STANDARD OPERATING PROCEDURES FOR

TELEDYNE ADVANCE POLLUTION INSTRUMENTS MODEL T400 AND 400E OZONE ANALYZER

AQSB SOP 002

Third Edition

MONITORING AND LABORATORY DIVISION

December 2019

Disclaimer: Mention of any trade name or commercial product in this standard operating procedure does not constitute endorsement or recommendation of this product by the California Air Resources Board. Specific brand names and instrument descriptions listed in the standard operating procedure are for equipment used by the California Air Resources Board's laboratory. Any functionally equivalent instrumentation is acceptable

CALIFORNIA AIR RESOURCES BOARD

Approval of Standard Operating Procedures

Title:	Teledyne Advanced Pollution Instruments (TAPI) Model T400 and 400E Ozone Analyzers
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Section:	Operations and Data Support
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Division:	Monitoring and Laboratory Division (MLD)
Prepared by:	Matthew Quok

Reviewed by:

Manisha Singh, Ph.D., Chief
Quality Management Branch

Date: 12/24/19

Approval by:

Reggie Smith, Manager
Air Quality Surveillance Branch

Date: 20 Dec 2019

Kathleen Gill

Kathleen Gill, Chief
Air Quality Surveillance Branch

Date: 12/23/19

TELEDYNE API MODEL T400/400E OZONE ANALYZER

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REVISION HISTORY

Edition	Release Data	Changes
First	Feb 2008	New Document
Second	May 2013	Added CARBLogger information Added T400 Updated QC and calibration forms
Third	Nov 2019	ADA Remediation Add T400 with NumaView language Remove ESC Logger information Incorporate CARB Gaseous QAPP information Revise verification and calibration criteria • Best-fit straight line method • Remove zero correction • Pass/Fail for pre/post zero checks • Lower calibration point to match low audit points Update QC and calibration forms

LIST OF ACRONYMS

AQS - Air Quality System
AQSB - Air Quality Surveillance Branch
CARB - California Air Resources Board
CFR - Code of Federal Regulations
DAS - Data Acquisition System
DMS - Data Management System
GUI – Graphical User Interface
iDAS - Internal Data Acquisition System (TAPI), previously referred to as DAS
IZS – Internal Zero/Span
LPM - Liters per Minute
MLD - Monitoring and Laboratory Division
MV - Millivolt
NIST - National Institute of Standards and Technology
ODSS - Operations and Data Support Section
O3 – Ozone
PMT - Photo Multiplier Tube
ppb - parts per billion
PQAO - Primary Quality Assurance Organization
PST – Pacific Standard Time
QA – Quality Assurance
QAS – Quality Assurance Section
QA/QC - Quality Control/Quality Assurance
SLPM - Standard Liters per Minute, gas flow at standard temperature and pressure
SOP - Standard Operating Procedure
Span Level - Instrument response level at approximately 80% of calibration range
TAPI - Teledyne Advanced Pollution Instrumentation
U.S. EPA – United States Environmental Protection Agency
UV – Ultra Violet

1.0 GENERAL INFORMATION

1.1 Introduction:

This Standard Operating Procedure (SOP) describes procedures used by the California Air Resources Board (CARB) Air Quality Surveillance Branch (AQSB) to operate, maintain and calibrate the Teledyne Advanced Pollution Instruments Model 400E Ozone Analyzer (400E) as well as the Teledyne/Advanced Pollution Instruments Model T400 Ozone Analyzer (T400) to measure ozone levels in ambient air. These two instruments will be collectively referred to as "the instrument" unless otherwise required. This procedure supplements the TAPI instrument operating manual by describing hardware or operating procedures as implemented by the CARB's AQSB for monitoring of ozone in the CARB's ambient air monitoring network. It is not the intent of this SOP to duplicate or replace the TAPI operating manual. Any references to the instrument manual refer to 400E Rev. F manual or the T400 Rev. F manual for the respective instruments.

1.2 Principle of Operation:

The instrument is designed to accurately measure ambient ozone concentrations, despite the presence of interfering compounds. It detects ozone by measuring the absorbance of 254 nm UV light emitted by a mercury vapor lamp and collected by a detector at the other end of the sample gas path. Using Beer-Lambert law, this UV absorbance can be correlated to the concentration of ozone and any other compound that may absorb UV light at this frequency.

$$A = \log_{10}\left(I_o / I\right)$$

Equation 1 - Beer-Lambert law where Io is the original intensity, I is the post intensity, and A is the absorbance.

In order to correct for interfering compounds, the instrument calculates each value by taking the difference of two measurements and subtracting the difference.

$$A_{total} = A_i + A_{O3}$$
$$A_{O3} = A_{total} - A_i$$

Equation 2 - In the above equation: A_{total}, Ai, and AO3 stand for total, interfering compound, and ozone absorbance respectively. Total absorbance can be measured in the O3 measurement sample. Absorbance of the interfering compounds is measured in the O3 reference sample. The partial absorbance of the ozone is then calculated as the difference of the two.

For the interference measurement, the UV light passes through a band-pass filter and through a glass tube which is filled with ambient air. The UV light absorbance is subsequently measured by the detector located on the opposite side of the chamber. This initial measurement is commonly referred to as Ozone Measured (displayed as "O3 Meas" on the front panel).

For the second measurement, sample air is scrubbed of all ozone and a resulting reference measurement is taken (displayed as "O3 Ref" on the front panel). The amount of UV radiation absorbed by ozone in the sample is then calculated as the difference of the actual absorbance during the O3 Meas and the scrubbed O3 Ref measurement cycles. For a more detailed discussion of the analyzer's measurement principle, please reference the manufacturer's instruction manual.

1.3 NumaView Software:

The NumaView Operating system is the next-generation operating system for Teledyne-API monitoring equipment. Teledyne-API began releasing instruments with the NumaView operating system in 2017. Analyzers purchased between 2017 and the Q2 2019 can operate in either the legacy mode or NumaView operating system. If NumaView is the operating system on the analyzer, please refer to the T400 with Numaview Software Manual on the Teledyne-API product manual website for additional information.

1.4 Legacy vs. NumaView Software Differences:

The table below highlights differences between the legacy software and the NumaView software for the most commonly used features. For a detailed list of changes, see Section 2, "Interface Orientation: T-Series Legacy-To-Numaview Software" in the Numaview Software Addendum For Analyzers", referenced above.

Legacy Software	Numaview Software
Push button and LED text display (400E) or graphical adaption of push button and LED display (T400)	New Graphical User Interface (GUI) display
Navigation via seven function keys	Faster navigation via left sidebar and top bar shortcut buttons
Scroll through diagnostic parameters using “<TST” and “TST>” buttons	The dashboard screen can be configured to display 12 diagnostic parameters per screen, user configurable
Faults are indicated by the red fault indicator light	Faults are indicated by an alert symbol in lower right corner
Read and clear fault messages one by one via function keys	Read and clear fault all fault messages in a pop up box on display
Text display for concentration, stability	Graphical display available for concentration and stability

Table 1. Legacy vs. NumaView Software

1.5 Safety Precautions:

Prior to cleaning the analyzer or performing any maintenance on the instrument, place the MAIN power switch to the OFF position, and unplug the power cord. Avoid the use of chemical agents that might damage components or interfere with the analytical method used by the analyzer.

Always use a three-prong, grounded plug on this analyzer. Adhere to general safety precautions when using compressed gas cylinders (e.g., secure cylinders, vent exhaust flows).

1.6 Personnel Qualifications:

Staff should be trained and familiar with basic air monitoring principles and procedures prior to operating any air monitoring equipment. Staff should complete any required safety training before operating any air monitoring equipment and working in the field. Staff should review this SOP, the operating manual, and complete any instrument related and air monitoring operations training required by their section manager prior to operating this analyzer.

2.0 INSTALLATION PROCEDURE

2.1 General Information:

The instrument is designed to operate at a temperature range between 5° and 40° C. However, good monitoring practices state that the instrument should be installed in a stable temperature controlled environment between 20 °C to 30 °C. Care should be taken to install the instrument in a standard 19" instrument rack such that it can be accessed for maintenance, repair work, troubleshooting etc. The standard 19" instrument rack should be bolted to the floor and properly grounded.

2.2 Physical Inspection:

Upon receiving the instrument, confirm that the instrument is in good working order and inspect for damage. If any damage is observed, photograph and document the damage and contact your supervisor. Prior to installation of the instrument, check the following:

1. All items and options are received.
2. Verify that there is no shipping damage.
3. Check that all connectors are fully inserted.
4. Check that all mechanical connections are tight.
5. Open and remove the internal shipping screws on the pump and the internal foam blocks.

2.3 Instrument Siting:

The instrument should be sited in accordance with the United States Environmental Protection Agency (U.S. EPA) Title 40, Code of Federal Regulations Part 58 Appendix E "Probe and Monitoring Path Siting Criteria for Ambient Air Quality Monitoring" and US EPA Designated Automated Equivalent Method EQOA-0992-087. See also the *Model 400E Ozone Analyzer Instruction Manual*, Section 2.2 "EPA Equivalency Designation" and the *Model T400 Photometric Ozone Analyzer*, Section 2.2 "EPA Equivalency Designation" for a detailed list of EPA designation related siting requirements.

2.4 CARBLogger Connection:

CARB utilizes a custom open source PC-based digital diagnostic and data logging system referred to as CARBLogger. When using CARBLogger, the RS-232 port on the instrument should be made active using the front control panel of the instrument. The following instrument communications settings should be verified to allow for digital communications with CARBLogger:

- COM2 on
- BAUD RATE=9600
- Instrument ID=400

After connecting an RS232 cable to the back of the instrument from the CARBLogger PC to the instrument COM 2 port, ensure that both the amber and green RX/TX lights located above the instruments COM 2 interface are lit. If not, toggle the DCE/DTE switch to change the RS-232 polarity. No additional connections are required.

Note: In this mode, USB ports located on the rear of the T400 will be disabled.

For assistance with specific CARBLogger configuration, contact the CARB's Operation and Data Support Section (ODSS).

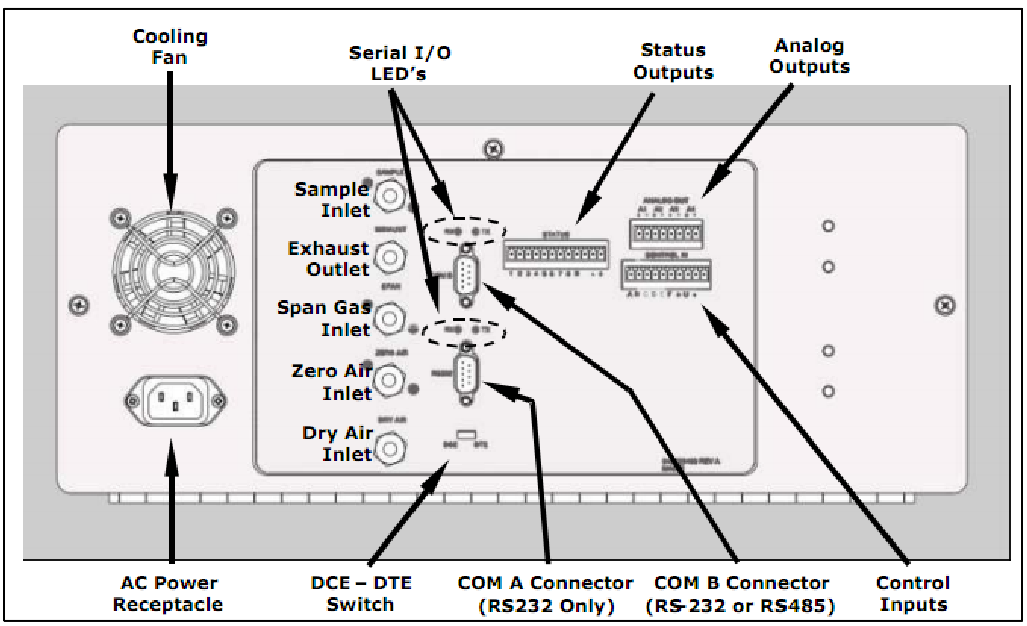

Figure 1: COMM 2 (Upper DB-232 connection)

2.5 Operational Verification:

NOTE: Prior to operation of the instrument, operators must read the respective operating manual to familiarize themselves with the operation of the instrument.

Before operating the instrument, ensure that the proper connections have been made. Typically, at CARB ambient air monitoring locations this includes the following connections:

- Connect the sample inlet line from the manifold to the sample port on the rear panel.
- Connect the pump exhaust to a suitable vent outside the analyzer area.
- Connect the power cord to a well-grounded and appropriate power outlet.
- Connect CARBLogger to RS232 on the rear panel.

After proper connections have been made, turn on the power switch. Allow approximately one hour for the instrument to stabilize before performing any further operations.

Figure 2: T400 Legacy Mode Front Display

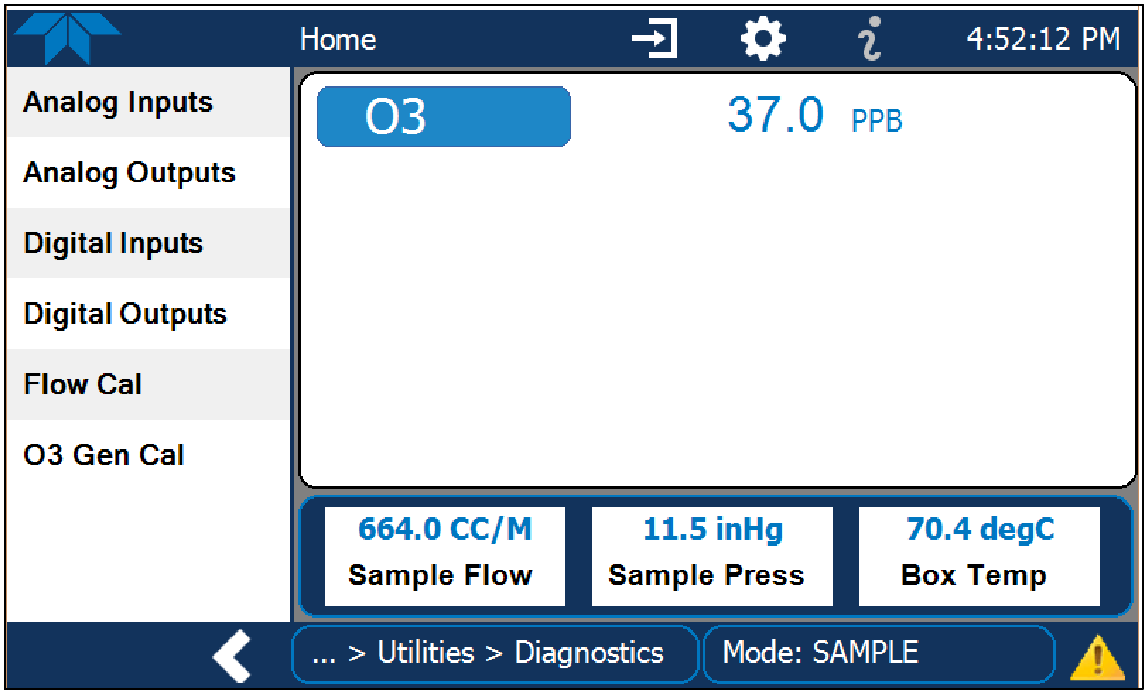

Figure 3: T400 with NumaView Front Panel Display

Review all diagnostic values by repeatedly depressing the first [<TST] or second [TST>] command keys on the front of the instrument for legacy configured instruments. For Numaview enabled instruments, diagnostic values can be viewed via the dashboard menu. Compare these values to those listed on the factory final checkout sheet in the instruction manual for new instruments or those listed on Table 2 for instruments in service.

If warning messages persist after the warm up period is over, investigate their causes using the troubleshooting guidelines provided in the instruction manual.

Note: When the T400 is connected to a CARBLogger using the T400 driver, all errors will be recorded, placed into the diagnostics email, and cleared from the instrument.

3.0 CONFIGURATION

3.1 Instrument Configuration:

The instrument is usually configured by the CARB's Operation and Data Support Sections Instrument Laboratory and requires no field configuration. **However, field staff MUST verify that their instrument is properly configured prior to field use.**

TEST PARAMETER	NOMINAL	RANGE
Time	Current PST time	+/- 2 minutes
Range (ppb)	500	0 to 500
O3 Meas (Current V/F conv MV, measured channel)	4000	2500 to 4900
O3 Ref (Current V/F conv MV, reference channel)	4000	2500 to 4900
O3 Gen (IZS ref channel feedback)	+/- 10% demand	80-5000 MV
O3 Drive (Drive voltage for O3 Gen Lamp)	+/- 10% demand	0-5000 MV
Pressure (Absolute Pressure, inHg)	Ambient Press.	29 to 31
Sample Fl (Sample Flow through Analyzer, c/min)	720	720 $\pm$ 80
Sample Temp (°C)	Ambient Temp	Ambient +/- 15°
Photo LMP (Photometer Lamp Housing Temp, °C)	58 C	58 +/- 2
O3 Gen Temp (O3 Generator Housing Temp, °C)	48 C	48 +/- 1°
Box Temp (Internal Box Temp, °C)	Ambient Temp	Ambient +/- 8°
Slope (Internal Formula, Slope)	1.00	0.85 to 1.15
Offset (Internal Formula, Offset)	0.0	-5.0 to 5.0

Table 2. Standard CARB Configuration Table

3.2 Data Logger Configuration:

CARBLogger provides minute-based, digital data recording and alerts for a variety of instruments. AQSB staff can configure CARBLogger by following the instructions on the text based user interface provided by the program. There are separate drivers for the 400E, T400, 400E Internal Zero/Span (IZS) , and T400 IZS models. **Care should be taken to install the proper CARBLogger driver for the instrument you are using.** Additional information can be found in the CARBLogger SOP (AQSB SOP 605). For additional questions or concerns, please contact the Operation and Data Support Section.

4.0 CALIBRATION OVERVIEW

4.1 Calibration Introduction:

A calibration is defined as the comparison of a measurement standard, instrument, or item with a standard or instrument of higher level to detect and quantify inaccuracies and to report or eliminate those inaccuracies by adjustment. To ensure the quality of the data provided by the 400E or T400, the analyzer should be calibrated in accordance with recommendations stated in this SOP.

Prior to implementation of any ambient air monitoring activities, ozone instruments are required to be calibrated by allowing the instrument to sample and analyze test atmospheres of known concentrations of the appropriate pollutants. Once an instruments' calibration relationship is established, periodic calibrations at reasonable frequencies confirm that the instrument remains in calibration.

To ensure the quality of the data collected within the CARB's air monitoring network, **ALL** instruments used in the network must be calibrated

- During initial field installation and every six months thereafter,
- Following physical relocation,
- Prior to instrument shut-down,
- After any major maintenance or repair,
- After an instrument has drifted outside of acceptable QC limits.

Performing frequent adjustments to instrumentation can cause additional measurements uncertainty. Calibration tolerances have been developed so that as long as the instruments are within the tolerances, frequent adjustments to instruments should not be made.

CARB utilizes two forms of field multi-point calibrations, nominally referred to as "AS-IS" verifications and "Final" calibrations. An "AS-IS" verification is performed initially to evaluate the instruments accuracy. No adjustments, modifications or repairs are made to the instrument prior to the "AS-IS" verification. This verifies accuracy of the recently generated data; usually back to the previous verification/calibration check.

A "Final" calibration is performed after an instrument has failed an "AS-IS" verification or has undergone major maintenance, repair, or an adjustment. The following sections provide a list of the required equipment and the recommended procedures to accurately calibrate the analyzer.

4.2 Calibration Overview:

Test concentrations for ozone must be obtained in accordance with UV photometric calibration procedures listed in 40 Code of Federal Regulations (CFR) 50 Appendix D (Measurement Principle and Calibration Procedure for the Measurement of Ozone in the Atmosphere) or by means of a certified ozone transfer standard. The transfer standard must be traceable to a primary ultraviolet photometer and recertified as required.

It is recommended that the test concentration for ozone using an ozone transfer standard be delivered directly into the station sample manifold.

4.3 Calibration Apparatus for Instrument:

- National Institutes of Standards and Technology (NIST) Traceable Certified ozone/gas transfer standard.
- Appropriate Teflon tubing for airflow connections.
- Certified clean zero air source.
- Calibrated laminar flow device for measuring airflow (mass flow meter).
- Calibration report forms.
- Conditioned calibration line if using calibrator for ozone source.

4.4 Calibration at Altitude:

Calibrating the instrument at altitude requires no special adjustments since the instrument compensates for changes in temperature and pressure. Prior to calibration, verify the operation of the internal temperature and pressure sensors in the instrument by recording the values of temperature and pressure from the instrument and from a certified temperature/pressure standard for a one point check.

NOTE: The air monitoring stations data acquisition system (DAS) is used for primary data recording, therefore the stations DAS data values should be used for calibration calculations in lieu of the analyzer display readings.

4.5 Calibration Scale:

Calibration Scale indicates the concentration range that an instrument is typically calibrated. CARB recommends that ozone instruments used in the ambient air monitoring network be calibrated over a range that represents concentrations likely to be found in the network while still being protective of concentrations exceeding the NAAQS. Hence, the instrument does not necessarily need to be calibrated or verified at concentration levels not normally measured by the monitor. The idea is that a monitoring organization select a calibration scale that provides more calibration points at the lower concentrations to establish a better test of linearity at the routine concentration ranges. The calibration scale minimally should cover the "controlling" NAAQS standard especially if the monitor is used for regulatory purpose (comparison to the NAAQS).

4.6 Calibration Equations:

The CARB calibration worksheet (Appendix B) uses various calculations when determining the performance of the analyzer during the verification or calibration. The calculations used in the calibration worksheet are outlined below.

- Arithmetic Mean of observed values

$$average = \frac{\sum_{i=1}^{n} x_i}{n}$$

- Percent Difference between observed and expected values

$$percent\ difference = \frac{observed - expected}{expected} * 100$$

- Difference between observed and expected values

$$difference = observed - expected$$

- Best Fit Regression

  Where:

  N = number of data points
  X = transfer standard ozone readings
  Y = observed ozone readings

$$m = \frac{(Nxy_{sum}) - (x_{sum}y_{sum})}{(Nx^2{}_{sum}) - (x_{sum}x_{sum})}$$

$$b = \frac{(x^2{}_{sum} y_{sum}) - (x_{sum} xy_{sum})}{(N x^2{}_{sum}) - (x_{sum} x_{sum})}$$

$x_{sum} = \sum x$ $\quad\quad$ $x^2{}_{sum} = \sum x^2$

$y_{sum} = \sum y$ $\quad\quad$ $y^2{}_{sum} = \sum y^2$

$xy_{sum} = \sum xy$

- Best Fit True Ozone

$$best\ fit\ true\ ozone\ value = m\ (corrected\ transfer\ standard\ value) + b$$

Where:

m = best fit regression slope
b = best fit regression intercept

- Percent Difference between best fit ozone and observed values

$$percent\ difference = \frac{observed - best\ fit\ ozone}{best\ fit\ ozone} * 100$$

- Difference between best fit ozone and observed values

$$difference = observed - best\ fit\ ozone$$

- Overall Accuracy (Summation Method)

$$Overall\%\ Accuracy = \left(\frac{S2 - S1}{S1}\right) * 100$$

Where:

S1 = Sum of expected values
S2 = Sum of observed values

4.7 AQSB Excel Calibration Form:

To facilitate the verification/calibration process, CARB's AQSB has developed calibration form AQSB Calibration Form 002 (Appendix B) for TAPI ozone analyzers. The calibration form automates calculations and provides indicators to the user regarding the pass/fail criteria of the verification or calibration. Key features of the calibration form are:

- No zero correction to calibration values
- Pass/fail criteria based on comparison to best-fit straight line
- Pass/fail criteria based on best-fit slope
- Notification of pass/fail
- Pass/fail criteria for pre/post zero checks

Table 3: Calibration Form Calculation Descriptions

Calculation	Description
Xfer Std Ave Display:	Display reading of ozone transfer standard.
True Ozone (ppm):	True ozone value (in ppm) generated using xfer std display corrected for true ozone correction factor (TOCF) from transfer standard certification equation.
Avg. DAS Display:	Average ozone reading as recorded from data acquisition system (data logger).
Analyzer Display (ppm):	Analyzer display reading.
Best Fit True O3:	Theoretical ozone values calculated from true ozone concentration and the best fit regression equation where true ozone is (x).
% from True (PTP):	The percent difference between the true ozone value and the analyzer response as read from DAS at each point.
Diff. from True (ppb):	The actual difference from true between the true ozone value and the average data logger display. Positive values indicate the data logger reading is higher than the true ozone value.
Best Fit % Difference:	Indicates the percent difference between the best-fit ozone concentration and the analyzer response as read from DAS.

Calculation	Description
Diff. from best-fit (ppb):	The actual difference between the best-fit ozone value and the average data logger display. Positive values indicate the data logger reading is higher than the true ozone value.
Best Fit Status:	Indicates the pass/fail status of each calibration point evaluated. Pass indicated if at each calibration point is within ± 2.1 percent or ± 1.5 ppb of the best-fit straight line whichever is greater.
Best Fit Regression Equ.:	Linear regression equation of the best-fit line where Y is the analyzer reading and X is the transfer standard true ozone concentration. m=slope, b=intercept, r2=correlation. If slope is greater than 1.05 or less than 0.95, cell will turn red, else cell will turn green.
Overall Deviation from True:	Indicated the overall percent deviation of the calibration using all calibration points. This calculation is referred to as the summation method.

5.0 VERIFICATION (AS-IS)

5.1 Verification Overview:

AS-IS instrument verifications should be made prior to making any analyzer repairs or adjustments. It is acceptable to change the particulate inlet filter prior to an AS-IS verification. Prior to beginning AS-IS verification, disable the appropriate DAS channels on the station data logger and record the instruments diagnostic parameters.

5.2 Verification Procedures:

1. Set-up the certified ozone/gas transfer standard to generate the test concentrations for ozone. Configure the transfer standard so that the ozone generated is measured by the transfer standards UV photometer. Using one-quarter inch (1/4" O.D.) Teflon tube, connect a zero air source and exhaust lines to the transfer standard. Connect a 1/4" O.D. Teflon line from the transfer standard's output port to the stations sample manifold.

2. Allow both the transfer standard and the analyzer being verified to warm-up for at least one hour. All instrument covers should be on during the verification, as the verification is dependent upon the internal temperature of the analyzer. The transfer standard diagnostic values should be stable; showing no upward or downward trend when operating temperature has been reached.

3. Record the station information, analyzer identification numbers, analyzer settings, calibration equipment information, and any other pertinent information on the calibration data sheet (Appendix B).

4. Obtain the instruments internal slope and offset following the steps detailed in the operating manual. Record the AS-IS slope and offset on the calibration data sheet. Confirm that the slope and offset values have not changed since previous verification or calibration. If values have changed, investigate when and why these values have changed prior to beginning verification.

5. Energize the zero air source and configure the transfer standard so that zero air is flowing through the calibration assembly. Calculate an appropriate transfer standard flow rate based on the manifold flow requirements, transfer standard requirements, and target levels and adjust the transfer standard total flow rate accordingly. Measure and record the AS-IS sample air flow rate of the instrument. Connect an 18 inch long Teflon line (1/4"

O.D.) to the vent port of the transfer standard and measure the vent flow. The vent flow should be greater than 0.5 LPM.

6. Adjust the transfer standard to output zero air. When a stable zero reading is reached (0 ± 3 ppb) and the instrument stability test function (a measure of the standard deviation taken from the last three data points) is less than 1 ppb, record 3 consecutive DAS display values, recorded approximately one minute apart. **These values are recorded in the calibration worksheet to document stability and are not used to zero correct calibration data points in the calibration worksheet.**

7. Set the transfer standard to produce an ozone concentration at the upper end of the calibration scale of the analyzer being verified or calibrated as read by the transfer standard. Typically, this value will be 320 ppb.

8. When the stability test function is less than 1 ppb, record three consecutive DAS values approximately one minute apart in the columns labeled "1st pt" for each analyzer. The calibration worksheet will calculate an average reading from the three entries.

9. Adjust the ozone transfer standard output to approximately 160, 70, and 30 ppb and repeat the procedure in step 8 for each point. Enter the data in calibration form columns 2nd pt, 3rd pt, and 4th pt respectively. Adjust the transfer standard to output zero air and repeat step 6. The calibration worksheet will automatically calculate averages for each set of values. The post-zero check is use to determine a pass/fail criteria for acceptable zero checks. The difference between the pre and post zero values for the analyzer and transfer standard must be within $\pm$ 3 ppb.

10. Each calibration or verification point must be within $\pm$ 2.1 percent or $\pm$ 1.5 ppb of the best-fit straight line whichever is greater to meet acceptable calibration criteria. The calibration worksheet will indicate a pass/fail status in the best-fit status row for each point evaluated. If any of the verification or calibration points indicate a fail status in the best-fit status cell, the analyzer fails the verification/calibration and corrective actions must be performed.

11. The best-fit regression equation on the calibration data sheet will automatically calculate the best-fit slope (m), intercept (b) and correlation (r) relationship of the best-fit straight line. These values are used to determine the best-fit true ozone, percent difference from best-fit ozone and difference from best-fit ozone. As noted above, the slope (m) of the best-fit straight line must be within 1.0 $\pm$ 0.05 (0.95 to 1.05) to meet acceptable

calibration criteria. If slope is greater than 1.05 or less than 0.95, cell will turn red. This indicates the analyzer fails the verification/calibration and corrective actions must be performed.

12. The calibration data sheet will automatically calculate the total percent difference of observed versus expected values. If these values are calculated manually, use the following equation.

$$Overall\%\ Accuracy = \left(\frac{S2 - S1}{S1}\right) * 100$$

Where:

S1 = Sum of expected values
S2 = Sum of observed values

13. Enter the previous best-fit calibration slope in the "previous cal. slope" cell. This will calculate the percent change from the previous calibration and display this value in the calibration summary section on page one of the calibration form. The calibration sheet will calculate this automatically.

14. Record the verification/calibration data on the Calibration Report (See References).

6.0 CALIBRATION (FINAL)

6.1 Calibration Overview:

As previously stated, a Final calibration is conducted when an instrument fails an AS-IS verification and/or after a major repair or maintenance. After performing the necessary maintenance, adjustments or instrument repairs, conduct a final calibration as follows:

6.2 Calibration Procedures:

1. Challenge the instrument with zero air until the reading stabilizes (not more than $\pm$ 2 ppb over a 5 minute period).

   NOTE: IF THE ANALYZER FAILS TO STABILIZE WHILE SAMPLING ZERO AIR, IT WILL BE IMPOSSIBLE TO ENTER ZERO AND IT WILL BE NECESSARY TO REFER TO THE TROUBLESHOOTING SECTION OF THE INSTRUCTION MANUAL.

2. Perform a zero alignment on the instrument by following the steps in the relevant instruction manual. For the 400E, refer to Section 8.2.3.2 "Zero/Span Point Calibration Procedure". For the T400, refer to Section 9.2.3.2 "Zero/Span Point Calibration Procedure". The instrument should now be zeroed, but the blinking cal light indicates that data is not being sent out. This status will last for approximately 5 minutes.

3. Challenge the instrument with an ozone concentration near the upper calibration range of the instrument. For CARB, this value will typically be 320 ppb. This level will be referred to as the span level. Allow the instrument to sample until a stable reading is achieved.

4. When the span level is stable, perform a SPAN adjustment to the instrument by performing the steps in the "Dynamic zero/span adjustment" section of the appropriate operating manual.

5. Obtain the instrument internal slope and offset from the instrument front display following the steps in the instruction manual. Record the final slope and offset on the Calibration Data Sheet (See References).

6. Return to Section 5.2 of this document, step 6-14 to complete the remaining steps of the final calibration. Ensure that the Final checkbox (on page one) is marked to indicated that this is a final calibration. Acceptable calibration criteria for the Final calibration is the same the criteria for a verification. If the analyzer still fails acceptable calibration criteria, refer to the instrument

operating manual for assistance in troubleshooting and repairing the analyzer or contact ODSS instrument laboratory staff.

6.3 Internal Ozone Generator Calibration:

The instrument can be configured with an optional IZS system. An internal ozone generator is included in this option which allows the instrument to feed a known amount of ozone through the analytical bench. **Historically this option was installed at ozone-only sites in the CARB monitoring network. However, field finding F04 in the 2015 US-EPA technical system audit indicated that the internal IZS system may not meet US-EPA requirements for one point precision checks. As a result, CARB will be phasing out the IZS system and installing stand alone ozone calibration systems to perform automated zero, precision and span checks.**

The ozone generator calibration (O3 Gen Cal) is used to calibrate the internal ozone generator output to match its generator lamp drive voltage. The lamp drive voltages and corresponding ozone levels produced are stored in an on-board lookup table which is used for future ozone generation tasks. The 400E and T400 IZS instruments measure the ozone generator lamp voltages and ozone concentration at five different levels. During the calibration process the screen will display the percent completed, taking approximately one hour to complete.

AQSB standard configuration indicates that the auto-calibration low span target value should be set for 70 ppb and the high span auto-calibration target value should be set for 320 ppb. Refer to the 400E instruction manual, section 7.4 "Manual Zero / Span (IZS) Calibration with Zero/Span Valve Option Installed" to set the IZS calibration parameters. Analogous documentation exists in the T400 instruction manual, section 3.8.4 "Initial Calibration and Conditioning of T400 Analyzers with the IZS Option Installed". Also, ensure that analyzers utilizing the IZS feedback option have their feedback mode set to *Ref*. If the IZS ozone concentration displays some fixed value higher or lower than 70 and 320, you may adjust these settings until the resulting display matches the targeted value.

At a minimum, the O3 Gen calibration must be performed following any change or rebuild of the sample pump, any adjustment of the flow rate, replacement of the photometer or O3 generator lamp, or any significant instrument repair or adjustment is made. **It is recommended to conduct an ozone generator calibration after an AS-IS verification, and required after a final calibration.**

Immediately following an O3 generator calibration, review nightly auto-calibration data and record the average of the next three precision and span values to determine the target values for precision, and span calibrations. These will become the new source values for use in determining for O3 precision and span percent from true values. Input the new precision and span values into the true value table in DMS.

6.4 Internal Zero/Span Check:

The IZS option allows the 400E/T400 to conduct automated internal zero, precision and/or span calibration checks on regular intervals. After conducting an ozone generator calibration, daily calibration checks can be scheduled. Detailed procedures can be found in the API 400E Instruction Manual, section 7.6 “Automatic Zero/Span Check with Zero/Span Valve Options Installed”. Analogous procedures can be found in the API T400 Instruction Manual, section 9.4 “Automatic Zero/Span Cal/Check (Autocal)”.

Note: No ZERO or SPAN adjustments to the instrument should be made based upon the results of the IZS zero/span checks.

7.0 OPERATIONAL AND ROUTINE SERVICE CHECKS

7.1 General Information:

The following routine service checks are to be performed in accordance with the maintenance schedule (Table 3). Perform the routine service checks at least at the prescribed intervals. **For instruments operated at highly polluted sites, site operators may need to perform these checks more frequently.** The AQSB Monthly Quality Control Check Sheet (See References) should be completed weekly and submitted monthly to the station operator's supervisor. The station operator must keep a copy of the Monthly QC Check Sheet in the air monitoring station records. Detailed routine maintenance procedures can be found in Chapter 11 of the operating manual.

Maintenance Task	Value/Action	Daily	Weekly	Monthly	Semi-Annual	Annually	As Required
Power On	On	X					
Error Flags/Review e-mail	None	X					
Review data systems/DAS	None	X					
Record Test Parameters	Record		X				
Change Inlet filter	Clean		X				
Fill out the AQSB QC Form	Complete		X				
Complete and Submit the AQSB QC Form	Submit			X			
Field calibration	Perform				X		
Change Sintered Filter and o-rings	Replace					X	
Perform Leak Check(1)	Perform					X	
Replace IZS Zero Air Scrubber	Replace					X	
Adjust photo lamp	< 2500 mV						X
O3 Gen Calibration	Perform						X
Clean Optical Chamber	Inspect/Clean						X

Table 4. Maintenance Schedule

(1) – Annually or after any maintenance or repair

7.2 Daily Checks:

Daily (or each site visit) review instrument diagnostic and concentration data, automated calibration values and chart recorders (if used) for any indication of analyzer malfunction. Review autoQC checks for values being flagged invalid. Check the instruments for any error messages.

Note: The T400/T400IZS CARBLogger driver clears warning messages in the legacy operating system, therefore, warning messages will not be displayed on the instrument front panel.

7.3 Weekly Checks:

Record test parameters on the AQSB QC Form 002 (API 400E/T400) check sheet. Change the particulate filter located inside the instrument.

7.4 Monthly Checks:

Complete and submit the AQSB QC Form 002 (API 400E/T400) check sheet to your supervisor along with station data.

7.5 Semiannual Checks:

Perform instrument multi-point calibration using the calibration sheet.

7.7 Annual Checks:

Inspect absorption tube, perform leak check and replace IZS zero air scrubber (IZS enabled units only).

Note: A leak check should also be performed after any maintenance or repair to the analyzer has occurred.

7.8 As Required Checks:

Clean optical chamber, absorption tube, and adjust photo lamp when O3 reference value is less than 2500 mV. In the event that this needs to be done, the instrument will require recalibration. Complete an ozone generator calibration upon completion of instrument calibrations, flow adjustments, pump changes or photometer and ozone generator lamp replacements. Record the date of any as required checks on the maintenance check list form attached to the instrument.

8.0 MAINTENANCE PROCEDURES

8.1 General Information:

The instrument is designed to operate unattended for long periods of time. Other than the routine service checks outlined in section 6.0 of this SOP, the 400E/T400 need very little maintenance. However, preventative maintenance requirements may vary from instrument to instrument, thus operators should refer to the instrument instruction manual to become familiar with maintenance requirements.

If station operators cannot repair an instrument using procedures stated in the instruction manual, contact the Operation Data Support Sections Instrument Laboratory for assistance.

9.0 TROUBLESHOOTING

9.1 General Information:

TAPI ozone analyzers have been designed to rapidly detect possible problems and allow for their quick evaluation and repair. During operation, the analyzer continuously performs self-test diagnostics and provides the ability to monitor the key operating parameters of the instrument without disturbing monitoring operations. If being run with CARBLogger, any diagnostic parameters which drift outside of the acceptable range will cause and alert to be emailed to the site operator.

The table below lists common errors and possible solutions. If the issue or solution is not listed in the table, operators should refer to Chapter 11, "Troubleshooting and Repair Procedures" in the 400E/T400 instruction manual. Operators can also contact ODSS instrument laboratory staff for additional assistance.

Problem	Solution
Low flow warning	Perform a leak check and verify only one in-line filter is in filter holder. If no leak found, rebuild or replace pump. Verify analyzer flow reading with an external flow meter.
Lamp or photometer reference warning	Check lamp voltage test function. Adjust or replace lamp. Lamp voltage should be between 2500 – 4900 mVDC.
Minute not matching CARBLogger error	Adjust analyzer clock to match time on CARBLogger.
Automated calibrations drift out of acceptable criteria ($\pm$ 7.1%)	Verify with certified standard, perform leak check, and replace Sample/Reference valve.

Table 5. Common Troubleshooting Issues

10.0 QUALITY CONTROL AND ASSURANCE

10.1 General Information:

CARB monitoring stations have been configured for automated QC checks. These checks are performed using the station gas dilution system or the IZS function of the 400E or T400 analyzer. Please refer to the appropriate gas dilution system SOP for more information.

10.2 Quality Control:

Station operators will monitor the automated QC checks on a daily basis using the guidelines below. Nightly zero checks are considered acceptable if the zero drift is < ± 3.1 ppb (24 hr) or < ± 5.1 ppb (>24 hr-14 day). Precision and span checks are considered acceptable when the percent difference from true is < ± 5%. The "warning" level is reached when the precision check is > ± 5%. The operator should observe the analyzer performance closely and if necessary, take corrective action prior to the analyzer exceeding ± 7.1% from true.

The "action level" is reached when the automated QC check response for ozone varies ± 7.1% from true. When the "action level" is reached, the station operator must take corrective actions. Corrective action means that calibration staff (staff independent from the site operator, if possible) using independent certified transfer standards, verify that QC check results are valid and are not simply caused by a problem with the calibration system (i.e., faulty O3 generator or zero air supply etc.). If it is determined that an instrument has malfunctioned or drift has occurred causing the instrument to read outside of acceptable criteria, staff should determine the cause of the problem, perform necessary maintenance or repairs and document the investigation. All corrective actions should be documented on QC maintenance sheets, recorded in station logbooks and optionally electronically documented in the data management system.

Any data collected when the analyzer exceeded the "action level" should be invalidated unless there is compelling evidence or reasons for not doing so. If the data is to remain valid, the data should be flagged with an appropriate AQS qualifier code. Refer to AQSB SOP 610, Data Review and Validation for additional guidance on data review and validation.

NOTE: Like air monitoring instruments, QC systems may fail, yielding invalid QC results. For this reason, ambient data should not be invalidated based solely on QC data. Reviewers must check all other available information to determine if any data should be invalidated.

10.3 Quality Assurance:

CARB Monitoring sites conform to the quality assurance procedures found in the CARB Quality Assurance Program Plan for Gaseous Pollutant Air Monitoring Program (QAPP). Please refer to the QAPP for additional information.

REFERENCES

- Primary Quality Assurance Organization (PQAO) website
  Link to PQAO Website
- CARB QAPP for Gaseous Pollutant Air Monitoring Program
- AQSB SOP 605 CARBLogger
- AQSB SOP 606 Data Management System
- AQSB SOP 610 Data Review and Validation
- Teledyne API Instrument Manual 400E Rev F
- Teledyne API Instrument Manual T400 Rev F
- Teledyne API Instrument Manual T400 w/ NumaView Software

APPENDIX A. AQSB MONTHLY MAINTENANCE QUALITY CONTROL FORM 002

CALIFORNIA AIR RESOURCES BOARD
MONTHLY MAINTENANCE QUALITY CONTROL FORM
TELEDYNE API MODEL T400/400E OZONE ANALYZER

Location: ______________ Month/Year: ______________
Station Number: ______________ Operator: ______________
Property Number: ______________ Agency: ______________

DIAGNOSTIC PARAMETER READINGS

Parameter	Acceptable criteria	Value	Value	Value	Value
DATE	Current date				
TIME (PST)	Current time of day (HH:MM)				
STATION TEMP	20 to 30 °C				
O3 MEAS	2500-4900 mV				
O3 REF	2500-4900 mV				
O3 GEN (IZS ONLY)	*80-5000 mV (Record Only)*				
O3 GEN DRIVE (IZS ONLY)	*0-5000 mV (Record Only)*				
PRES	*0-2" Hg < ambient (Record Only)*				
SAMPLE FLOW	720 ± 80 cc/min				
SAMPLE TEMP	Station Temp ± 15°C				
PHOTO LAMP	Photo Lamp Temp. 58 ± 1°C				
O3 GEN TEMP (IZS ONLY)	O3 Generator Temp. 48 ± 3°C				
BOX TEMP	Station Temp ± 8°C				
SLOPE	1.0 ± 0.15 – No Changes				
OFFSET	< ± 5 ppb – No Changes				

OPERATOR INSTRUCTIONS:

1. Daily Checks: Review DMS data, control charts and CL diagnostic e-mail.
2. Weekly Checks: Record test parameters.
   Change inline 5 μm particulate filters. Date:_____/_____/_____/_____/_____
3. Semi-Annual: Calibrate analyzer. Date last performed:________________
4. Annual: Replace sintered filter and o-rings. Date last performed:________________
   Replace zero air scrubber (IZS only) Date last performed:________________
   Perform leak check Date last performed:________________
5. As Required: Clean optical chamber
   Adjust photo lamp when O3 ref < 2500 mV
   Rebuild pump
   Replace O3 scrubber

Date	Comments or Maintenance Performed:

______________________ ______________________
Reviewed by: Date:

AQSB QC Form 002 TAPI T400 (November 2019)

APPENDIX B. AQSB CALIBRATION REPORT 002 (Page 1).

ARB Calibration Report -- Ozone Analyzer

Calibration Report:

ID Information: / **Instrument:** / **Calibration:**

Station Name:	Whoville-Main St.	Make:	API	"As Is"	X
AQS Site #:	06-001-0001	Model #:	T400	"Final"	
Station Address:	1234 Main St.	Property #:	2012000	Calib. Date	12/16/2019
Agency:	CARB	Serial #:	100	Report Date	12/20/2019

Flow Transfer Standard I.D.:

Make & Model:	ARB 4 in 1
Prop. #:	20021155
Cert. Date:	4/21/2019
Cert. Exp.:	4/21/2020

Meteorology:

Temp. (Deg. C):	18.0
Press. (mm Hg):	762.0
Elevation (Ft.):	5000
ACF:	0.8299

Flow Transfer Standard Equation:

	m:	x:		b:	
Air Flow =	1.0045	*Avg. Display	+/-	-0.0148	SLPM

Calibration Results:

Pollutant:		Ozone
Instrument Range, ppb:		0 -500
	Slope:	1.0527
Best Fit Line	Intercept:	-0.0021
	Correlation:	1.0000
"As Is" Percent Deviation from True:		4.2%
% Diff. from Prev. Cal. (2/23/2017)):		5.4%
Zero Air Verification		-1.0

Diagnostic Parameters:

Time:	13:05	hh:ss
Range:	500	(ppb)
Stabil:	0.55	
O3 Meas.:	4430	(mV)
O3 Ref.:	4430	(mV)
Xfr. Flow Std. Display:	0.609	(LPM)
O3 Inst. Flow Disp.:	601.0	(cc/m)
Xfr. Std True Flow :	596.9	(cc/m)
O3 Inst. Flow (Alt Corr.):	724.2	(cc/m)
Sample Pres.:	30.0	(" Hg)
Sample Flow:	720	(cc/m)
Sample Temp:	34.0	(°C)
Photo Lamp	58.0	(°C)
Box Temp.:	40.0	(°C)
Slope:	1.087	
Offset :	-0.3	(ppb)
*O3 Gen Temp:	40.0	(°C)
*O3 Gen:	4500.0	(mV)
*O3 Drive:	4500.0	(mV)

(* apply to IZS enabled instruments)

Zero Air Source:

Make:	API
Model:	751
Barcode:	2015000
Serial No:	1234

Ultrapure Air Cylinder:

Make & Model:	SM
Cylinder Number:	CC12345
Certification Date:	6/12/2019
Cylinder Press. (psi):	1400
Outlet Press. (psi):	25

Data Acquisition System (DAS):

Make:	CL
Model:	T610
Barcode:	20021256
Serial No:	1234

OzoneTransfer Standard I.D.:

Make & Model:	Tanabyte	O3 Lamp Temp (°C):	50.2
Property No.:	20062012	O3 Flow (LPM):	0.13
Serial No.:	186	O3 Press (mmHg):	753
Air Flow Setting:	6.0	Photometer Temp	27.3
Air Flow (slpm):	5.9	Photo Lamp Temp	44.5
Cert. Date:	4/12/2010	Photometer Flow	1.70
Cert. Exp.:	4/30/2011	Photometer Press	754

APPENDIX C. **AQSB CALIBRATION REPORT 002 (Page 2).**

ARB Calibration Report -- Ozone Analyzer

Ozone Transfer Standard Correction Equations:

	m :	x :		b :	
True Ozone =	1.0000	*Avg. Display	+/-	0.0000	ppm Ozone
True Air Flow=	0.9856	*Avg. Display	+/-	-0.0020	LPM

Calibration Data:

Zero Air Verification:

	Air Cylinder	Air Generator
Inst. Zero (ppb)	-1.0	0.0
Difference (ppb)	-1.0	

Difference must be less than +/- 3.0 ppb to use zero air generator

Transfer Standard Data:

Number Lamp Intensity (%)	Pre Zero	1st Point 28.5	2nd Point 23.2	3rd Point 18.9	4th Point 7.5	Post Zero
1	-0.0030	0.3980	0.2490	0.0890	0.0480	0.000
2	-0.0030	0.3980	0.2490	0.0890	0.0480	0.000
3	-0.0030	0.3980	0.2490	0.0890	0.0480	0.000
Xfer Std Ave Display:	-0.0030	0.3980	0.2490	0.0890	0.0480	0.000
True Ozone (ppm):		0.3980	0.2490	0.0890	0.0480	

Analyzer: Readings recorded by CARBLogger

Number Target (ppb)	Pre Zero	1st Point 320	2nd Point 160	3rd Point 70	4th Point 30	Post Zero
1	-0.0010	0.4170	0.2600	0.0910	0.0490	0.0000
2	-0.0010	0.4170	0.2600	0.0910	0.0490	0.0000
3	-0.0010	0.4170	0.2600	0.0910	0.0490	0.0000
Avg. DAS Display:	-0.0010	0.4170	0.2600	0.0910	0.0490	0.0000
Analyzer Display (ppm):	0.0000	0.4230	0.2600	0.0900	0.0490	0.0000
Best Fit True O3		0.4169	0.2600	0.0916	0.0484	
% from True (PTP):		4.77%	4.42%	2.25%	2.08%	
Diff. from True (ppb):	-0.002	19.0	11.0	2.0	1.0	0.000
Best Fit % difference		0.02%	-0.02%	-0.66%	1.15%	
Diff. from best fit (ppb)		-0.1	0.0	0.6	-0.6	
Best Fit Status:		Pass	Pass	Pass	Pass	

Best Fit Regression Equ.:

Analyz. Resp.= True O3 * x + b (ppm)	
x :	1.0527
b :	-0.0021
r^2	1.0000
Previous Cal. Slope:	0.9987

Overall Deviation from True:

Sum of Corr. TS Ave's. (S1):	
S1:	0.7840
Sum of Corr. DAS Ave's. (S2):	
S2:	0.8170
% Deviation:	4.2%

Pre/Post Zero Check

	Diff. (ppb)
Transfer Std.	0.003
Analyzer	0.001

Comments:	
Calibrated by:	**Reviewer:**

APPENDIX D. TELEDYNE STANDARD IDAS CONFIGURATION (Legacy).

The analyzer's internal data logger (iDAS) factory default configuration records hourly concentration data. The AQSB's Data Management System (DMS) is configured to ingest minute based data for most parameters. The AQSB's CARBLogger (CL) queries minute-based data from instruments that CL monitors. To provide an equivalent data back-up in the event that CARBLogger goes down, all ARB site operators should configure **ALL** TAPI instruments to record minute concentration data.

The procedures to program TAPI iDAS to record minute based data is as follows:

1. **WARNING: RECONFIGURING THE iDAS WILL CLEAR ALL RECORDS**. If you need to archive data, download the data from the analyzer prior to reconfiguring the iDAS. The iDAS can be reconfigured via the front panel controls. From the main menu, press the SETUP soft key.

2. Press the DAS key to view the iDAS settings. Next press the EDIT key to begin editing iDAS settings. The instrument will prompt for a password. Enter 929 and press ENTR to begin editing the iDAS settings.

3. The "Conc" channel is the default hourly average data channel. For all TAPI instruments this channel is pre-configured with the concentration data and on some instruments a diagnostic channel. Press the EDIT soft key to begin editing the channel.

4. Press [SET>] until the "Report Period" parameter is displayed. Press the [EDIT] key until the "Report Period Days" field is displayed. Ensure that "Report Period Days" is set to 000. Press [ENTR] to display the "Report Period Time". Set the "Report Period Time" field to "00:01" and select [ENTR].

5. Press [SET>] until the "number of records" parameter comes up. Press the [EDIT] key to change this value. To maximize storage of records, use the following procedure:

    a) The analyzer will prompt you to clear all data. Press [YES] if you have backed up your data and move on to step b, otherwise press [NO] and download the data from the analyzer. After downloading, perform steps 1-6 again.

b) Set the number of records to all zeroes. The [ENTR] button will only appear if the number of records is a valid number, and will disappear if the number of records exceeds available memory. Increment the highest digit (leftmost digit, will either be the "tens of thousands" digit or "hundreds of thousands" digit) by one until the [ENTR] button disappears. Lower the value by one and press [ENTR]. The value for this digit is now maximized.

c) Perform the procedure in step b for next digit to the right. Continue until all values have been maximized. Once the "ones" digit has been completed the maximum number of records will have been selected. Press the [ENTR] key to save the value.

6. Press the [SET>] key until "RS 232 Report" value appears. Set to [OFF] and press [ENTR], or press [SET>] if already the parameter is already set to [OFF].

7. Press the [SET>] key until "Channel Enabled" value appears. Set to [ON] and press [ENTR], or press [SET>] if the parameter is already set to [ON].

9. Press the [SET>] key until "Cal Hold" value appears. Set to [OFF] and press [ENTR], or press [SET>] if the parameter is already set to [OFF].

10. The iDAS is now configured to store 1 minute concentration averages. Press [EXIT]. The analyzer will display "Creating New Data File" and a percentage counter as it resets data storage. Continue pressing [EXIT] until the sampler returns to the main screen.