

Standard Operation Procedures for Air Toxics

In Use By

**Polk County Air Quality
Ambient Air Monitoring Personnel
For Calendar Year 2020**

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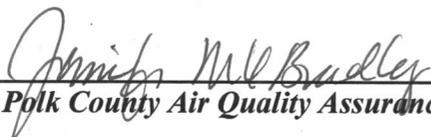
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3/10/2020
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SIGNATURES/APPROVALS



Polk County Air Quality Assurance Officer

3/10/2020
Date

**POLK COUNTY AIR QUALITY DIVISION
 STANDARD OPERATING PROCEDURE MANUAL FOR ATEC MODEL 2200 AIR TOXICS MONITORING**

Table of Contents	Page #
8.1 Purpose.....	2
8.2 Scope.....	2
8.3 References.....	2
8.4 Quality Control	2
8.4.1 Flow Checks	2
8.5 Summary of Method.....	3
8.6 Equipment Installation	4
8.7 Sample Set-Up Operation.....	5
8.7.1 Sampler Program Setup	6
8.7.2 Installation of Carbonyl Cartridge.....	6
8.7.3 Perform Leak Checks.....	7
8.7.4 Sample Pickup Procedures.....	8
8.7.4.1 Downloading Data.....	8
8.7.4.2 Carbonyl Cartridge Pickup.....	9
8.7.4.3 Carbonyl Validation Checks.....	9
8.8 Maintenance and Troubleshooting.....	10
8.8.1 Calibration of the Mass Flow Controller.....	11

FIGURES

Figure 8-1: Purge Flow Diagram.....	4
Figure 8-2: Model 2200 Front Panel View.....	5
Figure 8-3: Model 2200 Touch Screen.....	5
Figure 8-4: Model 2200 Flow Diagram.....	7
Figure 8-5: Leak Check Vacuum Train.....	8
Figure 8-6: Sample Carbonyl Cartridge Download	10

TABLES

Table 8-1: Field Validation Criteria.....	10
Appendix A-Forms and Field Sheets.....	12

8.0 STANDARD OPERATING PROCEDURES FOR AIR TOXICS

8.1 Purpose

To establish a standard operating procedure (SOP) manual for the Polk County Ambient Air Quality personnel concerning the setup, operation, audits and maintenance of the air toxic monitor maintained and operated by Polk County staff. This SOP is intended for individuals responsible for collecting ambient air monitoring data supported by the Polk County Air Quality Division.

8.2 Scope

These procedures are to be used by Polk County Air Quality Division personnel. The objective of this SOP is to familiarize the station operator with procedures used in the collection of air monitoring data. The accuracy of the data obtained from any instrument depends upon the instrument's performance and the operator's skill. It is important that the station operator become familiar with both this SOP as well as the manufacturer's instruction manual in order to achieve a high level of data quality. This SOP is to be used as an outline and is not intended to replace the equipment manufacturer's manual or procedures. This SOP describes the proper procedures for the setup, operation, calibrations, audits and maintenance of Air Toxics equipment operated by Polk County Air Quality personnel.

8.3 References

8.3.1 ATEC Model No.2200 Operations and Maintenance Manual, ATEC Atmospheric Technology, Version 2.0, March 7, 2014.

8.3.2 EPA Toxics Pilot Monitoring Study Measurement Guidelines.

8.4 Quality Control

- Sample duplicates as scheduled by State Hygienic Laboratory (SHL). (Minimum 10%)
- Sample field blanks as scheduled by SHL. (Minimum 10%)
- Carbonyl cartridge breakthrough samples as scheduled by SHL (Minimum 10%)
- Sampling flow for carbonyl cartridge adsorbent cartridges ~1 liter/min (Accuracy +/- 1% Full Scale – "FS").
- Annual audits or calibrations shall be run on the following portions of the sampling system:
 - Timer
 - Mass Flow controllers using Appendix A in the ATEC Model No.2200 Operations and Maintenance Manual

8.4.1 Flow Checks

Flow checks shall be made before and after each sampling event using the BIOS Defender for the carbonyl cartridge channels. Record values on the Field Sheet for both the ATEC sampler and external device.

8.5 Summary of Method

Using the ATEC Model 2200 Toxic Air Sampler, a 24-hour ambient air sample will be taken. Air will be drawn into cartridges for later analysis of Carbonyl compounds. The monitor has been pre-programmed to comply with EPA Methods TO-11A.

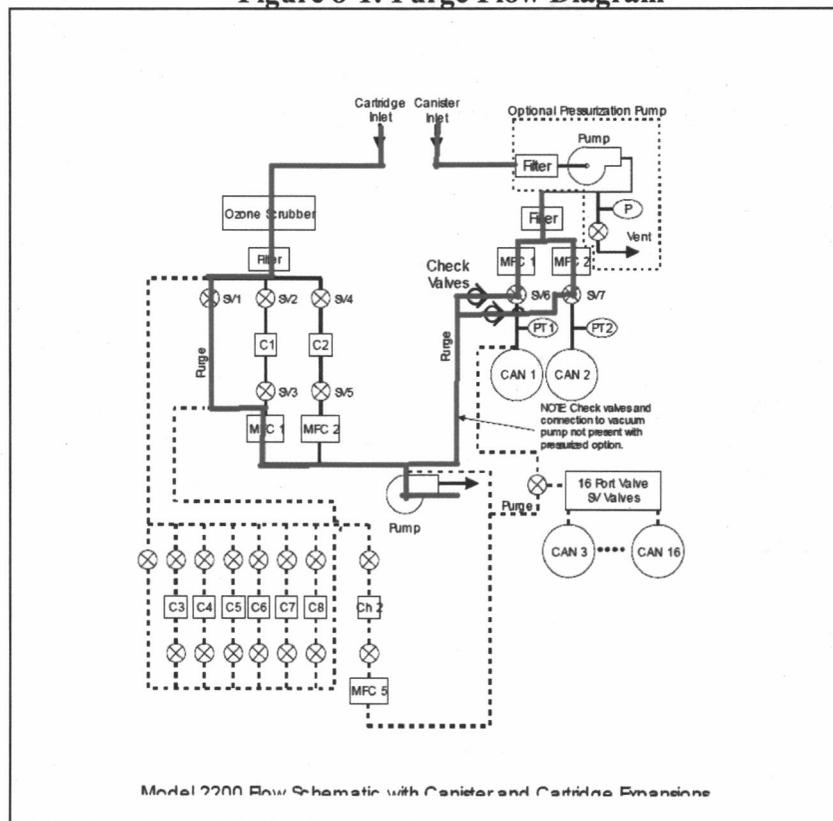
The sampler consists of a single pump that pulls ambient air into the sampler. In order to control and monitor the cartridge flow rates, there is an independent mass flow controller for each channel.

Polk County Air Quality operators will go into the field with a carbonyl adsorbent cartridge (cartridges to be kept cool to $< 4^{\circ}\text{C}$), supplied by SHL's lab. (**Note: Lab will supply materials to field operators at least two days in advance of sampling**). The operator will install the collection media, program sampler, retrieve collection media, fill out appropriate paperwork, and return samples to SHL's lab for analysis. See Appendix A, Form 1 for examples of Chain of Custody Sheets. Prior to sampling, the Model 2200 will purge the sample line, See Figure 8-1. The default purge time is one hour. After analysis, SHL will submit results to appropriate personnel for review before uploading to AIRS. Sampled carbonyl cartridges should be placed in cooler with ice packs after sampling for transport to maintain a temperature of $< 4^{\circ}\text{C}$.

The following materials are required:

- ATEC Model 2200 Toxic Air Sampler
- 1/8" and 1/4" Stainless Steel Sampling Tubing
- 1 - 7/16 wrench and 1 - 9/16 wrench
- 1 pair - Polyethylene gloves
- NIST Traceable BIOS Defender (100ml/min – 7 L/min)
- Carbonyl adsorbent cartridge(s) (**Note-DNPH cartridges should not be exposed to sunlight.**)
- Field data sheets
- Sampler Maintenance/Log book
- Computer with 2200 Data Retrieval Software or USB
- NIST Traceable Barometer
- NIST Traceable Thermometer
- Cooler and Ice Packs for Transport of DNPH Cartridges
- Site AIRS codes
- Calculator

Figure 8-1: Purge Flow Diagram



Purge Flow Diagram: Purge flow paths are shown in green. Sampler is purged for 60 minutes prior to the start of each sampling event.

8.6 Equipment Installation

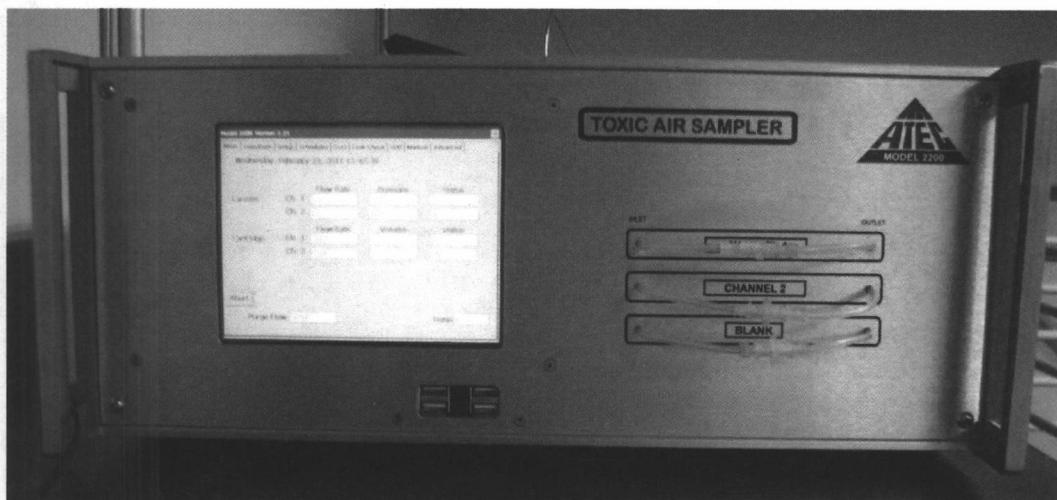
The ATEC Model 2200 Toxic Air Sampler (See Figure 8-2) should be set up in a weather protected area with 115 VAC current. Although not necessary, a controlled environment of 20-30°C is suggested for operation of the sampler.

Mobilize the unit to the field-sampling site and plug into a 115 VAC outlet. Move power switch to “On”. The system will “boot up” in ~ 30 seconds. The system is operated using the ¼ VGA LCD color touch screen display, which shows current status, and allows entry of information into the system’s computer. A pen may be used as a “stylus” to operate the touch screen’s buttons.

Run a ¼” diameter SS tube to the exterior of the sampling enclosure as a sample line. Using a ¼” Swagelok connector and ferrule, connect the sample line to the back of the sampler labeled “Input”.

Cut two pieces of 1/8” SS tube to a length of ~ 2ft. (or other length as needed to reach the sampling storage area for the Summa Canisters). Place 1/8” Swagelok connectors and ferrules on both ends of this canister line. Hook one end of each line to the positions labeled “Channel 1” and “Channel 2” on the back of the sample unit. The other end of these lines have quick connectors to attach to the Summa canisters for sampling.

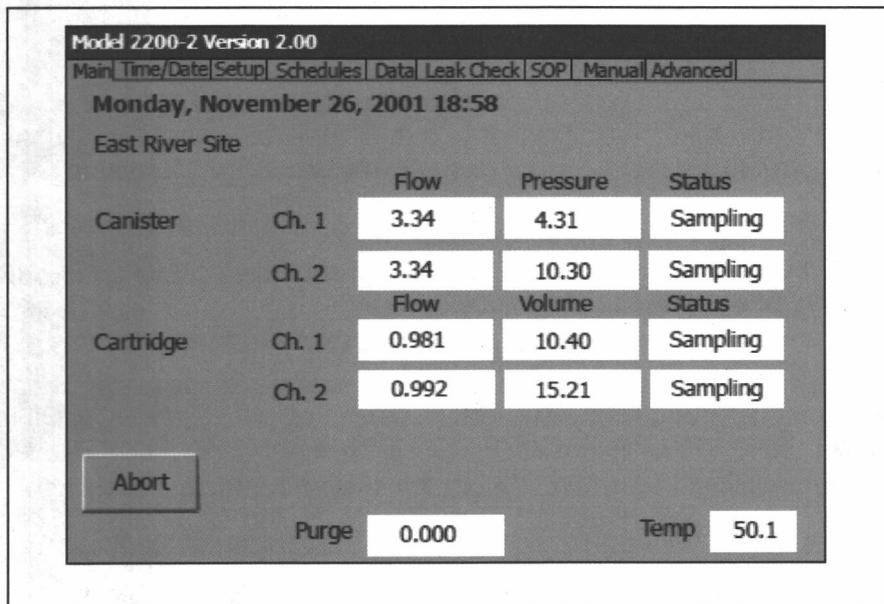
Figure 8-2: Model 2200 Front Panel View



8.7 Sample Set-up Operation

The following steps are necessary for the daily sample set-up. Values are entered or are pre-set and may be viewed on the Model 2200's touch screen, see Figure 8-3.

Figure 8-3: Model 2200 Touch Screen



8.7.1 Sampler Program Setup

Press the **Setup** button on the touch screen. This will show a green screen with “Canister and Carbonyl Parameters”.

Set “Cartridge Parameters” to the following numbers:

- Ch. 1 MFC Set Point: **.800** lpm
- Ch. 2 MFC Set Point: **.800** lpm
- Flow Leak Limit: **0.03** lpm
- Flow Tolerance: **0.05** lpm
- Data Write Interval: **5** min
- Site Label: **(Insert site name)**

Press **Set**.

NOTE: Model 2200 Mass flow controllers measure flow in Standard cc/min and L/min at 0°C and 1 atmosphere.

8.7.2 Installation of Carbonyl Cartridge

NOTE: Polyethylene Gloves should be worn whenever the DNPH-Carbonyl cartridges are being handled.

On the display screen select **Schedules** button. Change the date to the current date on the carbonyl cartridge Channel 1, change the start time to 5-minutes ahead of the current time, and leave the duration to 24-hour. Press **Exit**. The ATEC 2200 machine will begin to purge itself and then perform a leak check. Once this is complete the machine goes into sampling mode, disconnect the sample line and connect the BIOS Defender to the Channel 1 cartridge position on the exit side of the DNPH cartridge in the Carbonyl cartridge sample line. Initiate the flow using the manual control and measure local flow rate. Record the ATEC current flow in L/min.Std 0°C on the Carbonyl Cartridge Field Sheet (Appendix A, Form 1). Recording the average BIOS Defender flow rate in L/min local. Stop the BIOS Defender from taking reading and abort sampling on ATEC. **NOTE:** The ATEC is reading in Standard Conditions while the BIOS Defender is reading in Local. Therefore, it is necessary to take the barometric pressure and temperature readings to convert the local flow reading to Standard Condition Flow (0°C, 760 mmHg) using the following equation:

$$\text{Flow Rate Std (0°C)} = \text{Flow Rate Local} \times \frac{P_{\text{site}} \text{ mmHg}}{760\text{mmHg}} \times \frac{273^{\circ}\text{K}}{(\text{Temp}_{\text{site}}^{\circ}\text{C} + 273)}$$

This will give a comparison to the flow reading on the Model 2200. Record Standard BIOS Defender flow in L/min Std 0°C. If the percent difference is no greater than ± 2% between the ATEC and converted BIOS Defender reading then, with Polyethylene gloves on, attach the carbonyl cartridge to the appropriate Teflon sample line (Position 1 Sample/Position 2 Duplicate). Repeat this process for channel 2 if it is a duplicate sampling day. **NOTE:** If the percent difference is greater than ± 2%, a calibration will need to be performed. Instructions are in the ATEC Model No.2200 Operations and Maintenance Manual, pg. 40, Appendix A.

8.7.3 Perform Leak Checks/Setup.

Press **SOP**. A screen will appear. Select carbonyl(s) to run, and press **Next** to get to the Leak Screen. The instrument will run leak checks on any carbonyls that were selected in the first screen. Press **Next** to run the leak check. The carbonyl leak check will run for 20-seconds. Acceptance limit is set in Section 8.7.1. If leak rate is not met, connections on lock fittings should be checked and leak check re-run. If this does not solve the problem, ATEC should be contacted. Record all leak rates on the field sheets. Cartridge leak check will test the portion of the sample train from the closed upstream solenoid valves (SV1, SV2 & SV4) through the cartridge (C1 & C2), downstream solenoid valves (SV3 & SV5) and mass flow controllers (MFC1 & 2) on to the pump. See Figures 8-4 and 8-5 for details.

When the leak checks are complete, continue navigating through the SOP screens to schedule the next sample run. Enter start dates, start times, and durations of the carbonyls scheduled to run. Press **Next** after each carbonyl is scheduled to continue on to the next one. Upon completion, the SOP Summary Page will appear with a summary of everything scheduled to run. Confirm that the schedule is correct, and press **Next**. The instrument will return to the Main Screen. The status box for the carbonyls scheduled to run should say "waiting".

NOTE: If a problem is recognized while performing any maintenance, diagnostic, or flow checks which has or could affect data, a corrective action form is to be filled out describing the problem identified and the action taken to correct the problem. See Appendix A, Form 3.

Figure 8-4: Model 2200 Flow Diagram

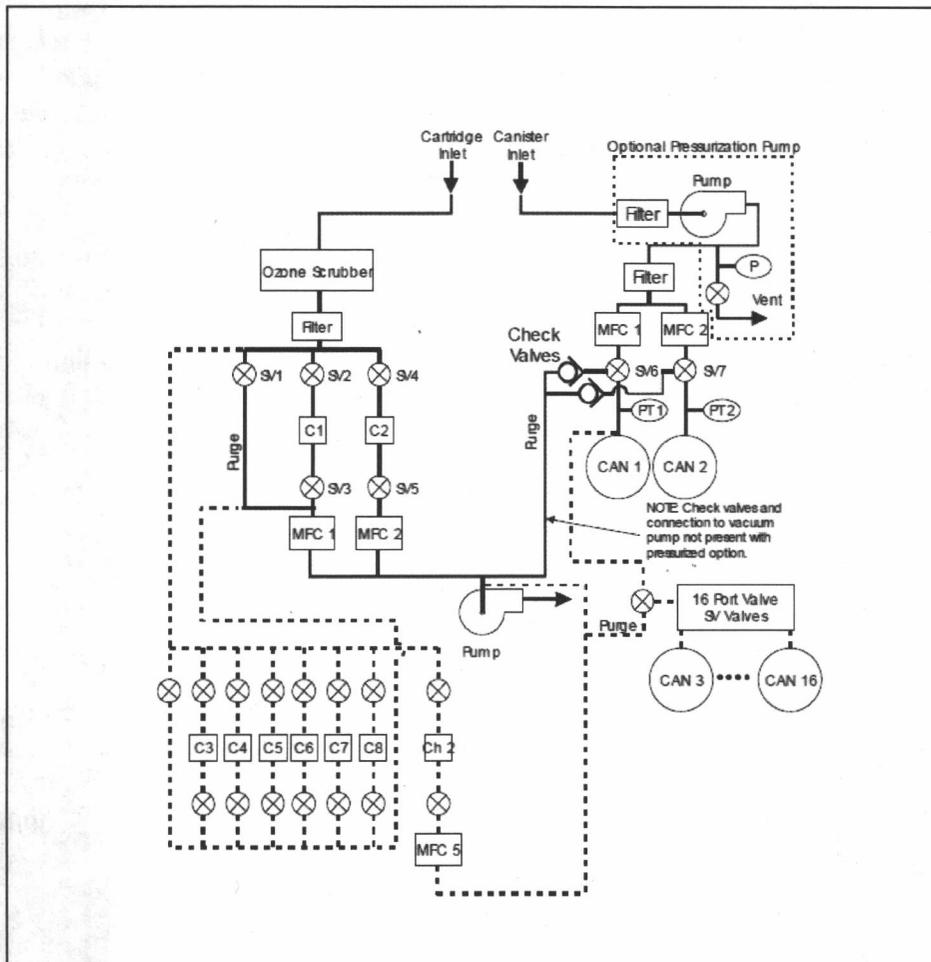
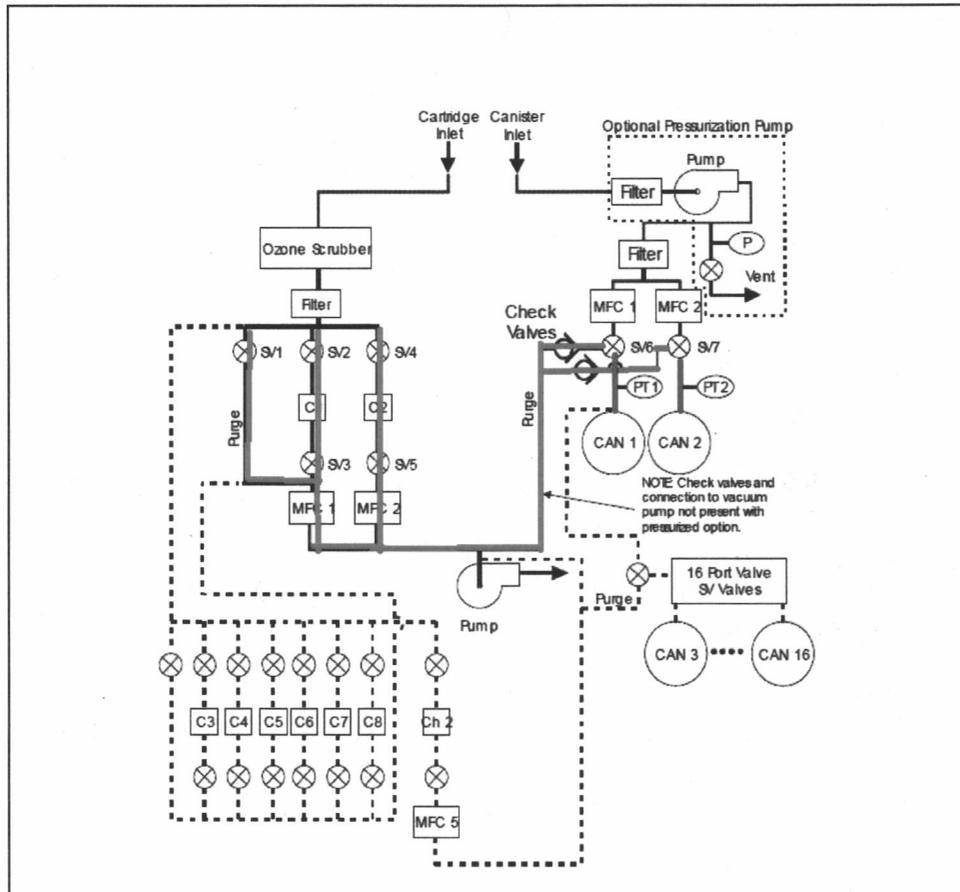


Figure 8-5: Leak Check Vacuum Train



Blue lines show sampling train under vacuum during cartridge leak check.

8.7.4 Sample Pickup Procedure

8.7.4.1 Downloading Data

Note: Data must be downloaded prior to proceeding with post-sampling checks. Otherwise, five minute data will be lost in the process.

Connect the USB Drive to the sampler's "Data" port on the front of the sampler. Press the **Data** button on the sampler. A screen will appear with the start date, stop date, flow, and time on it. Press the **Store** button on the sampler. When data transmission is complete, a screen will appear stating data was downloaded. Press **OK**. If during sampling a power failure occurs, the sampler will remain sampling according to schedule after power is resumed. No data should be lost, however on the downloaded data, a "power loss" error will show and there will be no data given for the powerless interval. For a 24-hour run, there will be approximately 300 lines of data. Figure 8-6 gives an example of the five minute data files.

8.7.4.2 Carbonyl Cartridge Pickup

Continue in the Data Screens to read the Post-Sampling Carbonyl data. Record the final total flow and time passed readings on the field sheet from Carbonyl 1.

Put on polyethylene gloves. Remove carbonyl cartridge from sampler and replace caps on the ends. Place into foil pouch labeled with sampler location, sampler system number and run date, and zip-lock the pouch shut. Store cartridge in the Air Toxics lab refrigerator which will be kept at 4°C until they can be transferred to SHL for analysis. Re-connect the carbonyl cartridge inlet tubes together and perform post sampling flow checks. Repeat procedures from Section 8.7.2 to determine final flow readings. Volume sampled will be in Standard Conditions of 0°C and 1 atmosphere-conversion will be made using the following equation:

$$\text{Total volume (from 2200) } 0^{\circ}\text{C, 1 atm} \times 1.0916$$

Record all readings on field sheet. Repeat for Carbonyl 2 if it is a duplicate sampling day.

Once ready to ship, pack cartridge(s) in cooler with ice packs for transport $<4^{\circ}\text{C}$ to SHL. Place the original field sheet and a completed chain of custody form (Appendix A Forms 1 and 2) inside the cooler and seal.

8.7.4.3 Carbonyl Validation Checks

Review the five minute data from Section 8.7.4.1 of this SOP. Verify that the minimum and maximum flow rates, located at the top of the cartridge run files, differ by no more than 0.020 LPM.

In the event that the minimum and maximum flow rates differ by more than 0.020 LPM, a graph will be generated from a download of the analyzer "run files". The Y axis of the plot will indicate the flow through the cartridge in LPM at 1 atm and 0°C . The X axis will indicate time. If a visual inspection of this plot indicates that the flow through the cartridge was not uniform during the course of the sample run, the cartridge will be invalidated. (Note: Since the flow during the first 5-minute average is typically erratic, that value will not be used to invalidate a cartridge). Appendix A form 4 shows a sample run that demonstrates constant flow, with the exception of the first five minutes.

Mark the field sheet appropriately. If the carbonyl is determined to be invalid, the "Field Sample Validity" line on the "Carbonyl Chain of Custody Sheet" will be marked invalid, and SHL should be notified by phone.

Prior to sending cartridges to SHL for analysis, Polk County personnel will verify that each of the validation criteria in Table 1 has been met. After AIRS strings have been generated by SHL, Polk County personnel will verify that the appropriate flags or void codes (as specified below) have been entered for questionable or voided samples.

Table 8-1: Field Validation Criteria

Void/Flag Criteria Table for Polk County Toxics Monitoring		
Criteria	Acceptable Range	Polk County Void/Flag
Scheduled but not collected		AF
Field Pick-Up	< 72 hrs from completion	3
Maintenance		BA
Cartridge		
Leak Rate Limit	0.03 lpm	AN
Sampling Period	1380-1500 minutes	AN
Flow rate validation	Max-min < 0.020 LPM	AN
Flow Rate Check	Difference between actual and indicated \pm 2%	AN

Figure 8-6: Sample Carbonyl Cartridge Download

Ch. 1 Cartridge

Started Saturday, January 07, 2017 0:00:04
 Flow Rate Set Point 0.80 l/min
 Stopped Sunday, January 08, 2017 0:00:23
 Total Volume 1151.16 liters
 Total Sample Time 24.00 hours
 Average Flow Rate 0.800 l/min
 Minimum Flow Rate 0.799 l/min
 Maximum Flow Rate 0.800 l/min
 Pre Start Leak Rate 0.010 l/min
 Ending Leak Rate -0.003 l/min
 Flow Controller Zero -0.004 l/min
 Error Code 0
 Error Status OK No Errors

Time	Flow Rate	Volume	Temp
Saturday, January 07, 2017 0:00:21	0.128	0.10	49.7
Saturday, January 07, 2017 0:05:24	0.800	4.13	50.1
Saturday, January 07, 2017 0:10:26	0.800	8.17	50.2
Saturday, January 07, 2017 0:15:29	0.799	12.21	50.1
Saturday, January 07, 2017 0:20:31	0.800	16.23	50.1

8.8 Maintenance and Troubleshooting

The ozone scrubber on the carbonyl cartridge sampling system should be replaced annually or after 83 days of sampler operation, whichever comes first. See page 32 of ATEC Model No.2200 Operations and Maintenance Manual for instructions.

The Teflon and sintered stainless steel filters in the cartridge should be replaced annually or when the flow rate through the carbonyls cannot be maintained. See page 32 of ATEC Model No.2200 Operations and Maintenance Manual for instructions.

Mass Flow controllers should be calibrated annually. See Appendix A of ATEC Model No.2200 Operations and Maintenance Manual for instructions. When calibrating the mass flow controllers, the flow measured by the transfer standard will need to be corrected to standard temperature and pressure (1atm and 0°C).

8.8.1 Calibration of the Mass Flow Controller

Calibration of the mass flow controller should be done annually, or any time major repairs are done to the instrument. Enter the **Manual** screen and without the pump running, observe the flow controller flow rate (the flow rate will vary). If it is not 0.00 ± 0.02 lpm, manually adjust the flow controller output by turning the zero adjust screw on the side of the flow controller. Go to the **Advanced** screen and enter 0.00 for the intercept for the channel being calibrated. Remove the Luer connector or cartridge on the channel to be calibrated and connect a calibrated flow standard on the Luer fitting on the outlet tubing on the front panel of the sampler. Under **Manual**, set the flowmeter set point to its normally operating value used in sampling, open the channel solenoid valve by checking Cart1 or Cart2, and activate the pump by checking Pump 1. Allow the flow to stabilize and record the flow rate shown in Flow3 or Flow4 (X) from the Manual screen. Read the calibrated flow unit value (Y). The slope is calculated by:

$$\text{Slope} = \frac{Y}{X}$$

Go to the **Advanced** screen and enter the new value for the slope. Enter the **Schedule** screen and program the sampler to start. After the sampler has started, verify that the flow rate displayed on the main screen is the same as the calibrated flow device. If the flow rates agree within $\pm 2\%$, then the channel has been calibrated correctly and the flow standard can be removed.

APPENDIX A- Critical Forms and Field Sheets

- Form 1..... Carbonyl Field Sheet**
- Form 2..... Carbonyl Chain of Custody Sheet**
- Form 3..... Corrective Action Form**
- Form 4..... Plot of Cartridge Showing Constant Flow**

Form 1 – Carbonyl Field Sheet



Carbonyl Field Sampling Sheet

Collection Site: 50224 Carpenter Des Moines
 Sample Duration: 24 hr
 Duplicate Event: Y N

Collection Date: _____
 Cartridge Lot #: _____

ATEC Serial #: 21134
 Calibration Date: 8/19/10
 Transfer Flow Standard Model: Bios DC Lite M
 Transfer Flow Standard S/N: 6350
 Transfer Flow Std Calibration Date: 5/10/10

Temperature Ref Model: Oakton
 Temperature S/N: 451025
 Temperature Calibration Date: 2/17/10
 Amb Press Ref Model: Cole Parmer Hand Held Baro
 Amb. Pressure S/N: 212

Audit: Y N Audit: Pre Sampling Post Sampling
 Audit Transfer Flow Standard Model: Defender 530 M
 Audit Flow Standard S/N:
 Audit Temperature Flow Std Calibration Date:

Audit Temp Ref Model: Oakton
 Audit S/N:
 Audit Temperature Calibration Date: 3/14/14
 Audit Ambient Press Ref Model: Cole Parmer Hand Held Baro
 Audit Pressure S/N:

Type of Sample (Circle One): Sample Duplicate Break-through Field Blank Trip Blank
 Set Up Date: _____ Set Up By: _____

Site Amb. Pressure: _____ in Hg Site Amb. Temp.: _____ °C
 Site Amb. Pressure: _____ mmHg (site press in Hg x 25.4) Site Amb. Temp.: _____ °K (site temp °C + 273)
 Amb. Pressure Calibration Date: _____

Pre-Sampling Bios Flow Rate: _____ L/min Local
 Pre-Sampling Bios Flow Rate Converted to Standard: _____ L/min Std 0°

$$\left\{ \frac{\text{Bios FR L/min} \times \left(\frac{\text{Site Pressure mm/Hg}}{760 \text{ mm/Hg}} \right) \times \left(\frac{\text{Site Temp K}}{\text{Site Temp } ^\circ\text{C} + 273} \right)}{\text{Flow Rate Setting}} \right\}$$

Pre-Sampling ATEC Flow Rate: _____ L/min Std 0° Flow Rate Setting: 800 L/min
 Flow Rate Difference: _____ % (Difference should be within +/- 2 %. If not within calibrate flow)
 ((ATEC L/min Std 0° - Bios L/min Std 0°)/Bios L/min Std 0°) X 100
 Pre-Sampling Leak Check Passed: Y N Leak Rate: _____ L/min

Recovery Date/Time: _____ Pick-up < 72 hours: Y N Recovered By: _____
 Cartridges Capped: Y N Total Volume (from 2200): _____ L (0°C, 1 atm)
 Total Time: _____ min Total Time between 1380-1500 (circle): Y N

Site Amb. Pressure: _____ in Hg Site Amb. Temp.: _____ °C
 Site Amb. Pressure: _____ mmHg (site press in Hg x 25.4) Site Amb. Temp.: _____ °K (site temp °C + 273)
 Amb. Pressure Calibration Date: _____

Post Sampling Bios Flow Rate: _____ L/min Local
 Post Sampling Bios Flow Rate Converted to Standard: _____ L/min Std 0°

$$\left\{ \frac{\text{Bios FR L/min} \times \left(\frac{\text{Site Pressure mm/Hg}}{760 \text{ mm/Hg}} \right) \times \left(\frac{\text{Site Temp K}}{\text{Site Temp } ^\circ\text{C} + 273} \right)}{\text{Flow Rate Setting}} \right\}$$

Post Sampling ATEC Flow Rate: _____ L/min Std 0°
 Flow Rate Difference: _____ % (Difference should be within +/- 2 %. If not within calibrate flow)
 ((ATEC L/min Std 0° - Bios L/min Std 0°)/Bios L/min Std 0°) X 100
 Total Volume Std. Condition (25°C, 1 atm): _____ L (Total volume (from 2200) 0°C, 1 atm, X 1.0916)
 Data Validation Check: Flow Rate (Max - Min < 0.020 LPM): Y N

Max: _____ Min: _____ Ave: _____ LPM: _____

Field Comments: _____

Pre-Sampling

Post-Sampling

Form 2 – Carbonyl Chain of Custody Sheet

Order #: 2372 Pages in Order: 1 of 1 Containers in Order: 1	REPORT TO: 1130 AIR QUALITY MANAGER SHL/AIR QUALITY UI RESEARCH PARK 2490 CROSSPARK RD CORALVILLE, IA 52241-	BILL TO: 514 IDNR AIR QUALITY SECTION SUITE 1 7900 HICKMAN RD WINDSOR HEIGHTS, IA 50324-
---	--	---

Requested Analyses/Tests

Carbonyls- epa 11a

Complete or correct the following information

Collected Date: _____ <small>yyyy-mm-dd</small>	Collected Time: 00:00 <small>24 hour format hh:mm</small>
Client Reference: lot# _____	Collector: _____ <small>Print last, first name</small>
Location: carpenter <small>kitchen sink, plant tap, etc.</small>	Location City: DES MOINES
Collector Phone: _____ <small>000/111-2222</small>	Description: _____
Project Name: dnr/air toxics <small>Laboratory approved projects only</small>	
Volume: _____	Null Data Code: _____
State Code: 19	County Code: 153
Site ID: 0030	Collection Frequency: 7
POC TO-11: 16	Sample Run Time: _____ <small>minutes</small>
Duplicate Event: _____ <small>yes/no</small>	Sample Valid: _____ <small>yes/no</small>

Chain of Custody/Tracking Signatures

Relinquished By: _____	Date/Time: _____ / ____ / ____ <small>year mm dd Military Time</small>
SHL Sample Receiving Custodian: _____	Date/Time: _____ / ____ / ____ <small>year mm dd Military Time</small>
Relinquished By: _____	Date/Time: _____ / ____ / ____ <small>year mm dd Military Time</small>
SHL Sample Receiving Custodian: _____	Date/Time: _____ / ____ / ____ <small>year mm dd Military Time</small>

For SHL Use Only – Please do not write below this line

Received By: _____	pH: _____
Evidence of Tampering: <input type="checkbox"/> Yes <input type="checkbox"/> No	Evidence of Cooling: <input type="checkbox"/> Yes <input type="checkbox"/> No
Date Printed: 2015-02-26	
Bottles Received: _____	Temperature (Celsius): _____

BUILD ID _____	BUILD ID _____	PLACE THE ACCESSION LABEL WITHIN THIS BOX
----------------	----------------	---

Environmental Sample Collection Form

State Hygienic Laboratory

Lakeside Laboratory
1838 Highway 85
Milford, IA 51551-7287
Phone # 712-337-3669

Ankeny Laboratory
2220 S. Ankeny Blvd.
Ankeny, IA 50023-6003
Phone # 515-725-1600
<http://www.shl.iowa.edu>

UI Research Park
2490 Crosspark Road
Coralville, IA 52241-14721
Phone # 319-335-1600 or
800-421-IOWA

EN 102014

Form 3 – Corrective Action Form

Polk County Air Quality - Corrective Action Form

To: _____ Polk County Air Quality _____
(position)

From: _____

Copies of completed form to: AQ Supervisor, File

Urgency: Emergency (immediate action needed) Urgent (24 Hr.)
 Routine (7 days) Next scheduled visit Information only

Problem Identification:

Site: _____
System: _____
Date: _____

Description of Problem: _____

Recommended Action: _____

Signature of Initiator: _____ Date: _____

Problem Resolution:

Date of Corrective Action: _____

Summary of Corrective Action: _____

Result of Corrective Action: _____

Signature of resolver: _____ Date: _____

Signature of QA Officer: _____ Date: _____

Form 4 – Plot of Cartridge Showing Constant Flow

