FORSYTH COUNTY OFFICE OF ENVIRONMENTAL ASSISTANCE AND PROTECTION

STANDARD OPERATING PROCEDURE (SOP)

Calibrators

Signature Page

By the signatures below, the Forsyth County Office of Environmental Assistance and Protection (FCEAP) certifies that the information contained in the following Standard Operating Procedure (SOP) is complete and fully implemented as the official guidance for our Office. However, due to circumstances that may arise during the sampling year, some practices may change. If a change occurs, a notification of change and a request for approval will be submitted to EPA Region 4 at that time.

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REVISIONS

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STANDARD OPERATING PROCEDURES FOR CALIBRATORS

Forsyth County Office of Environmental Assistance and Protection

12.1 General Overview

Calibrators are used to generate gas mix concentrations needed to calibrate instruments analyzing ambient air for different gases ($NO/NO_x/NO_2$, SO_2, or O_3) to a known gas concentration. In the Forsyth County Air Quality network (FCAQ) various different Calibrators are used:

At the Hattie Avenue site a Teledyne API 700EU Dynamic Dilution Calibrator is used for $NO/NO_x/NO_2$, SO_2 and O_3 calibrations.

At the Clemmons Middle and Union Cross sites Teledyne API 703E Photometric Ozone Calibrators are used to calibrate O_3 analyzers.

For audit purposes in the FCEAP a Teledyne API T750 Dynamic Dilution Calibrator (SN 123) (travel/audit standard) is used, which is recertified against a Teledyne API 703E Photometric Ozone Calibrator (SN 59) (laboratory bench standard).

For backup purposes a Teledyne API T700U Dynamic Dilution Calibrator and a Teledyne API 703E Photometric Ozone Calibrator are kept at the FCAQ office.

To supply the calibrators with clean air Zero Air Generators are connected to the zero air input of the calibrators. The typical Zero Air Generator configuration is a compressor connected to a drying and filtering system, followed by an activated charcoal and purafil system (see Section 13 Zero Air Generator SOP). The filtered air, now zero air, is used to mix with calibration gas, which is introduced to the analyzer to be calibrated.

In the FCEAP Teledyne API 701H, T701H and 751H Zero Air Generators are used.

12.2 Verification of Level 2 and Level 3 Transfer Standards

12.2.1 Transfer Standards Traceability

In ambient air monitoring applications, precise ozone concentrations called standards are required for the calibration of ozone analyzers. Gaseous ozone standards cannot be stored for any practical length of time due to the reactivity and instability of the gas. Therefore, ozone concentrations must be generated and 'verified' on site. When the monitor to be calibrated is located at a remote monitoring site, it is necessary to use a transfer standard that is traceable to a more authoritative standard. According to the International Standards Organization (ISO)-International Vocabulary of Basic Terms in Meteorology: Traceability is the 'property of a measurement result whereby the result can be related to a stated reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty'.

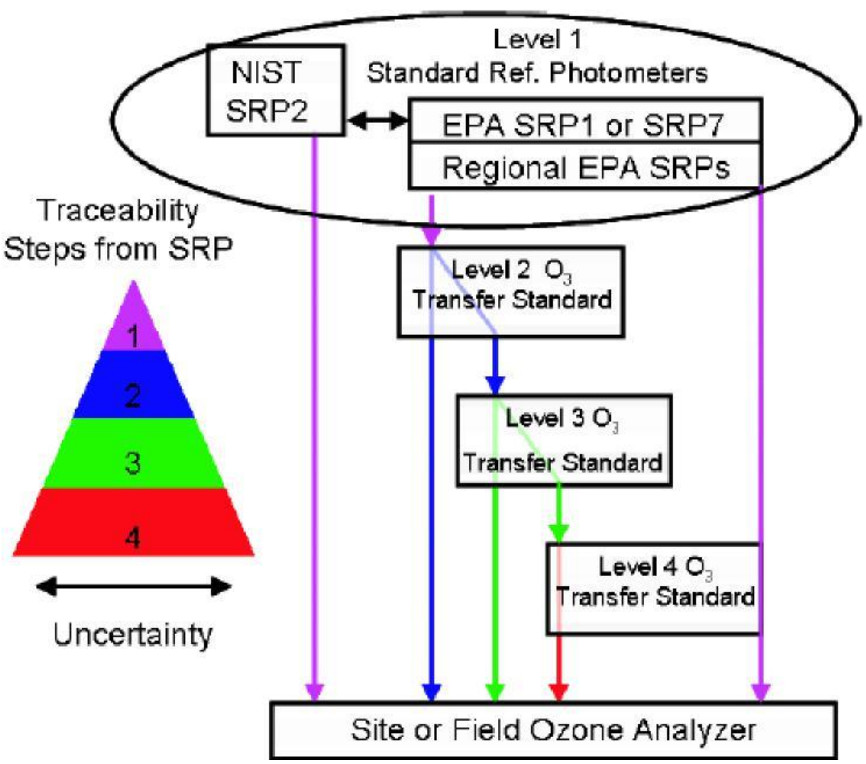

Figure 1. Transfer Standards for Calibration of Air Monitoring Analyzers for Ozone

At least one Level 2 Transfer Standard Photometer has to remain in a stable laboratory environment and is designated as the laboratory primary standard. Currently FCAQ utilizes two level 2 transfer standards. A Teledyne API 703E Photometric Ozone Analyzer (SN 59) (laboratory primary/bench standard) and a

Teledyne API T750 Dynamic Dilution Calibrator (SN 123) (trip/audit standard). **The SN 59 and T750 should be verified annually against a standard reference photometer (EPA Region 4 SRP#10) and all previous verifications (up to 6, if available) are used to calculate the SN 59 and T750 verification equation.** The SN 59 and T750 are verified by USEPA Region 4 annually, in accordance with USEPA Region 4 procedures.

All other photometers (Teledyne API 703E Photometric Ozone Calibrators, Teledyne API 700EU and T700U Dynamic Dilution Calibrators) operated by FCAQ are referenced to the T750 trip/audit standard or directly with the 703E (SN 59) lab/bench standard. Quality assurance checks (audits) of ozone instrumentation are compared to the T750 in the field.

12.2.2 Regulatory Requirements

12.2.2.1 40 CFR Appendix D to Part 50 - Measurement Principle and Calibration Procedure for the Measurement of Ozone in the Atmosphere - This regulation describes the calibration procedure of reference methods for measuring ozone in the atmosphere.

12.2.2.2 U.S. EPA, Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Ambient Air Quality Monitoring Program (EPA-454/B-08-003) - The handbook describes the Ambient Air Quality Surveillance Program and the data collection activities inherent to that program.

12.2.2.3 U.S. EPA, Transfer Standards, For the Calibration of Ambient Air Monitoring Analyzers for Ozone, Technical Assistance Document (EPA-454/B-10-001) - This guidance defines, specifies, and formalizes the verification of ozone transfer standards for calibrating ambient ozone analyzers.

12.3 Ozone Photometer Performance Verification, Calibration and Recertification

12.3.1 Ozone Photometer Tracking

12.3.1.1 All calibrators capable of Ozone generating are equipped with an Ozone photometer. The accuracy of the photometer is critical to ensure accurate calibration gas mixtures where O_3 is involved. Therefore, regular photometer verifications should be performed.

12.3.1.2 If the photometer verification shows more than 4% difference, calibration against an EPA certified photometer should be performed. See section 12.3.3 Ozone Photometer Calibrations.

12.3.1.3 Two Ozone Calibrators used by the FCAQ (Teledyne API 703E (SN 59) and Teledyne API T750 (SN 123)) are verified, if needed calibrated, and recertified yearly against the EPA Region 4 SRP #10 Level 1 Standard Reference Photometer. See section 12.4 Verification of Level 2 and Level 3 Transfer Standards.

12.3.2 Ozone Photometer Verifications

12.3.2.1 Teledyne API 700EU Ozone Photometer Verification

Refer to Teledyne 700EU Dynamic Dilution Calibrator Manual, Rev. B4 July 2009, Chapter 8.3.1 and Chapter 8.3.2

12.3.2.1.1 Connect the 700EU CAL 1 port to a recently calibrated and accurate O3 Analyzer sample inlet port (i.e. API Model 400E).

Alternatively you can connect the 700EU CAL 1 port to the PHOTO IN port of an level 2 transfer standard (i.e. 703E SN 59) which is generating 0 ppb ozone at 3 lpm. This is the same set up as for the ozone photometer calibration. See section 12.3.3.

12.3.2.1.2 Generate a 225 ppb (span) air concentration with the 700EU Calibrator and allow the 400E Analyzer to sample the test atmosphere for at least 30 minutes. Record the verification point in the 700U 703E O3 Calibrator In-Lab checks.xls (Fig. 2) file.

O3 Calibrator check

In lab checks only (these checks does **NOT** replace z/s/p checks, calibrations or audits!)
These checks are only to verify that the instrument is approximately reading what it is supposed to read.
Use after maintenance and repairs or to test a new instrument when receiving.

Date 3/8/2016 **Initials** RA

Reason for check

Maintenance

	Instrument	SN
Generating	700EU	616-S
Reading	703E	59
Gas Cylinder		

	zero	span	mid	prec	low
generate	0	225	150	70	40
read	0	226	151	71	41
stability					
ppb diff	0.00	1.00	1.00	1.00	1.00
% diff	na	0.44	0.66	1.41	2.44
		OK	OK	OK	OK

Observations

Figure 2: In-Lab checks worksheet

12.3.2.1.3 Repeat the data recording procedure used above generating different O_3 concentrations (i.e. 0 ppb, 150 ppb, 70 ppb, 40 ppb) and record the appropriate data.

12.3.2.1.4 A successful O3 photometer verification is achieved if all recorded concentrations are within

4% of the generated concentrations.

12.3.2.2 Teledyne API T700U Ozone Photometer Verification

Photometer verification of the T700U O3 Photometer is the same as the 700EU procedure. See section 12.3.2.1.1.

12.3.2.3 Teledyne API T750 Ozone Photometer Verification

Photometer verification of the T750 O3 Photometer is the same as the 700EU procedure. See section 12.3.2.1.1.

Note: Verification of the T750 (SN 123 trip/audit standard) O3 Photometer is performed annually against EPA Region 4 SRP #10 Level 1 Standard Reference Photometer.

12.3.2.4 Teledyne API 703E Ozone Photometer Verification

Photometer verification of the 703 O3 Photometer is the same as the 700EU procedure. See section 12.3.2.1.1.

Note: Verification of the 703E (SN 59 laboratory primary/bench standard) O3 Photometer is performed annually against EPA Region 4 SRP #10 Level 1 Standard Reference Photometer.

12.3.3 Ozone Photometer Calibrations

An ozone photometer has to be calibrated after the photometer bench was disassembled for maintenance or repairs and if verification of the ozone photometer shows a difference of more than 4% from the level 2 transfer standard. See section 12.6 for maintenance of the photometer bench.

Two Ozone Calibrators used by the FCEAP (Teledyne API 703E (SN 59) and Teledyne API T750 (SN 123)) are verified, if needed calibrated, and recertified yearly against the EPA Region 4 SRP #10 Level 1 Standard Reference Photometer.

12.3.3.1 Teledyne API 700EU Ozone Photometer Calibration

Refer to Teledyne API 700EU Dynamic Dilution Calibrator Manual, Rev. B4 July 2009, Chapter 8.3.3

12.3.3.1.1 Connect a zero air system (i.e. T701H) to the level 2 transfer standard (i.e. 703E SN 59 or T750 SN 123). The level 2 transfer standard should be supplied with >25 psig at >6-8 lpm flow. Connect the same zero air system to the 700EU Calibrator (level 3 transfer standard). The level 2 transfer standard and the level 3 transfer standard should utilize a common zero air source.

Verify that the internal regulators of the level 2 transfer standard and the 700EU Calibrator internal regulators are displaying approximately 10 psig. Verify that there is excess flow at the manifold vent port at the rear of both the level 2 transfer standard and the 700EU Calibrator by feeling for positive pressure coming out of the vent with your finger.

12.3.3.1.2 Connect the CAL OUT port of the level 2 transfer standard directly to the PHOTOMETER IN port of the 700EU Calibrator with a length of clean 1/4" OD Teflon tubing. **Verify that the level 2 transfer standard vent is open. Make sure the 700EU Calibrator vent is capped.**

12.3.3.1.3 Set the 700EU Calibrator to generate a 0 ppb O_3 concentration at 3 lpm. In the main menu press GEN, AUTO, adjust to 0 O_3, press ENTER, adjust to 3 lpm, press ENTER. Generate a zero air concentration with the level 2 transfer standard and allow the 700EU Calibrator to sample the test atmosphere for at least 30 minutes.

12.3.3.1.4 Record the test variables information from the 700EU Calibrator into the logbook. Also log the ozone reading from the photometer from the level 2 transfer standard and the level 3 calibrator to compare results.

12.3.3.1.5 Generate a 225 ppb O_3 (span) air concentration with the level 2 transfer standard calibrator and allow the 700EU Calibrator to sample the test atmosphere for at least 30 minutes.

12.3.3.1.6 Repeat the data recording procedure used above in section 12.3.3.1.4 and record the appropriate data.

12.3.3.1.7 Repeat step 12.3.3.1.3 generating zero air. When the 700EU has reached a stable zero reading, follow the instructions in the Teledyne API 700EU Dynamic Dilution Calibrator Manual, Rev. B4 July 2009, Chapter 8.3.4.1, to calibrate the zero point on the 700EU Calibrator. Once you see a stable O_3 reading with less than 1 ppb change in 5 minutes on the 700EU, press the CAL button and choose ZERO, press Enter. Return to the main screen (press Exit). The 700EU should now read zero, if not, repeat the adjustment steps above and inform the program manager.

It is recommended to wait for a good stability (less than 1 ppb change in 5 minutes) before calibrating the point instead of calibrating the point consecutively until the point becomes stable.

12.3.3.1.8 Repeat step 12.3.2.1.5 generating O_3 span gas. When the 700EU has reached a stable zero reading, follow the instructions in the Teledyne API 700EU Dynamic Dilution Calibrator Manual, Rev. B4 July 2009, Chapter 8.3.4.2, to calibrate the span point on the 700EU Calibrator. Once you see a stable O_3 reading with less than 1 ppb change in 5 minutes on the 700EU, press the CAL button and choose SPAN, press Enter. Return to the main screen (press Exit). The 700EU should now read span, if not, repeat the adjustment steps above or contact the program manager.

It is recommended to wait for a good stability (less than 1 ppb change in 5 minutes) before calibrating the point instead of calibrating the point consecutively until the point becomes stable.

12.3.3.1.9 Press ‘Stby’ on the 700EU Calibrator and level 2 transfer standard to bring both units back in Standby mode. Turn off the zero air generator.

12.3.3.2 Teledyne API T700U Ozone Photometer Calibration

Photometer verification and calibration of the T700U O3 Photometer is the same as the 700EU procedure. See section 12.3.2.1.

12.3.3.3 Teledyne API T750 Ozone Photometer Calibration

Photometer calibration of the T750 O3 Photometer is the same as the 700EU procedure. See section 12.3.3.1.

Note: Verification of the T750 (SN 123, trip/audit standard) O3 Photometer is performed annually against EPA Region 4 SRP #10 Level 1 Standard Reference Photometer. If the Verification shows more than 4% difference, the photometer is out of certification, and a calibration is performed against the EPA Region 4 SRP #10 Level 1 Standard Reference Photometer.

12.3.3.4 Teledyne API 703E Ozone Photometer Calibration

Photometer calibration of the 703E O3 Photometer is the same as the 700EU procedure. See section 12.3.3.1.

Note: Verification of the 703E (SN 59, laboratory primary/bench standard) O3 Photometer is performed annually against EPA Region 4 SRP #10 Level 1 Standard Reference Photometer. If the Verification shows more than 4% difference, the photometer is out of certification, and a calibration is performed against the EPA Region 4 SRP #10 Level 1 Standard Reference Photometer.

12.4 Verification and Calibration of Ozone Generators

Verification and Calibration of an Ozone Generator is an automated process stored in the instruments internal storage. Refer to Teledyne API Calibrator Manual to perform the Ozone Generator calibration.

12.4.1 Teledyne API 700EU Ozone Generator Verification and Calibration

12.4.1.1 Verifying the Teledyne API 700EU Ozone Generator

Connect a zero air system to the 700EU Calibrator which should supply the calibrator with >25 psig at >6-8 lpm flow. Connect the 700EU Calibrator to a level 2 transfer standard (SN 59 or T700U) as a reference photometer.

12.4.1.1.1 With the 700EU calibrator generate a 225 ppb O_3 concentration at 3-4 lpm. Observe the reference photometer. The observed O_3 concentration must be within ± 1%, if not the O_3 Generator has to be calibrated by running the automated process on the calibrator.

12.4.1.2 Calibrating the Teledyne API 700EU Calibrator O_3 Generator

Refer to Teledyne API 700EU Dynamic Dilution Calibrator Manual, Section 8.4.3.

The O_3 Generator of the 700EU Calibrator has to be calibrated after the generator is disassembled for maintenance or repairs and routinely at least once a year. See section 12.4.1 for maintenance of the O_3 Generator.

Record the performed O_3 Generator Calibration in the instrument log book.

12.4.2 Teledyne API T700U Generator Verification and Calibration

Verification and Calibration of a T700U O3 Generator is the same procedure as for a 700EU, see section 12.4.1

12.4.3 Teledyne API T750 Generator Verification and Calibration

Verification and Calibration of a T750 O3 Generator is the same procedure as for a 700EU, see section 12.4.1.

12.4.4 Teledyne API 703E Generator Verification and Calibration

Verification and Calibration of a 703E O3 Generator is the same procedure as for a 700EU, see section 12.4.1.

12.5 Mass Flow Controller Calibration

Applicable for Teledyne API 700EU, T700U and T750 Dynamic Dilution Calibrators

A separate flow measuring device (i.e. BIOS DryCal, Fig. 3 or Alicat flow device) is needed for this calibration procedure. The Diluent (DIL) Mass Flow Controller (MFC) and all Calibration Gas (CAL1 & CAL2) MFC's have to be calibrated electronically every 6 months. A total of 20 flow points have to be adjusted for each MFC. To reduce the amount of time for the MFC calibration, the Forsyth County Air Quality network (FCAQ) measures six flow points on each MFC. Using the resulting slope of the six points, the remaining flow values are calculated and then entered into the instrument (see Fig. 4).

Figure 3: BIOS DryCal flow measuring device.

The instruments MFC flows can be calibrated by either adjusting the Drive Voltage to receive a most accurate actual/desired flow or by input of the observed flow at certain Drive Voltage settings. The manufacturer Teledyne API advises to enter the observed flow corresponding with the pre set Drive Voltage. When the instrument is in use, it will internally adjust the Drive Voltage to meet the desired flow.

12.5.1 Teledyne API 700EU MFC Calibration

12.5.1.2 Start with the DIL1 MFC which regulates flow of 0-10 lpm. Set up the BIOS DryCal (Fig. 3) with the appropriate cell for the flow to be measured.

12.5.1.3 Connect the BIOS DryCal using a straight parallel cable to a PC and connect to it using HyperTerminal. Check for correct date and time settings on the BIOS DryCal unit.

12.5.1.4 Connect the BIOS DryCal cell inlet port directly to the 700EU MFC DIL1 outlet port facing the front side of the unit (flow direction is MFC → BIOS). Make sure the 700EU is connected to a source of zero air producing 30 psig. The Zero Air Supply has to able to produce up to 40 psig needed for higher DIL1 flows.

Repeat the following steps (12.5.1.5 – 12.5.1.9) for the flow points 1, 5, 9, 13, 17 and 20, using the appropriate cell (see Fig. 4).

12.5.1.5 Follow the procedure in the Teledyne API 700EU Dynamic Dilution Calibrator Manual, Chapter 8.2.

- Make sure the Drive Voltage is set to the manufacturers settings (see Fig. 4).

- Make sure the BIOS DryCal cell is appropriate for the flow to be observed. If you have to change the cell, make sure the BIOS DryCal is turned off.

- Make sure there is gas flow present at the outlet of the MFC.

12.5.1.6 To see the actual flow on the BIOS DryCal after turning on the unit, press the ENTER twice. This will take one single flow measurement. Press the BOOST button and the unit will start taking flow measurements and result in an average of five. Repeat the flow measurements few times to let the MFC adjust itself to the Drive Voltage.

12.5.1.7 Once you have a stable flow reading, copy the BIOS average output from the HyperTerminal and paste it into the *700EU Recertification mm-dd-yy.doc* file.

At this point do NOT change the flow settings on the 700EU.

12.5.1.8 Using the following worksheet *700EU recert mm-dd-yy.xls* (Fig. 4), record the observed average flow from the BIOS DryCal in the “Observed LPM” section. Flows between 0-6.9 lpm can be run with a zero air pressure of 30 psig. To run higher flows (7-10 lpm, points 17 and 20) increase the pressure on the zero air supply to 38 psig by turning the pressure adjustment knob.

Teledyne API 700EU Calibrator Recertification Operator: **RA** Date: **3/7/2016**

Dil1 MFC Range 0-10 LPM **3/7/2016**

BIOS DryCal **last certified** 2/22/2016 *** Used the raw readings from the BIOS unit and not the corrected number****

Base Unit # B 638 **Cylinder #** L 934 0.01-9.9 lpm point 1
Base Unit # B 638 **Cylinder #** S 2642 0.1-9.9 lpm points 5, 9
Base Unit # B 638 **Cylinder #** H 1432 0.05-50 lpm points 13, 17, 20

Point	mV	observed LPM	
	0	0.000	0.500
1	250	**0.52920**	0.702
5	1250	**2.66700**	0.996
9	2250	**4.84100**	1.000
13	3250	**7.05600**	1.000
17	4250	**9.33900**	1.000
20	5000	**11.08000**	1.000
	slope	0.0022207	
	intercept	-0.095719	

*Make sure the pressure on the zero air supply is adjusted to 38-40 PSI for the higher flow points (17 & 20).

**After higher flow points are complete adjust flow back to 30-31 on the zero air supply

Point	Drive Volts (mV)	Drive Volt correction	LPM ideal	Initial LPM set point	LPM calc	**% diff less than 1% does not need corre Stand. Div.	Corrected	ew LPM set po
0	0	0	0.000	0.000	0.000	0.500	n/a	
1	241	250	0.500	0.499	0.555	0.711	yes	
2	463	500	1.000	1.002	1.110	0.867	yes	
3	687	750	1.500	1.500	1.666	0.952	yes	
4	913	1000	2.000	1.999	2.221	0.987	yes	
5	1141	1250	2.500	2.499	2.776	0.997	yes	
6	1378	1500	3.000	3.001	3.331	1.000	yes	
7	1599	1750	3.500	3.499	3.886	1.000	yes	
8	1825	2000	4.000	4.000	4.441	1.000	yes	
9	2049	2250	4.500	4.502	4.997	1.000	yes	
10	2270	2500	5.000	4.998	5.552	1.000	yes	
11	2493	2750	5.500	5.499	6.107	1.000	yes	
12	2717	3000	6.000	6.000	6.662	1.000	yes	
13	2933	3250	6.500	6.498	7.217	1.000	yes	
14	3154	3500	7.000	6.999	7.772	1.000	yes	
15	3369	3750	7.500	7.500	8.328	1.000	yes	
16	3586	4000	8.000	8.000	8.883	1.000	yes	
17	3803	4250	8.500	8.501	9.438	1.000	yes	
18	4016	4500	9.000	9.000	9.993	1.000	yes	
19	4229	4750	9.500	9.504	10.548	1.000	yes	
20	4440	5000	10.000	10.010	11.104	1.000	yes	
					0.0022207			

Cal1 MFC Range 0-100 sCCM **3/7/2016**

BIOS DryCal **last certified** 2/22/2016 *** Used the raw readings from the BIOS unit and not the corrected number****

Base Unit # B 638 **Cylinder #** L 934 0.01-9.9 lpm points 1, 5, 9
Base Unit # B 638 **Cylinder #** S 2642 0.1-9.9 lpm points 13
Base Unit # B 638 **Cylinder #** H 1432 0.05-50 lpm points 17, 20

Point	mV	observed LPM	
	0	0.000	0.500
1	250	**0.00532**	0.502
5	1250	**0.02769**	0.511
9	2250	**0.04970**	0.520
13	3250	**0.07162**	0.529
17	4250	**0.09520**	0.538
20	5000	**0.11090**	0.544
	slope	0.0000223	
	intercept	-0.000312	

Point	Drive Volts (mV)	Drive Volt correction	LPM ideal	Initial LPM set point	LPM calc	**% diff less than 1% does not need corre Stand. Div.	Corrected	ew LPM set po
0	0	0	0.0000	0.0000	0.0000	0.500	n/a	
1	224	250	0.0050	0.0050	0.0056	0.502	yes	
2	448	500	0.0100	0.0100	0.0111	0.504	yes	
3	665	750	0.0150	0.0150	0.0167	0.507	yes	
4	889	1000	0.0200	0.0200	0.0223	0.509	yes	
5	1100	1250	0.0250	0.0250	0.0279	0.511	yes	
6	1322	1500	0.0300	0.0300	0.0334	0.513	yes	
7	1559	1750	0.0350	0.0350	0.0390	0.516	yes	
8	1778	2000	0.0400	0.0400	0.0446	0.518	yes	
9	2006	2250	0.0450	0.0450	0.0502	0.520	yes	
10	2229	2500	0.0500	0.0500	0.0557	0.522	yes	
11	2459	2750	0.0550	0.0550	0.0613	0.524	yes	
12	2682	3000	0.0600	0.0599	0.0669	0.527	yes	
13	2860	3250	0.0650	0.0650	0.0725	0.529	yes	
14	3085	3500	0.0700	0.0700	0.0780	0.531	yes	
15	3310	3700	0.0750	0.0750	0.0825	0.533	yes	
16	3533	4000	0.0800	0.0800	0.0892	0.536	yes	
17	3756	4250	0.0850	0.0850	0.0948	0.538	yes	
18	3889	4500	0.0900	0.0900	0.1003	0.540	yes	
19	4270	4750	0.0950	0.0950	0.1059	0.542	yes	
20	4518	5000	0.1000	0.0999	0.1115	0.544	yes	
					0.00002			

Cal 2 MFC Range 0-50 sCCM **8/26/2015**

BIOS DryCal **last certified** 2/22/2016 *** Used the raw readings from the BIOS unit and not the corrected number****

Base Unit # B 638 **Cylinder #** L 934 0.01-9.9 lpm points 1, 5, 9
Base Unit # B 638 **Cylinder #** S 2642 0.1-9.9 lpm points 13, 17, 20

Point	mV	observed LPM	
	0	0.000	0.500
1	250	**0.00289**	0.501
5	1250	**0.01434**	0.506
9	2250	**0.02549**	0.510
13	3250	**0.03666**	0.515
17	4250	**0.04735**	0.519
20	5000	**0.05622**	0.522
	slope	0.0000112	
	intercept	0.000254	

Point	Drive Volts (mV)	Drive Volt correction	LPM ideal	Initial LPM set point	LPM calc	**% diff less than 1% does not need corre Stand. Div.	Corrected	ew LPM set po
0	0	0	0.0000	0.0000	0.0000	0.500	n/a	
1	201	250	0.0025	0.0025	0.0028	0.501	yes	
2	411	500	0.0050	0.0050	0.0056	0.502	yes	
3	625	750	0.0075	0.0075	0.0084	0.503	yes	
4	851	1000	0.0100	0.0101	0.0112	0.504	yes	
5	1062	1250	0.0125	0.0125	0.0140	0.506	yes	
6	1280	1500	0.0150	0.0150	0.0167	0.507	yes	
7	1500	1750	0.0175	0.0176	0.0195	0.508	yes	
8	1720	2000	0.0200	0.0200	0.0223	0.509	yes	
9	1936	2250	0.0225	0.0225	0.0251	0.510	yes	
10	2132	2500	0.0250	0.0250	0.0279	0.511	yes	
11	2352	2750	0.0275	0.0275	0.0307	0.512	yes	
12	2575	3000	0.0300	0.0300	0.0335	0.513	yes	
13	2805	3250	0.0325	0.0326	0.0363	0.514	yes	
14	3033	3500	0.0350	0.0351	0.0391	0.516	yes	
15	3261	3750	0.0375	0.0376	0.0419	0.517	yes	
16	3482	4000	0.0400	0.0400	0.0447	0.518	yes	
17	3717	4250	0.0425	0.0426	0.0474	0.519	yes	
18	3947	4500	0.0450	0.0451	0.0502	0.520	yes	
19	4172	4750	0.0475	0.0475	0.0530	0.521	yes	
20	4402	5000	0.0500	0.0500	0.0558	0.522	yes	
					0.00001			

Figure 4. MFC Calibration worksheet

12.5.1.9 Repeat the above procedure for the remaining flow points. Once all six DIL1 MFC flows have been recorded (“Observed LPM”), the calculated “LPM calc” from the *700EU recert mm-dd-yy.xls* (Fig. 4) are to be used to update all 20 flow points on the 700EU.

12.5.1.9.1 To enter the “LPM calc” in the 700EU, press FLW, enter the “LPM calc” and press ENTER. Skip to the next flow and repeat for all flow points.

12.5.1.9.2 Once all LPM calc flow points have been entered, press ENTER. The 700EU will ask if the changes should be saved, press YES.

12.5.1.10 Connect the BIOS DryCal to the CAL1 MFC in the 700EU (0-100 sccm). Repeat steps 12.5.1.7-12.5.1.9.2 to calibrate the CAL1 MFC (0-100 sccm).

12.5.1.11 Once all six CAL1 MFC flows have been recorded (observed LPM), the calculated LPM calc from the *700EU recert mm-dd-yy.xls* (Fig. 4) are to be used to update all 20 flow points on the 700EU.

12.5.1.12 Connect the BIOS DryCal to the CAL2 MFC in the 700EU (0-50 sccm). Repeat steps 12.5.1.7-12.5.1.9.2 to calibrate the CA21 MFC (0-50 sccm).

12.5.1.13 Once all six CAL2 MFC flows have been recorded (observed LPM), the calculated LPM calc from the *700EU recert mm-dd-yy.xls* (Fig. 4) are to be used to update all 20 flow points on the 700EU.

12.5.1.14 After calibrating all three MFCs, disconnect the BIOS DryCal from the last 700EU MFC and from the PC.

12.5.1.15 Record a note in the ESC 8832 data logger logbook, graph and instrument logbook of the performed MFC Calibration.

12.5.2 Teledyne API T700U MFC Calibration

MFC Calibration on a Teledyne API T700U Dynamic Dilution Calibrator is the same procedure a on a Teledyne API 700EU Dynamic Dilution Calibrator, see section 12.5.1.

Use worksheets T700U Recertification mm-dd-yy.doc and T700U recert mm-dd-yy.xls to record the observed flow points.

12.5.3 Teledyne API T750 MFC Calibration

MFC Calibration on a Teledyne API T750 Dynamic Dilution Calibrator is the same procedure a on a Teledyne API 700EU Dynamic Dilution Calibrator, see section 12.5.1.

Use worksheets *T750 Recertification mm-dd-yy.doc* and *T750 recert mm-dd-yy.xls* to record the observed flow points.

12.6 Maintenance

12.6.1 Teledyne API 700EU Dynamic Dilution Calibrator

Once a year the Calibrator should be cleaned and checked for proper function. Before turning off the instrument, check the instruments diagnostics by using the 'Test' button on the front panel display. If there are any discrepancies to the manufacturer's specifications they should be addressed directly during maintenance. Refer to the respective Teledyne API 700x Dynamic Dilution Calibrator Manual, Rev. B4 July 2009, Chapter 10.2.

12.6.1.1 Open the instrument and clean the inside.

12.6.1.2 Check all pneumatic connections for tightness and all electrical connectors for proper seating.

12.6.1.3 Inspect the photometer bench (remove bench cover) and UV lamp seating.

12.6.1.4 Connect a zero air source to the instrument, turn the instrument on and let it warm up for at least 30 minutes.

12.6.1.5 Perform an auto leak check. Refer to Teledyne API Service Note 10-017A. Remember that the provided pressure is between 25-35 psi, if not, the leak check will fail! Refer to Teledyne API 700x Dynamic Dilution Calibrator Manual, Rev. B4 July 2009, Chapter 8.5 and 10.2.5.

12.6.1.6 Calibrate the regulator and ambient pressure sensors. Remember that the provided pressure is between 25-35 psi, if not, the leak check will fail! Refer to Teledyne API 700x Dynamic Dilution Calibrator Manual, Rev. B4 July 2009, Chapter 8.5.

12.6.1.7 Calibrate the photometer flow and output flow; refer to Teledyne API 700x Dynamic Dilution Calibrator Manual, Chapter 8.3.6. The instructions for the flow calibration in the manual are not fully correct! Use appendix A1. for a correct flow calibration!

12.6.1.8 Adjust the UV lamp output to 4400-4600 mV. Refer to Teledyne API 700x Dynamic Dilution Calibrator Manual, Rev. B4 July 2009, Chapter 10.2.3.

12.6.1.8.1 Check the UV lamp temperature reading for a stable reading at 58ºC. Loosen the UV lamp and turn it to a maximum mV output. Tighten UV lamp. (The manual might say turn UV lamp to minimum mV, this is incorrect! Contacting Teledyne API reconfirmed that a maximum mV output is desired for the UV lamp adjustment.)

12.6.1.8.2 On the other end of the photometer bench locate the gain adjustment pot under the small cap and adjust to 4400-4600 mV. Turn the pot very slowly and in small increments. Let the mV settle before continuing turning the pot.

12.6.1.9 Place the cover back on the instrument and perform a photometer dark calibration (this is an automated process). Refer to Teledyne API 700x Dynamic Dilution Calibrator Manual, Rev. B4 July 2009, Chapter 8.3.5.

12.6.1.9 Adjust the O3 generator UV lamp output to approximately 2500 mV. Refer to Teledyne API 700x Dynamic Dilution Calibrator Manual, Rev. B4 July 2009, Chapter 10.2.5.

12.6.1.10 Verify the 700x O3 Photometer Performance (see section 12.3.2).

12.6.1.11 Verify the 700x O3 Generator Performance (see section 12.4).

12.6.2 Teledyne API T700U Dynamic Dilution Calibrator

Maintenance procedures for a T700U Dynamic Dilution Calibrator are the same as for 700EU Dynamic Dilution Calibrator. See section 12.6.1.

12.6.3 Teledyne API T750 Dynamic Dilution Calibrator

Once a year, before Ozone season starts, every Ozone Calibrator should be cleaned and checked for proper function. Before turning the instrument off, check the diagnostics by using the test button on the front panel display. If there are any discrepancies to the manufacturer's specifications they should be addressed and the program manager informed of the issues. Refer to Teledyne API T750 Dynamic Dilution Calibrator Manual, Feb 2015, Chapter 8.2.

12.6.3.1 Open the instrument and clean the inside.

12.6.3.2 Check all pneumatic connections for tightness and all electrical connectors for proper seating.

12.6.3.3 Inspect the photometer bench (remove bench cover) and UV lamp seating.

12.6.3.4 Connect a zero air source to the instrument, turn the instrument on and let it warm up for at least 30 minutes.

12.6.3.5 Calibrate diluent, cal gas, regulator and ambient/sample gas pressure sensors. Refer to Teledyne

API T750 Dynamic Dilution Calibrator Manual, Feb 2015, Chapter 7.5.

12.6.3.6 Perform an auto leak check. Refer to Teledyne API T750 Dynamic Dilution Calibrator Manual, Chapter 8.2.1. Remember that the provided pressure is between 25-35 psi, if not, the leak check will fail!

12.6.3.7 Calibrate the photometer flow and output flow; refer to Teledyne API T750 Dynamic Dilution Calibrator Manual, Feb 2015, Chapter 7.3.6. <u>The instructions for the flow calibration in the manual are not fully correct! Use appendix A1. for a correct flow calibration.</u>

12.6.3.8 Adjust the UV lamp output to 4400-4600 mV. Refer to Teledyne API T750 Dynamic Dilution Calibrator Manual, Feb 2015, Chapter 8.2.4.

12.6.3.8.1 Loosen the UV lamp and turn it to a <u>maximum</u> mV output. Tighten UV lamp. (The manual might say turn UV lamp to minimum mV, this is incorrect! Contacting Teledyne API reconfirmed that a maximum mV output is desired for the UV lamp adjustment.)

12.6.3.8.2 On the other end of the photometer bench locate the gain adjustment pot under the small cap and adjust to 4400-4600 mV. Turn the pot very slowly and in small increments. Let the mV settle before continuing turning the pot.

12.6.3.9 Place the cover back on the instrument and perform a photometer dark calibration (this is an automated process). Refer to Teledyne API T750 Dynamic Dilution Calibrator Manual, Feb 2015, Chapter 7.3.5.

12.6.3.10 Adjust the O3 generator UV lamp output to approximately 2500 mV. Refer to Teledyne API T750 Dynamic Dilution Calibrator Manual, Feb 2015, Chapter 8.2.5.

12.6.3.11 Verify the T750 O3 Photometer Performance (see section 12.3.2).

12.6.3.12 Verify the T750 O3 Generator Performance (see section 12.4.).

12.6.4 Teledyne API 703E Photometric Ozone Calibrator

Once a year, before Ozone season starts, every Ozone Calibrator should be cleaned and checked for proper function. Before turning the instrument off, check the diagnostics by using the test button on the front panel display. If there are any discrepancies to the manufacturer's specifications they should be addressed and the program manager informed of the issues. Refer to Teledyne API 703E Photometric Ozone Calibrator Manual, May 2011, Chapter 8.3.

12.6.4.1 Open the instrument and clean the inside.

12.6.4.2 Check the Dry Air Pump. If needed, repair the pump; refer to Teledyne API 703E Photometric

Ozone Calibrator Manual, May 2011, Chapter 10.4

12.6.4.3 Check all pneumatic connections for tightness and all electrical connectors for proper seating.

12.6.4.4 Inspect the photometer bench (remove bench cover) and UV lamp seating.

12.6.4.5 Connect a zero air source to the instrument, turn the instrument on and let it warm up for at least 30 minutes.

12.6.4.6 Calibrate the regulator and ambient pressure sensors; refer to Teledyne API 703E Photometric Ozone Calibrator Manual, May 2011, Chapter 8.3.

12.6.4.7 Calibrate the photometer flow and output flow; refer to Teledyne API 703E Photometric Ozone Calibrator Manual, Chapter 8.4.1-8.4.2. <u>The instructions for the flow calibration in the manual are not fully correct! Use appendix A1. for a correct flow calibration.</u>

12.6.4.8 Adjust the UV lamp in output to 4400-4600 mV. Refer to Teledyne API 703E Photometric Ozone Calibrator Manual, May 2011, Chapter 10.5.

12.6.4.8.1 Check the UV lamp temperature reading for a stable reading at 58ºC. Loosen the UV lamp and turn it to a <u>maximum</u> mV output. Tighten UV lamp. (The manual might say turn UV lamp to minimum mV, this is incorrect! Contacting Teledyne API reconfirmed that a maximum mV output is desired for the UV lamp adjustment.)

12.6.4.8.2 On the other end of the photometer bench locate the gain adjustment pot and adjust to 4400-4600 mV. Turn the pot very slowly and in small increments. Let the mV settle before continuing turning the pot.

12.6.4.9 Adjust the O3 generator UV lamp output to approximately 2500 mV. Refer to Teledyne API 703E Photometric Ozone Calibrator Manual, May 2011, Chapter 10.7.

12.6.4.10 Place the cover back on the instrument and perform a photometer dark calibration (this is an automated process). Refer to Teledyne API 703E Photometric Ozone Calibrator Manual, May 2011, Chapter 8.1.4.

12.6.4.11 Verify the 703E O3 Photometer Performance (see section 12.3.2).

12.6.4.12 Verify the 703E O3 Generator Performance (see section 12.4.).

12.6.5 Documentation

Document all problems, maintenance, test results, and verifications completed on the calibrators using other calibrators and/or analyzers to track the quality of the calibrators performance. All results should be logged in the S:\A&M\Repair Supplies and Logs folder under the Ambient Equipment Repair Log

CAL.xls file. Find the corresponding tab for each unit based on serial number within the excel sheet and add documentation to track the equipment's history.

12.7 O3 Photometer Backpressure Compensation

At initial set up and any time the pneumatic configuration is changed (i.e. new line installed, change of line length, repositioning of vent…), the internal measure/reference pressure can be impacted and result in incorrect Ozone readings. Therefore the backpressure compensation should be performed.

12.7.1 - Backpressure Compensation Procedure

The backpressure compensation is an automated process, refer to the respective Teledyne API Dynamic Dilution/Photometric Ozone Calibrator Manual.

12.7.1.1 Make sure to bypass any solenoids incorporated in the line (usually in the Cal Gas line leading to the sample inlet at the probe box) to ensure a continuous air flow is possible.

12.7.1.2 For a more accurate backpressure compensation, detach the sample line on the back of any API 400E Ozone Analyzer that may be connected. The vacuum produced by the analyzer has a destabilizing effect on the backpressure compensation procedure.

12.7.1.3 After a successful backpressure compensation, reattach the sample line to the back of the analyzer and remove the solenoid bypass installed in step 12.7.1.1.

APPENDIX A

A1. Photometer and output flow calibration 703E/700EU

Photometer and output flow calibration 703 EU

As the instructions for the flow calibration in the 703 EU manual are not correct, useful, halfway complete…, FCEAP talked to API.

Following is the correct procedure as described by a technician who guided staff through the process while FCEAP performed the flow calibration.

Feed Zero air into the 703 EU.

The internal Zero Air pump has to be turned off during this procedure.

First adjust Sample and Regulator pressure on the 703 EU. See manual.

<u>To calibrate Photometer Gas Flow:</u>

Connect BiosDry Cal to the inlet port of the photometer bench, on the detector side. Flow will go from the Bios to the photometer bench, check for correct setup. All Output ports have to be plugged (Vent; Exhaust; Cal2). Keep only **Cal 1 open**.

Now refer to the 703 EU manual “Calibrating the photometer’s sample gas flow”.

Wait for flow and run the BiosDry Cal.

When prompted with the **Actual photo flow: 1.000 LPM**, do not hit Enter, instead **Exit out** up to the sub menu!

Note the flow value from the BioDry Cal.

Remove the BiosDry Cal from the photometer bench and put everything back to “normal”.

Restart the “Calibrating the photometer’s sample gas flow” from the manual and when prompted with the Actual photo flow: 1.000 LPM, enter the **BiosDry Cal value** you just noted. Push Enter to save.

<u>To calibrate the Output Gas Flow:</u>

Now connect the BiosDry Cal to the **CAL 1 port** on the back of the 703 EU. Flow will go from the 703 EU Cal 1 port to the BiosDry Cal.

Now refer to the 703 EU manual “Performing an output gas flow calibration”.

Exit out from the Actual photo flow and wait for the **Actual outputflow: 1.000 LPM**.

Run the BiosDry Cal and enter the observed flow. Hit enter to save.

REFERENCES

Transfer Standards for Calibration of Air Monitoring Analyzers for Ozone, Technical Assistance Document. EPA-600/4-79-056. United States Environmental Protection Agency, September 1979.

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