field and press the ENTER button on the keypad. Use the up and down arrows to cycle through the list to find the desired channel (see Table 1-1) and then press ENTER again to select it. The K-factor for that channel may now be entered.

The K factors are direct multipliers applied to the concentration measurements. All concentration data stored in the BC 1054 will be affected by these K factors. Only the values reported in the CALIBRATE AUDIT menu are not affected by these K factors.

Note: These user accessible K factors do not replace or modify the factory programmed calibration K factors listed on the calibration certificate nor are they applied during the Calibration Audit (see section 5.5).

5.7 Calibrate LED

Each LED have a detector range of 0 to 2500 mV which are calibrated at the factory. Due to detector alarms, it may be possible for the user to calibrate each LED using the Calibrate LED screen. **Note: Tape is required to calibrate the LEDs and therefor the instrument will check the tape upon entering the screen.**

MOVING TAPE
TO CLEAN SPOT
PLEASE WAIT
EXIT

After verifying the tape, the user must select the LED channel they want to calibrate. Manually adjust the Set Point (SP) so that the reference and signal values read valid values or use the AUTO ADJ feature which will automatically calibrate the selected LED to the proper value.

LED: 01 SP: 03.1 mA
SIGNAL: 1630.1 mV
REFERENCE: 1504.3 mV
AUTO ADJ EXIT

Press the AUTO ADJ button to have the BC 1054 automatically calibrate the selected LED to the best value. A status line will be shown and when finished the Set Point (SP) field will be updated to the new value.

LED: 01 SP: 03.1 mA
SIGNAL: 1630.1 mV
REFERENCE: 1504.3 mV
STATUS: AUTO ADJ

If the signal or reference is greater/less than the maximum/minimum limits, then a warning screen will be shown, and the user must manually adjust the set point so that both the signal and reference values are above and below the minimum/maximum limits.

WARNING!
SIGNAL IS > 2450
MAX LIMIT
NEXT

WARNING!
SIGNAL IS < 500
MIN LIMIT
NEXT

MANUALLY
ADJUST CURRENT
NEXT

6 MAINTENANCE and TROUBLESHOOTING

This section provides information about routine maintenance of the BC 1054, and for performing more detailed diagnostic tests if a problem is encountered. The instrument generates error messages on the display or in the data log if a failure or other problem is detected. Many times, there is a simple solution. Persistent errors often signify a failure that will require investigation.

6.1 BC 1054 Error & Alarm Event Descriptions

The BC 1054 contains a system of error and alarm codes that are used to alert the operator to any problems with the unit. The errors appear on the display and are stored in the digital alarm log with the time and type of the error. Corresponding alarm codes are stored in the data array.

The Alarm field is reported in data files by a numeric code. If multiple alarms are generated for a single data record, the reported alarm value is the sum of the alarm codes. The general alarm events are described in Table 6-1. Certain alarm events may not be posted to the data array if an alarm condition terminates operation before the end of a sample. Please consult the Alarm Log for more detailed information when an error is encountered.

| Code | Description | Causes | Corrective action |
|------|-----------------------------|--|--|
| 0 | No Alarm | System fully functional | None |
| 1 | Power Failure | Caused by a power cycle or a microprocessor reset. | Power off/on event logged. Ensure unit is provided with stable power |
| 2 | Digital Sensor Link Failure | Digital sensor link failure after 10 seconds of no communication with the BX-597A sensor. | <ol style="list-style-type: none"> 1. Ensure BX-597A sensor connection on back of BC 1054 are correct. Section 2.4 2. Ensure BX-597A sensor connector plugged in securely on bottom of BX-597A. Section 2.4 3. Possible bad BX-597A. Obtain factory replacement. |
| 4 | Tape Move Failure | <ol style="list-style-type: none"> 1. Tape roll exhausted 2. Tape break 3. Tape loose, not turning encoder 4. Encoder wheel turns, but not measuring tape movement | <ol style="list-style-type: none"> 1. Install new roll of tape. Section 2.6 2. Re-attach tape to take-up spool. Section 2.6 3. Raise nozzle, tighten tape so it's in contact with encoder wheel. Section 2.6 4. Optical encoder fault. Refer to qualified service technician |
| 8 | Maintenance | Stop for maintenance during normal operation. | "Stop Sample" logged. Not an error condition. |
| 16 | Flow Failure | <p>Failure when the flow is less than 1.0 LPM for greater than one minute, when the flow is 10% out of regulation for more than one minute, or when the flow is 5% out of regulation for more than five minutes.</p> <ol style="list-style-type: none"> 1. Flow controller out of position 2. Inlet hose kinked or other blockage on inlet 3. Debris filter clogged 4. Bad pump 5. Bad flow sensor or flow controller | <ol style="list-style-type: none"> 1. Perform flow audit and allow flow controller to regulate flow. Section 5.3 2. Un-kink hose or remove blockage, Clean cyclone, clean TSP head, replace inlet tubing 3. Clean or replace debris filter 4. Replace pump and re-calibrate flow. Sections 6.5.1, 5.3 5. Replace Flow System and re-calibrate flow. Sections 6.5, 5.3 |

| | | | |
|--------------|---------------------------------------|---|--|
| 32 | Automatic Tape Advance | The tape was advanced because of tape loading. Scheduled tape advances do not generate this notice. | Automatic tape advance logged. Not an error condition. |
| 64 | Detector Failure | <ol style="list-style-type: none"> 1. Misinstalled tape 2. Blocked Reference or Sample port 3. Light leak 4. Hardware Failure | <ol style="list-style-type: none"> 1. Verify tape is installed correctly. Section 2.6 2. Clear obstructions in the port below the tape (Sample detector window) or Reference port 3. Ensure door is closed and light shield is properly installed 4. Refer to qualified service technician |
| 128 | N/A | | |
| 256 | Sensor Range | A sensor is outside its designated limits. Check error log for abbreviation WS, WD, AT, RH, BP, FLOW, DFLOW, LED T, or DET T. | <ol style="list-style-type: none"> 1. AIO equipped: if WS, WD, AT, RH or BP, replace AIO. 2. BX-597A equipped: if AT, RH or BP, replace BX-597A. 3. If FLOW, DFLOW, LED T, DET T refer to qualified service technician |
| 512 | Nozzle Move Failure | Set when nozzle failed to move up or down. | <ol style="list-style-type: none"> 1. Lift motor not turning: Verify connection in cable 2. Lift motor turning, lift arm not moving: Lift bearing slipping on shaft, or shaft broken. Refer to qualified service technician 3. Lift motor turning, lift arm moving, nozzle not moving: lift bearing broken. Refer to qualified service technician 4. "UP" and/or "DOWN" opto not functioning. Refer to qualified service technician. |
| 1024 | SPI Link Failure | Internal communication failure with the Storage Processor | <ol style="list-style-type: none"> 1. Re-connect cable between 80880 and 30030. 2. Refer to qualified service technician |
| 2048 | Calibration Audit | A user Calibration Audit was being performed. | Calibration Audit activity logged. Not an error condition. |
| 4096 | Storage Processor Link Failure | Internal communication failure. | Refer to qualified service technician (unit still functional, data storage reduced to 14 days). |
| 65536 | Tape Move | System advances the filter tape. | Tape advance logged. Not an error condition. |

Table 6-1 Alarm Triggers

Detector Alarm Events: The detector alarm events are detailed in Table 6-2. Any detector failure event will stop machine operation, force a tape advance, and then attempt to resume normal sampling. Detector *warnings* will be logged but will not interrupt operation. The IR and UV detector ranges are 0.0 to 2500 mV. The limits are as follows:

Saturation Limit = 2450 Detector Limit = 100 Zero Limit = 20 mV

| Description | Causes |
|------------------------------|--|
| LED Failure | While an LED is ON, the signal and reference detector readings are below the Detector Limit. |
| Signal Detector Failure | While LED 1 is ON, the signal detector reading is below the Detector Limit and reference detector reading is above the Detector Limit. |
| Reference Detector Failure | While LED 1 is ON, the signal detector reading is above the Detector Limit and reference detector reading is below the Detector Limit. |
| Signal Zero Warning | When the signal zero is above the Zero Limit. |
| Reference Zero Warning | When the reference zero is above the Zero Limit. |
| Signal Saturation Failure | When any of the LED Signal readings is above the Saturation Limit. |
| Reference Saturation Failure | When any of the LED Reference reading is above the Saturation Limit. |

Table 6-2 Causes for Detector Failure Alarms

See section 5.7 for more information about calibrating the LEDs.

Sensor Outside Range Alarm Events: This alarm occurs if one of the BX-597A sensor parameters registers a value outside of its measurement range, indicating a possible sensor failure. It is intended to filter out and catch full scale readings which can occur from the ambient sensors.

| Sensor | Minimum | Maximum |
|-----------|----------|-----------|
| AT Sensor | -60.0 C | 80.0 C |
| BP Sensor | 400 mbar | 1200 mbar |

Table 6-3 Set Points for Out of Range Alarms

6.2 Basic Problem Causes/Solutions Table

The following table contains information on some of the more common BC 1054 problems that may be encountered, and some steps to identify and remedy the problems. Met One Instruments welcomes user suggestions for new items to include in this section of future manual revisions.

| Problem: | The instrument doesn't appear to be turning on or starting. |
|------------------------|--|
| Cause/Solution: | <ul style="list-style-type: none"> • Make sure the power supply and power cord are properly connected to a good electrical outlet. • Make sure the power switch on the back panel is in the ON position. It has a red indicator light that should be ON. • If the instrument is ON, the hum of the internal heater circulation fan should be audible. • The LCD display should come up any time power is applied. • The BC 1054 should start sampling within one minute after power-up. • After using the STOP SAMPLE function, sampling will resume after 30 minutes. |

| Problem: | Flow failures or low flow. |
|------------------------|--|
| Cause/Solution: | <ul style="list-style-type: none"> • Make sure the pump exhaust is not blocked. • Make sure that the tape is properly advancing the dirty spots. See Section 3.5.2 • DEFAULT the flow sensor calibrations and re-calibrate the flow. If corrupted flow calibration parameters are entered into the flow calibration, it may appear that the flow system is not working. See Section 5.3. • Verify the AT and BP sensor function. Failed ambient sensors will affect the flow. See sections 5.1-2. • Check the internal debris filter. If it is clogged, remove and clean (or replace) the filter element. • The sample pump itself will eventually wear out and need to be rebuilt or replaced. It should last at least two years under normal conditions. |

| Problem: | Leak check failures |
|------------------------|--|
| Cause/Solution: | <ul style="list-style-type: none"> • There is always a small amount of leakage at the filter tape interface. • Make sure the upper and lower nozzles are completely clean. • Check the push-to-connect tubing fittings inside the instrument. • The filter tape can be replaced with a small rubber sheet with a small hole positioned under the nozzle. This will eliminate the tape as the leak point to help isolate the leak source. <p>Note: nothing down-stream of the flow sensor is leak tested during the standard leak test procedure.</p> |

| Problem: | Optical system alarms and failures |
|------------------------|---|
| Cause/Solution: | <ul style="list-style-type: none"> • A Detector Failure will occur if no filter tape is installed in the measurement head. • Detector Failure will occur if an LED has failed, if either the Reference or Signal Detectors have failed or if there is a ZERO failure (high background). First, ensure tape is properly installed and covers are correctly installed. • Check for obstruction in the port below the tape above the detector window. |

| Problem: | Calibration Audit failures |
|------------------------|---|
| Cause/Solution: | <ul style="list-style-type: none"> • A Calibration Audit Failure can occur if the filter tape is moved during the Calibration Audit procedure. Care should be exercised to not move or damage the tape when performing the calibration audit. • A Calibration Audit Failure can occur if the Calibration Audit Membrane (81947-3) is inserted incorrectly. The Membrane should be fully seated against the back plate with the forks centered in the slot and the open hole on the LEFT. • A Calibration Audit Failure can occur if too much ambient light is allowed to enter the instrument during the process. Ensure the instrument shroud cover is ON and the door is closed during both the zero and ND Filter stages of the audit. • A Calibration Audit Failure can occur if the ND filter membrane in the 81947-3 span check membrane is damaged. A replacement 81947-3 membrane can be purchased from the Met One Instruments Service Department. |

Table 6-4 Common Problems and Solutions

6.3 Suggested Periodic Maintenance Intervals

Table 6-5 shows the Met One Instruments recommended periods for routine maintenance items. Some of these items will need to be performed more or less often depending on local conditions. Local monitoring program administrators may need to review these items and establish SOPs appropriate for local applications.

| Maintenance Item | Minimum Period | Manual Section |
|---|--------------------------------------|------------------------------|
| Replace filter tape | As Required (2-12 Months Typical) | 2.6 |
| Temperature, pressure, and flow audits | 2 Months | 5.1, 0, 5.3, 5.4 |
| Span check | 2 Months | 5.5 |
| Clean inlet particle traps (cyclone) | 2 Months | 6.6 |
| Clean cyclone | 3 Months | 6.6 |
| Replace cyclone O-rings | As Required | 6.6 |
| Leak test | 2 Months | 6.4 |
| Flow, temperature, and pressure full calibrations | As Required | 5.1, 0, 5.3, 5.4 |
| Clean the debris filter | 1 Year | 6.5 |
| Replace dilution system cartridge filter | 3 Years | 4.2 |
| Rebuild external pump | As Required | Contact Met One Service Dept |
| Replace dilution system pump | As Required | 4.2 |
| Replace dilution system flow sensor | As Required | 4.2 |
| Factory service | As Required | 1.2 |

Table 6-5 BC 1054 Maintenance Schedule

6.4 Flow System Leak Checks and Nozzle Cleaning

NOTE: Leak check should be performed with the tape installed.

The tape interface nozzles in the optical measurement head should be checked and cleaned on a routine basis, in order to prevent flow leaks at the filter tape interface. This requires removing the optical light shield and removing the filter tape. With the upper head raised, the parts can be

inspected and cleaned with a cotton-tipped applicator if needed. Be sure to replace the tape prior to beginning the leak check.

The BC 1054 flow contains an easy to maintain flow system (see Figure 4-1). To perform a leak test, remove the flexible tubing from the back of the monitor and place the vinyl cap (pn: 770025) over the inlet. Navigate to the TEST MENU > LEAK TEST menu as shown in Figure 6-2. The FLOW value is the output from the internal flow sensor.

If the Dilution Flow System is installed, the vinyl cap cover cannot be used. Instead, insert the nylon sealing plug (pn: 580183) into the tubing inlet. Be sure to fully insert the plug as shown in Figure 6-1.



Figure 6-1 Leak Check Sealing Plug Installation

Press the LEAK ON softkey. This will turn on the pump and stop the flow controller valve from attempting to regulate the flow while the vinyl cap is in place. If the Dilution Flow System is detected by the BC 1054, this action will also close the three-way solenoid valve in the dilution flow path to isolate it from the primary sample path. The PUMP ON key may be used to turn on the vacuum pump while leaving the flow controller active. This key will change to read PUMP OFF whenever the pump is running. The FLOW value should be 0.5 LPM or less for the leak test to be considered passing.

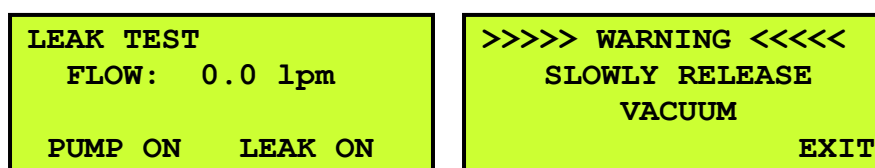


Figure 6-2 The BC 1054 Leak Test Menu

Once complete, press the PUMP OFF key to turn off the pump. **Slowly release the vacuum** in the system (by easing off the vinyl cap) ***before*** exiting this screen. The warning screen shown in Figure 6-2 will be displayed when exiting the Leak Test screen. Exiting the Leak Test screen before releasing the vacuum will cause the vacuum to be released rapidly. This can damage the tape and suck debris into the sample chamber which may require returning the monitor to the factory for service.

Reconnect the flexible tubing on the back of the monitor and resume sampling operations.

6.5 Debris Filter Changes

The BC 1054 contains a filter in the flow system, as described in Section 4.1.

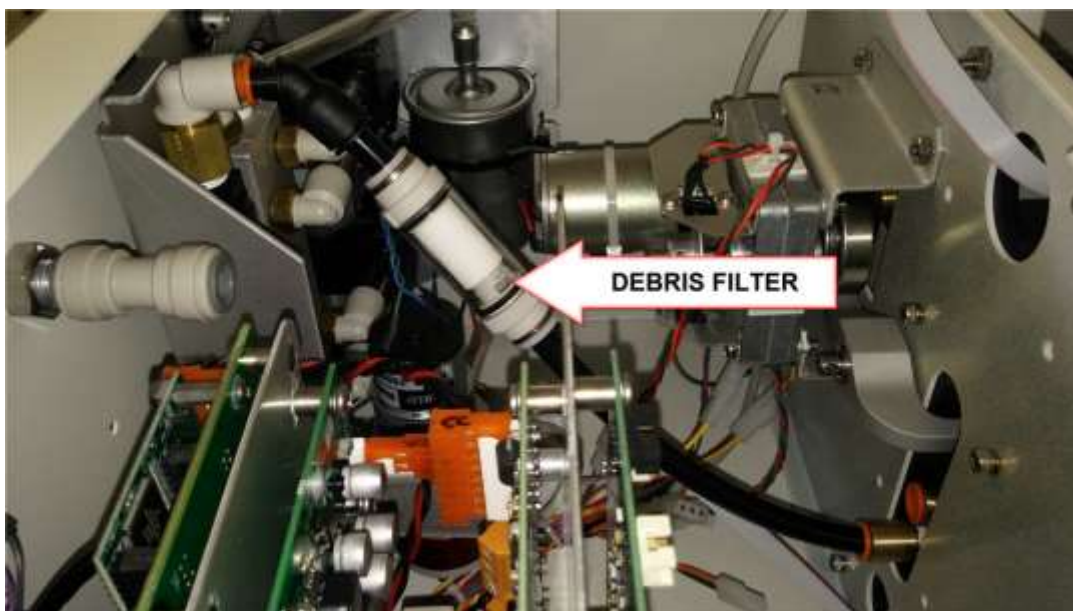


Figure 6-3 Debris Filter Location

This internal filter (see Figure 6-3) keeps filter tape debris out of the flow sensor and is not usually exposed to ambient particulate. It can be cleaned by turning the end of the housing to open it, then blowing any debris off of the element and reassembling. The element can be replaced if excessively dirty.

6.6 Inlet and Cyclone Cleaning

The BC 1054 inlet cyclones all need to be cleaned periodically. Met One recommends cleaning the inlet cyclone particle trap at least once per month in normal conditions. The main cyclone cavity should be disassembled and cleaned every three months during continuous use.



Figure 6-4 Unscrew and clean particle trap

Clean the cyclone particle trap by unscrewing the cap from the cyclone body, then wipe it out with a cloth or blow it clean with compressed air. Check the O-ring and lubricate if necessary. If the O-ring is damaged, replace it using part number 720079 found in the 8658-2 replacement O-ring kit.

Note: the dilution system cyclone is located behind the exterior cover of the dilution system. The cyclone particle trap can be accessed after removing the outer cover of the dilution system mounted on the back of the BC 1054.

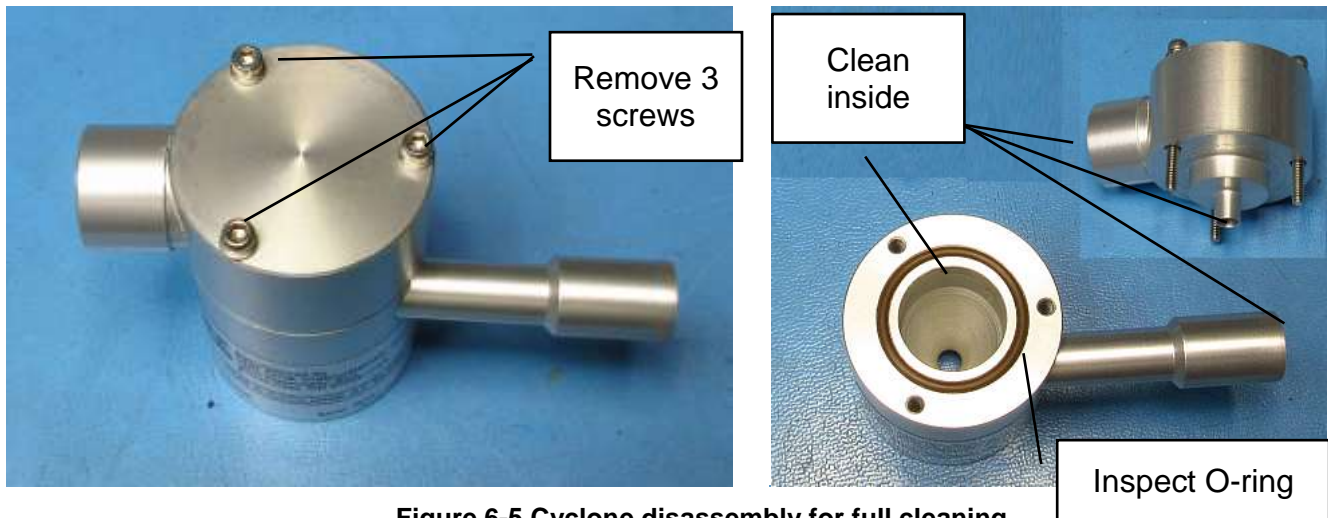


Figure 6-5 Cyclone disassembly for full cleaning

Full cleaning of the cyclone requires accessing the conical chamber inside. All of the inside surfaces must be cleaned. Isopropyl alcohol and cotton-tipped applicators work well.

Inspect the O-ring in the top of the cyclone body. Replace if damaged (720081 from 8658-2 O-ring kit).



Figure 6-6 Unscrew and clean particle trap

Inspect O-rings in cyclone inlet. If damaged, replace (720087 from 8658-2 O-ring kit).

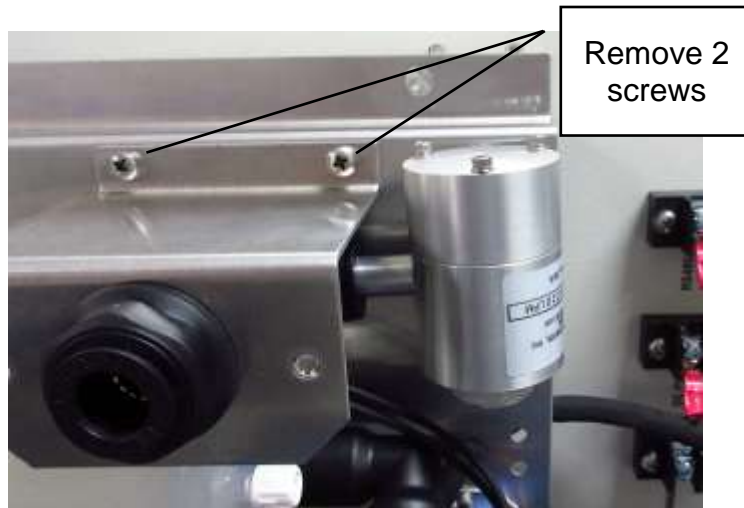


Figure 6-7 Remove inlet mounting screws

To remove the cyclone in the dilution system for full cleaning, remove the cover from the dilution system, then remove the two screws that mount the inlet.



Figure 6-8 Pull cyclone away from BC 1054 inlet fitting

Pull the cyclone and mounting bracket away from the back of the BC 1054.



Figure 6-9 Push and hold release ring

Push and hold the release ring on the dilution system inlet “TEE” fitting as the cyclone is pulled out of the “TEE” fitting.

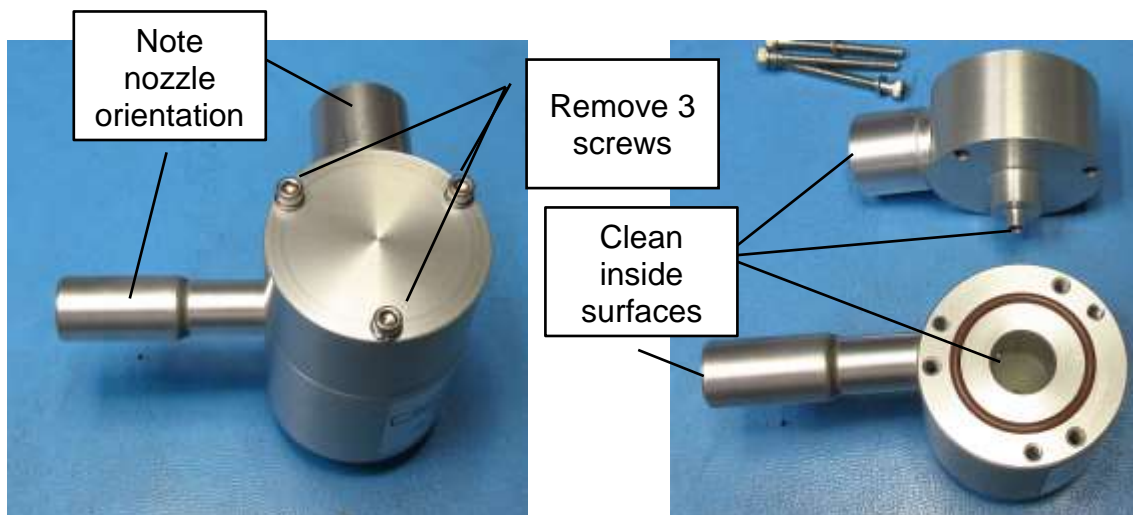


Figure 6-10 Note nozzle orientation of dilution system cyclone. Remove screws and clean interior surfaces for full cyclone cleaning.

The nozzles are oriented at 90° for the dilution system cyclone. Note two sets of threaded holes on the cyclone body allow re-assembly in both straight and 90° configuration.

Remove the 3 screws in the top of the cyclone to permit access to the interior of the cyclone for full cyclone cleaning.

After cleaning, reassemble in reverse order. For dilution system cyclone, ensure the nozzle orientation is as shown above, Figure 6-10.

When service and re-installation is complete on the dilution system cyclone, perform system leak check per Section 6.4.

6.7 Factory Service Interval

The BC 1054 recommended factory service interval is once every two years.

Factory service primarily consists of optical system cleaning, optics/detector checks, and a calibration check (and recalibration if needed) against a factory standard. As-found calibration checks can also be requested. Contact the Met One technical service department to schedule service. A Return Authorization number must be obtained before the unit is returned. See Section 1.2 for contact details.

6.8 TEST MENU Descriptions

The BC 1054 TEST MENU contains a system of screens that can be used to test the electrical and mechanical subsystems for troubleshooting purposes. Other than the filter tape loading functions, most of these test screens will never be used unless problems are encountered. The leak test is described in Section 6.4. The top TEST MENU is shown below:

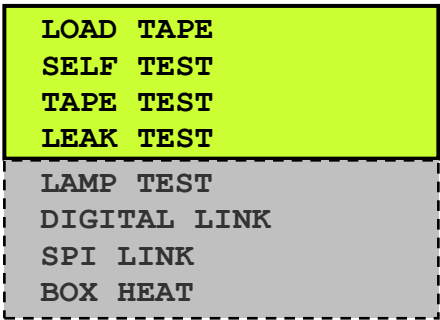


Figure 6-11 The BC 1054 Test Menu

6.8.1 The LOAD TAPE Screen

The LOAD TAPE menu is used to manually raise or lower the upper optical measurement head to allow for installing or replacing the filter tape and for re-setting the Tape Remaining counter.

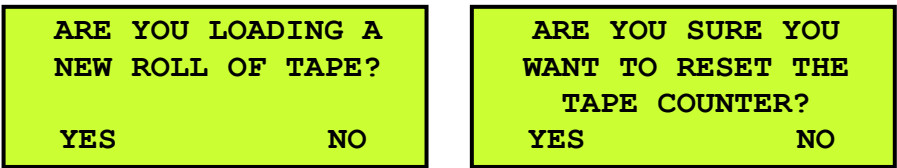


Figure 6-12 The BC 1054 Load Tape Screen

To re-set the Tape Remaining counter, select YES, otherwise, select NO to maintain the current tape counter. Selecting YES will display the confirmation screen shown above.
Select YES to confirm tape counter reset, NO to preserve the current reading.

The current tape REMAINING percentage and up/down status of the nozzle is shown on the screen.

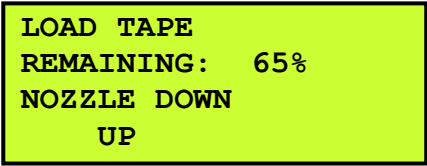


Figure 6-13 The BC 1054 Load Tape Screen

The UP or DOWN softkey can be used to raise or lower the nozzle. This label changes to indicate the action that will occur when the softkey is pressed. See Section 2.6 for filter tape loading instructions.

6.8.2 The SELF TEST Screen

The SELF TEST screen is used to activate an automatic test of most of the BC 1054 subsystems in order to verify that the instrument is in operational condition. On this screen, both softkeys under the START SELF-TEST label will start the self-test process.

Once the test is initiated, the instrument will test for properly loaded filter tape and test the function of all tape control hardware. The pump, flow sensor, LED light sources and detectors are also tested and any detected failures are shown on the display. If there is no Dilution Flow System installed, the self-test results are displayed as shown in Figure 6-14.

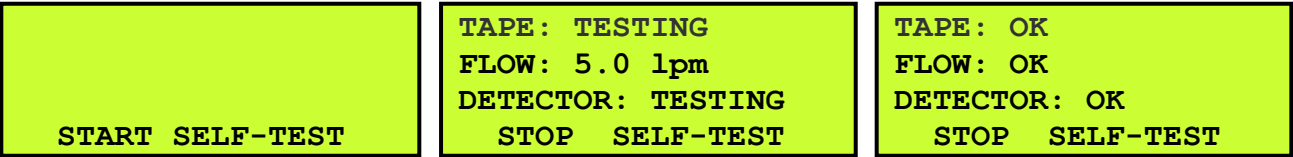


Figure 6-14 The BC 1054 Self-Test Screens – No Dilution Flow System

However, if the Dilution Flow System is detected, the FLOW results will include the expected sample flow rate of 2 LPM and next to it will be the configured dilution system flow rate as shown in Figure 6-15.

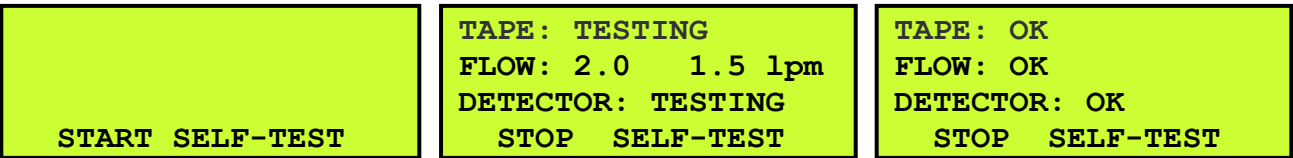


Figure 6-15 The BC 1054 Self-Test Screens –Dilution Flow System Installed

6.8.3 The TAPE TEST Screen

The TAPE TEST menu is used to manually advance the filter tape in order to spool up the end of a new roll of tape, or to test the tape motor and encoder. Press the MOVE softkey to start the tape advance. The amount of travel as measured by the encoder is displayed on the screen.

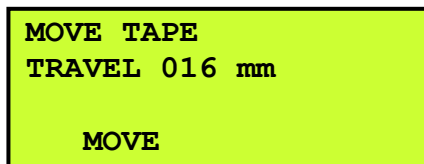


Figure 6-16 The BC 1054 Tape Test Screen

6.8.4 The LEAK TEST Screen

See Section 6.4 for a detailed explanation of the LEAK TEST screen and its use.

6.8.5 The LAMP TEST Screen

The LAMP TEST screen is used to test the individual LEDs and photodiode detectors for proper functionality, especially if optical system alarms are generated. The Signal and Reference values for each wavelength channel are displayed when an LED channel is selected. For channels BC1 to BC10, the LED field should be selected to read 01-10, respectively. To display the LED OFF or ZERO values, select LED 00. Filter tape must be installed for these tests.

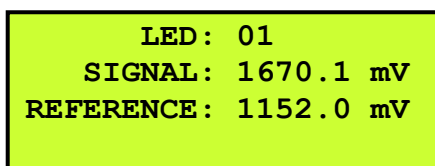


Figure 6-17 The BC 1054 Lamp Test Screen

The SIGNAL value is the voltage output from the main optical measurement light detector located directly under the sample spot. The REFERENCE value is the voltage output from the secondary reference light detector located under the filter tape, but outside of the sample spot, in order to measure and correct for the stability of the light signal regardless of the attenuation due to accumulation of PM onto the spot.

6.8.6 The DIGITAL LINK Screen

The DIGITAL LINK screen is used to test the serial link between the BC 1054 and the BX-597A ambient temperature/pressure/RH sensor. This is used for testing purposes if digital link errors or ambient sensor range errors are being generated by the instrument. Check the BX-597A sensor cable for correct connections at the BC 1054 rear panel terminals. The link status is shown at the bottom of the screen.

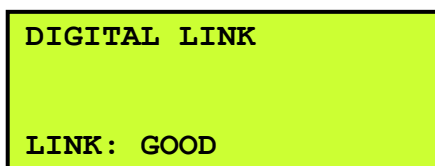
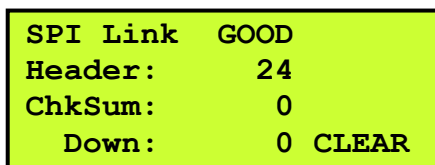


Figure 6-18 The BC 1054 Digital Link Test Screen

6.8.7 The SPI LINK Screen

The SPI LINK screen is used to test the interface between the internal storage processor and the main CPU board. It includes the overall status at the top along with data header and checksum values for factory diagnostic purposes. The last row shows the number of times that an internal link down between the CPU and the storage processor occurred along with the current status. The CLEAR softkey can be used to clear out these diagnostic counts. See Figure 6-19.



The screenshot shows a green rectangular box with black text. The text is as follows:

| | |
|----------|---------|
| SPI Link | GOOD |
| Header: | 24 |
| ChkSum: | 0 |
| Down: | 0 CLEAR |

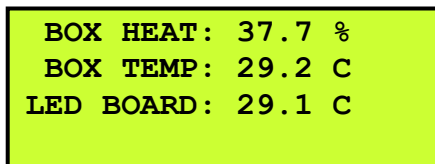
Figure 6-19 The BC 1054 SPI Link Test Screen

6.8.8 The BOX HEAT Screen

The BOX HEAT screen is used to view the current temperature from the LED (light source) circuit board (LED BOARD in Figure 6-20) and the internal box temperature (BOX TEMP in Figure 6-20).

The BC 1054 has a 40 Watt heater located inside the flow system enclosure in order to elevate the temperature inside the enclosure for stability purposes. The current heater power being used is displayed as a percentage in the BOX HEAT field as seen in Figure 6-20.

The heater is composed of two large power resistors mounted on a plate with a circulation fan. The fan is always on. The instrument firmware uses a PI loop proportional control output to regulate the heater and the temperature inside the enclosure to about 30C based on the Detector board temperature.



The screenshot shows a green rectangular box with black text. The text is as follows:

| | |
|------------|--------|
| BOX HEAT: | 37.7 % |
| BOX TEMP: | 29.2 C |
| LED BOARD: | 29.1 C |

Figure 6-20 The BC 1054 Box Heat Test Screen

6.8.9 The FLOW TEST Screen

The primary purpose of this screen is to allow for testing and troubleshooting of the BC 1054 flow controller. The flow controller is a multi-turn needle valve type controller. It can be damaged if opened or closed too far. To prevent this, a limit switch will remove power to the controller in the Open direction if it opens too far. However, it will still be possible to move the controller in the Close direction.

If a flow sensor failure is detected, or if the pump is not running, the flow controller cannot be adjusted.

NOTE: In this screen, the BC 1054 monitors and displays flow in Standard conditions at 0 °C sea level. *It does not use the Actual flow value on this screen!*

| |
|----------------------------|
| DIRECTION: INCREASE |
| FLOW: 1.73 lpm |
| TIME: 05.0 SEC |
| MOVE OVERRIDE |

Figure 6-21 The BC 1054 FLOW Test Screen

DIRECTION: This field determines whether the flow controller will attempt to raise or lower the flow rate when the MOVE softkey is pressed. Use the arrow keys to highlight this field, press the ENTER key to make it editable, use the UP and DOWN arrow keys to toggle between INCREASE or DECREASE, and then press the ENTER key again to lock the selection.

FLOW: This display only field shows the current flow rate in Standard conditions.

TIME: The duration, in seconds, to move the flow controller motor when the MOVE softkey is pressed. The default setting is 5.0 seconds. To change it, use the arrow keys to highlight this field, press the ENTER key to make it editable, use the arrow keys to set the desired movement time, and then press the ENTER key again to lock the selection

The two softkeys have the following functionality:

MOVE: Rotates the flow controller motor based on the configuration of the DIRECTION and TIME fields. For the settings displayed in Figure 6-21, pressing this key will cause the flow controller to raise the flow rate for 5.0 seconds.

OVERRIDE: This softkey will bypass the safety features for the flow controller and allow the valve to be positioned beyond the programmed safe limits. Pressing this softkey will display the warning screen shown in Figure 6-22.

| |
|-----------------------------|
| WARNING!! |
| POSSIBLE DAMAGE TO |
| FLOW CONTROLLER |
| CANCEL OVERRIDE |

Figure 6-22 The BC 1054 OVERRIDE Warning Screen

The OVERRIDE feature should **NEVER** be used unless directed to do so by Met One Instruments, Inc. personnel. If used, the outer case must be removed from the flow controller module so that the needle valve position can be verified.

7 DATA RETRIEVAL and COMMUNICATIONS

This section describes the methods used to retrieve data files from the BC 1054 carbon monitor. The unit has a single serial data output which can be routed through the RS-232 data port, "COMPUTER RS232", the RS-232 "MODEM" port, the USB serial converter port, or the Ethernet port. This is used for all digital data transfer and may be used with a local computer or digital data logger, or with a remote network connection. Access to the data through the serial ports is easy using a terminal emulation program (see section 7.3).

Note: Large data files take a long time to download, especially at low baud rates. Download the data on a regular basis and use the fastest baud rate that the connected data collection hardware can reliably support.

7.1 Collecting BC 1054 Data Using a USB Flash Drive

The BC 1054 can copy data files to a user-supplied USB flash drive. This drive must be inserted in the USB port located behind the front door, in the upper right corner of the tape transport.

From the main menu, select and enter the **COPY TO USB DRIVE** menu. Use the ▼▲ keys to select the PAST field, then press the ENTER key. Use the ▼▲ keys to set the desired number of days back to retrieve data (001 to 999 days), or leave it set to ALL to retrieve all data. Press ENTER again when done.

Use the ▼▲ keys to select the FILES field, then press the ENTER key. Use the ▼▲ keys to select the ALL, USER, or ARCHIVE data set. Press ENTER again when done. The FILES fields contain the following information:

USER Selecting this option downloads the User file, the Settings file, and the Alarm file. The User file contains the corrected concentrations and is in a format that users generally want.

ALL Selecting this option downloads the Settings file, the Alarm file, the User file, and the Data file. The Data file contains all the raw unformatted fields recorded by the BC 1054.

ARCHIVE Contains the raw Linux binary files for all the data recorded by the BC 1054. This is generally only useful for service issues.

Press the COPY softkey to transfer the selected files to the inserted flash drive. Do not remove the drive until the copy is finished! When the COPY process is complete “100% COMPLETE” will be displayed. See Figure 7-1 for an example of the export screen process.

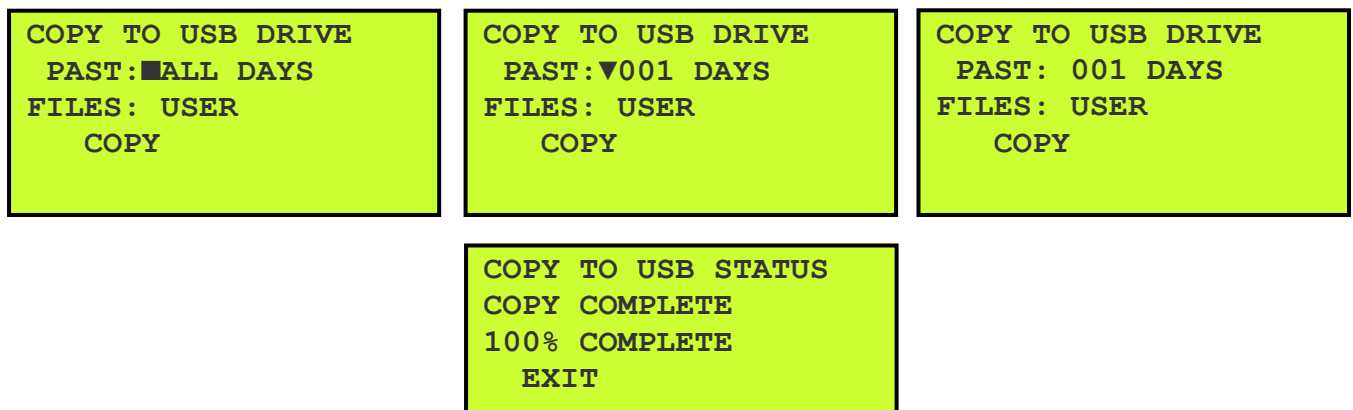


Figure 7-1 The BC 1054 Flash Drive Export Screens

7.2 BC 1054 Data Outputs and Data Examples

The BC 1054 outputs data files, SETTINGS files, and ALARM files. The raw format of these stored files is *.txt text (ALARM and SETTINGS) files or *.csv comma separated values format (data file) for import into a spreadsheet program.

The SETTINGS File:

The settings file contains most of the setup menu parameters for the BC 1054. This file should be reviewed periodically to ensure that no settings have been incorrectly changed. It also serves as a good data validation record. An example of a BC 1054 settings text file is shown in Figure 7-2.

```
BC 1054 Settings Report
2020-04-29 09:43:54

BC 1054, 82401, R3.1.0
CPLD, 81699, R1.0.0
30030, 82402, R1.0.0
Storage, 82403, R1.2.0
Digital Sen 1, 597, 10503-01, R01.0.0

Serial Number, U16130
Location, 1
Baud, 9600
Flow Control, NONE
Sample Period, 1 MIN
Pressure Units, mmHg
Tape Period, AUTO
Tape Spot, 1
Tape Remaining, 93 %
Load Enable, ON
Load Level, 100
Load Carbon, BC1
Flow Set Pt, 5 LPM
Dilution Ctrl, OFF
Dilution Pct, 60
50% Threshold, 7500
80% Threshold, 15000
N Spot Avg, 5
USB Days, ALL
User K1, 1.044
User K2, 1.036
User K3, 1.030
User K4, 1.040
User K5, 1.048
User K6, 1.049
User K7, 1.049
User K8, 1.054
User K9, 1.044
User K10, 1.055
FT Set Pt, 30.0
Box Set Pt, 30.0

Name, Offset, Slope
FLOW, 0.097, 1.043
DFLOW, 0.248, 1.091
AT, 1.990
BP, -0.000

Factory Settings
DQogICAgICBDLUZhy3RvcIwgMi42MTANCiAgICAg
CjAgICAgICAgICBBQjMyLCAXNS45MDENCiAgICAg
```

Figure 7-2 Settings Report

The settings file also contains encrypted Factory Settings at the end of the Settings file report.

The ALARM LOG File:

The BC 1054 alarm log contains the date, time, and type of each alarm or error encountered during data collection.

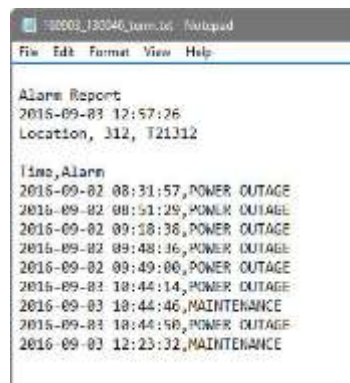


Figure 7-3 Alarm Log

The User File:

The top of the BC 1054 user file contains the header information for the file. The first line contains the name of the report, the second line contains the time stamp at which the report was requested, and the third line contains the location id and the serial number of the device.

Below the file header is the csv column header names which describe the data from each field. Below is a description for each header.

Time is the date and timestamp for the data record. The timestamp is end of the minute. For example, a timestamp of 08:21 would represent data collected from 08:20:00 through 08:20:59.

BCx(ng/m3) is the reported black carbon concentration for the indicated channel number (1-10). This is the corrected concentration that is corrected for tape loading effects.

DC(ng/m3) is the concentration of channel BC1 minus channel BC9, this channel is also known as delta carbon (DC).

Flow(lpm) is the average sample flow rate for the last minute.

DFlow(lpm) is the average dilution flow rate for the last minute.

WS(m/s) and **WD(Deg)** are the average wind speed and wind direction values from the optional WS/WD sensor.

AT(C), **RH(%)** and **BP(mbar)** are the average ambient temperature, relative humidity and barometric pressure for the last minute. These readings are from the BX-597A AT/BP/RH sensor.

Status is the alarm status (see Section 6.1).

Note: *Because the concentrations in the user report are corrected, the BC 1054 only reports data up to the last tape advance. The BC 1054 will continue to sample and record data, but data output in the user file is only available for correction up to when the last tape advance occurred.*

The Diagnostic File:

The top of the BC 1054 data files start with the time and date of the download followed by the LOCATION ID and the Met One serial number of the monitor. Next is the data file header that indicates the order and content of the data parameter columns. Each row contains one complete data record. See Figure 7-4 for an example.

Time is the date and timestamp for the data record. The timestamp is end of the minute. For example, a timestamp of 08:21 would represent data collected from 08:20:00 through 08:20:59.

SZ(mV) and **RZ(mV)** are the Sample and Reference, respectively, detector zero value (all LEDs off).

SBx(mV) and **RBx(mV)** are the Sample and Reference, respectively, detector readings when the LED for the indicated channel number (1-10) is on.

ATNx is the light attenuation for LED channel number (1-10) indicated.

BCx(ng/m3) is the reported carbon concentration for the indicated channel number (1-10). This value is NOT corrected for filter loading. Filter loading correction can be done using the BC Load Correction software package. Firmware version 2.2.0 and later automatically correct the data before reporting it to the USER data file. Diagnostic file data is always uncorrected.

Flow(lpm) is the average sample flow rate for the last minute.

DFlow(lpm) is the average dilution flow rate for the last minute.

WS(m/s) and **WD(Deg)** are the 1 minute average wind speed and wind direction values from the optional WS/WD sensor.

AT(C), **RH(%)** and **BP(mbar)** are the average ambient temperature, relative humidity and barometric pressure for the last minute. These readings are from the BX-597A AT/BP/RH sensor.

LED T(C) and **DET T(C)** are the LED and Detector board temperatures, respectively.

FT(C) is the sample air temperature (the Flow Temperature) after the optical measurement module.

Status is the alarm status (see Section 6.1).

Figure 7-4 shows the data file output with a complete data record (row) every minute. Figure 7-4 shows the data after it has been imported into a spreadsheet for analysis. This is raw data taken directly from the monitor that has not been processed with the BC Load Correction software.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z | AA | AB | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| 1 | Data Report | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| 3 | Location | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| 5 | Time | S2(mv) | S3(mv) | S80(mv) | R801(mv) | ATN1 | BC10(mv/S80(mv)) | R802(mv) | ATN2 | BC20(mv/S80(mv)) | R803(mv) | ATN3 | BC30(mv/S80(mv)) | R804(mv) | ATN4 | BC40(mv/S80(mv)) | R805(mv) | ATN5 | BC50(mv/S80(mv)) | R806(mv) | ATN6 | BC60(mv/S80(mv)) | R807(mv) | ATN7 | BC70(mv/S80(mv)) | R808(mv) | ATN8 | BC80(mv/S80(mv)) | R809(mv) | ATN9 | BC90(mv/S80(mv)) | R810(mv) | ATN10 | BC100(mv/S80(mv)) | R811(mv) | ATN11 | BC110(mv/S80(mv)) | R812(mv) | ATN12 | BC120(mv/S80(mv)) | R813(mv) | ATN13 | BC130(mv/S80(mv)) | R814(mv) | ATN14 | BC140(mv/S80(mv)) | R815(mv) | ATN15 | BC150(mv/S80(mv)) | R816(mv) | ATN16 | BC160(mv/S80(mv)) | R817(mv) | ATN17 | BC170(mv/S80(mv)) | R818(mv) | ATN18 | BC180(mv/S80(mv)) | R819(mv) | ATN19 | BC190(mv/S80(mv)) | R820(mv) | ATN20 | BC200(mv/S80(mv)) | R821(mv) | ATN21 | BC210(mv/S80(mv)) | R822(mv) | ATN22 | BC220(mv/S80(mv)) | R823(mv) | ATN23 | BC230(mv/S80(mv)) | R824(mv) | ATN24 | BC240(mv/S80(mv)) | R825(mv) | ATN25 | BC250(mv/S80(mv)) | R826(mv) | ATN26 | BC260(mv/S80(mv)) | R827(mv) | ATN27 | BC270(mv/S80(mv)) | R828(mv) | ATN28 | BC280(mv/S80(mv)) | R829(mv) | ATN29 | BC290(mv/S80(mv)) | R830(mv) | ATN30 | BC300(mv/S80(mv)) | R831(mv) | ATN31 | BC310(mv/S80(mv)) | R832(mv) | ATN32 | BC320(mv/S80(mv)) | R833(mv) | ATN33 | BC330(mv/S80(mv)) | R834(mv) | ATN34 | BC340(mv/S80(mv)) | R835(mv) | ATN35 | BC350(mv/S80(mv)) | R836(mv) | ATN36 | BC360(mv/S80(mv)) | R837(mv) | ATN37 | BC370(mv/S80(mv)) | R838(mv) | ATN38 | BC380(mv/S80(mv)) | R839(mv) | ATN39 | BC390(mv/S80(mv)) | R840(mv) | ATN40 | BC400(mv/S80(mv)) | R841(mv) | ATN41 | BC410(mv/S80(mv)) | R842(mv) | ATN42 | BC420(mv/S80(mv)) | R843(mv) | ATN43 | BC430(mv/S80(mv)) | R844(mv) | ATN44 | BC440(mv/S80(mv)) | R845(mv) | ATN45 | BC450(mv/S80(mv)) | R846(mv) | ATN46 | BC460(mv/S80(mv)) | R847(mv) | ATN47 | BC470(mv/S80(mv)) | R848(mv) | ATN48 | BC480(mv/S80(mv)) | R849(mv) | ATN49 | BC490(mv/S80(mv)) | R850(mv) | ATN50 | BC500(mv/S80(mv)) | R851(mv) | ATN51 | BC510(mv/S80(mv)) | R852(mv) | ATN52 | BC520(mv/S80(mv)) | R853(mv) | ATN53 | BC530(mv/S80(mv)) | R854(mv) | ATN54 | BC540(mv/S80(mv)) | R855(mv) | ATN55 | BC550(mv/S80(mv)) | R856(mv) | ATN56 | BC560(mv/S80(mv)) | R857(mv) | ATN57 | BC570(mv/S80(mv)) | R858(mv) | ATN58 | BC580(mv/S80(mv)) | R859(mv) | ATN59 | BC590(mv/S80(mv)) | R860(mv) | ATN60 | BC600(mv/S80(mv)) | R861(mv) | ATN61 | BC610(mv/S80(mv)) | R862(mv) | ATN62 | BC620(mv/S80(mv)) | R863(mv) | ATN63 | BC630(mv/S80(mv)) | R864(mv) | ATN64 | BC640(mv/S80(mv)) | R865(mv) | ATN65 | BC650(mv/S80(mv)) | R866(mv) | ATN66 | BC660(mv/S80(mv)) | R867(mv) | ATN67 | BC670(mv/S80(mv)) | R868(mv) | ATN68 | BC680(mv/S80(mv)) | R869(mv) | ATN69 | BC690(mv/S80(mv)) | R870(mv) | ATN70 | BC700(mv/S80(mv)) | R871(mv) | ATN71 | BC710(mv/S80(mv)) | R872(mv) | ATN72 | BC720(mv/S80(mv)) | R873(mv) | ATN73 | BC730(mv/S80(mv)) | R874(mv) | ATN74 | BC740(mv/S80(mv)) | R875(mv) | ATN75 | BC750(mv/S80(mv)) | R876(mv) | ATN76 | BC760(mv/S80(mv)) | R877(mv) | ATN77 | BC770(mv/S80(mv)) | R878(mv) | ATN78 | BC780(mv/S80(mv)) | R879(mv) | ATN79 | BC790(mv/S80(mv)) | R880(mv) | ATN80 | BC800(mv/S80(mv)) | R881(mv) | ATN81 | BC810(mv/S80(mv)) | R882(mv) | ATN82 | BC820(mv/S80(mv)) | R883(mv) | ATN83 | BC830(mv/S80(mv)) | R884(mv) | ATN84 | BC840(mv/S80(mv)) | R885(mv) | ATN85 | BC850(mv/S80(mv)) | R886(mv) | ATN86 | BC860(mv/S80(mv)) | R887(mv) | ATN87 | BC870(mv/S80(mv)) | R888(mv) | ATN88 | BC880(mv/S80(mv)) | R889(mv) | ATN89 | BC890(mv/S80(mv)) | R890(mv) | ATN90 | BC900(mv/S80(mv)) | R891(mv) | ATN91 | BC910(mv/S80(mv)) | R892(mv) | ATN92 | BC920(mv/S80(mv)) | R893(mv) | ATN93 | BC930(mv/S80(mv)) | R894(mv) | ATN94 | BC940(mv/S80(mv)) | R895(mv) | ATN95 | BC950(mv/S80(mv)) | R896(mv) | ATN96 | BC960(mv/S80(mv)) | R897(mv) | ATN97 | BC970(mv/S80(mv)) | R898(mv) | ATN98 | BC980(mv/S80(mv)) | R899(mv) | ATN99 | BC990(mv/S80(mv)) | R900(mv) | ATN100 | BC1000(mv/S80(mv)) | R901(mv) | ATN101 | BC1010(mv/S80(mv)) | R902(mv) | ATN102 | BC1020(mv/S80(mv)) | R903(mv) | ATN103 | BC1030(mv/S80(mv)) | R904(mv) | ATN104 | BC1040(mv/S80(mv)) | R905(mv) | ATN105 | BC1050(mv/S80(mv)) | R906(mv) | ATN106 | BC1060(mv/S80(mv)) | R907(mv) | ATN107 | BC1070(mv/S80(mv)) | R908(mv) | ATN108 | BC1080(mv/S80(mv)) | R909(mv) | ATN109 | BC1090(mv/S80(mv)) | R910(mv) | ATN110 | BC1100(mv/S80(mv)) | R911(mv) | ATN111 | BC1110(mv/S80(mv)) | R912(mv) | ATN112 | BC1120(mv/S80(mv)) | R913(mv) | ATN113 | BC1130(mv/S80(mv)) | R914(mv) | ATN114 | BC1140(mv/S80(mv)) | R915(mv) | ATN115 | BC1150(mv/S80(mv)) | R916(mv) | ATN116 | BC1160(mv/S80(mv)) | R917(mv) | ATN117 | BC1170(mv/S80(mv)) | R918(mv) | ATN118 | BC1180(mv/S80(mv)) | R919(mv) | ATN119 | BC1190(mv/S80(mv)) | R920(mv) | ATN120 | BC1200(mv/S80(mv)) | R921(mv) | ATN121 | BC1210(mv/S80(mv)) | R922(mv) | ATN122 | BC1220(mv/S80(mv)) | R923(mv) | ATN123 | BC1230(mv/S80(mv)) | R924(mv) | ATN124 | BC1240(mv/S80(mv)) | R925(mv) | ATN125 | BC1250(mv/S80(mv)) | R926(mv) | ATN126 | BC1260(mv/S80(mv)) | R927(mv) | ATN127 | BC1270(mv/S80(mv)) | R928(mv) | ATN128 | BC1280(mv/S80(mv)) | R929(mv) | ATN129 | BC1290(mv/S80(mv)) | R930(mv) | ATN130 | BC1300(mv/S80(mv)) | R931(mv) | ATN131 | BC1310(mv/S80(mv)) | R932(mv) | ATN132 | BC1320(mv/S80(mv)) | R933(mv) | ATN133 | BC1330(mv/S80(mv)) | R934(mv) | ATN134 | BC1340(mv/S80(mv)) | R935(mv) | ATN135 | BC1350(mv/S80(mv)) | R936(mv) | ATN136 | BC1360(mv/S80(mv)) | R937(mv) | ATN137 | BC1370(mv/S80(mv)) | R938(mv) | ATN138 | BC1380(mv/S80(mv)) | R939(mv) | ATN139 | BC1390(mv/S80(mv)) | R940(mv) | ATN140 | BC1400(mv/S80(mv)) | R941(mv) | ATN141 | BC1410(mv/S80(mv)) | R942(mv) | ATN142 | BC1420(mv/S80(mv)) | R943(mv) | ATN143 | BC1430(mv/S80(mv)) | R944(mv) | ATN144 | BC1440(mv/S80(mv)) | R945(mv) | ATN145 | BC1450(mv/S80(mv)) | R946(mv) | ATN146 | BC1460(mv/S80(mv)) | R947(mv) | ATN147 | BC1470(mv/S80(mv)) | R948(mv) | ATN148 | BC1480(mv/S80(mv)) | R949(mv) | ATN149 | BC1490(mv/S80(mv)) | R950(mv) | ATN150 | BC1500(mv/S80(mv)) | R951(mv) | ATN151 | BC1510(mv/S80(mv)) | R952(mv) | ATN152 | BC1520(mv/S80(mv)) | R953(mv) | ATN153 | BC1530(mv/S80(mv)) | R954(mv) | ATN154 | BC1540(mv/S80(mv)) | R955(mv) | ATN155 | BC1550(mv/S80(mv)) | R956(mv) | ATN156 | BC1560(mv/S80(mv)) | R957(mv) | ATN157 | BC1570(mv/S80(mv)) | R958(mv) | ATN158 | BC1580(mv/S80(mv)) | R959(mv) | ATN159 | BC1590(mv/S80(mv)) | R960(mv) | ATN160 | BC1600(mv/S80(mv)) | R961(mv) | ATN161 | BC1610(mv/S80(mv)) | R962(mv) | ATN162 | BC1620(mv/S80(mv)) | R963(mv) | ATN163 | BC1630(mv/S80(mv)) | R964(mv) | ATN164 | BC1640(mv/S80(mv)) | R965(mv) | ATN165 | BC1650(mv/S80(mv)) | R966(mv) | ATN166 | BC1660(mv/S80(mv)) | R967(mv) | ATN167 | BC1670(mv/S80(mv)) | R968(mv) | ATN168 | BC1680(mv/S80(mv)) | R969(mv) | ATN169 | BC1690(mv/S80(mv)) | R970(mv) | ATN170 | BC1700(mv/S80(mv)) | R971(mv) | ATN171 | BC1710(mv/S80(mv)) | R972(mv) | ATN172 | BC1720(mv/S80(mv)) | R973(mv) | ATN173 | BC1730(mv/S80(mv)) | R974(mv) | ATN174 | BC1740(mv/S80(mv)) | R975(mv) | ATN175 | BC1750(mv/S80(mv)) | R976(mv) | ATN176 | BC1760(mv/S80(mv)) | R977(mv) | ATN177 | BC1770(mv/S80(mv)) | R978(mv) | ATN178 | BC1780(mv/S80(mv)) | R979(mv) | ATN179 | BC1790(mv/S80(mv)) | R980(mv) | ATN180 | BC1800(mv/S80(mv)) | R981(mv) | ATN181 | BC1810(mv/S80(mv)) | R982(mv) | ATN182 | BC1820(mv/S80(mv)) | R983(mv) | ATN183 | BC1830(mv/S80(mv)) | R984(mv) | ATN184 | BC1840(mv/S80(mv)) | R985(mv) | ATN185 | BC1850(mv/S80(mv)) | R986(mv) | ATN186 | BC1860(mv/S80(mv)) | R987(mv) | ATN187 | BC1870(mv/S80(mv)) | R988(mv) | ATN188 | BC1880(mv/S80(mv)) | R989(mv) | ATN189 | BC1890(mv/S80(mv)) | R990(mv) | ATN190 | BC1900(mv/S80(mv)) | R991(mv) | ATN191 | BC1910(mv/S80(mv)) | R992(mv) | ATN192 | BC1920(mv/S80(mv)) | R993(mv) | ATN193 | BC1930(mv/S80(mv)) | R994(mv) | ATN194 | BC1940(mv/S80(mv)) | R995(mv) | ATN195 | BC1950(mv/S80(mv)) | R996(mv) | ATN196 | BC1960(mv/S80(mv)) | R997(mv) | ATN197 | BC1970(mv/S80(mv)) | R998(mv) | ATN198 | BC1980(mv/S80(mv)) | R999(mv) | ATN199 | BC1990(mv/S80(mv)) | R1000(mv) | ATN200 | BC2000(mv/S80(mv)) | R1001(mv) | ATN201 | BC2010(mv/S80(mv)) | R1002(mv) | ATN202 | BC2020(mv/S80(mv)) | R1003(mv) | ATN203 | BC2030(mv/S80(mv)) | R1004(mv) | ATN204 | BC2040(mv/S80(mv)) | R1005(mv) | ATN205 | BC2050(mv/S80(mv)) | R1006(mv) | ATN206 | BC2060(mv/S80(mv)) | R1007(mv) | ATN207 | BC2070(mv/S80(mv)) | R1008(mv) | ATN208 | BC2080(mv/S80(mv)) | R1009(mv) | ATN209 | BC2090(mv/S80(mv)) | R1010(mv) | ATN210 | BC2100(mv/S80(mv)) | R1011(mv) | ATN211 | BC2110(mv/S80(mv)) | R1012(mv) | ATN212 | BC2120(mv/S80(mv)) | R1013(mv) | ATN213 | BC2130(mv/S80(mv)) | R1014(mv) | ATN214 | BC2140(mv/S80(mv)) | R1015(mv) | ATN215 | BC2150(mv/S80(mv)) | R1016(mv) | ATN216 | BC2160(mv/S80(mv)) | R1017(mv) | ATN217 | BC2170(mv/S80(mv)) | R1018(mv) | ATN218 | BC2180(mv/S80(mv)) | R1019(mv) | ATN219 | BC2190(mv/S80(mv)) | R1020(mv) | ATN220 | BC2200(mv/S80(mv)) | R1021(mv) | ATN221 | BC2210(mv/S80(mv)) | R1022(mv) | ATN222 | BC2220(mv/S80(mv)) | R1023(mv) | ATN223 | BC2230(mv/S80(mv)) | R1024(mv) | ATN224 | BC2240(mv/S80(mv)) | R1025(mv) | ATN225 | BC2250(mv/S80(mv)) | R1026(mv) | ATN226 | BC2260(mv/S80(mv)) | R1027(mv) | ATN227 | BC2270(mv/S80(mv)) | R1028(mv) | ATN228 | BC2280(mv/S80(mv)) | R1029(mv) | ATN229 | BC2290(mv/S80(mv)) | R1030(mv) | ATN230 | BC2300(mv/S80(mv)) | R1031(mv) | ATN231 | BC2310(mv/S80(mv)) | R1032(mv) | ATN232 | BC2320(mv/S80(mv)) | R1033(mv) | ATN233 | BC2330(mv/S80(mv)) | R1034(mv) | ATN234 | BC2340(mv/S80(mv)) | R1035(mv) | ATN235 | BC2350(mv/S80(mv)) | R1036(mv) | ATN236 | BC2360(mv/S80(mv)) | R1037(mv) | ATN237 | BC2370(mv/S80(mv)) | R1038(mv) | ATN238 | BC2380(mv/S80(mv)) | R1039(mv) | ATN239 | BC2390(mv/S80(mv)) | R1040(mv) | ATN240 | BC2400(mv/S80(mv)) | R1041(mv) | ATN241 | BC2410(mv/S80(mv)) | R1042(mv) | ATN242 | BC2420(mv/S80(mv)) | R1043(mv) | ATN243 | BC2430(mv/S80(mv)) | R1044(mv) | ATN244 | BC2440(mv/S80(mv)) | R1045(mv) | ATN245 | BC2450(mv/S80(mv)) | R1046(mv) | ATN246 | BC2460(mv/S80(mv)) | R1047(mv) | ATN247 | BC2470(mv/S80(mv)) | R1048(mv) | ATN248 | BC2480(mv/S80(mv)) | R1049(mv) | ATN249 | BC2490(mv/S80(mv)) | R1050(mv) | ATN250 | BC2500(mv/S80(mv)) | R1051(mv) | ATN251 | BC2510(mv/S80(mv)) | R1052(mv) | ATN252 | BC2520(mv/S80(mv)) | R1053(mv) | ATN253 | BC2530(mv/S80(mv)) | R1054(mv) | ATN254 | BC2540(mv/S80(mv)) | R1055(mv) | ATN255 | BC2550(mv/S80(mv)) | R1056(mv) | ATN256 | BC2560(mv/S80(mv)) | R1057(mv) | ATN257 | BC2570(mv/S80(mv)) | R1058(mv) | ATN258 | BC2580(mv/S80(mv)) | R1059(mv) | ATN259 | BC2590(mv/S80(mv)) | R1060(mv) | ATN260 | BC2600(mv/S80(mv)) | R1061(mv) | ATN261 | BC2610(mv/S80(mv)) | R1062(mv) | ATN262 | BC2620(mv/S80(mv)) | R1063(mv) | ATN263 | BC2630(mv/S80(mv)) | R1064(mv) | ATN264 | BC2640(mv/S80(mv)) | R1065(mv) | ATN265 | BC2650(mv/S80(mv)) | R1066(mv) | ATN266 | BC2660(mv/S80(mv)) | R1067(mv) | ATN267 | BC2670(mv/S80(mv)) | R1068(mv) | ATN268 | BC2680(mv/S80(mv)) | R1069(mv) | ATN269 | BC2690(mv/S80(mv)) | R1070(mv) | ATN270 | BC2700(mv/S80(mv)) | R1071(mv) | ATN271 | BC2710(mv/S80(mv)) | R1072(mv) | ATN272 | BC2720(mv/S80(mv)) | R1073(mv) | ATN273 | BC2730(mv/S80(mv)) | R1074(mv) | ATN274 | BC2740(mv/S80(mv)) | R1075(mv) | ATN275 | BC2750(mv/S80(mv)) | R1076(mv) | ATN276 | BC2760(mv/S80(mv)) | R1077(mv) | ATN277 | BC2770(mv/S80(mv)) | R1078(mv) | ATN278 | BC2780(mv/S80(mv)) | R1079(mv) | ATN279 | BC2790(mv/S80(mv)) | R1080(mv) | ATN280 | BC2800(mv/S80(mv)) | R1081(mv) | ATN281 | BC2810(mv/S80(mv)) | R1082(mv) | ATN282 | BC2820(mv/S80(mv)) | R1083(mv) | ATN283 | BC2830(mv/S80(mv)) | R1084(mv) | ATN284 | BC2840(mv/S80(mv)) | R1085(mv) | ATN285 | BC2850(mv/S80(mv)) | R1086(mv) | ATN286 | BC2860(mv/S80(mv)) | R1087(mv) | ATN287 | BC2870(mv/S80(mv)) | R1088(mv) | ATN288 | BC2880(mv/S80(mv)) | R1089(mv) | ATN289 | BC2890(mv/S80(mv)) | R1090(mv) | ATN290 | BC2900(mv/S80(mv)) | R1091(mv) | ATN291 | BC2910(mv/S80(mv)) | R1092(mv) | ATN292 | BC2920(mv/S80(mv)) | R1093(mv) | ATN293 | BC2930(mv/S80(mv)) | R1094(mv) | ATN294 | BC2940(mv/S80(mv)) | R1095(mv) | ATN295 | BC2950(mv |
| 6 | S2(mv) | S3(mv) | S80(mv) | R801(mv) | ATN1 | BC10(mv/S80(mv)) | R802(mv) | ATN2 | BC20(mv/S80(mv)) | R803(mv) | ATN3 | BC30(mv/S80(mv)) | R804(mv) | ATN4 | BC40(mv/S80(mv)) | R805(mv) | ATN5 | BC50(mv/S80(mv)) | R806(mv) | ATN6 | BC60(mv/S80(mv)) | R807(mv) | ATN7 | BC70(mv/S80(mv)) | R808(mv) | ATN8 | BC80(mv/S80(mv)) | R809(mv) | ATN9 | BC90(mv/S80(mv)) | R810(mv) | ATN10 | BC100(mv/S80(mv)) | R811(mv) | ATN11 | BC110(mv/S80(mv)) | R812(mv) | ATN12 | BC120(mv/S80(mv)) | R813(mv) | ATN13 | BC130(mv/S80(mv)) | R814(mv) | ATN14 | BC140(mv/S80(mv)) | R815(mv) | ATN15 | BC150(mv/S80(mv)) | R816(mv) | ATN16 | BC160(mv/S80(mv)) | R817(mv) | ATN17 | BC170(mv/S80(mv)) | R818(mv) | ATN18 | BC180(mv/S80(mv)) | R819(mv) | ATN19 | BC190(mv/S80(mv)) | R820(mv) | ATN20 | BC200(mv/S80(mv)) | R821(mv) | ATN21 | BC210(mv/S80(mv)) | R822(mv) | ATN22 | BC220(mv/S80(mv)) | R823(mv) | ATN23 | BC230(mv/S80(mv)) | R824(mv) | ATN24 | BC240(mv/S80(mv)) | R825(mv) | ATN25 | BC250(mv/S80(mv)) | R826(mv) | ATN26 | BC260(mv/S80(mv)) | R827(mv) | ATN27 | BC270(mv/S80(mv)) | R828(mv) | ATN28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

For example, to view the current date setting type the letter D followed by the Enter key. The current date will be reported. The sequence would appear like this:

```
D<cr>
D 2013-01-18<cr><lf>
```

To change a setting, the typical sequence is to type the command, press the space bar one time, enter the new value in the same format that is displayed when checking the setting, and then pressing the Enter key.

Continuing the example above, to change the date setting type the letter D, space, and then the current date in YYYY-MM-DD format followed by the Enter key. A confirmation of the new date will be reported. The sequence would appear like this:

```
D 2016-02-28<cr>
D 2016-02-28<cr><lf>
```

Pressing <Esc> or Q<cr> will exit terminal mode.

For a detailed listing of all commands and their formats, consult the BC 1054 7500 document (contact the Met One Instruments service department. See section 1.2).

7.3.2 Computer Communication

In the Computer Communication mode, character echo is suppressed. This means if commands are issued in this mode using a keyboard, the characters *will not be displayed on the screen* as the keys are pressed. The command format includes a checksum to verify data integrity.

The mode is entered whenever an <Esc> character is sent to the instrument. Commands are issued using the following format:

```
<Esc>Cmd p1 p2*cs<cr>
```

Computer commands are prefaced with an <Esc> character followed directly by a command (Cmd).. After the command there can be zero or more parameter field (p1 and p2) where each field is separated by a space. The end of the message is signaled by the Checksum Delimiter character (*) followed by the checksum itself (cs). Finally, the command is terminated with a carriage return (<cr>).

A computer command example requesting the Model/Part/Revision numbers would look like this:

```
<Esc>RV*1234<cr>
```

All command responses are terminated with a checksum. The above command response would have this format:

```
BC 1054, 82401, R1.0.0
CPLD, 81699, R1.0.0
30030, 82402, R1.0.0
Storage, 82403, R1.0.2<cr><lf>
```


| COMMAND | DESCRIPTION |
|---------|--|
| H | Help Menu |
| 1 | Request settings report |
| 2 | Request All data report |
| 3 | Request New data report |
| 7 | Request alarm event report |
| C | Clear data log file – \$ |
| D | Get/Set date part of the real time clock – \$ |
| T | Get/Set time part of the real time clock – \$ |
| CA | Clear alarm log file – \$ |
| DS | Report data log channel descriptors– \$ |
| DT | Get/Set the date and time of the real time clock – \$ |
| ID | Get/Set location ID or address – \$ |
| OP | Get operation state – \$ |
| PR | Print report – 0-Settings, 1-User, 2-Alarm, 3-Factory Diagnostic |
| PU | Get/Set pressure units - \$ |
| PW | Unlock protected commands |
| QH | Report Data Record Header |
| RV | Report Model/Part/Revision |
| RQ | Get last data record (same as 4 command) |
| SB | Get/Set baud rate – \$ |
| SS | Get Met One serial number |
| ST | Get/Set sample time – \$ |
| SPW | Get/Set user password – \$ |
| FLSP | Get/Set flow set point – \$ |
| FTSP | Get/Set flow temperature set point – \$ |
| SPOT | Get/Set number of tape advance spots – \$ |
| TENA | Get/Set tape advance loading enable – \$ |
| TPER | Get/Set tape advance period – \$ |
| DSCRC | Get the data log channel descriptors CRC – \$ |
| TLOAD | Get/Set tape advance loading – \$ |
| TCARBON | Get/Set tape advance loading carbon type – \$ |
| DFCTL | Get/Set dilution control – \$ |
| DFPCT | Get/Set dilution flow percentage – \$ |
| DFSYS | Report Dilution System presence – \$ |
| K x | Get/Set User K factor for each channel, x = 1..10, k 1 = BC1, k 2 = BC2, etc |

Table 7-1 Available Terminal Mode and Escape Commands

For a listing of all commands and their formats along with additional in-depth Computer Communication details, consult the BC 1054 7500 document contained on the CD included with the sampler or contact the Met One Instruments service department. See section 1.2.

Table 7-2 shows the commands associated with editable settings, along with the default value for the setting and the settable range:

| DESCRIPTION | RANGE | DEFAULT | COMMAND |
|--|---|---------|---------|
| Location ID | 1 – 999 | 1 | ID |
| Tape advance period (HR) 0 = Advance on tape loading only | 0, 1, 2, 3, 4, 6, 8, 12, 24 | 0 | TPER |
| Number of tape advance spots | 1, 2 | 1 | SPOT |
| Tape advance loading enable | 0=OFF, 1=ON | 1 | TENA |
| Tape advance loading set point (%) | 75 to 125 | 100 | TLOAD |
| Tape advance loading carbon type | 0..9, 0=BC1, 1=BC2, etc | 0 | TCARBON |
| Serial port baud rate | 2=1200, 3=2400, 4=4800, 5=9600, 6=19200, 7=38400, 8=57600, 9=115200 | 5 | SB |
| Sample Period | 0=1min, 1=5min, 2=10min, 3=15min, 4=30min, 5=60min | 0 | ST |
| User password | 0 – 9999 | 0 | SPW |
| Ethernet Flow Control | 0 = NONE, 1 = RTS/CTS | 0 | HS |
| Number of days of data to copy to USB drive | 0 = All data, 1 - 999 days | 0 | UD |
| Flow set point | 0=2, 1=5 LPM | 1 | FLSP |
| User K-Factor K 1 = BC1, K 2 = BC2, etc | K 1 = BC1, K 2 = BC2 0.1 – 9.99 | 1.0 | K x |

Table 7-2 User Editable Settings

7.3.3 Bayern-Hessen Communication Protocol

The Gesytec (Bayern-Hessen) Protocol is provided to communicate with a BC 1054 from an established network. The protocol is used to retrieve measurement values at some periodic rate. This is a polled type protocol. Only the DA command (for Data Query) is supported for data retrieval.

When the DA command is sent, the BC 1054 responds with the current measurement data. The command structure for the DA data query command is as follows:

```
<STX>DA<address><ETX><BCC>
```

The <address> is optional and can be left out completely. If present, the <address> must match the Location ID of the monitor (see section 3.5.1). Additional space can be present after the address.

The <address> can be represented with either leading zeroes or leading <SP>'s. The following are different acceptable formats of the DA command with the Location ID of 5:

```
<STX>DA<CR>
```

```
<STX>DA005<CR>
```

```
<STX>DA<SP><SP>5<ETX><BCC>
```

```
<STX>DA<ETX><BCC>
```

The data query string is valid, and will be answered with a transmission, only if the command starts with <STX> followed by the characters DA, and the <address> (if present) matches the Location ID, and the command is terminated by either a <CR> or <ETX> followed by the correct checksum <BCC>.

If the query command is terminated with a <CR> the response will also be terminated with a <CR> and no <BCC> will be used. If the command is terminated with <ETX><BCC> then the response will also be required to terminate with <ETX><BCC>.

The format of the Response String is as follows.

```
<STX>MD[nn]<SP>  
[address]<SP>[measured value 1]<SP>[Status]<SP>[Serial #]<SP>[SFKT]<SP>  
[address+1]<SP>[measured value 2]<SP>[Status]<SP>[Serial #]<SP>[SFKT]<SP>  
...  
<ETX><BCC> or <CR><LF>
```

- [nn]:** Number of variables to follow. Two digits with leading 0 ie 02.
- [address]:** Location ID, 3 characters, leading zeros are transmitted.
- [Measured value]:** In exponential representation. 4 characters mantissa, 2 characters exponent each with a sign. The decimal point is implied to be after the first digit and is not transmitted. For example, 23.7 would be represented as +2370+01.
- [Status]:** Status consists of two parts, Operation Status and Error Status. These are two-character hexadecimal values separated by <SP> which represent status byte and error byte conditions indicated by bit positions. These values are shown in the accompanying tables.
- [Serial #]:** Three-digit Serial Number with leading zeros.
- [SFKT]:** Space provided for future use in special functions. It currently consists of a string of six zeroes.

An Example follows:

Inquiry:

```
<STX>DA<CR>
```

Response:

```
<STX>MD03 001 +2578+02 00 00 023 000000<SP>  
002 +5681+00 00 00 023 000000<SP>  
003 +1001+03 00 00 023 000000<CR><LF>
```

7.4 Flash Firmware Upgrades

The BC 1054 has the capability for flash firmware upgrades. This allows the field operator to reprogram or update the instrument operating system through the back-panel USB port using the Firmware Update Utility program. A Met One Instruments technician may supply the firmware update files by e-mail if a bug fix is released, or if additional features are added to the firmware program.

Ensure that the power source to the BC 1054 and the computer will not be interrupted during the update process! This may cause the firmware to become inoperative. If this happens the unit will have to be returned to the factory. Make sure the USB cable connection cannot come loose during the update.

The following must be performed to update the firmware:

1. It is advisable to download and save the data log and alarm log from the instrument before proceeding. Note: The firmware update process does not clear the instrument memory.
2. A PC or laptop with a USB port must be available and the USB drivers for the BC 1054 installed. Install the Firmware Update Utility program onto the computer by following the prompts after following the e-mail link to the Met One FTP site.
3. Connect the instrument USB serial port to the computer. Make sure that BC 1054 is set to the **9600 baud** rate.
4. Run the Firmware Update Utility. From the computer “Start” menu, go to: Programs/Met One/BC 1054/BC 1054 Master Program Installer (or similar directory). The program may prompt to press ENTER to begin the update.
5. A “Done!” message will be displayed at the end of the update process. Execution time is approximately five to fifteen minutes.

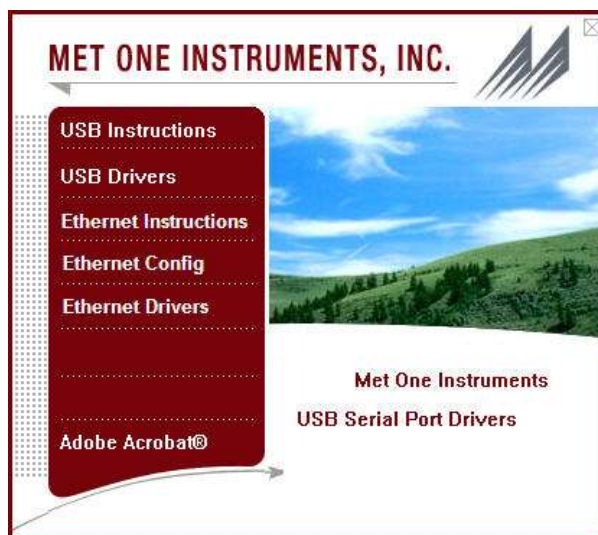
7.5 Ethernet Port Setup and Configuration

The Ethernet port must be configured with some drivers by the user. This section will cover assigning a static ip address to your device to allow users to connect to their device over their network.

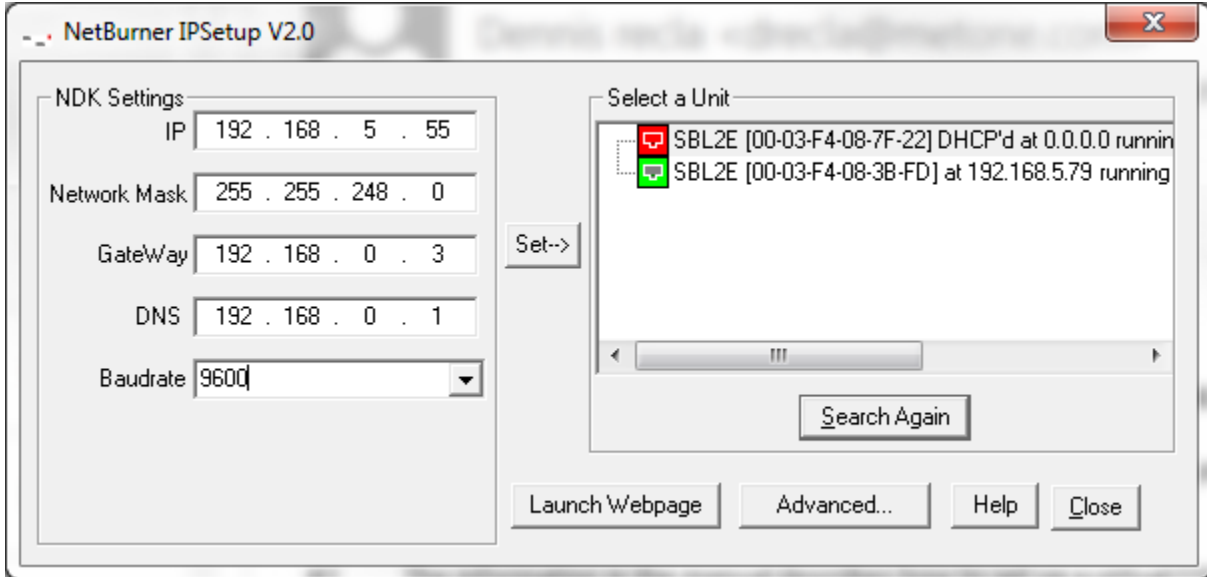
7.5.1 Setting the Static IP Address of Your Device

This section covers how to assign your static ip to your device. These steps assume that someone (an IT person) has setup a static ip address, a network mask, and gateway that you can use to assign to the device. Follow the steps below to assign this information to your device.

1. Connect CAT5 Ethernet cable between local network and Ethernet connector on the wiring panel of the device.
2. Insert the supplied USB/Ethernet Driver CD (part 80328) into your PC. The following menu window should appear:



3. Click on the Ethernet Config button. The following screen will appear:




4. The “Select a Unit” box displays a list of available static IP addresses on the network. Units with a “DHCP” mean they need to be configured and units without the “DHCP’d” means they have already been configured and you shouldn’t change them unless you know what you are doing.
 - a. When setting up the device for the first time, it will have an ip address of 0.0.0.0 and will be displayed in red as shown in the screen shot above.
 - b. If your device isn’t showing up in the list, confirm that you have enabled Ethernet in the device’s setup screen (not all devices need this step).
5. Select your device from the Unit list. It should be the ip address with a “DHCP’d” in it and an address of 0.0.0.0, because that unit is ready to be configured.
6. Type in your assigned static IP address in the IP window. Be sure to write this number down as you will need it later.
7. Type in a Network Mask in the Network Mask window, this may vary depending how your IT department has set up your network. Typical network mask is 255.255.255.0.
8. Set the gateway and DNS based on your company’s network settings.
9. Set the baud rate to the unit’s port baud rate. This can be adjusted in the device’s settings.
10. Select your device from the unit list and press the Set→ button to change the IP address of your device.
11. If the device disappeared from your list, press the search again button until it appears again with your newly assigned ip address.
12. Select the unit from the list and press the launch webpage button. This will launch the Netburner’s Ethernet configuration page.
13. At the top of the page, go to the Serial tab.

| Serial | PORT 0 | PORT 1 |
|---|-------------------------------------|-------------------------------------|
| Data port settings (DEBUG defaults to port 0 if both are set to DEBUG): | RS-232 ▼ | DEBUG ▼ |
| Data baud rate: | 38400 ▼ | 38400 ▼ |
| Custom baud rate: | 0 | 0 |
| Data bits: | 8 ▼ | 8 ▼ |
| Stop bits: | 1 ▼ | 1 ▼ |
| Data parity: | None ▼ | None ▼ |
| Flow control: | RTS/CTS ▼ | RTS/CTS ▼ |
| Allow AT commands: | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| AT attention command char: | 43 (+) | 43 (+) |

[Submit New Settings](#)

14. For Port 0, set the data port to RS-232, set the baud rate to match your device's baud rate, and the flow control to RTS/CTS.
15. For Port 1 set the dataport to DEBUG and match port 0 settings for the rest.
16. Press the 'submit new settings' button to save your changes. You should now be able to communicate with your device via Ethernet using your assigned static ip address and the set port number (default is 23).
17. To check the assigned port number, launch the Netburner Page and go to the Network tab. The Listening network port for Port 0 under incoming TCP Settings is where you can set

the port number. For example, in the screen shot below the port is set to 10023



[Network](#) | [Serial](#) | [GPIO](#) | [Password](#)

Network

Device name for DHCP:

Addressing mode:

| IP Settings | Static Settings | Current Values |
|---------------------|--|--|
| Device IP address: | <input type="text" value="192.168.5.29"/> | 192.168.5.29 |
| Device subnet mask: | <input type="text" value="255.255.248.0"/> | 255.255.248.0 |
| Device gateway: | <input type="text" value="192.168.0.3"/> | 192.168.0.3 |
| DNS server: | <input type="text" value="192.168.0.1"/> | 192.168.0.1 |
| Ethernet link: | <input type="text" value="Normal"/> | Physical power cycle required after change |

Incoming TCP Settings

| | PORT 0 | PORT 1 |
|--|-------------------------------------|-------------------------------------|
| Listen for incoming network connections: | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| Listening network port: | <input type="text" value="10023"/> | <input type="text" value="24"/> |
| Timeout and disconnect after this many seconds of inactivity: | <input type="text" value="60"/> | <input type="text" value="60"/> |
| Allow new connection if the existing connection has been idle for this many seconds: | <input type="text" value="30"/> | <input type="text" value="30"/> |

7.5.2 Setting up a Virtual COM Port

A virtual COM Port allows users to designate a COM port for their existing Ethernet setup for a Met One device. This is not necessary to be able to talk to your device, this just creates an alternative method for connecting to your device if TCP/IP is not an option for some software applications. This section covers the drivers needed and the steps necessary to set up a virtual COM port for your device.

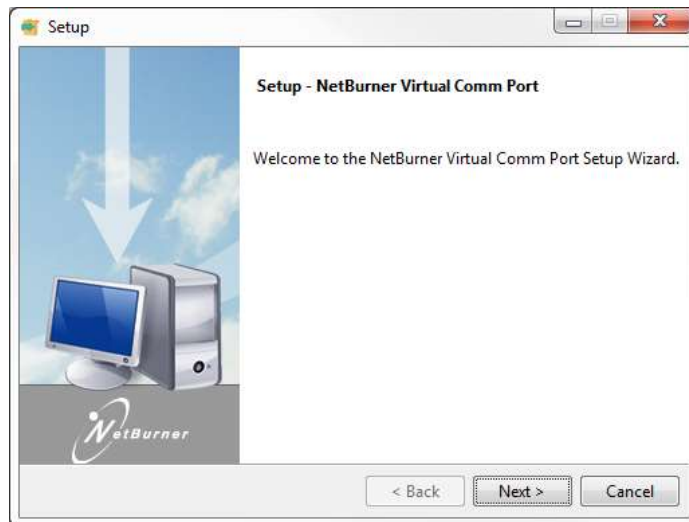
BC 1054-9800 Rev K

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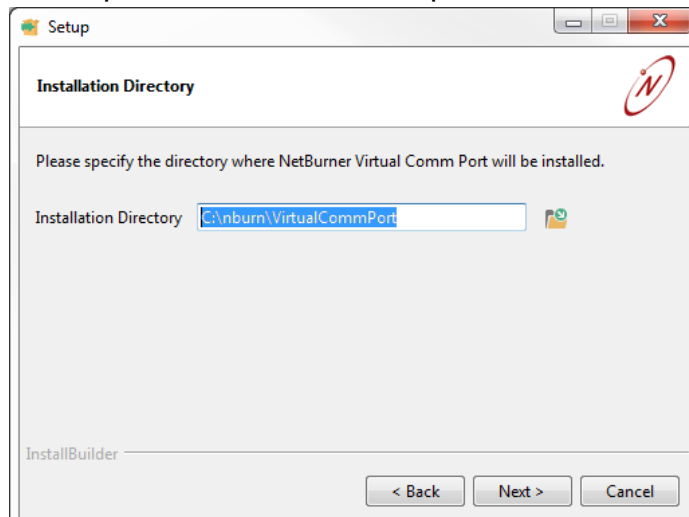
7.5.3 Installing Virtual COM Drivers



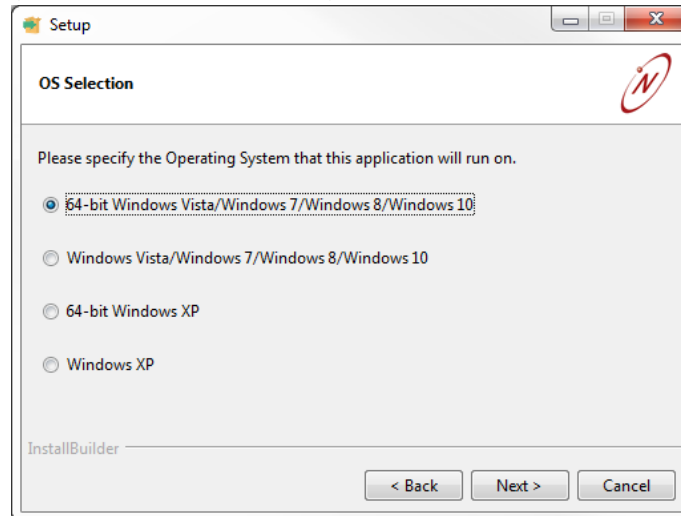
1. From the Drivers CD (shown above), click the Ethernet Drivers button. This will launch the Ethernet driver installation. If you downloaded the drivers from our website, run the VirtualCommPort-2.1.exe found in your zip file.
2. Press next to continue with the wizard.



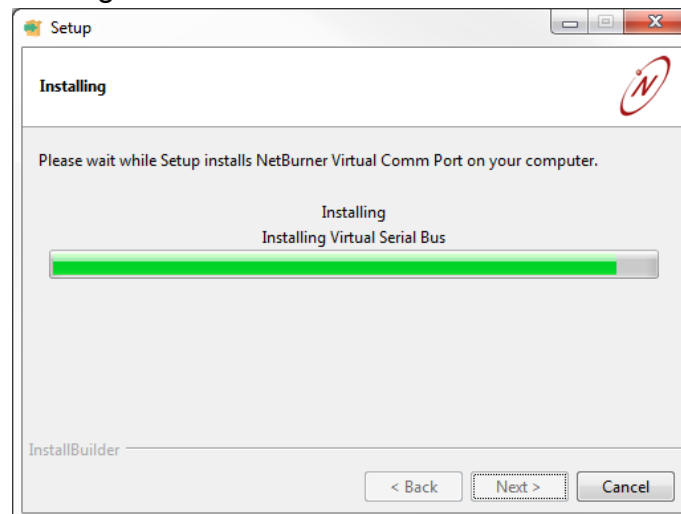
3. Select your own installation path or use the default path: C:\nburn\VirtualCommPort



4. Select which operating system you are using.



5. Press Next to finish installing the Ethernet drivers.



6. Wait for installation to finish and press finish to complete the installation. NOTE: A PC reboot may be required for the Ethernet drivers to function correctly. We recommend restarting your PC after this step.

7.5.4 Configuring Virtual COM Software

1. After restarting your PC, head to your installation folder and open NBVirtualCommPort.exe



2. Press the Add button
3. Select Client connection for the connection type.



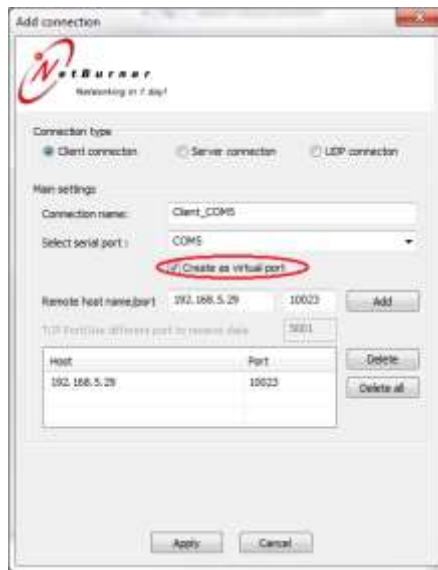
4. Under Select serial port, choose the COM port you would like to assign to your device.



5. Under Connection name, enter a descriptive name for this virtual com port.



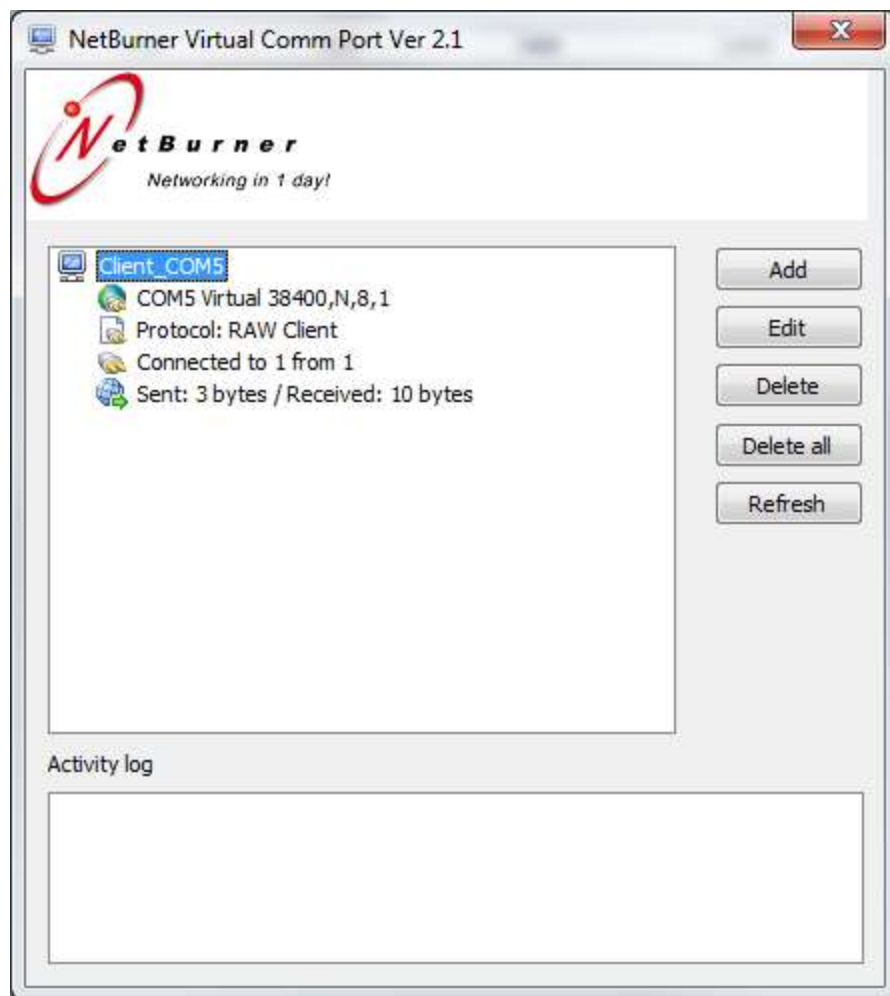
6. Make sure "Create as virtual port" is checked.



7. Enter your static ip address and port number into the Remote host name/port section.



8. Press Add to add this TCP/IP address.
9. Press Apply to add this virtual COM port
10. Now your setting should be displayed on the main page of the program. You can use the refresh button on the right hand side to refresh the status of the virtual port. As you can see in the image below, it found my settings to be 38400 baud, no parity, 8 databits, and 1 stopping bit. After talking to my device, I was able to refresh and see the amount of data sent/received.








8 ACCESSORIES and PARTS

The following parts are available from Met One Instruments for maintenance, replacement, service, and upgrades. If unsure about a part, 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 |
|--|-------------|---|
| Filter Tape Roll | 460211 |  |
| Span Check Membrane | 81947-3 |  |
| Debris Filter Assembly | 580356 |  |
| Debris Filter, Replacement Filter Element Only | 580292 | |
| Fuse, 8A | 590862 |  |
| Flow Control Assembly | 82322-1 |  |
| External AC Pump Box, 110 VAC | 83055 |  |
| External AC Pump Box, 220 VAC | 83054 | |
| Replacement AC Pump Assembly, 110 VAC | 83058 |  |
| Replacement AC Pump Assembly, 220 VAC | 83057 | |
| Pump Re-build kit | 83305 |  |
| Inlet Support Tube | 8936-5 |  |
| Sharp Cut Cyclone, PM 1, 2 LPM | SCC 111 | |
| Sharp Cut Cyclone, PM 2.5, 2 LPM | SCC 112 | |
| Sharp Cut Cyclone, PM 1, 5 LPM | 82344 | |
| Sharp Cut Cyclone, PM 2.5, 5 LPM | 82336 | |
| Dilution Flow System | 82480 |  |
| Plug, Push-To-Connect, 1/2" OD, Red | 580183 |  |
| Cap, Vinyl, 1/2" ID x1/2" Long, Black | 770025 |  |

| | | |
|--|-----------------|---|
| TSP Inlet | 9441 |  |
| Straight Fitting (Mates Tubing to the cyclone) | 580399 |  |
| Hose Clamp | 480773 |  |
| Tubing, Polyurethane, ESD, 90A, 1/2" x 3/8" | 960216 |  |
| Grounded Inlet Tubing Kit | 82934 |  |
| Ambient Temperature, Pressure, RH Combination Sensor | BX-597A |  |
| BX-597A Digital Sensor Cable, 25 foot length | 30010-25 |  |
| Power Supply, AC/DC Switching Adapter, 12V, 8.5A | 510634 |  |
| Flow Sensor Assembly (Dilution System) | 9049-5 |  |
| Pump Module, Dilution Flow System | 82885 |  |
| Solenoid, 3 Way, Dilution Flow System | 82886 |  |
| Filter, Dilution Flow System | 82887 |  |

| | | |
|--|---------------|---|
| Inlet cyclone O-Ring replacement kit | 8658-2 |  |
| Serial Cable, RS-232, DB-9 Male to Female | 550065 |  |
| Fan, Box Heater Circulation | 590080 |  |
| USB Cable | 500784 |  |
| BC Load Correction Software CD – Only needed for early firmware versions. Firmware version 2.2.0 and beyond automatically compensate for filter media loading. | 82478 |  |

9 PRINCIPLE OF OPERATION

Rosen, et. al.ⁱ established the relationship between the attenuation of laser light through quartz filters onto which ambient particulate samples containing soot had been collected and the concentration of “graphitic carbon” of the same samples thereby establishing the viability of optical BC monitoring techniques as determined by Raman scattering.

Gundel, et. al.ⁱⁱ later demonstrated reasonable linear correlation over a wide concentration range between measured attenuation of graphitic carbon collected onto quartz filters and “BC” concentrations determined by thermo-optical methods leading to an estimate of its “specific attenuation” σ .

BC concentration in the BC 1054 is determined by measuring the change in optical transmission as BC-containing particulate matter accumulates onto a filter and then converting this transmission data into BC concentration. In the Met One Instruments BC filter tape is used which extends the possible period of unattended operation to several months under most conditions.

In the BC 1054 transmission of light coming from light emitting diodes is measured across filter tape onto which sampled aerosol containing BC is being accumulated. Reference transmission across a clean portion of the filter tape is simultaneously measured. As BC accumulates onto the filter tape light transmission across the portion of the tape onto which BC is accumulating relative to the reference transmission will decrease.

9.1 Mass Calculation

There is not a universally agreed to soot reference material “SRM” that could be used to calibrate filter-based optical thermal-optical EC or filter-based BC analyzers such as the BC 1054.ⁱⁱⁱ Since a precise definition of soot does not exist, its exact quantification cannot be made. Instead, filter-based BC monitors such as the BC 1054 report BC concentrations based on a presumed relationship between measured optical attenuation through the filter tape as BC accumulates and ambient BC levels based on historical measurement data collected by thermo-optical methods, which are themselves only semi-quantitative. The default calibration settings on the BC 1054 are derived from those. The mass attenuation cross section “MACS” and its wavelength dependence are derived from the empirical relationship shown in Equation 1 based on absorption onto quartz filter media and thermo-optical measurements.^{iv v}

Equation 1: MACS Relationship

$$\sigma(m^2 g^{-1}) = \frac{14,625}{\lambda(nm)}$$

BC is calculated by measuring the changes in transmission of light through the portion of the filter accumulating particulate matter relative to the transmission of light through a portion of the filter not accumulating particulate matter. The relative measured intensity, I_t is defined as the measured signal at time t through the filter accumulating the PM divided by the measured signal at time t of light through the reference as shown in Equation 2.

Equation 2: Measured Relative Intensity

$$I_t = \frac{S_B(t) - S_Z(t)}{R_B(t) - R_Z(t)}$$

$S_B(t)$ is the measured signal at time “t” with the illumination source on through the sampled filter spot. $S_Z(t)$ is the measured signal at time “t” with the illumination source off through the sampled filter spot. $R_B(t)$ is the measured signal at time “t” with the illumination source on through reference portion of the filter and $R_Z(t)$ is the measured signal at time “t” with the illumination source off through the reference portion of the filter.

Equation 3: Attenuation

$$ATN(t) = -\ln \left[\frac{I_t}{I_0} \right]$$

$ATN(t)$ as defined in Equation 3 is calculated from the change in measured optical transmission through the filter that occurs over the time period Δt as PM accumulates. The filter-based aerosol absorption coefficient of the collected particulate matter is defined in Equation 4. A is the cross sectional area of the filter spot, Q is the volumetric flow rate, and $\frac{\Delta ATN}{\Delta t}$ is the measured change in attenuation during time Δt .

Equation 4: Aerosol Absorption Coefficient

$$b_{ATN} = \frac{A \Delta ATN}{Q \Delta t}$$

The filter-based aerosol absorption coefficient of the collected particulate matter is known to differ significantly from the true aerosol absorption coefficient of black carbon. Weingartner, et. al. describe an empirical formula used to connect the two in Equation 5.

Equation 5: True Aerosol Absorption Coefficient

$$b_{abs} = b_{ATN} \frac{1}{C \cdot R(ATN)}$$

C is the part of the difference between the true aerosol absorption coefficient and the filter-based aerosol absorption that is constant and depends only on the filter medium. $R(ATN)$ is the part of the difference between the true aerosol absorption coefficient and the filter-based absorption coefficient that is not constant, but instead is attenuation-dependent.

BC concentration is determined by dividing true aerosol absorption coefficient by the mass attenuation cross section as is shown in Equation 6.

Equation 6: Mass Calculation

$$M_{BC} = \frac{b_{abs}}{\sigma_{abs}} = \frac{b_{ATN}}{\sigma_{abs} \cdot C \cdot R(ATN)} = \left[\frac{A}{Q \cdot \sigma_{abs} \cdot C \cdot R(ATN)} \right] \frac{\Delta ATN}{\Delta t}$$

In the BC 1054, the spot size A , the flow rate Q , the mass absorption coefficient σ_{abs} , and the filter tape constant C , are constants. Therefore the BC concentration M_{BC} is calculated by multiplying

the change in attenuation over time $\frac{\Delta ATN}{\Delta t}$, as is measured by the BC 1054 by the inverse of $R(ATN)$ and a proportionality constant $\left[\frac{A}{Q \cdot \sigma_{abs} \cdot C}\right]$.

9.2 Instrument Calibration

The Met One Instruments BC 1054 has as its default calibration values the historically used mass absorption cross sections “MACS” shown in Equation 1 but adjusted for the change in filter media. This is shown in Equation 7 and Equation 8. Note that $C_{quartz} = 2.14$.

Equation 7: Filter Media Influence on MACS

$$\sigma(m^2 g^{-1}) = \sigma_{abs} \cdot C_{quartz} = \frac{14,625}{\lambda(nm)}$$

and

Equation 8: True Aerosol MACS used in BC 1054

$$\sigma_{abs}(m^2 g^{-1}) = \frac{6,834}{\lambda(nm)}$$

σ_{abs} is set to 7.770 m²/g for 880 nm illumination. In order to calculate the true aerosol absorption coefficients for other illumination wavelengths a 1/ λ wavelength dependence is presumed.

The true aerosol mass absorption coefficients σ_{abs} used in the BC 1054 are shown in the table below. For the glass fiber tape used by the BC 1054 C=2.61.

MACS Values for BC 1054

| $\lambda(nm)$ | $\sigma_{abs} (m^2/g)$ |
|---------------|------------------------|
| 370 | 18.48 |
| 430 | 15.90 |
| 470 | 14.55 |
| 525 | 13.02 |
| 565 | 12.10 |
| 590 | 11.59 |
| 660 | 10.36 |
| 700 | 9.77 |
| 880 | 7.77 |
| 950 | 7.20 |

9.3 Filter Media and Loading Effects

The convenience of using filter-based methods to measure BC is somewhat offset by several measurement artifacts caused by interaction between sampled BC and the filter media, non-linearity of response between measured absorption and BC concentration at high BC filter loadings, scattering of non-absorbing particulate matter and other issues. Non-linearity of response is often referred to as the “filter loading” effect and is more apparent in highly time resolved data where high BC concentrations are being tracked. The filter-loading effect for BC measurements may be mitigated somewhat by frequent tape advances.

For firmware versions preceding 2.2.0, the raw BC 1054 data may be processed into filter loading compensated data and M_{BC} by determining $R(ATN)$ as shown in Equation 6. This is done with the BC Load Correction software retrospectively. For data in which the measured attenuation is very close to 0 or when highly time resolved data is unnecessary $R(ATN) \approx 1$ and post processing of the data is unnecessary. A large quantity of data is generally batched processed with BC Load Correction in order to determine M_{BC} . Note that firmware version 2.2.0 and above automatically correct the data before reporting the values and no longer need this software processing.

ⁱ Rosen, H., Hansen, A. D., Gundel, L., and Novakov, T., "Identification of the optically absorbing component in urban aerosols." *Appl. Opt.* **17**:3859-3861 1978.

ⁱⁱ Gundel, L., Dod, R., Rosen, H., and Novakov, T., "*The relationship between optical attenuation and black carbon concentration for ambient and source particles.*" *The Science of the Total Environment*, **36**:197-202 1984.

ⁱⁱⁱ Baumgardner, D., Popovicheva, O., et. al., "*Soot reference materials for instrument calibration and intercomparisons: a workshop summary with recommendations.*" *Atmos. Meas. Tech.* **5**: 1869-1887, 2012.

^{iv} Gilardoni, S., Vignati, E., Wilson, J., "Using measurements for evaluation of black carbon modeling" *Atmos. Chem. Phys.* **11**:439-455 2011.

^v Jennings, S. G., Pinnick, R. G., "*Relationships between visible extinction, absorption and mass concentration of carbonaceous smokes*", *Atmospheric Environment* **14**:1123-1129 1980.