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Assessment of Acidic Deposition and Ozone Effects on Conifer Forests in the San Bernardino Mountains

Standard Operating Procedure Manual: Volume 2

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

AIR RESOURCES BOARD
Research Division

ASSESSMENT OF ACIDIC DEPOSITION AND OZONE EFFECTS ON CONIFER FORESTS IN THE SAN BERNARDINO MOUNTAINS

STANDARD OPERATING PROCEDURE MANUAL
VOLUME 2

Contract No. A032-180

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List of Standard Operating Procedures

VOLUME 2

Desert Research Institute:

1.0 GENERAL DISCUSSION

1.1 Purpose of Procedure

This document provides operation and maintenance procedures for the following continuous meteorological monitoring instruments:

- wind speed
- wind direction
- ambient temperature
- relative humidity
- solar radiation
- leaf wetness

A datalogger monitors sensors for each of these parameters. DRI SOP 07, Operation and Maintenance of the Campbell 21X Datalogger, provides operational procedures for use of the datalogger. In addition to the six parameters listed above, standard deviation of wind direction (sigma theta) and dew point are calculated from directly measured parameters.

Procedures for calculation of hourly average wind speed and direction are based on U.S. EPA guidelines (U.S. EPA, 1989).

1.2 Measurement Principle

1.2.1 Wind Speed

A 3-cup anemometer measures wind speed. A magnet assembly coupled to the cups rotates and causes a reed switch to close. Wind speed is linearly proportional to frequency of switch closures from the threshold speed of 0.447 m/s up to 45 m/s. The datalogger detects switch closures and converts frequency of switch closures to wind speed. Hourly average wind speed is calculated in two ways to give mean wind speed (scalar wind speed) and mean wind vector magnitude (vector wind speed).

1.2.2 Wind Direction

A wind vane coupled to a precision low torque potentiometer measures wind direction. The datalogger measures potentiometer resistance by applying an excitation voltage and measuring its voltage drop. It then converts the resistance to degrees of angle. Meteorological wind direction is defined as the direction from which the wind is coming, with angles measured in a clockwise direction with true north as 0 degrees. Wind direction is calculated in two ways to give both unit vector wind direction (scalar wind direction) and wind speed weighted wind direction (vector wind direction).

1.2.3 Ambient Temperature

Ambient temperature and relative humidity are measured by a probe containing both a thermistor for temperature measurement and a relative humidity sensor. The probe is housed in an aspirated radiation shield.

Ambient temperature is determined by measuring electrical resistance of the thermistor, which varies as a function of temperature. The datalogger converts resistance to temperature using a fifth order polynomial equation.

1.2.4 Relative Humidity

Relative humidity is determined in a manner analogous to ambient temperature, except that the electrical resistance of the sensor varies as a function of relative humidity rather than temperature. The datalogger converts resistance to relative humidity using a fifth order polynomial.

1.2.5 Solar Radiation

The sensor is a silicon photodiode (pyranometer) that generates an electrical current in the presence of sunlight. The datalogger determines generated current by measuring the voltage drop across a resistor, and translates current into units of energy flux (watts/m^2). The sensor is cosine corrected, which accounts for the variation in angle of incoming radiation.

1.2.6 Leaf Wetness

Leaf wetness is measured using a printed circuit board with closely spaced copper traces. As water bridges the circuit traces, resistance across the sensor decreases, leading to current flow through the sensor. The datalogger records current output from the sensor as a wet sensor condition. Data is processed by the datalogger to indicate the fraction of each hour that the sensor was wet.

1.2.7 Standard Deviation of Wind Direction

The datalogger resolves the instantaneous wind speed and direction signals into vector components, averages the components, and determines the average vector wind speed and direction. The datalogger computes the standard deviation of the instantaneous values from the wind direction sensor using the Yamartino algorithm (Campbell Scientific, Inc, 1991a). Standard deviation of wind direction is computed for 15 minute intervals, and then averaged to determine an hourly value.

1.2.8 Dew Point

Dew point is calculated from the ambient temperature and relative humidity values, using an equation reported by Robinson (1993).

1.3 Measurement Interference

1.3.1 Wind Speed, Wind Direction, and Standard Deviation of Wind Direction

A poorly sited instrument can cause the measured wind speed and direction to be unrepresentative of the general state of the atmosphere in the area. Nearby obstructions can modify both wind speed and direction. It is often not possible to find a site that meets all siting criteria. The deficiencies should be noted and quantified if possible.

Worn bearings and pivots can increase threshold responses. Mechanical damage to cups and/or vanes can result in inaccurate readings.

The accuracy of the wind direction measurements depends on the accurate alignment of the sensor with true north.

1.3.2 Ambient Temperature

A poorly sited instrument can cause the measured temperature to be unrepresentative of the general state of the atmosphere in the area. Nearby obstructions and surfaces can modify the temperature of the air as it passes by them. It is sometimes not possible to find a site that meets all siting criteria. The deficiencies should be noted and quantified if possible.

Direct sunlight or inadequate air flow across a shielded sensor can result in inaccurate readings. Accumulation of dirt and debris on the sensor can affect readings.

1.3.3 Relative Humidity

A poorly sited instrument can cause the measured relative humidity to be unrepresentative of the general state of the atmosphere in the area. Areas of standing water can modify the relative humidity of the air as it passes over. It is sometimes not possible to find a site that meets all siting criteria. The deficiencies should be noted and quantified if possible.

Sulfur and oil gases or compounds will rapidly deteriorate the relative humidity sensor. Do not smoke near the sensor.

Liquid water contacting the sensor causes temporary high readings. As the water evaporates, the readings will return to normal. Repeated contact with liquid water will cause corrosion of the gold plated spring clips which hold the sensor or lifting or flaking of the carbon electrode from the polystyrene wafer. This causes an increase in probe resistance and a permanent negative bias in relative humidity readings. The protective 40 mm stainless steel mesh screen minimizes liquid water formation on the sensor.

Application of direct current voltages, or alternating current voltages with a direct current component will cause a shift in calibration.

1.3.4 Solar Radiation

Neighboring equipment/structures that cast shadows or reflect radiation on the sensor during certain times of the day result in erroneous readings. Accumulations of dirt and debris cause inaccurate readings. Scratches on the face of the sensor diffuser alter its light transmission properties. The vertical edge of the diffuser must be clean in order to maintain accurate cosine correction. Accumulation of snow on the sensor will produce an inaccurate low reading.

1.3.5 Leaf Wetness

Accumulation of dirt and debris on the sensor grid can result in inaccurate readings. Shielding of the sensor by structure or plant growth can affect the readings. The sensor does not respond to snow or other forms of ice. Ice or snow that accumulates on the sensor and then melts will result in an indication of leaf wetness that may not be accurate.

1.4 Ranges and Typical Values

Ranges and typical values for meteorological parameters are as follows:

Parameter	Sensor Range	Typical Range
Wind speed	0.45 to 45 m/s	0 to 20 m/s
Wind direction	0 to 360°	0 to 360°
Ambient temperature	-40 to 56 °C	-5 to 45 °C
Relative humidity	12 to 100 %	0 to 100%
Solar radiation	0 to 3000 watts/m^2	0 to 1200 watts/m^2
Leaf Wetness	0 to 100%	0 to 100%

1.5 Lower Quantifiable Limits, Precision and Accuracy

Parameter	Lower Quantifiable Limit	Precision	Accuracy
Wind Speed	0.447 m/s	±1.5% or ±0.11 m/s	±1.5% or ±0.11 m/s
Wind Direction	N/A	±5° at windspeeds above 0.447 m/s	±5° at windspeeds above 0.447 m/s
Temperature	N/A	±0.4 °C over the range of -33 to +48 °C	±0.4 °C over the range of -33 to +48 °C
Relative Humidity	12%	±5%	±5%
Solar Radiation	1 watt/m^2	N/A	± 5%
Leaf Wetness	N/A	N/A	N/A

1.6 Responsibilities

The site operator carries out performance tests, routine maintenance and documents data collected and tasks performed in accordance with this standard operating procedure. The field supervisor provides supervision and guidance for the field operator and performs semi-annual calibration checks.

1.7 Definitions

Leaf wetness	Fraction of hour that leaf wetness sensor indicated wet condition.
Scalar wind speed	The simple average of instantaneous wind speed readings over the measurement interval.

Scalar wind direction	The direction computed from the simple average of instantaneous wind direction unit vectors over the measurement interval.
Vector wind speed	The "resultant" wind speed computed from the average of the product of instantaneous wind speed and direction vectors over the measurement interval.
Vector wind direction	The "resultant" wind direction computed from the average of the product of instantaneous wind speed and direction vectors over the measurement interval.
Sigma theta	Standard deviation of wind direction.
DDW	Distilled, deionized water, with conductivity > 18 megohms.
DAS	Data Acquisition System consisting of Campbell 21X datalogger, modem and on site computer.

1.8 Related Procedures

- Operation and Maintenance of the Campbell 21X Datalogger (DRI SOP 07)
- Meteorological and Continuous Gaseous Data Processing and Validation (DRI SOP 20)

2.0 APPARATUS, INSTRUMENTATION, REAGENTS AND FORMS

2.1 Apparatus and Instrumentation

2.1.1 Description

- Meteorological Instrumentation

Parameter	Manufacturer	Model
Wind Speed	Met One	014A
Wind Direction	Met One	024A
Temperature and Relative Humidity	Met One	207
Solar Radiation	LI-COR	LI-200S
Leaf Wetness	Campbell Scientific	237

- Apparatus for Routine Service
  - Optically soft cleaning tissue
  - Site visit forms
  - Tower climbing belt

- Apparatus for Calibration
  - Plumb and level
  - Compass with tripod
  - Degree wheel calibration fixture
  - Torque watch
  - Barometer
  - DRI Audit/Calibration software and portable computer
  - Constant speed motors - 300, 600 and 1800 RPM
  - Psychrometer with NIST-traceable thermometers
  - NIST-traceable pyranometer

2.1.2 Characterization

Refer to manufacturer's instrument manuals (Campbell Scientific, Inc. 1990a, 1990b, 1991b, 1991c, 1991d, Li-Cor 1991b) for complete instrument characterization and performance specifications.

2.1.3 Maintenance

Routine maintenance procedures are performed to reduce instrument down time. The following procedures are performed at the specified frequency. Refer to individual instrument manuals (Campbell Scientific, Inc., 1990a, 1990b, 1991b, 1991c, Li-Cor, 1991b) for more detailed instructions for each task, and for corrective maintenance procedures.

Sensor	Task	Frequency
Wind speed	Inspect cups for cracks and breaks. Check that arms are securely attached to hub. Check that vent hole is open.	6 - 12 months
	Replace bearings.	12 - 24 months or as needed
Wind direction	Inspect for physical damage.	6 - 12 months
Relative humidity	Replace RH sensor.	When carbon electrode lifts or flakes off polystyrene wafer
Solar radiation	Clean sensor.	Monthly

2.1.4 Spare Parts List

- Replacement wind speed cup assembly
- Replacement wind direction vane
- Replacement relative humidity sensor

2.2 Reagents

Not applicable.

2.3 Forms

The Meteorological System Site Visit Log is shown in Figure 2-1.

3.0 CALIBRATION STANDARDS

3.1 Wind Direction

If the sensor can be reached, use a compass to determine the bearing to one or more targets relative to true north. Determine correction for local magnetic declination from GEOMAG, a computer program of the USGS that gives several geomagnetic field elements at locations of known latitude, longitude, and elevation for a particular time. GEOMAG can be accessed by computer with a telephone and modem. Since the magnetic declination is changing about 3 minutes a year, declinations on older maps can be incorrect by several degrees. Compare readings with the head and tail of the vane pointed at the targets to compass readings. If these readings show that the sensor needs electronic alignment, use a degree wheel calibration fixture to measure the angle of the sensor and the voltage output.

If the sensor cannot be reached, remove it from the tower and use the degree wheel calibration fixture to calibrate. Use the compass to determine the orientation of the crossarm while it is on the tower. It should be oriented along a north-south line relative to true north before the sensor is removed and after it is replaced.

Check sensor bearings by rotating shaft manually or by using a torque watch.

3.2 Wind Speed

Calibrate wind speed using several constant speed motors. Remove the anemometer cup assembly and install the motors to turn the shaft at different speeds. The wind speeds for the frequencies generated by the motors are calculated from the manufacturer's calibration curve and compared to the datalogger readings.

Check bearings by rotating shaft manually or by using a torque watch.

3.3 Temperature

Check the temperature sensor using an aspirated NIST-traceable thermometer that is placed in the vicinity of the sensor. Check at several different temperatures.

3.4 Humidity

Check the humidity sensor using an aspirated NIST-traceable psychrometer that is placed in the vicinity of the sensor. Check at several different humidities.

3.5 Solar Radiation

The solar radiation sensor is calibrated at the factory; field calibrations are not practical. The zero of the instrument is checked weekly by tracking the nighttime values collected on the datalogger. Verify

Meteorological System Site Visit Log

Site________________ Operator________________ Month/Year__________

	Date					
	Time					
Visual Checks	Tower, Crossarm					
	Anemometer					
	Vane					
Wind Speed	DAS (m/s)					
	Visual					
Wind Direction	DAS (degrees)					
	Visual					
Ambient Temperature	DAS (°C)					
Relative Humidity	DAS (%)					
Solar Radiation	DAS (W/m^2)					
Leaf Wetness	DAS (kohms)					
	Precip. (Y/N)?					
Panel Temperature	DAS (°C)					
Shelter Temperature	DAS (°C)					

Date	Comments or Maintenance Performed

Reviewed by __________________ Date ______

Figure 2-1. The meteorological system site visit log.

readings by side-by-side comparison with a pyranometer of known response. Take readings at several different solar intensities.

3.6 Leaf Wetness

Check the leaf wetness sensor using distilled water. Place several drops of water on the sensor to confirm a positive voltage output that results in a datalogger reading of less than 200 kohms. The sensor gives a response of less than 200 kohms on the datalogger when it is wet, and greater than 200 kohms when it is dry.

4.0 PROCEDURES

4.1 General Flow Diagram

Figure 4-1 shows a general flow diagram of routine operating procedures.

4.2 Startup

4.2.1 Acceptance Testing

Acceptance test all new equipment prior to deployment in the field. Inspect each component for physical damage or loose connections. Check all cables for continuity. Bench test each instrument using the instrument manufacturer's operation and maintenance manuals.

4.2.2 Tower Installation

It is imperative that manufacturer's recommendations be followed for a safe tower installation. Pay special attention to procedures for securing the tower base, installing guy wire stakes, and securing cables.

Secure the tower base plate on the ground or platform. Install sections of triangular tower on top of base plate as needed to reach the desired height and attach guy wires from tower to secure stakes in ground. Install guy wires at intervals recommended by the manufacturer, and position guy wire stakes such that guy wires are at the proper angles. Install a lightning rod at the top of the tower, and install a ground wire.

4.2.3 Sensor Installation

- Install temperature/relative humidity sensor in gill radiation shield.
- Calibrate wind direction sensor according to the manufacturer's recommended procedure (Campbell Scientific, Inc., 1990a).
- Install bushing for wind direction sensor in wind speed and direction crossarm.
- Install wind speed and direction crossarm on one of three ends at top of tower. Determine bearing to true north with magnetic compass and current magnetic

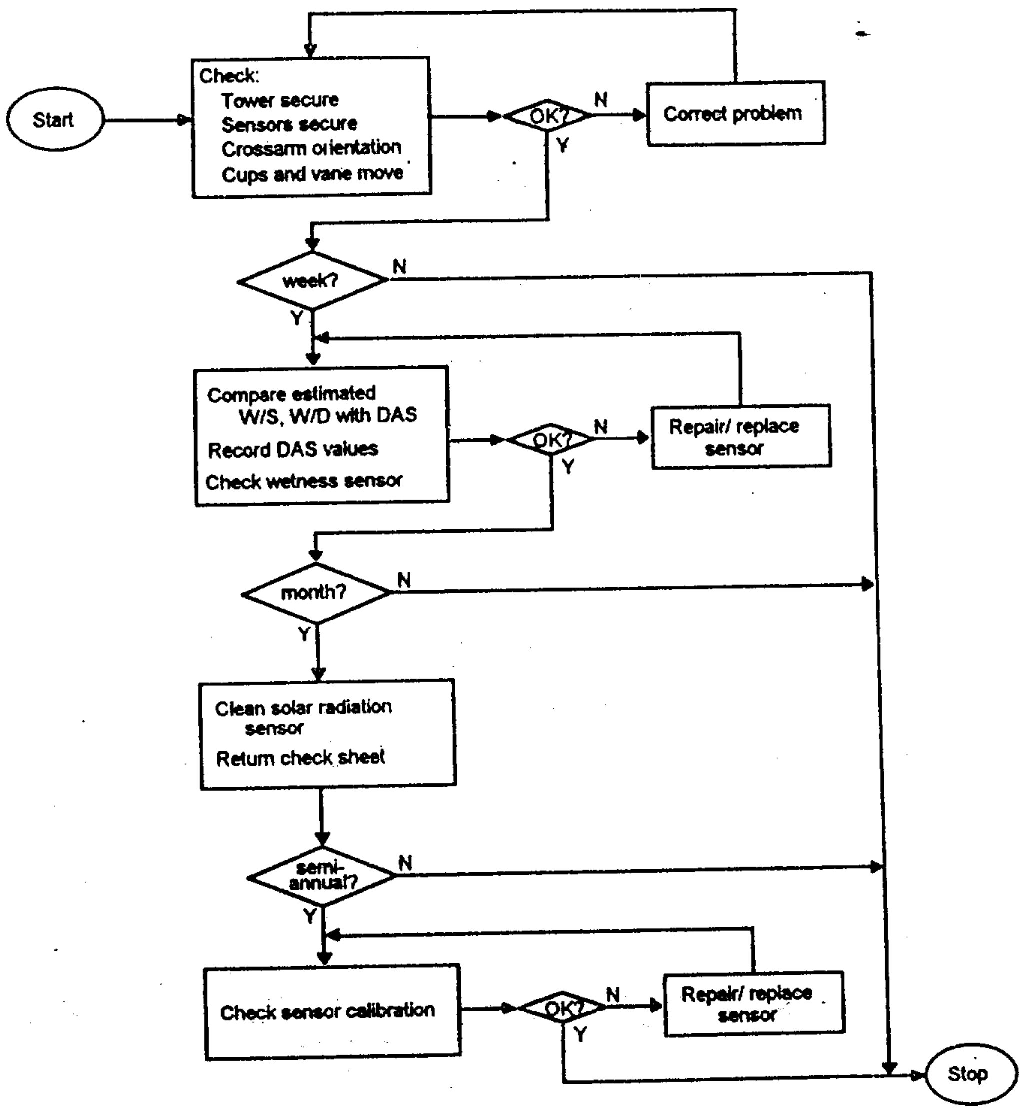

Figure 4-1. Meteorological system operating procedure flow diagram.

(applies to California), the bearing relative to true north is the sum of the magnetic bearing and the declination. With brace between crossarm and tower, secure crossarm with hose clamp so that arm cannot move. Check that crossarm is horizontal. Install wind speed and direction sensors on crossarm. The wind direction sensor is installed first in the keyed bushing and then in the mount on the crossarm. The key should point towards the south and should line up with the crossarm. Check that sensors are vertical and adjust crossarm if necessary.

- Attach gill radiation shield with installed temperature/relative humidity sensor near the top of the tower. Orient so that interference from the tower to prevailing winds is minimized.

- Install solar radiation sensor support arm on tower. Orient the support arm (install on south side of tower) so that shadows from the tower or any other nearby object will not fall on the sensor. Install solar radiation sensor in mount, and attach to support arm. Use bubble level on mount to set sensor horizontal.

- Install leaf wetness sensor above platform roof so that it is not obstructed by any nearby objects. Make sure that it is not below tower or tower guy wires from which water could drip.

- Attach all cables to sensors, secure them to the tower, and run them into shelter. Patch hole around wires with putty.

4.2.4 Datalogger Programming

Complete programming instructions for the Campbell 21X datalogger are given by Campbell Scientific, Inc., (1991a). Program the datalogger in accordance with those instructions, the requirements of the monitoring program, and the programming instructions in the sensor manuals (Campbell Scientific, Inc., 1990a, 1990b, 1991b, 1991c, 1991d). Note that the wind direction sensor program instructions require a calibration factor determined experimentally, and the pyranometer program instructions require a calibration factor derived from the manufacturer's calibration (Li-Cor, Inc., 1991a). The datalogger program for the Barton Flats site is given in Appendix A of the Campbell 21X datalogger SOP (DRI SOP 07).

4.2.5 Sensor Checks

- Attach sensor cables to datalogger terminals. Refer to the DAS SOP for details.

- Perform sensor calibration checks for each sensor as described in section 5.0. Note: In some cases it may not be practical to perform sensor calibration checks after they are installed on the tower. Check these sensors by connecting to the datalogger and performing calibration checks before installation on the tower.

4.3 Routine Operations

The station is serviced at least once a week. Following are procedures required for each visit as well as procedures required at prescribed intervals:

4.3.1 Each Site Visit

- Verify sensors are intact and tower is secure.
- Check cross arm orientation. It should line up along a north-south line.
- Check that cups and vane move if wind is not calm.

4.3.2 Weekly

Fill out the Meteorological System Site Visit Log. Refer to Operation and Maintenance of the Campbell 21X Datalogger SOP for instructions to display current sensor readings.

- Check that tower and guy wires are secure, crossarm is oriented north to south, and that anemometer and wind vane are intact and operating (cups should rotate and vane should move unless there is a dead calm). Write "OK" on the log form if there are no problems, otherwise record the nature of the problem and correct. Call the field supervisor for instructions if necessary.
- Visually estimate wind speed into one of four speed categories: calm, light, moderate, or strong. Compare with datalogger readings and record on the log form. Datalogger readings will vary over time, so estimate a time weighted average wind speed. Compare visual estimate with datalogger readings using the table below; initiate repair or replacement of the sensor if there is a discrepancy.

Category	Speed (m/s)
Calm	< 0.5
Light	0.5 - 2
Moderate	2 - 10
Strong	> 10

- Visually estimate wind direction into one of eight direction categories: north, northeast, east, southeast, south, southwest, west, or northwest. Compare with datalogger readings and record on the log form. Datalogger readings will vary over time, so estimate a time weighted average wind direction. Compare visual estimate with datalogger readings using the table below; initiate repair or replacement of the sensor if there is a discrepancy.

Category	Direction (degrees)
North	337.5 to 22.5
Northeast	22.5 to 67.5
East	67.5 to 112.5
Southeast	112.5 to 157.5
South	157.5 to 202.5
Southwest	202.5 to 247.5
West	247.5 to 292.5
Northwest	292.5 to 337.5

- Record temperature, relative humidity, solar radiation, panel temperature and shelter temperature readings on the log form.

- If precipitation is occurring, enter "Y" for Leaf Wetness Precipitation and record the sensor resistance (kohms) on the log form. Make a note on the log form if precipitation is snow. If the sensor is dry, disable sensor readings from hourly average by pressing function key F1 on the computer. The "Flag 1" indicator on the screen will be highlighted. Place a small drop of distilled deionized water on the sensor and record sensor resistance. After the sensor has dried, toggle Flag 1 off by pressing function key F1.

4.3.3 Monthly

- If solar radiation sensor is accessible, clean by squirting with DDW to dislodge particle accumulations on the vertical edge of the diffuser. Blot with KimWipe to dry. Be careful not to scratch the sensor by rubbing dislodged particles across the surface of the sensor when drying.

- File a copy of the Meteorological System Site Visit Log (Figure 2-1) at the site and return original to field supervisor.

4.3.4 Semi-Annually

Perform calibration check procedures detailed in section 5.0 for each sensor.

5.0 QUANTIFICATION

5.1 Recording Calibration Data

All calibration results are recorded and calculations performed by the DRI Audit/Calibration software running on a portable computer. Refer to the Audit/Calibration software manual (DRI, 1991) for instructions.

5.2 Wind Direction Calibration

5.2.1 Initial Sensor Calibration

Perform the initial sensor calibration before the sensor is installed as detailed in Campbell Scientific, Inc., (1990a). The multiplier calculated from this initial calibration must be used in the datalogger program.

5.2.2 Crossarm Check

- Take magnetic bearing along crossarm from south of sensors. Take readings a sufficient distance away from metal structures such as towers and shelters to avoid interference. Add current magnetic declination to magnetic bearing to obtain bearing relative to true north. The true bearing should be 0° ± 3°.

- Take magnetic bearing along crossarm from north of sensors. Make sure that compass is not affected by the presence of nearby metal structures. Add current magnetic declination to magnetic bearing to obtain bearing relative to true north. The true bearing should be 180° ± 3° and should differ from the first by 180° ± 1°.

- Check that key on wind direction sensor is aligned with the crossarm.

5.2.3 Two Point Calibration Check

- Determine the magnetic and true bearing to two targets that are separated by about 90°.

- Point the vane at each of the targets (orientation as viewed from above the vane).

  - Turn vane counter-clockwise 2 times and point tip at target. This should give a reading between 0 and 360°.

  - Turn vane counter-clockwise 1/2 turn and point tail at target. This should give a reading between 0 and 360° and should differ from the previous reading by 180°.

  - Turn vane clockwise 2 times and point tip at target. This should give the same reading as when rotating the vane counter-clockwise.

  - Turn vane clockwise 1/2 turn and point tail at target. This should give a reading between 0 and 360° and should differ from the previous reading by 180°.

- If all directions are within ±5° of the bearing values, the sensor does not require adjustment. If all the directions differ by a fixed value from the bearing values, there is a fixed bias attributable to either incorrect bearings, misaligned crossarm, or misaligned sensor.

5.2.4 Sensor Bearing Check

- Remove vane from sensor and gently turn sensor shaft to see if it turns smoothly with little resistance. If the shaft turns roughly, the bearings should be replaced.

- If you cannot ascertain the condition of the bearings from the previous step, check with torque watch. Attach the torque watch adapter to the shaft and insert weighted screws in increasingly higher torque positions until the shaft begins to turn. The maximum torque from repeated tests is the starting torque. If the torque exceeds the manufacturer's specifications, replace the bearings.

5.2.5 Sensor alignment check

If the sensor fails the two point calibration check, perform the following alignment check.

- Install degree wheel calibration fixture on fixed shaft and pointer on rotating shaft of sensor.

- Using a similar sequence as the two point check, place pointer and tail at 4 locations to obtain 8 directions. Compare datalogger value to calibration fixture.

- If readings are not within $\pm 5°$ of true values, repeat initial calibration as in step 5.2.1.

5.2.6 Reinstall Sensor

If sensor was removed from crossarm, install in crossarm with key pointing along arm towards south. Visually observe the orientation of the vane and estimate the wind direction. Compare the reading on the datalogger to the estimated direction. They should not differ by 180°.

5.3 Wind Speed Calibration

5.3.1 Bearing Check

- Remove cups from sensor and gently turn sensor shaft to see if it turns smoothly with little resistance. If the shaft turns roughly, the bearings should be replaced.

- If you cannot ascertain the condition of the bearings from the previous step, check with torque watch. Attach the torque watch adapter to the shaft and insert weighted screws in increasingly higher torque positions until the shaft begins to turn. The maximum torque from repeated tests is the starting torque. If the torque exceeds the manufacturer's specifications, replace the bearings.

5.3.2 Sensor Check

Remove cups. Attach one of several synchronous motors to the rotating shaft of the sensor and allow to run. Compare the datalogger outputs to the wind speed associated with the imposed frequency of the particular motor. The frequencies of the motors are found from the equation

$$\text{Freq[Hz]} = (\text{Motor RPM}) \times (\text{Holes in Chopper})/60.$$

Refer to the instrument manual (Campbell Scientific, Inc., 1990b) for the multiplier and offset to convert frequency to wind speed.

5.4 Temperature Calibration

If the sensor is not easily accessible while on the tower, remove it for calibration check. Check temperature at several different times of the day to obtain data at different temperatures.

Place aspirated thermometer as close to sensor as possible and allow to come to equilibrium. Shade thermometer from direct sun light. Air flow to thermometer should be similar to air flow to site temperature sensor. Compare calibration thermometer reading to DAS reading for site temperature sensor.

5.5 Relative Humidity Calibration

If the sensor is not easily accessible while on the tower, remove it for calibration check. Check relative humidity at several different times of the day to obtain data at different humidities.

- Place aspirated psychrometer as close to sensor as possible and allow to come to equilibrium. Shade psychrometer from direct sun light. Air flow to psychrometer should be similar to air flow to site relative humidity sensor. Record wet and dry bulb temperatures and datalogger relative humidity reading.
- Measure barometric pressure at site with barometer or estimate pressure from site elevation or nearby National Weather Service office.
- Calculate relative humidity from wet and dry bulb and pressure readings using menu options in the audit/calibration program. Compare calibration relative humidity to DAS reading for relative humidity sensor.

5.6 Pyranometer Calibration

Place calibration pyranometer as near the site sensor as possible such that calibration instrument is similarly illuminated as the site instrument. In most cases, the two sensors are not easily placed side-by-side. The calibration pyranometer may have to be located at some point lower than the site instrument. The calibration pyranometer should be place so that reflected solar radiation is minimized.

Measure the output of the calibration pyranometer using a DVM. Convert voltage output to solar radiation using the reference pyranometer calibration data. Compare to DAS reading of the site pyranometer. If possible, the checks should be done on a clear day with the sun at a high elevation. Clouds result in variable radiation readings because of reflections and shadows.

Make comparisons at more than one point by doing the checks at more than one time during the day. At least one of the points should be done when the sun is at a high elevation.

5.7 Wetness Sensor Calibration

Wet the sensor with a few small drops of DDW. The reading should drop to less than 200 kohms. As the sensor dries out, the reading should increase to 99999 kohms.

5.8 Calculations

5.8.1 Sensor Output to Engineering Units

- $$WindDirection(degrees) = \frac{V \times 360}{FSIV}$$

  where V = output voltage
  FSIV = full scale input voltage as determined in Campbell Scientific, Inc., (1990a).

- $Wind\ Speed\ (m/s) = F \times 0.800 + 0.447$

  where F = output frequency in Hz.

- Temperature (°C) is computed by applying the ratio of output voltage to excitation voltage to a fifth order polynomial as described in Campbell Scientific, Inc. (1991b).

- Relative humidity (%) is computed by applying the ratio of output voltage to excitation voltage to a fifth order polynomial as described in Campbell Scientific, Inc. (1991b).

- $$SolarRadiation(W/m^2) = \frac{mV \times 1000}{C}$$

  where C = Li-Cor's calibration of sensor (mA/1000 w/m²) x 0.1
  mV = sensor output in mV.

- Leaf wetness sensor resistance is calculated from the equation:

$$R_S = \frac{1}{V_S/V_X} - 101$$

where R_s = sensor resistance (kohms)
V_s = sensor output (mV)
V_x = excitation (mV).

5.8.2 Hourly Averages

- Scalar wind speed

$$S=\frac{\sum S_i}{N}$$

where S = hourly average scalar wind speed (m/s),
S_i = instantaneous wind speed (m/s),
N = number of measurements in hour.

- Scalar wind direction

$$\Theta 1 = \arctan(U_X/U_Y)$$

where $\Theta 1$ = hourly average scalar wind direction (degrees),
U_x = $\Sigma(\sin \Theta_i)$ / N,
U_y = $\Sigma(\cos \Theta_i)$ / N,
Θ_i = instantaneous wind direction (degrees).

- Vector wind speed

$$U=\sqrt{U_e^2+U_n^2}$$

where U = hourly average vector wind speed (m/s),
U_e = $\Sigma(S_i \sin \Theta_i)$ / N,
U_n = $\Sigma(S_i \cos \Theta_i)$ / N.

- Vector wind direction

$$\Theta u = \arctan(U_e/U_n)$$

where Θu = hourly average vector wind direction (degrees).

- Sigma theta

$$\sigma(\Theta 1)=\sqrt{\frac{\sum(\sigma\Theta_j)^2}{4}}$$

where $\sigma(\Theta 1)$ = sigma theta (degrees),
$\sigma\Theta_j$ = $\arcsin(\epsilon) \times (1 + 0.1547\,\epsilon^3)$ for the j^{th} 15 minute period during the hour,
ϵ = $[1 - (U_x^2 + U_y^2)]^{1/2}$.

- Temperature

$$T=\frac{\sum T_i}{N}$$

where T = hourly average temperature (°C),
T_i = instantaneous temperature (°C).

- Relative humidity

$$RH=\frac{\sum RH_i}{N}$$

where RH = hourly average relative humidity (%),
RH_i = instantaneous relative humidity (%).

- Solar radiation

$$R=\frac{\sum R_i}{N}$$

where R = hourly average solar radiation (W/m^2),
R_i = instantaneous solar radiation (W/m^2).

- Leaf wetness

$$W_l=\frac{N_s}{N}$$

where W_l = leaf wetness (fraction of hour),
N_s = number of readings in hour where R_s > 200.

- Dew point

$$T_d=\frac{(RH/100)^{1/8}\times(201.8+1.62\times T)-201.8+0.18\times T}{1.8}$$

where T_d = dew point temperature (°C).

6.0 QUALITY CONTROL

Quality control for this procedure is maintained by routine site visits, scheduled calibrations, and routine preventative maintenance checks.

7.0 QUALITY ASSURANCE

All site instrumentation will be audited semi-annually.

8.0 REFERENCES

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Campbell Scientific, Inc. (1990b). Model 014A Met One Wind Speed Sensor Instruction Manual, Revision Date: 10/90, Logan, UT 84321.

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Robinson, N. F. (1993). Personal communication, December, 1993.

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1.0 GENERAL DISCUSSION

1.1 Purpose of Procedure

This document provides operation and maintenance procedures for the Dasibi Model 1008 AH analyzer and should be used in conjunction with the 1008 AH operating manual (Dasibi, 1990). Portions of this SOP were taken from Revision 4, Volume II, Appendix A of the CARB Air Monitoring QA Plan.

1.2 Measurement Principle

The 1008 AH measures ozone by ultraviolet (UV) absorption spectrophotometry. Ambient air is introduced into an optics bench with a lamp at one end and a photodiode at the other. Ozone absorbs UV light at a wavelength of 253.7 nm; the amount of UV light absorption in the optics bench is related to ozone concentration by Beer's law. The low pressure mercury vapor lamp produces 92 percent of its output at the 253.7 nm emission line. The cesium telluride vacuum photo detector has a broad passband centered near that line so that 99.5 % of the total system response is from the 253.7 nm line.

Ambient air entering the monitor is routed to one of two paths via a solenoid activated valve. The first path leads directly into the optics bench; the second path first passes through an ozone scrubber and then into the optics bench. The ozone scrubber contains MnO_2 coated copper screens which catalyze the reaction of ozone to diatomic oxygen but leave other components unchanged. The solenoid switches the valve at regular intervals so that the photo detector alternately measures the amount of light absorbed by the ozone-laden air (ambient sample) and the amount absorbed by ozone-free air (reference gas).

Ozone concentration is calculated electronically by comparing UV absorption of sample and reference gas streams and displayed in a digital readout on the front panel and sent to a data acquisition system by an analog output. Figure 1-1 provides a block diagram of the optical, pneumatic and electronic components of the analyzer.

1.3 Measurement Interferences and Their Minimization

Ozone will react with most surfaces other than glass or Teflon. Use of materials other than glass or Teflon in the inlet system, or deposits of air particulates on inlet surfaces will reduce ozone concentration before the sample enters the analyzer. The sample manifold and inlet lines have no internally exposed surfaces other than glass or Teflon, and ambient air is drawn through the manifold at a rate sufficient to prevent degradation of ozone. The manifold and inlet lines are cleaned periodically to prevent a build up of particulate deposits.

Particles in ambient air may also interfere with the optical attenuation measurement. A Teflon filter is placed in line with the inlet to prevent this and to prevent particulate deposition in sample lines and the optical cell in the analyzer. The filter is replaced periodically.

Some components such as benzene which may be present in ambient air absorb 253.7 nm light to some extent. Since these species are present in both the reference and sample gas streams at the same concentration, measurement of ozone concentration is unaffected.

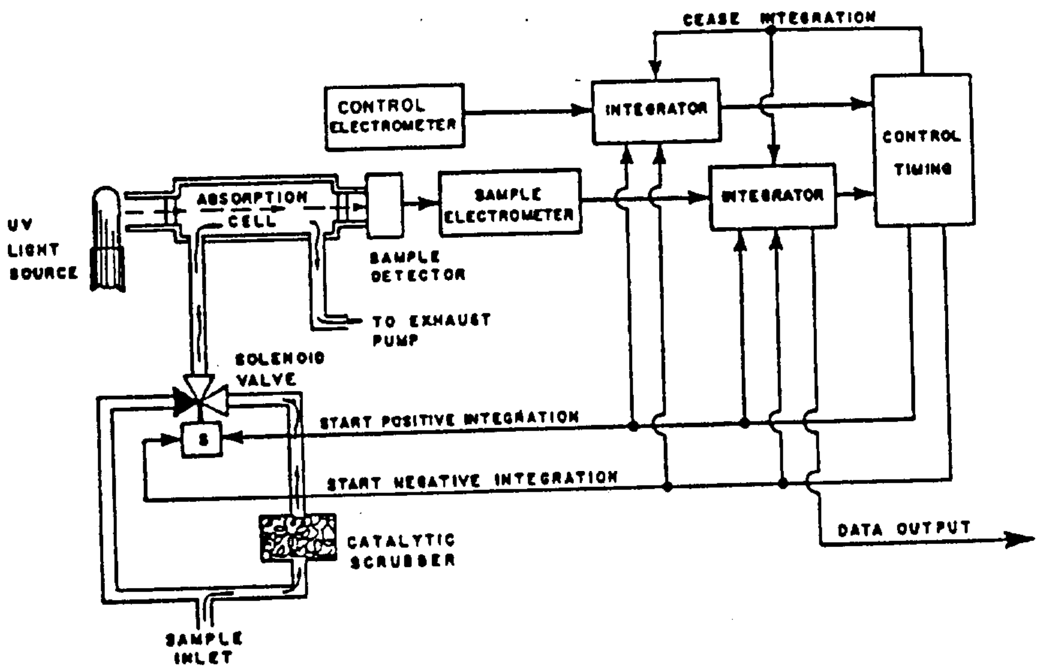

Figure 1-1. Block diagram of Dasibi 1008 AH optic, pneumatic and electronic components.

1.4 Ranges and Typical Values

The instrument range is 0.0 to 1.0 ppm. The Federal ambient air quality standard is 120 ppb. Exceedances of this level are observed in some urban areas, and occasionally in rural areas subject to urban plume transport. "Background" concentrations are usually at least 20 ppb at most continental locations.

1.5 Typical Lower Quantifiable Limits, Precision, and Accuracy

Generally the lower quantifiable limit, precision and accuracy are 1 ppb, ± 3% and ± 1% respectively.

1.6 Personnel Responsibilities

The site operator is responsible for routine instrument checks and maintenance. If the 1008 AH is down for more than one day, the site operator will reconFigure the 1003 PC analyzer from its use as the site calibrator to operate as the ambient monitor.

The field supervisor is responsible for training the site operator, overseeing weekly operations, calculating and recording precision check results, semi-annual performance audits, coordinating non-routine maintenance and repair operations and data collection and validation.

1.7 Definitions

Optics bench	Also called absorption cell. Consists of Pyrex tubes or Kynar lined aluminum tubes optically coupled by quartz mirrors, a mercury vapor lamp at one end and a cesium telluride photodetector at the other end. The sample or reference gas is introduced at one end while the other end is connected to the sample pump. Quartz windows and gaskets provide gas-tight interface of the lamp, detector, mirror and tubes. The total path length is 71 cm.
Reference Gas	Ambient air which enters the analyzer and is diverted by the solenoid valve through the ozone scrubber is called the reference gas. Its composition is the same as ambient air except that ozone is converted to diatomic oxygen. Light absorption in ambient air is compared to that in the reference gas to determine ozone concentration.
Zero Air	Ambient air stripped of ozone, particulates and water vapor is called zero air. For calibration, zero air is generated by drawing ambient air through canisters filled with desiccant, Purafil and charcoal.
Span Number	The span number controls the "sensitivity" of the analyzer, i.e. for a given ozone concentration, what reading is displayed. The span number is set electronically by adjusting the span switches on the D/A board to 308 when setting up the instrument. This corresponds to the absorption coefficient of ozone, 308.3 cm^{-1} atm^{-1} at 253.7 nm wavelength.

Sample Frequency	An electronic circuit called the sample electrometer converts the low level electrical current from the photo detector to a signal whose frequency is proportional to the current in the photo defector. Sample frequency is the frequency of this signal when reference gas is present in the absorption cell. Sample frequency is initially set to 450 - 480 KHz. The display shows 1/10 of the sample frequency in KHz, e.g. 480 KHz = 48.000 displayed.
Control Frequency	A control frequency signal is generated by a fixed frequency oscillator to provide timing signals to the analyzer to switch from reference to sample gas streams. The control frequency is 500 KHz (50.000 displayed).
DAS	Data Acquisition System consisting of Campbell 21X datalogger, modem and on site computer.

1.8 Related Procedures

- DRI SOP 03, Operation and Maintenance of the Dasibi 1003 PC Ozone Calibrator
- DRI SOP 07, Operation and Maintenance of the Campbell 21X Datalogger
- DRI SOP 20, Meteorological and Continuous Gaseous Data Processing and Validation

2.0 APPARATUS, INSTRUMENTATION, REAGENTS, AND FORMS

2.1 Apparatus and Instrumentation

2.1.1 Description

The Dasibi 1008 AH ozone analyzer is a self-contained unit about 57 cm deep by 44 cm wide by 13 cm high, weighing 13 kg. Controls for normal operation procedures are mounted on the front panel along with a digital display. Connections for power, sample line and datalogger are on the back panel (Figures 2-1 and 2-2).

The analyzer is designed to operate continuously, providing "real time" ozone concentration measurements which are updated every 10 seconds. The analyzer compares light absorption of ambient air to the reference gas every measurement cycle so that problems of zero and span drift are minimized.

Ambient air is supplied through a glass sampling manifold though which air is pulled at a rate sufficient to eliminate ozone degradation due to contact with manifold surfaces. The analyzer is connected to an ozone calibrator which supplies daily zero and span checks under datalogger control.

Other apparatus needed for calibration and maintenance:

- Dasibi Model 1003 PC Ozone Analyzer/Calibrator transfer standard. This can be either the site calibrator or a transfer standard brought to the site.

- DRI Audit/Calibration software and portable computer.

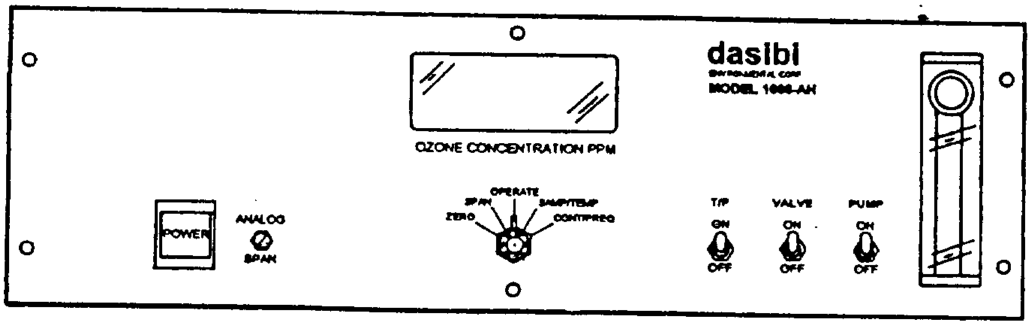

Figure 2-1. Dasibi 1008 AH front panel.

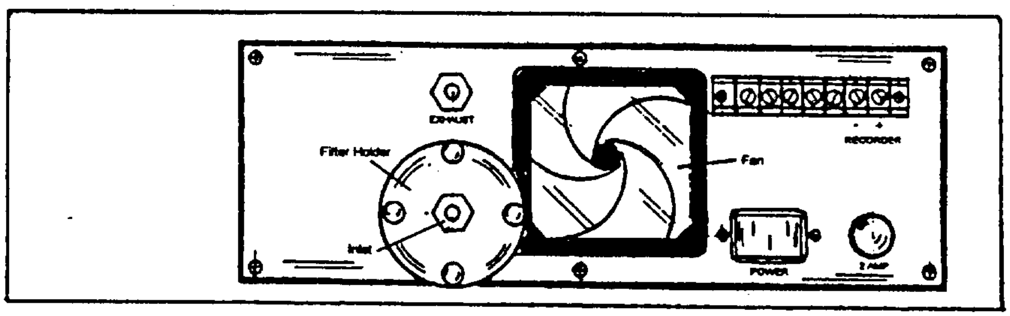

Figure 2-2. Dasibi 1008 AH back panel.

- One-quarter inch Teflon tubing for airflow connections.
- Large KimWipes for cleaning sampling manifold.
- Zero air scrubber consisting of activated charcoal, Purafil and desiccant canisters.
- 0 - 0.5 CFH flowmeter.
- Digital voltmeter (DVM).
- Frequency counter (optional).

Sampling manifold parts and their part numbers, from Ace Glass, Vineland, NJ, 609-692-3333 are listed below.

- Sampling cane 7493-12
- Sampling Tee 7495B-27
- Sampling bottle 7501-11
- Roof attachment 7508-06
- Blower mount 7509-09
- Blower motor 7511-10
- Air sampling manifold 7488E-34
- Bushing, 3 ea. 7506-31
- Coupling, 3 ea. 5841-50

2.1.2 Characterization

The Dasibi 1008 AH analyzer is designated a Federal equivalent (EPA, 1988) method instrument when operated under the following conditions:

Range: 0 - 0.5 ppm or 0 - 1.0 ppm
Line Voltage: 105 - 125 VAC
Temperature Range: 20 - 30 °C

The instrument does not have a range switch but meets the EPA designated range requirements for 0 to 0.5 or 0 to 1.0 ppm.

See Table 1-3 in the operating manual (Dasibi, 1990) for performance specifications.

2.1.3 Maintenance

Cautions

- Light from this analyzer's ultraviolet lamp can cause burns to the cornea. Use protective glasses to view the lamp or look at it only for a few seconds at distances of two or more feet.
- This analyzer contains a 200 volt DC power supply and a 1400 volt AC supply. In addition, the lamp start up voltages exceed 1000 volts. When working on this analyzer use normal high voltage precautions.
- Clean the optical tubes carefully to guard against damaging their Kynar linings.

Routine maintenance procedures are performed to assure validity and accuracy of measurements and to reduce instrument down time. The following procedures are performed at the specified frequency. Refer to section 4.4 in this procedure and section 6 in the operation manual (Dasibi, 1990) for detailed instructions for each task.

	TASK	FREQUENCY
1.	Replace air inlet filter	Monthly or sooner if particulate is visible and/or flow rate decreases
2.	Clean optics	As needed
3.	Clean sampling manifold	Quarterly
4.	Replace solenoid valve	As needed
5.	Replace UV lamp	As needed
6.	Replace Selective Ozone Scrubber	Annually

If the 1008 AH will be inoperable for an extended period of time (more than 1 day), it should be replaced with the 1003 PC calibrator. Operation and installation of the 1003 PC is similar to that of the 1008 AH. Substituting the 1003 PC for the 1008 AH is intended to reduce data loss due to instrument malfunction.

2.1.4 Spare Parts and Expendable Supplies

A complete spare parts list is given in section 7.4 of the operating manual (Dasibi, 1990). Commonly used parts and supplies and their stock numbers are listed below.

- UV Lamp — A-0204-S
- O-rings — A-0205, A-0207, A-0212
- Ozone scrubber — Z-0284-S
- Particulate filters — A-0000 or equivalent (Millipore Mitex 5.0 μm Teflon filter)

- Sample pump A-0218H-S
- Solenoid valve A-0203-S

2.2 Reagents

No chemical reagents are employed in this procedure

2.3 Forms

Results of performance checks and maintenance procedures performed are recorded on a Maintenance and Performance Check Sheet (Figure 2-3). Calibration data are recorded in computer files using a portable computer and DRI calibration software (DRI, 1991).

3.0 CALIBRATION STANDARDS

A Dasibi 1003 PC Ozone Analyzer located at the ambient monitoring site is used for daily span and zero checks, and may also serve as a calibration transfer standard. A Dasibi 1003 PC Ozone Analyzer (or equivalent) is transported to the site for semi-annual calibrations. Typically the accuracy of the transfer standards is ± 1%.

4.0 PROCEDURES

4.1 Flow Diagram

Figure 4-1 shows a flow diagram of routine operating procedures.

4.2 Startup

- Install the glass sampling manifold so that the inlet is about 1 meter above the roof line of the shelter and is clear of any obstructions. Support the manifold and blower securely and in a location to minimize chance of breakage. It should also be positioned to minimize the length of Teflon tubing needed to attach to the ozone analyzer.
- If the ozone analyzer is new or has been shipped, remove the top and check for loose printed circuit boards.
- Connect Teflon filter holder with Millipore Mitex 5.0 μm Teflon filter to inlet at rear of instrument with 1/4 inch Teflon tubing. Connect holder to normally open (manifold) side of manifold/calibration solenoid with 1/4 inch Teflon tube. Connect the sampling manifold to solenoid inlet using 1/4 inch Teflon tubing. Make the Teflon tube lengths as short as is practical. Remove cap from the exhaust port.
- Clean the optics as outlined in section 4.4.4.

Dasibi 1008 AH Ozone Analyzer Maintenance and Performance Check Sheet

Project ______________________ Month/Year ____________

Site ______________________ Site Operator ____________

Analyzer Serial No. ______________

				Front Panel					DAS		
Date	Initial or Final	Sample Flow (lpm)	Leak Check (lpm)	Ambient (ppm)	Zero	Span	Cont. Freq	Samp. Freq	Ambient (ppb)	Zero	Span
	Initial										
	Final										
	Initial										
	Final										
	Initial										
	Final										
	Initial										
	Final										
	Initial										
	Final										
	Initial										
	Final										

Date	Comments or Maintenance Performed

Last Calibration: Date __________
Conc = ____ x True + _____

Precision:
P_{400} _____% (ave relative diff at 400 ppb)
P_{100} _____% (ave relative diff at 100 ppb)
P_0 _____ppb (ave absolute diff at 0 ppb)

Date scrubber changed ___________

Reviewed by ____________________ Date ________

Figure 2-3. Maintenance and performance check sheet.

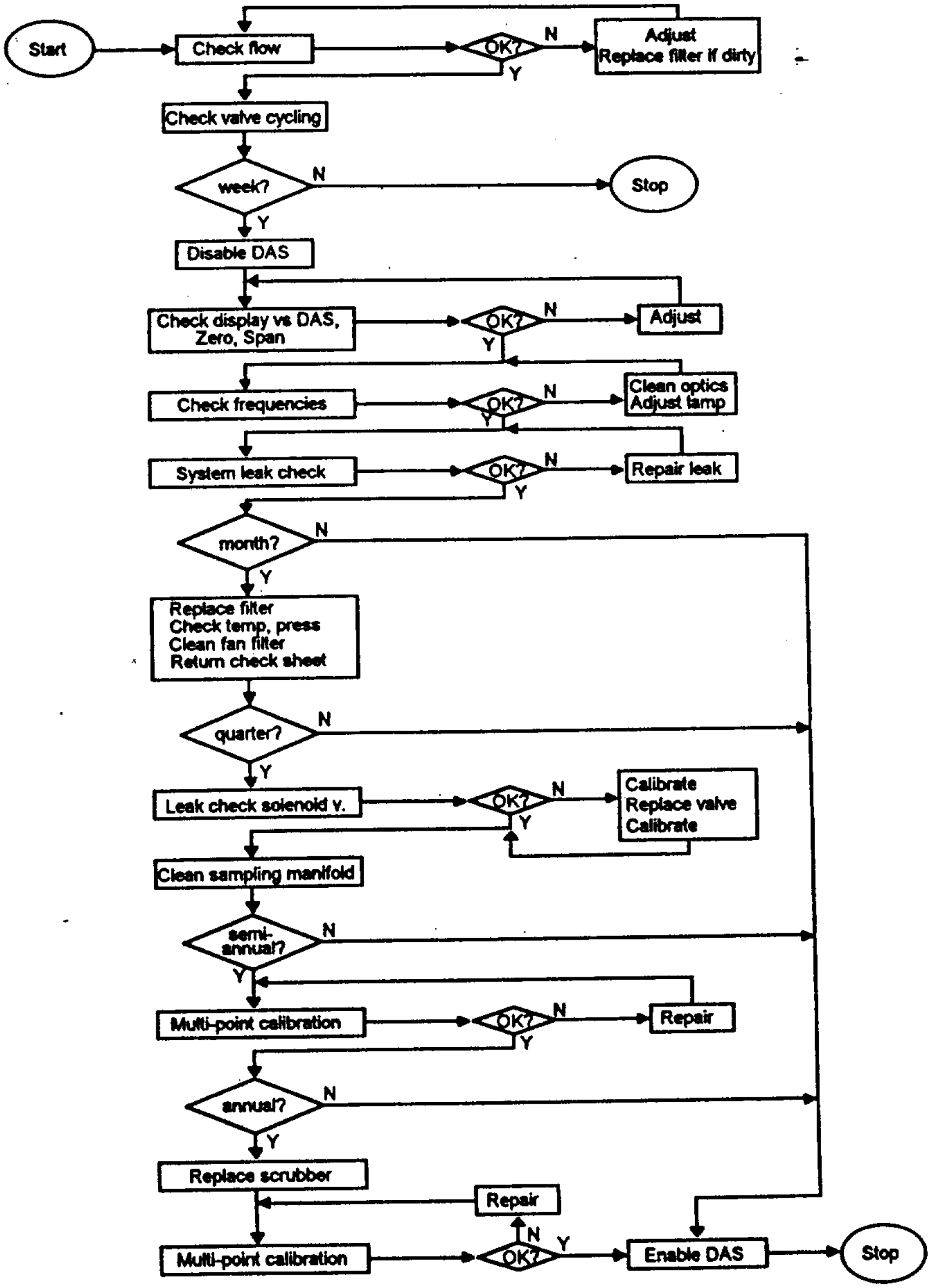

Figure 4-1. Dasibi 1008 AH operating procedure flow diagram.

- Connect recorder output to Campbell 21X datalogger. Refer to the datalogger SOP for details.

- Turn on analyzer power and set the mode switch to OPERATE, T/P switch ON, VALVE switch ON, PUMP switch ON and sample flow to 2.0 lpm. The numeric display and power button should be lighted when power is applied.

- Allow at least a 30-minute warm-up period.

- Set the mode switch to SPAN. The first three numbers that appear in the display should be 30.8 (the last two digits are determined by zero offset, below). This number indicates a span of 308 (first three digits × 10). If the span is not 308, remove the analyzer top cover and adjust the SPAN selector switches on the D/A board inside the analyzer to 308.

- The last two digits displayed indicate the zero offset. Zero offset is adjustable from 0 to 9 ppb or from 0 to 90 ppb in steps of 10 ppb, depending on the analyzer. The zero offset feature is designed to allow recording values near zero (such as zero air checks) where slight drift may result in negative numbers that cause problems with strip chart or some data recording systems. No zero offset is normally required, as the DAS correctly handles negative numbers. Small negative instrument offsets may be compensated for by adjusting the zero offset to a non-zero value. Set zero offset by turning the mode switch to OPERATE and the PUMP switch OFF. Set the ZERO switch on the D/A board to the value that gives the lowest positive displayed value (average 10 readings). Return the mode switch to SPAN. The last two digits displayed indicate the zero offset.

- Set the DIGIT SELECTOR switch on the D/A board to 1. This selects the last 3 digits of the display for the recorder output.

- Follow steps in section 4.4.1 and 4.4.2 to adjust the Analog Zero and Span. This ensures that the DAS and analyzer display indicate the same ozone concentrations.

- Set the mode switch to SAMP/TEMP and the T/P switch OFF. Depending on the condition of the lamp and cleanliness of the absorption chamber, a number between 45.000 and 48.000 will appear, indicating a sample electrometer frequency of 450 to 480 KHz. See section 4.4.5 if sample frequency is not in this range.

- Set the mode switch to CONT/PRESS and T/P switch OFF. The display should read 50.000, indicating a control electrometer frequency of 500 KHz.

- Set mode switch to ZERO. Display should be 0.000.

- Perform a multipoint calibration according to Section 5.1.4 using 1003 PC.

4.3 Routine Operation

4.3.1 General Information

Perform the following maintenance and instrument performance checks routinely according to the noted frequency.

For all checks that affect analyzer output (all except those in section 4.3.2), prevent the DAS from recording ozone values before performing checks. Start the TERM program on the site computer (see Operation and Maintenance of the Campbell 21X Datalogger SOP) and disable recording of ozone values by pressing function key F2. The "Flag 2" indicator will be highlighted and the ozone sample counter will stop incrementing. The computer display in this configuration will also display ozone values as measured by the DAS, which is required for some of these procedures.

After completing performance checks, return analyzer to normal operation by setting mode switch to OPERATE, T/P switch ON, VALVE switch ON and PUMP switch ON. Return DAS to recording ozone values by pressing function key F2. The "Flag 2" indicator highlighting will disappear and the ozone sample counter will begin incrementing.

4.3.2 Every Site Visit

- Check that front panel flowmeter indicates a standard flow of 2 to 3 SLPM and has not changed from last check. Adjust flow if necessary. NOTE: Ambient ozone data is subject to invalidation if flow drops below 2.0 SLPM.

- Verify that the solenoid valve is cycling and that display is updating. The switching of the solenoid valve should be audible, should occur about every 20 seconds, and should have about the same time from one audible click to the next. The sample update light on the left-hand-side of the display should flash every 10 seconds.

4.3.3 Weekly

Record results of the following checks on lines marked as "initial" on the Maintenance and Performance Check Sheet (Figure 2-3). If an adjustment is made, record the "final" value also. For current ozone concentration, span and zero checks, record both the analyzer display reading and the DAS ozone value. Perform checks in the order listed here, not the order of the columns on the check sheet. Record any maintenance operations in the comments section.

- Current ozone concentration - Display and DAS values should be within ± 3 ppb. Correct if necessary when doing zero and span checks.

- Sample Flow - Check that front panel flowmeter indicates a flow of 2 to 3 SLPM and has not changed from last check. If flow has decreased, the in-line filter may have become dirty. Examine the filter and replace according to steps in section 4.4.3 if particles are visible. Adjust flow to 2.0 if necessary.

- Zero Check - Turn the mode switch to ZERO. The display should read 00.000. The DAS should read 0 ± 3. If it does not, adjust the recorder zero offset control (section 4.4.1).

- Span Check - Turn the mode switch to SPAN. The display should read 30.8xx (the last two digits are determined by the zero offset). The DAS should have a reading of within ± 3 of the last three digits × 1000. If it does not, adjust analog span (section 4.4.2).

- Control Frequency - Set the mode switch to CONT/PRESS and T/P switch OFF. The control frequency is determined by the fixed frequency oscillator, which is 500 KHz (50.000 displayed). Contact the field supervisor if control frequency is incorrect.

- Sample Frequency - Set the mode switch to SAMP/TEMP, T/P switch OFF, and VALVE switch OFF. The sample frequency of a properly adjusted analyzer with a clean optical bench and new lamp should be between 450 and 480 KHz (45.000 and 48.000 displayed). If the sample frequency drops below 300 KHz, refer to procedures for cleaning and adjusting optics, given in sections 4.4.4 and 4.4.5.

- System Leak - Set the PUMP switch ON and VALVE switch ON. Remove the sample line from the filter holder on the back of the analyzer. Plug filter holder inlet port with your finger. Flow should drop from 2.0 to 0.0. Record ending flow reading. If flow does not drop to zero, locate and repair leak.

4.3.4 Monthly

Record results of the following checks in the comments section of the Maintenance and Performance Check Sheet (Figure 2-3).

- Temperature - Set the mode switch to SAMP/TEMP and the T/P switch ON. Actual temperature reading will depend on shelter and ambient air temperatures. If it appears that temperature reading is in error, contact field supervisor.

- Pressure - Set the mode switch to CONT/PRESS and the T/P switch ON. Displayed reading is pressure in atmospheres. Compare with on site barometer if available.

Some instruments are equipped with a cooling fan on the back panel. If so equipped, check that the filter pad is clean. If necessary, pry off the cover and rinse the filter pad in water to clean. Allow to dry before replacing.

Replace particulate filter by following steps in section 4.4.3.

File a copy of the Maintenance and Performance Check Sheet (Figure 2-3) at the site and return the original to the field supervisor.

4.3.5 Quarterly

Leak check the solenoid valve using the procedure below.

- Turn off analyzer power and disconnect power cord.

- Disconnect Teflon filter holder from analyzer inlet and cap off sample inlet to analyzer.

- Remove analyzer cover and ozone scrubber.

- Connect outlet of a flowmeter (0 to 0.5 SCFH or equivalent), to the normally open (NO) zero air port of the solenoid valve. Reconnect power cord and turn on power. Set the mode switch to OPERATE, T/P switch ON, and VALVE switch ON and PUMP switch ON. The flowmeter should indicate zero air flow during last half of the analysis cycle, otherwise the solenoid valve is leaking.

- Turn off analyzer power and disconnect power cord. Connect the outlet of the flowmeter to the normally closed (NC) port of the solenoid valve at open leg of inlet Tee. Reconnect power cord and turn on power. The flowmeter should indicate zero air flow during the first half of the analysis cycle, otherwise the solenoid valve is leaking.

- Turn off analyzer power and disconnect power cord. Disconnect flowmeter from NC port of solenoid. Reinstall ozone scrubber and leak check system (section 4.3.3).

NOTE: If the low flow rate flowmeter indicated above is not available, you may use the flow meter on the front panel and alternately plug the NC and NO ports of the solenoid valve with your finger. The flow should drop to zero during the corresponding part of the analysis cycle. However, the range of the front panel flowmeter is so high that it may not detect small leaks.

If the solenoid valve leaks, perform a multipoint "as is" calibration (section 5.1), replace the solenoid valve, and then perform a "final" multipoint calibration. Record date and results of solenoid leak test on Maintenance and Performance Check Sheet.

Examine the sampling manifold for particulate deposits. If significant amounts of particulate have accumulated, clean the manifold using the procedure in section 4.4.7.

4.3.6 Semi-Annual

Perform a multipoint calibration with an external calibration standard as in section 5.1 once every six months of operation, upon relocation, and after major repairs. One month prior to the recalibration due date, contact the field supervisor to arrange for a multipoint calibration.

4.3.7 Annual

Replace the ozone scrubber as outlined in section 4.4.6.

4.4 Maintenance and Alignment Procedures

Prevent the DAS from recording ozone values before beginning any of the procedures in this section. Start the TERM program on the site computer (see Operation and Maintenance of the Campbell 21X Datalogger SOP). Press function key F2. The "Flag 2" indicator will be highlighted and the ozone sample counter will stop incrementing.

The computer display in this configuration will also display ozone values as measured by the DAS, which is required for some of these procedures.

The following adjustments are for an analyzer operating on a full scale range of 1.0 ppm and an analog output full scale response of 1.0 volt.

After completing maintenance and alignment procedures, return the analyzer to normal operation. Set mode switch to OPERATE, T/P switch ON, VALVE switch ON, PUMP switch ON and sample flow to 2.0 lpm. Return DAS to recording ozone values by pressing function key F2. The "Flag 2" indicator highlighting will disappear and the ozone sample counter will begin incrementing

4.4.1 Analog Zero

- Connect a digital voltmeter (DVM) to the Dasibi analog output in parallel with the DAS.
- Set function switch to ZERO. Display should read 00.000.
- Remove the top cover and adjust the RECORDER ZERO OFFSET pot until the DVM reads 0.000 ± 0.003 volts and the DAS reads 0 ± 3 ppb. The pot is located on the D/A board between the DIGIT SELECTOR and SPAN switches. The D/A board is one of several that plug in vertically to edge connectors on the motherboard. Consult the board assembly diagram (Figure 3-12) in the operating manual (Dasibi, 1990) to identify the D/A board. If the readings from the DVM and DAS do not agree, one or both are in error and must be repaired.

4.4.2 Analog Span

- Connect a digital voltmeter (DVM) to the Dasibi analog output in parallel with the DAS.
- Set function switch to SPAN. Display should read 30.8xx with the last two digits determined by the zero offset.
- Adjust the ANALOG SPAN pot on the front panel so that the DVM reading is within ± 0.003 volts of the last three digits of the display, and the DAS reads within ± 3 ppb. If the readings from the DVM and DAS do not agree, one or both are in error and must be repaired.

4.4.3 Replace Particulate Filter

Remove the four thumbscrews from the filter holder connected to the inlet on the back panel of the analyzer. Discard the old filter and replace with a Millipore Mitex 5.0 μm Teflon filter or equivalent. Reassemble the filter holder and perform system leak check (section 4.3.3).

4.4.4 Clean Optics

Even though the inlet air is filtered, the optics of the analyzer can become dirty over time. Dirty optics, as well as decreased lamp output and decreasing detector efficiency result in decreasing sample frequencies. Correct by periodically cleaning the optical bench, including absorption tubes, mirrors and detector windows.

A properly cleaned and aligned analyzer, will have a sample frequency of 450 to 480 KHz. This frequency is not critical; an instrument with a sample frequency as low as 150 KHz, will still operate correctly. However, a significant drop in sample frequency from an initial value of 450 - 480 KHz to 300 - 330 KHz (a drop of 150 KHz) may indicate the accumulation of enough particulate matter in the optics system to cause ozone degradation as sample air passes through the system.

Follow the procedures in section 6.7 of the operating manual (Dasibi, 1990) to clean the optics. Perform a system leak check after the optics are reassembled.

If sample frequency is still lower than 450 KHz after cleaning the optics, adjust sample frequency as indicated in the next section.

4.4.5 Adjust Sample Frequency

Sample frequency decreases as dirt particles collect throughout the optical path, as the UV lamp output decays, or as the efficiency of the detector diminishes. Sample frequency should be between 450 and 480 KHz (45.000 and 48.000 displayed). If the optics are clean and analyzer doesn't meet these specifications, make the following adjustments.

NOTE: Take care not to short the detector terminals on the 15 volt power supply.

- If analyzer has been off, allow at least thirty (30) minutes for warm-up before checking the frequency.
- Set function selector switch to SAMP/TEMP, T/P switch OFF and VALVE switch OFF.
- Connect a frequency counter to sample frequency and ground pins on the logic board. If a frequency counter is not available use analyzer's digital display.
- Loosen ultraviolet (UV) lamp lock screw and reposition lamp until frequency is within specifications. Slide UV lamp into its socket to increase the frequency and slide it out to decrease the frequency. Rotate the UV lamp to effect additional change. Carefully tighten UV lamp lock screw when adjustments are complete.
- Make further adjustments if necessary by repositioning sample detector. To accomplish this, loosen set screw holding detector using a 1/16th inch Allen wrench and slide detector in to increase and out to decrease frequency. Tighten set screw securely after adjustment is complete.

When cleaning and adjusting procedures fail to restore the frequency to adequate levels, replace the UV lamp and/or electrometer board and detector as necessary.

4.4.6 Ozone Scrubber Replacement

Replace the ozone scrubber only after performing an "As Is" calibration. After replacing an ozone scrubber, leak check the system and perform a final multipoint calibration.

For analyzers operating continuously for a full year, replace the ozone scrubber during the pre-ozone season calibration.

4.4.7 Clean Glass Sampling Manifold

Particulates that collect on the interior surfaces of the glass sampling manifold over time must be removed by periodically cleaning the manifold to prevent degradation of ozone.

- Disconnect Teflon sampling lines to prevent accumulation of dislodged particles.
- Remove blower and disassemble all parts of the sampling manifold carefully to avoid breakage.
- Clean interior surfaces by pushing water dampened KimWipe towels through, then dry.
- Reassemble manifold and connect Teflon sampling lines.

4.5 Shut Down

Perform a final multipoint calibration before shutting down operation of the 1008 AH.

4.6 Check Lists

Maintenance and Performance Check Sheet, Figure 2-3.

5.0 QUANTIFICATION

5.1 Calibration

5.1.1 A Dasibi Model 1003 PC Ozone Analyzer/Calibrator (transfer standard), standardized against a primary standard laboratory ultraviolet photometer is used in calibrations. The response of the analyzer being calibrated is compared to the response of the transfer standard. Calibration results are recorded and calculations performed by the DRI Audit/Calibration software running on a portable computer. Refer to the Audit/Calibration software manual (DRI, 1991) for instructions.

5.1.2 "As Is" Calibration - Perform an "As Is" calibration following the steps in section 5.1.4 prior to making any instrument repairs or adjustments other than routine checks or adjustments. If the results of the "As Is" calibration are not within ± 10% of the transfer standard, take corrective action and perform a "Final" calibration.

5.1.3 "Final" Calibration - Perform a "Final" calibration following the steps in section 5.1.4 after replacing the scrubber or solenoid valve or performing other non-routine adjustments or maintenance.

5.1.4 Calibration procedure.

- Prevent the DAS from recording ozone values. Start the TERM program on the site computer (see Operation and Maintenance of the Campbell 21X Datalogger SOP). Press function key F2. The "Flag 2" indicator will be highlighted and the ozone sample counter will stop incrementing.

- Connect the zero air scrubber to the zero air inlet of the transfer standard analyzer, and the ozone outputs to the transfer standard and site analyzer inputs using Teflon tubing as shown in Figure 5-1. The airflow in the zero air scrubber should flow first through the desiccant, then Purafil, then charcoal. Use a flush Tee on the ozone connection to the site analyzer, and use a Teflon particulate filter on the site analyzer inlet. Remove caps from unused ozone outlet ports on the transfer standard and from the exhaust ports on both instruments.

- Set the mode switch on the 1008 AH to OPERATE, the T/P switch ON, the VALVE switch ON and the PUMP switch ON. Set controls on the transfer standard to normal operating positions with ozone generator OFF, ozone pump ON, and no zero offset. Set ozone flow to maximum and sample air flow rate to 2 lpm.

- Sample zero air while allowing both the transfer standard and the 1008 AH to warm-up for at least one hour. The covers of both instruments should be on during the calibration, as the calibration is dependent upon the internal temperature of the analyzer. The control frequency reading should be stable, showing no upward or downward trend when the analyzer has reached operating temperature.

- Start the ozone audit program and record the network information and the analyzer identification and settings for both the site instrument (1008 AH) and audit instrument.

- While the analyzer and transfer standard are sampling zero air, record the nominal ozone concentration (0), and 10 consecutive digital display values from both analyzers. If the transfer standard is not a 1008 PC, record analyzer internal temperature with the supplied digital thermometer and pressure also. Record the DAS ozone value for one of the 10 readings.

- Switch on ozone generator and pump. Set ozone flow to maximum. Set the lamp intensity control of the transfer standard to produce an ozone concentration of approximately 400 ppb ozone as read by the transfer standard.

- Allow instruments to stabilize. Record ten consecutive digital display values for each analyzer along with the nominal ozone concentration. If the transfer standard is not a 1008 PC, record analyzer internal temperature with the supplied digital thermometer and pressure also. Record DAS ozone value for one of the 10 readings.

- Repeat previous step for nominal ozone concentrations of 300, 200, 100 and 50 ppb.

- Switch off the ozone generator and pump and repeat the measurement of zero air as before.

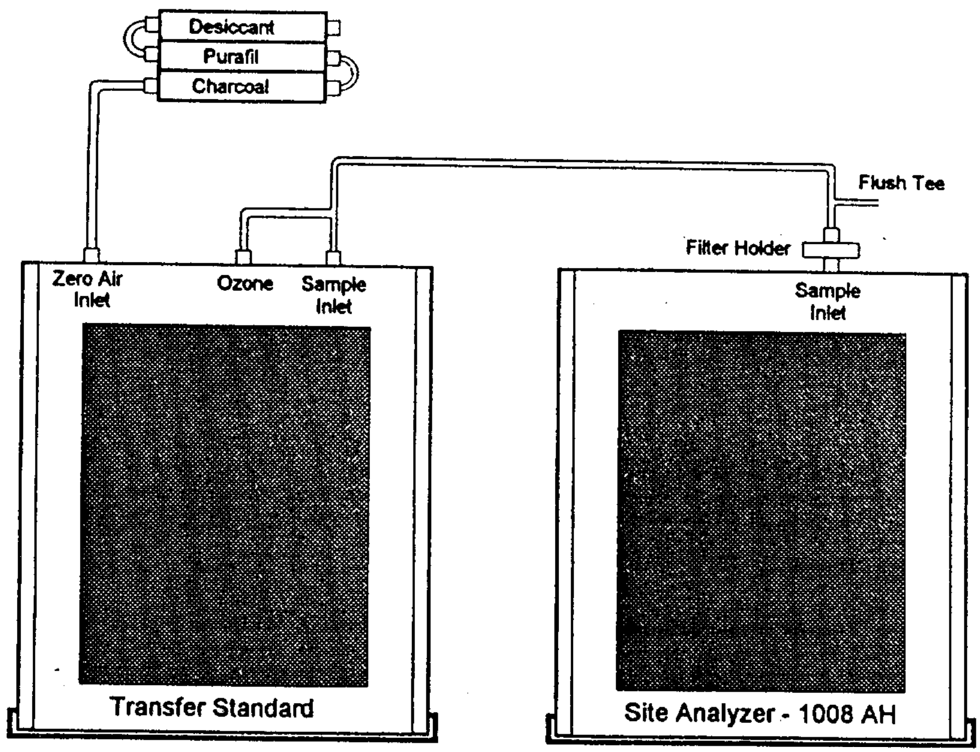

Figure 5-1. Connections for calibration of Dasibi 1008 AH.

- Use the appropriate menu options and data entry screens in the audit program to perform the calculations listed in this paragraph. Calculate average concentrations measured at each ozone level. The 1008 AH site analyzer and 1008 PC transfer standards do not require temperature and pressure corrections. The 1003 PC transfer standard requires temperature and pressure corrections. Enter the average of the initial and final zero air readings where the program requests the zero correction. This is done separately for the transfer standard and the site analyzer. Calculate deviation of the site analyzer from the transfer standard. Calculate slope and intercept of the calibration data. Exclude the zero points from the regression line.

- Compare results of the calibration audit to the criteria in the following table. If any of the three parameters is in the "suspect" category, flag all ozone data collected since the last audit as suspect. If this is a "final" calibration and any of the parameters is in the "suspect" or "recalibrate" categories, return the analyzer to the laboratory for repair/calibration. If this is a "final" calibration and any of the parameters is in the "warning" category, repair or recalibration may be warranted; consult the field supervisor.

Parameter	OK	Warning	Recalibrate	Suspect
Average % difference	± 0 - 5	± 5 - 10	± 10 - 15	> 15
Slope	0.95 - 1.05	0.90 - 0.95 or 1.05 - 1.10	0.85 - 0.90 or 1.10 - 1.15	< 0.85 or > 1.15
Intercept as % of full scale	< 1	1 - 2	2 - 3	> 3

5.2 Calculations

5.2.1 Calibration calculations

Mean and standard deviation for all readings flagged as valid are calculated separately for each calibration concentration level for both transfer standard and site analyzer.

Mean concentrations for transfer standard are corrected for temperature and pressure (if T/P correction option was chosen during calibration), for zero correction, and for transfer standard slope and intercept values.

$$C_T = \left[(A_T - Z_T) \times \frac{760 \times (T+273)}{P \times 273}\right] \times M_T + B_T$$

where C_T = corrected transfer standard concentration, ppb
A_T = average uncorrected transfer standard concentration, ppb
Z_T = zero correction (average reading for zero air), ppb
P = atmospheric pressure, mb
T = analyzer temperature, Celsius

M_T = transfer standard calibration slope
B_T = transfer standard calibration intercept

Mean concentrations for the site 1008 AH analyzer are calculated as shown below.

$$C_S = A_S - Z_S$$

where C_S = corrected site analyzer concentration, ppb
A_S = average uncorrected site analyzer concentration, ppb
Z_S = site analyzer zero correction, ppb

Percent deviation D is calculated for each calibration concentration level by

$$D = \frac{(C_S - C_T)}{C_T} \times 100$$

and the average deviation is computed for all points included in the linear regression fit. A least squares linear regression is used to calculate the slope and intercept of the calibration data.

$$C = m \times T + b$$

where C = site analyzer concentration, ppb
m = calibration line slope
T = transfer standard concentration, ppb
b = calibration line intercept, ppb

5.2.2 Routine Calculations

Ozone concentrations as measured by the 1008 AH and recorded by the DAS are direct reading and are corrected for temperature and pressure changes. No corrections should be necessary.

Use daily zero, span (nominal 400 ppb), and precision (nominal 100 ppb) checks from the site 1003 PC analyzer to assess precision of the measurements. Precision of the span and precision check values is expressed as average relative percent difference between true (as measured by 1003 PC) and ambient (as measured by 1008 AH) concentration measurements. Precision of the zero check is expressed as average absolute difference between true and ambient ozone measurements. Discard the sign when computing differences. Calculate precision monthly as shown below and record results on the Maintenance and Performance Check Sheet.

$$P_{400} = 100 \times \frac{\sum \left(\frac{|A_{400} - T_{400}|}{T_{400}} \right)}{n}$$

where P_{400} = relative precision at nominal 400 ppb concentration level, %

A_{400} = daily average of last five 1-minute 1008 AH readings during nominal 400 ppb ozone span check
T_{400} = daily average of last five 1-minute 1003 PC readings during nominal 400 ppb ozone span check
n = number of daily span check measurements during month

$$P_{100} = 100 \times \frac{\sum \left(\frac{|A_{100} - T_{100}|}{T_{100}} \right)}{n}$$

where P_{100} = relative precision at nominal 100 ppb concentration level, %
A_{100} = daily average of last five 1-minute 1008 AH readings during nominal 100 ppb ozone precision check
T_{100} = daily average of last five 1-minute 1003 PC readings during nominal 100 ppb ozone precision check

$$P_0 = \frac{\sum |A_0 - T_0|}{n}$$

where P_0 = absolute precision at zero ozone concentration, ppb
A_0 = daily average of last five 1-minute 1008 AH readings during zero check
T_0 = daily average of last five 1-minute 1003 PC readings during zero check

6.0 QUALITY CONTROL

Quality control for this procedure is maintained by routine performance checks , scheduled preventative maintenance procedures, electronic zero and span checks, and daily zero and span checks against an on-site calibrator.

7.0 QUALITY ASSURANCE

Quality assurance is maintained by performing semi-annual calibration audits using a standard independent of the site operation.

8.0 REFERENCES

Dasibi (1990). "Model 1008 U.V. Photometric Ozone Analyzer (For Models AH, PC, RS and HC) Operating and Maintenance Manual." Dasibi Environmental Corporation, 1990.

DRI (1991). "DRI Software Manual for: Audit Software & Calibration Software." Desert Research Institute, 1991.

U.S. Environmental Protection Agency (1988). "National Primary and Secondary Ambient Air Quality Standards. Appendix D - Measurement Principle and Calibration Procedure for the Measurement of Ozone in the Atmosphere." 40 CFR Chap. 1, Part 50

1.0 GENERAL DISCUSSION

1.1 Purpose of Procedure

This document provides operation and maintenance procedures for the Dasibi Model 1003 PC analyzer and should be used in conjunction with the 1003 PC operating manual (Dasibi, 1990). Portions of this SOP were taken from Revision 4, Volume II, Appendix A of the CARB Air Monitoring QA Plan.

1.2 Measurement Principle

The 1003 PC is configured as an ozone calibrator, containing an ozone generator and an ultra-violet (UV) photometer. Ozone concentrations from 40 to 1000 ppb at 5 lpm are produced by adjusting the intensity of the ozone generating lamp.

The 1003 PC measures ozone by ultraviolet (UV) absorption spectrophotometry. Ozone absorbs UV light at a wavelength of 253.7 nm; the amount of UV light absorption in the optics bench is related to ozone concentration by Beer's law. The low pressure mercury vapor lamp produces 92 percent of its output at the 253.7 nm emission line. The cesium telluride vacuum photo detector has a broad passband centered near that line so that 99.5 % of the total system response is from the 253.7 nm line.

Generated ozone is routed to one of two paths via a solenoid activated valve. The first path leads directly into the optics bench; the second path first passes through an ozone scrubber and then into the optics bench. The ozone scrubber contains MnO_2 coated copper screens which catalyze the reaction of ozone to diatomic oxygen but leave other components unchanged. The solenoid switches the valve at regular intervals so that the photo detector alternately measures the amount of light absorbed by the ozone-laden air (sample gas) and the amount absorbed by ozone-free air (reference gas).

Ozone concentration is calculated electronically by comparing UV absorption of sample and reference gas streams and displayed in a digital readout on the front panel and sent to a data acquisition system by an analog output. Figure 1-1 provides a block diagram of the optical, pneumatic and electronic components of the photometer.

1.3 Measurement Interferences and Their Minimization

Ozone will react with most surfaces other than glass or Teflon. Use of materials other than glass or Teflon in the inlet or sample lines, or deposits of air particulates on inlet surfaces will reduce ozone concentration before the sample enters the analyzer. The sample inlet lines have no internally exposed surfaces other than Teflon. Sample lines are kept short and sufficient sample flow rate is maintained to prevent degradation of ozone.

A Teflon filter is placed in line with the inlet to prevent particulate deposition in sample lines and the optical cell in the analyzer. The filter is replaced periodically.

1.4 Ranges and Typical Values

The instrument range is 0.0 to 1.0 ppm. The Federal ambient air quality standard is 120 ppb. Ozone concentrations during calibration range from 0 to 400 ppb.

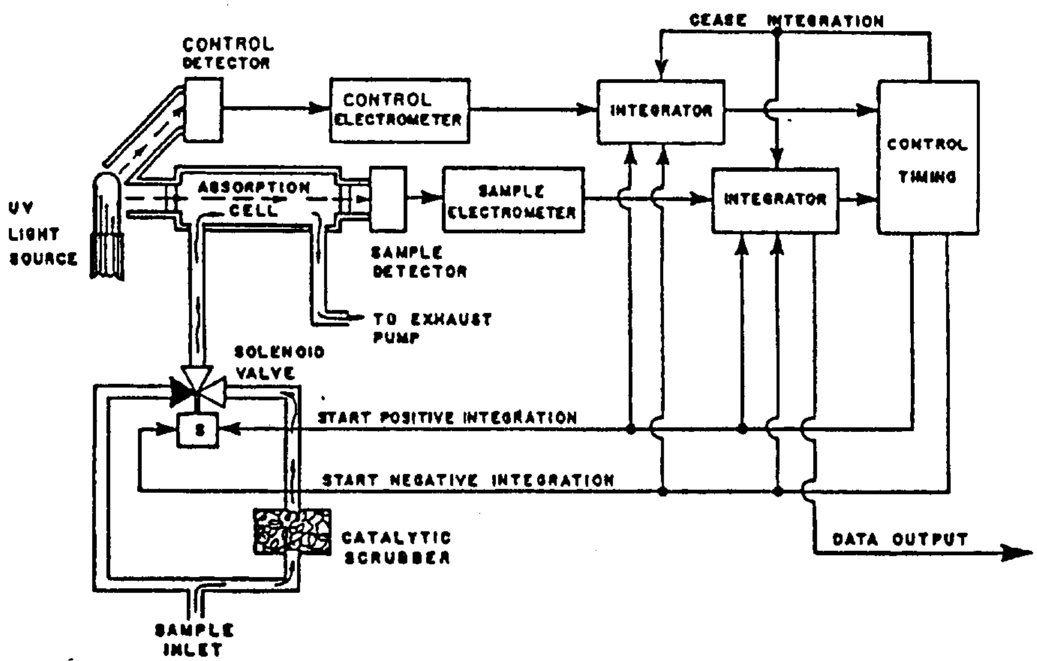

Figure 1-1. Block diagram of Dasibi 1003 PC optic, pneumatic and electronic components.

1.5 Typical Lower Quantifiable Limits, Precision, and Accuracy

Generally the lower quantifiable limit, precision and accuracy are 1 ppb, ± 3% and ± 1% respectively.

1.6 Personnel Responsibilities

The site operator is responsible for routine instrument checks and maintenance. If the 1008 AH is down for more than one day, the site operator will reconfigure the 1003 PC analyzer from its use as the site calibrator to operate as the ambient monitor.

The field supervisor is responsible for training the site operator, overseeing weekly operations, semi-annual performance audits, coordinating non-routine maintenance and repair operations and data collection and validation.

1.7 Definitions

Optics bench — Also called absorption cell. Consists of Pyrex tubes or Kynar lined aluminum tubes optically coupled by quartz mirrors, a mercury vapor lamp at one end and a cesium telluride photodetector at the other end. The sample or reference gas is introduced at one end while the other end is connected to the sample pump. Quartz windows and gaskets provide gas-tight interface of the lamp, detector, mirror and tubes. The total path length is 71 cm.

Reference Gas — Air which enters the analyzer and is diverted by the solenoid valve through the ozone scrubber is called the reference gas. Its composition is the same as sample gas except that ozone is converted to diatomic oxygen. Light absorption in the sample gas is compared to that in the reference gas to determine ozone concentration.

Zero Air — Ambient air stripped of ozone, particulates and water vapor is called zero air. For calibration, zero and span checks, zero air is generated by drawing ambient air through canisters filled with desiccant, Purafil and charcoal.

Span Number — The span number controls the "sensitivity" of the analyzer, i.e. for a given ozone concentration, what reading is displayed. The span number is set electronically by adjusting the span switches on the front panel. The correct span number is 525 times an altitude correction factor (section 4.1).

Sample Frequency — An electronic circuit called the sample electrometer converts the low level electrical current from the photo detector to a signal whose frequency is proportional to the current in the photo detector. Sample frequency is the frequency of this signal when reference gas is present in the absorption cell. Sample frequency is initially set to 450 - 480 KHz. The display shows 1/10 of the sample frequency in KHz, e.g. 480 KHz = 48.000 displayed.

Control Frequency — An electrometer connected to a photo detector that monitors the lamp output directly generates a signal whose frequency is proportional to the current in the photo detector. Control frequency is the frequency of this signal, and is initially set to 230 - 280 KHz (23.000 - 28.000 displayed).

DAS — Data Acquisition System consisting of Campbell 21X datalogger, modem and on site computer.

1.8 Related Procedures

- DRI SOP 02, Operation and Maintenance of the Dasibi 1008 AH Ozone Analyzer
- DRI SOP 07, Operation and Maintenance of the Campbell 21X Datalogger
- DRI SOP 20, Meteorological and Continuous Gaseous Data Processing and Validation

2.0 APPARATUS, INSTRUMENTATION, REAGENTS, AND FORMS

2.1 Apparatus and Instrumentation

2.1.1 Description

The Dasibi 1003 PC ozone analyzer is a self-contained unit about 57 cm deep by 44 cm wide by 13 cm high, weighing 13 kg. Controls for normal operation procedures are mounted on the front panel along with a digital display, while connections for power, zero air, sample inlet, ozone output, exhaust and datalogger are on the back panel (Figures 2-1 and 2-2).

The 1003 PC is configured to provide daily zero and span checks for the site ambient ozone analyzer. Upon command from the datalogger, the ozone and sample pumps turn on and a solenoid controlled valve switches the inlet for the ambient analyzer from the ambient air sampling manifold to the ozone manifold on the 1003 PC. Both analyzers measure zero air produced by the 1003 PC for ten minutes. Then the ozone generator is switched on by the datalogger and ozone produced by the 1003 PC is measured for fifteen minutes, again by both analyzers.

Other apparatus needed for operation, calibration and maintenance:

- DRI ozone calibrator to datalogger interface.
- Solenoid controlled valve to switch between sampling manifold and calibrator.
- Dasibi 1003 PC or 1008 PC Ozone Analyzer/Calibrator transfer standard.

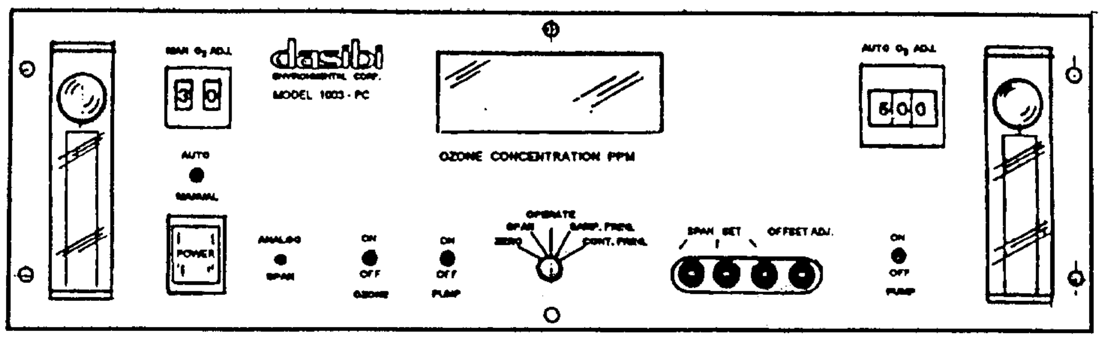

Figure 2-1. Dasibi 1003 PC front panel.

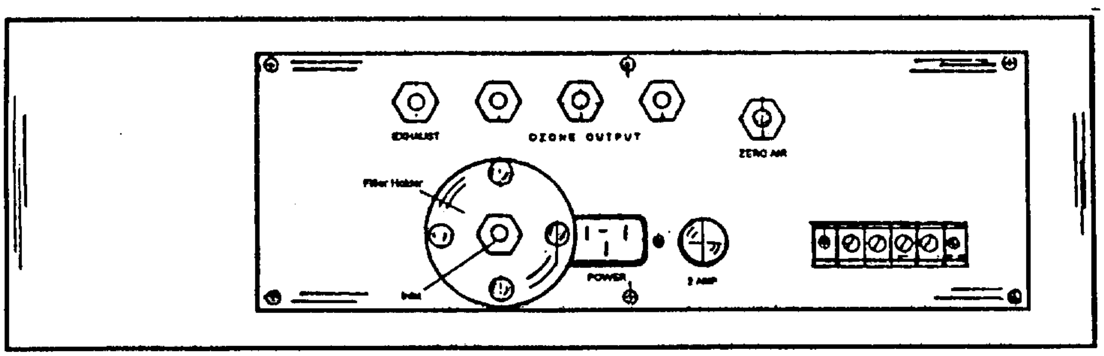

Figure 2-2. Dasibi 1003 PC back panel.

- DRI Audit/Calibration software and portable computer.
- One-quarter inch Teflon tubing for airflow connections.
- Zero air scrubber consisting of activated charcoal, Purafil and desiccant canisters.
- 0 - 0.5 CFH flowmeter.
- Digital voltmeter (DVM).
- Frequency counter (optional).

2.1.2 Characterization

The Dasibi 1003 PC analyzer is designated a Federal equivalent (EPA, 1988) method instrument when operated under the following conditions:

Range: 0 - 0.5 ppm or 0 - 1.0 ppm
Line Voltage: 105 - 125 VAC
Temperature Range: 20 - 30 °C

The instrument does not have a range switch but meets the EPA designated range requirements for 0 to 0.5 or 0 to 1.0 ppm.

See Tables 1-3 and 1-4 in the operating manual (Dasibi, 1990) for performance specifications.

2.1.3 Maintenance

Cautions

- Light from this analyzer's ultraviolet lamp can cause burns to the cornea. Use protective glasses to view the lamp or look at it only for a few seconds at distances of two or more feet.
- This analyzer contains a 200 volt DC power supply and a 1400 volt AC supply. In addition, the lamp start up voltages exceed 1000 volts. When working on this analyzer use normal high voltage precautions.
- Clean the optical tubes carefully to guard against damaging their Kynar linings.

Routine maintenance procedures are performed to assure validity and accuracy of measurements and to reduce instrument down time. The following procedures are performed at the specified frequency. Refer to section 4.4 in this procedure and section 6 in the operation manual (Dasibi, 1990) for detailed instructions for each task.

	TASK	FREQUENCY
1.	Replace air inlet filter	Monthly
2.	Clean optics	As needed
3.	Replace solenoid valve	As needed
4.	Replace UV lamp	As needed
5.	Replace Selective Ozone Scrubber	Annually

If the 1008 AH ambient analyzer will be inoperable for an extended period of time (more than 1 day), it should be replaced with the 1003 PC calibrator. Operation and installation of the 1003 PC is similar to that of the 1008 AH. Substituting the 1003 PC for the 1008 AH is intended to reduce data loss due to instrument malfunction.

2.1.4 Spare Parts and Expendable Supplies

A complete spare parts list is given in section 7.3 of the operating manual (Dasibi, 1990). Commonly used parts and supplies and their stock numbers are listed below.

- UV Lamp — A-0204-S
- O-rings — A-0205, A-0207, A-0212
- Ozone scrubber — Z-0284-S
- Particulate filters — A-0000 or equivalent (Millipore Mitex 5.0 μm Teflon filter)
- Sample pump — A-0218H-S
- Solenoid valve — A-0203-S
- Ozone generator pump — A-218C-S
- Ozone generator lamp — C-0120-S

2.2 Reagents

No chemical reagents are employed in this procedure

2.3 Forms

Results of performance checks and maintenance procedures performed are recorded on a Maintenance and Performance Check Sheet (Figure 2-3). Calibration data are recorded in computer files using a portable computer and DRI calibration software (DRI, 1991).

3.0 CALIBRATION STANDARDS

A Dasibi 1003 PC Ozone Analyzer (or equivalent) is transported to the site for semi-annual calibrations. Typically the accuracy of the transfer standards is ± 1%.

Dasibi 1003 PC Ozone Analyzer Maintenance and Performance Check Sheet

Project ______________________

Month/Year ____________

Site ______________________

Site Operator ____________

Analyzer Serial No. ______________

					Front Panel					DAS	
Date	Initial or Final	Sample Flow (lpm)	Ozone Flow (lpm)	Leak Check (lpm)	Span Set.	Zero	Span	Control Freq	Sample Freq	Zero	Span
	Initial										
	Final										
	Initial										
	Final										
	Initial										
	Final										
	Initial										
	Final										
	Initial										
	Final										
	Initial										
	Final										

Date	Comments or Maintenance Performed

Last Calibration: Date ________
Conc = ____ x True + ____

Date scrubber changed ________

Reviewed by ________________ Date ________

Figure 2-3. Maintenance and performance check sheet.

4.0 PROCEDURES

4.1 Flow Diagram

Figure 4-1 shows a flow diagram of routine operating procedures.

4.2 Startup

- If the ozone analyzer is new or has been shipped, remove the top and check for loose printed circuit boards.
- Fill zero air scrubber containers with desiccant, Purafil and activated charcoal, and connect outlet of scrubber to ZERO AIR INLET on the 1003 PC back panel. The airflow in the zero air scrubber should flow first through the desiccant, then Purafil, then charcoal.
- Connect Teflon filter holder with Millipore Mitex 5.0 μm Teflon filter to SAMPLE INLET. Connect filter holder to one of the OZONE OUTLET ports on the back of the analyzer.
- Connect another one of the OZONE OUTLET ports to the normally closed (calibration) side of manifold/calibration solenoid. Remove cap from the remaining OZONE OUTLET and the EXHAUST port. Make all connections with 1/4 inch Teflon tubing, using tube lengths as short as is practical. Connections are shown in Figure 4-2.
- Connect recorder output and signal lines for ozone generator and pump and sample pump to the ozone calibrator interface, and from the interface to the Campbell 21X datalogger. Connect manifold/calibration solenoid to datalogger. Refer to the datalogger SOP for details.
- Clean the optics as outlined in section 4.4.4.
- Turn on analyzer power and set the mode switch to OPERATE, OZONE and ozone PUMP (left side of front panel) OFF, AUTO/MANUAL switch to MANUAL, Campbell/Manual switch to MAN, and sample PUMP (right side of front panel) OFF. The numeric display and power button should be lighted when power is applied.
- Allow at least a 30-minute warm-up period.
- Adjust SPAN SET switches to the correct span number. The correct span number is 525 for operating altitudes < 1000 feet. For altitudes above 1000 feet, use the span number indicated in Table 4-1.
- Set the mode switch to SPAN. The first three numbers that appear in the display should be the span number selected in the last step divided by 10, e.g. span number 525 displays as 52.550 (the last two digits are always 50).

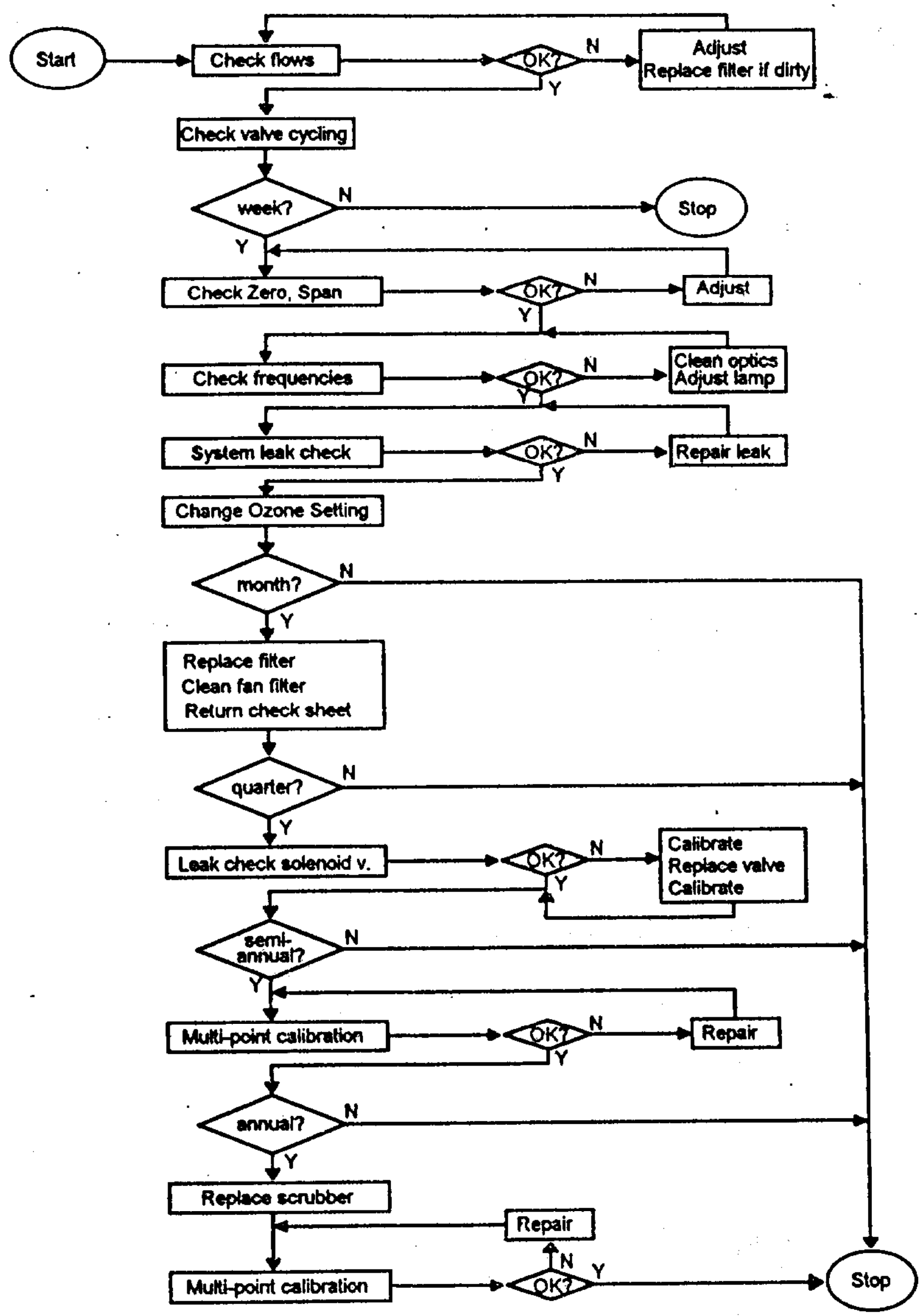

Figure 4-1. Dasibi 1003 PC operating procedure flow diagram.

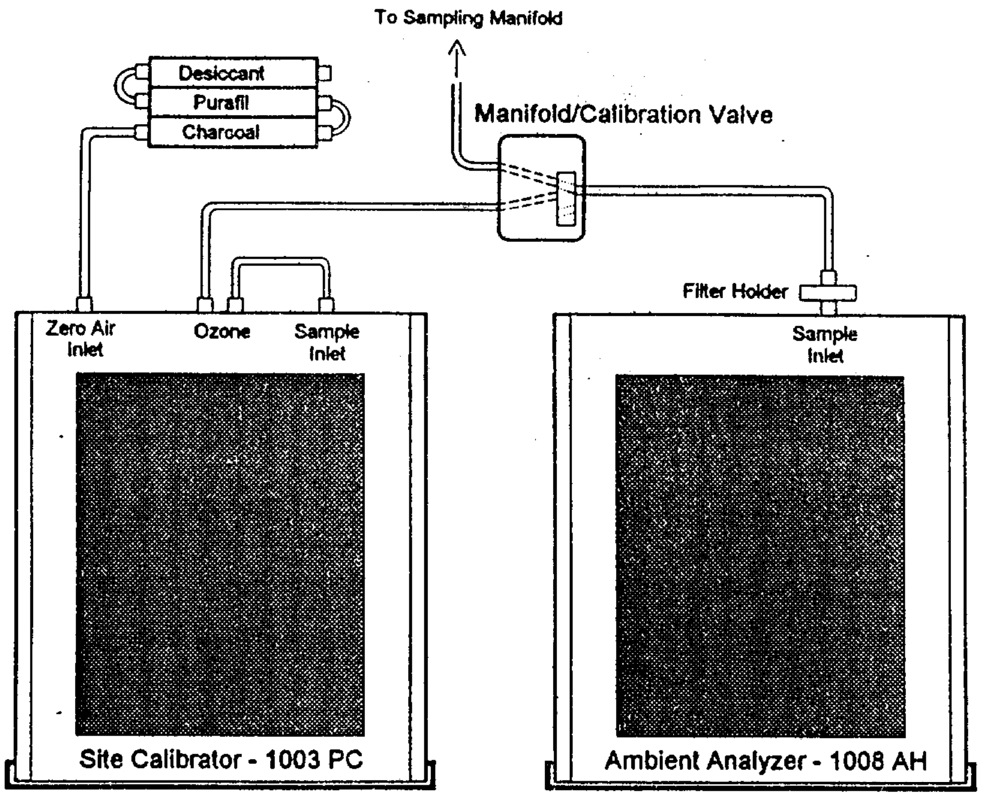

Figure 4-2. Dasibi 1003 PC connections for routine monitoring.

Table 4-1

Span Correction With Altitude

Elevation (Feet Above Sea Level)	Altitude Correction Factor	Correct Span Setting
0	1.000	525
500	1.000	525
1000	1.037	545
1500	1.056	555
2000	1.075	565
2500	1.095	575
3000	1.116	585
3500	1.136	595
4000	1.158	605
4500	1.179	615
5000	1.202	635
5500	1.225	645
6000	1.248	655
6500	1.272	665
7000	1.296	685
7500	1.321	695
8000	1.347	705
8500	1.372	725
9000	1.399	735
9500	1.426	745
10000	1.454	765

- Zero offset is adjustable from -40 to +50 ppb in steps of 10 ppb, and is equal to 50 - (10 x switch setting). The zero offset feature is designed to allow recording values near zero (such as zero air checks) where slight drift may result in negative numbers that cause problems with strip chart or some data recording systems. No zero offset is normally required, as the DAS correctly handles negative numbers. Set zero offset to 0 by setting switch to 5.

- Follow steps in section 4.4.1 and 4.4.2 to adjust the Analog Zero and Span. This ensures that the DAS and analyzer display indicate the same ozone concentrations.

- Set the mode switch to SAMP FREQ. Depending on the condition of the lamp and cleanliness of the absorption chamber, a number between 45.000 and 48.000 will appear, indicating a sample electrometer frequency of 450 to 480 KHz. See section 4.4.5 if sample frequency is not in this range.

- Set the mode switch to CONT FREQ. Depending on the condition of the lamp, a number between 23.000 and 28.000 will appear, indicating a control electrometer frequency of 230 to 280 KHz. See section 4.4.6 if control frequency is not in this range.

- Set mode switch to ZERO. Display should be 0.000.

- Perform a multipoint calibration according to Section 5.1.4 using 1003 PC or equivalent transfer standard.

- Determine setting for MAN O_3 ADJ for precision check. Set mode switch to OPERATE, OZONE and ozone PUMP ON, AUTO/MANUAL switch to MANUAL, Campbell/Manual switch to MAN, and sample PUMP ON. Adjust the MAN O_3 ADJ setting to a value that gives an ozone reading of about 100 ppb.

- Determine setting for MAN O_3 ADJ for span check. Adjust the MAN O_3 ADJ setting to a value that gives an ozone reading of about 400 ppb. Mark the precision and span settings on the front panel.

- Set analyzer to normal operation by setting mode switch to OPERATE, OZONE and ozone PUMP OFF, AUTO/MANUAL switch to MANUAL, MAN O_3 ADJ to predetermined precision check point, Campbell/Manual switch to CAMPBELL, and sample PUMP OFF.

4.3 Routine Operation

4.3.1 General Information

Perform the following maintenance and instrument performance checks routinely according to the noted frequency.

Start the TERM program on the site computer (see Operation and Maintenance of the Campbell 21X Datalogger SOP). The computer in this configuration will display ozone values as measured by the DAS, which is required for some of these procedures. It is not necessary to disable the DAS from recording 1003 PC values during performance checks.

Switch the Campbell /Manual switch to MAN before beginning tests.

After completing performance checks, return analyzer to normal operation by setting mode switch to OPERATE, AUTO/MANUAL switch to MANUAL, Campbell/Manual switch to CAMPBELL, OZONE and ozone PUMP (left side of front panel) OFF, and sample PUMP (right side of front panel) OFF.

4.3.2 Every Site Visit

- Switch on ozone generator pump and sample pump. Check that ozone generator flow is > 5 lpm and sample flow is 2 to 3 lpm. Adjust flow if necessary. The ozone generator and pump switches, and flowmeter are on the left side of the front panel and the sample flow pump switch and flowmeter are on the right side. Switch both pumps off after checking flow.

- Verify that the solenoid valve is cycling and that display is updating. The switching of the solenoid valve should be audible, should occur about every 12-15 seconds, and should have about the same time from one audible click to the next. The sample update light on the left-hand-side of the display should flash every 24-30 seconds.

4.3.3 Weekly

Record results of the following checks on lines marked as "initial" on the Maintenance and Performance Check Sheet (Figure 2-3). If an adjustment is made, record the "final" value also. For span and zero checks, record both the analyzer display reading and the DAS reading. Perform checks in the order listed here, not the order of the columns on the check sheet. Record any maintenance operations in the comments section.

- Ozone Generator Flow - Switch ON the ozone generator pump and check that front panel flowmeter indicates a flow of >5 lpm. Adjust if necessary.

- Sample Flow - Switch ON the sample pump and check that front panel flowmeter indicates a flow of 2 to 3 lpm and has not changed from last check. Adjust flow to 2.0 if necessary. Switch the sample and ozone generator pumps OFF.

- Zero Check - Turn the mode switch to ZERO. The display should read 00.000. The DAS should read 0 ± 3. If it does not, adjust the recorder zero offset control (section 4.4.1).

- Span Check - Record position of SPAN SET and OFFSET ADJ switches. Turn the mode switch to SPAN. The first three numbers that appear in the display should be the span number divided by 10, e.g. span number of 525 displays as 52.550 (the last two digits are always 50). The DAS should have a reading of within ± 3 of the last three digits × 1000. If it does not, adjust analog span (section 4.4.2).

- Control Frequency - Set the mode switch to CONT FREQ. Depending on the condition of the lamp, a number between 23.000 and 28.000 will appear, indicating a control electrometer frequency of 230 to 280 KHz. See section 4.4.6 if control frequency is not in this range.

- Sample Frequency - Set the mode switch to SAMP FREQ. The sample frequency of a properly adjusted analyzer with a clean optical bench and new lamp should be between 450 and 480 KHz (45.000 and 48.000 displayed). If the sample frequency drops below 300 KHz, refer to procedures for cleaning and adjusting optics, given in sections 4.4.4, 4.4.5 and 4.4.6.

- System Leak - Set the sample PUMP switch ON. Remove the sample line from the filter holder on the back of the analyzer. Plug filter holder inlet port with your finger. Flow should drop from 2.0 to 0.0. Record ending flow reading. If flow does not drop to zero, locate and repair leak.

Change the MAN O_3 ADJ control setpoint so that precision and span checks are performed alternate weeks.

4.3.4 Monthly

Some instruments are equipped with a cooling fan on the back panel. If so equipped, check that the filter pad is clean. If necessary, pry off the cover and rinse the filter pad in water to clean. Allow to dry before replacing.

Replace particulate filter by following steps in section 4.4.3.

File a copy of the Maintenance and Performance Check Sheet (Figure 2-3) at the site and return the original to the field supervisor.

4.3.5 Quarterly

Leak check the solenoid valve using the procedure below.

- Turn off analyzer power and disconnect power cord.

- Disconnect Teflon filter holder from analyzer inlet and cap off sample inlet to analyzer.

- Remove analyzer cover and ozone scrubber.

- Connect outlet of a flowmeter (0 to 0.5 SCFH or equivalent), to the normally open (NO) zero air port of the solenoid valve. Reconnect power cord and turn on power. Set the mode switch to OPERATE and sample PUMP switch ON. The flowmeter should indicate zero air flow during last half of the analysis cycle, otherwise the solenoid valve is leaking.

- Turn off analyzer power and disconnect power cord. Connect the outlet of the flowmeter to the normally closed (NC) port of the solenoid valve at open leg of inlet Tee. Reconnect power cord and turn on power. The flowmeter should indicate zero air flow during the first half of the analysis cycle, otherwise the solenoid valve is leaking.

- Turn off analyzer power and disconnect power cord. Disconnect flowmeter from NC port of solenoid. Reinstall ozone scrubber and leak check system (section 4.3.3).

NOTE: If the low flow rate flowmeter indicated above is not available, you may use the flow meter on the front panel and alternately plug the NC and NO ports of the solenoid valve with your finger. The flow should drop to zero during the corresponding part of the analysis cycle. However, the range of the front panel flowmeter is so high that it may not detect small leaks.

If the solenoid valve leaks, perform a multipoint "as is" calibration (section 5.1), replace the solenoid valve, and then perform a "final" multipoint calibration. Record date and results of solenoid leak test on Maintenance and Performance Check Sheet.

4.3.6 Semi-Annual

Perform a multipoint calibration with an external calibration standard as in section 5.1 once every six months of operation, upon relocation, and after major repairs. One month prior to the recalibration due date, contact the field supervisor to arrange for a multipoint calibration.

4.3.7 Annual

Replace the ozone scrubber as outlined in section 4.4.7.

4.4 Maintenance and Alignment Procedures

Start the TERM program on the site computer (see Operation and Maintenance of the Campbell 21X Datalogger SOP). The computer in this configuration will display ozone values as measured by the DAS, which is required for some of these procedures. It is not necessary to disable the DAS from recording 1003 PC values during these procedures.

The following adjustments are for an analyzer operating on a full scale range of 1.0 ppm and an analog output full scale response of 1.0 volt.

After completing maintenance and alignment procedures, return analyzer to normal operation by setting mode switch to OPERATE, AUTO/MANUAL switch to MANUAL, MAN O_3 ADJ to predetermined precision check point, Campbell/Manual switch to CAMPBELL, OZONE and ozone PUMP (left side of front panel) OFF, and sample PUMP (right side of front panel) OFF.

4.4.1 Analog Zero

- Connect a digital voltmeter (DVM) to the Dasibi analog output in parallel with the DAS.

- Set function switch to ZERO. Display should read 00.000.

- Remove the top cover and adjust the analog OFFSET ADJ pot until the DVM reads 0.000 ± 0.003 volts and the DAS reads 0 ± 3 ppb. The pot is located on the upper right-hand side of the D/A board. The D/A board is one of several that plug in vertically to edge connectors on the motherboard. Consult the board assembly diagram (Figure 3-5) in the operating manual (Dasibi, 1990) to identify the D/A board. If the readings from the DVM and DAS do not agree, one or both are in error and must be repaired.

4.4.2 Analog Span

- Connect a digital voltmeter (DVM) to the Dasibi analog output in parallel with the DAS.

- Set function switch to SPAN. The first three digits displayed should be the selected span number divided by 10, and the last two digits are 50, e.g. span of 525 displays as 52.550.

- Adjust the ANALOG SPAN pot on the front panel so that the DVM reading in volts is within ± 0.003 of the last three digits of the display, and the DAS reads within ± 3 ppb. If the readings from the DVM and DAS do not agree, one or both are in error and must be repaired.

4.4.3 Replace Particulate Filter

Remove the four thumbscrews from the filter holder connected to the inlet on the back panel of the analyzer. Discard the old filter and replace with a Millipore Mitex 5.0 μm Teflon filter or equivalent. Reassemble the filter holder and perform system leak check (section 4.3.3).

4.4.4 Clean Optics

Even though the inlet air is filtered, the optics of the analyzer can become dirty over time. Dirty optics, as well as decreased lamp output and decreasing detector efficiency result in decreasing sample frequencies. Correct by periodically cleaning the optical bench, including absorption tubes, mirrors and detector windows.

A properly cleaned and aligned analyzer, will have a sample frequency of 450 to 480 KHz. This frequency is not critical; an instrument with a sample frequency as low as 150 KHz, will still operate correctly. However, a significant drop in sample frequency from an initial value of 450 - 480 KHz to 300 - 330 KHz (a drop of 150 KHz) may indicate the accumulation of enough particulate matter in the optics system to cause ozone degradation as sample air passes through the system.

Follow the procedures in section 6.7 of the operating manual (Dasibi, 1990) to clean the optics. Perform a system leak check after the optics are reassembled.

If sample frequency is still lower than 450 KHz after cleaning the optics, adjust sample frequency as indicated in the next section.

4.4.5 Adjust Sample Frequency

Sample frequency decreases as dirt particles collect throughout the optical path, as the UV lamp output decays, or as the efficiency of the detector diminishes. Sample frequency for an analyzer with clean optics and a new lamp should be between 450 and 480 KHz (45.000 and 48.000 displayed). If the optics are clean and analyzer doesn't meet these specifications, make the following adjustments.

NOTE: Take care not to short the detector terminals on the 15 volt power supply.

- If analyzer has been off, allow at least thirty (30) minutes for warm-up before checking the frequency.
- Set function selector switch to SAMP FREQ.
- Connect a frequency counter to sample frequency and ground pins on the logic board. If a frequency counter is not available use analyzer's digital display.
- Loosen ultraviolet (UV) lamp lock screw and reposition lamp until frequency is within specifications. Slide UV lamp into its socket to increase the frequency and slide it out to decrease the frequency. Rotate the UV lamp to effect additional change. Carefully tighten UV lamp lock screw when adjustments are complete.
- Make further adjustments if necessary by repositioning sample detector. To accomplish this, loosen set screw holding detector and slide detector in to increase and out to decrease frequency. Tighten set screw securely after adjustment is complete.

When cleaning and adjusting procedures fail to restore the frequencies to adequate levels, replacement of the UV lamp and/or electrometer board and both detectors is necessary.

Changing the lamp position will affect the control frequency. After adjusting sample frequency, check and adjust control frequency.

4.4.6 Adjust Control Frequency

Control frequency decreases as the UV lamp output decays or as the efficiency of the detector diminishes. The optimum control frequency for an analyzer with a new lamp is between 230 and 280 KHz (23.000 and 28.000 displayed). This frequency is not critical; an instrument with a control frequency as high as 480 KHz or as low as 14 KHz will still operate correctly. Adjust control frequency to the optimum range using the following steps.

NOTE: Take care not to short the detector terminals on the 15 volt power supply.

- If analyzer has been off, allow at least thirty (30) minutes for warm-up before checking the frequency.
- Set function selector switch to CONT FREQ.

- Connect a frequency counter to control frequency and ground pins on the logic board. If a frequency counter is not available use analyzer's digital display.

- The control detector is contained in the 1 inch diameter cylinder positioned perpendicular to the absorption tubes. Make coarse adjustments to control frequency by turning the adjustment screw in the middle of the control detector block. This varies the size of the aperture between the UV lamp and the control detector.

- Make fine adjustments if necessary by loosening the control detector set screw with a 1/16 th inch Allen wrench and sliding the detector into or out of the housing. Tighten set screw securely after adjustment is complete.

When cleaning and adjusting procedures fail to restore the frequencies to adequate levels, replacement of the UV lamp and/or electrometer board and detector is necessary.

4.4.7 Ozone Scrubber Replacement

Replace the ozone scrubber only after performing an "As Is" calibration. After replacing an ozone scrubber, leak check the system and perform a final multipoint calibration.

For analyzers operating continuously for a full year, replace the ozone scrubber during the pre-ozone season calibration.

4.5 Shut Down

Perform a final multipoint calibration before shutting down operation of the 1003 PC.

4.6 Check Lists

Maintenance and Performance Check Sheet, Figure 2-3.

5.0 QUANTIFICATION

5.1 Calibration

5.1.1 A Dasibi Model 1003 PC Ozone Analyzer/Calibrator or equivalent (transfer standard), standardized against a primary standard laboratory ultraviolet photometer is used in calibrations. The response of the analyzer being calibrated is compared to the response of the transfer standard. Calibration results are recorded and calculations performed by the DRI Audit/Calibration software running on a portable computer. Refer to the Audit/Calibration software manual (DRI, 1991) for instructions.

5.1.2 "As Is" Calibration - Perform an "As Is" calibration following the steps in section 5.1.4 prior to making any instrument repairs or adjustments other than routine checks or adjustments. If the results of the "As Is" calibration are not within ± 10% of the transfer standard, take corrective action and perform a "Final" calibration.

5.1.3 "Final" Calibration - Perform a "Final" calibration following the steps in section 5.1.4 after replacing the scrubber or solenoid valve or performing other non-routine adjustments or maintenance.

5.1.4 Calibration procedure.

- Connect the transfer standard zero air scrubber device to the zero air inlet of the transfer standard analyzer, and the ozone outputs to the transfer standard and site analyzer inputs using Teflon tubing as shown in Figure 5-1. The airflow in the zero air scrubber should flow first through the desiccant, then Purafil, then charcoal. Use a flush Tee on the ozone connection to the site analyzer, and use a Teflon particulate filter on the site analyzer inlet. Remove caps from unused ozone ports on the transfer standard and from the exhaust ports on both instruments.

- Set the mode switch on the site analyzer to OPERATE, OZONE and ozone PUMP (left side of front panel) OFF, Campbell/Manual switch to MAN, and sample PUMP (right side of front panel) ON.

- Set controls on the transfer standard to normal operating positions with ozone generator OFF, ozone pump ON, and no zero offset. Set ozone flow to maximum and sample air flow rates on both transfer standard and site analyzer to 2 lpm.

- Sample zero air while allowing both the transfer standard and the site analyzer to warm-up for at least one hour. The covers of both instruments should be on during the calibration, as the calibration is dependent upon the internal temperature of the analyzer. The control frequency readings should be stable, showing no upward or downward trend when the analyzers have reached operating temperature.

- Start the ozone audit program and record the network information and the analyzer identification and settings for both the site instrument (1003 PC) and audit instrument.

- While the site analyzer and transfer standard are sampling zero air, record the nominal ozone concentration (0), and 10 consecutive digital display values from both analyzers. If the transfer standard is not a 1008 PC, record analyzer internal temperature with the supplied digital thermometer and pressure also. Record the DAS ozone value for one of the 10 readings.

- Switch on ozone generator and pump. Set ozone flow to maximum. Set the lamp intensity control of the transfer standard to produce an ozone concentration of approximately 400 ppb ozone as read by the transfer standard.

- Allow instruments to stabilize. Record ten consecutive digital display values for each analyzer along with the nominal ozone concentration. If the transfer standard is not a 1008 PC, record analyzer internal temperature with the supplied digital thermometer and pressure also. Record DAS ozone value for one of the 10 readings.

- Repeat previous step for nominal ozone concentrations of 300, 200, 100 and 50 ppb.

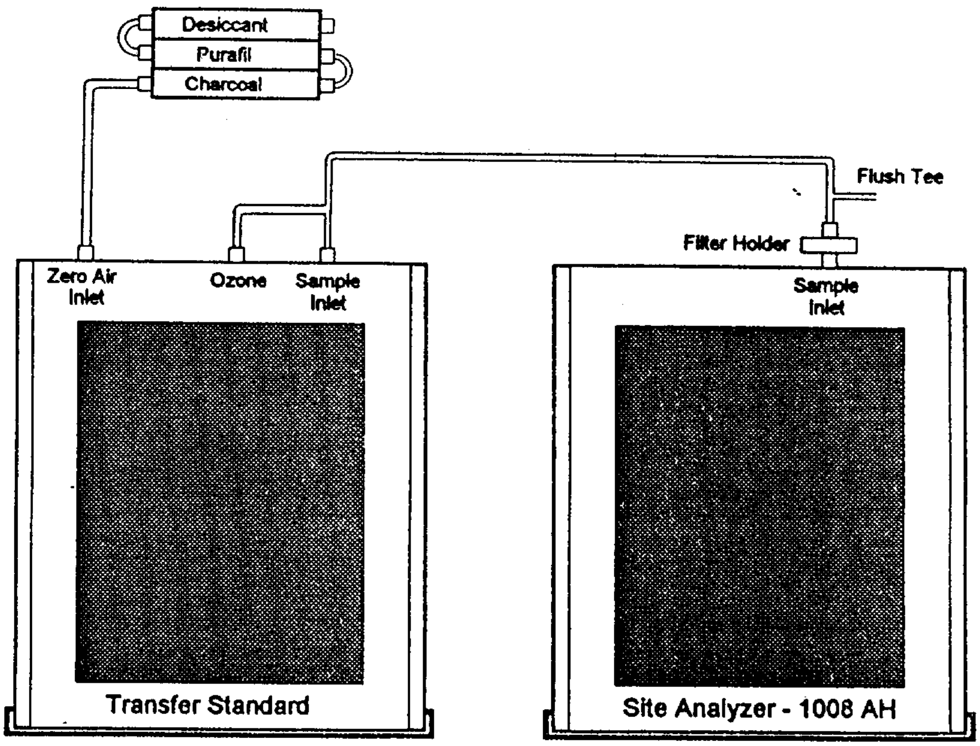

Figure 5-1. Connections for calibration of Dasibi 1003 PC.

- Switch off the ozone generator and pump and repeat the measurement of zero air as before.

- Use the appropriate menu options and data entry screens in the audit program to perform the calculations listed in this paragraph. Calculate average concentrations measured at each ozone level. The 1008 PC transfer standards do not require temperature and pressure corrections. The 1003 PC transfer standard and the 1003 PC site analyzer requires temperature and pressure corrections. Enter the average of the initial and final zero air readings where the program requests the zero correction. This is done separately for the transfer standard and the site analyzer. Calculate deviation of the site analyzer from the transfer standard. Calculate slope and intercept of the calibration data. Exclude the zero points from the regression line.

- Compare results of the calibration audit to the criteria in the following table. If any of the three parameters is in the "suspect" category, flag all ozone data collected since the last audit as suspect. If this is a "final" calibration and any of the parameters is in the "suspect" or "recalibrate" categories, return the analyzer to the laboratory for repair/calibration. If this is a "final" calibration and any of the parameters is in the "warning" category, repair or recalibration may be warranted; consult the field supervisor.

Parameter	OK	Warning	Recalibrate	Suspect
Average % difference	± 0 - 5	± 5 - 10	± 10 - 15	> 15
Slope	0.95 - 1.05	0.90 - 0.95 or 1.05 - 1.10	0.85 - 0.90 or 1.10 - 1.15	< 0.85 or > 1.15
Intercept as % of full scale	< 1	1 - 2	2 - 3	> 3

5.2 Calculations

5.2.1 Calibration calculations

Mean and standard deviation for all readings flagged as valid are calculated separately for each calibration concentration level for both transfer standard and site analyzer.

Mean concentrations for transfer standard are corrected for temperature and pressure (if T/P correction option was chosen during calibration), for zero correction, and for transfer standard slope and intercept values.

$$C_T = \left[(A_T - Z_T) \times \frac{760 \times (T+273)}{P \times 273} \right] \times M_T + B_T$$

where C_T = corrected transfer standard concentration, ppb
A_T = average uncorrected transfer standard concentration, ppb
Z_T = zero correction (average reading for zero air), ppb
P = atmospheric pressure, mb
T = analyzer temperature, Celsius
M_T = transfer standard calibration slope
B_T = transfer standard calibration intercept

Mean concentrations for the site 1003 PC analyzer are calculated as shown below.

$$C_S = A_S - Z_S$$

where C_S = corrected site analyzer concentration, ppb
A_S = average uncorrected site analyzer concentration, ppb
Z_S = site analyzer zero correction, ppb

Percent deviation D is calculated for each calibration concentration level by

$$D = \frac{(C_S - C_T)}{C_T} \times 100$$

and the average deviation is computed for all points included in the linear regression fit. A least squares linear regression is used to calculate the slope and intercept of the calibration data.

$$C = m \times T + b$$

where C = site analyzer concentration, ppb
m = calibration line slope
T = transfer standard concentration, ppb
b = calibration line intercept, ppb

5.2.2 Routine Calculations

Ozone concentrations as measured by the 1003 PC and recorded by the DAS are direct reading, and are corrected for average pressure difference from standard due to altitude. They are not corrected for day to day temperature and pressure changes. The difference between 1003 PC and 1008 AH concentrations therefore reflects instrumental precision plus the effects of temperature and pressure changes on the 1003 PC readings.

6.0 QUALITY CONTROL

Quality control for this procedure is maintained by routine performance checks , scheduled preventative maintenance procedures, electronic zero and span checks, and daily zero and span checks against an on-site calibrator.

7.0 QUALITY ASSURANCE

Quality assurance is maintained by performing semi-annual calibration audits using a standard independent of the site operation.

8.0 REFERENCES

Dasibi (1990). "Model 1003 U.V. Photometric Ozone Analyzer (For Models AH, PC, RS and HC) Operating and Maintenance Manual." Dasibi Environmental Corporation, 1990.

DRI (1991). "DRI Software Manual for: Audit Software & Calibration Software." Desert Research Institute, 1991.

U.S. Environmental Protection Agency (1988). "National Primary and Secondary Ambient Air Quality Standards. Appendix D - Measurement Principle and Calibration Procedure for the Measurement of Ozone in the Atmosphere." 40 CFR Chap. 1, Part 50

1.0 GENERAL DISCUSSION

1.1 Purpose of Procedure

The objectives of this standard operating procedure are to:

- Provide a basic understanding of the principles of operating an Aerochem Metrics Model 301 Precipitation Collector.
- Describe routine operation of the Aerochem Metrics Model 301 Precipitation Collector.

This procedure will be followed by all technicians in the Environmental Analysis Facility of the Energy and Environmental Engineering Center of the Desert Research Institute.

1.2 Measurement Principle

The Aerochem Metrics Model 301 is a wet/dry precipitation collector. Wet and dry precipitation is collected in either of two 3.5 gallon plastic buckets. Wet bucket contents are analyzed on site for precipitation volume, pH, and conductivity before the contents are shipped to the laboratory. At the laboratory, wet bucket contents are analyzed for pH, conductivity, acidity, and Na^+, Mg^{2+}, K^+, Ca^{2+}, NH_4^+, Cl^-, NO_3^- and SO_4^{2-} ions. In the study entitled "Assessment of Acidic Deposition and Ozone Effects on Conifer Forests in the San Bernardino Mountains," contents of the dry deposition bucket are not analyzed. The dry deposition bucket is periodically cleaned and reinstalled on the sampler.

1.3 Measurement Interferences and their Minimization

- Avoid contamination of the sample buckets at all times. Even a fingerprint on the inside wall of the bucket can cause erroneous ion analyses. Field and laboratory personnel wear clean PVC non-powdered gloves when handling the buckets. Do not exhale into or close to the bucket; human breath contains ammonia.
- Ammonia may evaporate from the sample if left at room temperature. Store samples in cold storage and ship with Blue Ice.

1.4 Ranges and Typical Values of Measurements Obtained by this Procedure

Precipitation amount and frequency varies widely over space and time. Some locations may rarely experience precipitation while others may have precipitation nearly every week during certain times of the year. Average annual precipitation ranges from 4 to 60 inches for most regions in the U.S.

Ranges for pH and ion concentrations listed below are annual precipitation weighted means from the National Atmospheric Deposition Program network (NADP/NTN, 1991). Ion concentration units are mg/l.

Species	Minimum	Maximum
pH	4.2	6.3
Cl^-	0.07	2.5
NO_3^-	0.1	2.2
$SO_4^=$	0.2	3.5
NH_4^+	0.02	1.0
Na^+	0.03	1.4
Mg^{++}	0.009	0.18
K^+	0.01	0.12
Ca^{++}	0.02	0.4

1.5 Typical Lower Quantifiable Limits, Precision, and Accuracy

The Aerochem Metrics Model 301 Precipitation Collector is capable of collecting up 8 - 9 inches of precipitation (~3.5 gallons). If no sample is collected, a "blank rinse" measurement is made. If the collected sample volume is less than 25 ml (about 0.015 inches of precipitation), the sample is diluted with DDW before measurements are made. Lower quantifiable limits, precision and accuracy for chemical measurements are discussed in the appropriate analytical procedure.

1.6 Personnel Responsibilities

All field technicians should read and understand the entire standard operating procedure before performing wet/dry precipitation collection. The technician is expected to follow this procedure step by step to perform routine system collection. The field manager is responsible for ensuring that the wet/dry precipitation collection procedures are properly followed, to examine all data and to deliver analysis results to the project manager within the specified time period.

The quality assurance (QA) officer of DRI's Energy and Environmental Engineering Center (EEEC) is responsible for determining the extent and methods of quality assurance to be applied to each project, for estimating the level of effort involved in this quality assurance, for identifying the appropriate personnel to perform these QA tasks, for updating this procedure periodically, and for ascertaining that these tasks are budgeted and carried out as part of the performance on each contract.

1.7 Definitions

DDW - distilled, deionized water.

1.8 Related Procedures

- DRI SOP 08 — Conductivity Measurements
- DRI SOP 09 — pH Measurements
- DRI SOP 05 — Operation of the Belfort Rain Gage
- DRI SOP 2-209.3 — Sample Shipping, Receiving and Chain-of-Custody

- Aerochem Metrics Inc. — Assembly and Operation Instructions for the Aerochem Metrics Model 301 Automatic Sensing Wet/Dry Precipitation Collector

2.0 APPARATUS, INSTRUMENTATION, REAGENTS, AND FORMS

2.1 Apparatus and Instrumentation

2.1.1 Description

The Aerochem Metrics Model 301 Wet/Dry Precipitation Collector is designed to operate on 110 VAC, 50-60 cycle power, or, with modification, 12 VDC. It consists of an aluminum table, two 3.5 gallon plastic buckets, movable sampler roof, rain sensor, and motor. When the rain sensor becomes wet, its electrical resistance decreases which triggers movement of the sampler roof from the wet-side bucket to the dry-side bucket. When water evaporates from the sensor, its electrical resistance increases which allows the return of the sampler roof from the dry-side bucket to the wet-side bucket.

When the sensor is dry, it is heated by a thermistor controlled heater to 8 °C so that snow will melt and trigger a precipitation event. When the sensor is wet, it is heated to 50 °C to quickly evaporate water as soon as the precipitation has ended and thus minimize the exposure of the wet sample to contamination by dry deposition.

The drive motor crank arm is provided with a torque limit clutch. This is set at 800 in.oz. torque at the motor shaft. Loads in excess of this amount will cause the clutch to disengage for one revolution. You can stop the roof from moving midway between the buckets without damage to the motor as the motor will rotate through the detente. Do not attempt to manually shift the roof from one bucket to the other. You can move the roof between the buckets with the power OFF by turning the crank arm on the motor shaft.

A spring pressure device in the arm connecting the motor crank arm to the roof support arms provides positive pressure between the foam roof seal and the bucket rim. This device also prevents damage to the system in the event that an obstruction on the bucket rim prevents the cover from moving the last one-half inch or so to the bucket top.

2.1.2 Characterization

Not applicable.

2.1.3 Maintenance

- The sampler requires no routine periodic maintenance. In case of malfunction of the sensor, roof transport mechanism, or other component, refer to the manufacturer's instruction sheet and contact the field operations manager.

- For winter operation, remove buildup of snow or ice on the sampler roof and sensor grid after a snow event. If necessary to prevent the roof arms from freezing to the table, wrap plastic sheeting around each roof arm to make a boot. Tape one end of the boot to the table and the other end to the arm. Check that the arm moves freely and does not tear the boot. If necessary, request and attach a peaked roof to prevent buildup of snow. Once installed, the peaked roof should remain on the sampler year round.

- Verify that the roof transport mechanism operates correctly and that the rain sensor controls movement of the roof when wetted and again when it dries out during each site visit.

2.1.4 Temperature Adjustment

- The heater circuit can be adjusted to change the drying temperature attained by the rain sensor. If the setting is too high, the collector roof will tend to cycle frequently during light precipitation. If the setting is too low, there will be a considerable time delay between the conclusion of a rain event and the time at which the roof will return over the wet-side bucket. Do not change the factory settings without consulting the field operations manager.

- To adjust the temperature settings, separate the sensor head from the tube stand by removing the four screws on the underside of the head. The temperature potentiometer "TH", nearest the end of the card, controls the wet collection (high temperature) settings. The 20-turn potentiometer is rotated clockwise to increase the temperature at the rain sensor plate to between 23-120°C. (The pot adjustment is not linear). The heater itself is thermistor limited at 50-60°C.

2.1.5 Balance

Use an Ohaus Heavy Duty Solution Balance, capacity 20 Kg for weighing.

2.2 Reagents and Supplies

- Distilled Deionized Water (DDW) having a conductivity reading of less than 0.056 μmho/cm or a resistance of at least 18 megohm-cm is required for all procedures. DDW is prepared in the laboratory and shipped to the field in polyethylene containers.
- PVC gloves, talc free.
- Parafilm.
- KimWipes.
- Alconox laboratory detergent.
- 1000 ml graduated cylinder.

2.3 Forms

Wet Deposition Measurement Form - Figure 2-1.

Desert Research Institute
Energy and Environmental Engineering Center

WET DEPOSITION MEASUREMENT FORM

Site Name: Barton Flats ______________ Field Technician: ______________

Start Date (MM/DD/YY): ___/___/___ Time (HH:MM): ___:___ (00:00 - 24:00)
Stop Date (MM/DD/YY): ___/___/___ Time (HH:MM): ___:___ (00:00 - 24:00)
Dry Bucket Cleaned (Y/N)? ________ Sample ID:

RAIN GAUGE:

	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Week Total
Type (R,S,M,U)									
Amount (inches)	.	.	.	.	.	.	.	.	.

WET BUCKET: Rinse Blank (Y/N)? __
Bucket Weight (grams): Final - Initial = Net
______ ______ ______
Inches of Precipitation (ml or grams X 0.0006) = ______

Volume DDW Added: _____ml
Graduated Cylinder Volume: _____ ml

CONDUCTANCE (μs/cm):

	Temp (°C)	cv	X	k	=	C	C(t)
Bucket Rinse:	____	____		____		____	____
DDW:	____	____		____		____	____
Working Std:	____	____		____		____	____
Sample:	____	____		____		____	____

pH:
Calibration Std. (pH4): ______ (pH7): ______ Sample: ______

COMMENTS:

____
____
____
____
____
____
____

Figure 2-1. Wet deposition measurement form.

3.0 CALIBRATION STANDARDS

Not applicable

4.0 PROCEDURES

4.1 General Flow Diagram for the Aerochem Metrics Model 301.

Figure 4-1 shows the flow diagram for routine operation of the Wet/Dry Precipitation Collector.

4.2 Start Up

Assemble the sampler according to the manufacturer's instructions (Aerochem Metrics, Inc., 1991). Install sampler at site using bolts through the bottom of the legs secured to the sampling platform. Make sure the tops of the buckets are level. Avoid locations where water may drip into the buckets from nearby trees, guy wires for tower support, etc. Connect power cord to a 110 VAC 50-60 Hz source. Use plastic electrical tape if connecting to an extension cord to prevent the connection from getting wet.

4.3 Routine Operation

4.3.1 Sampling Frequency

- Change the wet sampling bucket every Tuesday at 0900 PST, including during precipitation events.
- In very heavy rain conditions replace the wet bucket before it is completely full (about 9 inches of rain) even though the sample week is not completed. Treat each bucket as a separate weekly sample.
- In heavy snow conditions replace the wet bucket before it is completely full. In some cases it may not be possible to anticipate that a bucket will fill with snow before the end of the sample week. In this case replace the wet bucket as soon as possible after it is full and note that it was full on the field data sheet. Treat each bucket as a separate weekly sample.

4.3.3 Changing Sample Buckets

- Put on PVC gloves to prevent contamination of the sample. Even while wearing gloves, avoid touching the inside or top edge of the buckets.
- Where physically possible approach the sampler and work from the downwind side to prevent windblown contaminants from entering the buckets.
- Inspect the dry-side bucket for wet precipitation which is evidence of sampler malfunction. If there is a malfunction, ascertain the source and report it on the report form. Correct the problem before proceeding.

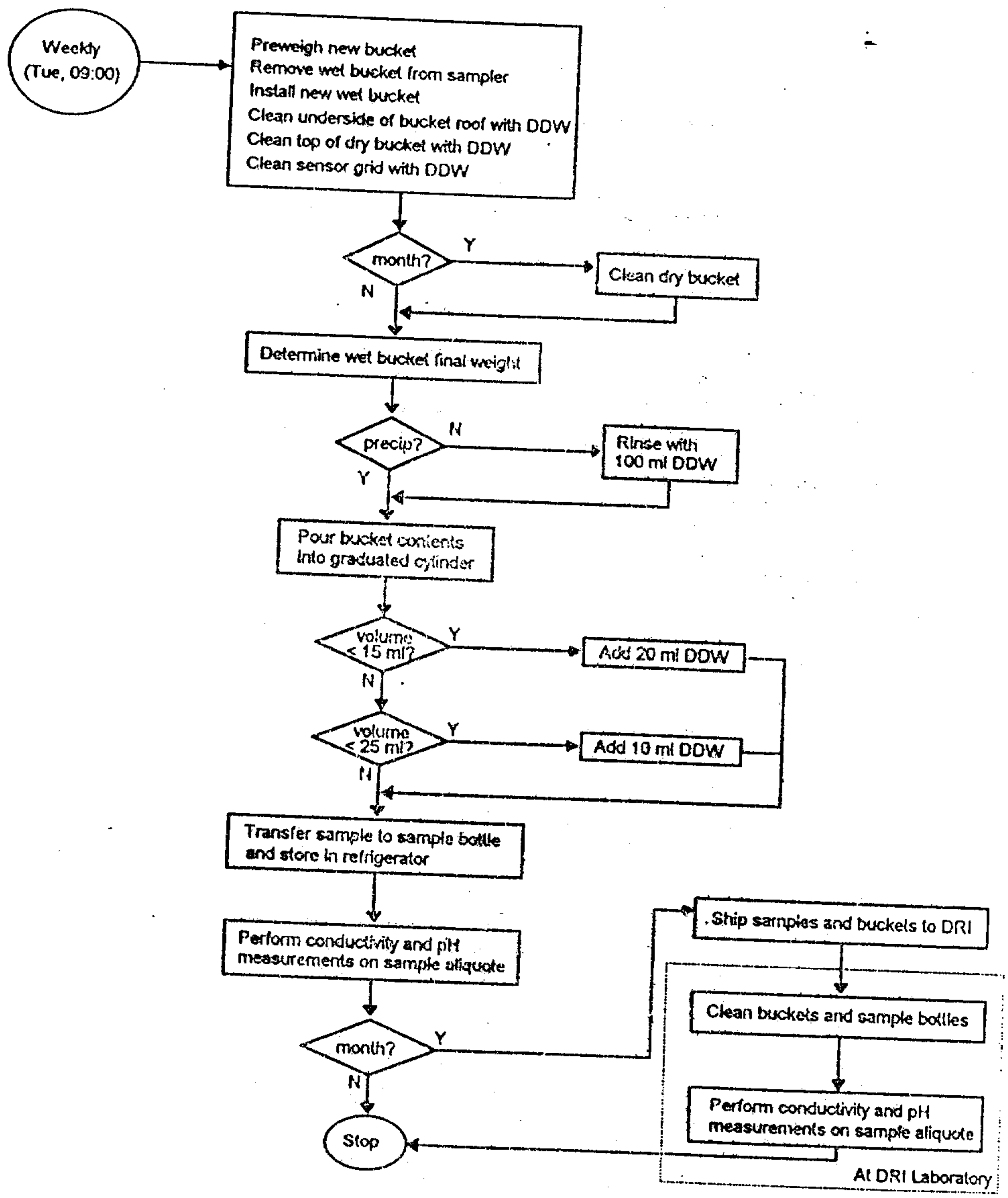

Figure 4-1. Precipitation collector operating procedure flow diagram.

- Verify that you have the correct Wet Deposition Measurement Form by comparing the wet bucket ID on the form and the bucket in the sampler. Record the date and time of removing the wet bucket.

- Short out the sensor by placing a paper clip across the sensor face to allow access to the wet bucket. Take a clean lid from its plastic bag and cap the wet bucket. Remove the capped bucket from the collector. Note: Buckets sometimes contain foreign objects such as insects, feathers, bird droppings, etc. Never attempt to remove any contaminant from the bucket. Identify the contaminant on the sample report form.

- Remove the new, preweighed bucket (section 4.3.4) from its plastic bag and install on the sampler. Return the bucket lid to the plastic bag. Verify that the ID's on the bucket and the data form match, and record the date and time of installation.

- Remove the paper clip from the sensor and, stopping the roof half-way between the buckets, clean the underside of the roof with a wash bottle of DDW and wipe dry with a clean KimWipe. Make sure the roof moves back to the correct position. Clean the top edge of the dry bucket where it comes in contact with the roof using a KimWipe wetted with DDW.

- Clean the sensor grid with DDW. If any debris is lodged in the sensor, remove it by sliding a strip of cardboard cut from a manila folder between the grid and plate. If necessary, use a toothbrush and detergent (Alconox) to remove stubborn dirt films. Verify that the roof operates properly when the sensor is wetted and again when it dries out.

- Once each month, remove the dry bucket from the sampler, thoroughly clean and rinse using DDW, and reinstall in the sampler. Record Y or N on the report form where it asks if the dry bucket was cleaned.

4.3.4 Bucket Weighing Before Sampling

- Put on PVC gloves to prevent contamination of the bucket. Even while wearing gloves, avoid touching the inside or top edge of the bucket.

- With the balance level, zero the balance.

- Remove a clean sample bucket and the Wet Deposition Measurement Report Form from the plastic bag. Place matching bar code ID labels on both the bucket and the Wet Deposition Measurement Report Form.

- Pop out the segments of the lid on the edge one by one with your hands, and remove the lid from the bucket and return it to the plastic bag by holding the edge only.

- Weigh the empty bucket (without lid) and record the bucket ID and weight to the nearest gram on a new Wet Deposition Measurement Form.

- Put the bucket back in the plastic bag and reseal the plastic bag.

4.3.5 Bucket Weighing After Sampling

- Put on PVC gloves to prevent contamination of the sample and buckets. Even while wearing gloves, avoid touching the inside or top edge of the buckets.
- With the balance level, zero the balance.
- If the bucket contains precipitation, allow any snow or ice in the bucket to melt completely and the sample to attain room temperature (25°C) before proceeding.
- Tap the lid to knock off any water drops off the inside surface of the lid. Wipe the outside of the bucket dry. Remove the lid.
- Verify that the ID on bucket and form match. Weigh the bucket (without lid) and record the bucket weight to the nearest gram on the Wet Deposition Measurement Form.
- Subtract the initial from the final weight to obtain the precipitation sample weight. Multiply the precipitation weight by 0.0006 to calculate the inches of precipitation. Record the values on the report form.

4.3.6 Sample Preparation and Volume Measurement.

- Put on PVC gloves to prevent contamination of the sample and buckets. Even while wearing gloves, avoid touching the inside or top edge of the buckets.
- If the bucket contains precipitation, allow any snow or ice in the bucket to melt completely and attain room temperature (25°C) before proceeding.
- Verify that the ID on the bucket and the report form match. Wipe the outside of the bucket dry. Remove the lid.
- If no precipitation has collected in the wet-side bucket, rinse the bucket with 100 ml (measured with graduated cylinder) of DDW. Identify the sample as a "Rinse Blank" on the report form. Enter sample volume of 0 on the report form.
- If the bucket contains more than 1000 ml, rinse the graduated cylinder with about 200 ml of the sample.
- Pour the total contents or the remaining contents of the bucket into the 1000 ml graduated cylinder. If the sample is not a blank rinse, record the total volume (including graduated cylinder rinse volume, if any) to the nearest 5 ml on the report form.
- If the total volume of the sample is greater than 0 ml and less than 15 ml, add 20 ml DDW. If the sample volume is larger than 15 ml and less than 25 ml add 10 ml DDW. Record the volume of DDW added on the report form.

- Select a new sample bottle and write the sample ID # which is listed on both the wet bucket and form on the bottle. Pour out the DDW from the sample bottle. Shake out all the DDW from the cap and the sample bottle. If sample volume > 100 ml, rinse the inside of the bottle and cap with about 10 ml of sample from the graduated cylinder.

- Transfer up to 115 ml of the graduated cylinder contents to a clean 125 ml polyethylene bottle, saving a small (3.0 ml) aliquot for the field conductivity and pH measurements. Double check that sample ID's on the bottle, the data form and the bucket match.

- Perform the field conductivity and pH measurements according to those procedures.

- Rinse the graduated cylinder three times with DDW and cover and seal the opening with Parafilm. Place the 125 ml sample bottle in cold storage until ready to ship. Ship the 125 ml bottle sample, the wet bucket and lid and the Wet Deposition Measurement Form to the DRI Environmental Analysis Laboratory. See DRI SOP #2-209.3 for labeling and shipping information.

4.3.7 Wet Bucket Cleaning

- Wear disposable, non-powdered PVC gloves to prevent contamination of the buckets during cleaning. Avoid breathing into the buckets.

- Remove the ID label. Wash the outside surfaces of the lid and the bucket with Alconox, a clean sponge and tap water.

- Wash the interior surface of the bucket and lid similarly, especially the rubber O-ring of the lid. Use a clean sponge and Alconox to remove the water-line stains and dirt. Use DDW for the interior of the bucket and lid. Make sure all stains in the interior are completely removed.

- Rinse the interior of the bucket and lid with DDW successively at least three times. Use about 300 ml of DDW every time. Measure the conductance of the final rinse. If it is greater than 2.0 μmho/cm, repeat the cleaning steps.

- Record the date and the conductance of the final rinse on a new Wet Deposition Measurement Form. Put the lid on the bucket (but do not lock it on) and carry it to the laminar flow hood. Keep the Wet Deposition Measurement Form with the bucket.

- Clean the surface of the laminar flow hood with DDW wetted KimWipes (wearing gloves) and lay out dry KimWipes. Without breathing into or touching any interior surface of the lid or the bucket, shake off the excess water and place the bucket upside down and the lid top side down on the KimWipes in the laminar flow hood.

- When dry, put on the lid, again wearing gloves. Using pressure from the palms of your hands only, lock the lid onto the bucket along the entire rim. Seal the bucket in a clean plastic bag and prepare for shipping.

4.3.8 Sample Bottle Cleaning

- Wear disposable, non-powdered PVC gloves to prevent contamination of the bottles during cleaning. Avoid breathing into the bottles.
- Remove the old sample label.
- Flush with DDW successively at least three times from the tap on the deionizing unit. Pay particular attention to the interior of the bottle and cap. If any stain in the bottle or cap is not removed, discard.
- Fill each bottle completely with DDW and cap it securely. Dry off the outside of the bottle.
- Wait a minimum of 24 hours before using the bottles.

5.0 QUANTIFICATION

Conversion of sample volume into inches of precipitation:

The bucket opening is 28.9 cm in diameter, or 656 cm^2 in area. One cm^3 of water (or 1 gram of water) divided by 656 cm^2 area equals 0.0015 cm of precipitation, or 0.0006 inches of precipitation.

6.0 QUALITY CONTROL

Quality control for this procedure is maintained by adherence to procedural steps that ensure clean handling of the buckets, sample bottles and graduated cylinder. Monitoring data from rinse blanks and bucket rinses after cleaning provides a check against potential contamination. Proper operation of the wet/dry bucket roof is checked weekly.

7.0 QUALITY ASSURANCE

Review and validation of chemical analysis data from wet deposition samples provides an implicit check of the sample collection procedures described in this document. Deficiencies in sampling procedures detected during data validation will be addressed as necessary.

8.0 REFERENCES

Air Resources Board (1990). "Procedure for the Preparation and Physical Measurements of Wet Deposition Samples," SOP No. MLD 109, Effective Date 9/17/90. Southern Laboratory Branch Monitoring & Laboratory Division, State of California.

NADP/NTN (1991). NADP/NTN Annual Data Summary, Precipitation Chemistry in the United States, 1990, NADP/NTN Coordination Office, Fort Collins, CO, September 1991.

Aerochem Metrics, Inc. (1991). "Assembly and Operating Instructions , Aerochem Metrics Model 301 Automatic Sensing Wet/Dry Precipitation Collector," Aerochem Metrics, Inc., Bushnell, FL.

1.0 GENERAL DISCUSSION

1.1 Purpose of Procedure

The objectives of this standard operating procedure are to:

- Provide a basic understanding of the principles of operating a Belfort Model 5-780 Universal Rain Gage.
- Describe routine operation of the Belfort Model 5-780 Universal Rain Gage.

1.2 Measurement Principle

The Belfort Model 5-780 Universal Rain Gage is a weighing-type gage in which a weighing mechanism converts the weight of rainfall caught in a bucket through a circular, horizontal opening at the top of the gage into the vertical movement of a recording pen which makes an inked trace on a paper chart. The chart is graduated in inches of rainfall and is wrapped around a vertical cylinder which is rotated by a battery-powered chart drive.

1.3 Measurement Interferences and Their Minimization

Location of the rain gage directly affects measurement accuracy. In areas that are relatively open, nearby individual or small, isolated groups of objects may cause turbulence during windy conditions. This turbulence increases with increasing wind speeds and tends to carry precipitation away from the gage. To minimize the effect of turbulence, the distance between objects and the rain gage should be at least twice their height above the gage.

In areas with a large number of objects near the gage (rather than single objects or isolated groups of objects), their presence tends to reduce prevailing wind speeds, and thus the effects of air turbulence. Distance between objects and rain gage should be at least one half their height above the gage.

The opening of the gage must be horizontal. A carpenter's level is used during installation to assure the gage is level.

1.4 Ranges and Typical Values of Measurements

Precipitation amount and frequency varies widely over space and time. Some locations may rarely experience precipitation while others may have precipitation nearly every week during certain times of the year. Average annual precipitation ranges from 4 to 60 inches for most regions in the U.S.

1.5 Typical Lower Quantifiable Limits, Precision and Accuracy

The accuracy of the rain gage is 0.06 inches of precipitation (1/2 of 1% full scale) over a temperature range of -40° to 125° F. The sensitivity is 0.01 inches of precipitation and the chart timing accuracy is within 14 minutes per week.

1.6 Responsibilities of Personnel

All field technicians should read and understand the entire standard operating procedure before performing precipitation collection. The technician is expected to follow this procedure step by step to perform routine precipitation measurement. The field manager is responsible for ensuring that the rain gage procedures are properly followed, to examine all data and to deliver results to the project manager within the specified time period.

The quality assurance (QA) officer of DRI's Energy and Environmental Engineering Center (EEEC) is responsible for determining the extent and methods of quality assurance to be applied to each project, for estimating the level of effort involved in this quality assurance, for identifying the appropriate personnel to perform these QA tasks, for updating this procedure periodically, and for ascertaining that these tasks are budgeted and carried out as part of the performance on each contract.

1.7 Definitions

Not applicable

1.8 Related Procedures

DRI SOP 04 Operation of the Aerochem Metrics Model 301 Precipitation Collector.

2.0 APPARATUS, INSTRUMENTATION, REAGENTS, AND FORMS

2.1 Apparatus and Instrumentation

2.1.1 Description

The Belfort Model 5-780 Universal Rain Gage is a weighing-type gage in which a weighing mechanism converts the weight of precipitation into vertical movement of a recording pen which makes an inked trace on a rectangular paper chart. Figure 2-1 shows an example of a recorded chart. The chart is graduated in inches of rainfall and is wrapped around a vertical cylinder which is rotated by a battery-powered chart drive.

Precipitation coming through an eight inch diameter horizontal opening is caught in a bucket resting on a platform mounted to a vertically moveable bracket. The bracket is supported from the mechanism frame by a precision spring assembly. The movement of the bracket as the weight of collected precipitation compresses the spring is translated to movement of the recording pen by a connecting linkage. The capacity of the gage is reached after a double traverse of the pen on the chart; 0 - 6 inches from bottom to top, then 6 to 12 inches moving from top to bottom.

Limit screws prevent the recording pen from striking the chart cylinder flange or falling off the top of the chart cylinder when the bucket is removed or filled to capacity. The bottom of the movement bracket is linked to the piston of a damping device, a dashpot, to reduce pen arm vibrations due to wind gusts.

The gage is equipped with coarse and fine zero adjustments with which the pen may be set on the zero-line of the chart. Proper adjustment of the linkage mechanism provides a calibrated linear response of the pen to precipitation amount.

2.1.2 Characterization

Not applicable.

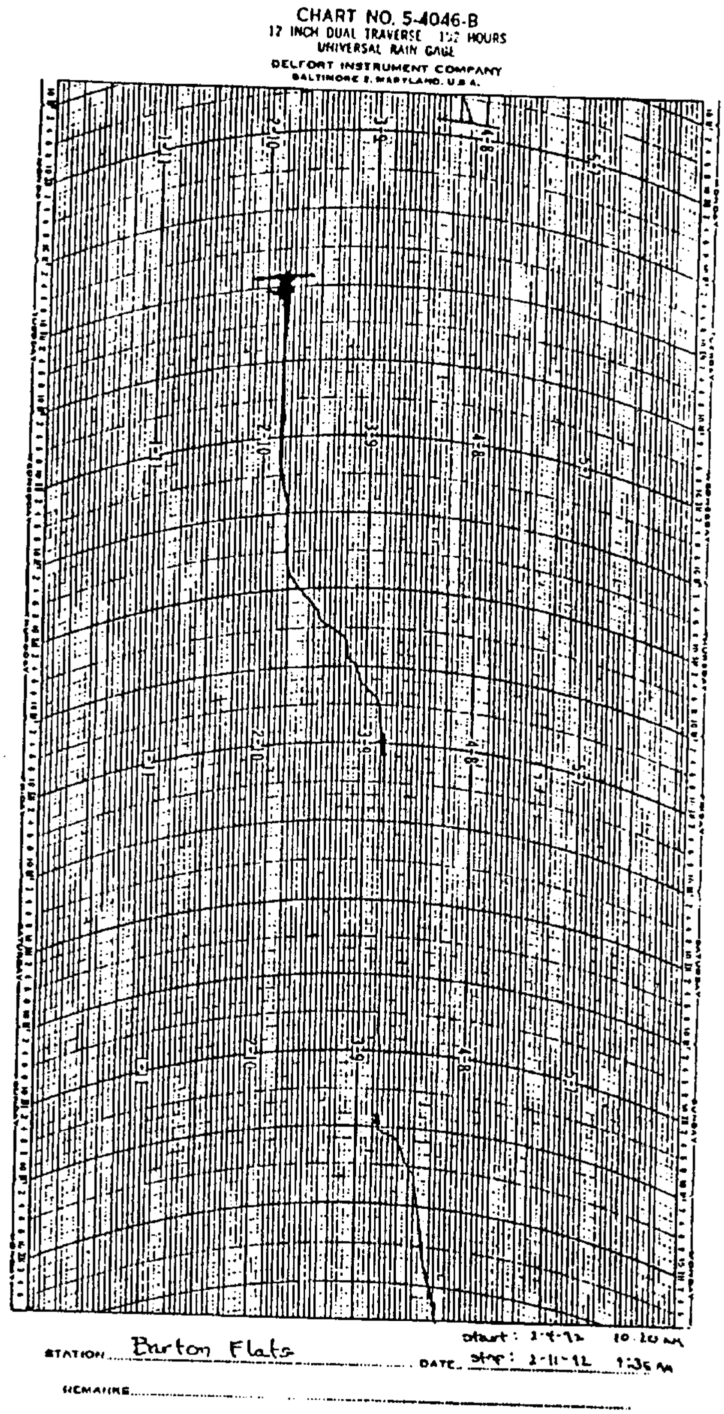

Figure 2-1. Example of completed rain gage chart.

2.1.3 Maintenance

Check the gage frequently to determine if any parts need servicing. Use the following procedures; refer to section 5 in the manufacturer's instruction manual (Belfort 1986a) for complete details.

- Clean the bucket thoroughly from time to time. Avoid accumulation of foreign matter with sufficient weight to prevent zero adjustment of the gage.
- Clean the pen; see sections 3.3, 3.4 and 3.5 in Belfort (1986b).
- Inspect the chart drive and if necessary service it. Never oil any other part of the gage. If the chart drive requires oiling, use a light machine oil only.
- Add silicone fluid, if necessary, to cover the piston when it is in its uppermost position (gage zero).
- Examine the weighing mechanism linkage for evidence of excessive friction. If corrections for this fault require significant disassembly or part replacement, recalibrate as described in Section 6 of Belfort (1986a).

2.1.4 Spare Parts List

See section 7 in Belfort (1986a).

2.2 Reagents and Supplies

Winterizing solution-	Two pints of ethylene glycol and three pints of methanol plus six ounces of 10W motor oil to retard evaporation.
Chart paper	12 inch dual traverse, 192 hour chart paper, Belfort no. 5-406-B
Chart ink	Belfort No. 5592 ink for temperatures above 0° F, Belfort No. 5593 for temperatures down to -60° F.
Batteries	2 each 1.5 volt size C dry cells.

2.3 Forms

Wet Deposition Measurement Form - Figure 2-2.

3.0 CALIBRATION STANDARDS

A set of a 12 "one-inch" calibration weights (822.7 g each) and a 1 kg bucket equivalent weight or equivalent.

Desert Research Institute
Energy and Environmental Engineering Center

WET DEPOSITION MEASUREMENT FORM

Site Name: Barton Flats ______ Field Technician: ______

Start Date (MM/DD/YY): __/__/__ Time (HH:MM): __:__ (00:00 - 24:00)
Stop Date (MM/DD/YY): __/__/__ Time (HH:MM): __:__ (00:00 - 24:00)
Dry Bucket Cleaned (Y/N)? ______ Sample ID:

RAIN GAUGE:

	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Week
Type (R,S,M,U)									Total
Amount (inches)	.	.	.	.	.	.	.	.	.

WET BUCKET: Rinse Blank (Y/N)? __ Volume DDW Added: ____ml
Bucket Weight (grams): Final - Initial = Net Graduated Cylinder
Volume: ____ ml
Inches of Precipitation (ml or grams X 0.0006) = ______

CONDUCTANCE (μs/cm):

	Temp (°C)	cv	X	k	=	C	C(t)
Bucket Rinse:							
DDW:							
Working Std:							
Sample:							

pH:
Calibration Std. (pH4): ______ (pH7): ______ Sample: ______

COMMENTS:

Figure 2-2. Wet deposition measurement form.

4.0 PROCEDURES

4.1 General Flow Diagram

Figure 4-1 shows a general flow diagram of routine operating procedures.

4.2 Start-Up

4.2.1 Installation

Install the rain gage on a secure footing such that the inlet of the gage is approximately on the same height as the top of the bucket on the Aerochem Metrics Model 301 Wet/Dry Precipitation Collector. Install in a location that minimizes precipitation loss due to turbulence (section 1.3). Consult section 3 of Belfort (1986a) for detailed instructions on mounting and installation.

4.2.2 Winterizing the Rain Gage

Protect the gage against damage from snow, ice and freezing at the beginning of the season when freezing temperatures may occur.

- Remove the funnel fixed to the bottom of the collector. Rotate the funnel until its bead clears the pens in the collector tube and lift off.
- Empty the catch bucket, replace it in the gage and add to it the winterizing solution.
- Do not make any adjustment to the gage after adding the winterizing solution; the gage will indicate a rainfall level of about 2-3/4 inches.
- Empty the catch bucket and recharge with fresh winterizing solution whenever the gage level rises above five inches.

Return the gage to normal configuration after the threat of freezing temperatures is past. Dispose of winterizing solution properly.

4.3 Routine Operation

Change the chart each week on Tuesday at 09:00 using the following steps. At the end of each month, return all charts and Wet Deposition Measurement Forms to DRI.

4.3.1 Remove Chart of Prior Week.

- Open the sliding access door, and make a short vertical mark (time-check) on the chart by lightly touching the bucket platform. If the chart drive has stopped, turn the chart cylinder slightly in both direction to mark the existing pen position. If the pen is not making a trace, indicate the pen position by a dot enclosed in a circle
- Lift the pen off the chart by moving the pen shifter.

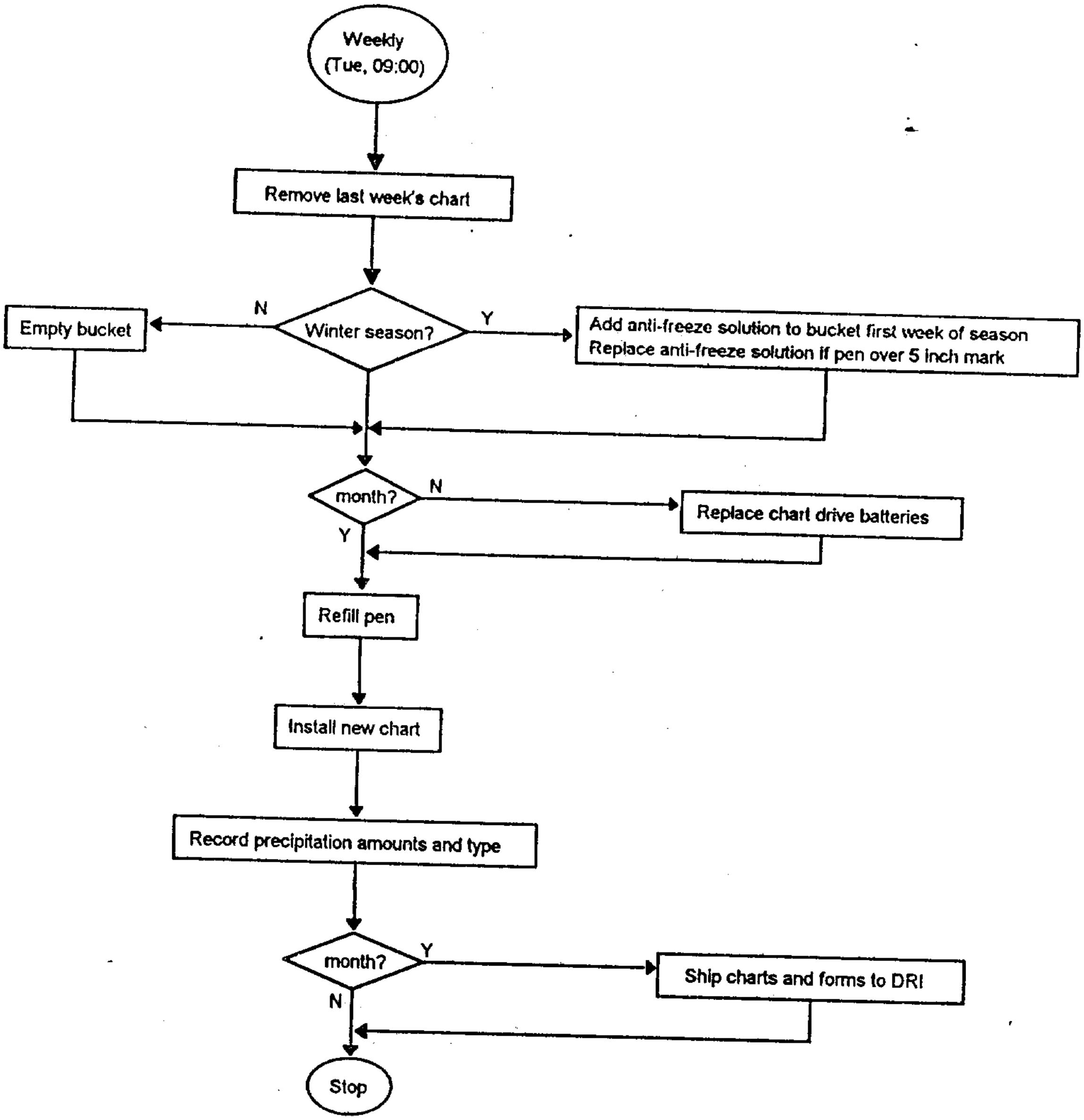

Figure 4-1. Rain gage routine operating procedure flow diagram.

- Remove the chart cylinder thumb-nut and remove the cylinder by lifting it up and off its spindle. Release the chart clip holding the chart and remove the chart. Note the date and time on the chart. Take care not to smudge the pen trace; allow the pen trace to dry completely before storing the chart.

- If the bucket has been winterized (section 4.2.2), remove the collector (top of the rain gage) and replace anti-freeze solution if the trace on the chart is greater than 5 inches. If the bucket has not been winterized, remove the collector and empty any accumulated precipitation from the catch bucket. Replace bucket and collector.

4.3.2 Install New Chart.

- Check to see if chart drive is ticking. Replace batteries every 4 to 6 weeks.

- Clean and refill the pen if necessary as detailed in sections 3.3, 3.4 and 3.5 of Belfort (1986b).

- Record site name, start date and standard time (not daylight time) on the chart in the spaces for station and date.

- Fold right hand tab with site name and date under back of chart and wrap chart snugly around cylinder so the folded end overlaps the blank end of the chart. Make sure that the bottom edge of the chart is against the cylinder flange all the way around the cylinder and that corresponding rainfall graduations meet. Also make sure that the crease in the fold is at the right-hand edge of both the notch in the upper edge of the cylinder and the slot in the cylinder flange.

- Clamp the chart to the cylinder by replacing the chart paper clip.

- Replace the chart cylinder and thumbnut on the chart drive spindle making certain that the mechanism pinion and cylinder gear mesh.

- Push in pen shifter to return pen almost to the chart surface. If the catch bucket is not winterized, and the pen does not indicate zero within 0.25 inches, set the pen to the zero line with the coarse and fine adjustment screws.

- Set chart to standard time by first turning the cylinder clockwise past the correct time and then returning it counterclockwise to the correct time. Be sure the time is correct in regards to AM or PM.

- Push the pen shifter all the way in. Lightly touch the bucket platform to make a time check on the chart. Close and latch the access door.

4.3.3 Record Precipitation Data.

Estimate precipitation for each day as the difference in pen trace height on the chart from midnight to midnight (except Tuesday) and record values on the Wet Deposition Measurement Form (Figure 2-2). There are two columns on the form for Tuesday; the first is for 09:00 to 24:00 at the beginning of the sample week and the second is for 00:00 to 09:00 at the end of the sample week. Estimate precipitation amounts to the nearest 0.01 inches. The chart has markings every 0.05 inches.

The chart may show a slight response of about 0.05 inches to change in temperature. Readings will increase slightly in midday the then drop back to earlier values. Ignore these periodic deviations in the pen trace.

Record the type of precipitation (rain, snow, mixed) for each day with the letter R, S or M, if known. Otherwise enter U for unknown.

5.0 CALIBRATION

See Section 6 of the Belfort (1986a) for step-by-step procedures to calibrate the rain gage.

6.0 QUALITY CONTROL

Quality control for this procedure is maintained by adherence to procedural steps that insure proper recording of precipitation.

7.0 QUALITY ASSURANCE

Periodic audits of the rain gage calibration provide quality assurance of precipitation measurement. In addition, precipitin values from the collocated wet/dry precipitin sampler provide comparison with an independent measurement method.

8.0 REFERENCES

Belfort (1986a). "Instruction Manual Catalog Number 5-780 Series Universal Recording Rain Gage," Instruction Manual Number 8777, December 15, 1986, Belfort Instrument Company, Baltimore, Maryland,.

Belfort (1986b). "Instruction Book for Chart Drive Mechanism," Book No. 12049, October 15, 1986, Belfort Instrument Company, Baltimore, Maryland,.

1.0 GENERAL DISCUSSION

1.1 Purpose of Procedure

This procedure describes the sampler configuration and instructions for operating the DRI MEDVOL particle sampler in four filter pack parallel mode. Suspended particulate matter in the 0 to 2.5 ($PM_{2.5}$) or 0 to 10 (PM_{10}) micrometer size ranges and gaseous species are collected on filter substrates which are subsequently analyzed for different chemical species. Up to four filter packs are collected simultaneously. Two sets of four filter packs can be collected sequentially between sample changes.

Filter media are chosen so that concentrations of mass, trace elements, ions, organic and elemental carbon, and gaseous nitric acid, ammonium, sulfur dioxide and nitrogen dioxide are collected and quantified by laboratory analyses.

1.2 Measurement Principle

The sampler can be fitted with either a $PM_{2.5}$ or a PM_{10} inlet. For the $PM_{2.5}$ inlet equipped sampler, particles larger than 2.5 micrometers in aerodynamic diameter are removed from the air stream with a Bendix 240 cyclone operating at a flow rate of 113 liters per minute (lpm). For the PM_{10} inlet equipped sampler, particles greater than 10 micrometers in aerodynamic diameter are removed from the air stream with a Sierra Andersen 254 size-selective PM_{10} inlet operating at a flow rate of 113 lpm. The $PM_{2.5}$ or PM_{10} sized aerosol is routed into a conical plenum. The conical shape of the plenum diffuses the airflow and minimizes particle deposition. Particles and gases are collected on open faced filter packs inserted in the base of the plenum. The filter packs are connected to pump vacuum through switchable solenoid valves. Flow rates are controlled by differential pressure regulators that maintain constant pressure across ball valves. A programmable timer activates two vacuum pumps and switches solenoid valves for sample collection. Up to twenty to thirty lpm of air flow are drawn through four filter packs simultaneously. The additional flow required to maintain the total flow rate of 113 lpm through the inlet is drawn through a makeup air tap in the base of plenum.

The base has thirteen filter holder ports. The sampler is configured to allow two sets of four filter packs to collect sequentially. A third set of four filter packs, through which no air is drawn, serve as field blanks. The final port is plugged with a blank filter holder. Three of the ports (one each for the first filter pack set, the second filter pack set, and the field blank set) are fitted with aluminum annular denuders to remove nitric acid. Each filter pack can contain up to 3 separate 47 mm diameter filter substrates which collect particles and gases for later analyses. The filter holders are made by Savillex of PFA Teflon to minimize their reaction with the sample and contain redesigned filter backing trays that reduced flow restriction and provide uniform deposition. Filters that are used include PTFE Teflon membranes (e. g., Gelman (Ann Arbor, MI) polyolefin ringed, 2.0 μm pore size, (#R2PJ047)) for gravimetric and x-ray fluorescence analysis); pre-fired quartz fiber filters (e. g., Pallflex (#2500QAOT-UP)) for soluble ion and carbon analyses, cellulose filters (e. g., Whatman 41) impregnated with K_2C0_3 to collect $S0_2$; with NaCl to collect volatile nitrates, and with TEA to collect $N0_2$; and nylon filters to collect volatile nitrate.

The sampler has a programmable timer that controls the sampling schedule. A possible sampling schedule for routine operations is one daytime and one nighttime sample on EPA's every-sixth day schedule. Table 1-1 presents the EPA sampling days for 1991 through 1994. Elapsed time

Table 1-1

Sampling Schedule for the EPA Particulate Network

1991 Sampling Dates

January 6 12 18 24 30	February 5 11 17 23	March 1 7 13 19 25	April 6 12 18 24 30
May 6 12 18 24 30	June 5 11 17 23 29	July 5 11 17 23 29	August 4 10 16 22 28
September 3 9 15 21 27	October 3 9 15 21 27	November 2 8 14 20 26	December 2 8 14 20 26

1992 Sampling Dates

January 1 7 13 19 25 31	February 6 12 18 24	March 1 7 13 19 25 31	April 6 12 18 24 30
May 6 12 18 24 30	June 5 11 17 23 29	July 5 11 17 23 29	August 4 10 16 22 28
September 3 9 15 21 27	October 3 9 15 21 27	November 2 8 14 20 26	December 2 8 14 20 26

Table 1-1 (continued)

Sampling Schedule for the EPA Particulate Network

1993 Sampling Dates

January	1	February	6	March	2	April	1
	7		12		8		7
	13		18		14		13
	19		24		20		19
	25				26		25
	31						
May	1	June	6	July	6	August	5
	7		12		12		11
	13		18		18		17
	19		24		24		23
	25		30		30		29
	31						
September	4	October	4	November	3	December	3
	10		10		9		9
	16		16		15		15
	22		22		21		21
	28		28		27		37

1994 Sampling Dates

January	2	February	1	March	3	April	2
	8		7		9		8
	14		13		15		14
	20		19		21		20
	26		25		27		26
May	2	June	1	July	1	August	6
	8		7		7		12
	14		13		13		18
	20		19		19		24
	26		25		25		30
					31		
September	5	October	5	November	4	December	4
	11		11		10		10
	17		17		16		16
	23		23		22		22
	29		29		28		28

indicators (ETI) measure the duration of each sample. A pressure-activated switch is included to turn the ETI's off if vacuum is lost in the flow system because of pump or other component failure.

1.3 Measurement Interferences

1.3.1 Passive Deposition

Passive deposition occurs when particles deposit on and gases are absorbed by filters prior to and after sampling. Field blanks are used to quantify this bias, which is usually less than 30 μg of particle mass per filter.

1.3.2 Inlet Loading and Re-entrainment

Material collected in the size-selective inlet can become re-entrained in the sample flow. The inlets are cleaned semi-annually to minimize overloading and re-entrainment.

1.3.3 Pump Exhaust Recirculation

Recirculation occurs when the pump exhaust, which contains carbon and copper particles from the pump vanes and motor armature, is entrained in the sampled air. Recirculation is minimized by re-conditioning the pumps annually, filtering exhausted air with a total filter, and locating pump exhaust inside an enclosure over one meter below the sampling inlet. Exhaust filters are replaced regularly. When the pumps are new or when the vanes are replaced, the pumps are allowed to run for 24-hours without a load to break-in the vanes and lessen the subsequent wear on the vanes.

1.3.4 Particle Volatilization

Ammonium nitrate can dissociate and the particulate nitrate can escape as nitric acid gas. This effect can be quantified by placing a nylon backup filter behind a quartz filter to absorb volatilized nitric acid. The PFA Teflon Savillex filter holder has been shown to be inert to nitric acid absorption and can accommodate multiple filters. Filters are unloaded and kept under refrigeration after sampling to minimize long-term volatilization.

1.3.5 Filter Gas Absorption

Quartz fiber filters have been shown to absorb significant quantities of organic vapors which are measured as organic particulate carbon. A quartz backup filter can be placed behind the Teflon filter to quantify this artifact and to allow for its subtraction, if it is deemed necessary. The Savillex filter holder can accommodate such a stack. Quartz fiber filters have been shown to absorb insignificant amounts of sulfur dioxide, nitric acid, and nitrogen oxides. Nitric acid absorbed by nylon or NaCl-impregnated filters will appear as nitrate in the analysis. An aluminum annular denuder removes gaseous nitric acid.

1.3.6 Filter Integrity and Contamination

Filter integrity is compromised by handling which causes pieces of the filter to be lost after the pre-exposure weighing. Filter contamination results from material other than sampled aerosol being deposited on the filter (e.g. fingerprints, dirt). The effects of filter material losses are minimized by performing gravimetric analysis on Teflon membrane filters which are less friable than the quartz fiber filters. Filter material losses and contamination are minimized by the placement and removal of filters to and from filter holders in controlled laboratory conditions. Gloved hands and forceps are used in this filter processing. Spare, loaded filter holders are provided in the field to remove the need for field loading and unloading. Each filter holder is separately sealed prior to and after sampling. Batches of filters are inspected and submitted to chemical analysis prior to use to assure that they meet adequate standards when received from the manufacturer.

1.3.7 Particle Loss During Transport

Coarse particles (greater than 2.5 μm) have been found to be shaken from filters during transport on heavily loaded filters. Flow rates are adjusted to minimize overloading of filters. Loss of $PM_{2.5}$ particles is insignificant.

1.3.8 Transmission Losses

The necessity of particles to pass through a size-selective inlet could result in particle losses. Distances between the inlet and the filter surfaces have been minimized to reduce these potential losses, and airflow paths have been designed to minimize the chance of particle impaction.

Nitric acid reacts with most surfaces other than Teflon and glass. All sampling surfaces of the $PM_{2.5}$ sampler, including the inlet, cyclone, bug screen and plenum are coated with PTFA Teflon to minimize nitric acid loss. Teflon tubing connects the two halves of the inlet; filter holder parts that contact sampled air are constructed of Teflon.

1.4 Ranges and Typical Values

The range of concentrations measured by this method depends on local air quality conditions. For mass, the concentration range is typically 5 to 300 $\mu g/m^3$.

1.5 Typical Lower Quantifiable Limits, Precision, and Accuracy

Lower quantifiable limits and precision are species dependent, and are determined by the sensitivity of the analysis method and the variability of field blank concentrations. The mass lower quantifiable limit is about 1 $\mu g/m^3$. Mass precision is approximately $\pm$ 5% relative, for mass concentrations which exceed ten times the lower quantifiable limit. Accuracy is generally $\pm$ 10% relative, for mass determinations.

1.6 Responsibilities

The field technician is responsible for carrying out this standard operating procedure and for the completion and submission of all documents. The field operations supervisor is responsible for scheduling the field technician's visits, reviewing documentation, identifying and reviewing deficiencies, and receiving samples from and transmitting samples to the laboratory. The laboratory supervisor is responsible for preparing filter substrates, transmitting them to the field, and receiving them from the field.

1.7 Definitions

DRI MEDVOL	The entire sampling unit.
PM_{10} Inlet	Sierra Andersen 254 size-selective inlet.
$PM_{2.5}$ Inlet	Two metal cylindrical containers, both open on the bottom, held side by side with brackets. Containers are connected with an inverted "U" shaped Teflon tube through openings in the container tops. One container has a bug screen mounted on the bottom and a Bendix 240 cyclone inside. The other container mounts on top of the plenum.
Plenum	The conical chamber into which filter holders are inserted.
DDW	Distilled, deionized water.

1.8 Related Procedures

This standard operating procedure covers all aspects of sampler operation.

Rotameter calibration is covered in SOP 2-210.1: "CADMP Sampler: Calibration of Flow Meters" dated 2nd quarter 1990.

Siting criteria are contained in "Quality Assurance Handbook for Air Pollution Measurement Systems. Volume II. Ambient Air Specific Methods", section 2.0.2.

Filter pack preparation is covered in DRI 18: "Filter Pack Assembly, Disassembly, and Cleaning Procedure."

2.0 APPARATUS, INSTRUMENTATION, SUPPLIES, AND FORMS

2.1 Apparatus and Instrumentation

2.1.1 DRI MEDVOL Particle Sampler.

The sampler is pictured in Figure 2-1. Air enters the inlet, and flows into the conical plenum where filter holders are inserted into the base. Annular aluminum nitric acid denuders, not shown in the drawing, extend below the plenum base for three ports. The air flows through four of eight possible filter packs, then through open solenoid valves, differential pressure flow controllers, ball valves, and flow rate indicator orifices to one of

two GAST 1022/1023 carbon vane pumps. These pumps have sufficient capacity to pull up to 30 lpm through most filter packs and enough additional flow through the makeup air port to produce a total flow rate of 113 lpm.

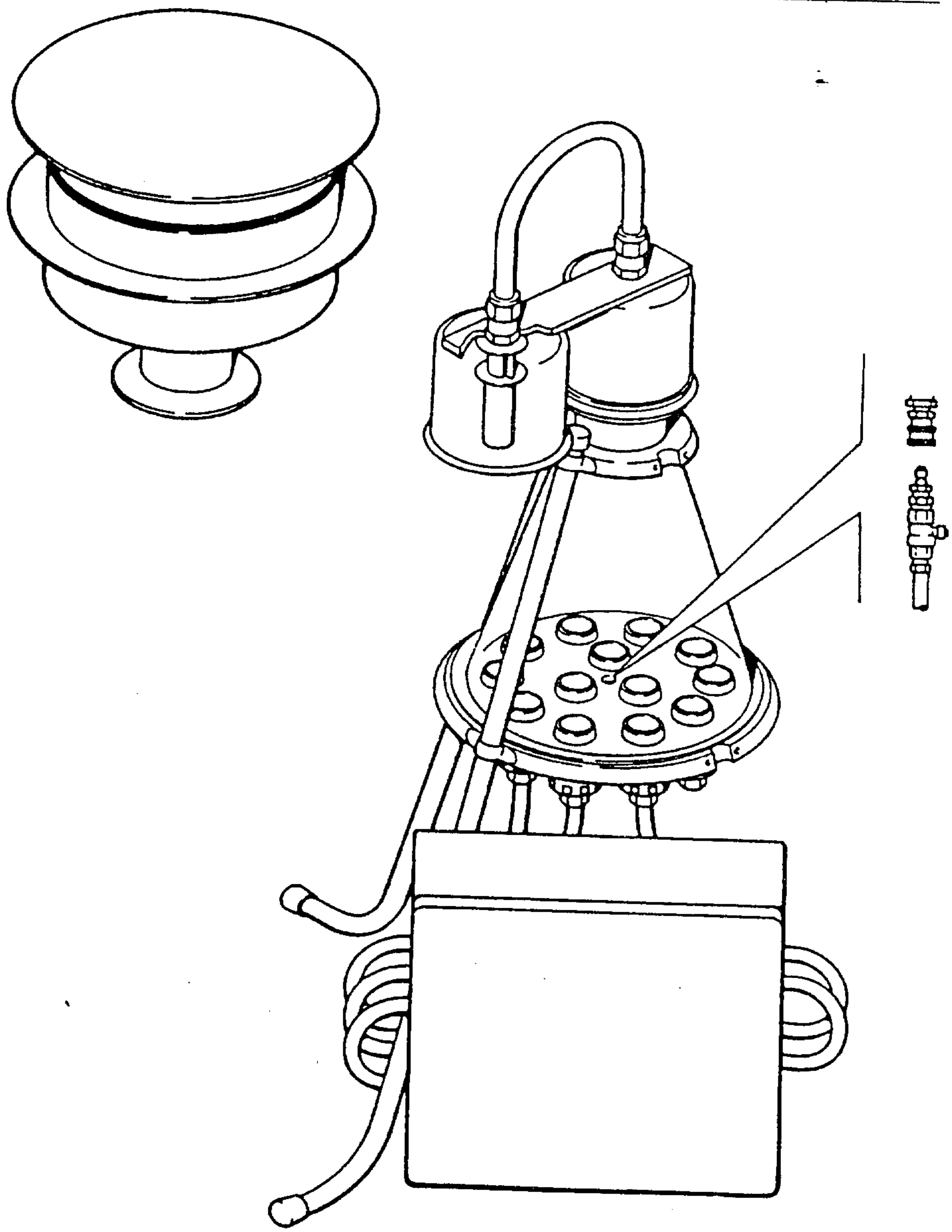

Figure 2-1. Schematic of DRI MEDVOL Particle Sampler

The differential pressure flow controllers maintain constant pressure, and therefore a constant flow rate, across ball valves for the sampling ports containing filters. This is needed because of the increased resistance caused by filter loading during sampling. As the filter loads up, the pressure drop across this valve decreases which sends a signal to the valve to open further and allow more air to pass. This then equalizes the pressure across the valve.

Magnehelic differential pressure meters are connected across the inline orifices and, when calibrated against flow rate, are used to indicate the flow rate through the filter packs. The makeup flow rate is controlled by a ball valve and also has a Magnehelic across an inline orifice for a flow rate indicator. Table 2-1 lists each component of the sampler and its function. Literature describing the timer, differential pressure regulator, Magnehelics, and pumps are attached to this procedure.

2.1.2 Savillex Filter Holders.

The filter holders are open faced and accommodate 47 mm diameter filters. Figure 2-2 shows an example of the filter holder and the placement of filters in them. Labels with ID numbers for the filters are attached to the filter holders when the filters are loaded. Plugs for the holders are provided to block the flow when holders are not used.

2.1.3 Dwyer 0 to 100 SCFH Rotameter

This rotameter is used to set and verify flow rates through the filter packs. It is fitted with Tygon tubing and a number 9.5 rubber stopper adapter that fits into filter holder receptacle.

2.1.4 Dwyer 0 to 400 SCFH rotameter.

This rotameter is used to measure the makeup air flow rate and to verify the total flow rate into the inlet.

2.1.5 Dwyer 0 to 5 lpm rotameter.

This rotameter is used to set and verify flow rate through the filter pack used to collect NO_2.

2.1.6 Total Flow Adapter.

This adapter is placed on the conical plenum in place of the inlet to verify the total flow rate and check for leaks.

2.2 Maintenance

2.2.1 Change Pump Exhaust Filters

For pumps with the glass jar filters, change the fiber exhaust filter once a quarter. Unscrew the glass jar enclosing the exhaust filter. Grasp the filter (work gloves may be desirable to avoid fiber slivers in the hands), pull downward slightly and unscrew the

Table 2-1

Components of the MEDVOL PM_{10} / Gas and $PM_{2.5}$ / Gas Sampling Systems

Code	Part Name	Specification and Rationale
1	PM_{10} Inlet	Sierra Anderson SA-254 medium volume PM_{10} Inlet, provides a 50% size cut of 10 μm at a flow rate of 113 lpm. This is the only medium volume inlet which is commercially available.
2	$PM_{2.5}$ Inlet	Two cylindrical containers connected by a Teflon tube. First container holds Bendix 240 cyclone separator. Second container mounts to plenum. This inlet provides a 50% size cut of 2.5 μm at a flow rate of 113 lpm. All internal surfaces coated with Teflon.
3	Inlet Connection	Gasket seal with clamp connects $PM_{2.5}$ or PM_{10} inlet to plenum.
4	Plenum and Base	Spun aluminum cone welded to inlet flange attached to removable base of machined aluminum with internal o-rings to allow press fit of Savillex filter holders into base. All internal surfaces coated with Teflon.
5	PFA Teflon Injection Molded Filter Holder with ferrule nut	Savillex 47 mm diameter three stage PFA Teflon Molded Filter Holders (Catalog #6T-47-6T) with 3/8" tubing and 3" long open face receptacle (Catalog #4750). The only Teflon/stacked filter holder available within the U.S. Support grids have been modified to provide homogeneous porosity. Open face needed for uniform deposit on filter.
6	Vinyl Tubing	3/8" O.D. vinyl tubing connects Savillex holders to vacuum manifolds. 1/2" O.D. vinyl tubing connects makeup flow fitting to vacuum manifold. 1/4" O.D. vinyl tubing connects orifices to Magnehelic pressure gauges.
7	Solenoid Valves	Skinner Electric Valves, model V52DA 3012. One solenoid valve for each filter flow path.
8	In-line Orifice	Custom built, stainless steel. This orifice creates a small pressure drop which is measured by Magnehelic pressure gauge to monitor flow rate.
9	Differential Pressure Gauge	Dwyer Magnehelic Low Pressure o to 5 inches H_2O Pressure Differential gauge. Used to measure pressure drop across orifice for flow rate measurement. One Magnehelic for ports 1 and 2, one for ports 4 and 5, one for ports 7 and 8, one for ports 10 and 11, and one for makeup flow port.
10	Differential Pressure Regulator	Conoflow Regulator & Controls, GH21XTXM series fixed differential regulators. Maintains a fixed differential pressure across a valve downstream from the regulator.
11	Ball Valve	Red-White 3/8" stainless steel ball with brass body. This valve is adjusted to set flow rates at desired values for filters and makeup.
12	Legs	Four legs to obtain necessary inlet height
13	Control Box	Contains flow distribution, flow rate setting, and timing mechanisms.

Table 2-1 (continued)

Components of the MEDVOL PM_{10} / Gas and $PM_{2.5}$ / Gas Sampling Systems

Code	Part Name	Specification and Rationale
14	Elapsed Time Indicator	Cramer Elapsed Time Indicator. Minute meter with 0.1 minutes resolution (Catalog #35F3803) type 10184K/115 A.C., 6 figures, non reset, rectangular shape. Monitors sample duration.
15	Relay	Square D A.C. Control Relay, DPST-2NO 10 AMP at 277 VAC/ 5 AMP at 600 VAC, Coil 120 V/60 Hz. Turns pumps on.
16	Timer	Grasslin model Digi 56-72. A programmable 2 channel microprocessor-based controller with program storage. This timer controls sample start and stop times and channel switching.
17	Pressure Sensor	Micro Pneumatic Logic, MPL-533, pressure sensor switch to turn Elapsed Time Indicators off if pump or vacuum lines fail.
18	Pump	GAST 1023 carbon vane pump, 3/4 HP. Pumps pull 25" vacuum, applicable for 113 lpm sampling flow rate.
19	Absolute Filter	Whatman HEPACAP 75. VWR #28137-886 Capsule Filter. Installed on exhaust port of carbon vane pump. Prevents exhaust recirculation.
20	Internal Filter	GAST 1023 has internal filters in inlet and exhaust, #AK524.
21	Pump Kit	Service kit for GAST 1023, #K479, contains vanes, gasket, and two internal filters.
22	Pump Enclosure	Mail box protects pumps from exposure.
23	Fan	Installed in pump enclosure to facilitate cooling.

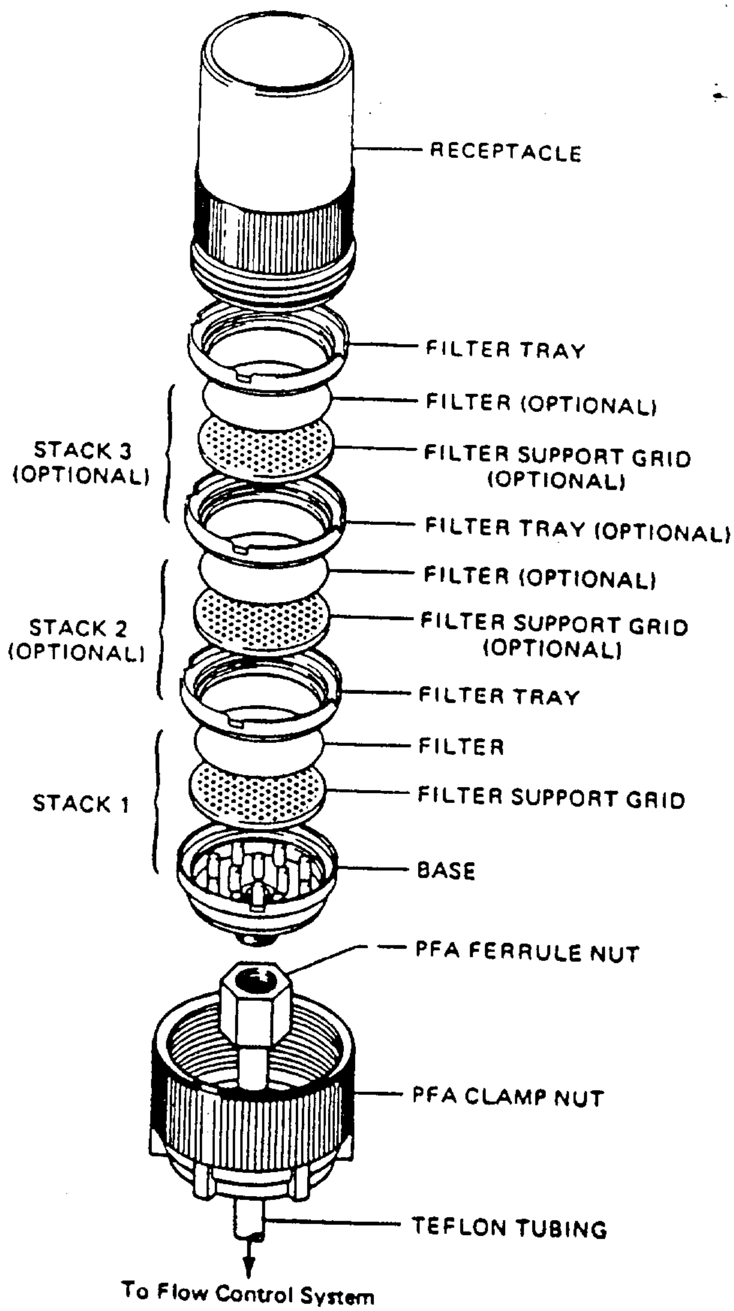

Figure 2-2. Exploded View of Savillex Filter Holder

bottom filter retainer plate. Insert a new filter and finger-tighten the retaining plate. Wipe residue from the glass jar and replace. Change inlet filter once a year. For pumps with cartridge exhaust filters, change the filter once every six months.

2.2.2 Clean PM_{10} Inlet

Clean inlet every six months. Remove the Sierra Andersen 254 inlet by loosening the collar and pulling it off. Wipe out the inside of the plenum with a DDW dampened Kimwipe until all soil is removed. Dry it with a clean Kimwipe. Disassemble the inlet by removing the center screw and pulling the top off. Remove the impaction jets by removing the hold-down screws and pulling it out. Earlier versions of this inlet were sealed with silicon sealer. Cut this sealer with a utility knife to remove it. Place flat door insulation around the inside mounting ring when replacing the impactor jets, as this is what has been done with more recent versions of this inlet. With the impaction jets removed, wipe the impaction surface and inside of the inlet with a DDW dampened Kimwipe until all dirt is removed. Scrub out the inside of the impactor jets with a tubular brush (like a test tube brush). Dry all surfaces with clean Kimwipes. If soiling is still observed on the Kimwipes, the inlet is not yet clean.

2.2.3 Clean $PM_{2.5}$ Inlet

Clean inlet every six months. Remove the $PM_{2.5}$ inlet assembly from the top of the plenum by loosening the collar and pulling it off. Remove bug screen and cyclone from inlet, taking care not to scratch Teflon coating. Clean inside surfaces of both inlet containers with DDW dampened Kimwipes, and dry with a clean Kimwipe. Clean Teflon tube by rinsing with DDW and dry by pushing a small piece of Kimwipe through with a section of smaller diameter Teflon tubing. Install new cyclone that was cleaned and greased at the laboratory. Make sure the connecting nut holds the cyclone tightly, and that the cyclone has a cap on the bottom. Install bug screen.

2.2.4 Clean Plenum

Clean plenum every six months. Wipe out the inside of the plenum with DDW dampened Kimwipes until all soil has been removed. Dry it with a clean Kimwipe.

2.2.5 Change "O"-Rings in Filter Ports

Replace the "O"-rings in the filter ports of the plenum base annually. Remove each "O"-ring with a small pointed object, taking care not to scratch the "O"-ring groove in the sampler , and install a new "O"-ring making sure it is in groove all the way and not twisted. In addition to the annual schedule, replace the "O"-rings if they become hard or cracked or if filter holders become loose in their ports

2.3 Supplies

Kimwipes	Large size, to clean inlets and plenum.
DDW	To clean inlets.

Pump Exhaust Filters	GAST #A393 cylindrical exhaust filters or Gelman capsule filter #12116.
"O" Rings	To seal and hold filter packs in plenum base.

2.4 Forms

The data sheet for recording field data is shown in Figure 2-3.

3.0 CALIBRATION STANDARDS

The transfer standards for flow rates are the rotameters specified in section 2.1. They are all calibrated before use against a positive displacement Roots meter, model 1.5M125, serial number 8623119. Elapsed time indicators are checked against a stopwatch that has been checked against WWV time.

4.0 SAMPLER OPERATION

4.1 Flow Diagram

Figure 4-1 summarizes the routine operating procedure for the DRI MEDVOL. For routine sampling, samples are normally changed every sixth day. Flow rate checks and a leak check are made monthly to track sampler performance. Exhaust filters are changed every quarter or six months (depending on type). Every six months, the inlet and plenum are cleaned and a cleaned and regreased cyclone is installed.

4.2 Sampler Installation and Start Up

4.2.1 Installation

Sampler location should follow EPA siting criteria for particulate sampling. The height of the inlet should be 2 to 15 meters above the ground. The distance to horizontal obstacles should be greater than 2 meters and should be at least twice the height that the obstacle protrudes above the sampler. The sampler should be more than 20 meters from trees. There should be unrestricted air flow through 270° around the sampler. No furnace or incinerator flues should be nearby to cause undue influences from minor pollutant sources. A site survey of within 100 meters of the sampling site should be made to determine heights of obstacles along with their distances and directions relative to the sampler. Nearby sources should be documented.

The MEDVOL sampler should be installed on a wooden platform, if possible. The sampler requires one square meter of space for itself along with a work area space of one square meter in front, one square meter to the rear and one square meter to at least one side. The inlet should be separated from the inlets of other samplers by a distance of at least two meters. Make sure inside of plenum and base plate are clean. Place large "O"-ring in groove in base plate and attach plenum to plate. Install small "O"-rings in grooves that are in the holes in the base plate. Attach four legs loosely to plenum with metal conduit straps.

DRI Sequential Filter Sampler Field Data Sheet

Network Name: ____________ Sampler ID: ____________ Date Shipped from DRI: ____________ By: ______
Site Name (code): ____________ Technician: ____________ Date Shipped to DRI: ____________ By: ______
Date Received at DRI: ____________ By: ______

Filter ID	Port ID	Particle Size[a]	Sampling Date (YYMMDD)	Sampling[b] Period HHMM to HHMM	Elapsed Time (min)		ΔTime(min)	Flow Rate (SCFH)[c]		Flags	Comments
					Start	End		Initial	Final		

[a] Particle Size: Use T for PM_{10}, F for $PM_{2.5}$, and C for $PM_{2.5}$ to PM_{10}
[b] Sampling Period: Circle time zone: Pacific (PST, PDT), Mountain (MST, MDT), Eastern (EST, EDT)
[c] Flow rate: Rotameter reading in Standard Cubic Feet per Hour (SCFH)

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Figure 2-3. Example of Data Sheet for Recording Field Data.

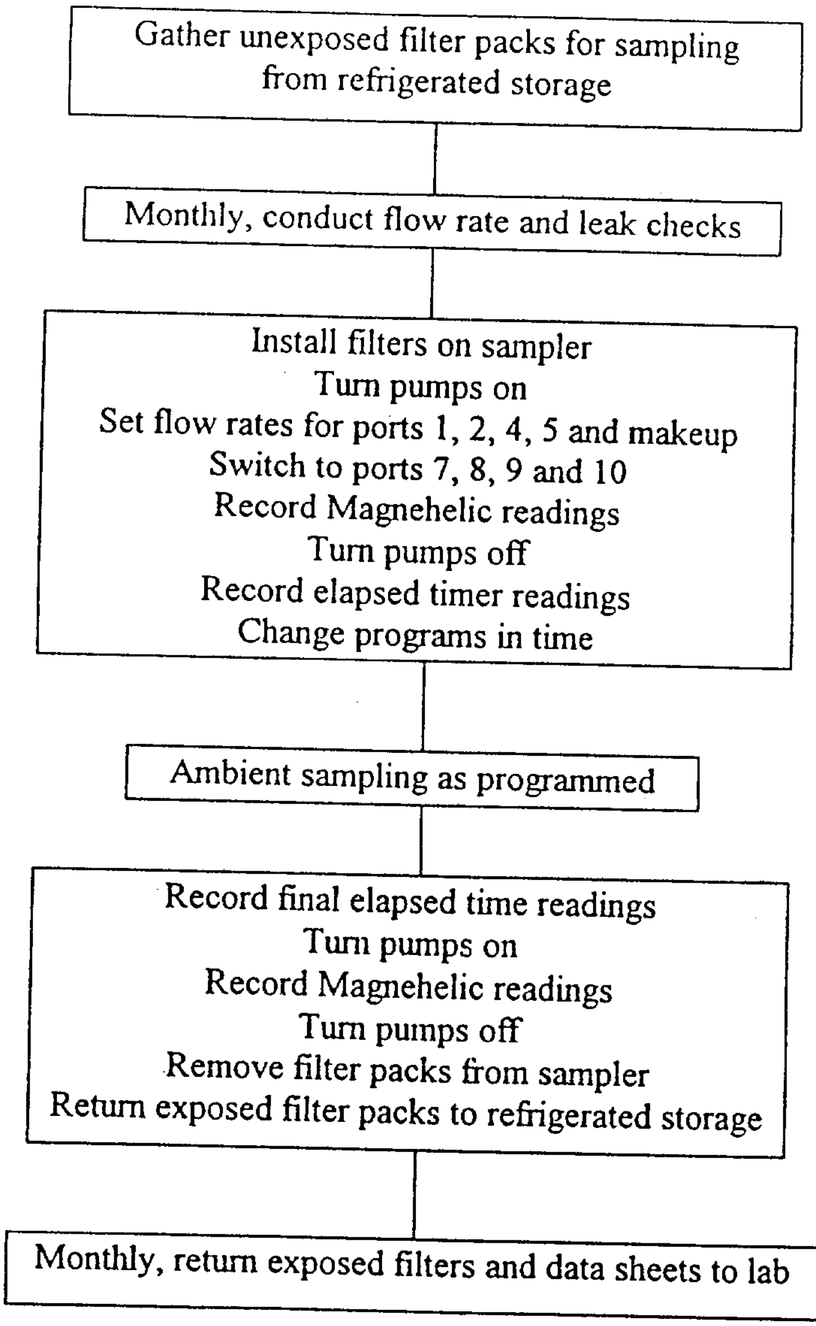


Figure 4-1. Flow Diagram for Routine Operations

Secure the four legs of the sampler to the platform with similar metal straps. Even legs on plenum so that base is horizontal and tighten straps.

Attach control box to two of legs. If external tubing has not been attached, attach 3/8 inch ID soft plastic tubing to solenoid valves on both sides of control box by passing tubing through holes in sides of box. Solenoids 1 - 6 are on the right-hand side while 7 - 12 are on the left-hand side. Secure plastic tubing with hose clamps. Insert three inch-long, 3/8 inch-diameter hard plastic tubes in ends of soft plastic tubing and secure with hose clamps. Score exposed ends of hard tubes with 3/8 inch scoring tool and insert into filter holder nuts. The nuts will stay with the sampler, not the filter holders.

Attach 3/8 inch ID flexible plastic tubing to makeup air flow line through left-hand side of control box. Attach quick disconnect fitting to tubing.

Place a Teflon plug on five empty filter holders and install one in the number 13 port and the others in the field blank ports 3, 6, 9 and 12. If a full complement of filter holders will not be used, place plugs on as many holders as necessary and install in base plate.

For PM_{10} sampler, check that Sierra Andersen model 254 size selective inlet is clean. If necessary, clean inlet following instructions in section 2.2.2. Place inlet on top of flange on plenum with gasket in between and attach clamp.

For $PM_{2.5}$ sampler, place 1/2 inch Swagelock bulkhead fitting on end of a cleaned and greased cyclone using a nylon ferrule. Install bulkhead fitting through bottom of one of the two inverted Teflon coated containers with cyclone inside. This chamber acts to still the air entering the cyclone. Install a second bulk head connector through the hole in the bottom of the second container with a piece of gasket material around the connector. Attach a 1/2 inch Teflon tube to the two bulk head connectors. Place red end cap on cyclone. Place screen over stilling chamber and attach with small screws. The screen will prevent large bugs from entering the sampler. Place gasket on top of flange on plenum, place second container (the one without cyclone) on gasket and secure with clamp.

Under high wind conditions, it may be necessary to guy the inlets to the platform to prevent their being blown over.

Place the pumps below and as far away from the sampling inlet as possible. Even though the pump exhaust is filtered, it is good practice to have it removed from the sample inlet. If possible, place the pumps underneath the platform. This may require increased length of tubing and electrical cord. Attach 1/2 inch braided plastic tubing to exhaust of sampler and inlet of pump. Plug electrical cords from pump boxes into receptacles on sides of control box. Plug power cord from sampler into 110 VAC power. The sampler requires two separate 15 amp circuits. Turn power switch in control box on.

4.2.2 Set Time on Timer

The time for the sampler is generally Local Standard Time and should remain so throughout the year. The time should be set using a watch known to be accurate to ±5 minutes as determined from WWV radio or other means.

If circumstances require the use of Daylight Time, pushing a small pointed object into the hole marked "±1 hr" will add or subtract an hour on the display. Pushing once will add an hour to obtain Daylight Time. Pushing a second time will subtract an hour to return to Standard Time.

To set the time, hold "Set Time" button in while performing the following operations:

1. Push day of week button so that LCD bar is above the proper day.
2. Push h+ (or h-) button until proper hour is shown (including AM or PM).
3. Push m+ (or m-) button until one minute more than current time is shown.
4. Release "Set Time" button when minute on watch changes to next value.

The clock will start running when "Set Time" button is released. The current time should be verified on each site visit and re-set if it is not within five minutes of watch time. A built-in rechargeable NiCd battery will maintain the correct time for up to 100 hours in the event of a power outage.

4.2.3 Set Flow Rates.

Follow the calibration procedure described in section 5 to set flow rates for 20 to 30 lpm (as specified by the field operations supervisor) for filters and the appropriate value for a makeup flow rate to total 113 lpm.

4.2.4 Check for Leaks.

Remove inlet from plenum and insert the total flow adapter in the top of the plenum. Insert filter holders containing test filters into all open ports in the base of the plenum and connect all sample tubes. Turn on pumps and adjust Magnehelics to their calibrated setpoints determined in section 5. Turn off pumps, attach the 0 to 400 SCFH rotameter to the total flow adapter at inlet of plenum, turn pumps on, and measure total flow rate into plenum. The flow rate through the total flow adapter and the sum of the flow rates through all filter packs plus makeup air port should agree to within five lpm. If they do not, then there are excessive leaks in the sampler which must be identified and eliminated. These can occur 1) where the filter holders insert into the plenum, 2) through the filter holders, 3) through the solenoids and manifolds, 4) through any of the tubing and connections up to the valves, or 5) where the rotameter adapter is connected to the plenum. Record the results of the test in the station log and flow calibration sheet.

4.2.5 Program Timer

The timer has two channels. Channel 1 turns the pumps on and off. Channel 2 switches the solenoid valves in sequence. Both channels can be turned on and off manually by pushing the respective "OVERRIDE" button. To manually switch solenoid valves using Channel 2, it is necessary to pause several seconds after turning the channel off before turning it back on. Always return Channel 2 to off by pressing "OVERRIDE" again after changing solenoid valves. All operations require two programs: the first to turn a channel on and the second to turn it off. All sets of programs are entered in the following manner:

Program 1:

1. Push timer button corresponding to day that sample will start.

2. Push +h (or -h) to display starting hour. Make sure AM or PM is correct.

3. Push +m (or -m) to display starting minute.

4. Push I/O button once to display a bar below I (for ON) for desired channel.

5. Push "WRITE" to save this program.

Program 2:

6. Push timer button corresponding to day that sample will end.

7. Push +h (or -h) to display ending hour. Make sure AM or PM is correct.

8. Push +m (or -m) to display ending minute.

9. Push I/O button twice to display a bar below O (for OFF) for desired channel.

10. Push "WRITE" to save this program.

4.2.5.1 To review programs

First push "SET TIME" to return current time display. Then push "READ" to display first stored program. Each subsequent push of "READ" displays another program until all have been displayed. All programs should be reviewed each site visit and particularly after any programs are added, modified, or deleted.

4.2.5.2 To change a program

First display program to change by pushing "READ". Then enter desired change. Note that to change day, the button for the old day has to be pushed to remove the bar for that day. After the new day and time are displayed, push "WRITE" to save the new program. Both the original program and the changed program are now in memory. Delete the original program (see below) if it is no longer needed. To produce a series of similar programs, make changes to the original program as described above, without deleting original program, and repeat until all programs have been changed. All changes should be reviewed.

4.2.5.3 To delete a program

First display the program to delete by pushing "READ". Then press the "CANCEL" button to delete the program. Full programming instructions are appended to these procedures.

4.2.5.4 Routine Programs

For routine sampling on the EPA six-day schedule with 24-hour samples, the sequencing feature would generally not be used. Since exposed filters should be removed as soon after the sample as possible to reduce losses of volatile components, only one set of filters should be installed on the sampler at one time. It is only necessary to turn channel 1 (pump) on and off at the desired times while leaving solenoids for ports 1, 2, 4 and 5 open. Channel 1 is turned on at 00:00 beginning the EPA sampling day and off twenty-four hours later. The steps on the timer are as follows:

Step	Time	Day	Channel	Operation	Description
1	00:00A	EPA Sampling Day	1	I	Pump On
2	00:00A	EPA Day + 1	1	O	Pump Off

Note: Filters are loaded in ports 1, 2, 4 and 5. Stepper switch is left on 1, 2, 4 and 5.

For more frequent sampling, the sequencing feature will likely be used. As an example, consider a sample schedule with daytime (06:00 to 18:00) and nighttime samples (18:00 to 06:00 next day) every third day (to include EPA sampling day). The sampler would be loaded with two sets of four filter packs (three sets if a field blank is collected). The sampler stepper switch should be left on sample ports 1, 2, 4 and 5 before the first sample. At the end of sampling, the stepper switch will be on ports 7, 8, 10 and 11. The steps on the timer are as follows:

Step	Time	Day	Channel	Operation	Description
1	06:00A	EPA Sampling Day or EPA Day + 3	1	I	Pump On
2	06:00A	EPA Day + 1 or EPA Day + 4	1	O	Pump Off
3	06:00P	EPA Sampling Day or EPA Day + 3	2	I	Switch sampling ports from 1, 2, 4 and 5 to 7, 8, 9 and 10
4	06:01P	EPA Sampling Day or EPA Day + 3	2	O	Turn stepper switch solenoid off

Note: Filters are loaded in ports 1, 2, 4 and 5 (daytime), 7, 8, 10 and 11 (nighttime), and 3, 6, 9 and 12 (field blank). Before sampling, stepper switch is left on ports 1, 2, 4 and 5.

For studies that do not sample the same day(s) each week, it is more convenient to store programs needed for the first set of samples, as shown above, then change timer day for subsequent sample runs than to change all programs in the timer to a new day.

4.2.5.5 Non-Routine or Intensive Programs

The actual timer instructions for intensive sampling will depend on the design of the study. In general, all sampling ports will be used while the pump will run continuously.

4.3 Sampler Operations

The normal operation of the MEDVOL sampler consists of installing and removing filters, checking flow rate indicators before and after sampling, recording the elapsed time readings, and performing periodic flow rate checks. Samples are delivered to the site or site operator with field data sheets that specify sample IDs and sampling date and time.

Remove filters as soon after sampling as possible to reduce loses of volatile species such as ammonium nitrate and some organic carbon compounds. After removal, refrigerate the samples until they are analyzed to reduce loses. In some programs, it is desirable to install filters the day before sampling and to remove them the day after sampling. The installation and removal procedures are detailed in the following sections.

Manual control of the vacuum pumps and solenoids during sample loading and unloading is accomplished by pressing the "OVERRIDE" buttons on the timer for Channel 1 and Channel 2, respectively. When selecting solenoids, always observe the following instructions: 1) to manually switch solenoid valves using Channel 2, pause several seconds after turning the channel off before turning it back on, and 2) always return Channel 2 to off by pressing "OVERRIDE" again after switching the solenoid valves.

4.3.1 Installation of Filters

4.3.1.1 Check Timer

Open control panel door and compare time on timer to time on accurate watch. Reset time if error is more than five minutes.

4.3.1.2 Inspect Unexposed Filters.

As each filter holder is installed, inspect each one for obvious foreign material on the filter and inside the holder receptacle, and for tears or misalignment of the filter. Replace those which do not pass inspection with one of the holders designated as a spare, if available, or with a field blank. Change sample ID on the field data sheet accordingly.

4.3.1.3 Install Unexposed Filters.

Remove the filter pack designated on the field data sheet for port 1 from its Ziplock bag. Remove the large top cap by gently prying the side of the cap up until it is off. Then remove the small bottom cap. This cap removal method prevents air from being pulled through the filter in the wrong direction with possible filter damage. Return top and bottom caps to the Ziplock bag and seal it to keep them clean. Check that filter holder receptacle is snug but do not over-tighten. Attach tube for port 1 to bottom of filter holder and install holder in plenum by pushing the receptacle into port number 1 in bottom of the plenum until the knurled portion of the receptacle comes into contact with the plenum base.

Similarly install remaining holders in plenum. Install field blanks if they are listed on the field data sheet. After all samples are installed, double check that sample IDs, port numbers, and air flow tube numbers match the field data sheet. Check that unused ports have filter holders with plugs installed.

CAUTION. It is essential that you double check IDs as indicated above EVERY time you load samples. Loading errors cannot be identified or corrected after sampling is completed.

4.3.1.4 Set Pre-Exposure Flow Rates

Open the sampler control box door all the way. Check that Magnehelic pressure gauges are reading 0 ± 0.05 inches of H_2O. Adjust to zero if necessary by rotating the zero adjust screw on the front of the gauge. Turn pumps on. A light on the stepper switch box indicates which ports are activated. If necessary, activate stepper switch to open ports 1, 2, 4 and 5.

Adjust flows for the makeup air port first, and then ports 1, 2, 4 and 5 by adjusting the ball valves until the Magnehelics read to within 0.05 inches H_2O of their setpoints. If one channel requires a large adjustment, other channels may require readjustment. Record all Magnehelic readings on the field data sheet in the "Initial Flow Rate" column to the nearest 0.05 inches H_2O.

Switch to ports 7, 8, 10 and 11. Do not adjust flows; they will be slightly different than for the first set of ports. Record all Magnehelic readings on the field data sheet in the "Initial Flow Rate" column to the nearest 0.05 inches H_2O.

Switch to sample ports 1, 2, 4 and 5. DOUBLE CHECK that the proper ports are sampling by observing that the timer for ports 1, 2, 4 and 5 is rotating, then switch the pump off. DOUBLE CHECK that Channel 2 is off.

4.3.1.5 Record Initial Elapsed Time

Record the elapsed time indicator readings on the field data sheet in the "Elapsed Time Start" box. There are two timers, one for ports 1, 2, 4 and 5 and the other for ports 7, 8, 10 and 11.

4.3.1.6 Reset Timer Day

For studies that do not sample the same day(s) each week, it is more convenient to store programs needed for the first sample run, then change timer day for subsequent sample runs, than to change all programs in the timer to a new day. Skip to section 4.3.1.7 if samples are collected the same day(s) each week.

Set the timer day so that samples are collected on the proper day, taking into account the number of days before samples are to run and the day that programs are stored in the timer. For example, assume the next sampling day is Sunday, you are loading samples on Friday, (two days before sampling), and programs are stored in the timer for Wednesday. Set the timer day to Monday (two days before Wednesday). For samples collected every sixth day, this is accomplished by advancing the timer day by one day for each sample run.

4.3.1.7 Verify Programs

Verify that all programs are correct by pressing "READ" button successively until all programs are reviewed. If any changes are made, verify the changes. Record timer day and date of sample loading on a blank line of the field data sheet.

4.3.2 Removal of Filters

4.3.2.1 Inspect MEDVOL Sampler and Record Final Elapsed Time

Open control panel door and compare time on timer to time on accurate watch. If more than five minutes off, note discrepancies on field data sheet. Record timer day and date of sample unloading on field data sheet. Record elapsed time indicator values in the "Elapsed Time End" space. Calculate the sample elapsed time and record on field data sheet. It should be within a few minutes of the scheduled time. Note any discrepancies on the data sheet.

4.3.2.2 Record Post-Exposure Magnehelic Readings

Open the sampler control panel door all the way. Check that Magnehelic pressure gauges are reading 0 ± 0.05 inches of H_2O. Adjust to zero if necessary by rotating the zero adjust screw on the front of the gauge. Turn pumps on. Check that open ports are the expected ones for the last sample. Record Magnehelic readings for all ports on field data sheet in "Final Flow Rate" column. Switch ports to open 1, 2, 4 and 5 (if both sets of ports were sampled). Record all Magnehelic readings. Turn pump off.

4.3.2.3 Remove Exposed Filters

Remove the exposed filter holders by pulling them from the plenum one at a time starting with port 1. Verify that filter ID on filter pack, port number, and flow tube number match the information on the field data sheet; note any discrepancies. Remove top and bottom caps from the Ziplock bag, check that they are clean, place them on filter holder, and reseal filter pack in Ziplock bag. Place the top cap on before the bottom cap to prevent pressure buildup in the filter holder caused by compressing air under the cap.. When all filters are unloaded, place them in refrigerated storage.

4.3.3 Return Samples

Return collected samples monthly to DRI. Place all sampled filters including field blanks in a cooler with Blue Ice. Enclose field data sheets and flow check data in Ziplock bag. Ship as instructed by field operations supervisor.

4.3.4 Flow Rate Performance Test and Leak Check

Conduct a flow rate performance test and leak check once a month. Check zero values of Magnehelics and adjust to 0 ± 0.05 inches H_2O if necessary. Load a set of test filter packs in ports 1, 2, 4 and 5 and plugged filter packs in the remaining ports. Turn on pumps and adjust ball valves so that all Magnehelics are at their setpoints. Remove port 1 filter pack from sampler, measure flow rate through filter, then replace filter pack in sampler. Measure flow rate by connecting outlet of 0 - 100 SCFH rotameter to filter pack receptacle with Tygon tubing and rubber stopper flow adapter. Use the 0 - 5 lpm rotameter for ports that collect NO_2. Repeat for ports 2, 4 and 5. Measure make up air flow rate by disconnecting the make up air tube from the bottom of the plenum and connect to the outlet of the 0 - 400 SCFH rotameter. Reconnect makeup flow tube to sampler and turn pumps off. Remove inlet and place total flow adapter in top of plenum. Connect 0 - 400 SCFH rotameter to the total flow adapter, turn on pumps and measure total flow rate. Make sure that rotameters are level when taking readings. Record all Magnehelic and rotameter readings as they are taken.

4.4 Shutdown

At the end of the sampling program, conduct a leak check and flow performance test. Record the condition of the sampler in the station logbook.

5.0 QUANTIFICATION

5.1 Flow Rate Calibration

Magnehelic differential pressure gauges installed in each flow leg of the sampler act as flow indicators. The Magnehelics measure pressure drops in the range of 0 to 5 inches of water across orifices in the flow lines. During calibration, flow rates through the filter and makeup air ports are measured with calibrated rotameters and the relationship between flow rate and pressure drop is determined. Setpoint values appropriate for the temperature and pressure conditions at the site ensuring a total flow rate of 113 lpm are determined. Magnehelic readings are used during routine sampling to set and measure flow rates.

The required flow rate through the cyclone is 113 ± 10 lpm referenced to average site conditions. The flow rates through the individual filter holders are 20 to 30 lpm. Flow rate for filter packs collecting NO_2 is 2 lpm.

5.1.1 Install Test Filter Packs

Install a set of test filter packs as in section 4.3.1.3 for both sets of ports (ports 1, 2, 4 and 5 plus ports 7, 8, 9 and 10). Insert plugged filter holders in remaining ports. Check that Magnehelic pressure gauges are reading 0 ± 0.05 inches H_2O, and adjust if necessary. Turn on pumps, set sampling ports to 1, 2, 4 and 5, and set Magnehelics to their setpoints determined at last calibration.

If this is the first calibration, adjust flow rates to their design values (usually 20 - 30 lpm, except 2 lpm for NO_2 sampling) using a rotameter. Adjust makeup air flow rate so that total flow into the sampler is 113 lpm.

5.1.2 Leak Check

Conduct a leak check as described in section 4.2.4.

5.1.3 Collect Flow Versus Pressure Readings

On Calibration Data Sheet (Figure 5-1), enter project, site, sampler ID, operator name, date, and filter types. Enter rotameter ID, calibration date, and coefficients of latest rotameter calibration equation (rotameter reference flow rate, Q_R, versus indicated flow rate, Q_I). Remove filter pack from port 1 and connect to inlet of 0 - 100 SCFH rotameter.

Adjust flow to maximum (or full scale on Magnehelic) by opening ball valve. Read and record pressure drop reading (ΔH) versus indicated flow (Q_I). Take multiple readings, decreasing flow between readings by 4 SLPM or less until flow rate is lower than 75% of design flow rate. Record pressure drop to nearest 0.01 inches H_2O and flow rates to nearest 0.5 SCFH. Repeat one of the readings by setting pressure drop to a previous value near the middle of the range. Record pressure drop and flow rate and indicate it is a duplicate. Flow rate should be within 1 SLPM of the previous value. If it is not, there are probably leaks in the rotameter to filter pack connections. Correct and take measurements again before proceeding.

Repeat for ports 2, 4 and 5 and makeup air port. Use the 0 - 5 lpm rotameter for NO_2 ports and take readings at 0.4 lpm or smaller intervals. Use the 0 - 400 SCFH rotameter and take readings at 10 SCFH or smaller intervals. Switch to ports 7, 8, 9 and 10 and repeat measurements.

5.2 Flow Rate Computations

5.2.1 Calculate Power Fit Curves

Convert indicated flow (Q_I) to rotameter reference flow (Q_R) and calculate least squares power fit of pressure drop to Q_R values by running Basic program CADMPFLW.BAS. This program requires an input file that contains ΔH versus Q_I readings as well as rotameter calibration coefficients for all ports, and creates a file that has Q_R calculated as well as results of least squares power fit. Plot ΔH (x-axis) versus Q_I on log-log scale. Exclude points at the upper or lower end of the range if they do not fall on a straight line. A sudden drop in regression coefficient R calculated by the program also indicates when a curve becomes non-linear. Run the program again, if necessary, to exclude non-linear points at the ends of the curve. The program calculates linear least squares curve for the equation

$$Q_R = C(\Delta H)^D$$

where C is magnitude and D is power as calculated by the program.

Magnehelic Calibration Form

SITE ______________ SAMPLER ______________ MODULE ______________

OPERATOR ______________ FLOW TYPE ______________ DATE ______________

Rotameter ______________ Cal Date ______________

Calibration Equation: Q_R = ________ Q_I + ________

Magnehelic Reading, ΔH inches H_2O	Indicated Flow, Q_I SCFH	Rotameter Flow, Q_R SCFH

Q_R versus Magnehelic Reading:

$Q_R = C(\Delta H)^D$

C = ______________

D = ______________

Correlation Coef = ______________

Figure 5-1. Example Flow Calibration Data Sheet

5.2.2 Calculate Temperature/Pressure Correction

Calculate temperature/pressure correction factor (TP_{CORR}) from the following equation. Actual flow rate (Q_A) equals the product of Q_R and TP_{CORR}.

$$TP_{CORR} = [(760 / P_{ACT}) \times (T_{ACT} / 298)]^{1/2}$$

where P_{ACT} = site pressure during calibration, mm Hg
T_{ACT} = site temperature during calibration, °K.

If pressure is not measured, estimate from site elevation from the following equations (NOAA, 1976):

$$P_{ELEV} = P_{1ATM} \times [1 - (Z_M/44331)]^{5.256}$$

or

$$P_{ELEV} = P_{1ATM} \times [1 - (Z_F/145442)]^{5.256}$$

where P_{1ATM} is pressure at sea level (1 atm, 1013.25 mb, 760 mm Hg, 29.92 in Hg)
P_{ELEV} is pressure at site in same units as P_{1ATM}
Z_M is altitude in meters
Z_F is altitude in feet.

Pressures calculated by these equations are given in Tables 5-1 and 5-2

5.2.3 Calculate Magnehelic Setpoints

Run Basic program FORSTSM3.BAS to convert Q_R to Q_A, to convert flows from SCFH to lpm (except for ports that use rotameter calibrated in lpm), and to determine Magnehelic setpoints. This program requires an input file with design flow rates, calibration curve coefficient C and power D, and TP_{CORR}. Record Magnehelic setpoints on the sampler.

5.2.4 Calculate Air Volume for Ambient Samples

Sample volume for ambient samples is determined from the following equation:

$$V = (ET_F - ET_I) \times Q_A$$

where V = sample volume, m^3
ET_F = final elapsed time reading, in minutes
ET_I = initial elapsed time reading, in minutes
Q_A = flow rate at ambient conditions, lpm
$Q_A = Q_R \times 0.472 \times TP_{SEAS}$
$Q_A = Q_R \times TP_{SEAS}$ (for filter packs calibrated using rotameter with lpm scale)
$Q_R = C \times (\Delta H)^D$
ΔH = average of initial and final Magnehelic readings
$TP_{SEAS} = [(760 / P_{SEAS}) \times (T_{SEAS} / 298)]^{1/2}$
P_{SEAS} = seasonal average pressure, mm Hg
T_{SEAS} = seasonal average temperature, °K.

Table 5-1

Pressure of Standard Atmosphere as a Function of Elevation in Feet

Elevation	Pressure			
Feet	Atm	mb	mm Hg	in Hg
0	1.000	1013.3	760.0	29.921
250	0.991	1004.1	753.2	29.652
500	0.982	995.1	746.4	29.385
750	0.973	986.1	739.6	29.119
1000	0.964	977.2	732.9	28.856
1250	0.956	968.3	726.3	28.594
1500	0.947	959.5	719.7	28.335
1750	0.938	950.8	713.2	28.077
2000	0.930	942.1	706.7	27.821
2250	0.921	933.5	700.2	27.567
2500	0.913	925.0	693.8	27.315
2750	0.905	916.5	687.4	27.065
3000	0.896	908.1	681.1	26.817
3250	0.888	899.8	674.9	26.570
3500	0.880	891.5	668.7	26.326
3750	0.872	883.3	662.5	26.083
4000	0.864	875.1	656.4	25.842
4250	0.856	867.0	650.3	25.603
4500	0.848	859.0	644.3	25.365
4750	0.840	851.0	638.3	25.130
5000	0.832	843.1	632.4	24.896
5250	0.824	835.2	626.5	24.664
5500	0.817	827.4	620.6	24.434
5750	0.809	819.7	614.8	24.205
6000	0.801	812.0	609.0	23.978
6250	0.794	804.4	603.3	23.753
6500	0.786	796.8	597.7	23.530
6750	0.779	789.3	592.0	23.308
7000	0.772	781.8	586.4	23.088
7250	0.764	774.5	580.9	22.870
7500	0.757	767.1	575.4	22.653
7750	0.750	759.8	569.9	22.438
8000	0.743	752.6	564.5	22.225
8250	0.736	745.5	559.1	22.013
8500	0.729	738.3	553.8	21.803
8750	0.722	731.3	548.5	21.595
9000	0.715	724.3	543.3	21.388
9250	0.708	717.3	538.0	21.183
9500	0.701	710.4	532.9	20.979
9750	0.694	703.6	527.7	20.777
10000	0.688	696.8	522.7	20.577

Table 5-2

Pressure of Standard Atmosphere as a Function of Elevation in Meters

Elevation Meters	Pressure Atm	mb	mm Hg	in Hg
0	1.000	1013.3	760.0	29.921
100	0.988	1001.3	751.0	29.568
200	0.977	989.5	742.2	29.219
300	0.965	977.7	733.4	28.872
400	0.953	966.1	724.6	28.529
500	0.942	954.6	716.0	28.190
600	0.931	943.2	707.5	27.853
700	0.920	931.9	699.0	27.520
800	0.909	920.8	690.6	27.190
900	0.898	909.7	682.3	26.863
1000	0.887	898.7	674.1	26.540
1100	0.876	887.9	666.0	26.220
1200	0.866	877.2	657.9	25.902
1300	0.855	866.5	649.9	25.588
1400	0.845	856.0	642.0	25.277
1500	0.835	845.6	634.2	24.969
1600	0.824	835.2	626.5	24.664
1700	0.814	825.0	618.8	24.363
1800	0.804	814.9	611.2	24.064
1900	0.794	804.9	603.7	23.768
2000	0.785	794.9	596.3	23.475
2100	0.775	785.1	588.9	23.185
2200	0.765	775.4	581.6	22.898
2300	0.756	765.8	574.4	22.614
2400	0.746	756.3	567.2	22.332
2500	0.737	746.8	560.2	22.054
2600	0.728	737.5	553.2	21.778
2700	0.719	728.2	546.2	21.505
2800	0.710	719.1	539.4	21.235
2900	0.701	710.0	532.6	20.968
3000	0.692	701.1	525.9	20.703

The seasons for averaging temperature and pressure are generally spring, summer, fall, and winter but are not necessarily constrained to being 4 months long. As an example, in the Southwest desert, the temperatures often fall into the following categories: spring, 2 months (March, April); summer, 5 months (May through September); fall, 2 months (October, November); and winter, 3 months (December through February). The average temperature is about the same in spring and fall while it is much higher in summer and somewhat lower in winter. The pressure is sometimes measured but more often is estimated from the elevation of the site as in section 5.2.2. If estimating average temperature, be sure to consider daytime lows as well as high temperatures.

6.0 QUALITY CONTROL

6.1 Calibration Checks

Flow rate performance checks as described in Section 4.3.4 are made monthly.

6.2 Leak Checks

A leak check as described in Section 4.2.4 is performed monthly.

7.0 QUALITY AUDITING

Audits of flow rates are performed by an independent auditor with independent standards on a regular schedule, usually twice a year.

8.0 REFERENCES

NOAA, 1976. "U. S. Standard Atmosphere, 1976" by the National Oceanic and Atmospheric Administration, Washington, DC, Oct. 1976.

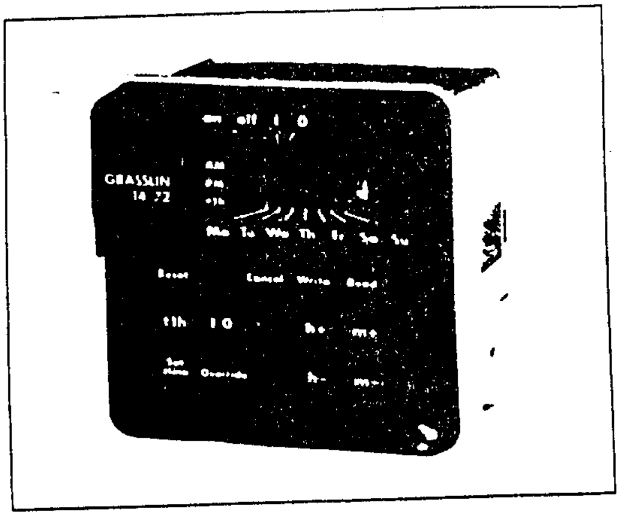
Appendix A

Component Instructions

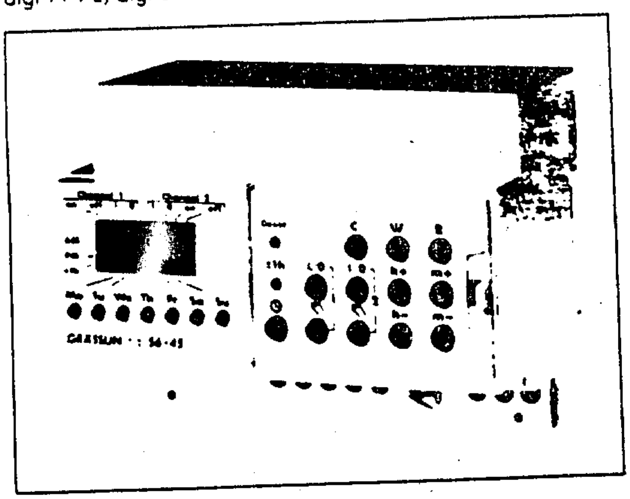
GRASSLIN

digi 14, digi 56

One or Two Circuit Electronic Time Switches by Grasslin



digi 14-72, digi 56-72



digi 56-45

OPERATING INSTRUCTIONS

Application

The digi 14 and 56 series are one or two channel freely programmable time switches for the control of HVAC equipment, lighting control and other time based switching requirements. All models incorporate a 7-day time base.

The digi 14-72 is a single circuit unit while the digi 56-72 and 56-45 are available as one or two circuit time switches. Programming is identical for all of these units.

Features

- One or two freely programmable channels.
- digi 14-14 programs for 98 on / off events.
- digi 56-56 programs for 392 on/off events per channel.
- Block programming for any combination of weekdays.
- 100 hours of battery powered reserve.
- Daylight / standard time adjustment.
- AM / PM LCD display.

TECHNICAL DATA

- Switching capacity
- 10 A / 250 VAC (resistive)
- 2 A / 250 VAC (inductive)
- Switches 1 or 2 SPDT circuits
- 100 hours reserve, LCD intact
- Supply voltages 24, 120 or 220 VAC, 45-60 Hz
- Shortest switch time - 1 minute
- Manual override for each circuit
- Ambient Temperature Range: - 4° to + 122° F
- AM / PM display

To the Installer:

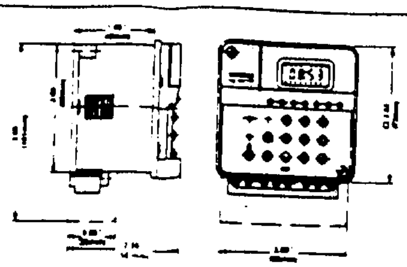
1. Read operating instructions carefully.
2. Check the input and output ratings marked on the unit to make sure this product is suitable for your power supply and application.
3. Disconnect power supply prior to installation to prevent electrical shock.
4. Damage to the relay-contacts caused by short circuiting will void warranty.
5. Wire in accordance with National and Local electrical code requirements.

INSTALLATION

Installation Checklist

1. Operating temperature must be within - 4° to + 122° F.
2. The time switch should be located at least 5 feet away from any large electrical contractor or machinery to avoid possible electrical interference problems.
3. The time switch should have its own independent circuit for power supply.
4. Since all electronic instruments are sensitive to voltage spikes, close attention must be paid to the following:
   a) If possible, power to the electronic time switch should be supplied from a phase different from the one supply power to the load.
   b) INDUCTIVE-LOADS should have suitable Varistor or a RC network (—ww—|—) across the supply terminals to reduce voltage spikes.
   c) DC OPERATED INDUCTORS should have a diode across their terminals to eliminate back EMF of the inductor.
   d) HIGHLY INDUCTIVE LOADS, especially fluorescent lights may require a relay in which case (a) and (c) apply.

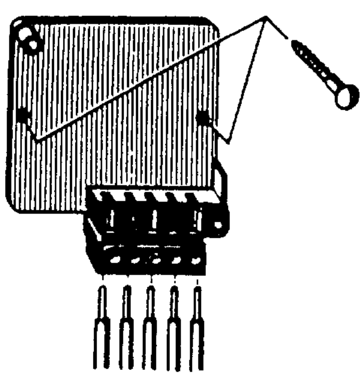
digi 14-72, digi 56-72



The digi 14-72 and 56-72 units can be surface or flush mounted. Lift off front cover and loosen the two screws on opposite corners. Pull off plug-in base with a left-to-right rolling motion.

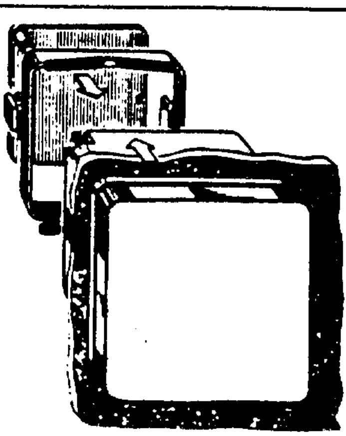
SURFACE MOUNTING (inside panel)
Place screw through pre-set holes in base and screw to back of panel or wall.

Wire in accordance with instructions. Depending upon the specific installation, you may find it more convenient to have wiring completed before attaching the base.



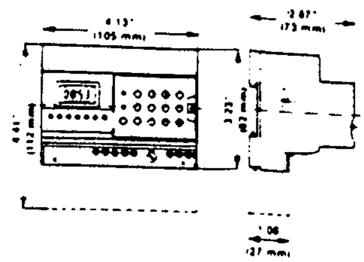
lace terminal cover over terminal block and by lining up the wo screws with corner holes in base, push timer firmly onto lug-in base. Tighten the two screws.

ANEL MOUNTING (Flush mounting through panel door)
ut a square hole 2 5/8" x 2 5/8" (66 x 66 mm) in the front of the anel. Remove plug-in base and insert the time switch through e opening. Place the flush mounting bracket over rear of the nit to secure to the panel door.



Wire according to instructions; replace plug-in base, tighten mounting screws in front. Discard terminal cover.

digi 56-45



The digi 56-45 units can be surface or rail mounted.

SURFACE MOUNTING (inside panel)
Loosen front screw and pull off plug-in base with a left-to-right rolling motion. Place screws through holes in opposite corners in base and screw to back of panel or wall.

Wire in accordance with instructions. Depending upon the specific installation, you may find it more convenient to have wiring completed before attaching the base.

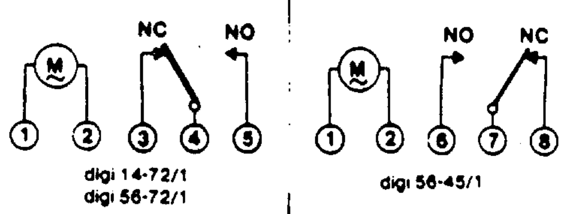
Place timer on plug-in base and push in firmly. Place terminal cover over terminal block and tighten front screw.

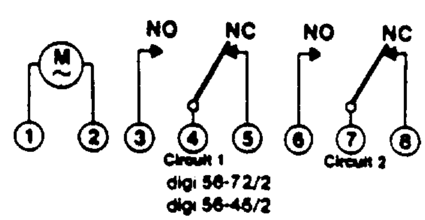
RAIL MOUNTING
The digi 56-45 is equipped with a rail mounting attachment built into the plug-in base. Without taking the timer off its base, simply place the two protruding guides, which are on the top rear of the rail cutout slot, over the top lip of the installed rail; then snap the bottom in place. Wire in accordance with instructions and place terminal cover on unit.

For stand-alone installations, all digi 14 und 56 units may be surface mounted inside an indoor enclosure which is available from Grasslin Controls or your wholesaler.

WIRING
1. Wire 24, 120 or 220 VAC to input terminals 1 and 2 (make sure to apply correct voltage; use of incorrect voltage will void warranty).
2. Connect wires to the screw terminals in accordance with the wiring diagrams shown (use 12 to 22 AWG wire).

TERMINAL CONNECTIONS





PROGRAMMING

SYMBOLS

Mo thru Su	- Day Selector
Reset	- Cancels all programs
+ / - 1 h	- Daylight savings / standard time change
Set Time	- Enter time base
1 / 0	- On / Off command for each channel
Override	- Manual override (temporary until next program)
Cancel	- Cancel program
Write	- Program entry and storage
Read	- Program readout
h +	- Hour advance
h -	- Hour reverse
m +	- Minute advance
m -	- Minute reverse

Depress »Reset« key to clear entire memory, the display will show 12:00 AM.

Please Note:
When no key is pressed for 15 seconds or when the »Set Time« key is depressed, the time will automatically be displayed. In that case reenter the program.

DAYLIGHT / STANDARD TIME CHANGEOVER
Press »± 1 h« button once if the unit is installed during daylight savings time, the LCD status indicator will appear next to »+ 1 h« in the display. No function is required if installed during standard time.

Setting the time

(Example: Monday 8:38 AM)

Hold	»Set Time«	button depressed during entire time setting procedure
Press	»Mo«	button - bar shows above Mo
Press	»h +«	button until 08:00 AM shows in display and bar shows next to AM
Press	»m -«	button until 08:38 shows in display
Release	»Set Time«	button - seconds dot flashes

Entering Programs

Please Note:
Each program requires an ON time or an OFF time, at least one DAY, and at least one CHANNEL selection.
The »Write« key must be used to enter data.

PROGRAM ON
(Example: Monday on at 8:05 AM, channel 1)

Press	»Mo«	bar shows above Mo
Press	»h +«	until 08: - AM shows in display
Press	»M +«	until 08:05 AM shows in display
Press	»1 / 0«	for channel 1, bar appears in display below 1 for channel 1
Press	»Write«	for program entry

PROGRAM OFF
(Example: Monday off at 5:05 PM, channel 1)

Press	»Mo«	bar shows above Mo
Press	»H -«	until 05:- PM shows in display
Press	»m +«	until 05:05 PM shows in display
Press	»1 / 0«	for channel 1, twice - bar appears in display below 0
Press	»Write«	for program entry

REPEAT DAILY SCHEDULE
(Example: Mo-Fri ON at 8:05 AM, channel 2)

Press	»Mo, Tu...Fri.«	bar appears above days
Press	»h +«	until 08:- AM shows in display
Press	»m +«	until 08:05 AM shows in display
Press	»1 / 0«	for channel 2, bar appears in display below 1 under channel 2
Press	»Write«	for program entry

REPEAT CHANNEL SELECTION
(Same program for more than one load)
If a load controlled by the other channel is required to be turned on or off at the identical time, the »1 / 0« selector key can be depressed for the additional channel prior to writing the program into the memory. This feature allows for more than one load to be switched on with one program. It also allows for one or more channels to be switched on and other channels to be simultaneously switched off.

Operation and Checkout

1. After being programmed, the outputs will not immediately assume the programmed on or off position. Switching will only commence when the actual time of day and weekday coincide with the programmed time. To energize the load at this time, the manual override key should be used.
2. Always verify all program entries before leaving the site. Use the Program Read-Out procedure.

Program read-out

Press »Read«
Each time key is depressed, the stored programs appear in the display in the order in which they were entered. After all programs have been shown, the display becomes blank and the process repeats itself.

Cancelling programs

Press »Read«
bring program to be cancelled in display
Press »Cancel«
program is cancelled. To cancel all programs, depress reset key. This clears entire memory, including time base and program storage.

Changing programs

Use »Program Readout« procedure to recall the programs to be changed. To change weekdays, press the individual day keys to delete or add days. Use the hour and minutes keys to change time-of-day. Change the ON or OFF command by using the »1 / 0« keys, for Channel 1 or 2. Press »Write« to store the new program and delete the old program.

Press »Override«
to turn loads on or off at any time without affecting the stored programs. Each channel has its own override key. A bar in the display will temporarily become blank when the override key is pressed. The override is automatically reset by next on or off program.

Daylight savings / standard time change

When a time change to Daylight Savings time is required, press »± 1 h« once. The time base in the unit will automatically advance by one hour and a bar will appear in the display next to ± 1 h.
To change to Standard time, press »± 1 h« again; the time base is set back one hour and the bar next to ± 1 h will disappear.

Battery-powered reserve

In case of power failure, the built-in nickel-cadmium battery maintains the time of day, program storage and the LCD display for 100 hours (4 days). During this time, all programmed switching events will be carried out but the relays will not operate

Please Note:
The battery reserve operates to its full capacity only if the uni has been connected to electrical power for at least 70 hours

PROGRAMMING RECORD

digi 14, 56

Comments	Day	Time	1 = ON 0 = OFF	Channel	Date Entered

RASSLIN CONTROLS CORPORATION
5 Spear Road, Ramsey, NJ 07446

WA EKI 1222 12 88 EDV Nr 80 10 04797

ITT CONOFLOW
REGULATORS & CONTROLS
P.O. Box 768
St. George, S. C. 29477-0768
(803) 563-9281 TELEX 4945706

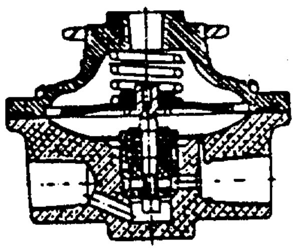
WARNING

Conoflow's products are designed and manufactured using materials and workmanship required to meet all applicable industry standards. The use of these products should be confined to services specified and/or recommended in the Conoflow catalogs, instructions or by Conoflow application engineers (i.e. exceeding pressure-temperature rating or using device for services other than those specified).

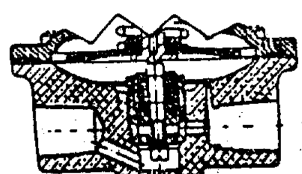
To avoid personal injury or equipment damage due to misuse or misapplication of product it is necessary to select the proper materials of construction and pressure temperature ratings which are consistent with performance requirements.

R&C
FOREMOST IN CONTROL ELEMENTS

INSTRUCTION AND MAINTENANCE MANUAL
GH21/41 SERIES
FIXED DIFFERENTIAL REGULATORS



GH21XTXM



GH41XTXM
SOFT SEAT NOZZLE

PRINCIPLE OF OPERATION

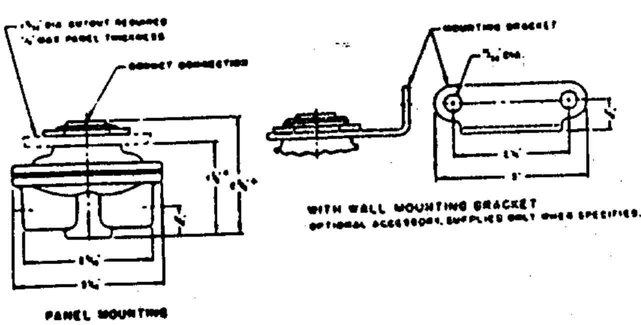
The GH21/41 Series Regulators are used to maintain a fixed differential pressure across a needle valve downstream from the regulator. The spring in the bonnet of the regulator exerts a fixed force on the diaphragm assembly which requires approximately 3 psi underneath the diaphragm to balance with zero signal pressure. As signal pressure is applied to the bonnet connection, an increase in output pressure is required to keep the forces on the diaphragm assembly balanced. In equilibrium, the force due to the output pressure will be equal to the force from the spring plus the force due to the signal pressure. Since the spring force is equivalent to 3 psi, the output pressure will always be 3 psi **greater** than the signal pressure.

If the output pressure drops below the equilibrium point, there is a net downward force on the diaphragm assembly. This force causes the nozzle plug to open allowing supply pressure to flow downstream until the output pressure returns to its equilibrium value.

If the output pressure rises above the equilibrium point, th diaphragm seat lifts from the nozzle plug allowing it to clos The nozzle remains closed until the excess pressure is di sipated downstream.

The operation of the GH41XT is the same as the GH21XT e cept that a molded rubber seat is provided on the nozzle pl for applications requiring positive shut-off.

DIMENSIONS



NOTES
1) ALL CONNECTIONS ARE ¼ N.P.T.
2) "+" ADD ¼ TO THIS DIM FOR GH21XTXXXK AND GH31XTXXXK GH21XTXXXS AND GH31XTXXXS

FOR CERTIFIED DIMENSIONAL DRAWING, REFER TO A17-18

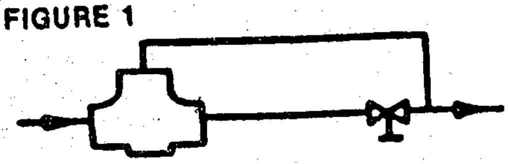
INSTALLATION

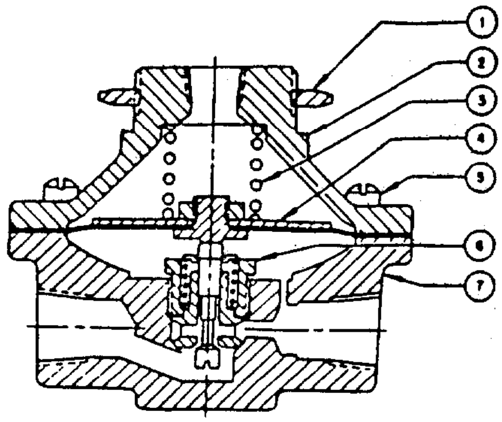
CAUTION: Maximum Supply Pressure Is 100 PSI.

Unit has three ¼" N.P.T. connections. The inlet connectior marked "IN". The outlet connection is piped to the meter device. The bonnet connection is piped downstream of metering device (See Figure 1). **IT IS RECOMMENDED TH A FILTERED AIR SUPPLY BE USED.**

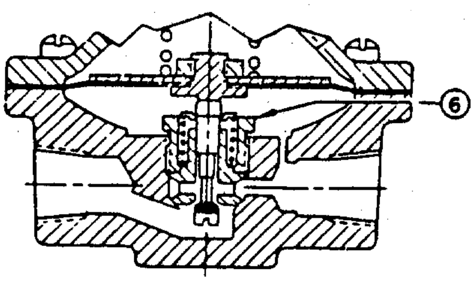
Check all connections for leakage after installation.

FIGURE 1





GH21XTXM



GH41XTXM
SOFT SEAT NOZZLE

MAINTENANCE

Remove air supply pressure and bleed off output pressure prior to performing maintenance.

Periodic replacement of the diaphragm assembly and nozzle assembly is recommended for services where the unit is on stream continuously and where consistent, high accuracy regulation is required. The frequency of replacement will depend on the nature of the service, cleanliness of air, humidity of the air, etc.

To replace the diaphragm assembly (4), remove six screws (5) and lift off bonnet (2), and spring (3). Place new diaphragm assembly (4) over body with diaphragm plate up. Place spring (3) on diaphragm assembly (4), reinstall bonnet (2) and tighten six screws (5). The six screws (5) should be tightened alternately.

To replace nozzle assembly (6) proceed as above. Use ¾" socket wrench to remove and replace nozzle assembly to avoid damage to the nozzle. Nozzle assembly may be cleaned by immersion in a suitable solvent and blowing dry with air stream.

EM 'O.	DESCRIPTION	QTY. REQ'D.	GH21XTXM(2) GH41XTXM(2)	GH21XTXKXK(2) 303 St Stl.	GH21XTXKXS(2) 316 St. Stl.
1	Locknut	1	6017628	6017636	6017636
2	Bonnet	1	6020309	6018659	6018659
3	Spring (Yellow)	1	6017511	6018733	6384846
4(1)	Diaphragm Assembly	1	6018311	6018584	6385161
5	Fill. Hd. Screw #8-32 x ⅜" Lg.	6	6900046	6900046	6900046
5	Nozzle Assembly GH21	1	6347843	6020986	6384841
	GH41	1	6018741	.....	.....
7	Body	1	6018642	6018675	6018675

ES 1 Recommended Spare Part
2 For definition of catalog number, refer to Control Engineering Data Sheet C 9006
3 When ordering spare parts, specify complete catalog no., item no. and part no. This will permit positive identification and rapid handling of order.

CONOFLOW
REGULATORS & CONTROLS

PO Box 768
St George, S. C. 29477-0768
(803) 563-9281 TELEX 4945706

RATEMASTER® FLOWMETER
Instructions

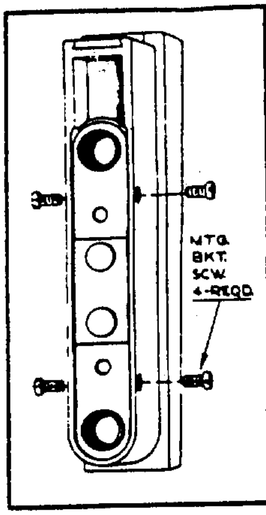


Figure 3


Figure 4

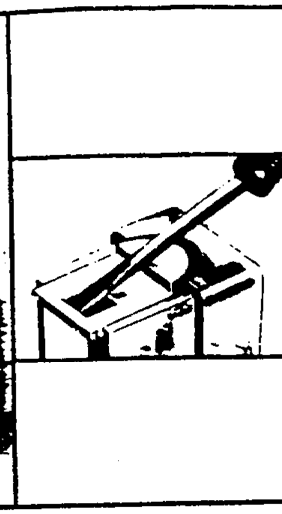


Figure 5


Figure 6

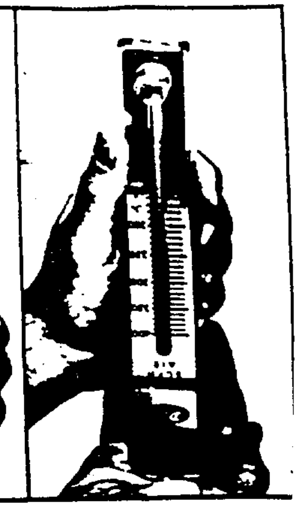


Figure 7

SURFACE MOUNTING: Drill appropriate holes in panel using the dimensions shown in Figure 1. Hold the flowmeter in position in front of the panel and install the clamp bolts through the panel from the rear. (The mounting clamps may be used as washers if desired by installing them backwards or straightening them out.) Pipe up inlet and discharge following the directions in previous sections.

SURFACE MOUNTING ON PIPING ONLY: An alternate method of surface mounting omitting the clamp bolts and supporting the Rate-Master Flowmeter on the connecting piping only is possible. For this method extra long or straight pipe threads should be used so that nuts may be run onto the pipe and later tightened against the back of the panel to retain the unit in proper position. Use the appropriate hole layout information from Figure 1, but omit the small holes.

MOUNTING ON PIPING ONLY WITHOUT PANEL: For a temporary or laboratory type installation, the panel may be omitted altogether and the flowmeter installed directly in rigid piping. Its light weight permits this without difficulty.

OPERATION

To start system, open the valve slowly to avoid possible damage. Rate of flow is read at the point of maximum horizontal width for spherical floats or at the top of the largest diameter for non-spherical floats. Control valves on BV and SSV models are turned clockwise to reduce flow, counter-clockwise to increase flow. A nylon insert is provided in the threaded section of the valve stem to give a firm touch to the valve and to prevent change of setting due to vibration.

CAUTION

Do not completely unscrew valve stem unless flowmeter is unpressurized and drained of any liquid. Removal while in service will allow gas or liquid to flow out front of valve body and could result in serious personal injury. For applications involving high pressure and/or toxic gasses or fluids, special non-removable valves are available on special order. Contact factory for details.

MAINTENANCE

The only maintenance normally required is occasional cleaning to assure reliable operation and good float visibility.

DISASSEMBLY: The flowmeter can be disassembled for cleanir simply as follows:

1. Remove valve knob from RMB or RMC — BV or S units by pulling the knob forward. It is retained by spri pressure on the stem half-shaft so that a gentle pull will move it. On RMA-BV or SSV models, turn the valve kn counter-clockwise until the threads are disengaged. Then wi draw the stem from the valve by gently pulling on the kn

2. Remove the four mounting bracket screws located in sides of the flowmeter. See Figure 3.

Pull the flowmeter body gently forward away from the b plate and pipe thread connections. Keep the body para with the back plate to avoid undue strain on the body. Le the piping connections intact. There is no need to disturb th See Figure 4.

3. Remove the slip cap with a push on a screwdriver as sh in Figure 5. Remove the plug-ball stop as shown in Figu using allen wrench sizes as follows: Model RMA — 1/4". M RMB — 1/2", and Model RMC — 3/4".

4. Take out the ball or float by inverting the body and al ing the float to fall into your hand as shown in Figur (Note: It is best to cover the discharge port to avoid lo the float through that opening.)

CLEANING: The flow tube and flowmeter body can be cleaned with a little pure soap and water. Use of a b brush or other soft brush will aid the cleaning. Avoid ben: acetone, carbon tetrachloride, alkaline detergents, caustic s liquid soaps (which may contain chlorinated solvents), etc. avoid prolonged immersion which may harm or looser scale.

REASSEMBLY: Simply reverse Steps 5A, 1 through 4 place back in service. A little stop cock grease or petro jelly on the "O" rings will help maintain a good seal a as facilitate assembly. No other special care is required.

ADDITIONAL INFORMATION

For additional flowmeter application information, conv curves, factors and other data covering the entire line of Rate-Master Flowmeters, send for Bulletin F-41.

56-440197-00

Lithographed in U.

RATEMASTER® FLOWMETER
Installation and Operating Instructions

DIMENSIONS & MOUNTING INFORMATION

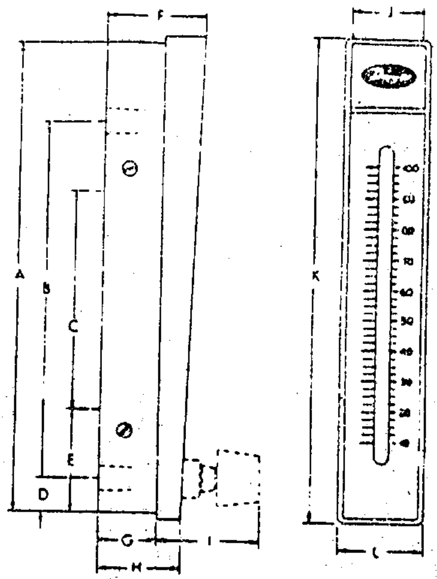
DIMENSIONS – IN INCHES			
	RMA	RMB	RMC
	4 5/16	8 1/2	15 1/8
	3	6 7/16	12 1/4
	1/8 NPT CONN	1/4 NPT CONN	1/2 NPT CONN
	1 5/8	3 15/16	8 3/4
	10 32 THDS	1/4 28 THDS	3/8 24 THDS
	3/8	5/8	1
	1 1/16	1 7/8	2 3/4
	1 3/16	1 3/4	2 1/4
	11/16	1	1 7/16
	1	1 7/16	1 31/32
PEN	1 3/8	1 13/16	2 1/2
	3/4	1 1/4	2
	4 13/16	8 3/4	15 3/8
	1	1 1/2	2 1/4

PANEL CUT OUT
(FOR FLUSH MOUNTING)

	4 5/8	8 9/16	15 3/16
	7/8	1 5/16	2 1/16

PANEL HOLE SIZES
(FOR SURFACE MOUNTING)

	7/16	5/8	15/16
	1/4	9/32	13/32



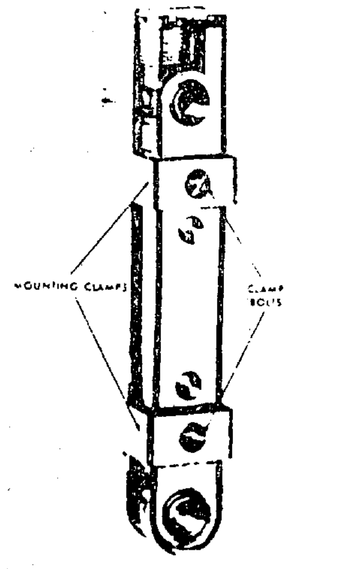


Figure 2

r Rate-Master Series RM Flowmeters are furnished in models (see Figure 1) each available in a broad choice w ranges with direct reading scales for air, gas or water. llation, operation and maintenance are very simple and a few common sense precautions must be observed to e long, trouble-free service.

CAUTION

wyer Rate-Master® flowmeters are designed to provide tisfactory long term service when used with air, water, or her compatible media. Refer to factory for information on estionable gases or liquids. Caustic solutions, anti-freeze hylene glycol) and aromatic solvents should definitely t be used.

CALIBRATION

Dwyer flowmeter is calibrated at the factory. If at any luring the meter's life, you wish to recheck its calibration, only with devices of certified accuracy. DO NOT attempt ck the Dwyer Rate-Master Flowmeter with a similar eter as seemingly unimportant variations in piping and ressure may cause noticeable differences in the indicated g. If in doubt, return your Dwyer flowmeter to the . It will be calibration checked for you at no charge.

proceeding with the installation of your Dwyer Rate- Flowmeter, check to be sure you have the model and nge you require.

LOCATION

ERATURE, PRESSURE, ATMOSPHERE, AND VIBRA- Rate-Master Polycarbonate Flowmeters are exceptionally and strong. They are designed for use at pressures up PSI (RMB units 70 PSI, RMC 35 PSI) and temperatures 130 deg. F. DO NOT EXCEED THESE LIMITS! The tion should not be exposed to strong chlorine atmos- or solvents such as benzene, acetone, carbon tetra- e, etc. The mounting panel should be free of excessive on since it may prevent the unit from operating properly.

INLET PIPING RUN: It is good practice to approach the flowmeter inlet with as few elbows and restrictions as possible. In every case the inlet piping should be at least as large as the connection to the flowmeter i.e. 1/8" Iron Pipe Size for RMA, 1/4" IPS for RMB and 1/2" IPS for RMC. Length of inlet piping makes little difference for normal pressure fed flow-meters.

For flowmeters on vacuum air service the inlet piping should be as short and open as possible. This will allow operation near atmospheric pressure and thereby insure the accuracy of the device. (Note that for vacuum air service the flow control valve if any, should be on the discharge side of the flowmeter. Either the TMV unit or a separate in line valve may be applied.)

DISCHARGE PIPING: As on the inlet, discharge piping should be at least as large as the flowmeter connection. In addition, for pressure fed flowmeters on air or gas service the discharge piping should be as short and open as possible. This will allow operation of the flow tube at near atmospheric pressure and insure the accuracy of the device. This is of less impor-tance on water or liquid flowmeters since the flowing medium is generally incompressible and moderate back pressure will not affect the accuracy of the instrument as calibrated.

POSITION AND MOUNTING

All Rate-Master Flowmeters must be mounted in a vertical po-sition with the inlet connection at the bottom rear and outlet at top rear.

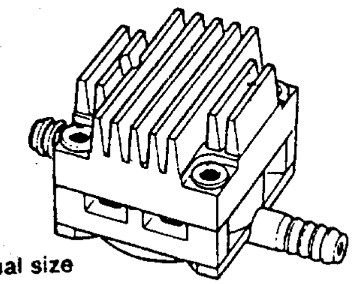
BEZEL OR THROUGH PANEL MOUNTING: Make the panel cutout using the appropriate dimensions from Figure 1. Flow-meter must fit into the panel freely without force or squeeze.

Insert the Rate-Master Flowmeter from the front of the panel and install the mounting clamps from the rear, insert and tighten the clamp bolts in the locations shown in Figure 2. Do not exceed 5 in./lbs. Make connections to inlet and outlet ports using small amount of RTV sealant or Teflon® thread tape to avoid leakage. Avoid excess torque which may damage flowmeter body.

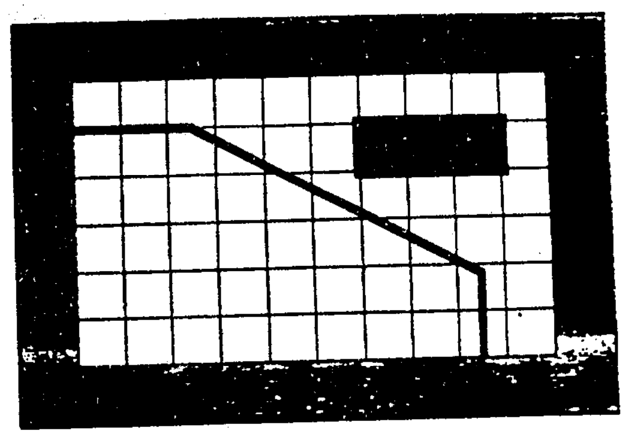
MPL-533 PRESSURE SENSOR

Highlights

The MPL-533 is a sensitive, compact, adjustable pressure sensor with a self contained triac capable of switching loads up to 5 Amps. Pressure, vacuum or differential port configurations are offered. This unique design is ideally suited for use in HVAC controls, appliances, office equipment and more.



Shown actual size



Description

A hybrid mechanical/solid state sensor, the MPL-533 combines high sensitivity, fast response and minimum on/off differential with high current load capability. The pressure diaphragm is selected to meet the requirements for temperature range and media compatibility. The diaphragm activates low-stressed gold inlay contact surfaces instead of sliding or pivoting parts. This results in high reliability and long contact life. Both normally open and normally closed models are available. The vernier adjustment screw permits accurate setting at the factory. The deflecting contact member is selected for best operation at the desired setting range. The die cast cover is a heat sink for the integral AC solid state static switch (triac). No external power source is required, other than the AC load being controlled. In normal operation the gold inlay contact surfaces exhibit very low contact resistance. However the internal triac will trigger reliably even if contact resistance is as high as 8 kilohms. Therefore long life and high reliability are expected even when the device is mounted in hostile environments. For inductive loads a varistor or R-C snubber circuit is recommended. The MPL-533 sensor can be readily mounted with #2 screws. An MPL-50304 adapter is also available which allows the MPL-533 to be snapped in place. Printed circuit terminals are available for direct board mounting.

Electrical Rating

The current capacity of the MPL-533 is limited by the duty cycle (percent on-time) and the ambient temperature. See the accompanying chart for the operating range. The MPL-533 is designed to control AC loads with source voltages from 6 to 250 VAC. The sensor can also be used to control DC devices in a latching mode.

Features

- Miniature size, light weight and low cost
- Adjustable to desired pressure or vacuum setting
- Switches continuous loads up to 5 Amps at 25°C
- Reliable gold inlay contact surfaces
- Quality materials

Specifications

MATERIALS:	Housing—glass-filled polyester, grade SEO Cover—aluminum-zinc alloy Diaphragm—Teflon or other materials are available Contacts—phosphor bronze with gold inlay Terminals—brass/gold plated
OPERATING TEMPERATURE:	−40°C to 85°C (−40°F to 185°F) [see operating range chart] temperature range restricted for some diaphragm materials
OPERATING PRESSURE RANGES:	Within 0.05 to 550 inches H_2O (.12 millibar to 1.37 bar)
BURST PRESSURE:	25 psig (1.73 bar)
CONTACT FORM:	SPST-NO (Form A) or SPST-NC (Form B)
DIMENSIONS:	1.75 x 1.2 x 0.8 inch (44.5 x 30.5 x 20.3 mm)
WEIGHT:	1.05 ozs (29.7 grams)

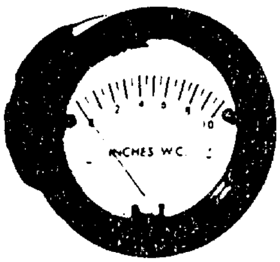
Micro Pneumatic Logic, inc

2890 N.W. 62nd Street, Fort Lauderdale, FL 33309 • Telephone: (305) 973-6166 • TELEX: 52-2316 • FAX: (305) 973-633

BULLETIN NO. A-36

INSTALLATION AND OPERATING INSTRUCTIONS

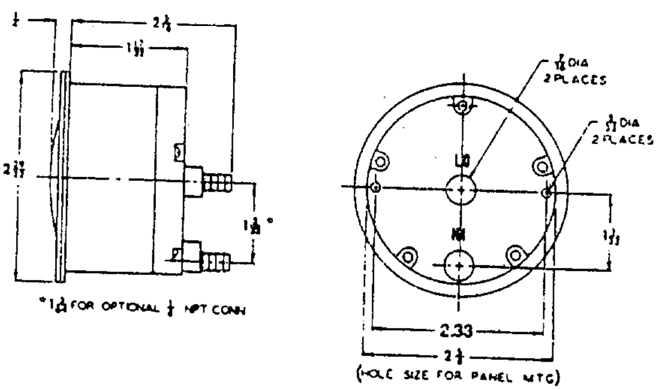
Minihelic II Differential Pressure Gage



PHYSICAL DATA — SPECIFICATIONS

Dimensions: $2\frac{23}{32}$" x $2\frac{1}{16}$"
Weight: 6 oz.
Rated Total Pressure: 50 PSIG surge, 30 PSIG continuous to either pressure connection.
Ambient Temperature Range: 20°F to 120°F
Finish: Black
Accuracy: ±5% of full scale at 70°F
Housing: filled nylon case; high impact acrylic lens
Connections: standard; barbed for $\frac{3}{16}$" I.D. tubing, optional; $\frac{1}{8}$ NPT male
Standard Accessories: (2) 4-40 x $1\frac{5}{8}$" mounting studs, (2) 4-40 hex nuts, (1) .050" hex allen wrench, (1) panel mounting bracket.
Caution: Use with air or compatible, non-corrosive gases only.

DIMENSIONS — MOUNTING HOLE SIZES AND LOCATIONS



INSTALLATION

1. Select a location free from excessive vibration and where the ambient temperature will be between 20-120°F. Sensing lines may be any length necessary without affecting accuracy. However, long runs of tubing will dampen readings slightly and cause a minor increase in response time. If pulsing pressure or vibration cause excessive pointer oscillation, contact factory for ways to provide additional damping.
2. The gage is calibrated and zeroed in the vertical position at the factory. If the gage is used in any other position, it must be rezeroed each time the position is changed. Gages with ranges under 5 in. w.c. or equivalent should be used only in the vertical position unless special calibration was specified when ordering.

Continued

PANEL MOUNTED INSTALLATION

3. To surface mount gage, drill two 5/32" holes on a horizontal line, 2.33" apart for mounting screws. Next drill two 7/16" holes 1 1/32" apart on a vertical line for pressure connections. Install mounting studs in back of gage, insert through holes in panel and secure with hex nuts provided. Be careful not to block the slotted hole near the right hand mounting hole. This provides a path for pressure relief in the event of overpressurization.
4. To panel mount gage, cut a 2 5/8" dia. hole. Install mounting studs in back of gage, position gage in panel and place bracket over studs. Thread hex nuts over studs and tighten.
5. After installation, the gage may need to be zeroed before placing in operation. If re-zeroing is required, firmly hold case of gage with one hand and unscrew front cover with the palm of the other hand in a counterclockwise direction. If difficult to loosen, place a small sheet of rubber between the cover and the palm of the hand. Zero adjust screw is located behind the scale at the point marked "zero". Use hex allen wrench supplied and adjust until pointer is on zero. This must be done with both pressure connections vented to atmosphere and the gage oriented in the final mounting position. Replace cover.
6. To measure positive pressure, connect tubing to port marked "HI" and vent "LO" port to atmosphere. For negative pressure (vacuum) connect to port marked "LO" and vent "HI" port to atmosphere. For differential pressure connect higher pressure to port marked "HI" and lower to "LO" port. If gage is supplied with 1/8" NPT connections, be careful not to overtighten fittings to avoid damage to the gage.

CALIBRATION CHECK

Select a second gage or manometer of known accuracy and in an appropriate range. Use short lengths of rubber or vinyl tubing to connect the high pressure side of the Minihelic gage and the test gage to two legs of a tee. Very slowly apply pressure through the third leg. Allow enough time for pressure to equalize throughout the system and for fluid to drain if a manometer is being used. Compare readings. If gage being tested exceeds rated accuracy, it should be returned to the factory for recalibration.

MAINTENANCE

No lubrication or periodic servicing is required. Keep case exterior and cover clean. Occasionally disconnect pressure lines to vent both sides of gage to atmosphere and re-zero per paragraph 5.

Litho in U.S.A. 11/89

FR. NO. 14-440434-00

1.0 GENERAL DISCUSSION

1.1 Purpose of Procedure

This procedure describes the installation, setup, and operation of the Campbell 21X datalogger (21X) for meteorological and continuous gas analyzer instruments.

1.2 Measurement Principle

Meteorological instruments and continuous gas analyzers produce electrical signal outputs based on sensor response. The electrical signal produced may be a voltage signal or a pulse rate signal. Some sensors require an excitation voltage for operation. The 21X measures low voltage input signals, reads pulse rate signals, and provides calibrated excitation signals. In addition, it provides digital control ports to switch external devices. The 21X makes voltage measurements by integrating the analog sensor signal for a fixed time, then performing an analog to digital conversion. The 21X takes readings of all sensors once every two seconds, computes hourly averages, and stores hourly data for downloading upon external command.

1.3 Measurement Interferences and Their Minimization

Electrical ground differences between the 21X and a sensor will cause errors in a single-ended voltage measurement. The error is significant only if the difference in grounding potential is significant with respect to the measurement voltage. All sensors are grounded to a common point. For low voltage sensors, a differential voltage measurement is used which first measures the high input relative to the low input, then again with the inputs reversed and averages the magnitude of the readings. This eliminates errors due to ground potential differences.

When the 21X switches an analog input into the measurement circuitry, it allows a 450 μsecond settling time before beginning measurement. Long sensor leads can increase electrical capacitance in the lead to a level where settling time of a signal is greater than 450 μseconds, causing error in the voltage measurement. Maximum sensor lead length depends on the specific wire used, and the resistance of the sensor and voltage used. All of the sensors use lead lengths less than 100 feet, which is well under the length that may cause signal settling time problems.

1.4 Ranges and Typical Values of Measurements Obtained by this Procedure

The 21X analog input voltage full scale ranges are selectable from $\pm$5 mv to $\pm$5000 mv. Maximum pulse rate frequency is 250 kHz. All sensors operate within these ranges.

1.5 Typical Precision and Accuracy

Accuracy of differential and positive single-ended analog inputs is 0.05% of full scale over the temperature range of 0 - 40 °C, and 0.06% of full scale for negative single-ended inputs. Resolution is 0.0067% of full scale for differential inputs and 0.013% of full scale for single-ended inputs.

1.6 Responsibilities of Personnel

The Field Technician is responsible for routine operation. The Field Supervisor is responsible for installation, data downloading, and troubleshooting.

1.7 Definitions

(Not applicable)

1.8 Related Procedures

Related procedures include the following:

- Operation and Maintenance of Meteorological Instruments (DRI 01)
- Operation and Maintenance of the Dasibi 1008 AH Ozone Analyzer (DRI 02)
- Operation and Maintenance of the Dasibi 1003 PC Ozone Calibrator (DRI 03)
- Meteorological and Continuous Gaseous Data Processing and Validation (DRI 20)

2.0 APPARATUS, INSTRUMENTATION, REAGENTS, AND FORMS

2.1 Apparatus and Instrumentation

- Datalogger: Campbell Scientific 21XL Micrologger with rechargeable lead acid cells. The 21X has 8 differential analog voltage inputs (or 16 single-ended inputs), 4 pulse counter inputs, 4 excitation outputs, 4 digital control ports, keypad and LCD for programming and data query, and a serial port for communication with external devices. Complete specifications are given by Campbell Scientific, 1991.
- Campbell Scientific SC32A optically isolated RS232 Interface

- Campbell Scientific SC532 9-Pin Peripheral to RS232 Interface
- Campbell Scientific SM192 Storage Module
- Campbell Scientific DC112 Modem
- Campbell Scientific SC12 serial cable
- An MSDOS based microcomputer at the sampling site with an 80386 or higher processor, 2 serial ports, and modem; equipped with Procomm communications software and Campbell datalogger software.
- An MSDOS based microcomputer at the laboratory with modem, capable of running and equipped with Windows 3.1, FoxPro 2.5 for Windows, Procomm and the Campbell datalogger software.
- DRI ozone control isolation interface. This interface provides electrical isolation of control signals generated by the 21X and sends them to the ozone calibrator.
- DRI solenoid control interface. This contains a DC relay that switches the ozone manifold/calibrator solenoid.
- DRI phone line switch control. This device switches between 2 phone line connections upon a control signal generated by the 21X.
- Phone/modem switch box
- Furon Delta solenoid valve, model DV3-224A1

2.2 Reagents

(Not applicable)

2.3 Forms

(Not applicable)

3.0 CALIBRATION STANDARDS

(Not applicable)

4.0 PROCEDURES

4.1 General Flow Diagram

(Not applicable)

4.2 Start-Up

Installation, configuration and programming of the 21X must be customized for the specific monitors used. The details specified in this section are specific to the FOREST monitoring program.

4.2.1 Connections

Make connections from sensors to the 21X as shown in Table 4-1. Refer to the Meteorological Instrument SOP for details of wire color codes used for each sensor. The analog input connections from the ozone analyzers are from the recorder output terminals on the back of the analyzers; connect the + terminal to analog input and the - terminal to ground. The connections for the wet/dry bucket position are from the event recorder screw terminals on the sampler; connect + to analog input and - to ground.

Connections for the DRI ozone control isolation interface are as follows. The 21X control output terminals 1, 2, 3 and 4 go to input connections 1, 2, 3 and 4, respectively, on the control interface. Likewise, +12 V and ground connections go to +12 V and ground on the input side of the control interface. Connect 5 V and ground output terminals from the control interface to 5 V and ground terminals on the Dasibi 1003 PC calibrator. Connect output terminals 1,2 and 4 from the control interface to "Gen", "Sam" and "O3" terminals, respectively, on the 1003 PC. Connect output terminals 3 and ground to the DRI solenoid control interface, and plug the solenoid control into 115 VAC power. Connect the solenoid control to the ozone manifold solenoid.

Connect the phone line coming into the shelter to the phone/modem switch box. Connect the phone to the jack labeled "Phone" on the phone/modem switch box. Connect the jack labeled "modem" to the input line on the DRI phone line switch control. Connect the normally closed output of the phone line switch control to the Campbell DC112 modem, and the normally open output to the modem installed in the computer. Connect a ground wire from the DC112 modem to the 21X. The DC power and control signal input of the phone line switch control are already connected to the 21X.

Table 4-1
Electrical Connections to Campbell 21X Datalogger

Terminal Group	Parameter	Sensor/Device	Terminal	Wire
Analog Input	Wind direction	Met One 024A	1 high	Red
	Temperature	Met One 207	1 low	Red
	Relative humidity	Met One 207	2 high	White
	Temperature, relative humidity	Met One 207	1 ground	Clear
			1 ground	Purple
	Ozone	Dasibi 1008 AH	2 low	Clear
			2 ground	Black
	Ozone calibrator	Dasibi 1003 PC	3 high	Clear
			3 ground	Black
	Leaf wetness	Campbell Sci. 237	3 low	Red
	Solar radiation	Li-Cor LI200SZ	4 high	Red
			4 low	Black
			4 ground	Clear
	Shelter temperature	Thermocouple	5 high	Blue
			5 low	Red
	Wet/dry bucket position	Wet/dry bucket	6 high	Orange
			6 ground	Black
	Auxiliary ozone	Dasibi 1003 AH	6 low	Orange
			6 ground	Black
Pulse Input	Windspeed	Met One 014A	1	Black
			ground	White
			ground	Clear
Excitation Output	Wind direction	Met One 024A	1	Black
			2 ground	White
			2 ground	Clear
	Temperature, relative humidity	Met One 207	2	Black
	Leaf wetness	Campbell Sci. 237	3	Black
			4 ground	Purple
			4 ground	Clear
Control Output	Ozone pump	DRI control interface	1	Black
	Ozone calibrator sample pump	DRI control interface	2	White
	Ozone manifold/calibrator select	DRI control interface	3	Green
	Ozone generator	DRI control interface	4	Red
	Phone/modem select	DRI phone line switch	6	Green
+12 V	Phone/modem select	DRI phone line switch	+12 V	Red
			ground	Black
	Ozone calibration control	DRI control interface	+12 V	Clear
			ground	Black

This connection scheme allows one to call the voice phone at the site when the phone/modem switch is in the phone position. When switched to the modem position, the DC112 modem is connected, allowing remote control of the 21X. By setting the proper program flag while controlling the 21X remotely, the phone line switch control is activated, switching the phone line from the DC112 modem to the computer modem. This terminates the connection, and allows you to redial, connecting with the computer modem. The 21X switches the phone line back to the DC112 modem after a preset time.

Connect the 21X serial port to the SM192 storage module and the DC112 modem with a SC12 cable. The cable has a male connector that fits the serial port on the 21X, and two female connectors that fit the peripheral ports. Connect the SM192 to the connector in the middle of the cable, and the DC112 to the connector at the end of the cable. Connect the SC32A RS-232 interface to a serial port on the computer.

4.2.2 Software Configuration- Site Computer

Include the Procomm directory in the PATH statement in the AUTOEXEC.BAT file. Include the lines

```
cd \ campbell
pcplus/fhost
```

as the last two lines of the AUTOEXEC.BAT file. Create an ASCII file named HOST.ASP in the Procomm directory with a single line as follows.

```
host
```

Create another ASCII file named PCPLUS.USR in the Procomm directory with a single line as follows.

```
<lastname>;<firstname>;<password>;1;
```

Substitute the field supervisor's name and a password; do not include the < > characters but do include the ; characters. The "1" status code allows complete access to all directories on the computer. Whenever the computer is rebooted, it will change to the Campbell directory, load Procomm and go into host mode, where it is able to answer calls. The field supervisor can dial and connect to the site computer by logging on with his name and password, and transfer files, leave email for the site operator, etc.

Configure the Campbell TERM program for communicating with the datalogger by changing to the Campbell directory, then typing

term bartonfl

at the DOS prompt (text that you type or keys to press are underlined). The program displays a screen with prompts for datalogger type, communications adapter, baud rate, and interface device. Select among the available options by pressing the space bar, and proceed to the next prompt by pressing the Return key. Select "21X" for datalogger type, "9600" for baud rate, and "End" for interface device. Select the appropriate communications adapter based on how the serial port is configured. When all options are selected, choose "Save and quit editing" and then "Q" to quit the program.

4.2.3 Laboratory Computer

Set up the TERM program as for the site computer, except select the communications adapter to which the modem is connected, select "1200" for baud rate, "Hayes Modem" for interface device, and enter the site phone number.

Set up the TELCOM program by typing

telcom bartonfl

at the DOS prompt. Prompts for various options are displayed as shown in Screen 4-1. Make option selections and move from one prompt to the next as you did for the TERM program. Answer the prompts as shown in Screen 4-1, but substitute the correct COM port and phone number.

4.2.4 Datalogger Program

The datalogger program is designed specifically for the sensors and connections already made. The program records hourly averages of meteorological variables and ozone measurements, and maximum and minimum instantaneous wind speed. Hourly averages are based on a two second sample interval. Both scalar and vector wind speed and wind direction are recorded. Sigma theta is calculated by averaging 4 sub intervals of 15 minutes each hour. Final hourly data and ozone calibration data are written to 21X internal memory and the Campbell SM192 Storage Module as a backup. Wet/dry sampler bucket position, power outage events and, if enabled, real time data are also written to internal memory and SM192 Storage Module. The program initiates an ozone calibration check sequence once each day at 05:00. Ozone calibration data based on 1 minute averages over a 30 minute calibration cycle are recorded. A program listing is included in this SOP as Appendix 1.

```
                     Station File Name: bartonfl

            Datalogger or Command Type: 21X                Security Code: 0
   Fix Datalogger Clock Using PC Clock: No


                Data Collection Method: Since Last Call; Append File;
 Nbr of Arrays to Backup on First Call: 0
                      Data File Format: Comma Delineated ASCII

      Primary Call Interval (minutes): 1440
  Recovery Call Interval #1 (minutes): 15
  Repetitions of Recovery Interval #1: 4
  Recovery Call Interval #2 (minutes): 1440
Maximum Time Call Will Take (minutes): 10
                    Next Time To Call: 12/22/94  0:17:00

       Interface Devices:
      COM1                Baud Rate: 1200
      Hayes Modem            Number: 919097941171V681
      End

      ^O = Save/Resume      ^P = Save/Done      ESC = Abandon Edit
```

Screen 4-1. TELCOM setup dialog.

4.3 Routine Operation

4.3.1 Site Visit

- Switch phone/modem switch box to "Phone".
- Turn up brightness and contrast on computer monitor.
- The computer is in host mode in Procomm. Check to see if you have email by pressing function key F2. Answer Y to the prompts "Continue to answer calls?" and "Logon as SYSOP?". Press R to read mail. Press L to leave mail if you wish and G when you are finished with email. Press Esc to exit host mode, then Alt-F4 to shell out to DOS.
- Remove the blue serial line cable from the DC112 modem and connect it to the SC32A RS-232 interface.
- Type term bartonfl and press Return key. Press m to monitor input locations, then press Return when prompted with "(BARTONFL.DLD) file containing labels." Press l (that is the letter l, not the number 1) to specify the number of locations to display, followed by 1..20 and Return.

The display now shows data in real time as it being collected by the 21X. Conduct the parameter checks as detailed in the Meteorological Instruments and Ozone Analyzer SOPs. Leave the display in this mode throughout the duration of the site visit. Just before leaving the site, perform the following steps.

- Press Esc to exit the input location monitor. Press Q to exit the TERM program and return to DOS.
- Type exit to leave the DOS shell and return to Procomm. Press Alt-Q to initialize host mode.
- Remove the blue serial line cable from the SC32A RS-232 interface and connect it to the DC112 modem.
- Turn down brightness and contrast controls on the monitor to prevent phosphor burn.
- Switch phone/modem switch box to "Modem".

4.3.2 Download Data

Data are accumulated in the 21X in a 40 Kbyte memory. This is enough memory to hold about 2.5 weeks of data. When the memory fills, new data are written over the oldest data. Data are simultaneously written to the SM192 storage module; the SM192 can be accessed as a backup to 21X memory, and to retrieve older data since it has a larger memory.

Download data from the 21X to the laboratory computer on a weekly basis using the following steps.

- Change to the Campbell data directory. Type telcom bartonfl. The TELCOM program dials the modem and initiates transfer of all data in the 21X that has not be already downloaded. Data are saved in the comma delimited ASCII file BARTONFL.DAT. If a file of this name existed before the transfer, the new data are appended. The 21X sets a pointer to the last data that was transferred.
- Start FoxPro, and switch to the project's Campbell data directory by typing

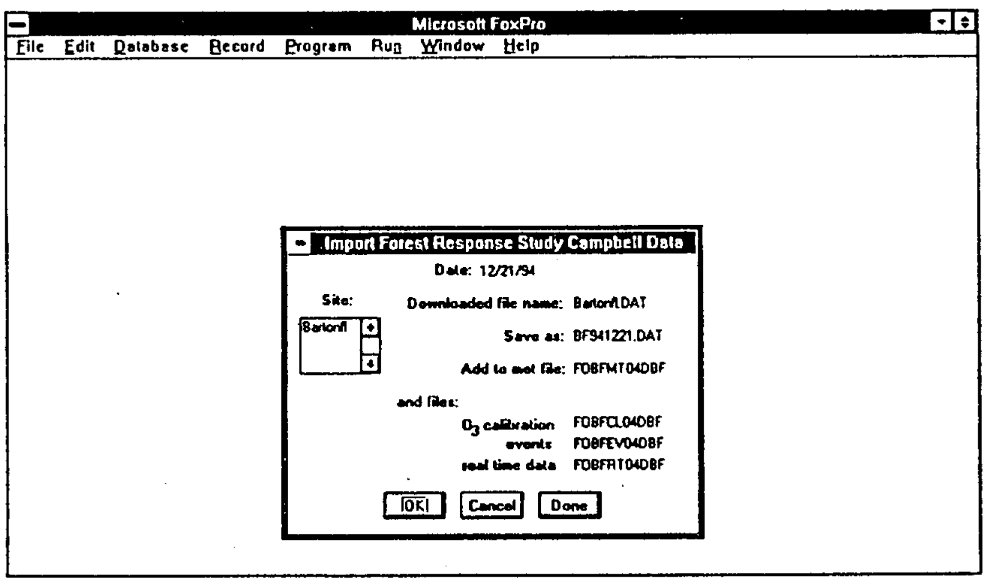
  set default to <pathname>

  in the command window, where <pathname> is the project's Campbell data directory.

- Convert the data from the comma delimited ASCII to FoxPro by typing

  do logfomet

  in the command window. A dialog screen appears as shown in Screen 4-2 which has fields for entering input and output file names. The default site name is Bartonfl. Press Return to show default names for the rest of the files. The default file name for the downloaded data is BARTONFL.DAT. This file is copied to a file name based on site code and download date so that a permanent record of the original datalogger data is maintained. Default file names for met data, for ozone calibration data, for event data, and for real time data are shown. Change the batch number (the last two characters before the extension) of the met file if necessary, and all the other output file names will change accordingly. When file names are correct, select the OK button to translate data.



Screen 4-2. LOGFOMET file name dialog.

- New data are appended to data in the FoxPro met file. After appending, a BROWSE screen opens. Scan the new data for problems or unusual values. Look especially for very high or very low values, out of range values that appear as asterisks, or values that remain constant or nearly constant over long time interval. Make note of any problems. After scanning the data, close the BROWSE window.

The program then adds data to the ozone calibration data file, the event data file, and the real time data file in turn. Scan each of these files as before.

- If any data appear to have problems, determine the source of the problem and resolve as soon as possible.

4.3.3 Check Current Sensor Readings

Check current sensor readings on a weekly basis after downloading data. Start the TERM program and monitor input data locations as in section 4.3.1. Look for readings that are not reasonable, or may suggest a possible sensor malfunction. Verify current site conditions with the site operator, if any readings are questionable. If any sensors are malfunctioning, determine the source of the problem and resolve as soon as possible. Press Esc and Q to terminate the connection.

4.3.4 Access Site Computer

Access the site computer from the laboratory computer to upload or download files, send or read email to/from the site operator, etc. Follow the steps below to access the site computer.

- While the TERM program is running and input data locations are displayed, press I.

- The prompt at the bottom of the screen reads "Change Input Location value 11:". Enter 16:30 after the prompt and press Return. This loads the value 30 into input location 16, which is the number of minutes that the phone line is switched to the computer modem after triggering the phone line switch control. Enter a smaller or larger number as needed.

- Press the F6 function key. The phone line switch control is activated, and the connection to the Campbell is terminated.

- Start Procomm and dial the site computer. Log on with name and password as prompted.

4.4 Shut-Down

(Not applicable)

5.0 QUANTIFICATION

All computations performed by the 21X are fully documented in the datalogger operating manual (Campbell, 1991).

6.0 QUALITY CONTROL/ASSURANCE

The major potential source of error in this procedure is data transmission errors during data downloading. The TELCOM software has data verification procedures built in so that transmission errors are caught and corrected. If the phone line is too noisy to allow error free transmission, the transfer is aborted. Data are scanned immediately after loading into FoxPro files; errors in data transmission are likely to produce out of range or invalid numbers which are easy to detect while scanning.

7.0 REFERENCES

Campbell Scientific, 1991. *21X Micrologger Operator's Manual, Revision 8/91*. Campbell Scientific, Inc. August, 1991, Logan, Utah.

APPENDIX 1: Campbell 21X Datalogger Program BARTONFL.DAT

```
Program:  Campbell 21X Datalogger program for
          Forest Response Study, Barton Flats Site

          C.A. Frazier, 10/22/91

     Modified 6/22/92, CAF.  Version 2
       -  Add extra ozone channel for temporary
          comparison of new ozone monitor to existing
          ozone monitor.
       -  Add flag to disable wetness sensor averaging.

     Modified 6/23/92, CAF.  Version 3
       -  Add wet/dry bucket position indicator.
       -  Add power out event recorder.
       -  Add real time data output option.

     Modified 6/24/92, CAF.  Version 4
       -  Add data value to power out and wet/dry
          bucket position indicator.
       -  Change ozone zero and calibration check times
          from 15 minutes each to 10 minutes for zero
          and 15 minutes for calibration.

   Program Notes:

          This program records hourly averages of
     meteorological variables and ozone measurements,
     maximum and minimum instantaneous wind speed.
     Ozone calibration data based on 1 minute averages
     over a 30 minute calibration cycle is recorded
     per day.
          Hourly averages are based on a 2-second
     sample interval.  Both scalar and vector wind
     speed and wind direction are recorded.  Sigma
     theta is calculated by averaging 4 sub intervals
     of 15 minutes each hour.
          Final hourly data and ozone calibration data
     are written to the Campbell SM192 Storage Module.
     Wet/dry sampler bucket position, power outage
     events and, if enabled, real time data are also
     written to Final Storage and SM192 Storage Module.

   Flag Usage:

     Flag 1 - High to exclude leaf wetness from hourly
                average, low to include sample in ave.
     Flag 2 - High to exclude 1008 AH ozone from h
                average, low to include sample in ave.
     Flag 3 - High for 1- minute ozone calib. output,
                low otherwise.
     Flag 4 - High for Wet/Dry bucket = wet, low for
                bucket = dry.
     Flag 5 - High for battery < 13 v., low otherwise.
     Flag 6 - High for computer modem, low for Campbel
                modem (enter from monitor mode in TERM).
     Flag 7 - High for real time data output.
```

Page 2 Table 1

Single Ended Analog Input Channel Usage:

Channel	Variable	Sensor
1	wind direction	Met One Model 024A
2	temperature	Met One Model 207
3	relative humidity	Met One Model 207
4	ozone	Dasibi 1008 AH
5	ozone calibrator	Dasibi 1003 PC
6	leaf wetness	Campbell Sci. Model 237
11	wet/dry bucket pos.	Aerochemitrics Wet/Dry
12	ozone (temporary)	Dasibi 1003 AH

Double Ended Analog Input Channel Usage:

Channel	Variable	Sensor
4	solar insolation	Li-Cor LI200SZ pyranom.
5	shelter temp.	thermocouple

Pulse Input Channel Usage:

Channel	Variable	Sensor
1	windspeed	Met One Model 014A

Excitation Channel Usage:

Channel	Variable
1	wind direction
2	temperature, relative humidity
3	leaf wetness

Control Port Usage:

Channel	Variable	Status
1	ozone pump	high=on, low=off
2	1003 PC sample pump	high=on, low=off
3	ozone calib. valve	high=calib low=manifld
4	ozone generator	high=on, low=off
5	not used	
6	modem	high=cmptr, low=campbl

Input Storage Locations:

1 - wind speed (m/s)
2 - wind direction (degrees)
3 - ambient temperature (C)
4 - relative humidity (%)
5 - ozone (ppb)
6 - ozone calibrator (ppb)
7 - leaf wetness sensor voltage ratio
8 - leaf wetness sensor resistance (kohms)
9 - solar insolation (W/m2)
10 - panel temperature (C)
11 - shelter temperature (C)

Page 3 Table 1

12 - power supply voltage (V)
13 - counter - no. of samples in hourly ave.
14 - counter - no. of samples in ozone h. ave
15 - program signature
16 - minutes to shut off Campbell modem - (entered from monitor mode in TERM)
17 - counter for Campbell modem shutoff
18 - wet/dry bucket pos. (>3v=wet, else dry)
19 - temporary ozone (ppb)
25 - mean wind speed (from instruction 69)
26 - vector W/S (resultant W/S from 69)
27 - vector W/D (resultant W/D from 69)
28 - Campbell weighted sigma theta (from 69)

Final Storage Locations (Hourly Data):

1 - output array ID (1 = hourly data)
2 - year
3 - julian day
4 - hour-minute (end of hour)
5 - scalar wind speed (m/s)
6 - scalar wind direction (degrees)
7 - sigma theta from 15-minute variances (degrees)
8 - vector wind speed (m/s)
9 - vector wind direction (degrees)
10 - maximum instantaneous wind speed (m/s)
11 - minimum instantaneous wind speed (m/s)
12 - mean temperature (C)
13 - mean relative humidity (%)
14 - mean average ozone (ppb)
15 - time of wetness (fraction)
16 - solar insolation (W/m2)
17 - hourly mean shelter temperature (C)
18 - power supply voltage (V)
19 - total sample count for hourly values
20 - total sample count for hourly ozone value
21 - signature
22 - temporary ozone (ppb)

Final Storage Locations (1-minute Ozone Calib. Data):

1 - output array ID (2 = 1-minute ozone)
2 - year
3 - julian day
4 - hour-minute
5 - ozone - 1008 AH
6 - ozone - 1003 PC

Final Storage Locations (Wet/Dry bucket pos. and Power Outage Events)

1 - output array ID (3 = Wet/Dry = wet)
(4 = Wet/Dry = dry)
(5 = Battery < 13 v)
(6 = Battery > 13 v)

```
Page 4   Table 1

           2 - year
           3 - julian day
           4 - hour-minute
           5 - second
           6 - data value        (bucket pos. sensor volt.
                                 (or battery voltage)


Final Storage Locations (Real Time Data)

           1 - output array ID (7 = real time data)
           2 - year
           3 - julian day
           4 - hour-minute
           5 - second
           6 - wind speed (m/s)
           7 - wind direction (degrees)
           8 - temperature (C)
           9 - relative humidity (%)
          10 - ozone (ppb)
          11 - solar insolation (W/m2)


*      1        Table 1 Programs
  01: 2         Sec. Execution Interval

01:  P32        Z=Z+1
  01: 13        Z Loc [:# Samples]        ; # samples in hourly ave

02:  P91        If Flag
  01: 22        2 is reset                ; if not doing ozone calib
  02: 30        Then Do

03:  P32        Z=Z+1
  01: 14        Z Loc [:# Ozone  ]        ; increment O3 sample counter

04:  P95        End

05:  P91        If Flag                   ; if computer modem selected
  01: 16        6 is set                  ; (from monitor mode in TERM)
  02: 30        Then Do

06:  P86        Do
  01: 46        Set high Port 6           ; switch to computer modem

07:  P37        Z=X*F
  01: 16        X Loc Modem off           ; # min to connect to computer
  02: 30        F                         ; modem X 30 =
  03: 17        Z Loc [:Modem ctr]        ; # program cycles

08:  P37        Z=X*F
  01: 17        X Loc Modem ctr
  02: -1        F                         ; use neg. so we can count
  03: 17        Z Loc [:Modem ctr]        ; cycles up to 0.
```

```
Page 5   Table 1

09:  P86        Do
 01: 26         Set low Flag 6              ; reset flag so this branch
                                            ; executed only once.

10:  P95        End

11:  P89        If X<=>F
 01: 17         X Loc Modem ctr             ; if computer modem counter
 02: 4          <
 03: 0          F                           ; not up to 0 yet,
 04: 30         Then Do

12:  P32        Z=Z+1                       ; increment counter for
 01: 17         Z Loc [:Modem ctr]          ; computer modem

13:  P94        Else                        ; if counter is up to 0,

14:  P86        Do
 01: 56         Set low Port 6              ;switch back to Campbell modem

15:  P95        End

16:  P3         Pulse
 01: 1          Rep
 02: 1          Pulse Input Chan
 03: 22         Switch closure; Output Hz.
 04: 1          Loc [:W/S (m/s)]
 05: .8         Mult
 06: .447       Offset

17:  P4         Excite,Delay,Volt(SE)
 01: 1          Rep
 02: 14         500 mV fast Range
 03: 1          IN Chan
 04: 1          Excite all reps w/EXchan 1
 05: 2          Delay (units .01sec)
 06: 985        mV Excitation
 07: 2          Loc [:W/D (deg)]
 08: .72258     Mult
 09: 0.0000     Offset

18:  P11        Temp 107 Probe
 01: 1          Rep
 02: 2          IN Chan
 03: 2          Excite all reps w/EXchan 2
 04: 3          Loc [:Temp (C) ]
 05: 1          Mult
 06: 0.0000     Offset

19:  P12        RH 207 Probe
 01: 1          Rep
 02: 3          IN Chan
 03: 2          Excite all reps w/EXchan 2
 04: 3          Temperature Loc Temp (C)
 05: 4          Loc [:RH (%)    ]
 06: 1          Mult
 07: 0.0000     Offset
```

```
Page 6   Table 1

20:  P1          Volt (SE)
  01: 2          Reps
  02: 15         5000 mV fast Range
  03: 4          IN Chan
  04: 5          Loc [:O3 (ppb) ]
  05: 1          Mult
  06: 0          Offset                     ; offset matches 1008 AH

21:  P5          AC Half Bridge
  01: 1          Rep
  02: 13         50 mV fast Range
  03: 6          IN Chan
  04: 3          Excite all reps w/EXchan 3
  05: 4800       mV Excitation
  06: 7          Loc [:Wet (V/V)]           ; measured/excitation volts
  07: 1.0        Mult
  08: 0.0        Offset

22:  P42         Z=1/X
  01: 7          X Loc Wet (V/V)            ; invert voltage ratio,
  02: 8          Z Loc [:Wet(kohm)]

23:  P34         Z=X+F
  01: 8          X Loc Wet(kohm)
  02: -92.5      F                          ; and subtract 101
  03: 8          Z Loc [:Wet(kohm)]         ; to get k ohms

24:  P2          Volt (DIFF)
  01: 1          Rep
  02: 2          15 mV slow Range
  03: 4          IN Chan
  04: 9          Loc [:Rad(W/m2)]
  05: 92.336     Mult                       ; see Campbell and Lycor
  06: 0          Offset                     ; doc. for calibration

25:  P17         Panel Temperature
  01: 10         Loc [:Panel Tmp]

26:  P14         Thermocouple Temp (DIFF)
  01: 1          Rep
  02: 1          5 mV slow Range
  03: 5          IN Chan
  04: 1          Type T (Copper-Constantan)
  05: 10         Ref Temp Loc Panel Tmp
  06: 11         Loc [:Shelt Tmp]
  07: 1          Mult
  08: 0          Offset

27:  P10         Battery Voltage
  01: 12         Loc [:Batt (V) ]

28:  P89         If X<=>F
  01: 13         X Loc # Samples
  02: 1          =
  03: 1          F                          ; first sample of each hour,
  04: 30         Then Do
```

```
Page 7   Table 1

29:  P19        Signature
  01: 15        Loc [:Signature]

30:  P95        End

31:  P1         Volt (SE)
  01: 1         Rep
  02: 15        5000 mV fast Range
  03: 11        IN Chan
  04: 18        Loc [:Wt/Dr Pos]      ; >3 v = wet, else dry
  05: 1         Mult
  06: 0         Offset

32:  P1         Volt (SE)
  01: 1         Rep
  02: 15        5000 mV fast Range
  03: 12        IN Chan
  04: 19        Loc [:New O3    ]
  05: 1         Mult
  06: 0         Offset

33:  P92        If time is
  01: 0         minutes into a            ; hourly...
  02: 60        minute interval
  03: 10        Set high Flag 0 (output)

34:  P80        Set Active Storage Area
  01: 03        Input Storage Area          ; output to Input Storage
  02: 25        Array ID or location        ;locations 25 - 28 because

35:  P69        Wind Vector                 ; we want to keep only
  01: 1         Rep                         ; vector W/S, vector W/D
  02: 450       Samples per sub-interval    ; from this instruction
  03: 02        Polar Sensor/(S, U, DU, SDU)
  04: 1         Wind Speed/East Loc W/S (m/s)
  05: 2         Wind Direction/North Loc W/D (deg)

36:  P78        Resolution
  01: 1         High Resolution

37:  P80        Set Active Storage Area
  01: 1         Final Storage Area         ; now set output to Final
  02: 1         Array ID or location

38:  P77        Real Time
  01: 1220      Year,Day,Hour-Minute

39:  P69        Wind Vector
  01: 1         Rep
  02: 450       Samples per sub-interval
  03: 00        Polar Sensor/(S, D1, SD1)     ; scalar W/S, W/D,
  04: 1         Wind Speed/East Loc W/S (m/s)     ; sigma theta
  05: 2         Wind Direction/North Loc W/D (deg)
```

```
Page 8   Table 1

40:  P70        Sample
  01: 2         Reps
  02: 26        Loc                          ; vector W/S, W/D

41:  P73        Maximize
  01: 1         Rep
  02: 0         Value only
  03: 1         Loc W/S (m/s)

42:  P74        Minimize
  01: 1         Rep
  02: 0         Value only
  03: 1         Loc W/S (m/s)

43:  P71        Average
  01: 2         Reps
  02: 3         Loc Temp (C)                ; temp, humidity

44:  P91        If Flag
  01: 12        2 is set
  02: 19        Set high Flag 9 ; exclude when doing ozone calib.,

45:  P71        Average
  01: 1         Rep
  02: 5         Loc O3 (ppb)       ; ozone from average.

46:  P86        Do
  01: 29        Set low Flag 9

47:  P91        If Flag
  01: 11        1 is set
  02: 19        Set high Flag 9

48:  P75        Histogram
  01: 1         Rep
  02: 1         No. of Bins
  03: 1         Closed form
  04: 8         Bin Select Value Loc Wet(kohm)
  05: 0         Frequency Distribution
  06: 0         Low Limit         ; fraction of readings 0 - 200 kohms
  07: 200       High Limit        ; = fraction sensor is wet

49:  P86        Do
  01: 29        Set low Flag 9

50:  P71        Average
  01: 1         Rep
  02: 9         Loc Rad(W/m2)

51:  P71        Average
  01: 1         Rep
  02: 11        Loc Shelt Tmp

52:  P70        Sample
  01: 4         Reps                ; volts, samples, O3 smp, sig.
  02: 12        Loc Batt (V)
```

```
Page 9   Table 1

53:  P71        Average
  01: 1         Rep
  02: 19        Loc New O3

54:  P91        If Flag
  01: 10        0 (output) is set                ; if hourly output
  02: 30        Then Do

55:  P30        Z=F
  01: 0         F                        ; reset counters for
  02: 13        Z Loc [:# Samples]       ; # samples,

56:  P30        Z=F
  01: 0         F
  02: 14        Z Loc [:# Ozone  ]       ; and # ozone samples,

57:  P95        End

58:  P92        If time is
  01: 285       minutes into a           ; at 04:45
  02: 1440      minute interval
  03: 30        Then Do

59:  P86        Do
  01: 41        Set high Port 1          ; turn on ozone pump

60:  P86        Do
  01: 42        Set high Port 2          ; turn on 1003 PC sample pump

61:  P86        Do
  01: 43        Set high Port 3          ; switch inlet to calibration

62:  P86        Do
  01: 12        Set high Flag 2  ; exclude 1008 AH ozone from hr. ave.

63:  P86        Do
  01: 13        Set high Flag 3          ; set ozone calib. output flag

64:  P95        End

65:  P92        If time is
  01: 295       minutes into a           ; at 04:55
  02: 1440      minute interval
  03: 44        Set high Port 4          ; turn on ozone generator

66:  P92        If time is
  01: 310       minutes into a           ; at 05:10
  02: 1440      minute interval
  03: 30        Then Do

67:  P86        Do
  01: 54        Set low Port 4           ; turn off ozone generator

68:  P86        Do
  01: 53        Set low Port 3           ; switch inlet to manifold
```

```
Page 10   Table 1

69:  P86        Do
  01: 52        Set low Port 2          ; turn off 1003 PC sample pump

70:  P86        Do
  01: 51        Set low Port 1          ; turn off ozone pump

71:  P86        Do
  01: 23        Set low Flag 3          ;turn off 1 min. ozone output

72:  P95        End

73:  P92        If time is
  01: 315       minutes into a          ; at 05:15
  02: 1440      minute interval
  03: 22        Set low Flag 2      ; include 1008 AH ozone in hr. ave.

74:  P91        If Flag
  01: 13        3 is set             ; if ozone calib. output selected,
  02: 30        Then Do

75:  P92        If time is
  01: 0         minutes into a
  02: 1         minute interval
  03: 10        Set high Flag 0 (output)      ; output...

76:  P80        Set Active Storage Area
  01: 1         Final Storage Area
  02: 2         Array ID or location

77:  P77        Real Time
  01: 1220      Year,Day,Hour-Minute

78:  P71        Average
  01: 2         Reps
  02: 5         Loc O3 (ppb)             ; 1008 AH and 1003 PC ozone

79:  P95        End

80:  P91        If Flag
  01: 21        1 is reset          ; if wetness data not excluded,
  02: 30        Then Do             ; check wet/dry position.

81:  P89        If X<=>F
  01: 18        X Loc Wt/Dr Pos     ; if wt/dr pos = wet
  02: 3         >=
  03: 3         F                   ; (>= 3 = wet), ...
  04: 30        Then Do

82:  P91        If Flag             ; and only if
  01: 24        4 is reset          ; 1st time in wet event, ...
  02: 30        Then Do

83:  P86        Do
  01: 10        Set high Flag 0 (output)  ; output...
```

```
Page 11   Table 1

84:  P80       Set Active Storage Area
  01: 1        Final Storage Area          ; to final storage ...
  02: 3        Array ID or location

85:  P77       Real Time
  01: 1221     Year,Day,Hour-Minute,Seconds ; time event started.

86:  P70       Sample
  01: 1        Rep
  02: 18       Loc Wt/Dr Pos

87:  P86       Do
  01: 14       Set high Flag 4     ; set high so record only 1st time.

88:  P95       End                 ; if flag 4 is reset (step 82).

89:  P94       Else                ; if wt/dr pos = dry, ...

90:  P91       If Flag             ; and only if
  01: 14       4 is set            ; 1st time back to dry, ...
  02: 30       Then Do

91:  P86       Do
  01: 10       Set high Flag 0 (output)  ;output ...

92:  P80       Set Active Storage Area
  01: 1        Final Storage Area          ; to final storage ...
  02: 4        Array ID or location

93:  P77       Real Time
  01: 1221     Year,Day,Hour-Minute,Seconds ; time event ended.

94:  P70       Sample
  01: 1        Rep
  02: 18       Loc Wt/Dr Pos

95:  P86       Do
  01: 24       Set low Flag 4       ; set low so record only once.

96:  P95       End                 ; flag 4 is set (step 89)

97:  P95       End                     ; if Loc [18] >= 3 (step 81)

98:  P95       End                     ; if flag 1 reset (step 80)

99:  P89       If X<=>F            ; if batt. voltage < 13 v ...
  01: 12       X Loc Batt (V)
  02: 4        <
  03: 13       F
  04: 30       Then Do             ; (indicates power outage) ...

100: P91       If Flag             ; and only if
  01: 25       5 is reset          ; 1st time in power out event, ...
  02: 30       Then Do
```

```
Page 12   Table 1

101: P86       Do
  01: 10       Set high Flag 0 (output)   ; output ...

102: P80       Set Active Storage Area
  01: 1        Final Storage Area          ; to final storage ...
  02: 5        Array ID or location

103: P77       Real Time
  01: 1221     Year,Day,Hour-Minute,Seconds ; time event started.

104: P70       Sample
  01: 1        Rep
  02: 12       Loc Batt (V)

105: P86       Do
  01: 15       Set high Flag 5   ; set high so record only 1st time.

106: P95       End                  ; if flag 5 is reset (step 98)

107: P94       Else                ; if batt voltage not low, ...

108: P91       If Flag             ; and only if 1st time back
  01: 15       5 is set            ; from power outage event, ...
  02: 30       Then Do

109: P86       Do
  01: 10       Set high Flag 0 (output) ; output ...

110: P80       Set Active Storage Area
  01: 1        Final Storage Area        ; to final storage ...
  02: 6        Array ID or location

111: P77       Real Time
  01: 1221     Year,Day,Hour-Minute,Seconds ; time event ended.

112: P70       Sample
  01: 1        Rep
  02: 12       Loc Batt (V)

113: P86       Do
  01: 25       Set low Flag 5     ; set low so record only once.

114: P95       End                  ; if flag 5 is set (step 105).

115: P95       End                  ; if Loc [12] < 13 (step 97).

116: P91       If Flag             ; if real time data flag set, ...
  01: 17       7 is set
  02: 30       Then Do

117: P86       Do
  01: 10       Set high Flag 0 (output) ; output...

118: P80       Set Active Storage Area
  01: 1        Final Storage Area       ; to final storage.
  02: 7        Array ID or location
```

```
Page 13   Table 1

119: P77         Real Time
  01: 1221       Year,Day,Hour-Minute,Seconds

120: P70         Sample
  01: 2          Reps                       ; W/S, W/D
  02: 1          Loc W/S (m/s)

121: P70         Sample
  01: 3          Reps                        ; temp, humidity, ozone
  02: 3          Loc Temp (C)

122: P70         Sample
  01: 1          Rep
  02: 9          Loc Rad(W/m2)

123: P95         End                        ; if flag 7 set (step 112)

124: P96         Serial Output
  01: 30         SM192/716

125: P           End Table 1


*       2        Table 2 Programs
  01: 0.0000     Sec. Execution Interval

01:   P          End Table 2


*       3        Table 3 Subroutines

01:   P          End Table 3


*       4        Mode 4 Output Options
  01: 00         (Tape OFF) (Printer OFF)
  02: 00         Printer 300 Baud


*       A        Mode 10 Memory Allocation
  01: 28         Input Locations
  02: 64         Intermediate Locations


*       C        Mode 12 Security (OSX-0)
  01: 00         Security Disabled
  02: 0000       Security Code
```

```
Page 14     Input Location Assignments (with comments):

Key:
T=Table Number
E=Entry Number
L=Location Number

T:  E:  L:
1: 16:  1:  Loc [:W/S (m/s)]
1: 17:  2:  Loc [:W/D (deg)]
1: 18:  3:  Loc [:Temp (C)  ]
1: 19:  4:  Loc [:RH (%)    ]
1: 20:  5:  Loc [:O3 (ppb)  ]
1: 21:  7:  Loc [:Wet (V/V)]            ; measured/excitation volts
1: 22:  8:  Z Loc [:Wet(kohm)]
1: 23:  8:  Z Loc [:Wet(kohm)]          ; to get k ohms
1: 24:  9:  Loc [:Rad(W/m2)]
1: 25: 10:  Loc [:Panel Tmp]
1: 26: 11:  Loc [:Shelt Tmp]
1: 27: 12:  Loc [:Batt (V)  ]
1:  1: 13:  Z Loc [:# Samples]        ; # samples in hourly ave
1: 55: 13:  Z Loc [:# Samples]       ; # samples,
1:  3: 14:  Z Loc [:# Ozone   ]       ; increment O3 sample counter
1: 56: 14:  Z Loc [:# Ozone   ]      ; and # ozone samples,
1: 29: 15:  Loc [:Signature]
1:  7: 17:  Z Loc [:Modem ctr]        ; # program cycles
1:  8: 17:  Z Loc [:Modem ctr]        ; cycles up to 0.
1: 12: 17:  Z Loc [:Modem ctr]        ; computer modem
1: 31: 18:  Loc [:Wt/Dr Pos]        ; >3 v = wet, else dry
1: 32: 19:  Loc [:New O3    ]
```

Page 15 Input Location Labels:

1:W/S (m/s)	6:O3 Calib	11:Shelt Tmp	16:Modem off
2:W/D (deg)	7:Wet (V/V)	12:Batt (V)	17:Modem ctr
3:Temp (C)	8:Wet(kohm)	13:# Samples	18:Wt/Dr Pos
4:RH (%)	9:Rad(W/m2)	14:# Ozone	19:New O3
5:O3 (ppb)	10:Panel Tmp	15:Signature	20:__________