



CO L O R A D O

**Department of Public
Health & Environment**

Air Pollution Control Division

Technical Services Program

APPENDIX QA2

**Standards Verification and Calibration Standard Operating
Procedures**

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1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure is to ensure that all standards used within the Colorado Department of Public Health and Environment (CDPHE) Air Pollution Control Division's (APCD) compliance air monitoring network are properly calibrated and/or hold current verifications against a National Institute of Standards and Technology (NIST) traceable standards. It is imperative that all standards be highly accurate and maintain the fewest amount of steps removed from a NIST standard as possible. Some of the data may be used as evidence in court proceedings. Accurate equipment is required to ensure that all data quality objectives have been met.

2.0 SUMMARY OF THE SYSTEM

The Colorado Department of Public Health and Environment (CDPHE) APCD maintains a standards laboratory that houses all of APCD's laboratory grade standards. Routine comparisons of transfer standards to the laboratory standards occur within the Standards Laboratory. The Quality Assurance (QA) unit has the primary responsibility of maintaining all laboratory standards and performing all general laboratory maintenance. The Gaseous and Meteorological Monitoring (GMM) group and the Particulate Monitoring (PM) Group also provide support in the maintenance of laboratory standards and general laboratory maintenance.

At regular intervals all standards used within the APCD must be certified against a standard of a known quantity. These comparisons can be either made by the APCD or by a contract laboratory. If the APCD maintains the operation of a laboratory grade standard then certification of transfer standards can be performed at the APCD's Standards Laboratory. Standard operating procedures for these comparisons are covered within this document. If a laboratory standard is not available within APCD to certify a transfer standard, then that transfer standard must be shipped to a contract laboratory for certification. Quality Assurance Project Plans (QAPP) and subsequent standard operating procedures for these measurements are maintained at the contract laboratory.

3.0 DEFINITIONS AND ACRONYMS

Accuracy – The degree to which a measurement, or an estimate based on measurements, represents the true value of the attribute that is being measured.

APCD – Air Pollution Control Division – A division within the Colorado Department of Public Health and Environment

Calibration – The adjustment of a physical parameter as measured by a standard or piece of equipment to match that of a known quantity.

Certification – The documentation associated with a standard or piece of equipment that shows a physical parameter meets/fails verification or calibration criteria.

CDPHE – Colorado Department of Public Health and Environment

CO – Carbon Dioxide

EPA – Environmental Protection Agency

GMM – Gaseous and Meteorological Monitoring Group

High-Volume Sampler – A particulate matter sampler that operates with a flow of 1.0 m³/min or greater

Laboratory Standard – A high accuracy standard that is protected in a laboratory environment and is used to perform verifications and/or calibrations on transfer standards. Laboratory standards may or may not be classified as a primary standard. This definition of laboratory standard is synonymous with EPA's definition of a primary standard.

Low-Volume Sampler – A particulate matter sampler that operates with a flow of 50 L/min or lower

Met – Short for Meteorological

NIST – National Institute of Standards and Technology. A governmental agency that supports, develops and maintains source standards for public and private comparisons.

NO_x – Oxides of Nitrogen

O₃ – Ozone

OAPP – Quality Assurance Project Plan

OAQPS – EPA's Office of Air Quality Planning & Standards

PM₁₀ – Particulate matter with an aerodynamic diameter of 10 microns or less

PM_{2.5} – Particulate matter with an aerodynamic diameter of 2.5 microns or less

Primary Standard – A high accuracy standard whose principle of operation is founded on a physical or chemical property that does not change with time. A mercurial thermometer and barometer are examples of primary standards. Digital thermometers and barometers are examples of standards that are not primary standards. Primary standards can be used as laboratory standards or as transfer standards.

SO₂ – Sulfur Dioxide

TEOM – Tapered Element Oscillating Microbalance

Transfer Standard – A standard that is used in the field to calibrate or audit field equipment. Transfer standard calibrations are compared to the laboratory standard for accuracy.

TSP – Total suspended particulates

Verification – The process of demonstrating that a physical parameter as measured by a standard or piece of equipment matches that of a known quantity.

4.0 SYSTEM DESIGN

The APCD employs the use of laboratory standards for routine calibration and verification of field transfer standards. Laboratory standards hold certification that are at most, two steps removed from an NIST standard and have accuracies that are equal or greater than those used as field transfer standards. All laboratory standards are kept in the Standards Laboratory, and comparisons of those standards to the field transfer standards occur within the protected confines of the QA Standards Laboratory. All laboratory standards are sent out for a NIST traceable (or equivalent) certification on a routine or on an as needed basis. The following is a table that summarizes all of the APCD’s laboratory standards.

Figure 4-1 Summary of Laboratory Standards			
Parameter	Manufacture / Model	Accuracy	Certification
Flow Rate (5 scc/min – 20 sL/min)	Bios ML500	±0.25% (of reading volumetric)	- Return to factory or independent flow laboratory every 1 year for service and NIST traceable (or equivalent) calibration and/or verification
Flow Rate (10 cc/min – 20 l/min)	InFlow System (critical and sub-critical flow nozzles)	±0.5% (of reading.)	- Send to independent flow laboratory every 3 years for service and NIST traceable (or equivalent) calibration and/or verification
Flow Rate (500 l/min – 10,000 l/min)	Dresser Roots Meter Model 5M125	±0.5% (from current cert.)	-Return to factory or independent flow laboratory every 3 years for service and NIST traceable (or equivalent) calibration and/or verification
Temperature (-50 °C - 150 °C)	VWR - ASTM Precision Thermometer	±0.1 °C	- Ice-point verification annually - Multi-point NIST traceable (or equivalent) verification every year
Pressure (14.7 inHg - 32.6 inHg)	Paroscientific Digiquartz Pressure Transducer, Model 745	±0.08 hPa (±0.0024 inHg)	-Return to factory every 3 years for service and NIST (or equivalent) traceable calibration / verification
Ozone (0 ppb - 500 ppb)	Thermo 49i Primary Std.	1 ppb (precision) 1.08% (SRP cert)	-Annual verification to EPA’s SRP
Voltage (50mV - 250V)	EXTECH CMM-17	0.001 (resolution)	-Annual independent certification
Wind Speed (100 - 10,000 rpm)	RM Young Model 18811	0.1 rpm (resolution) 0.1 rpm (time ref)	-Annual factory certification
Laboratory Parameters Supported by Contract Laboratories			
Compressed Gas Concentrations (CO, SO ₂ , NO _x)			
Humidity			
Mass			
Time			
Wind Speed			

The APCD employs the use of transfer standards for routine calibration and verification of field equipment. Transfer standards hold a certification that are at the most three steps removed from an NIST standard and have accuracies that meet all federal criteria designated in the Code of Federal Regulations (CFR) and guidance documents. All transfer standards are compared routinely to APCD’s laboratory standards within the Standards Laboratory. When the APCD does not maintain a laboratory standard, transfer standards must be sent out to contract laboratories for verification and calibration. APCD does not maintain laboratory standards for the following parameters: mass, humidity and wind direction. The following table summarizes certification requirements for all APCD transfer standards.

Figure 4-2 Transfer Standards Certification Requirements

<u>Parameter</u>	<u>Standard Type</u>	<u>Requirement</u>
Flow Rate	High Volume Orifice	Annual Calibration
“	Low Volume Orifice	Annual Calibration
“	Bios Dry Cals	Annual Verification / Calibration
“	Mass Flow Controllers	Annual Verification / Calibration
Gasses Concentration (CO, SO ₂ , NO ₂)	Compressed Gas	As Per Manufacture’s Expiration Date
Humidity	Hygrometer	Annual Verification / Calibration
Mass	Ultra Class Mass Standards	Annual Verification / Calibration
“	TEOM Mass Verification Standards	Annual Verification / Calibration
Pressure	Aneroid/Digital Barometers	Annual Calibration/Verification (minimum by QA) Quarterly Verification (operational goal by operators)
“	Manometers	Annual Calibration/Verification
Ozone	Roving Calibrators	Quarterly Verification Roving/Non Roving site calibrators every 6 months.
Temperature	Digital Thermometers	Annual Calibration/Verification (minimum by QA) Quarterly Verification (operational goal by operators)
Voltage	Digital Volt Meters	Annual Verification / Calibration
Wind Direction	Transit	Annual Verification / Calibration
Wind Speed	Wind Speed Motor and Controller	Annual Verification / Calibration

Primary Standard Tracking Procedures

APCD designates primary standards that are used to certify and maintain traceability on all APCD field standards. Primary standards, in practice, should never go into the field and should remain in a laboratory environment for stability purposes. Primary standards must be sent out to a secondary laboratory for National Institute of Standards and Technology (NIST) traceable certifications / calibrations on a scheduled basis. Some primary standards must be sent out annually while other primary standards are sent out on a two or three year basis depending on the standard requirements. When sending a primary standard out for recertification, it is best practice to obtain pre-certification and post-certification data associated with the standard in an effort to ensure stability over time and traceability of the standard. Before a primary standard is sent out for recertification or calibration and when practical, it should be verified against another standard to ensure that the primary standard maintained accuracy during the time it was used to verify and calibrate field standards and to verify the external laboratory’s accuracy. The APCD also verifies the primary standard after it comes back from its certification to make sure stability and accuracy is maintained and traced. Below is the procedure for each primary standard used in the APCD laboratory.

1. Bios ML500: this instrument is used to calibrate and verify MFC’s in gaseous dilution calibrators and measure flow in various capacities within the APCD laboratory. This standard is currently sent out to Mesa Labs with a pre and post data package received. Mesa Labs cleans, inspects and replaces the instruments’ internal batteries when needed after an as found verification is performed. Before packaging and sending this unit out for certification a flow verification should be performed through the whole flow range on an MFC in a dilution calibrator that will not be taken in the field while the primary standard is gone. Another verification should also be

performed when the primary standard is received back from its' yearly certification. Comparing the two verifications (pre and post NIST certification) will give information as to whether or not anything had changed with the instrument in regards to flow measurements throughout the year and documents primary standard stability. Please see section 5.3 within this document for the Teledyne Mass Flow Controller verification procedure.

2. In-Flow System: this device is used to calibrate the low volume flow orifices. It uses critical orifices in the process to measure flow. These critical orifices are made of stainless steel and do not change over time. It is sent out every three years to verify the pressure transducers and temperature sensors have remained stable. A calibration of a low volume orifice throughout the entire flow range used by the In-Flow System should be performed before sending the unit out and after receiving it back.
3. Dresser Roots Meter: this device is used to calibrate the high volume flow orifices which are, in turn, used to calibrate high volume PM₁₀ samplers. It is currently being sent to Koons Gas Measurement Company. A calibration of the QA Unit Control Orifice serial number 8031483 is performed before the roots meter is sent out for certification and when the roots meter is received back from certification. Those two calibrations are compared to make sure the roots meter has not changed drastically during its' NIST traceable certification. See section 5.1 in this document for the High Volume Orifice Calibration procedure.
4. Temperature: a new NIST traceable digital thermometer (accurate 0.1°C) is purchased every year to certify all of APCD's field thermometers. The new thermometer is designated as APCD's primary thermometer standard and is not used in the field and kept in the laboratory. After being used as the primary for a year it is put into circulation as a field standard.
5. Pressure: the Paroscientific Digiquartz model 745 has been designated as APCD's primary pressure standard. It is sent back to Paroscientific every three years for a NIST traceable certification. Before sending the Paroscientific back, it is compared to another barometer by logging the readings of each instrument with a date and time and also compared to the same standard when it returns to check for any changes in calibration and to document stability.
6. Voltage: the EXTECH CMM 17 has been designated as APCD's primary voltage standard. It is currently being sent back to TRANSCAT in Aurora CO. A verification of an APCD field volt meter is performed before sending the primary out and when it is received back from certification is a recommended procedure. See section 14.1 in this document for the voltage verification procedure.
7. Wind Speed: the RM Young model 18811 selectable speed calibrating unit is designated as APCD's primary wind speed standard and is used with the RM young serial number E3751 motor. It is sent out for a yearly NIST traceable certification to RM Young. A comparison to a wind speed calibrator used in the field is preferred before sending the unit out and after getting the unit back to track stability and external lab accuracy.

5.0 FLOW RATE CALIBRATION / VERIFICATION PROCEDURES

5.1 High Volume PM₁₀/TSP Orifices

Orifice flow rate transfer standards are used for calibrations and performance audits of high flow rate manual particulate samplers. These are commonly referred to in the industry as TSP (Total Suspended Particulate) monitors and PM₁₀ monitors, and are either volumetric or mass flow controlled. The pressure differential measured across the orifice can be related to air flow. Because these devices do not provide a direct measure of air flow, they are regularly certified against an NIST traceable air flow standard. Certification of the APCD orifice transfer standards are consistent with the procedures detailed in the *Quality Assurance Handbook for Air Pollution Measurement Systems* Volume II Section 2.2.

Orifice Calibration Procedure

- 1) Assemble the following equipment:

- Positive displacement standard volume meter (hereafter referred to as the Rootsmeter) traceable to the NIST, calibrated every three years by an outside agency and verified each year with an in-house standard.
 - The orifice transfer standard to be calibrated.
 - Two (2) oil manometers, 0-20 inch range, with minimum scale divisions of 0.1 inch. One is designated the orifice manometer and the other is designated the Rootsmeter manometer.
 - Variable voltage transformer.
 - High volume blower motor connected to the variable voltage transformer.
 - Voltmeter (capable of measuring 0-130 volts AC) connected to the variable voltage transformer.
 - Stopwatch.
 - Thermometer capable of measuring temperature over the range of 0-50°C to the nearest $\pm 1^\circ\text{C}$ and referenced to a NIST or American Society for Testing and Materials (ASTM) thermometer with $\pm 2^\circ\text{C}$ at least annually.
 - Barometer capable of measuring ambient barometer pressure over the range of 500-800 mmHg to the nearest mmHg and referenced with $\pm 5\text{mmHg}$ to a barometer of known accuracy at least annually.
 - Print a copy of the “High Volume Orifice Calibration” form, from the “Verifications.mdb” database located within the CDPHE TSP network. The file path for the database is: J:\QA Audit Programs\Verifications\Verifications.mdb. Use this printed form to transcribe data taken during the orifice calibration, or similar self-manufactured form to record data (Figure 5-1).
- 2) On the “High Volume Orifice Calibration Form”, record the orifice number, date, operator’s name, name and address of orifice owner, Rootsmeter serial number, and Rootsmeter certification date (date the Rootsmeter was last certified to a NIST traceable flow standard).
 - 3) Observe the ambient barometric pressure and record it on the “High Volume Orifice Calibration Form”.
 - 4) Refer to Figure 5-2, Orifice Transfer Standard Calibration Setup.
 - 5) Connect the orifice transfer standard being calibration to the inlet (top) of the Rootsmeter. If the orifice is the variable type, adjust it to the maximum open position (turn fully counter clockwise).
 - 6) Connect the Rootsmeter manometer to the Rootsmeter inlet pressure tap, making sure there are no leaks in the manometer.
 - 7) Connect the orifice manometer to the orifice transfer standard pressure tap, making sure there are no leaks in the manometer.
 - 8) Connect the hi-volume blower motor to the outlet side of the Rootsmeter (below).
 - 9) Check the spirit levels on the table to ensure the table is level. If necessary, adjust the table legs to level the table.
 - 10) Leak Check – Check for leaks by temporarily clamping both manometer lines (to avoid fluid loss) and blocking the orifice transfer standard with a rubber stopper, duct tape or other suitable means. Start the hi-volume blower motor by adjusting the variable transformer. Adjust the variable transformer until the voltmeter indicates approximately 120 volts. Note any change in the Rootsmeter dial indicator.

CAUTION – Avoid running the hi-volume blower motor for longer than 30 seconds with the orifice blocked. The precaution will prevent overheating and damage to the motor. The Rootsmeter dial should remain constant. If the reading changes, locate any leaks by listening for a

whistling sound and/or re-tightening all connections, making certain all gaskets are properly installed.

- 11) After completing the leak check, turn off the hi-volume motor by decreasing the voltage with the variable voltage transformer.
- 12) Check the manometers for an indication of zero. Adjust the sliding scale if necessary.
- 13) Turn on the hi-volume motor with the variable voltage transformer. It should be noted that an orifice could be used in the field to calibrate or audit either a TSP, RAD, PUFF or a PM₁₀ air monitor. TSP monitors operate at a higher flow rate than do mass flow controlled PM₁₀ monitors, thus necessitating two orifice calibrations to accommodate the higher flow rates for a TSP and lower rates for a PM₁₀ and even lower flow rates for a RAD and PUFF calcs. Voltages and corresponding flow rates for each calibration, be it TSP, RAD, PUFF or PM₁₀, can be seen in Figure5-3. For this discussion, only the PM₁₀ orifice calibrations will be discussed; TSP, RAD and PUFF will mirror PM₁₀, except for the differences in flow rates. Adjust the transformer until the voltmeter reads 63 volts, this produces an air flow of approximately 1.30 m³/min. Let the motor run at least one minute to stabilize.
- 14) Proceed to fill-in the appropriate information on the “High Vol. Orifice Calibration Form” as follows: In Row 1 – Observe the Rootsmeter volume reading and simultaneously start the stopwatch. In the “Vi” column, record the initial volume indicated by the Rootsmeter when the stopwatch was started. Maintain this constant flow rate until at least 4.00m³ of air has passed through the Rootsmeter and orifice. As air is passing through the Rootsmeter, record the initial ambient temperature in degrees Celsius in the “Ta-Initial” column, from the verified temperature standard within the Rootsmeter room. Record the Rootsmeter inlet pressure manometer reading in inches H₂O in the “H20-Root” column, and record the ΔH₂O for the Orifice manometer reading in the “H20-Orifice” column.
- 15) After at least 4.00m³ of air has passed through the orifice and Rootsmeter, observe the Rootsmeter volume reading while simultaneously stopping the stopwatch. In the “Vf” column, enter the final volume that the Rootsmeter was indicating when the stopwatch was stopped.
- 16) In the “Time (entry)” min/sec column, enter the elapsed time (ΔT) indicated on the stopwatch in MM.SS.HH (minutes.seconds.hundredths of a second). Record the final ambient temperature.
- 17) Adjust the variable voltage transformer until the voltmeter reads 60 volts, this produces an air flow of approximately 1.24 m³/min. Repeat steps 14, 15 and 16, filling in the boxes of the associated row on the “High Vol. Orifice Calibration Form”.
- 18) Adjust the variable voltage transformer until the voltmeter reads 57 volts, this produces an air flow of approximately 1.20 m³/min. Repeat steps 14, 15 and 16, filling in the boxes of the associated row on the “High Vol. Orifice Calibration Form”.
- 19) Adjust the variable voltage transformer until the voltmeter reads 53 volts, this produces an air flow of approximately 1.13 m³/min. Repeat steps 14, 15 and 16, filling in the boxes of the associated row on the “High Vol. Orifice Calibration Form”.
- 20) Adjust the variable voltage transformer until the voltmeter reads 48 volts, this produces an air flow of approximately 1.05 m³/min. Repeat steps 14, 15 and 16, filling in the boxes of the associated row on the “High Vol. Orifice Calibration Form”.
- 21) Adjust the variable voltage transformer until the voltmeter reads 44 volts, this produces an air flow of approximately 1.02 m³/min. Repeat steps 14, 15 and 16, filling in the boxes of the associated row on the “High Vol. Orifice Calibration Form”.

- 22) Adjust the variable voltage transformer until the voltmeter reads 38 volts, this produces an air flow of approximately 0.90 m³/min. Repeat steps 14, 15 and 16, filling in the boxes of the associated row on the “High Vol. Orifice Calibration Form”.

NOTE: The dial-in voltage values and corresponding approximate air flow values will be different (higher) for TSP calibrations and lower for PUFF and RAD calibrations. The voltage range will be from 57 to 113, and the corresponding air flow range will be from 1.0 to 1.8 m³/min.

- 23) Turn the variable voltage transformer off. Disconnect the orifice manometer tubing from the orifice transfer standard. Remove the orifice transfer standard from the Rootsmeter. Cover the Rootsmeter inlet to prevent dust/dirt from getting into the Rootsmeter.
- 24) The data on the Orifice Flow Transfer Standard Certification Worksheet can now be entered into the Verifications database.
- 25) The Verifications database can be located on the J-Drive within the TSP network. The file path is: J:\QA Audit Programs\Verifications\Verifications.mdb.
- 26) After opening the Verifications database click the “High Vol. Orifice Calibration” button to be directed to the “High Vol Orifice Calibration Form”.
- 27) After entering the form, the person performing the calibration can begin entering the associated data.
- 28) Start by entering the date the calibration took place, the ambient pressure (taken from the Paroscientific primary pressure standard), the operator’s initials, the Rootsmeter serial number and cert. date (the Rootsmeter cert date will be populated in the form automatically but to verify the actual date, the verification paperwork will be stored in the filing cabinet next to the Rootsmeter, within the Rootsmeter file.)
- 29) Enter the rest of the data onto the “High Vol Orifice Calibration Form” taken during the orifice calibration (use Figure 5-1 as an example).
- 30) Print a copy of the completed “High Vol Orifice Calibration Form” by clicking the little printer button in the upper right hand corner of the access database main page.
- 31) After printing the worksheet click “Capture Data” on the calibration form. This will add the file to the “Orifice Calibrations” table within the database creating an electronic copy of the calibration.
- 32) Click the “Certification Report” button to create a certification report for each calibration performed. This report will detail the calibration coefficients and the formulas for creating them.
- 33) Send the original printed High Vol Orifice Calibration Form and the Certification of Calibration to the customer with their calibrated orifice. Retain the copies of these documents in the QA file cabinet under the Flow Transfer Standard Calibrations.



COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

Air Pollution Control Division - Technical Services Program
 PM10 High Volume Orifice Calibration Form



Date (mm/dd/yy)	10/12/2010	Cal Type:	PM10	Rootsmeter S/N:	7807140	Pa (inHg):	24.99
Operator Initials:	cws	Orifice S/N:	BG 2	Roots Cert. Date:	8/11/2010	Pa (mmHg):	634.75

Company:	CDPHE / APCD / QA
Contact Person:	Cindy Wike
Address:	4300 Cherry Creek Drive South
City and ZIP:	Denver, CO 80246-1530

(Target flowrate is 1.13 m3/min; the calibration should have at least three points within 1.02 - 1.24 m3/min.)

Nominal (m3/min)	Volts (AC)	Ta - Initial (C)	Vi (m3)	H2O - root (inches)	H2O - Orifice (inches)	Vf (m3)	Time (entry) (min) (sec)	t (total) (min)	Ta - final (C)
1.30	63	23.00	149.00	4.900	3.500	154.40		4.242	23.30
1.24	60	23.30	155.30	4.500	3.200	160.80		4.502	23.60
1.20	57	23.60	162.00	4.100	2.900	166.00		3.443	23.70
1.13	53	23.70	167.80	3.700	2.600	172.60		4.346	23.70
1.05	48	23.70	174.00	3.200	2.300	177.40		3.336	23.80
1.02	44	23.80	178.30	2.725	1.950	182.20		4.110	23.80
0.90	38	23.80	182.90	2.100	1.500	186.10		3.860	23.80

All calculated values have been rounded to the displayed values!

Vnet (m3)	Ta - avg (K)	Va (m3)	Qa (m3/min)	(Y) (see below)	(X) ln(H2O-orifice)	Qa - Calc (m3/min)	%D (+/- 2%)	(Y') (see below)	(X') (m3/min)	Qa-Calc' (m3/min)	%D' (+/-2%)
5.40	296.3	5.32215	1.255	0.14022	1.25276	1.258	0.24%	1.278	1.255	1.259	0.32%
5.50	296.6	5.42718	1.206	0.09989	1.16315	1.204	-0.17%	1.223	1.206	1.204	-0.17%
4.00	296.8	3.95175	1.148	0.05026	1.06471	1.146	-0.17%	1.164	1.148	1.146	-0.17%
4.80	296.9	4.74774	1.092	0.00008	0.95551	1.085	-0.64%	1.103	1.092	1.085	-0.64%
3.40	296.9	3.36799	1.010	-0.07798	0.83291	1.020	0.99%	1.037	1.010	1.020	0.99%
3.90	297.0	3.86873	0.941	-0.14891	0.66783	0.939	-0.21%	0.955	0.941	0.939	-0.21%
3.20	297.0	3.18023	0.824	-0.28168	0.40547	0.823	-0.12%	0.838	0.824	0.823	-0.12%

Notes: (Y) = ln[Qa Sqrt((Pa/7600*(298.16)))] Units in ln(m3/min); (Y') = Sqrt[H2O-orif(Ta/Pa)], Units in Sqrt[(inH2O)(K/inHg)]
 Vnet = Vf - Vi; Ta - avg = [(Ta-initial+Ta-final)/2]+273.15; Va=Vnet*[Pa-(H2O-root/13.6)]/Pa
 Qa=va/t; Qa-calc= A(H2O)expB*sqrt[(760/Pa)*(Ta/298.16)] where Pa is tin mmHg and Ta is in Kelvin

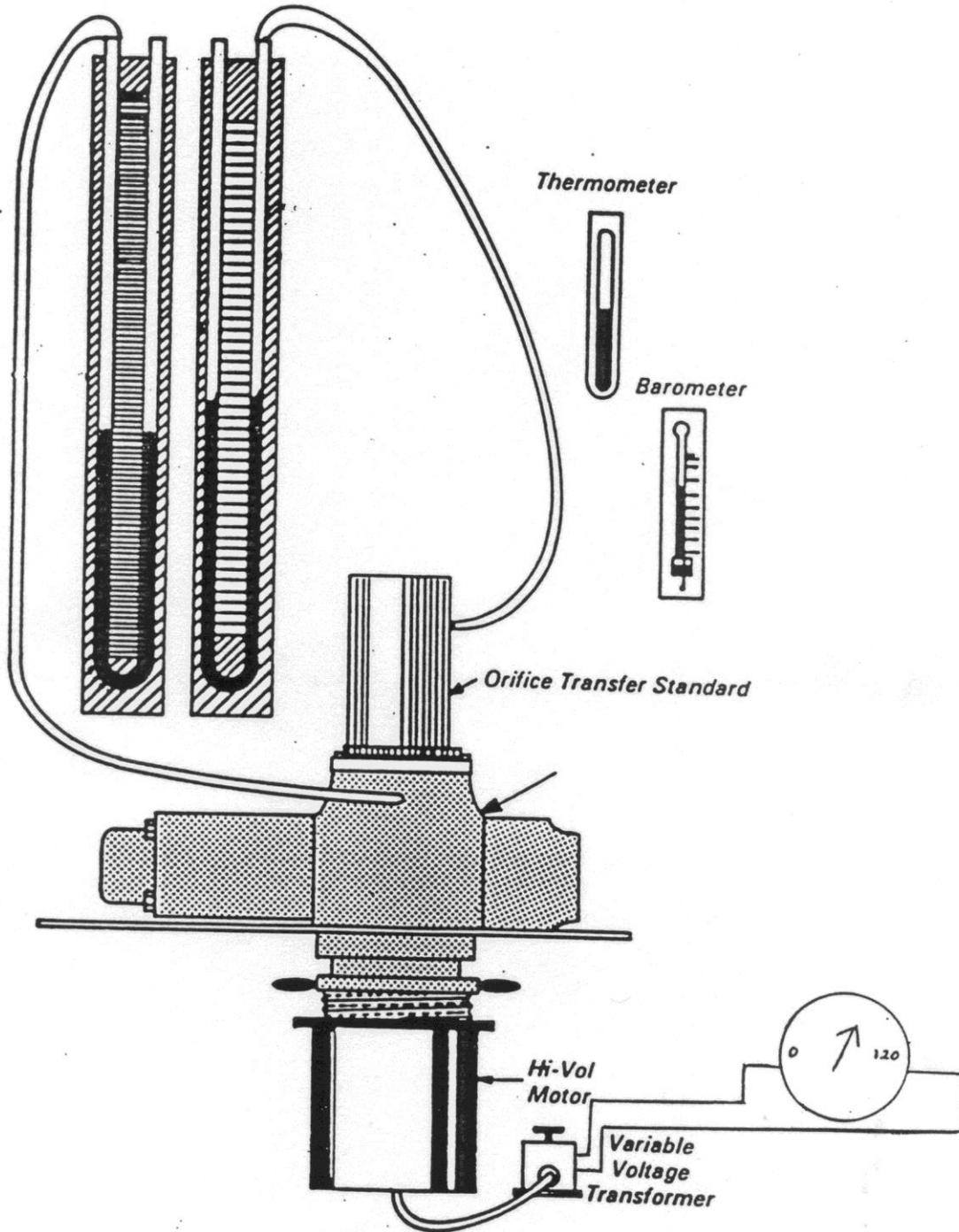
<p>(CDPHE Method) Plot ln[Qa Sqrt((Pa/760)*(298.15/Ta))] against ln(H2O)</p> <div style="display: flex; justify-content: space-between;"> <div style="border: 1px solid black; padding: 5px; width: 45%;"> <p style="font-size: x-small; margin: 0;">Linear Regression Results of Plot:</p> <p style="margin: 0;">m = 0.50219 b = -0.48617 r = 0.9994</p> </div> <div style="border: 1px solid black; padding: 5px; width: 45%;"> <p style="font-size: x-small; margin: 0;">Power Regression Results:</p> <p style="margin: 0;">B = m = 0.50219 A = (e)expb = 0.61498</p> </div> </div> <p style="font-size: x-small; margin-top: 5px;">For subsequent flow rate calculations: Qa = A(H2O)expB * Sqrt[(760/Pa)*(Ta/298.15)] Qstd = A(H2O)expB * Sqrt[(Pa/760)*(298.15/Ta)]</p>	<p>(EPA 2.11 Method) Plot Sqrt[H2O(Ta/Pa)] against Qa</p> <div style="border: 1px solid black; padding: 5px; width: 100%;"> <p style="font-size: x-small; margin: 0;">Linear Regression Results of Plot:</p> <p style="margin: 0;">m = 1.01022 b = 0.00651 r = 0.9994</p> </div> <p style="font-size: x-small; margin-top: 5px;">For subsequent flow rate calculations: Qa = (Sqrt[H2O(Ta/Pa)]-b)/(1/m) Qstd = Qa(Pa/760)(298.16/Ta)</p>
---	---

Comments:

Signature _____

Figure 5-1 High Vol. Orifice Calibration Form

Figure 5-2 Orifice Transfer Standard Calibration Setup



Example of orifice transfer standard calibration setup.

Figure 5-3 Voltage Settings and Approximate Corresponding Flow Rates

PM₁₀		TSP		PUFF		RAD	
Volts	QA (m³/min)	Volts	QA (m³/min)	Volts	QA (m³/min)	Volts	QA (m³/min)
38	0.90	36	0.85	15	.11	24	.68
44	1.02	40	1.00	20	.16	27	.74
48	1.05	56	1.15	25	.21	31	.79
53	1.13	66	1.30	30	.26	34	.85
57	1.20	76	1.45	35	.31	38	.91
60	1.24	86	1.60	40	.36	43	0.99
63	1.30	96	1.74	45	.41	47	1.05

5.2. Low Volume PM_{2.5}Orifices, SASS Orifices, and Bios DryCals

5.2.1. Background

The Visibility, Research and QA unit, the PM unit and the GMM unit use low-volume PM_{2.5}, TEOM and SASS orifices, and Bios Flow meters during calibration and performance audits of APCD air monitoring equipment.

At least once per year the QA staff certifies all flow standards used in the field to take measurements of Colorado's air monitoring network. Orifice standards (for PM_{2.5}, GRIMM, TEOM, and SASS) are calibrated annually. The new calibration coefficients are compared to historical calibration coefficients for consistency. Orifices that have new calibration coefficients that deviate from historical values are evaluated for damage and recalibrated. Volumetric flow standards are verified against the laboratory standard. Volumetric standards that do not meet factory accuracy specifications are evaluated for damage and calibrated (if possible). If the differences cannot be rectified, the standard is returned to the manufacture for repair and recalibration. An InFlow flow bench is used to perform these certifications. The lab standard is sent to an independent flow laboratory at least once every three years for recertification. The lab standard has direct traceability by the manufacturer to a NIST standard. The result is the Inflow, Inc. Air Calibration Flow Standard, referred to in this document as the 'Skid'.

5.2.2. Definitions

ANSI

The American National Standards Institute - ANSI - is a private, non-profit organization that administers and coordinates the U.S. voluntary standardization and conformity assessment system.

ASME

Manufacturing codes and standards defined by the American Society of Mechanical Engineers.

ASTM

American Society for Testing and Materials - is a scientific and technical organization that develops and publishes voluntary standards on the characteristics of material, products, systems and services.

Critical Flow Element

A nozzle used in the InFlow flow bench in which air velocity through the nozzle is restricted to its critical flow velocity. While holding velocity constant (critical flow velocity), the mass of the air can be varied by adjusting air density.

InFlow Flow Bench

A flow bench utilized by the Colorado Department of Public Health and Environment Air Pollution Control Division that utilizes sonic nozzles and restrictor valves to provide high accuracy flow measurements for flow rates between ~20cc/min to 26Lpm.

ISO

ISO - International Organization for Standardization

Mass Flow

The flow rate of a liquid or a gas given as units of mass (mass of molecules) per units of time. The number of molecules in a given volume of gas will vary with pressure and temperature due to changes in density.

MIL-STD

Military Standards – Code and standards defined for military purposes.

Sonic Flow Element

See Critical Flow Element

Volumetric Flow

The uncorrected flow measured with a flow meter. This is a measure of the total volume of the flow being measured. The volume of a given number of molecules will vary with pressure and temperature due to changes in density. Volumetric flow must be compensated for pressure and density in order to be comparable with mass flows.

5.2.3. InFlow System

5.2.3.1. Background

The InFlow flow bench is a mass/volumetric flow standard for the calibration of flow meters and associated instruments using critically choked flow elements. The flow elements are designed using ASME manufacturing standards for the larger elements (sonic nozzles), and contoured restrictors (sapphire nozzles) for the smaller sizes. Critically choked flow elements are an excellent calibration standard in that they have no moving or wearing parts, are extremely stable over time, and are provided with a NIST traceable calibration with an uncertainty of 0.35% of a reading, with an overall system uncertainty estimated at approximately 0.5% of a reading.

Each nozzle is operated over varying inlet pressures to provide an approximate 6:1 turndown in flow. Over the nozzle set, this provides for an overall flow range from ~20 cc/min – 26 lpm. The vacuum pump and manual control valve allows nozzle inlet pressures from ~1.75 to 12.0 psi_A at Denver’s altitude. Figure 5-5 lists information for each nozzle used in the InFlow flow bench.

Specific test articles do require some modifications to the general procedures listed below. However, the system has a high degree of flexibility to compensate for the variations. The system is designed to be operated in a dedicated area with filtered dry air available at approximately 12 psi_A and 70° F. Other environmental effects such as high humidity, or lower pressure will adversely affect the systems’ performance.

Humidity

The basic equation for a critically choked nozzle is:

$$Mass\ Flow\ (lb/sec) = \frac{P_o \times A \times C^* \times C_d}{\sqrt{R \times T_o}}$$

$$Volumetric\ Flow\ (ft^3/sec) = Z \times A \times C^* \times \sqrt{R \times T_o}$$

- Where:
- P_o= nozzle inlet pressure, psi_A
 - A = nozzle throat area, in²
 - C* = critical flow function
 - C_d = discharge coefficient, from calibration
 - R = universal gas constant
 - T_o = nozzle inlet temperature, R
 - Z = compressibility factor

In either calculation the Mol. Wt. (contained in the “R” term) is used and normally calculated assuming dry conditions (0%RH). Because water vapor in the air has a SG=0.622, the higher percentage of water in the air, the lower the actual Mol. Wt. and the greater the flow error if dry conditions are assumed. Following are some approximate values of air at different RH conditions all at 72°F.

Figure 5-4 Humidity Effect On Mass Flow			
% RH	lbs H ₂ O / lbs Dry Air	Adjusted Mol. Wt.	Mass Error %
0	0.00000	28.96247	0.00
10	0.00157	28.94531	-0.06
38	0.00614	28.89566	-0.23
90	0.01521	28.79846	-0.57

The APCD InFlow system is equipped with a humidity sensor that measures ambient room humidity. Data from this sensor allows for a humidity feedback as a transmittal input into the LabView software for humidity compensated readings. This setup only works if ambient room air is pulled through the system. This system does not account for humidity that is added to or removed from the ambient air prior to the InFlow system. Flow standards such as bubble meters will theoretically increase humidity of the airflow through the InFlow system to 100%, while only correcting the reading to the humidity value observed in ambient air. As can be seen, humidity unaccounted for, will create a moderate flow error.

5.2.3.2. System Overview

A flowmeter is essentially a group of linked components that will deliver a signal uniquely related to the flow rate or quantity of fluid flowing in a conduit, despite the influence of installation and operating environment. The InFlow System utilizes six different critical flow venturi nozzles to cover a mass flow range from 0.000612 lb h⁻¹ to nearly 3 lb h⁻¹. The choice of sonic nozzles over other types of flow elements was relatively simple and mainly involved one effect that occurs when gas flows at high velocities through a nozzle. When gas is sucked through the nozzle, the velocity of the air increases as the cross-section of the nozzle passage decreases. At the throat (the narrowest section of the nozzle), the maximum achievable velocity is sonic - the speed of sound. Downstream of the throat, the velocity will return to subsonic and the line pressure will increase towards atmospheric. The effect of sonic conditions at the throat is that changes in the flow downstream of the throat have no effect on conditions upstream. The sonic or critical condition creates a sonic shockwave, which blocks any information, in the form of the flow dynamic, that is trying to penetrate upstream. This effect renders the measurement of gas via critical nozzles very stable and subject to less uncertainty than other flow measurement systems. Additional considerations of the sonic condition are that the mass flow rate is a function of the gas properties (e.g. composition, density, etc.), the upstream stagnation temperature and pressure, and the area of the throat. This is all provided that the nozzle is actually running at critical conditions (which can be ascertained by checking the downstream pressure). More important, to the stability and certainty of the measurement, is that the nozzle acts as a flow controller, creating steady conditions upstream even though conditions downstream may be unsteady.

Figure 5-5 InFlow, Inc. Air Calibration Flow Standard Diagram

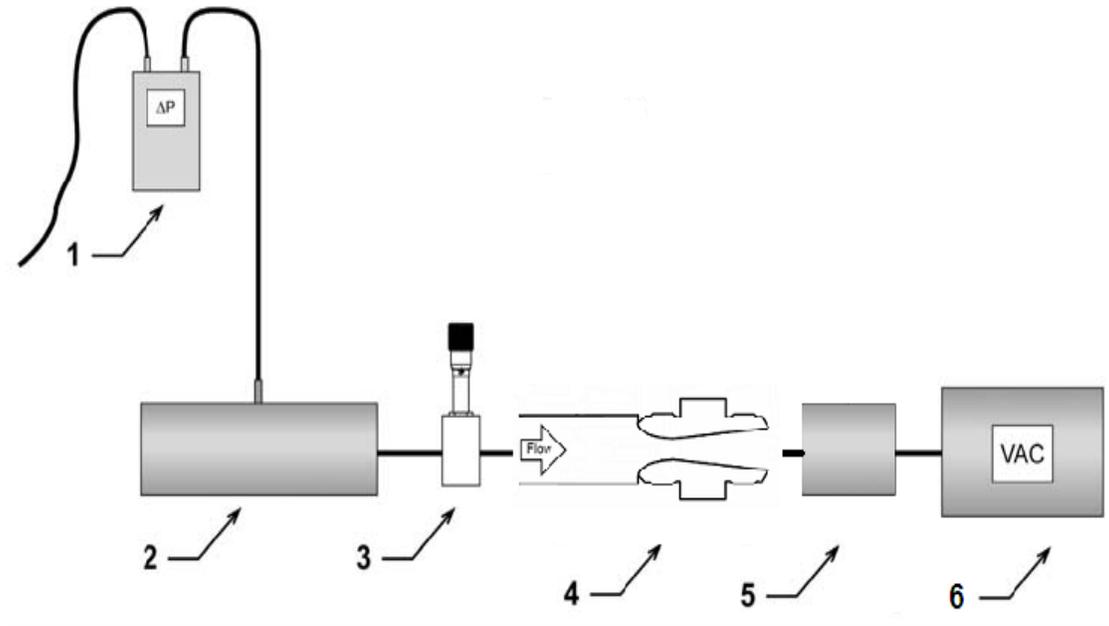


Diagram Key:

1. Differential Pressure Meter
2. Flow Transfer Standard under Test (Test Article)
3. Metering Valve
4. Sonic Nozzle Assembly, including pressure, temperature, and relative humidity sensors
5. Dampening Tank
6. Vacuum Pump

InFlow System Inlet

The InFlow System can be equipped with a variety of inlet connections to accommodate all flow transfer standards currently in use by APCD. This includes the nozzle-type assemblies used for calibration of the PM2.5 instruments, BGI's TRICAL, and BIOS Piston Meters...

Metering Valve Assembly

Downstream from the inlet there is a manifold of three needle valves situated so that flow must be directed through at least one of the valves prior to entering the critical nozzle. The valves are arranged so that the operator can vary the flow through the entire range of the test article. This 'metering' capability allows the operator to verify the response of the transfer standard at a specific point in addition to allowing calibrations to occur in a very repeatable fashion.

Critical Flow Venturi Nozzles (Sonic Nozzles)

The Skid utilizes six different nozzles of varying throat diameter to cover the entire range of anticipated volumetric flow rates from approximately 19 l m⁻¹ (actual) down to 10 cc m⁻¹. The Table 5-7, identifies the nozzles and offers the characteristics of each.

Figure 5-6 InFlow System Nozzle Information							
Nozzle ID	Nozzle Throat Diameter (in)	Mass Flow - high (Pounds hr-1)	@psi _A	Mass Flow - low (Pounds hr-1)	@psi _A	Vol. Flow - high (lpm)	Vol. Flow - low (lpm)
1	0.0595	2.982	13.66	1.277	6.06	18.785	8.04
6	0.0365	1.16	13.91	0.119	2.53	7.33	0.75
2	0.024	0.5086	13.76	0.049	2.5	3.203	0.31
3	0.011	0.08982	14.01	0.0117	2.985	0.5658	0.074
4	0.0059	0.027	14.05	0.0022	2.784	0.169	0.014
5	0.003	0.00612	14.05	0.0006	2.75	0.038	0.004
7	0.070	3.5892	11.61	1.6344	5.79	26	18

As you can see from the last column there is coverage from a maximum flow rate of approximately 26 sLmin-1 through 4cc min-1. Nozzle 6 was purchased after the original system to bridge the gap between nozzles 1 and 2. Each nozzle housing is marked with a nozzle ID and nozzle throat diameter for easy identification. Additionally, there is an arrow etched into each housing to indicate how the nozzle should be loaded into the assembly. As a general reminder the nozzle should be loaded so that the pressure recovery side is downstream and the nozzle side upstream. Nozzles 1, 2, 3 & 6 were made to conform to ASME MFC-7M-1987. The small size of the throat diameters of nozzles 4 and 5 preclude any positive control over the physical characteristics of the nozzle(s). The throat diameters were assigned after the nozzles were compared with a primary standard and reflect the nominal values based on the results. All original nozzle calibrations comply with MIL-STD-45662A, ANSI Z540-1-1994, ISO Guide 25, and ISO 9002:1994.

Sonic Nozzle Assembly

The critical venturi assembly is downstream of the metering valve manifold. This component consists of upstream and downstream lock nuts secured to the manifold via flange fitting. Any of the six nozzles may be threaded into the lock nuts and tightened down by hand. The secure seat is provided by O-rings on each face of the nozzle itself; the locknuts secure the nozzle in the assembly and flatten each O-ring against each flange as the nuts are tightened down. Each nozzle body is identical to the others and is consequently easy to interchange during a verification/calibration.

Nozzle Stagnation Pressure Measurement

This measurement is provided via Druck Incorporated model PTX 610 pressure sensor (SN 1598467). The sensor was calibrated by Druck at their facility in New Fairfield, CT in accordance with ISO 9001 4.11. It is also traceable to NIST and is recertified at least every three years.

Downstream Pressure Recovery Measurement

This measurement is provided via Druck Incorporated model PTX 510 pressure sensor (SN 1598466). The sensor was calibrated by Druck at their facility in New Fairfield, CT in accordance with ISO 9001 4.11. It is traceable to NIST and is recertified at least every three years.

Nozzle Temperature Measurement

This measurement is provided via MINCO Products ambient temperature RTD. The sensor was calibrated by MINCO at their facility in Minneapolis, MN in accordance with their standards and is recertified every three years.

Ambient Temperature Measurement

This measurement is provided via Rotronic Instrument Corp. model F22H-65/HYGROCLIP humidity/temperature transmitter (SN 79398/79399). The transmitter was calibrated by Rotronic at their facility in Huntington, NY in accordance with ASTM standard E104-85. It is traceable to NIST and is recertified every three years.

Relative Humidity Measurement

This measurement is provided via Rotronic Instrument Corp. model F22H-65/HYGROCLIP humidity/temperature transmitter (SN 79398/79399). The transmitter was calibrated by Rotronic at their facility in Huntington, NY in accordance with ASTM standard E104-85. It is traceable to NIST and is recertified every three years.

Signal Evaluation and Computer Control

All the sensors are connected to a National Instruments analog board. The analog signals from each sensor are converted to a digital signal and transmitted to a monitoring computer via serial cable. The digital sensor output is then used as input to a controller program created by Inflow, Inc. using LabView graphical programming software. The program allows the operator to view inputs and outputs, select which nozzle is in use, and identify the article under test. Data from each calibration or verification can be saved as a tab-delimited text file. The LabView software has been programmed to utilize flow calculations from ASME MFC-7M-1987.

Pump Dampening Tank

The pump dampening tank was installed between the pump and the rest of the measurement system in the belief that it would be better to isolate the sensors from pump vibrations. There is a valve between the tank and the rest of the system that serves to isolate the manifold assembly and can be used to leak check the system. There is another valve between the pump and the tank that allows the vacuum in the tank to be released should this be necessary. If there is sufficient vacuum in the tank the pump will 'dead-head' upon initial startup and will not operate until the vacuum is alleviated. It is certain that once critical flow has been achieved, anything that happens to the flow downstream of the nozzle will not have any effect on the flow upstream of the nozzle. While this is true of the flow characteristics it may not be true regarding the rest of the measurement system, especially the sensors. The relative scale(s) of measurement and voltage output(s) of the sensors are small, and a small change in output from one sensor can have a noticeable effect on the overall measurement.

5.2.3.3. Health and Safety

Cautions

The assembly must be warmed up sufficiently prior to use. As a general rule the operator should have the pump, the National Instrument analog board, and the LabView software 'running' for no less than 15 minutes prior to the first run.

Interferences

None

Personnel Qualifications

Prior to use of the standards, the operator should be trained by qualified personnel to run the InFlow System and transfer standard systems, and have read this standard operating procedure (SOP) and the manufacturer's SOPs.

5.2.3.4. Procedure

NIST has demonstrated the long-term stability of sonic nozzles. Consequently, the nozzles don't require periodic calibration. For consistency the coefficients of each nozzle are to be verified periodically, in a NIST traceable flow lab. The measurement of flow is much more a function of the individual measurement sensors and computer control than the nozzles themselves. The entire InFlow System should be verified periodically with individual components recalibrated if the verification results indicate the need. Historically, APCD has verified the entire flow measurement system every three years.

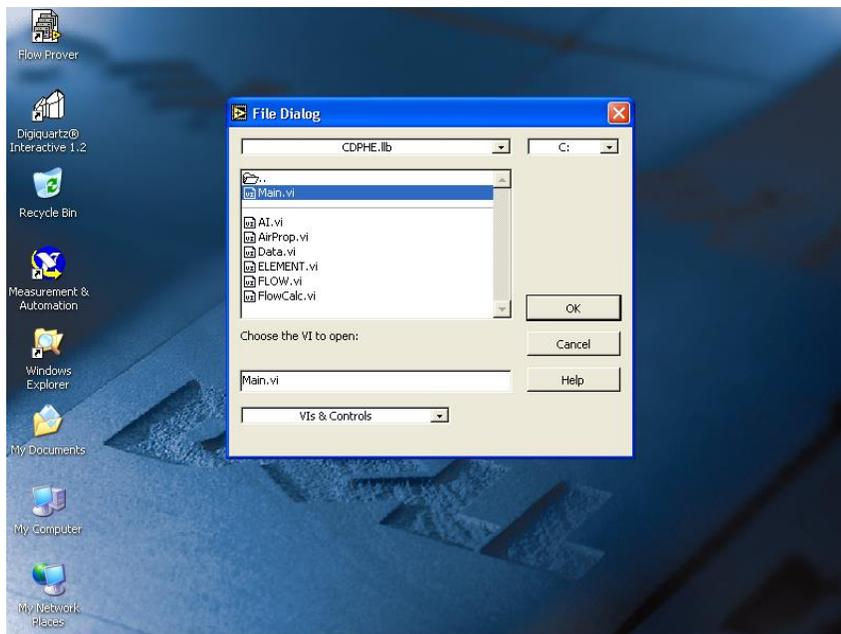
Skid Operation

- 1) Ensure the analog board is plugged in.
- 2) Turn on the computer.

- 3) Click on **the InFlow** user group
- 4) Double click on the **LabVIEW** shortcut.
- 5) On the **LabVIEW dialog**, click on **Open VI**.

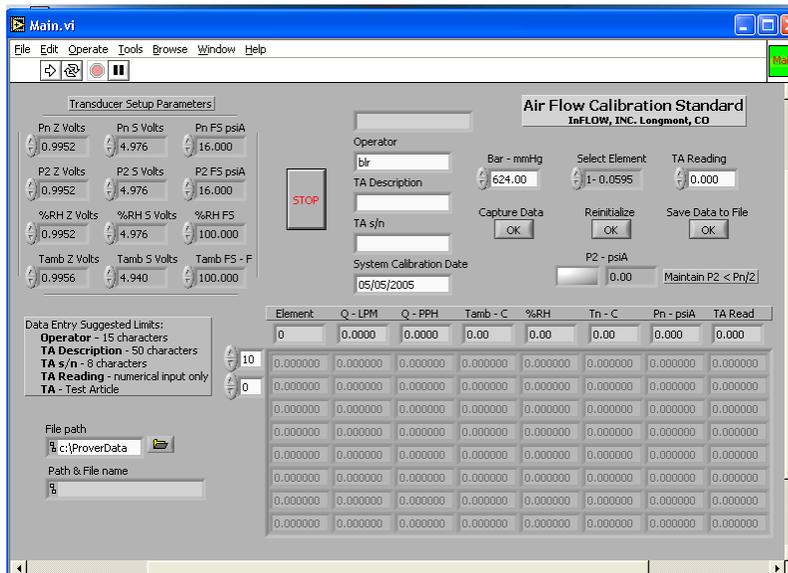


- 6) On **Choose the VI to Open**, double click on **CDPHE**.
- 7) On **File Dialog**, double click on **Main. vi**.

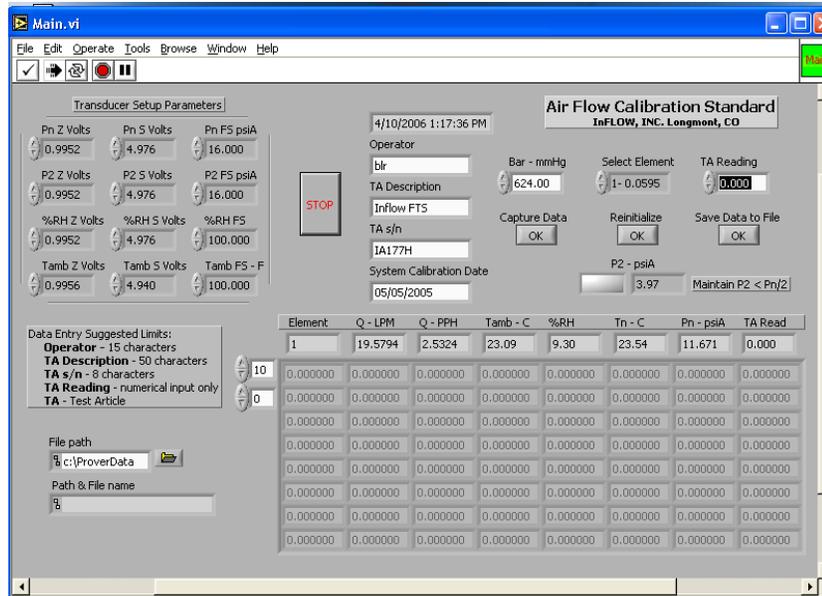


- 8) Ensure there is no vacuum in the tank by opening the tank valve; after relaxing any vacuum ensure the valve is closed.
- 9) Install the correct nozzle for the test article (see Table 5.2.3-1 for nozzle flow ranges), select the nozzle by using the pull down menu in the LabView control program titled "Select Element".

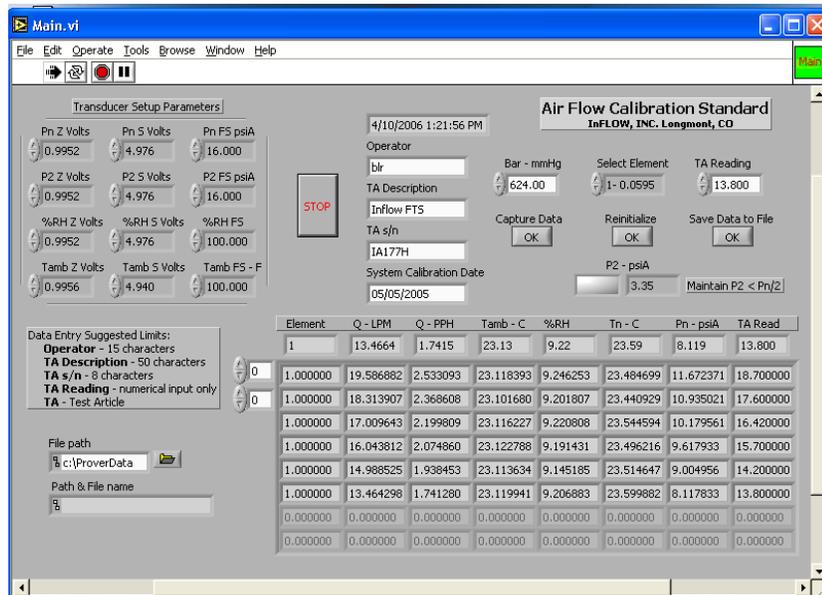
- 10) Start the pump, verify that the appropriate metering valves are wide open to challenge the sensors.
- 11) Click on => (Arrow) at left top of page to start program.
- 12) Allow the pump and the program to run for at least 20 minutes.
Note: When using the small nozzles (i.e. Nozzles 4 or 5) the pump can be used to pressurize the tank and then turned off. The subsequent test can be run utilizing the vacuum created in the dampening tank to supply the flow through the Skid.
- 13) Enter the appropriate information to the LabView control program, including:
 - a. Enter Operator Initials in the box titled “Operator”
 - b. Enter Test Article Serial Number in the box titled “TA s/n”.
 - c. Enter Test Article Description in the box titled “TA Description”.
 - d. Enter Barometric Pressure in appropriate units in the box titled “Bar-mmHg”
- 14) Install the Test Article onto the InFlow System.
- 15) Click the “Reinitialize” button to delete any 'leftover' data.



- 16) Adjust the metering valves to set the first point.
- 17) Allow the flow to stabilize.
Note: The lower the flow the longer the time needed to stabilize.
- 18) Enter the appropriate value in the 'TA Reading' space.



- 19) Click “Capture Data”, clicking this button takes a 'snapshot' of the data.
Note: The operator may wish to take a number of points at each level to get a better estimate of the actual value than the 'snapshot' offers.
- 20) Repeat Steps 17 through 20 until enough points have been taken for a valid calibration (or verification). Note: The number of points required varies upon the test article and the range over which the article is being calibrated. Generally speaking the operator should take no less than 12 points, regardless of range.



- 21) Note the ambient pressure, take the average of the pre-test pressure and post-test pressure and enter this value into the box titled “Bar-mmHg”.
- 22) Verify that the points taken are satisfactory (the number of points is satisfactory and there were no data entry errors, etc).

- 23) If the points and the number of them are satisfactory click the 'Save Data to File' button.
- 24) Install the next Test Article and repeat the process, above until data for all the Test Articles have been taken.
- 25) Click the 'Reinitialize' button.
- 26) Click the 'Stop' button.
- 27) Close the LabView control program.
- 28) Turn off the pump.
- 29) Rename all the files according to the following convention:

TA'SN_yymmdd.txt' where:
'TA' refers to 'Test Article',
SN should be the TA serial number, e.g. GN002,
yyymmdd refers to the year (yy), month (mm), and day (dd) that the calibration was performed, 'txt'
needs to be added as the LabView control program won't give the file(s) any extension.
- 30) Transfer the newly created *.txt files to the appropriate network computer for processing.

5.2.3.5.Maintenance

Leak Checks

The InFlow System needs to be leak tested periodically. Because the long-term stability of nozzles isn't questioned, for this reason PM2.5 transfer standards should be used for calibration variation evaluations. Variations in transfer standard calibrations are indicative of a problem, most likely operator error or a leak. Turning the pump around can pressurize the system, downstream of the metering manifold. Once the system is pressurized and the valve separating the pump and dampening tank from the InFlow System has been closed the InFlow System can be inspected for leaks by applying a liquid leak detector (e.g. 'Snoop') to the joints and connections. Capping of the inlet to the InFlow System and opening of the valve, the presence of a leak upstream of the nozzle assembly can be evaluated. A leak upstream of the nozzle assembly must result in (after the leak has been fixed) reruns of all suspect test articles. A leak downstream of the nozzle assembly should be fixed but will not affect calibration results. If the operator wishes to leak check the entire InFlow System, then a suitable plug must be installed upstream of the nozzle assembly after which the InFlow System can be pressurized and tested for leaks in the same manner described above.

Nozzle Cleaning

The nozzles should be inspected periodically for the presence of dust or debris in the throats. If some material is found, the operator should attempt to blow the material out of the nozzle throat from the rear of the nozzle. Pressurized, clean air can be used. In pertaining to the small nozzles, it is most unlikely that inspection will reveal the presence of material. Consequently, special care should be taken so that the possibility of introducing dust or other debris to the nozzle can be minimized.

5.2.4. Low Volume PM_{2.5} and SASS Orifices Data Processing

Once the data has been generated and checked for data entry errors it can be transferred into the FTS calibration database. The database serves as the storage location for all FTS calibration data and can be used to produce the necessary FTS calibration coefficients, compare historical calibrations, produce summary results, and track FTS usage.

Data from the InFlow system is stored in tab delimited text files. For each test article an individual text file is created and stored on the InFlow system at C:\ProverData. Data from the data file can be imported into a spreadsheet or a database for data evaluation and analysis. An example data file is given below.

Example Data File From The InFlow System

```
2/7/2005 9:58:07 AM gjh Gilibrator 7491 12039-H 624.450 3/8/2002
2.000000 2.535933 0.328056 23.119098 14.634817 23.489305 9.004061 2.536000
6.000000 5.132303 0.663716 23.208808 14.802859 23.581451 8.089598 5.124000
1.000000 10.020248 1.295405 23.301101 14.941480 23.756536 6.109295 9.940000
1.000000 15.028513 1.942991 23.283118 14.914618 23.662083 9.031459 14.870000
1.000000 19.707095 2.547743 23.300332 14.801781 23.470877 11.742175 19.430000
```

Inflow data files can be directly loaded into a flow certification spreadsheet that is located on the internal CDPHE network at J:\QA Program Files\Verifications\Flow Verification\FLOW RECERT.xls. See figures below. The use of this spreadsheet is not a requisite, however, the use of other spreadsheets and databases must document and evaluate all of the standards information and criteria. Data from an InFlow data file can be manually entered into the Cert Form or it can be copied into the spreadsheet and visual basic macros can format and insert the data into the Cert Form. In order for the data input macros to work properly the raw performance data must:

- 1) be in numerical order from highest to lowest or lowest to highest;
- 2) if multiple points are taken at each flow level, the number of points at each level must be the same;
- 3) number of points at each flow level cannot exceed 5;
- 4) Number of flow levels cannot exceed 12.

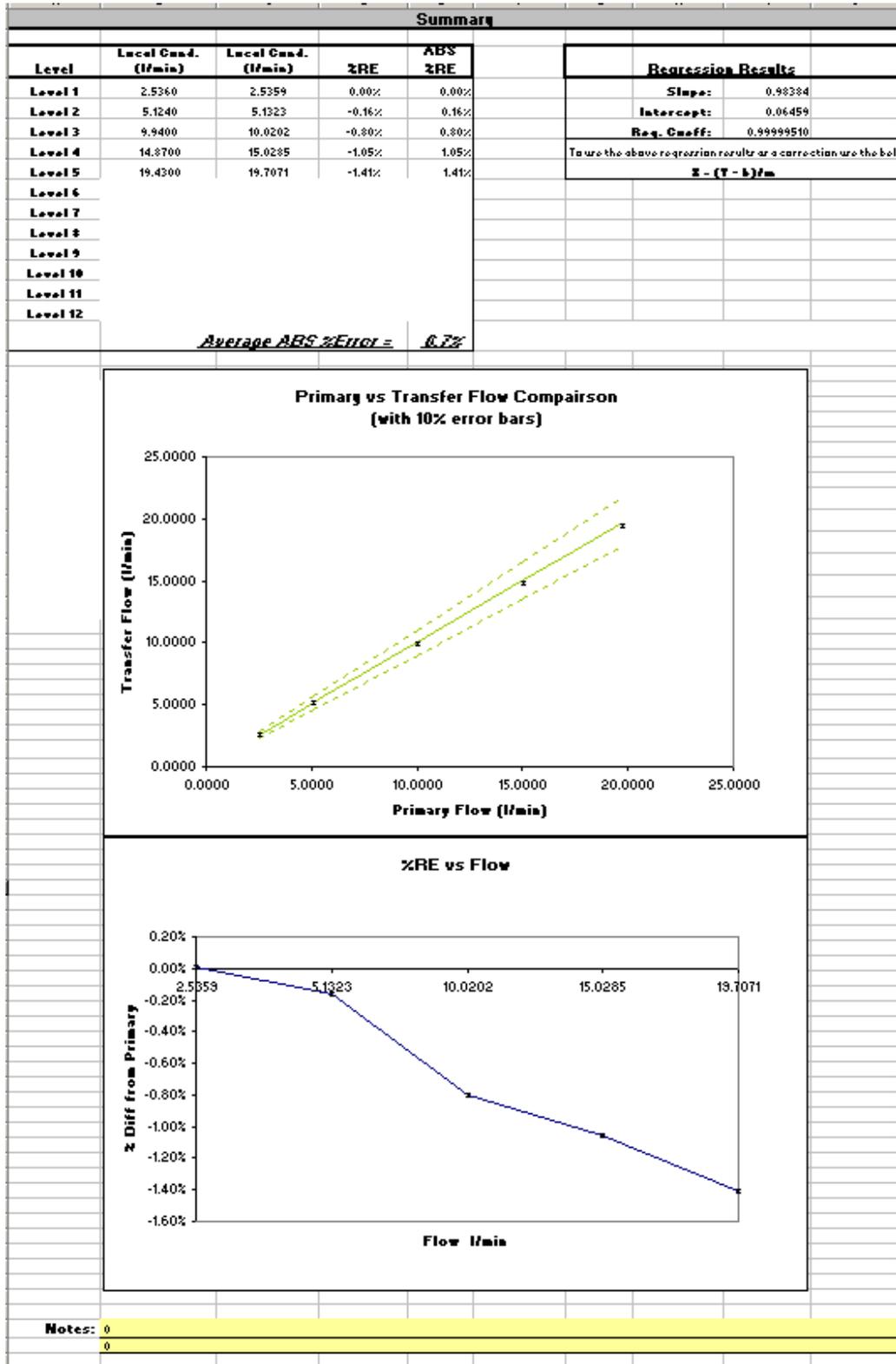
If the above conditions are met, the data input and processing procedure below can be used.

UPDATE ON THIS SECTION PENDING:

- 1) Open the following Excel spreadsheet, J:\QA Program Files\Verifications\Flow Verification\FLOW RECERT.xls.
- 2) Open the InFlow text data file in Excel. Upon opening, a text import wizard will prompt you for file information. Enter the appropriate information for the importing of a tab delimited text file.
- 3) Manually copy all data from the Excel data file and paste it in the home position on the Raw Data sheet within the FLOW RECERT.xls spreadsheet.
- 4) Save and close the Excel data file.
- 5) From the Cert sheet within the FLOW RECERT.xls spreadsheet verify that you are in “certification mode” by observing the large button across the top of the sheet. If you are not in “certification mode” press the button to switch to toggle between “archive mode” and “certification mode”.
- 6) From the “transfer standard’s information” area, select the standard you are evaluating from the dropdown box. If the standard you are evaluating is not in the drop down list then you must enter it into the hidden sheet titled “Flow Type”. To unhide this sheet, from the main dropdown bar select <Format> <Sheet> <Unhide> and “Flow Type”. Save the information and re-hide the sheet by selecting <Format> <Sheet> and <Hide>.
- 7) From the “transfer standard’s information” area, select the box for the flow condition at which the reported flows are given in.

- 8) From the “primary standard’s information” area, select the primary standard from the dropdown box. If the standard is not in the drop down list then you must enter it into the hidden sheet titled “Flow Type”. To unhide this sheet, from the main dropdown bar select <Format> <Sheet> <Unhide> and “Flow Type”. Save the information and re-hide the sheet by selecting <Format> <Sheet> and <Hide>.
- 9) From the “primary standard’s information” area, select the box for the flow condition at which the reported flows are given in.
- 10) From the “comparison” area, select the boxes for the conditions you would like to see the comparison results presented. If you want to observe data at a reference condition, then enter the reference temperature and pressure.
- 11) Enter the number of flow levels that were performed by pressing the button immediately following the prompt. This will activate an input box where you can enter the number of levels.
- 12) Enter the number of points that were taken at each flow levels by pressing the button immediately following the prompt. This will activate an input box where you can enter the number of points.
- 13) To import data into the form select the “Get In-Flow Data” button.
- 14) The spreadsheet calculates the difference between the transfer standard and the primary standard. The differences between the two standards cannot exceed the manufactures accuracy specifications. If the differences are greater than the accuracy specifications, then the verification procedure should be redone to verify results. If the differences continue to exceed the accuracy specifications, then the transfer standard must be repaired and/or recalibrated.
- 15) Print a hard copy of the verification and file it in the standard’s file located in the flow category of the QA filing cabinet.
- 16) Press the “Archive” button to save the record to archive.
- 17) Using a waterproof permanent marking pen, fill out a label for each transfer standard that passed the verification procedure with the **date verified**, the **initials of the person who performed the verification** and the **due date for the next verification** and **calibration coefficients**. Attach the label to the back of the transfer standard. Place a piece of clear tape over the label to protect the writing.

Figure 5-7 Flow Recertification Form (Page 2)



5.2.5. References

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5.3. Mass Flow Controllers – Dilution Systems

5.3.1. Teledyne Advanced Pollution Instrumentation (TAPI) 700 Calibrators

5.3.1.1. Scope

The following procedure is taken from the TAPI 700 MFC Calibration Service Note

MFC's will change over time. However, with the TAPI software you can correct for this by doing the MFC calibration that is described in this procedure. This procedure discusses differences in flow measurements and presents a way of accurately measuring flow in the Model 700 calibrator.

NOTE: This procedure should be followed prior to sending in any MFC's to TAPI. Most problems with MFC's will be fixed by following this procedure.

5.3.1.2. Tools

- Mass flow meter with temperature and pressure compensation.
- Wrenches: $\frac{7}{16}$, $\frac{1}{2}$, $\frac{9}{16}$
- Phillips head screwdriver
- Flat tip screwdriver
- Manufacturers' Operations/Service Manual

5.3.1.3. Definitions:

Volumetric Flow:

The uncorrected flow measured with a flow meter. This is a measure of the total volume of the flow being measured. The volume of a given number of molecules will vary with pressure and temperature due to changes in density. Volumetric flow must be compensated for pressure and density in order to be comparable with mass flows.

Mass Flow:

The flow rate of a liquid or a gas is given as units of mass (mass of molecules) per units of time. The number of molecules in a given volume of gas will vary with pressure and temperature due to changes in density.

Mass Flow Controller:

The device that controls flow in the Model M700 Calibrator. Because this is a mass flow device, correction must be applied to **volumetric** flow measurements taken from the M700 output. The MFC in the M700 is corrected to Standard Temperature and Pressure.

M700 MFC Standard Temperature and Pressure (STP):

A reference temperature and pressure in which volumetric flow rates can be corrected. The M700 MFCs are standardized to 0°C and 29.92 inHg.

EPA Standard Temperature and Pressure (STP):

A reference temperature and pressure used by EPA, in which volumetric flow rates can be corrected to. EPA flow rates are standardized to 25°C and 29.92 inHg.

Other Standard Temperature and Pressure (STP):

Care must be used when comparing flow rates standardize to different reference temperature and pressures. Different countries use different reference conditions. The most common reference conditions, aside what are listed above, are 20°C and 29.92 inHg.

5.3.1.4. Background

There has been some confusion regarding calibration and flow verification of the mass flow controller, (MFC's) in the model 700 calibrator. This confusion stems from difference in the way flow measurements are made. These differences result from making measurements of volumetric flow vs. mass flow. When the pressure or temperature changes, the volume of a given number of molecules (mass), will change as the result of an increased or reduced density. Thus, when measuring flow, a mass flow of 1 lpm for the MFC could result in a volumetric flow that is much smaller or larger than 1 lpm.

Since the MFC is a mass flow device, if you are using a volumetric measuring device, you must correct the volumetric flow for temperature and pressure to accurately represent the flow that the calibrator's MFC is putting out. If you are trying to verify calibrator flow, and you do not correct to STP, the flow will not match the expected values of the calibrator. If you try to adjust the MFC to tables based on volumetric, (uncorrected) flow, the calibrator will not give a correct mixture.

5.3.1.5. Procedure

Remove the calibrator from operation and move it to a desk so that you can work on it. Remove the cover of the calibrator.

Note: There is high voltage and moving parts in the calibrator, use caution when working in the calibrator. If you are not sure if something has power on it, check it with a meter on both AC and DC voltages before you touch it.

- 1) Leak check the calibrator by doing the following: if your calibrator has a photometer in it, you will have to bypass the pump and the flow meter in the calibrator. To bypass the pump and flow meter use the clamps provided by Teledyne and install the clamp on the outlet portion of the pump. Install the second clamp on the PI side of the flow meter.
- 2) If equipped, cap the internal vent with a 1/8th in. cap. Use the ¼ in. caps to cover the exhaust, vent and calibration gas out ports. See figure 5-9.
- 3) Go to the rear panel of the calibrator and use a tee and a reducer to jumper the dilution air to the port 1 calibration gas input. This air is going to be used for the auto leak check and the gas flow through both the dilution MFC and the Cal-Gas MFC for the measurement of the flow through the MFCs. See Figure 5-9.
- 4) Now push "SETUP", "MORE", "DIAG", "NEXT" to "AUTO LEAK CHECK" push "ENTER" and "ENTER".

- 5) If the leak check passes then proceed to the next step. If the leak check fails, then you must find the leak. Do not continue with this procedure until you find and fix the leak.
- 6) When you have completed the leak check put the tubes back to their original location. That is to say, put the pump back into the circuit so that it will work when you turn it on.
- 7) Setting up for measuring MFC flows.
- 8) If you have not yet removed the cover from the calibrator, do so now.
- 9) It is recommended that you measure the flows through the mass flow meters and then enter your results into the Verifications Database form (figure 5-11). The Verifications Database is located on the APCD's internal network at J:\QA Audit Programs\Verifications\. Once you have measured all the flows, you can then look at the data and decide if you need to make a correction to the MFC look-up table.
- 10) Ensure that the flowmeter is in "STD" mode and the temperature and pressure values/units on the flowmeter are the same as on the MFC label.
- 11) Look at the MFC's in the calibrator and determine their flow ranges. The standard MFC's are 10 lpm for the dilution MFC and 100 cc/min for the cal gas MFC. Enter the ranges of the MFCs into the Verifications form.
- 12) Put the calibrator in STANDBY by pushing the STANDBY button on the front panel. You should have STANDBY in the upper left-hand corner of the display.
- 13) Place your flow meter onto the cal gas output of the calibrator. You should not measure any flow. If you measure flow you have a valve leaking in the calibrator. To figure out what valve is leaking remove the tube that is going to the cal gas input port 1 and cap the tube so that the air stops leaking. Now measure the flow at the rear panel again. If the flow stopped then you have a leaking valve at the cal gas manifold. If the air did not stop, then put the air back to the port 1 input and remove the dilution air input from the rear panel. If the flow stops then you have a leaking valve at the dilution gas manifold.
- 14) Fix any leaks before continuing with the MFC calibration.
- 15) Enter the Transfer standard (calibrator MFC) and the Primary Standard data into the Verifications Form
- 16) Pres "SETUP", "MORE", "DIAG", "ENTER", "NEXT" to "MFC CALIBRATION" and "ENTER".
- 17) Now you can select the MFC 1 or MFC 2. MFC 1 is the larger dilution MFC and MFC 2 is the smaller Cal Gas MFC. Select "MFC 1".
- 18) You should now see the following on the front panel of the calibrator:

a. DIAG MFC	0)	CAL DRV=0	FLW=0.000
b. PREV	DRIVE	FLOW	ON PRNT EXIT
- 19) You are now at the 0 drive voltage point on the MFC.
- 20) Push the button under OFF to turn the MFC on.

Even though the MFC is ON, there is no drive voltage to the MFC. This means that you should have very little flow through the MFC. All MFCs "leak" when they are at zero. The spec from the manufacture is < 2% of full scale of the MFC. Measure the flow at the Cal gas output port of the

calibrator. Calculate what 2% of full scale is and determine if the MFC is within specifications. Repair if necessary.

- 21) Press “EXIT” and now turn on MFC 2.
- 22) Again the leakage on MFC 2 should be < 2% of full scale.
- 23) Once it is established that the MFCs are not leaking, you can now perform the MFC verification or calibration.

Measuring MFC flows.

- 24) Select the MFC 1 and push the “NEXT” button until you get to a drive voltage of 5000 mv and the look-up table on the front panel of the calibrator is at the full scale of the MFC. You should see:
 - a. DIAG MFC 20) CAL DRV=5000 FLW=0.1000
 - b. PREV DRIVE FLOW ON PRNT EXIT
- 25) When you look at this menu you can see that the MFC is ON, that the drive voltage is at 5000 mv (full scale) and that the MFC is at 100 cc/min (full scale).
- 26) Enter the Transfer standard and the primary standard data into the Verifications form.
- 27) Measure the flow at the output of the MFC with a mass flow meter in the STD mode. Using the burst mode of the mass flow meter, 10 measurements will be taken and averaged. Enter the average measured flow into the Verifications form under the primary standard column on the left side by the Pre-Verification/Calibration section. Enter the calibrator flow, displayed on the front panel, into the Verifications Database form under the Transfer Standard column.
- 28) Now press the “PREV” button and go to the 4750 mv drive voltage and measure the flow. Again enter this flow onto the Verifications form on the 4750 mv drive voltage line.
- 29) Press the “PREV” button and measure the flow. Enter the flows into the Verifications form.
- 30) Continue doing this until you have measured all 20 flows at all 20 drive voltage points.
- 31) When you are done with MFC 1, press the ON button and turn the MFC off. Now push “EXIT” and “MFC 2”. Now turn on MFC 2 and again measure all the flow at MFC output for all 20 of the drive voltages. Enter the measurements into the Verifications form.
- 32) When you are done with measuring all the flows, turn the MFC off.

Adjusting/Calibrating MFC Flow

- 33) The Verifications database form will compute the criteria to determine whether or not the MFC needs to be calibrated.
 - a. Pass = ABS avg <1%
 - b. Warning = ABS avg >1%
 - c. Fail = ABS avg >2%
- 34) If the MFC fails then a calibration must be preformed (go to next step). If it passes then nothing else is to be done, except capture the data into the Verifications Database and print out the form. Place the hardcopy of the form in the appropriate calibrator folder within the QA cabinet.
- 35) If the verification fails, go back into the DIAG function and go into the MFC1 lookup table. Push the “NEXT” button until you come to the flow that you need to change. Press the “FLOW” button and enter in the flow that you measured and press “ENTER”. Enter in all the flows that you are going to change and then exit back out to the main menu.

- 36) Measure all twenty flows with the newly calibrated MFC values and enter the data into the Verifications form on the Post Verification/Calibration side (right side) of the form (see Step 30).
- 37) Ensure that the MFC passes the verification. Press the capture button on the Verifications Database form and print the form. Place the form in the appropriate calibrator folder.

Figure 5-8 TAPI M700 Internal Components

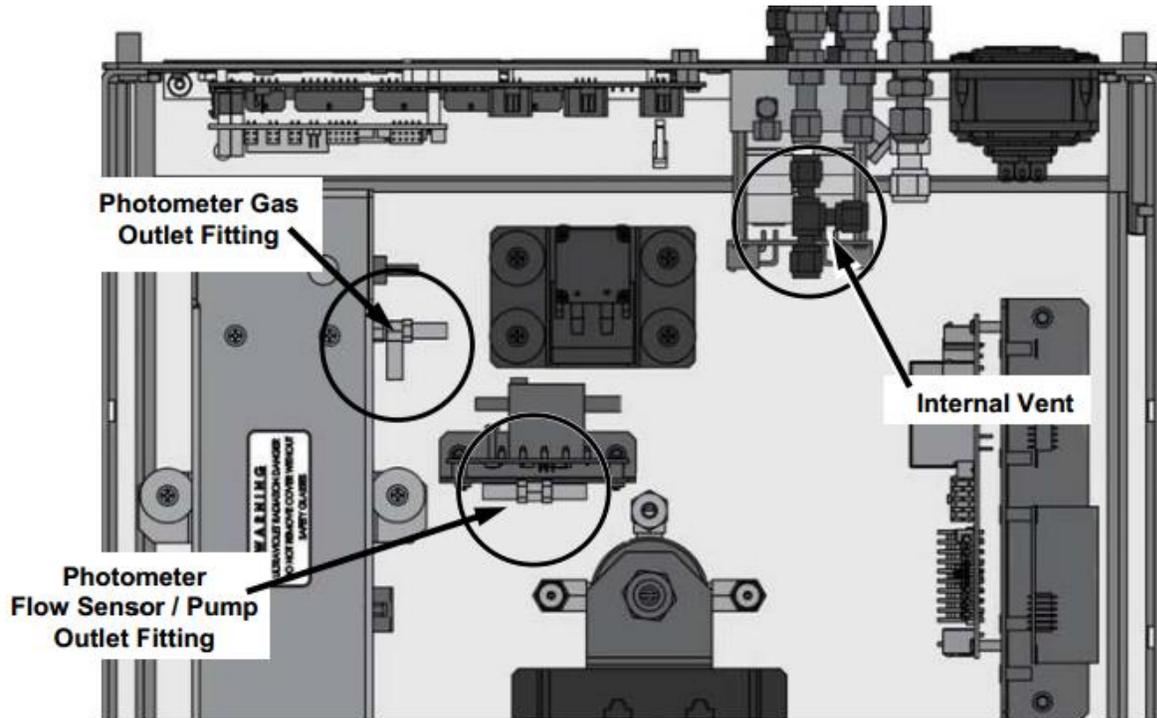


Figure 5-9 API/Thermo 700 Back Panel

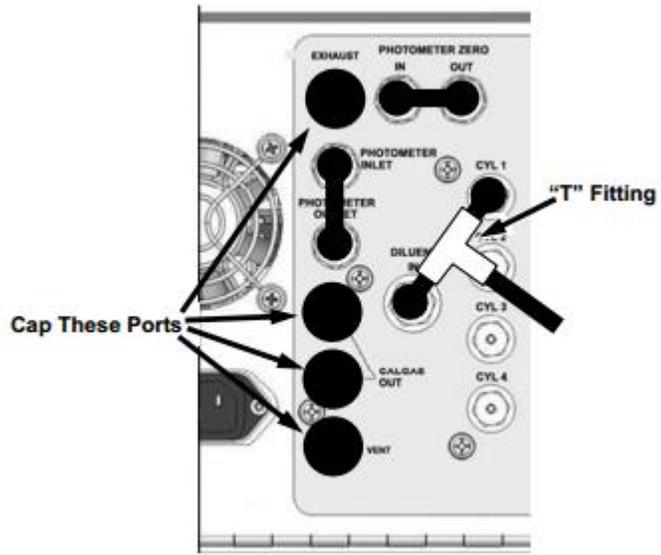


Figure 5-10 APCD MFC Verification Form

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT Air Pollution Control Division - Technical Services Program MFC Teledyne Verification Form													
Verification Date (mm/dd/yy):				Initials:									
Transfer Standard						Primary Standard							
Transfer Std. Info.	Calibrator SN:				Make:				Primary Std. Info.	Model:			
	Calibrator Make:				Base SN:					Cell SN:			
	Calibrator Model:				Cell Range:					Standard Temp (C):			
	MFC Number:				Standard Press (mmHg):					Accuracy:			
	Range:				Owner:					Date of Previous Verification:			
	Standard Temp (C):				Date of Next Verification:								
	Standard Press (mmHg):												
	Accuracy:												
	Owner:												
	Date of Previous Verification:												
Date of Next Verification:													
Comparison Data													
	Drive Voltage	Primary Standard (lpm)	Transfer Standard (lpm)	Diff.	% Diff.	ABS % Diff.	Primary Standard (lpm)	Transfer Standard (lpm)	Diff.	% Diff.	ABS % Diff.		
Level 20	5000 mv												
Level 19	4750 mv												
Level 18	4500 mv												
Level 17	4250 mv												
Level 16	4000 mv												
Level 15	3750 mv												
Level 14	3500 mv												
Level 13	3250 mv												
Level 12	3000 mv												
Level 11	2750 mv												
Level 10	2500 mv												
Level 9	2250 mv												
Level 8	2000 mv												
Level 7	1750 mv												
Level 6	1500 mv												
Level 5	1250 mv												
Level 4	1000 mv												
Level 3	750 mv												
Level 2	500 mv												
Level 1	250 mv												
Level 0	0 mv												
Criteria:													
Fail: ABS Avg > 2%													
Warning: ABS Avg > 1%													
Pass: ABS Avg < 1%													
		Averages											
		Pre					Post						
		<input type="radio"/> 20 Point Average					<input type="radio"/> 20 Point Average						
		<input type="radio"/> 5 Point Average					<input type="radio"/> 5 Point Average						
Comments:													
Calibrators Signature:													

6. GAS CONCENTRATION VERIFICATION PROCEDURES

6.1. CO, SO₂, NO₂

Gaseous pollutant concentration standards used to provide test concentrations of CO, SO₂, or NO_x must be traceable to standard reference materials produced by the National Institute of Standards and Technology (NIST). The APCD uses compressed gas cylinders of CO, SO₂, and NO during calibration and audits. These compressed gas cylinders are provided by a private supplier and have an established traceability to NIST reference standards consistent with all aspects of the *Revised EPA Protocol for Assay and Certification of Compressed Gas Calibration Standards*. All records of these gas concentration certifications are available for review and are maintained by GMM Unit and QA Unit staff. All gas cylinders have a known shelf life and a designated expiration date. Table 6.1-1 shows the certification periods for compressed gas calibration standards in passivated aluminum cylinders used by the Technical Services Program. Upon meeting the expiration date, the gas cylinder must be returned to the manufacture for recertification or to be discarded.

Figure 6-1 Certification Periods for Compressed Gas Calibration Standards

Certified components	Balance gas components	Concentration range	Certification period in months
Carbon Monoxide	Ultrapure air	> 8 ppm	36
Nitric Oxide	Air	>4 ppm	24
Sulfur Dioxide	Nitrogen	40-499 ppm	24
Sulfur Dioxide	Nitrogen	10-39 ppm	6
Sulfur Dioxide (Recertification)	Nitrogen	10-39 ppm	24

6.2. Catalytic Oxidizer

The GMM Unit uses catalytic oxidizers (cat-ox) during continuous CO analyzer calibrations to provide CO free zero air. The CO in ambient air is oxidized on a heated catalyst to CO₂. The CO₂ does not affect the analyzer's readings.

All catalytic oxidizers of the GMM unit are certified once per year. In the certification, a properly calibrated Teco 48 CO analyzer is zeroed with bottled zero air. Then an approximately 10 ppm CO concentration is directly introduced to the cat-ox (refer to the owner's manual for proper operation and temperature of the cat-ox). The analyzer samples the output of the cat-ox, with enough flow excess at an open tee to prevent back flush of ambient air into the analyzer. If the analyzer reads any CO at all the catalyst element or the catalyst oven assembly (see cat-ox manual) needs to be replaced.

Then an approximately 50 ppm CO concentration is introduced directly to the cat-ox. If the TECO 48 reads ≥0.5 ppm then the catalyst element or the catalyst oven assembly needs to be replaced.

7. HUMIDITY VERIFICATION PROCEDURES

7.1. Hygrometers

The APCD maintains the use of digital hygrometer to audit the humidity of the gravimetric laboratories and the meteorological humidity sensors. The hygrometer reports both temperature and humidity and is stored in the Standards Laboratory. Because the APCD does not have the facilities or equipment to verify this standard, they are shipped annually to a contract metrology laboratory for certification. Certification documentation is stored in a filing cabinet within the Standards Laboratory.

8. MASS VERIFICATION PROCEDURES

8.1. Gravimetric Laboratory Mass Standards

The APCD maintains the use of several mass standards to audit the gravimetric laboratories that perform the routine analysis of PM₁₀/TSP and PM_{2.5} filters. They are Ultra-Class standards and are stored in the Standards Laboratory. Because the APCD does not have the facilities or equipment to verify these standards, they are shipped annually to a contract metrology laboratory for certification. Certification documentation is stored in a filing cabinet within the Standards Laboratory.

8.2. TEOM Mass Standards

The APCD maintains the use of several mass standards to audit the spring constants (K_o) of the tapered oscillating element within the PM₁₀ and PM_{2.5} TEOMs. Unless taken to the field, these standards are stored in a desiccator within the Standards Laboratory. Because the APCD does not have the facilities or equipment to verify these standards, they are shipped annually to a contract metrology laboratory for certification. Certification documentation is stored in a filing cabinet within the Standards Laboratory.

9. METEOROLOGICAL VERIFICATION PROCEDURES

9.1. Wind Direction

The APCD QA group uses a transit to audit the orientation of each meteorological tower cross-arm. Because the APCD does not have the facilities or equipment to verify this standard, it is shipped annually to a contract meteorology laboratory for certification. Certification documentation is stored in a filing cabinet within the Standards Laboratory.

Calibration and audit of the wind direction sensor is accomplished with the use of a fitted metal Degree Wheel Calibrator which is a manual device that does not require periodic certification and is simply replaced when worn out, and no longer legible. Sensor bearing response thresholds can be tested in the controlled environment of the APCD laboratory with a torque wheel which is a manual device that does not require frequent recertification. As part of the orientation procedure the magnetic declination at each site is updated at least once per year from the NOAA's National Geophysical Data Center (NGDC.) The Uniform Resource Locator (URL) address of the Web site is currently located at <https://www.ngdc.noaa.gov/geomag-web/#declination>.

9.2. Wind Speed

Calibration and audit of the wind speed sensors is accomplished with the use of a precision synchronous motorized field standard. Field standards are compared to the laboratory standard which is sent to the manufacturer yearly for recertification. Certification documentation is stored in a filing cabinet within the Standards Laboratory. Sensor bearing response thresholds can be tested in the controlled environment of the APCD laboratory with a torque wheel which is also a manual device that does not require frequent

recertification. Field wind speed motor verification is accomplished by comparing the voltage response of the NIST traceable certified primary laboratory motor on at least a yearly basis. The primary laboratory motor is not taken out of the laboratory unless it is sent back for NIST certification at least yearly. This comparison is completed on a laboratory wind speed sensor that is designated for this use. Voltage readings are compared to the primary standard coming out of a translator that is set up just like a field site at 5 or more points in both clockwise and counter clockwise directions. If voltage readings deviate by more than $\pm 0.005V$ from the primary standard, then the motor must be sent back to the manufacturer for repair, calibration or decommissioned and disposed of. Comparison data is stored in a spread sheet located on APCD's local area network at J:\QA Audit Programs\WS-Temp-Volt\WSverifications.xls.

9.3. Temperature

Meteorological temperature sensors are compared to the handheld field temperature standards during calibration or audit. See section 12.1 for verification of the field thermometers.

10. PRESSURE VERIFICATION PROCEDURES

The Visibility, Research and Quality Assurance Unit, the Particulate Monitoring Unit and the GMM Unit use hand-held aneroid and digital barometers, and manometers during calibration and performance audits of APCD air monitoring equipment.

It is an operational goal to perform verifications and calibrations on all hand-held aneroid digital barometers against the in-house lab standard by the staff responsible for the assigned barometers least once per quarter. Because of the remoteness of many field operators, quarterly verifications are not feasible and are therefore not a requisite. At least once per year the QA staff and or PM2.5 staff, certifies every hand held barometer used in the field to take measurements for APCD's air monitoring network. Adjustments and or repairs will be made if necessary. A Paroscientific Digiquartz barometer is used for these certifications. The lab standard is sent back to the manufacturer at least once every three years for recertification. The lab standard has direct traceability by the manufacturer to a National Institute of Standards and Technology (NIST) standard.

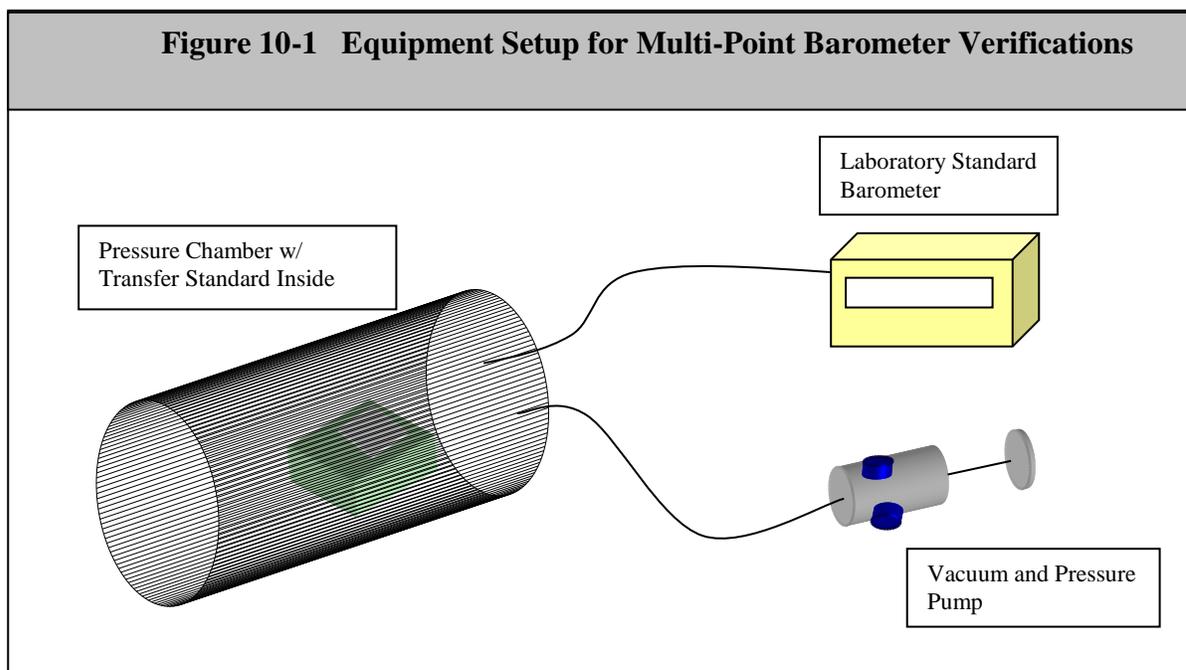
Note: According to ASTM Standard D 3631 (ASTM 1977), a barometer can be calibrated by comparing it with a secondary standard traceable to a NIST primary standard.

The Paroscientific Digiquartz is a quartz crystal type barometer. It operates on fundamental principles of crystal resonance and is highly accurate due to high repeatability, low hysteresis and excellent stability. By comparison, the precision aneroid barometer is an evacuated capsule with a flexible bellows coupled through mechanical linkage to an indicator. It is less accurate than the quartz crystal type but can be transported with less risk to the reliability of its measurements and is preferred for use in the field because of its portability. The quartz crystal type of barometer is best employed as a high quality laboratory standard that is used to adjust and certify an aneroid barometer in the laboratory. Verification of field barometers to the laboratory standard is accomplished by direct comparison of absolute pressures. Because manometers report a differential gauge pressure, verification of field manometers to the laboratory standard are accomplished by comparing the manometer read to the differential pressure of the laboratory standard on an absolute scale.

Precautionary Note: Protect all barometers from violent mechanical shock and sudden changes in pressure. A barometer subjected to either of these events must be recalibrated. Locate the instrument so as to avoid direct sunlight, drafts, and vibration. It has been APCD's experience that digital aneroid barometers are more reliable and repeatable than mechanical aneroid barometers. After wide elevation swings due to travel in Colorado, electronic aneroid barometers have shown little or no shift in accuracy. Mechanical aneroid barometers have shown in the past an unacceptable amount of shift in accuracy.

10.1. Aneroid and Digital Barometers

- 1) For convenience, adjust the laboratory standard so that it displays the same pressure units as the field barometer. The Paroscientific Model 745 features an RS-232 serial ASCII interface with Paroscientific software located on the QA laboratory computer. This software allows for a user interface with the Paroscientific Digiquartz standard in which display units can be modified. For more detailed information regarding the changing of units on the Paroscientific Digiquartz standard refer to its Programming and Operation Manual.
- 2) Determine if a single-point verification or a multi-point verification is required. A single-point verification at ambient pressures is sufficient to verify the accuracy of the field barometer. If a barometer is acting erratic or is suspect, a more rigorous multi-point verification can be performed. A multi-point verification is more complex and requires the use of a pressure chamber. While not covered in detail in this SOP, the multi-point verification procedure is essentially the same as the single-point verification however, additional verification points are performed at different absolute pressures. Different absolute pressures are created by the use the of a pressure chamber.
- 3) For a single-point verification place the field barometer next to the laboratory standard. Note the measurement of the field barometer and the laboratory standard.



- 4) Record and store all of the data in the Verifications database. The database is located within the TSP network at J:\QA Audit Programs\Verifications\Verifications.mdb. Once you have opened the database click the “Barometers” button to open the barometers verification spreadsheet. Spreadsheets from previous years barometer verifications can be found at J:\QA Audit Programs\Verifications\Barometer\Baro Recert.xls (see Figure 10-2). The use of this spreadsheet is not a requisite, however, the use of other spreadsheets and databases must document and evaluate all standards information and criteria.
- 5) For each verification performed, enter the requested information in to all of the boxes within the spreadsheet. Once the data has been entered and a passing or failing value has been obtained, press the “Capture Data” button, saving the data to the database. To retrieve a data record from archive press the “Go to Archive” button and select the record of interest from the dropdown box at the top of the spreadsheet. Changes made to an archived record must be completed by pressing the “Overwrite Record” button.
- 6) The spreadsheet calculates the difference between the transfer standard and the laboratory standard. The differences between the two standards cannot exceed the manufactures accuracy specifications. If either of the differences are greater than the accuracy specifications, then the verification procedure should be redone to verify results. If the differences continue to exceed the accuracy specifications, then the transfer standard must be repaired and/or recalibrated.
- 7) After completing all the Barometer verifications for that year, an annual report can be created, detailing all the specifics for all the Barometers from that year’s verifications. This can be accomplished after entering all the Barometer verifications into the database, by clicking the “Go to Archive” button, then clicking the “Annual Report” button within the verifications database. These reports are then printed and filed by year in the filing cabinet within the Rootsmeter room.

Procedure for Adjusting the Hand Held Digital Aneroid Barometers

Adjust the hand-held digital barometer reading to within 0.01” mmHg of that of the corrected laboratory standard reading. Very few of the hand-held digital barometers have a small adjustment potentiometer that

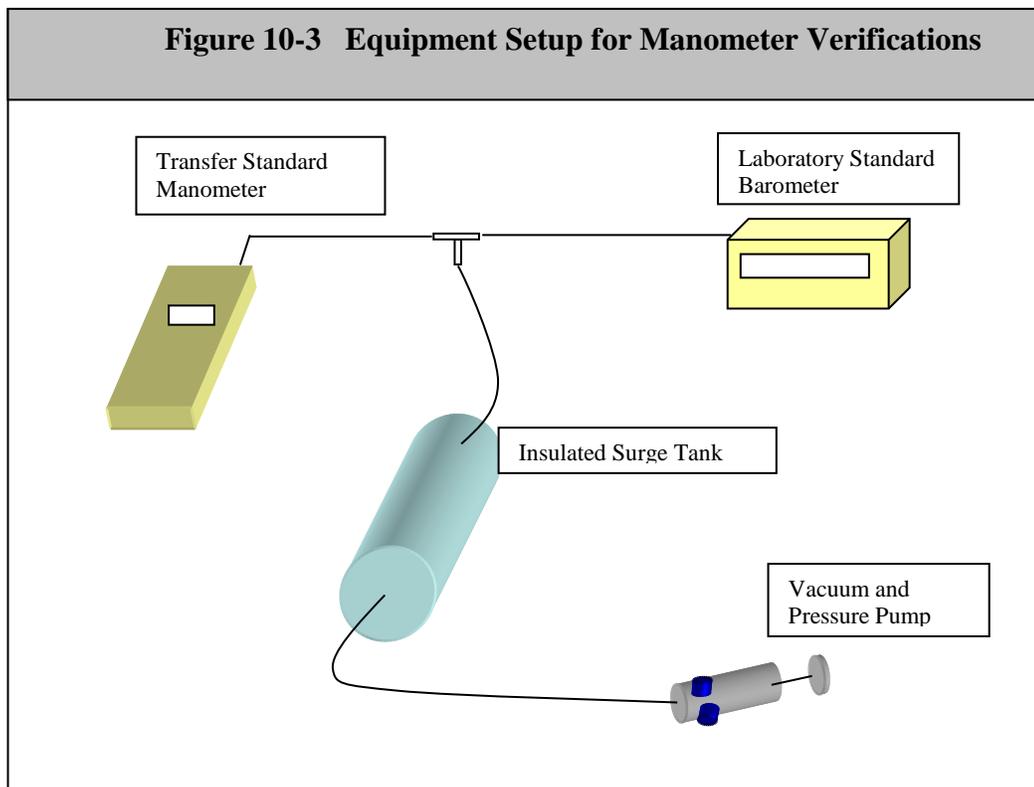
can be turned with a small screwdriver. This potentiometer is typically located on the main circuit board and turning this potentiometer will adjust the hand-held barometer reading.

Figure 10-2 Barometer Verification Form

 COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT Air Pollution Control Division - Technical Services Program Barometer Verification Form										
Search Site Name: <input type="text" value="26754"/>										
Verification Date (mm/dd/yy): <input type="text" value="1/3/2011"/>		Initials: <input type="text" value="CWS"/>								
Transfer Std. Info.	Transfer Standard				Primary Std. Info.	Primary Standard (Paroscientific SN = 81396)				Go To New Data
	Barometer SN:	<input type="text" value="26754"/>				Barometer SN:	<input type="text" value="81396"/>			Delete Record
	Make:	<input type="text" value="Pretel"/>				Make:	<input type="text" value="Paroscientific"/>			Overwrite Record
	Model:	<input type="text" value="A2"/>				Model:	<input type="text" value="740-16B"/>			Annual Report
	Range:	<input type="text" value="15.5 to 31.0 inHg"/>				Range:	<input type="text" value="23.4 to 32.57 inHg"/>			
	Resolution:	<input type="text" value="0.01 inHg"/>				Resolution:	<input type="text" value="0.01 inHg"/>			
	Accuracy:	<input type="text" value="unknown"/>				Accuracy:	<input type="text" value="+/- 0.01 inHg"/>			
Owner:	<input type="text" value="mk"/>			Owner:	<input type="text" value="primary"/>					
Date of Previous Verification:	<input type="text" value="12/29/2009"/>			Date of Previous Verification:	<input type="text" value="8/1/2007"/>					
Date of Next Verification:	<input type="text" value="1/3/2012"/>			Date of Next Verification:	<input type="text" value="7/31/2010"/>					
Comparison Data					Comments:	<input type="text" value="Replaced Battery."/>				
	Transfer Std.	Primary Std.	Difference	% Difference						
Level 1	<input type="text" value="24.62"/>	<input type="text" value="24.6"/>	<input type="text" value="0.02"/>	<input type="text" value="0.00"/>						
Level 2	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>						
Level 3	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>						

10.2. Manometers

- 1) For convenience, adjust the laboratory standard so that it displays the “User Defined” units and verify that the factor is 27.70851. The Paroscientific Model 760 features an RS-232 serial ASCII interface with Paroscientific software located on the QA laboratory computer. This software allows for a user interface with the Paroscientific Digiquartz standard in which display units can be modified. For more detailed information regarding the changing of units on the Paroscientific Digiquartz standard refer to its Programming and Operation Manual.
- 2) A multi-point verification that brackets the expected operational use of the standard is suggested. A single-point verification can be performed as a troubleshooting technique if a manometer is acting erratic or is suspect. The manometer verification procedure requires the use of an insulated surge chamber. Because manometers report a differential gauge pressure, verification of field manometers to the laboratory standard are accomplished by comparing the manometer reading to the differential pressure of the laboratory standard on an absolute scale.
- 3) For a multi-point verification, setup equipment as detailed in Figure 10-3. Verify the chamber has no large leaks. Using the vacuum/pressure pump apply a vacuum to the system (be sure not to exceed the operational limitation of the laboratory standard). Apply differing vacuums that span the operational use of the field manometer. At each vacuum level note the pressure values of the field manometer and the laboratory standard. At each vacuum level take three separate measurements of each standard. Three measurements are required because small leaks and differences in atmospheric temperatures and pressure induce a small vacuum drift within the system. These three values are to be averaged together. Take precautions to minimize factors that cause system drift.



- 4) Record all the data in the “Verifications” database. The Verifications database can be found within the TSP network at J:\QA Audit Programs\Verifications\Verifications.mdb. Once you have opened the Verifications database click the “Manometers” button to open the manometer verification form. Spreadsheets from previous years manometer verifications can be found at J:\QA Audit Programs\Verifications\Manometer\YYYY-YYYY Manometer Recert.xls (see Figure 10-4), where YYYY are the beginning four digit years of the verification cycle or, in the verifications database by clicking the “Go to Archive” button. The use of this spreadsheet is not a requisite, however, the use of other spreadsheets and databases must document and evaluate all standards information and criteria.
- 5) The form calculates the difference between the transfer standard and the laboratory standard. The differences between the two standards cannot exceed the manufactures accuracy specifications. If either of the difference is greater than the accuracy specifications, then the verification procedure should be redone to verify results. If the differences continue to exceed the accuracy specifications, then the transfer standard must be repaired and/or recalibrated.
- 6) Using a waterproof permanent marking pen, fill out a label for each transfer standard that passed the verification procedure with the **date verified**, the **initials of the person who performed the verification** and the **due date for the next verification**. Attach the label to the back of the transfer standard. Place a piece of clear tape over the label to protect the writing.
- 7) After completing all the Manometer verifications for that year, an annual report can be created, detailing all the specifics for all the Manometers from that year’s verifications. This can be accomplished after entering all the Manometer verifications into the database, by clicking the “Go to Archive” button, then clicking the “Annual Report” button within the verifications database. These reports are then printed and filed by year in the filing cabinet within the Rootsmeter room.

Example Verification Label for Field Manometers

Date of Verification_____
Initials_____
Date of Next Verification_____

Figure 10-4 Manometer Verification Form

		COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT									
Air Pollution Control Division - Technical Services Program											
Manometer Verification Form											
Verification Date (mm/dd/yy) <u>1/29/2010</u>				Initials: <u>cs</u>							
Transfer Std. Info.	Transfer Standard			Primary Std. Info.	Primary Standard (Paroscientific SN = 81396)						
	Manometer SN:	<u>405PUL365</u>			Manometer / Barometer SN:	<u>81396</u>					
	Make:	<u>Dwyer</u>			Make:	<u>DigiQuartz</u>					
	Model:	<u>475-1-FM</u>			Model:	<u>740-16B</u>					
	Range (inH2O):	<u>20</u>			Range:	<u>30</u>					
	Resolution:	<u>0.01</u>			Resolution:	<u>0.01</u>					
	Accuracy:	<u>0.005</u>			Accuracy:	<u>0.0001</u>					
	Owner:	<u>ga</u>			Owner:	<u>primary</u>					
Date of Previous Verification:	<u>1/12/2009</u>		Date of Previous Verification:	<u>8/1/2007</u>							
Date of Next Verification:	<u>1/29/2011</u>		Date of Next Verification:	<u>7/31/2010</u>							
Comparison Data											
	Primary Std. 81396	Primary Reference Corr.	Primary Group Average	Primary Drift Correction	Transfer Std. 81396	Transfer Reference Corr.	Transfer Group Average	Transfer Drift Correction	Diff.	% Diff	ABS (Diff)
Level 1 (zero)	336.41	0.00			0.00	-0.01					
	336.41	0.00			0.01	0.00					
	336.41	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	-100.0%	0.00
Level 2 (~23)	316.76	19.65			19.68	19.67					
	316.77	19.64			19.67	19.66					
	316.77	19.64	19.64	19.64	19.67	19.66	19.67	19.67	0.02	0.1%	0.02
Level 3 (~18)	321.60	14.81			14.84	14.83					
	321.60	14.81			14.84	14.83					
	321.60	14.81	14.81	14.81	14.84	14.83	14.83	14.84	0.03	0.2%	0.03
Level 4 (~13)	326.01	10.40			10.42	10.41					
	326.01	10.40			10.42	10.41					
	326.01	10.40	10.40	10.40	10.42	10.41	10.41	10.42	0.01	0.1%	0.01
Level 5 (~8)	329.11	7.30			7.32	7.31					
	329.11	7.30			7.32	7.31					
	329.11	7.30	7.30	7.31	7.32	7.31	7.31	7.32	0.02	0.2%	0.02
Level 6 (~4)	332.18	4.23			4.23	4.22					
	332.18	4.23			4.23	4.22					
	332.18	4.23	4.23	4.24	4.23	4.22	4.22	4.24	0.00	0.0%	0.00
Level 7 (zero)	336.40	-0.01			-0.01	-0.02					
	336.40	-0.01			-0.01	-0.02					
	336.40	-0.01	-0.01	0.00	-0.01	-0.02	-0.02	0.00	0.00		0.00
										Average Diff.:	0.01
										% of Full Scale:	0.07%
										Pass / Fail:	Pass
Comments:											

11. OZONE VERIFICATION PROCEDURES

11.1. Background

In order to ensure a common basis for all APCD ozone measurements, the QA and GMM Units certify their level 3 ozone photometer transfer standards against the APCD level 2 ozone photometer laboratory standard at least twice per calendar year (once per calendar quarter for QA) which is consistent with the minimum requirements detailed in *Transfer Standards for Calibration of Air Monitoring Analyzers for Ozone* (November 2010). In order to clear up confusion, the EPA in the above mentioned document, defines the Standard Reference Photometer (SRP) as a level 1 standard. Beyond the level 1 standard, all other standards are considered transfer standards. The transfer standards are numbered based on the “distance in the traceability chain”. Thus, the “primary laboratory standard” at APCD is now the level 2 ozone standard and the “transfer standards” are now level 3 transfer standards. Additionally, the set of level 3 precision ozone generators dedicated for use as precision level sources are certified against the APCD level 2 ozone standard at the beginning and end of the ozone season or once every 6 months, whichever is less. The level 2 laboratory ozone standard is a TECO 49iPS and the backup level 2 ozone standard is a TECO 49C. The response of both the level 2 and backup level 2 laboratory ozone standards are regularly compared to that of a SRP maintained by the EPA Regional Offices. These verification runs are performed annually at the Air Quality Laboratories of either EPA Region VII (Kansas City, KS) or EPA Region VIII (Denver, CO).

The Accuracy of a level 3 transfer standard is established by: (1) relating the output to a level 2 O₃ standard and (2) demonstrating that the repeatability of the level 3 transfer standard is within the specified limits. A good level 3 transfer standard is precise and repeatable. Its accuracy is entirely relative and comes strictly by certification to the higher level 2 ultraviolet O₃ standard. Certification establishes a precise quantitative relationship between the outputs of the level 3 transfer standard to a series of level 2 O₃ concentration readings. The level 2 O₃ concentrations are measured by an ultraviolet photometer that meets all primary O₃ standard criteria set forth by EPA. After a level 3 transfer standard has been shown to meet the qualification requirements, the level 3 transfer standard must be certified against the level 2 standard before it can be used. This certification process is described in detail below.

11.2. Summary of Method

Verification of APCD level 2 ozone standard to EPA’s SRP

The APCD level 2 ozone standard is annually verified against the response of EPA’s SRP instrument. The acceptance criteria from the linear regression relationship are a slope of 1.00 ± 0.03 , and an intercept of ≤ 3 ppb. Consistent with EPA guidance, no corrections are made to the TSP level 2 laboratory standard responses from this linear regression when updating the transfer standards.

Verification of APCD’s level 3 transfer standards to APCD’s level 2 ozone standard

For multipoint transfer standards, the new comparison of the certification of the transfer standards consists of generating between 5 and 10 different ozone concentration levels, plus a zero air point by the audit or calibration equipment (the level 2 laboratory standard’s zero air source must be the same as that of the level 3 transfer standard). These ozone concentrations are sampled by the TSP laboratory standard and transfer standard. For each ozone level, ten readings are taken from the transfer standard and laboratory standard and then averaged and recorded as the display response. Each new comparison is compared to the previous six verification relationships and must meet the repeatability requirements designated in the EPA document *“Transfer Standards for Calibration of Air Monitoring Analyzers for Ozone”*. The slope and intercept for each new comparison is generated and weighted against the previous six verifications (the verification relationship). Each slope must be less than $\pm 5\%$ from the six-day average. The relative standard deviations should equal 3.7% or less. The standard deviations of the 6 intercepts must be ≤ 1.5 ppb. For recertification, a new comparison is performed and is used as the new sixth averaged slope value. This new slope value must be within $\pm 5\%$ of the previous six run average slope.

Running averages of the last six verification relationships' slope, intercept, and correlation coefficient are kept for each transfer standard (all previous verification relationship forms and results are kept in permanent files). These averages are used to correct the responses of each transfer standard when doing an audit or calibration on an ozone analyzer.

11.3. Required Maintenance prior to Certification/Recertification

The following Maintenance procedures were adapted from the Teledyne *Instruction Manual O3 Calibrator Analyzer Model 401* and the Teledyne *Operator's Manual Model 703E Photometric O3 Calibrator*, for the 401 and 703 O3 level 3 standards, respectively.

1) Leak Check

401 models

1. Generate a Zero on the 401
2. Scroll through the test functions on the front panel to SAMP FL
3. Remove the line on the front of the photometer bench, cap the port on the bench
4. Watch the SAMP FL test function and it should go to zero or XXXX flow
5. Any flow indicates a leak in the photometer cell and must be fixed
6. Replace the line onto the front of the photometer bench
7. Scroll to the O3 Flow test function
8. Cap the dry air in port and the internal vent
9. Watch the O3 Flow test function and it should fall to <0.1LPM (There will be some flow due to the age of the pumps)
10. A flow reading >0.1 LPM indicates a leak in the calibrator and must be fixed

703 models

The 703 contains a small diaphragm sample pump that can be damaged by vacuuming the unit down as in the 401 leak check procedure above. Thus, on the 703 you must bypass the sample pump and pressurize the 703 to check for leaks.

1. Turn off power to the 703.
2. Remove the lines from the internal sample pump (small blue pump near the rear of the unit).
3. Place a union between the lines removed
4. Attach a pressure check apparatus, which consists of a pressure gauge, regulator with a gauge, and a shut off valve to the cal gas out port.
5. Cap the internal vent, exhaust and remaining open vent ports.
6. Pressurize the unit, ensuring that it does **not exceed 15psi**.
7. Close the shut off valve
8. Watch the pressure gauge for pressure drop, indicating a leak.
9. To pass the leak down check, there must be less than 1psi drop per 5 minutes.
10. Return 703 to operational status by removing pressure check apparatus, caps, and union.

2) Pressure Check

401 models

1. With the calibrator in STANDBY, scroll to the PRES test function
2. Compare the reading with the pressure transfer standard
3. Adjust the pressure reading by changing the pot of the Sample press on the pressure/flow sensor module located towards the rear of the instrument.
4. The sample press pot is the first pot from the left, adjust until the correct reading is observed on the front panel

703 models

1. With the calibrator in STANDBY, press SETUP>MORE>DIAG>PRESSURE CALIBRATION>ENTER
2. Take pressure transfer standard reading
3. Input reading into the Sample Pressure field.
4. Press ENTER, EXIT
5. Continue to press EXIT to return to the home screen

3) Flow Check/Calibration

401 models

Sample flow

1. Using the hand held Bios Definer flow meter in volumetric mode, measure the flow of the photometer
2. Remove the tube from the front of the photometer bench and connect the flow meter tube
3. Connect the other end of the tube to the top port of the flow meter (vacuum)
4. Generate a zero
5. Scroll to the SAMP FL test function
6. Take flow measurements with the Bios Definer in burst mode
7. Compare the average flow from the flow meter to the front panel reading
8. If it is different, and the 401 has passed the leak check, adjust the flow sensor
9. Locate the pressure/flow sensor module towards the rear of the instrument
10. Adjust the third pot from the left until the correct reading is observed on the front panel

O3 flow

1. Using the hand held Bios Definers in volumetric mode, measure the flow of the O3 output
2. Remove the ¼ inch tube from the manifold and connect the flow meter to this tube
3. Connect the other end of the tube to the bottom port of the flow meter (pressure)
4. Generate a zero
5. Scroll to the O3 Flow test function
6. Take flow measurements with the Bios Definer in burst mode
7. Compare the average flow from the flow meter to the front panel reading
8. If it is different, and the 401 has passed the leak check, adjust the flow sensor
9. Locate the pressure/flow sensor module towards the rear of the instrument
10. Adjust the second pot from the left until the correct reading is observed on the front panel

703 models

Sample flow

1. Using the hand held Bios Definer flow meter in volumetric mode, measure the flow of the photometer
2. Connect the flow meter to the exhaust port and the other end of the tube to the bottom port of the flow meter
3. From the front panel press: SETUP>MORE>DIAG and toggle to the FLOW CALIBRATION and press ENTER.
4. The photo flow pump will turn on and display a flow
5. Take flow measurements with the Bios Definer in burst mode
6. Compare the average flow from the flow meter to the front panel reading
7. If it is different, and the 703 has passed the leak check, adjust the flow sensor by toggling the values on the front panel to match the flow meter average and press ENTER
8. PRESS EXIT>EXIT to get back to the DAIG menu

O3 flow

1. Using the hand held Bios Definers in volumetric mode, measure the flow of the O3 output

2. Cap the 1/8th in. internal vent, and the two analyzer vent ports
3. Connect the flow meter to the open analyzer out port and the other end of the tube to the bottom port of the flow meter (pressure)
4. From the front panel press: SETUP>MORE>DIAG and toggle to the FLWO CALIBRATION and press ENTER
5. The photo flow pump will turn on and display a flow, press EXIT to get to the O3 Flow
6. The internal zero air pump will turn on and display a flow reading
7. Take flow measurements with the Bios Definer in burst mode
8. Compare the average flow from the flow meter to the front panel reading
9. If it is different, and the 703 has passed the leak check, adjust the flow sensor by toggling the values on the front panel to match the flow meter average and press ENTER
10. PRESS EXIT repeatedly to get back to the Home menu
11. Remove the internal vent cap, and the two analyzer vent caps

4) Digital to Analog (D/A) Check/Calibration

401 models

D/A check

1. Connect the DVM to the REC (+) (-) connector on the back of the instrument which runs to the data logger
2. Press: SETUP>DIAG>ENTER
3. This will cycle through the full D/A output by 20% increments
4. To hold the output press the button below the percentage indicator
5. Compare the output of the DVM and the data logger and the 401 front panel
6. If the readings are significantly different a D/A calibration must be done

D/A Calibration

1. With the DVM still connected from the D/A check, press: SETUP>MISC>D/A
2. Ensure that the range is correct by pressing RNGE
3. Make sure that there are no offsets by pressing OFFS
4. To calibrate press CAL
5. The first point will be 10.0 MV, adjust the voltage by pressing either UP or DOWN buttons until the DVM or data logger reads as close to 10.0 MV as possible
6. Press ENTR
7. Next calibrate the 1080.0 MV point by adjusting the voltage by pressing either UP or DOWN until the DVM or data logger reads as close to 1080.0 MV as possible
8. Press ENTR>ENTR>ENTR and a % Calibrating will appear, once it reaches 100% the D/A output has been calibrated

703 models

D/A check

1. Connect the DVM to the Analog out connector on the back of the instrument which runs to the data logger
2. Press: SETUP>MORE>DIAG>ANALOG OUT>ENTER
3. This will cycle through the full D/A output by 20% increments
4. To hold the output press the button below the percentage
5. Compare the output of the DVM and the data logger and the 703 front panel
6. If the readings are significantly different a D/A calibration must be done

D/A Calibration

1. With the DVM still connected from the D/A check, press: SETUP>MORE>DIAG and toggle to ANALOG I/O CONFIGURATION
2. Press SET> until you reach TEST_OUTPUT and press EDIT
3. Continue pressing SET> until you reach the TEST_OUTPUT: AUTO CAL: ON
4. Press EDIT>ON>ENTER, to toggle it off
5. Press SET> until TEST_OUTPUT: CALIBRATED: YES

6. To calibrate press CAL
7. The first point will be 0.0 MV, adjust the voltage by pressing either UP or DOWN buttons until the DVM or data logger reads the as close to 0.0 MV as possible
8. Press ENTR
9. Next calibrate the 900.0 MV point by adjusting the voltage by pressing either UP or DOWN until the DVM or data logger reads as close to 900.0 MV as possible
10. Press ENTR>ENTR>ENTR and a % Calibrating will appear, once it reaches 100% the D/A output has been calibrated
11. Press <SET to get back to TEST_OUTPUT: AUTO CAL: ON
12. Press EDIT>OFF>ENTER, to toggle it on
13. Continue pressing EXIT to get back to the home menu

5) Photometer cell visual inspection

401 and 703 models

Visual Cell Inspection

1. Turn the O3 calibrator power off
2. Remove the cover
3. Locate the photometer bench on the left side of the instrument
4. Remove the pressure regulator (on 401)
5. Remove the photometer top cover
6. Inspect the cell for dirt/debris/moisture
7. If nothing visible is found replace the photometer cover and regulator, otherwise clean the photometer bench

Photometer Bench Cleaning

Bench Removal and disassembly

1. With the O3 calibrator power off, remove the pressure regulator (on 401) and place aside
2. Remove the photometer cover and unbolt the photometer bench from the chassis
3. Unplug the temperature sensors, heater, UV lamp, and detector
4. Disconnect the input and output tubes from the photometer bench
5. Gently remove the photometer from the instrument
6. Place the photometer on a clean paper towel on the work bench
7. Remove the hold down screws from both sides of the bench that hold the cell in place
8. Remove the screws that hold the detector housing to the bench, be sure to hold the housing so that it does not break the photometer cell
9. Gently remove the detector housing from the photometer cell end
10. Gently remove the cell from the analysis lamp housing and place on the paper towel
11. Remove the screws on the bottom of the analyzer lamp housing and place the housing on the paper towel

Cell cleaning

1. Inspect the inside of the cell for dirt/debris and clean out either by blowing out with compressed zero air, or running DI water down the inside
2. Make sure the cell is completely dry before reassembly
3. Replace the cell o-rings as needed

Detector window cleaning

1. Remove the detector from the detector housing and inspect the window
2. Clean the detector window as necessary, with DI water and dry with a soft cloth (lint free)
3. Replace the detector window o-ring if deteriorated or worn
4. Reassemble the detector housing

Analysis lamp window cleaning

1. Remove the UV lamp from the analysis lamp housing, but first mark the lamp's orientation to the housing for easier peaking of the UV lamp
2. Blow off any potting material on the UV lamp (white dust) and place the UV lamp on the paper towel
3. Disassemble the analysis lamp housing by removing the four long screws, which will separate the two blocks
4. Clean the analysis lamp window of any dirt/debris with DI water and dry with a soft cloth
5. Blow out the UV lamp housing of any dirt/debris
6. Reassemble the analysis lamp housing and replace any damaged or worn o-rings

Photometer bench reassembly and install

1. Connect the analysis lamp housing to the bench
2. Insert the cell into the analysis lamp housing
3. Carefully bring the detector housing to the cell and insert the cell
4. Hold the detector housing and attach to the bench
5. Push the cell all the way till it stops against the detector housing and tighten the holder
6. Tighten the cell holder on the analysis lamp housing
7. Reinstall the photometer bench into the instrument, hook up all wires/tubes, and replace cover and pressure regulator

Post Photometer cleaning tasks

1. Turn the O₃ calibrator power on and let it settle for several hours
2. Once the UV lamp has settled it may need to be re-peaked by adjusting the UV lamp orientation and inspecting the O₃ REF measurement
3. Perform a Dark Cal
4. Compare the 401/703 level 3 standard output with the level 2 standards and calibrate as necessary

6) DFU inspection

DFU 401 and 703 models

1. Disposable Filter Unit (DFU) is spent when enough particulates have collected on the paper element turning it a grayish/black color
2. Inspect the color of the DFU and replace as necessary

7) Test Function check

- a. On 703 ensure that test function "O₃ DRV" is set to zero during standby mode.
- b. If not, set to zero via SETUP>MORE>VARS>...>"O₃ DRV">EDIT

8) Fix issues before running Certification.

11.4. Procedure For Certification Of Field Level 3 Standards

11.4.1. Certification/Verification Process

The following procedure is from EPA's Transfer Standard for Calibration of Air Monitoring Analyzers for Ozone.

A certified level 3 transfer standard must be recertified at least twice per calendar year to maintain continuous certification. A level 3 transfer standard that loses its certification may cause the loss of ambient O₃ measurements made with ambient monitors that were calibrated with the level 3 transfer standard. Consequently, more frequent recertification schedule will reduce the magnitude and risk of any such loss. More frequent recertification may also provide better accuracy; particularly for level 3 transfer standards that

show slow but steady change over long periods of time. The QA Unit typically recertifies level 3 transfer standards used for audits once per calendar quarter.

Certification requires the averaging of 6 comparisons between the level 3 transfer standard and a level 2 standard. Each comparison typically covers between 6 and 10 ozone levels, including at least one zero level, with 10 readings taken at each point. Each of the 6 comparisons is to be carried out on different days. Individual comparisons are to be entered into the Ozone Cert database, which is located on the APCD's internal network at J:\QA Audit Programs\Ozone Recertifications\Ozone Cert.mdb. Within the Ozone Cert database there are two types of certification forms; 7-point certification forms (Figure 11-1, 11-2), and 10-point certification forms (Figure 11-3, 11-4). The only difference between these forms is the number of ozone concentration levels evaluated. The equations used to determine compliance with criteria are the same between the two types of forms. The GMM unit typically uses the 7-point certification forms for stationary field transfer standards. The QA unit typically use the 10-point certification forms for the audit transfer standards.

Each comparison must consist of at least 6 or more individual comparison points, including 0 and (90 ± 5) % of the upper range limit of the level 3 transfer standard. The other points must be approximately evenly spaced between these points. For each comparison, the slope and intercept is computed by a least squares linear regression. Most assay-type transfer standards will be linear and the linear regression can be calculated directly. However, for non-linear transfer standards or generation type transfer standard where the output is related to a control setting or an adjustable parameter, a preliminary calibration relationship must be created. This preliminary calibration should also include any necessary correction formulas for defined variables. A smooth curve fitting the points should be calculated. There are no specific requirements on the form, number of points, linearity, or frequency of repetition for the preliminary calibration. However, excessive inaccuracy in this relationship will show up as variability in the certification comparison and may cause failure of the certification specifications. During the certification comparison, the preliminary calibration relationship is used to obtain the indicated O_3 concentration used in the linear regression calculations. The evaluation of the six individual comparisons is to be entered into one of the certification forms within the Ozone Cert database (Figure 11-2 & 11-4). The 6x certification forms are used to evaluate the 6 individual comparisons.

When 6 comparisons have been complete, compute the average slope (m) from the 6 individual slopes (m_i), and the average intercept (I) from the 6 individual intercepts, (I_i).

$$\text{i. } m = \frac{1}{6} \sum_{i=1}^6 m_i$$

$$\text{ii. } I = \frac{1}{6} \sum_{i=1}^6 I_i$$

Compute the relative standard deviation (s_m) of the 6 slopes (m_i) and the quantity S_I defined for the 6 intercepts (I_i)

$$\text{iii. } s_m = \frac{100}{m} \sqrt{\frac{1}{5} \left[\sum_{i=1}^6 (m_i)^2 - \frac{1}{6} \left(\sum_{i=1}^6 m_i \right)^2 \right]}$$

$$\text{iv. } s_I = \frac{100}{m} \sqrt{\frac{1}{5} \left[\sum_{i=1}^6 (I_i)^2 - \frac{1}{6} \left(\sum_{i=1}^6 I_i \right)^2 \right]}$$

Compare s_m to the 3.7% specification, and compare S_I to the 1.5 ppb specification. If either of these specifications is exceeded, it indicates that the level 3 transfer standard has too much variability, and corrective action must be taken to reduce the variability before the level 3 transfer standard may be certified.

If the specifications are met, the certification relationship for the transfer standard consists of the average slope (m) and the average intercept (I). Note that the qualification restriction must also be included with the certification relationship and should be shown on a plot of the certification relationship. When the level 3 transfer standard is subsequently used, the standard O_3 concentration is calculated.

$$v. \quad \text{Std. } O_3 \text{ conc.} = \frac{1}{m} (\text{Indicated } O_3 \text{ conc.} - I)$$

- 1) The first step in the recertification procedure is to carry out a comparison to an O_3 level 2 transfer standard. Figure 11-2 & 11-4 shows the 7-point and 10-point certification forms from the Ozone Cert database.
- 2) To maintain certification, the linear regression slope of the new comparison (m^*) must be within $\pm 5\%$ of the average slope of the current certification relationship (m) (i.e., the average slope of the last 6 comparisons). Thus, m^* must be within the interval $0.95m < m^* < 1.05m$.
- 3) If the new slope is within the $\pm 5\%$ specification, then a new average slope (m) and new average intercept (I) are calculated using the new comparison and the 5 most recent previous comparisons. Thus (m) and (I) are running or moving averages always based on the 6 most recent comparisons.
- 4) New values for the relative standard deviation of the slopes (s_m) and the quantity (S_I) are calculated based on the new comparison and the 5 most recent previous comparisons. This can be accomplished through the Ozone Cert database certification forms (Figure 11-2, 11-4)
- 5) The new s_m and s_I must again meet the respective 3.7% and 1.5 ppb specifications. If all specifications are met, then a new certification relationship (based on the updated (m) and (I)) is established.

If the certified level 3 transfer standard fails to meet one of the recertification specifications, it loses its certification. Recertification then requires 6 new sets of comparisons according to the entire certification procedure (Section 11.4.2 or 11.4.3). This failure could be due to malfunction, which obviously should be corrected before repeating the certification procedure.

11.4.2. Procedure to set up the 401 level 3 standard for certification

- 1) Turn the O_3 level 2 standards and 401 calibrator power on and let warm up for at least half an hour
- 2) Check the Silica for the lab zero air pack
 - a. It is below the level 2 standards, inside the zero air pack, in a clear canister
 - b. If no longer blue, change out with new silica
- 3) Hook up the connections for the 401
 - a. Remove the cap on the top of the charcoal canister
 - b. Place the cap on the dry air in port
 - c. Attach the female quick connect to the charcoal canister that you removed the cap from
 - d. Insert the zero air male quick connect line (orange tubing) to the female connection on the charcoal canister
 - e. Configure the input zero air from the 401's internal air pump to a common external pump that supplies zero air to both the level 2 lab standard and the 401. Turn the 401 pump switch to the "lab" or "off" position. (This turns off the internal zero air pump, so that both the 401 and the level 2 standards are using the same zero air pack)

- f. Connect the data logger analog communication wire
- g. Connect the ZSP contact closure wire
- h. Connect the serial cable with the null modem attached
- i. Connect the output line to the output port of the small valve on the back of the 401 level 3 standard.

Certification run procedure

- 1) Start the zero air pack pump
 - a. The power strip switch is behind the laptop hanging from the rack
 - b. Let the pump pressurize the zero air pack (~25psi)
- 2) On the 401 change the event to AZ5S from the front panel:
 - a. Press SETUP>EVENT>ASEQ>AZ5S
- 3) Turn the pumps on for the level 2 O3 standards
 - a. (Thermo 49C & Thermo 49C-PS) Move the silver pump switch on the front of the analyzer to the up position
 - b. (Thermo 49i PS) Press the main menu button and select the Instrument Controls sub-menu. Select PUMP and press enter to toggle the pump off.
- 4) Press ZERO on the 401 front panel
 - a. Ensure that there is excess flow at the sampling manifold. Here excess is defined where the flow rate into the sampling manifold is greater than the total flow required by the level 2 transfer standards. Typically 10 to 30 ccm of excess flow. If not then adjust regulator on 401.
 - b. Let the ZERO run for at least 15 minutes and take readings or collect Ozone concentration values with a data logger
- 5) Depending upon the programming in the calibrator, attainment of the ozone levels can be achieved manually or automatically by running a sequence programmed in the 401 calibrator.
 - a. Automatically – All stationary field transfer standards are programmed with verification sequences. To initiate this sequence press ASEQ on the 401 front panel
 - i. Enter the O3 set point of 240 ppb
 - ii. This will automatically run the O3 concentration points 48, 96, 144, 192, and 240 ppb, respectively
 - b. Manually – Press O3GEN on 401 model and key in the desired Ozone concentration level and press ENTER. Let the calibrator stabilize and take readings.
- 6) Once the ASEQ is complete run another ZERO from the front panel for at least 15 minutes

Collect data logger data procedure

- 1) On the ENVIDAS desktop open the ENVIDAS Ultimate Reporter
 - a. Click “Ok” to login as default
 - b. Click on the Tools tab
 - c. Click Export to open the Export options
 - d. Select the 401, T48iPS, and T49cPS O3 channels
 - e. Under Duration section select “period”
 - i. Enter the date and times of the recertification
 - f. Set the Timebase to 1 minute
 - g. Change the file name and change the file path to where the files will be written to
 - h. Press Ok, a window will pop up indicating the status of the export.
 - i. When finished do the above but for a Timebase of 5 minutes and use a different filename.

Collect Diagnostic parameters in operational mode

- 1) Once the recertification run is finished, set up the 401 for field use and collect the diagnostic parameters for the 7 point form (Figure 11-7) during a span point. This will give site operators a reference for operational diagnostic values while in the field.
 - a. Turn the level 2 standards pumps off
 - b. Remove the ZERO air tube from the charcoal canister and replace the cap from the dry air in port
 - c. Connect a canister of desiccant to the dry air in port

- d. Move the 401 pump switch to “Field” or “On” position
- e. Generate a span point on the 401
- f. Turn the level 2 standards pumps on
- g. During the span, record the diagnostic parameters
 - i. Level 2 standards: Press Menu and scroll to Diagnostics and press enter. For each field in the 7 point form, record the values (Figure 11-7)
 - ii. Level 3 standard (401), record the test functions on the 7 point form (Figure 11-7). Remotely connect to the 401 via HyperTerminal and collect the variables and test functions
 - a. Type in the HyperTerminal window
 - i. V list
 - ii. T list
 - iii. V list!
 - iv. T list all
 - v. D print
 - b. Copy or save all the data from HyperTerminal

Charcoal Check (optional)

The purpose of this test is to determine if the charcoal in the 401 canister is still usable, if less than 6 months old. The charcoal is to be replaced every recertification cycle (6 months) at minimum.

- 1) Generate and record the zero from the level 2 and 3 standards once the 401 is stable
- 2) Generate and record the span from the level 2 and 3 standards once the 401 is stable
- 3) Check that the offset from zero and span on the level 2 standard is within 2 ppb, if not change the charcoal.

ZSP sequence trigger check (optional)

The purpose of this test is to check the integrity of the data logger to initiate zero/span/precision sequences through the contact closures. This test is optional, but good practice and must be performed if the sequence triggering was suspected as an issue in the field prior to certification.

- 1) From the Data logger run the O3ZSP calibration
 - a. From the Home menu type: C C S and select the O3ZSP and press enter
 - b. This should trigger the Zero/Span/Precision Sequences in the 401
- 2) Verify that each sequence is triggered correctly.

Shut down procedure

- 1) Once the cert run is complete
 - a. Turn the zero air pack pump off
 - b. Turn the O3 level 2 standards pumps off (silver switch in the down position)
 - c. Turn the O3 level 2 standards OFF
- 2) On the 401 ensure the event is set to AZ2S and the set point is 240 ppb
- 3) Enter the 5m average data into the J:\QA Audit Programs\Ozone Recertifications\Ozone Cert.mdb
- 4) Evaluate whether the level 3 standard passed the certification run from the 7 point 6x6 certification form or the 10 point 6x6 certification form
- 5) Repeat the certification procedure for a total of 6 times, one per day.

11.4.3. Procedure to set up the 703 level 3 standard for certification

- 1) Turn the O3 level 2 standards and 703 calibrator power on and let warm up for at least half an hour
- 2) Check the Silica for the lab zero air pack
 - a. It is below the level 2 standards in the zero air pack in a clear canister
 - b. If no longer blue change out with new silica
- 3) Hook up the connections for the 703
 - a. Remove the cap on the zero air in port on the back of the 703

- b. Remove the charcoal canister tube and place the cap on the dry air in port
- c. Attach the female quick connect to zero air in port
- d. Insert the zero air male quick connect line (orange tubing) to the female connection on the zero air in port
- e. Connect the data logger wire
- f. Connect the ZSP contact closure wire
- g. Connect the serial cable
- h. Connect the output line to the cal gas out port of the 703
- i. From the front panel turn the internal zero air pump off
 - i. Press: SETUP>MORE>VARS and scroll to ZA_PUMP_ENAB
 - ii. Press EDIT>OFF>ENTER
 - iii. Exit out to the main menu

Certification run procedure

- 1) Start the zero air pack pump
 - a. The power strip switch is behind the laptop hanging from the rack
 - b. Let the pump pressurize the zero air pack (~25psi)
- 2) Turn the pumps on the level 2 O₃ standards
 - a. (Thermo 49C & Thermo 49C-PS) Move the silver pump switch on the front of the analyzer to the up position
 - b. (Thermo 49i PS) Press the main menu button and select the Instrument Controls sub-menu. Select PUMP and press enter to toggle the pump off.
- 3) Depending upon the programming in the calibrator, attainment of the ozone levels can be achieved manually or automatically by running a sequence programmed in the 703 calibrator.
 - a. Automatically – All stationary field transfer standards are programmed with verification sequences. To initiate this sequence press SEQ on the 703 front panel and select O₃_CERT and press ENTER
 - b. Manually – Press GEN on the 703 model and key in the desired Ozone concentration level. Let the calibrator stabilize and take readings.
- 4) Ensure excess flow at sampling manifold immediately after starting first point. Typically 10 to 30 ccm of excess flow. If not, adjust output regulator on 703.

Collect data logger data procedure

- 3) On the ENVIDAS desktop open the ENVIDAS Ultimate Reporter
 - a. Click “Ok” to login as default
 - b. Click on the Tools tab
 - c. Click Export to open the Export options
 - d. Select the 401, T48iPS, and T49cPS O₃ channels
 - e. Under Duration section select “period”
 - i. Enter the date and times of the recertification
 - f. Set the Timebase to 1 minute
 - g. Change the file name and change the file path to where the files will be written to
 - h. Press Ok, a window will pop up indicating the status of the export.
 - i. When finished do the above but for a Timebase of 5 minutes and use a different filename.
 - j.

Collect Diagnostic parameters in operational mode

- 2) Once the certification run is finished, set up the 703 for field use and collect the diagnostic parameters for the 7 point form (Figure 11-7) during a span point. This will give site operators a reference for operational diagnostic values while in the field.
 - a. Turn the level 2 standards pumps off
 - b. Remove the ZERO air tube from the charcoal canister and replace the cap from the dry air in port
 - c. Connect a canister of desiccant to the dry air in port

- d. Turn on the zero air pump, SETUP>MORE>VARS>NEXT, until ZA_PUMP_ENAB then hit ENTER>EDIT>OFF>ENTER and then EXIT to the home menu.
- e. Generate a span point on the 703
- f. Turn the level 2 standards pumps on
- g. During the span, record the diagnostic parameters
 - i. Level 2 standards: Press, Menu and scroll to Diagnostics and press enter. For each field in the 7 point, form record the values (Figure 11-7)
 - ii. Level 3 standard (703), record the test functions on the 7 point form (Figure 11-7). Remotely connect to the 703 via HyperTerminal and collect the variables and test functions
 - a. Type in the HyperTerminal window
 - i. V list
 - ii. T list
 - iii. V list!
 - iv. T list all
 - v. D print
 - b. Copy or save all the data from HyperTerminal

Charcoal Check (optional)

The purpose of this test is to determine if the charcoal in the 703 canister is still usable if less than 6 months old. The charcoal is to be replaced every recertification cycle (6 months) at a minimum.

- 1) Generate and record the zero from the level 2 and 3 standards once the 703 is stable
- 2) Generate and record the span from the level 2 and 3 standards once the 703 is stable
- 3) Check that the offset from zero and span on the level 2 standard is within 2 ppb, if not change the charcoal.

ZSP sequence trigger check (optional)

The purpose of this test is to check the integrity of the data logger to initiate zero/span/precision sequences through the contact closures. This test is optional, but good practice and must be performed if the sequence triggering was suspected as an issue in the field prior to certification.

- 1) From the Data logger run the O3ZSP calibration
 - a. From the Home menu type: C C S and select the O3ZSP and press enter
 - b. This should trigger the Zero/Span/Precision Sequences in the 703
- 2) Verify that each sequence is triggered correctly.

Shut down procedure

- 1) Once the cert run is complete
 - a. Turn the zero air pack pump off
 - b. Turn the O3 level 2 standards pumps off (silver switch in the down position)
 - c. Turn the O3 level 2 standards OFF
- 2) On the 703 ensure the ZA_PUMP_ENAB variable is set to on. Enter the 5m average data into the J:\QA Audit Programs\Ozone Recertifications\Ozone Cert.mdb
- 3) Evaluate whether the level 3 standard passed the certification run from the 7 point 6x6 certification form or the 10-point 6x6 certification form
- 4) Repeat the certification procedure for a total of 6 times, one per day.

Figure 11-2 7-Point 6x Certification Form (GMM)

Colorado Department of Public Health and Environment								
Air Pollution Control Division - Technical Services Program								
Ozone 7 Point Certification Form								
<u>Analyzer Certified :</u>				<u>Serial No:</u>				
<u>Certification Date:</u>								
<u>Stationary Unit Recert Due On:</u>								
<u>Rover Unit Recert Due On:</u>								
Summary of Averages								
			Slope	Intercept	Corr. Coeff.			
Average :								
Re-Certification PASS/FAIL Criteria						Previous Certification Information		
% STD DEV (+/- 3.7%) =						Capture Cert. Values		
Intercept Quantity (+/- 1.5 ppb) =						Previous Cert. Date : 12/31/1899		
Deviation from Previous Cert. Avg. Slope (+/- 0.05) =						Previous Slope : 1.00000		
						Previous Intercept : 0.00000		
Transfer Std	Transfer SN	Cert Date	Cert Time	Standard	Slope	Intercept	Corr. Coeff	
Start								
Record 1								
Record 2								
Record 3								
Record 4								
Record 5								
Record 6								



Ozone Transfer Standard Certification			
Cert. Date		Serial No: 	
Stationary Unit Recert Due On:		Field Setup Check Out	
Rover Unit Recert Due On:		Empty <input type="checkbox"/> Sample Flow Check: <input type="checkbox"/>	
Empty		Empty <input type="checkbox"/> O3 Gen Flow Check: <input type="checkbox"/>	
Empty	Empty	Empty <input type="checkbox"/> Visual Cell Check: <input type="checkbox"/>	
Empty	Empty	Empty <input type="checkbox"/> Charcoal Renew	
Empty	Empty	Empty <input type="checkbox"/>	
Empty	Empty	Empty <input type="checkbox"/>	
Empty	Empty	Empty <input type="checkbox"/>	
Empty	Empty	Empty <input type="checkbox"/>	
Empty	Empty	Empty <input type="checkbox"/>	
Empty	Empty	360 ppb (+/- 10%) = 325 - 396 (ppb)	
Empty	Empty	90 ppb (+/- 10%) = 81 - 99 (ppb)	

Figure 11-3 10-Point Recertification Form (QA)

Colorado Department of Public Health and Environment													
Air Pollution Control Division - Technical Services Program													
Ozone Certification Data													
		Date: <input style="width: 100px;" type="text"/>			Initials: <input style="width: 100px;" type="text"/>								
Transfer Standard:					Lab Standard:						Lab Std. SRP Cert Date: <input style="width: 100px;" type="text"/>		
Transfer Std. SN:					Lab Std. SN:						SRP (Slope): <input style="width: 100px;" type="text"/>		
Transfer Std. Slope:					Lab Std. Slope:						SRP (Intercept): <input style="width: 100px;" type="text"/>		
Transfer Std. Int. (ppb):					Lab Std. Int. (ppb):								
	Pt.	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	Avg	Zero Correct
Zero	Lab Std.												
	Lab Std. Corr												
	Transfer												
.450 ppm	Lab Std.												
	Lab Std. Corr												
	Transfer												
.400 ppm	Lab Std.												
	Lab Std. Corr												
	Transfer												
.350 ppm	Lab Std.												
	Lab Std. Corr												
	Transfer												
.300 ppm	Lab Std.												
	Lab Std. Corr												
	Transfer												
.250 ppm	Lab Std.												
	Lab Std. Corr												
	Transfer												
.200 ppm	Lab Std.												
	Lab Std. Corr												
	Transfer												
.150 ppm	Lab Std.												
	Lab Std. Corr												
	Transfer												
.100 ppm	Lab Std.												
	Lab Std. Corr												
	Transfer												
.050 ppm	Lab Std.												
	Lab Std. Corr												
	Transfer												
											Slope :	<input style="width: 100px;" type="text"/>	
											Intercept :	<input style="width: 100px;" type="text"/>	
											Corr. Coeff. :	<input style="width: 100px;" type="text"/>	
<p>The above slope and intercept are derived from a regression of the average of Lab Std. (X) readings and the average of the Transfer (Y) readings. They do not include any zero</p>													

Figure 11-4 10-Point 6x Certification Form (QA)

Colorado Department of Public Health and Environment Air Pollution Control Division - Technical Services Program Ozone Certification Form								
<u>Analyzer Certified</u> : API 401			<u>Serial No.</u> : 190					
<u>Certification Date:</u>								
<u>Cert. Expiration Date:</u>								
Summary of Averages								
Slope			Intercept			Corr. Coeff.		
Average :								
Re-Certification PASS/FAIL Criteria						Previous Certification Information (Enter Manually)		
% STD DEV (+/- 3.7%) =						FAIL		
Intercept Quantity (+/- 1.5 ppb) =						FAIL		
Deviation from Previous Cert. Avg. Slope (+/- 0.05) =						FAIL		
						Previous Cert. Date : 12/31/1899		
						Previous Slope : 1.00000		
						Previous Intercept : 0.00000		
	<u>Transfer Std</u>	<u>Transfer SN</u>	<u>Lab Std</u>	<u>Lab SN</u>	<u>Date</u>	<u>Slope</u>	<u>Intercept</u>	<u>Corr. Coeff.</u>
<u>Record 1</u>	API 401	190	TECO 49C	389				
<u>Record 2</u>	API 401	190	TECO 49C	389				
<u>Record 3</u>	API 401	190	TECO 49C	389				
<u>Record 4</u>	API 401	190	TECO 49C	389				
<u>Record 5</u>	API 401	190	TECO 49C	389				
<u>Record 6</u>	API 401	190	TECO 49C	389				

Analyzer Label =

Colorado Department of Public Health and Environment Air Pollution Control Division - Technical Services Program Ozone Certification Lable			
<u>Analyzer Certified</u> :		API 401	
<u>Serial No.</u> :		190	
<u>Certification Date:</u>			
<u>Cert. Expiration Date:</u>			
Slope		Intercept	
Average :			
% STD DEV (+/- 3.7%) =		FAIL	
Intercept Quantity (+/- 1.5 ppb) =		FAIL	
Deviation from Previous Cert. Avg. Slope (+/- 0.05) =		FAIL	

12. TEMPERATURE VERIFICATION PROCEDURES

12.1. Hand Held Digital Thermometers

Purpose:

The Visibility, Research and Quality Assurance Unit, the Particulate Monitoring Unit and the GMM Unit use hand-held digital thermometers during calibration and performance audits of APCD air monitoring equipment.

It is an operational goal to perform verifications and calibrations on all hand-held thermometers against the in-house lab standard by the staff responsible for the assigned thermometers least once per quarter. At least once per year the QA staff certifies every hand held thermometer used in the field to take measurements of the air monitoring network. Adjustments will be made if necessary. A high precision Digital Thermometer is used for these certifications and has direct traceability by the manufacturer to a National Institute of Standards and Technology (NIST) standard. The primary lab standard is purchased yearly with a NIST traceable certification. The laboratory standard should perform within the manufactures specifications.

Supplies needed:

- 1) NIST traceable Primary Standard thermometer that has been certified to +/- 0.5°C.
- 2) A burette stand with clamps to hold the Primary Standard Thermometer.
- 3) A beaker or wide mouth Thermos™ bottle between 500 mLs and a Liter.
- 4) Something to stir water with to ensure thermal mixing.
- 6) Fine tipped, waterproof permanent marking pen (e.g., Sharpie®).
- 7) Clear plastic tape to cover and protect the label in the coolers.

Laboratory Standard “Ice-Point” Verification Procedure:

Prior to performing annual verifications on field thermometers an “Ice-Point” verification must be performed on the laboratory standard. In this procedure, the laboratory standard is submerged into an ice bath (0°C). The thermometer must perform within all manufactures specifications at that temperature.

- 1) One container of ice water will be used for the “ice-point” verification. The temperature of the water must be at 0°C. Using an insulated container, fill the container with ice (crushed ice preferably), then fill with purified water.
- 2) Stir the bath and allow for temperature equilibration (5 min).
- 3) Submerge the laboratory standard thermometer probes in the water. The probe should be submerged to the submersion line etched on the thermometer. While continuing to stir, let the thermometers equilibrate for at least 5 minutes. Be sure that the temperature is stable before taking a reading.
- 4) Take a total of three readings at 3-minute intervals. Average these reading and compare them to the nominal value of the ice bath (0°C). The laboratory standard must perform within the manufactures accuracy specification prior to performing the annual verifications of field thermometers.

- 5) Record all the data in a spreadsheet or database. The “Verifications” database is the preferred method for documenting all thermometer verifications. The Verifications database can be found within the TSP network at J:\QA Audit Programs\Verifications\Verifications.mdb. Once you have opened the Verifications database click the “Thermometers” button to open the thermometer verification spreadsheet. Spreadsheets from many previous years thermometer verifications can be found at J:\QA Audit Programs\Verifications\Thermometers\Therm YY Recert.xls (see Figure 12-1), where YY is the two digit year of the verification cycle. Or, by clicking the “Go to Archive” button within the verifications database. The use of either of these spreadsheets are not a requisite, however, the use of other spreadsheets and databases must document and evaluate all standards information and criteria.
- 6) Enter 0 (°C) in the Transfer column at Level 1, then enter the average of the three readings from the primary standard in the Primary column at Level 1. The difference between the two readings cannot exceed the accuracy of the laboratory standard.
- 7) If the laboratory standard is within its manufactures specifications, then capture that record into the verifications database.

Field Transfer Standard Verification Procedure:

- 1) A minimum of two containers of water at two different temperatures will be used to verify the thermometers. The lower temperature will be less than 4°C, the higher temperature should be between 20°C and 30°C. Be sure that all field transfer standard thermometers are reading in the same temperature units as the laboratory standard.
- 2) For the lower temperature verification use ice mixed with cold tap water to achieve a temperature below 4°C. Using a burette stand, secure the primary standard thermometer with its probe/bulb submerged in the water. Being careful not to hit or damage the primary standard thermometer, stir the water until the temperature has fallen below 4°C. Stir an additional 2 minutes to be sure that the temperature of the water has stabilized on the NIST thermometer and is thermally well mixed.
- 3) Submerge the field thermometer probes in the water. The probes should be kept close to and at the same depth as the primary standard's lower end. If multiple thermometers are being verified, their probes can be rubber banded together for easier handling. While continuing to stir, let the thermometers equilibrate for at least 5 minutes. When the thermometer's display of the probe's temperature is stable, verify that the temperature reading is stable before taking a reading. Note the readings of the transfer and laboratory standards on a notepad or form.
- 4) For the higher temperature verification, use a beaker or wide mouth Thermos™ bottle and fill it with water at a temperature between 20°C and 30°C. Using a burette stand, secure the primary standard thermometer with its probe/bulb submerged in the water.
- 5) Submerge the field thermometer probes in the water. The probes should be kept close to and at the same depth as the primary standard's lower end. If multiple thermometers are being verified, their probes can be rubber banded together for easier handling. While continuing to stir, let the thermometers equilibrate for at least 5 minutes. When the thermometer's display of the probe's temperature is stable, verify that the temperature reading is stable before taking a reading. Note the readings of the transfer and laboratory standards on a notepad or form.
- 6) Record all the data in a spreadsheet or database. The “Verifications” database is the preferred method for documenting all thermometer verifications. The Verifications database can be found within the TSP network at J:\QA Audit Programs\Verifications\Verifications.mdb. Once you have opened the Verifications database click the “Thermometers” button to open the thermometer verification spreadsheet. Spreadsheets from many previous years thermometer verifications can

be found at by clicking the “Go To Archive” button within the verifications database or by going to J:\\QA Audit Programs\\Verifications\\Thermometers\\Therm YY Recert.xls (see Figure 12-1), where YY is the two digit year of the verification cycle. The use of this spreadsheet is not a requisite, however, the use of other spreadsheets and databases must document and evaluate all standards information and criteria.

- 7) After opening the Thermometers form, within the Verifications database, fill in the appropriate fields with the date, operator, primary standard information and transfer standard information. The operator should be ready to begin the verification.
- 8) Enter into the spreadsheet all the raw performance data for each transfer standard. Performance data from the 4°C verifications are to be entered as Level 1 and subsequent verifications are to be entered as Level 2 and Level 3 (if performed).
- 9) The form calculates the difference between the transfer standard and the laboratory standard. The differences between the two standards cannot exceed the manufactures accuracy specifications. If either of the differences are greater than the accuracy specifications, then the verification procedure should be redone to verify results. If the differences continue to exceed the accuracy specifications, then the transfer standard must be repaired, recalibrated and or discarded.
- 10) After completing all the Thermometer verifications for that year, an annual report can be created, detailing all the specifics for all the Thermometers from that year’s verifications. This can be accomplished after entering all the Thermometer verifications into the database, by clicking the “Go to Archive” button, then clicking the “Annual Report” button within the verifications database. These reports are then printed and filed by year in the filing cabinet within the Rootsmeter room.

Figure 12-1 Annual Thermometer Verification Form

		COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT			
Air Pollution Control Division - Technical Services Program					
Thermometer Verification Form					
Verification Date (mm/dd/yy)		1/3/2011		Initials: CWS	
Transfer Std. Info.	Transfer Standard				
	Thermometer SN:	120209001			
	Probe SN:	na			
	Make:	VWR			
	Model:	100A			
	Range:	-40 to 150 C			
	Resolution:	0.1 (C / F)			
	Accuracy:	+/- 0.2 C			
	Owner:	qa			
	Date of Previous Verification:	1/27/2010			
Date of Next Verification:	1/3/2012				
Primary Std. Info.	Primary Standard(638168)				
	Thermometer SN:	638168			
	Probe SN:	na			
	Make:	VWR			
	Model:	61099-036			
	Range:	-8 to 32 C			
	Resolution:	0.1 C			
	Accuracy:	+/- 0.1 C			
	Owner:	primary			
	Date of Previous Verification:	1/27/2010			
Date of Next Verification:	1/26/2013				
Comparison Data					Comments:
	Transfer Std.	Primary Std.	Difference	% Difference	
Level 1	0	0.1	-0.10	-1.00	
Level 2	12.5	12.6	-0.10	-0.01	
Level 3	23.1	23.1	0.00	0.00	
Level 4	31.3	31.2	0.10	0.00	

13. Time Verification Procedures

13.1. Watches and Cell Phones

The Quality Assurance Unit, Particulate Monitoring and the Continuous Monitoring, Data System Support Unit use both digital watches and cell phones during calibration and performance audits of APCD air monitoring equipment. Annual verifications of time on all watches is required and must be within ± 30 seconds of the time standard. Additionally, it is an operational goal to perform quarterly verifications on all watches with cell phones. Because the APCD does not maintain a laboratory grade time standard, external sources of time must be used. Accurate time can be found from the atomic clock in Boulder, Colorado by calling 303 499-7111 or via the Internet at <http://www.time.gov>

14. Voltage Verification Procedures

14.1. Digital Volt Meters

All field personnel of the Quality Assurance Unit and the GMM Unit use voltmeters in their operations. These voltmeters must periodically be calibrated and certified against an in-house voltage lab standard. The Technical Services Program voltage laboratory standard is an Extech CMM 17voltage source manufactured by Martel Electronics. It is never moved outside of the lab except when it is sent back every other year to the manufacturer or local electronics lab for calibration and recertification. The manufacturer

calibrates the Extech CMM 17 against their own voltage laboratory standard with traceability to NIST standards and to the tolerances of the military specification MIL-STN-45662A.

Calibration of Voltmeters

Each voltmeter, which is used in the field, is given at least once per year to a designated member of the Quality Assurance unit, who verifies it against the lab standard.

For a verification, the calibrator records the calibrated voltmeter's readings from a test point in the 200 to 400 mV range settings, two test points in the 2 to 4V range settings, and one test point in the 20 or 40 V range settings. The voltmeter's readings are recorded on the voltmeter's certification form and a calibration due sticker is put on the voltmeter (see Figure 14-1).

Figure 14-1 Voltmeter Calibration Due Sticker

Calibration Check	
Cal Date: _____	
Initials: _____	
Remarks:	

A separate dedicated voltmeter is used only to set and adjust all the data collection nodes voltage boards that log the data from the analyzer. This is to provide a common reference between the different data loggers and the data they collect.

Typically the calibrator performs a 21 point per range test to fully characterize the voltmeter. These test results are logged on a form shown in Figure 14-2. Print a hardcopy of the verification spreadsheet and file it in the QA filing cabinet by serial number.

