



Air Monitoring Directive Chapter 7: Verification and Calibration

Amends the original Air Monitoring Directive published
June, 1989

DRAFT Version 2026

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1.0 Purpose

This Verification and Calibration document forms a part (Chapter 7) of Alberta's Air Monitoring Directive (Alberta Environment and Parks 2016, as amended from time to time) and will hereafter be referred to as the Verification and Calibration Chapter (formerly known as the Calibration Chapter; all references to the Calibration Chapter should be understood to refer to this document). Refer to the AMD Introduction (Chapter 1) for requirements and definitions that apply to all parts of the AMD, a list of what components constitute the AMD, and details on review of and revisions to the AMD.

The purpose of the Verification and Calibration Chapter is to:

- outline the minimum requirements for verification and calibration of continuous ambient air analyzers and meteorological sensors; and
- promote consistent use of air monitoring equipment across the province.

The multi-point as found verification is a robust quality control check that challenges the analyzer with known calibration gas concentrations across its calibration scale to ensure the analyzer is working as it should be and that any error in its measurement is still within acceptance criteria. When performed on an operational analyzer in the field, the verification demonstrates the “as found” status of the analyzer and can be used to verify past data before an analyzer is tested, while calibration adjusts analyzer settings, as required, to assure future data validity.

Calibration of an analyzer establishes the quantitative relationship between known substance concentration in an input gas stream (derived from traceable standards – referred to as a “calibration gas”) and the analyzer's response (output volts, digital output, etc.). The relationship between the input gas stream and the analyzer response is used to adjust analyzer response values to corresponding pollutant concentrations (in ppm, ppb, $\mu\text{g m}^{-3}$, etc.). Since analyzer response can change somewhat with time (drift), a verification must be conducted periodically to maintain a high degree of accuracy.

In summary, verifications are different from calibrations. “Verification” should be understood to mean that the instrument is not adjusted, whereas “calibration” indicates an adjustment to the instrument. See Table 1 for further details.

VC 1-A	<i>The person responsible must comply with the requirements in the Verification and Calibration Chapter on or before MMMM DD, YYYY for all continuous ambient air analyzers and meteorological sensors.</i>
VC 1-B	<i>The person responsible must conduct verifications and calibrations on continuous ambient air analyzers and meteorological sensors (a) in accordance with the requirements of the Verification and Calibration Chapter and (b) as specified in the analyzer's operation or instruction manual.</i>
VC 1-C	<i>Any conflict between the Verification and Calibration Chapter and an analyzer manufacturer's instruction or operation manual must be resolved in favour of the Verification and Calibration Chapter, unless otherwise authorized in writing by the Director.</i>

1.1 Amendments

2026 – As drafted here; will be updated and dated for final release.

1. This update represents a substantial change from previous versions. The title is changed to “Verification and Calibration,” to reflect the addition of multi-point as found verifications, and clauses are now numbered “VC” instead of “Cal” accordingly. References are updated throughout. Whereas this change log previously had detailed notes on incremental edits to highlight the differences as they could otherwise be overlooked, this version should be read as if it were a new document. For that reason, the amendments for this version will note the broader and/or significant differences from the previous version, and the amendments between older versions have been removed from this document. Archived versions of the chapter are available on the Open Government website, however, for historical purposes. Clauses referenced refer to this version.
2. Update to document design/branding.
3. Noted all references to “Calibration chapter” should be understood to refer to this document in section 1.0.
4. Added description of verification and updated description of calibration.
5. Updated effective date in VC 1-A.
6. Major update to section 2.0 to include verification, and added Table 1 to describe and define calibration and verification and summarize when each are needed.
7. Collected requirements for when a verification is needed in VC 2-A.
8. Added extensive general guidance on calibrations and verifications.
9. Collected requirements for when a calibration is needed in VC 2-B.
10. Added a flowchart (Figure 1) to visualize when verification, calibration, and corrective action are required.
11. Clarified requirements for in-person vs. remote work in VC 2-C and following guidance.
12. Clarified equipment temperature requirements in VC 2-D and following guidance.
13. Corrected range requirement relative to Alberta Ambient Air Quality Objectives in VC 2-J.
14. Clarified requirements for non-linear analyzers VC 2-K and following guidance.
15. Clarified that “calibration gas” refers also to gas used for verifications in section 3.0, and added guidance on cylinders that are past their certification expiry date.
16. Clarified in section 3.3 that the published flow measurement procedure is optional by noting operator ability to specify flow rate measurement procedures in their SOP.
17. Added description of zero/span tests in section 4.0.
18. Removed guidance suggesting zero/span tests be run from 45 minutes past the hour to 15 minutes past the hour due to difficulty in accomplishing these tests in this timeframe.
19. Added flexibility in timing and duration of zero/span tests in VC 4-A(a) and (b) and associated guidance.
20. Added guidance on when zero/span tests are and are not considered uptime.
21. Reduced lower end of span gas concentration range from 40% to 25% in VC 4-A(d).
22. Section 5.0 has been substantially updated to provide guidance and requirements on the multi-point as-found verification procedure. VC 5-A contains the general requirements of verifications and calibrations, while the procedural requirements are in VC 5-B through VC 5-G, and have been extensively changed. At this time, specific considerations for verifications and calibrations of direct NO₂ analyzers are still in development.
23. Removed permeation as a verification and calibration method. Retained requirements and guidance on use of permeation devices for daily span tests and as a method for challenging scrubber efficiency.
24. Updated clause and guidance on location of introduction of calibration gas in VC 5-A(a).
25. Updated clause and guidance on unadjusted data in VC 5-A(b).
26. Updated clause and guidance on calibration system temperature in VC 5-A(c).
27. Updated clause and guidance on purging the regulator in VC 5-A(d).

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28. Updated clause and guidance on calibration system temperature in VC 5-A(g).
29. Noted verification required for all parameters measured by a multi-parameter instrument in VC 5-A(i).
30. Updated guidance to reflect addition of verification in sections 5.1 to 5.3.
31. Condensed procedural clauses in section 5.2.2 to improve readability.
32. Updated requirement in VC 5-N to respond to out-of-range converter efficiency to take corrective action.
33. Added section 2.2 with clause and guidance on PM_{2.5} analyzer verifications.
34. Minor updates in section 6.0 to change “instruments” to “sensors” or “systems”
35. Major update to section 7.0 to simplify requirements from prescribed steps to following of manufacturer specified methods, added reference to acceptance criteria in Table 5.
36. Minor update to section 8.0 to reflect renaming of the chapter.
37. Major update to section 9.0 to collect verification and calibration acceptance criteria for continuous gas analyzers (Table 3), continuous meteorological sensors (Table 4), and continuous and integrated particulate analyzers (Table 5). Criteria are now noted in these tables rather than in clauses for simplicity, and added guidance on gas analyzer criteria.
38. Added requirements to investigate root cause of failure to meet criteria and flagging measurements in VC 10-C. Added guidance on determining validity of data, and on need to report contraventions requiring corrective action.
39. Removed digital system time resolution specification from VC 11-C.
40. Updated report requirements in VC 11-D to reflect verification, and add elements such as the reason for the verification or calibration, whether it was routine or non-routine, response error results, previous correction factors, percent difference of correction factors, and graph of analyzer output.
41. Provided requirements for particulate analyzer verification reports in VC 11-E.
42. Removed previous Appendix B – zero and span control chart sample as this is now generated by most DAS software.
43. Appendix B now contains expanded guidance on calculation of acceptance criteria.
44. Modified description of Least Square Regression Analysis in Appendix B to note that the calculations are available in off-the-shelf software, however formulas are retained for reference.
45. Simplified Appendix C and clarified its applicability to daily span tests.
46. Combined dilution and gas phase titration calculations into Appendix D for simplicity.
47. Corrected equation for conversion of volumetric to mass flow in Appendix E.
48. Updated example reports in Appendix G. Example reports will now only be found within the chapter, and not hosted separately on the web site.

2.0 Multi-point As Found Verification and Calibration Requirements

Verification and calibration are used to verify and establish the accuracy and linearity of analyzers, and ultimately ensure collection of quality assured data. Table 1 defines multi-point as found verification and calibration and summarizes when each is used. Detailed guidance on the different considerations operators will have to make when undertaking multi-point as found verifications and calibrations follows.

Table 1 Verification and Calibration Description and Frequency

Description / Purpose	When is this required?
<p>Multi-point as found verification Challenge of the analyzer, using traceable standards and materials, across its calibration range to initially establish and subsequently verify accuracy and linearity at regular intervals to ensure data validity (includes zero and at least three upscale points)</p>	<ul style="list-style-type: none"> • At least once every three months • When daily zero and span test results do not meet defined tolerance levels • Prior to analyzer repair, maintenance, modification, or calibration • Prior to decommissioning a station, or taking an analyzer out of service • After interruption in operation of more than four consecutive days
<p>Calibration Instrument adjustment that establishes a quantitative relationship between instrument response and expected concentration (includes a zero and upscale adjustment at the analyzer's calibration range)</p>	<ul style="list-style-type: none"> • After setting up a station, adding a new analyzer, or replacing a defective analyzer • After analyzer repair, maintenance, or modification either as a result of corrective action following multi-point as found verification results outside defined tolerance levels or for any other reason • According to the minimum frequency specified by the analyzer manufacturer

VC 2-A *The person responsible must conduct a multi-point as found verification, provided the analyzer is responsive to calibration gas, at a minimum:*
 (a) *at least once every 3 months;*

The three-month frequency in VC 2-A(a) should be interpreted as applying to calendar months. For example, if a multi-point as found verification is performed on any date in the month of January, then the next multi-point as found verification must be performed no later than the last day of April.

The frequency of at least once every three months for routine multi-point as found verifications is a minimum. The person responsible may conduct multi-point as found verifications more frequently as an interim check to confirm data validity (for example monthly or weekly remote multi-point checks in between in-person verifications every three months). This may be dependent on the analyzer's specific requirements, including drift history, or the ability of the person responsible to track analyzer diagnostics in between routine multi-point as found verifications. The person responsible may conduct routine multi-point as found verifications more frequently if the system is not capable of storing and providing access to analyzer diagnostics and trends for ongoing evaluation. Routine additional multi-point as-found verifications that are documented in the QAP, whether performed in-person or remotely, would count as operational time.

Technological improvements have brought enhancements to tracking of internal instrument diagnostics. Examples of diagnostics that could be reviewed and tracked between routine verifications may include (as applicable): sample flow rate and various internal instrument temperatures, pressures, and voltages. Daily zero and span test results as well as hourly data should be regularly reviewed to catch potential issues and avoid data loss. Automatic alarms may also be set up to alert operators when tolerances set by the person responsible have been exceeded. Operators should strongly consider making use of such advancements to maintain equipment in top working order.

(b) within 72 hours of (i) any daily span test result that deviates from the expected response by $> \pm 10\%$, (ii) any daily zero test result that deviates from zero by $> \pm 3\%$ of the analyzer's calibrated range, or (iii) restoration of operation following an interruption in operation of > 4 consecutive days; or

The tolerance levels for the daily zero and span tests in VC 2-A(b)(i) and (ii) are maximums for triggering a multi-point as found verification. The person responsible may choose to set a lower tolerance level to initiate a multi-point as found verification sooner. This must be specified in the QAP.

If the person responsible can reasonably demonstrate that a daily span test result $> \pm 10\%$ or zero test result $> \pm 3\%$ is due to an error with the zero-span system or a data system or communication error, they must address the error and repeat the zero and span test. A multi-point as found verification would not be required if the follow up test meets the tolerance level in VC 2-A(b); however, the additional zero and span test would not count as operational time because it would be outside of normal and planned QA/QC activities. See the Data Quality Chapter (Chapter 6) of the AMD for additional details.

If an MAFV following daily zero-span results outside of the criteria in VC 2-A(b)(i) and (ii) shows results within acceptance criteria and the analyzer appears to be working properly, that suggests an issue with the zero-span system. This should be investigated and corrected to prevent recurrence.

(c) prior to (i) any repair or maintenance work or (ii) shut down of an analyzer for removal or replacement.

Maintenance refers to planned activities consisting of either adjustments to analyzer electronics, optical settings or factors used by the analyzer logic (excluding zero and span calibration factors), or scheduled replacement of components (excluding inlet filter change) based on manufacturer recommended or SOP derived intervals. The analyzer is assumed to be functioning correctly before this planned maintenance; the maintenance activities are intended to optimize analyzer operation and prevent future breakdowns.

Maintenance can be scheduled around the routine multi-point as found verification to make efficient use of time and reduce station visits.

Repair refers to activities targeted at correcting a problem with an analyzer. The issue may be chronic (a longer term persistent problem) or acute (sudden failure of an analyzer sub-system). If the analyzer is functioning highly incorrectly, and / or is not responsive to calibration gas a multi-point as found verification would not be possible.

Some routine activities do, and some do not require the operator to first perform a multi-point as found verification. Anything that is not expected to result in a change to analyzer response does not require a multi-point as found verification. Examples include changing the inlet particulate filter, changes to parts not in line with the analyzer, exchanges of carrier gas such as nitrogen support gas for hydrocarbon or BTEX analyzers or hydrogen for THC analyzers, or inlet or manifold cleaning (or any other components upstream of the inlet filter assembly).

However, other activities could result in a change to analyzer response and would require a multi-point as found verification to first be performed. These include changes to anything in the pump or analyzer, anything in sample line downstream of the filter (except the filter itself), any changes to the zero air generator, or exchange of the daily span gas cylinder. Note, if span results after a multi-point as found verification and exchange of the span gas cylinder are not within the criteria listed in VC 2-A(b)(i) and (ii) then corrective action should be taken.

Shut down of an analyzer refers to shut down prior to removal of the analyzer from the station or removal of the station as a whole.

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When conducting multi-point as found verifications, the analyzer's response will be verified for all parameters that the analyzer is designed to measure. The objective of the multi-point as found verification is to demonstrate whether the analyzer continues to meet performance acceptance criteria for linearity and accuracy. The results of the multi-point as found verification are then used to determine if there is a need for maintenance and/or repair and subsequent adjustment. The procedure before maintenance or repair is a verification of system performance, not a calibration, and no adjustments are made. The verification is critical to assess performance and validate the data obtained backward in time to the previous verification or calibration prior to making any changes (e.g., maintenance) to an analyzer.

VC 2-B Calibration of gas analyzers must be conducted by the person responsible per manufacturer specified procedures, at a minimum:

- (a) within 3 days of initial installation of the analyzer;*
- (b) after repairs or maintenance work, if conducting a calibration is possible; or*
- (c) according to the minimum frequency specified by the analyzer manufacturer.*

The person responsible may choose to set criteria to initiate a calibration after the full completion of the multi-point as found verification based on the results of the multi-point as found verification. This would need to be specified in the QAP, but time spent on such a calibration would be considered routine maintenance and would not count against operational time.

See Figure 1 for an illustration of daily zero and span test and multi-point as found verification frequency, tolerance levels and acceptance criteria. Note that this is not a full flowchart; it only shows the criteria that would trigger an action. Under routine operation, and when acceptance criteria are met, many of these steps will likely not be required.

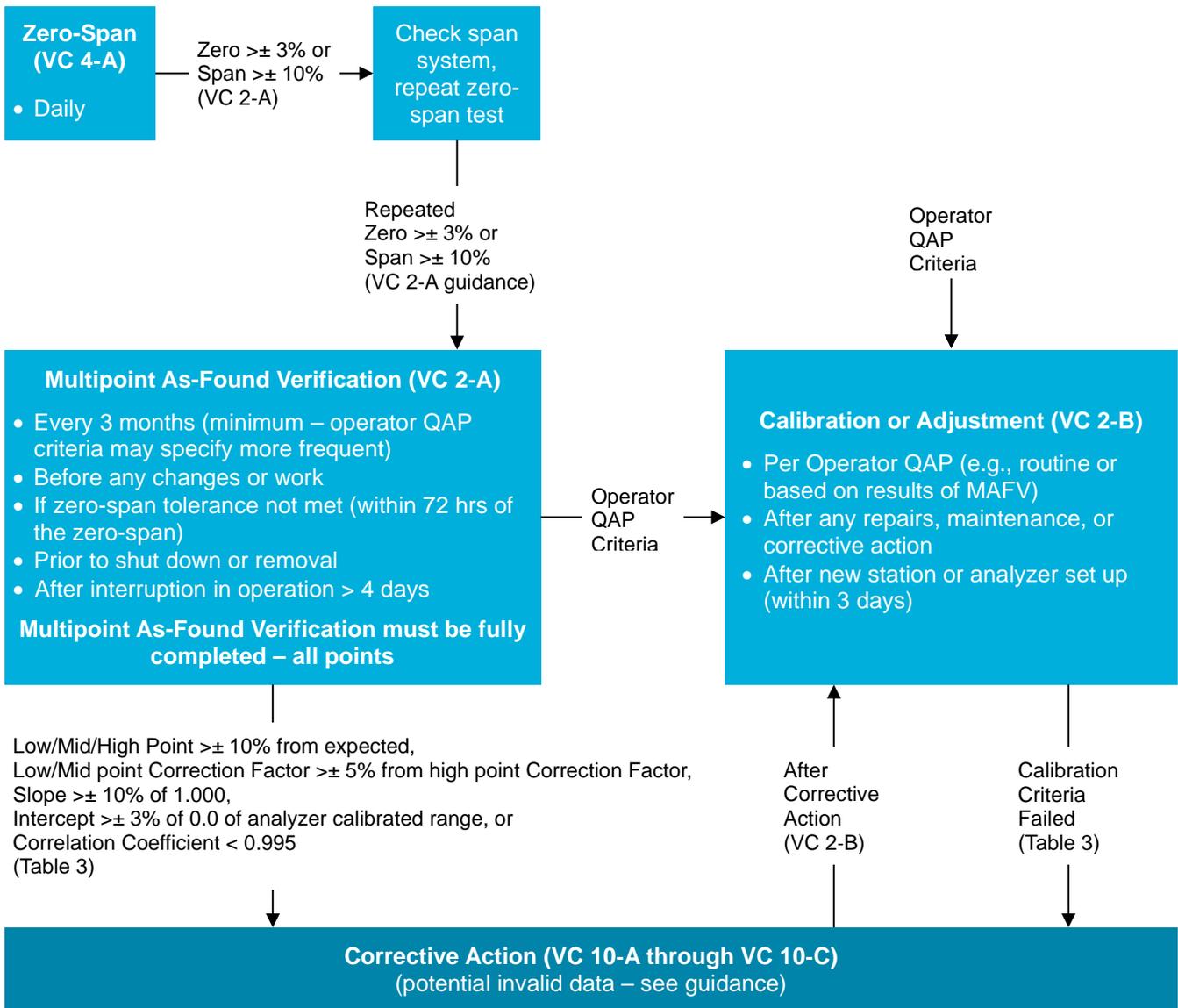


Figure 1 Flowchart of Zero-Span, Verification, and Calibration Requirements

2.1 General Requirements

The station operator should perform a visual inspection of wind sensors and function checks on continuous analyzers during each visit to the continuous ambient air monitoring station. Function checks on continuous analyzers should include checking for abnormal performance, including:

- excessive signal noise;
- unstable baseline;
- positive and/or negative drift;
- spiking;
- long response time;
- incorrect flow/pressure readings;
- warning light indications; and
- pump or power failure.

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Corrective action should be taken to restore analyzer performance if performance is not up to specifications.

The Audit Chapter (Chapter 8) of the AMD outlines requirements for verifying the accuracy of calibrators on an annual basis as well as other requirements related to audits.

VC 2-C The person responsible must conduct multi-point as found verifications on each analyzer at the field monitoring site where the analyzer operates, unless (a) conducting an additional system check more frequently than the requirements in VC 2-A, or (b) authorized in writing by the Director.

In VC 2-C, the person responsible is able to conduct additional system checks remotely outside of routine verification or response to an analyzer issue or change as specified in VC 2-A. Any such additional checks under VC 2-C(a) must be described in the QAP. Otherwise, the multi-point as found verification must be performed in-person unless authorized by the Director under VC 2-C(b) (e.g., for personnel safety reasons such as inability to safely access the field monitoring site due to wildfire).

VC 2-D The person responsible must keep (a) the analyzer and (b) all calibration equipment within the equipment operating temperature range specified by the manufacturer prior to and during a multi-point as found verification or calibration.

In the case of a compact, modular-style air quality monitoring system, minimizing the tubing length for connection to external span gas, use of insulated tube wrapping, keeping external span gas and calibration equipment in a temperature-controlled environment, and avoiding verification or calibration during extreme ambient temperatures are possible ways of maintaining equipment operating temperature.

VC 2-E While conducting a multi-point as found verification or calibration, the person responsible must:
(a) have the analyzer operating in its normal sampling mode; and
(b) sample the test atmosphere through all filters, scrubbers, conditioners, and other components used during normal ambient sampling and through as much of the ambient air inlet system as is practicable.

VC 2-F The person responsible must conduct the multi-point as found verification or calibration at the analyzer's normal operating range.

Analyzer operating range requirements are outlined in the Monitoring Chapter (Chapter 4) of the AMD.

VC 2-G When an analyzer will be used for more than one range, or when an analyzer has auto ranging capability, the person responsible must verify and calibrate the analyzer separately on each applicable range.

VC 2-H During a multi-point as found verification or calibration, the person responsible must:
(a) log all data collected; and
(b) flag the data system to ensure the data is not reported as valid ambient data.

VC 2-I When conducting the multi-point as found verification in VC 2-A and the calibration in VC 2-B, the person responsible must include a zero concentration and a minimum of three test concentrations within the analyzer's operating range.

VC 2-J *In the event that the AMD does not specify an operating range for an analyzer:*
(a) the full scale of the analyzer must be, at a minimum, two times the short-term Alberta Ambient Air Quality Objective, when an Alberta Ambient Air Quality Objective exists, unless otherwise authorized in writing by the Director; and
(b) a minimum of three concentrations must be spaced equally over the scale range at (i) 10-20%, (ii) 30-40%, and (iii) 60-80% of full scale.

In the absence of an Alberta Ambient Air Quality Objective for the compound of interest, a concentration between 60% and 80% of the full scale range of the analyzer undergoing verification or calibration should be used for the highest upscale point.

VC 2-K *When verifying or calibrating an analyzer whose output to a data logger is non-linear (a) by design and (b) over any part of the measurement range over which it will be operated, the person responsible must include a minimum of 5 upscale points, unless the instrument manufacturer clearly specifies an alternate number of upscale points for verification or calibration that may be used, in which case the person responsible may follow the manufacturer's requirements.*

If possible, verification points for analyzers non-linear by design should be plotted or evaluated statistically as they are obtained (i.e., if the analyzer provides this capability) so that any irregular points can be investigated or repeated immediately using one of the following methods:

- the analyzer readings are plotted against the respective test concentrations, and the best nonlinear curve to fit the points is determined; or
- least squares regression analysis (see Appendix B), with an appropriate transformation of the data for non-linear analyzers.

VC 2-L *For analyzers in routine operation, the person responsible must not make any adjustments prior to performing as-found zero and span tests or multi-point as-found verifications.*

VC 2-M *For zero and high point adjustments, the person responsible must not use data that has been corrected for zero or slope.*

VC 2-N *Analyzers that have zero and high concentration adjustment controls must be adjusted based on the (a) zero and (b) highest test concentrations, respectively, during adjustment.*

2.2 PM_{2.5} Verification

VC 2-O *The person responsible must verify the operation of continuous PM_{2.5} monitors in accordance with manufacturer specified procedures and established standard operating procedures:*
(a) at least once every 3 months;
(b) upon instrument installation or relocation;
(c) prior to (if possible) and following any repairs or maintenance work that may affect instrument calibration; and
(d) prior to instrument shut down.

For the verification in VC 2-O, see section 9.0 for verification acceptance criteria, and section 10.0 for corrective actions in the event the criteria are not met. Such verifications must be documented as described in VC 11-E.

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3.0 Calibration Standards

VC 3-A *When verifying or calibrating an analyzer, the person responsible must use calibration gases of the compound the analyzer is designed to analyze.*

Whether referring to a verification or a calibration, the term “calibration gas” is used in the Verification and Calibration Chapter for consistency.

VC 3-B *All calibration gases and measurement devices used by the person responsible must be:*
(a) *certified as traceable to either:*
(i) *the U.S. National Institute of Standards and Technology (NIST);*
(ii) *the Dutch Metrology Institute (VSL) primary standard; or*
(b) *derived from local or working standards (e.g., cylinders of compressed gas).*

Calibration gases are not considered traceable after the expiration date indicated on the cylinder's certificate. It is therefore important to track cylinder expiration dates and order new cylinders with sufficient lead time to ensure traceable gas is always available. Costs can be mitigated by ordering cylinders of appropriate size so that there are not excessive amounts of gas remaining as of the expiration date.

VC 3-C *A working standard, also known as the secondary standard, used by the person responsible must be certified directly to the Standard Reference Material or Certified Reference Material.*

3.1 Zero Standards

Test concentrations at zero concentration are considered valid standards. Although zero standards are not required to be traceable to a primary standard, care should be exercised to ensure that zero standards are indeed adequately free of all substances likely to cause a detectable response from the analyzer. Zero concentrations can be acquired through zero air generation devices or purchased standards.

3.2 Standards for Ozone

VC 3-D *Test concentrations of ozone used by the person responsible must be traceable to a primary standard UV photometer as described in US EPA 40 CFR Part 50 Appendix D.*

Procedures for certifying transfer standards for ozone against UV primary standards are provided in Transfer Standards for the Calibration of Ambient Air Monitoring Analyzers for Ozone (EPA-454/B-10-001, November 2010).

VC 3-E *As mentioned in section 5.2, a previously calibrated NO/NO₂/NO_x analyzer and a NO in N₂ calibration gas mixture can be used to determine O₃ concentrations provided the following conditions are met:*
(a) *the NO/NO₂/NO_x analyzer used to determine the O₃ concentrations must be located at the same site as the O₃ analyzer that is being calibrated;*
(b) *calibration or verification of the O₃ analyzer using the GPT derived O₃ concentrations from the calibration or verification of the NO₂ channel of the NO/NO₂/NO_x analyzer*

must be conducted within 24 hours of the GPT calibration or verification of the NO/NO₂/NO_x analyzer;

- (c) if the calibration or verification is not conducted within 24 hours of the GPT calibration, flows must be confirmed with a measurement device that is traceable to a primary standard;*
- (d) the NO in N₂ calibration gas mixture must be certified by a third party as not containing > 1% NO₂;*
- (e) the calibration system used to generate the test concentrations must use variation of light intensity of a UV-type O₃ generator;*

A photometer controlled and measured system is preferred for ozone generation.

- (f) the total flows used to generate each test concentration of O₃ must be equivalent to the gas and diluent flows associated with the generation of each test concentration during the GPT; and*
- (g) the calculated O₃ concentration must be adjusted in the event that flow changes are observed.*

If ozone generators are used in Gas Phase Titrations or ozone calibrations or verifications, the generators should be calibrated regularly against an ozone primary standard (photometer). This is to ensure that variations in lamp power fluctuations are minimized.

As per VC 3-E(c), ozone calibrations or verification using the Gas Phase Titration method need to be done immediately following the NO/NO₂/NO_x analyzer calibration or verification. This will ensure no variation in flows or determined ozone concentrations will be seen. If using the Gas Phase Titration method the next day (within 24 hours) then it is recommended the flows be verified to ensure the accuracy of the ozone concentration. A simple calculation can be used to determine the concentrations:

$$C_2 = \frac{V_1 C_1}{V_2}$$

Where:

C₁ = ozone concentration determined from the previous NO/NO₂/NO_x calibration or verification

C₂ = new concentration

V₁ = total flow from the previous NO/NO₂/NO_x calibration or verification

V₂ = total flow as measured for new ozone concentration determination

E.g.,:

$$C_2 = \frac{5020 \text{ sccm} \times 0.400 \text{ ppm}}{4998 \text{ sccm}} = 0.402 \text{ ppm}$$

This shows about a 1% change from the previous calibration (within 24 hours).

3.3 Flow Calibration

Flow calibrations are required to be conducted on field calibration devices, as they can be one of the largest sources of error in a dilution calibration. A possible procedure for measuring flow rate is provided on the AMD website, however the person responsible may opt to specify their own procedures in their SOP.

VC 3-F	<i>The person responsible must derive calibration flow rates from all field calibration devices used for multi-point as found verifications by either: (a) measuring flows on field calibration devices for all test points; or (b) equipping in-situ calibration devices with a calibrated mass flow controller (VC 3-H).</i>
VC 3-G	<i>The person responsible must have flow measuring devices certified at least annually against a NIST primary standard or other authoritative standards such as a traceable bubble flow meter or gas meter.</i>
VC 3-H	<i>The person responsible must conduct a flow calibration on all mass flow controller equipped calibration devices using a certified flow measuring device at all test concentration points: (a) annually, at a minimum, if flow rates are measured during the multi-point as found verification procedure as in VC 3-F(a); or (b) bi-annually, at a minimum, if calibration flow rates are derived from mass flow controllers as in VC 3-F(b).</i>
VC 3-I	<i>Corrective action must be taken when measured calibrator flows drift outside of the manufacturer's tolerance levels.</i>

4.0 Daily Zero-Span Test Procedure

The zero and span tests are instrument checks that introduce, respectively, pollutant-free gas to check an instrument's response below detection limits, and a known concentration of gas near the calibration range compared to a reference span value established at the time of verification or calibration.

The following daily zero-span test procedure is only adequate for commercial analyzers which have not undergone any modifications that have resulted in a substantial change in the performance characteristics of the analyzer.

VC 4-A	<i>The person responsible must conduct scheduled automated or manual daily zero-span tests in accordance with the following requirements: (a) once every calendar day, either 24-hours apart or on a repeating pattern of ≤ 6 days in length;</i>
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The daily zero-span in VC 4-A(a) is generally conducted in the early morning hours to allow for review and to address any non-compliant response, and to avoid data loss during the part of the day when people are more active. The test may be performed in the same hour every day or, if the operator's automation system can support it, on a repeating pattern in different hours each day so as to avoid loss of data for the same hour every day. The daily zero-span test schedule must be captured in the operator's QAP.

<i>(b) daily zero-span test time must not result in the loss of > 1 hour of reportable data for commercial ambient air quality analyzers;</i>
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If a scheduled zero-span test is missed due to equipment malfunction or another issue, and if the issue can be rectified, a zero-span may be completed later on in the day. In such a case, the hour during which the zero-span test is completed would need to be flagged as zero-span. This would be noted in the monthly report.

After one zero-span test is completed in a day, any additional zero-span tests would contribute to accrued downtime for unplanned maintenance.

(c) zero and span gases used must be kept or generated at the monitoring location;

Zero and span gases should also be kept at a similar temperature to the monitoring equipment.

- (d) the span gas concentration must range between 25% to 80% of the analyzer's operating range;*
- (e) a minimum of 10 minutes stability must be achieved for the response to be considered a valid response;*
- (f) for auto range analyzers the daily zero-span test must be conducted on the lowest range;*
- (g) analyzer sensitivity must not be corrected based on the daily zero-span test;*

The zero baseline output of the analyzer may be corrected based on the daily zero-span test.

- (h) analyzers with automatic dynamic span adjustment capability must not have the automatic dynamic span adjustment feature activated;*
- (i) Data Acquisition Systems with automatic dynamic span adjustment capability must not have the automatic dynamic span adjustment feature activated; and*
- (j) zero and span control charts must be used to monitor the performance of the analyzers.*

For VC 4-A(j), most DAS software generate zero and span control charts.

5.0 Multi-point As Found Verification and Calibration Procedures

Three commonly used types of verification and calibration methods for continuous ambient air analyzers are:

- dilution based on certified gas cylinders;
- gas phase titration; and
- UV photometer.

Table 2 provides an overview of acceptable verification and calibration methods used for continuous ambient air analyzers.

Table 2 Acceptable Verification and Calibration Methods

Parameter	Verification and Calibration Methods		
	Cylinder Dilution	Gas Phase Titration	UV Photometer
SO ₂	X		
H ₂ S	X		
NO	X		
NO ₂		X	
O ₃		X	X
CO	X		
Hydrocarbons	X		
NH ₃	X		
Ethylene	X		
TRS	X		
BTEX	X		
Styrene	X		

The person responsible should not begin a verification or calibration:

- until all functional and operational checks are complete,
- if there are elevated readings (so a potential exceedance is not missed), or
- if the monitoring station temperature is outside of the appropriate range (see the Site Selection Chapter (Chapter 3) of the AMD).

VC 5-A *The person responsible must conduct multi-point as found verifications and calibrations according to the following minimum requirements, in addition to any procedures specified in the analyzer's operation or instruction manual:*

(a) *all gases must be introduced upstream from the inlet filter and through all filters, scrubbers, conditioners, and other components used during normal ambient sampling and through as much of the ambient air inlet system as is practicable;*

The purpose of VC 5-A(a) is to assess the quality of data collected through as much of the sampling system as possible during the as found response.

(b) *only raw unadjusted data as recorded by the data acquisition system must be used for verification and calibration purposes;*

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For VC 5-A(b), this applies to correction factors applied to the output of the analyzer. It does not apply to analyzer output that is internally corrected (e.g., non-linear analyzers).

(c) the calibration system components must be within the manufacturer required operating temperature prior to verification or calibration, including gas cylinders and necessary regulators at room temperature;

For VC 5-A(c), a calibrator that has been left out in cold weather may take 3 hours or longer to warm up to room temperature. Gas cylinders and regulators can take 12 to 24 hours to warm up to room temperature after exposure to cold.

(d) the cylinder gas regulator and lines must be purged prior to use for portable calibration systems;

A step-by-step procedure for purging a regulator has been provided in Appendix A. Purging is critical for mitigating the risk of contamination that could impact verification and calibration results and ensures stabilization of the high point within the time requirements in VC 5-B(b) and (c). Contamination could be introduced through zero air systems, permeation through tubing, regulator systems under pressure, corrosion, or condensation from temperature variations. When possible, in-situ calibration systems should also be purged at each use.

(e) the output from the calibrator must be at ambient pressure to avoid pressurizing the analyzer;

The equipment manufacturer's manual should be referred to for acceptable methods to achieve ambient pressure as referred to in VC 5-A(e).

- (f) where required as per VC 3-F(a), the flow rate(s) of the calibrator must be checked with a certified flow meter against the operating specifications to achieve the desired concentrations required for the verification or calibration;*
- (g) where required as per VC 3-F(a), flow rates must be corrected to standard temperature and pressure (STP) conditions;*
- (h) the calibrator total airflow output must be set to provide excess flow at a minimum 2.5 times the intake flow rate of the analyzer; and*
- (i) when conducting multi-point as found verifications, the analyzer's response must be verified for all parameters that the analyzer is designed to measure.*

Regarding VC 5-A(i), for example in the case of a chemiluminescence ammonia analyzer, NO, NO₂, NO_x, and NH₃ all require multi-point as found verification.

VC 5-B *The person responsible must conduct multi-point as found verifications, prior to taking corrective action or making an adjustment, according to the following procedure, in addition to any procedures specified in the analyzer's operation or instruction manual:*

- (a) Stable "as-found" responses must be demonstrated for a minimum of 15 minutes and recorded after introduction of each of the following test concentrations into the analyzer:
 - (i) zero gas;*
 - (ii) the highest concentration (60-80% of the operating range);*
 - (iii) the mid test concentration (30-40% of the operating range); and*
 - (iv) the low test concentration (10-20% of the operating range).**
- (b) the maximum time required to reach a stable response must not exceed 20 minutes;*

- (c) for NH₃, the time required to reach a stable response must not exceed 45 minutes;*
- (d) the calibrator must be set to deliver zero gas to complete the multi-point as found verification; and*
- (e) using the readings obtained, a least square regression analysis using standard equations must be performed to obtain the verification results and prove the linearity of the analyzer.*

Setting the calibrator to deliver zero gas assists in purging the analyzer of calibration gas.

If the results of the multi-point as found verification indicate a failure to meet acceptance criteria during the verification (e.g., high point deviates more than 10%), check tubing and other equipment for potential issues, check flows, etc. If an issue is identified in the equipment, tubing or any other part of the calibration system only, correct it and restart the multi-point as found verification. Otherwise, the multi-point as found verification must be completed without any change made to the analyzer.

Under normal conditions, if the full multi-point as found verification procedure in VC 5-B(a) through (d) is not completed prior to taking corrective action or making an adjustment it would not be considered to have been completed unless there are compelling extenuating circumstances (e.g., if there is an egregious failure discovered during a multi-point as found verification that is likely to preclude the ability to complete the verification or lead to results with no diagnostic or validation merit such as the analyzer being non-responsive to calibration gas, stability cannot be reached, etc.). Simply failing to meet the acceptance criteria is not in itself sufficient cause to stop the multi-point as found verification. Any criteria set by operators on whether to stop a multi-point as found verification must be identified in their QAP.

Failure to complete the multi-point as found verification calls into question the validity of the data back to the time of the previous multi-point as found verification. However, in the event the acceptance criteria are not met, a completed multi-point as found verification may assist in identifying the root cause, and support invalidating data back only to the point of an identified root cause.

- VC 5-C Following replacement of the sample inlet filter, exchange of support gas, or both, stable responses must be reached and recorded after re-introduction of each of the following test concentrations:
 - (a) zero gas; and*
 - (b) the highest concentration (60-80% of the operating range).**
- VC 5-D If the high point analyzer response in VC 5-C deviates from the expected concentration by > 10%, corrective action must be performed as detailed in section 10.0.*

Reintroducing the zero- and high-point gases after changing the filter and checking the response against the criteria ensures that the sampling system has not been altered after the filter change.

If the following conditions are met:

- the full multi-point as found verification is not required as per the requirements in VC 2-A (e.g., one was performed one or two months ago, or no changes are being made to the sampling system except for a filter change following heavy wildfire smoke);
- the high-point check in VC 5-B(a)(ii) does not exceed the 10% tolerance in VC 5-D; and
- the sample inlet filter is the only component replaced, and no other changes are made to the sampling system downstream of the filter except exchanges of carrier gas such as nitrogen support gas for hydrocarbon or BTEX analyzers or hydrogen for THC analyzers;

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then the mid- and low-test concentrations in VC 5-B(a)(iii) and (iv) are not required, nor is proving linearity in (e), and the person responsible may proceed to change the filter, perform the steps in VC 5-C and VC 5-D and then run the daily zero-span as in VC 5-F to complete the verification. However, if the 10% tolerance in VC 5-D is exceeded then the full multi-point as found verification is required, followed by corrective action.

The above steps describe the verification process. If calibration of the instrument is required (e.g., following analyzer installation, repair, replacement, maintenance, or modification; following corrective action if the verification results are outside defined tolerance levels, or if any sample component other than the filter is changed), then proceed with the steps in VC 5-E.

VC 5-E The person responsible must conduct adjustments, when required as per VC 2-B, according to the following procedure, in addition to any procedures specified in the analyzer's operation or instruction manual:

- (a) all previous correction factors, slope/intercept, and coefficients must be removed from the data acquisition system;*
- (b) derive and record gas flow and total flow according to VC 3-F;*
- (c) after reintroduction of (i) the zero gas and (ii) the high-test concentration, stable responses must be obtained before any adjustment, and final values recorded after adjustment and demonstration of 15 minutes of stable response;*

When performing the adjustment in VC 5-E(c), it is recommended that 5 minutes of stable response be obtained prior to adjustment of the zero- and high-points. The 15 minutes of stable response after adjustment serves to check that the adjustment did not affect stability.

- (d) span changes must not be conducted after demonstration of 15 minutes of stable response;*
- (e) after the zero and high point settings are satisfactory, consecutively lower gas concentrations of (i) 30-40% then (ii) 10-20% of operating range must be introduced into the analyzer and output values recorded after demonstration of 15 minutes of stable response;*
- (f) using the readings obtained, a least square regression analysis using standard equations must be performed to obtain the calibration results and prove the linearity of the analyzer; and*

If the person responsible wishes to introduce additional test concentrations below 10-20% of the operating range in VC 5-E(e), they may do so. However, such additional test concentrations must not be used in demonstrating compliance with the verification and calibration criteria established in section 9.0.

Appendix B outlines how to establish regression parameters and provides a least square calculation procedure. Linearity cannot be proven in VC 5-E(f) for non-linear analyzers. Refer to VC 2-K for guidance on verification or calibration results for non-linear analyzers.

(g) during multi-point verifications or calibrations TRS and H₂S analyzers must be checked for SO₂ scrubber efficiency for possible interference of SO₂.

A measurable response to SO₂ greater than the analyzer detection limit indicates interference from SO₂, and therefore a defective scrubber. Only SO₂ gas should be used for checking the SO₂ scrubber. Blended gases may add an erroneous response on H₂S/TRS analyzers. The SO₂ scrubber is tested during the multi-point verification or calibration. Completing this test after the multi-point verification or calibration could lead to discrepancies in data collected due to SO₂ interferences found after the multi-point is completed.

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Amends the original Air Monitoring Directive published June, 1989

The use of a calibrator with dual calibration gas blending allows for testing SO₂ scrubbers during multi-point verifications or calibrations at all three test concentrations of SO₂ on H₂S/TRS analyzers. This is the method used by the auditor to check for SO₂ scrubber efficiency. The H₂S/TRS analyzer can be challenged at a single SO₂ test concentration, at minimum, prior to the verification or calibration. This test concentration should exceed the operating range of the H₂S/TRS analyzer and should be a minimum of 15 minutes in length.

An alternative method for checking SO₂ scrubber efficiency is to deploy an SO₂ permeation device inside the H₂S/TRS permeation oven (if in use and if the permeation oven is capable of holding two devices). This allows for daily tests of the SO₂ scrubber. The SO₂ permeation device must permeate at a rate such that the test concentration exceeds the operational range of the H₂S/TRS analyzer. A benefit to this method is that it removes the requirement to test with SO₂ gas prior to or during the H₂S/TRS calibration as it would be done daily.

An automated daily zero-span typically occurs prior to the verification or calibration and is repeated after the multi-point verification or calibration as required in VC 5-G.

VC 5-F The daily automated zero-span test cycle must be used to zero and span the analyzer following verification or adjustment of the analyzer.

This serves to re-establish the zero air and the span gas concentration for the required daily zero-span test. The zero and span values obtained from the post verification or calibration zero-span automated run are used as the true reference values to compare the ongoing zero and span tests.

VC 5-G Any verification or calibration conducted, as listed in Table 1, must be documented as required by section 11.0.

5.1 Dilution Verification or Calibration

Dilution verifications or calibrations use a calibration gas that is derived from a compressed gas cylinder. The accuracy of the verification or calibration is directly dependent upon the accuracy of flow measurements and corrections applied to those flows.

VC 5-H The person responsible must follow the applicable multi-point verification or calibration procedure in VC 5-A through VC 5-G when conducting dilution verifications or calibrations.

Calculations for determining the concentration of calibration gas after dilution are included in Appendix D.

Descriptions of flow measurement devices (bubble flow meter, mass flow meter, rotameter or orifice with pressure chart) and correction calculations are included in Appendix E.

5.1.1 Hydrocarbons Verification or Calibration by Dilution Method

Reactive hydrocarbons are described as non-methane hydrocarbons. The term hydrocarbons is used to include all organic compounds which give response to the Flame Ionization Detector.

VC 5-I The person responsible must verify or calibrate all total hydrocarbon ambient analyzers with a mixture of methane and propane.

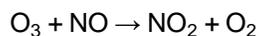
The balance gas in the mixture can be air, nitrogen or another gas that does not cause a detector response.

VC 5-J When the person responsible verifies or calibrates reactive hydrocarbon or total hydrocarbon analyzers, the calibration gases used must be expressed as “methane equivalent”.

The calculations for methane equivalent are included in Appendix F.

5.2 Gas Phase Titration

Gas Phase Titration (GPT) may be used as a method of generating primary standards for nitrogen dioxide and ozone. The reaction which takes place when O₃ is added to NO is:



The reaction relationship is 1:1 in theory, but in practice the perfect stoichiometry is never achieved. However, since the GPT method does yield better than 99% conversion, it is very useful for:

- verification or calibration of NO/NO₂/NO_x analyzers;
- verification or calibration of O₃ analyzers;
- verification of O₃ generators; and
- determination of NO₂ – NO converter efficiency.

The calibration system used for GPT is essentially the same as the dilution system outlined in section 5.1, but incorporates an ozone generator to the dilution side of the flow system. Refer to the equipment manufacturer’s manual for details.

The accuracy of the calibration gas is directly related to the following parameters:

- quality of dilution zero air;
- accuracy of compressed NO gas standard;
- accuracy of flow measurements and stability of flows;
- stability of the ozone generator and stability of flow through the ozone generator chamber;
- compatibility of materials used in the construction of the calibration system; and
- condition of analyzers being calibrated or used as a reference.

All of the above items can significantly affect the accuracy, linearity and repeatability of the verification or calibration.

Calculations for GPT are included in Appendix D.

5.2.1 NO/NO_x Verification or Calibration

VC 5-K When conducting NO/NO_x verifications or calibrations, the person responsible must follow the applicable multi-point verification or calibration procedures in VC 5-A through VC 5-G.

5.2.2 NO₂ Verification or Calibration

*VC 5-L The person responsible must use the following steps for all NO₂ verifications or calibrations:
(a) at the end of the NO/NO_x verification or calibration do not run the zero-span test;*

(b) the presence of any NO₂ impurity in the NO gas standard must be taken into account in the NO portion of the calibration;

The NO and NO_x channels may or may not be at exactly the same level depending on NO₂ impurity in the gas standard.

(c) reintroduce the highest NO concentration which was generated in the NO portion of the verification or calibration;
(d) let stabilize for 15 minutes;
(e) do not make adjustments to the analyzer at this stage;
(f) introduce ozone such that 60% to 70% of the highest NO concentration used to calibrate the analyzer is converted to NO₂;

This high point (VC 5-L(f)) is the first point for calibration of the NO₂ channel.

(g) 15 minutes of stable readings must be demonstrated;
(h) adjust the analyzer's NO₂ output, as per the manufacturer's procedure, to the introduced gas concentration once a stable reading is achieved;
(i) repeat steps (f) and (g) introducing ozone such that:
(i) 30% to 40%; and then
(ii) 10% to 15% of the NO concentration is converted to NO₂; and
(iii) do not adjust the analyzer output for these second and third points;

These are the mid- (VC 5-L(i)(i)) and low-points (VC 5-L(i)(ii)) for verification or calibration of the NO₂ channel.

(j) plot the NO₂ increase versus the NO decrease to produce a calibration curve; and
(k) the overall average converter efficiency, averaged over all calibration points, for the calibration must be (i) calculated and (ii) recorded.

Absolute converter efficiency can be determined using electronic factors that are stored in most analyzers. Refer to the analyzer operation manual for further information on determining converter efficiency.

VC 5-M *When conducting a multi-point as found verification on NO/NO₂/NO_x and O₃ analyzers by gas phase titration, as per Table 1, VC 2-A, and VC 2-B, the person responsible must follow VC 5-L, except bullet (h).*

For a verification no adjustment is made to the analyzer.

VC 5-N *The person responsible must take corrective action if the converter efficiency as calculated in above falls outside the range (96 to 104%).*

5.3 Ozone Calibration

VC 2-O When conducting ozone verifications or calibrations, the person responsible must follow the applicable multi-point calibration procedures in VC 5-A.

5.3.1 Method 1 - Varying Dilution Gas Flow

An ozone analyzer can be calibrated by using a fixed UV generator setting along with a fixed flow through the O₃ generator chamber. The O₃ concentration is then varied by changing the dilution flow.

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Amends the original Air Monitoring Directive published June, 1989

5.3.2 Method 2 - Varying UV Lamp Power

An ozone calibration may also be conducted using fixed flows and varying the ozone lamp setting. However, some inaccuracy may result due to lamp variation from one calibration to another.

An ozone generator with a photometric bench provides a feedback loop to vary the ozone lamp setting to provide a desired ozone concentration. This is typically more accurate than an ozone generator that only varies the lamp setting.

5.3.3 Method 3 - Direct Gas Phase Titration

Calibration results from the GPT portion of a NO/NO₂/NO_x calibration conducted within the previous 24 hours can be used to conduct an ozone analyzer calibration. This includes:

- introducing ozone from the calibrator using the same ozone lamp output setting and flow rate as was used during the high NO₂ point of the recent NO/NO₂/NO_x calibration;
- adding the flow rate value used for NO calibration gas during the high point of the NO/NO₂/NO_x calibration to the dilution flow rate for the O₃ calibration being conducted; and
- calculating the O₃ concentrations for all O₃ calibration points by subtracting the NO value after the O₃ was introduced from the NO value prior to any O₃ introduction during the recent NO/NO₂/NO_x calibration.

If the above procedure is used to calibrate an ozone analyzer, determination of what points will be used based on the range of the NO/NO₂/NO_x analyzer being calibrated have to be considered. This would be for operating ranges of 0.5 to 1.0 ppm full-scale and NO concentrations of 0.800 ppm and/or 0.400 ppm at 5000 sccm total flow.

- For 1.0 ppm full-scale NO/NO₂/NO_x analyzers, consider using two upscale high points: the 60% - 70% range for the NO₂ calibration high point and an additional point in the 45% - 55% range to be used for the ozone analyzer upscale high point. Both the mid-point and low-point values are not affected. This would add 4 points to the NO/NO₂/NO_x GPT calibration instead of the usual 3 points typically used.
- For 1.0 ppm full-scale NO/NO₂/NO_x analyzers, consider using a value in the 55% range of the ozone high point. This would bring the ozone high point into a working range for ozone analyzer calibration purposes but it would not meet the Gas Phase Titration requirements for doing a NO₂ calibration for the high point only (60% - 70%).
- For 0.5 ppm full-scale NO/NO₂/NO_x analyzers, consider upscale points of approximately 0.300 ppm for the high point, 0.200 ppm for the mid-point, and 0.100 ppm for the low point. This will ensure these data used for ozone calibration purposes meet the AMD calibration requirements.

6.0 Calibration of Wind Sensors

The Monitoring Chapter (Chapter 4) of the AMD provides minimum performance specifications for wind sensors.

VC 6-A	<i>The person responsible must remove all mechanical wind sensors from the tower at least once a year for:</i> <ul style="list-style-type: none"><i>(a) mechanical inspection;</i><i>(b) mechanical alignment;</i><i>(c) electronic alignment; and</i><i>(d) calibration.</i>
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When inspecting mechanical wind sensors, bearings and potentiometers should be checked to ensure they are in good working condition. An RPM generator can be used to calibrate wind speed and devices are available to help align the sensor properly. Alternatively, the sensor can be sent for factory calibration.

*VC 6-B The person responsible must have all ultrasonic wind systems:
(a) electronically inspected once a year; and
(b) factory calibrated at a minimum every 2 years.*

Inspection of ultrasonic wind systems should follow manufacturer specifications.

When inspecting ultrasonic wind systems, the person responsible should ensure that the aviary spikes are in their proper place and not touching the heaters, that heaters are functioning properly, and that wind speed is being registered. More frequent calibrations may be required if the ultrasonic wind head is in a high humidity area or on a mobile monitoring unit.

*VC 6-C For all monthly reports, the person responsible must:
(a) note the date of the last wind system calibration; and
(b) submit to the Regulator a copy of the wind sensor calibration (for the month in which the calibration was conducted).*

The Reporting Chapter (Chapter 9) of the AMD provides requirements for monthly reports.

VC 6-D If > 10% of the monthly operating time of wind sensors is used for calibration, the person responsible must count the time exceeding 10% as down time.

VC 6-E The person responsible must keep a service record for each wind sensor which contains all work performed to bring the sensor back to original operating conditions.

7.0 Calibration of High Volume Samplers

VC 7-A The person responsible must calibrate high volume samplers at least once every three months.

VC 7-B The person responsible must calibrate high volume samplers in accordance with methods specified by the analyzer manufacturer, established SOPs, or both.

*VC 7-C For calibration of high volume samplers, the person responsible must meet the following calibration acceptance criteria:
(a) criteria in Table 5 for particulate matter; and
(b) any calibration acceptance criteria specified by the analyzer manufacturer.*

8.0 Calibration of Other Analyzers

VC 8-A For methods not detailed in the Verification and Calibration Chapter, the person responsible must obtain written authorization from the Director for calibration methodologies before use.

9.0 Verification and Calibration Acceptance Criteria

Acceptance criteria in this section apply to both calibration types in Table 1, i.e., multi-point as found verifications and calibrations.

VC 9-A	<i>For all calibrations and verifications conducted by the person responsible, the results must comply with each of the acceptance criteria specified in Table 3, Table 4, Table 5 and VC 9-C to VC 9-D, inclusive.</i>
VC 9-B	<i>In the event that calibration or verification results do not meet the requirements of VC 9-A, the person responsible must take corrective action as specified under VC 10-C.</i>
VC 9-C	<i>For calibration or verification of gas analyzers, the person responsible must generate a calibration curve from (a) at least three, non-zero concentrations of the gas being used and (b) a calibration zero air source.</i>

Table 3 Acceptance criteria for Continuous Gas Analyzers

Parameter	Calculation Method (see example calculations in Appendix B)	Verification Acceptance Criteria	Calibration Acceptance Criteria
High point response accuracy	% Error Cc vs. Ci	The high point percent error must be $\leq \pm 10.000\%$	
Mid and low point response accuracy	% Error Cc vs. Ci	The mid and low point percent error must be $\leq \pm 10.000\%$	N/A
Mid and low point response linearity	% Difference of correction factors	The percent difference between the high point correction factor and the mid and low point correction factors must be $\leq \pm 5.000\%$	
Slope of the calibration curve	Least square regression analysis	The slope (m) of the analyzer calibration curve must be ≥ 0.900 and ≤ 1.100	
Y-intercept of the calibration curve	Least square regression analysis	The intercept (b) of the analyzer calibration curve must be within $\pm 3.000\%$ of the analyzer calibrated range of 0	
Correlation coefficient of the calibration curve	Least square regression analysis	The correlation coefficient (r) of the analyzer calibration curve must be ≥ 0.995	

The high-point response error must always be within 10% to ensure that the instrument is reporting accurate and precise data at the high end of its operating range. This is important to have high confidence that Alberta Ambient Air Quality Objectives are not exceeded when readings are close to Alberta Ambient Air Quality Objectives but not above, and that if they are exceeded that the reported exceedance is valid.

As the instrument response may drift over time following an adjustment, it is important that the mid and low point responses also be within 10% to have confidence in the accuracy of the instrument across the range. This test is not required after a calibration (adjustment), as the combination of the high-point response error and linearity assessment of all three points is sufficient to ensure accuracy across the range.

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The linearity assessment which compares the mid and low point correction factors to the high point correction factor serves a different purpose to the percent error. It is possible for all points to be well within 10% error, and for the regression analysis criteria to be satisfied, though an instrument may be experiencing non-linear response; for instance, if the mid-point error is negative and the low and high point errors are positive. Requiring that the percent difference of correction factors between the high point and the low and mid points be less than 5% ensures that the instrument response is linear, as it demonstrates that any drift affects the instrument range approximately equally.

Refer to Appendix B for guidance on calculations of response error, linearity, and establishing regression parameters.

Table 4 Acceptance Criteria for Continuous Meteorological Sensors

Parameter	Calculation Method	Acceptance Criteria
Wind speed	As per manufacturer specified procedure	The measured wind speed readings must be within manufacturer specified accuracy
Wind direction	As per manufacturer specified procedure	The measured wind direction readings must be within manufacturer specified accuracy
Wind sensor alignment	Compass reading true north $\pm 5^\circ$	The wind system must be aligned to true north $\pm 5^\circ$
Other wind sensor verification parameters	As per manufacturer specified procedure	Parameters such as vane or propeller torque must be within manufacturers specifications
Temperature	Temperature difference - measured vs. indicated	The measured temperature value must not deviate from the displayed temperature value by $> \pm 2^\circ\text{C}$
Pressure	Pressure difference - measured vs. indicated	The measured pressure value must not deviate from the displayed pressure value by $> \pm 10\text{ mmHg}$
Relative humidity	RH difference - measured vs. indicated	The measured humidity value must not deviate from the displayed humidity value by $> 10\%$
Other meteorological parameters	Value measured vs. standard	The indicated value must be within $\pm 15\%$ of the verification standard value

Table 5 Acceptance Criteria for Continuous and Integrated Particulate Analyzers

Parameter	Calculation Method	Acceptance Criteria
Flow	% Deviation (measured flow vs. indicated flow)	As per manufacturer specified tolerances
Temperature	Temperature difference - measured vs. indicated	The measured temperature value must not deviate from the displayed temperature value by $> \pm 2^\circ\text{C}$
Pressure	Pressure difference - measured vs. indicated	The measured pressure value must not deviate from the displayed pressure value by $> \pm 10\text{ mmHg}$
Relative humidity	RH difference - measured vs. indicated	The measured relative humidity value must not deviate from the displayed relative humidity value by $> 10\%$
Leak check	As per manufacturer specified procedure	The leak check value must be within manufacturer specified tolerance

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Detector / measurement verification (for continuous only)	As per manufacturer specified procedure	The analyzer detector verification (e.g., foil verification, K _o confirmation, span dust check) must be within manufacturer specified tolerance
Other sampler-specific parameters	As per manufacturer specified procedure	As per manufacturer specified tolerances

VC 9-D For digital systems, calibration data points used for digital printouts or graphical plots must, at minimum, be based on 1 second averaging to a maximum of 5 minute (300 second) averaging.

The calibration results should be supported by recorder traces (or digital printouts or graphical plots in the case of digital systems) to demonstrate the stability and accuracy of the measurement.

10.0 Assessment and Corrective Action

Data flags are used to mark data when calibration results are found to be outside the acceptable criteria prescribed in the Verification and Calibration Chapter.

VC 10-A When the acceptance criteria in VC 9-A are exceeded, measurements are deemed to be invalid and the person responsible must flag ambient measurements back to the most recent point in time where such measurements are known to be valid.

Usually this point in time is the previous verification or calibration (or accuracy audit), unless some other point in time can be identified and related to the probable root cause of the failure to meet acceptance criteria (such as not allowing enough time for analyzer response to stabilize, power failure or malfunction, or malfunctioning of the span equipment).

VC 10-B The person responsible must flag data collected following an analyzer malfunction or interruption in operation as invalid until the next multi-point as found verification, unless the verification results meet the acceptance criteria as set out in section 9.0.

VC 10-C When analyzer performance does not meet the verification or calibration acceptance criteria as set out in section 9.0, the person responsible must

- (a) investigate to determine the root cause;*
- (b) take immediate corrective action to ensure the analyzer is operating within the manufacturer's specifications and the calibration acceptance criteria; and*
- (c) flag ambient measurements back to the time of the root cause or most recent point in time where measurements can be shown to be valid.*

If a root cause is determined, including the time it occurred, and there is strong empirical evidence that the data collected before the root cause is still valid, data would only be invalidated back to that point in time. However, if a root cause, or the time it occurred, cannot be determined, or it cannot be demonstrated that the data collected prior to the occurrence of the root cause is still valid, data would be invalidated back to the last successful verification or calibration.

Note that in the event that an analyzer fails to meet the acceptance criteria as set out in section 9.0, corrective action taken under VC 10-C does not replace or supersede the need to report non-compliances of other requirements under the AMD that may be caused by such a failure, including, but not limited to, failure to meet

uptime requirements due to time required to take corrective action and/or invalidation of past data, reporting of damage to an analyzer discovered in the investigation, etc.

11.0 Records for Multi-point Verifications and Calibrations

- VC 11-A *The person responsible must (a) record and (b) retain electronically, for a minimum of three years and in a manner accessible from the continuous ambient air monitoring station, all data and calculations involved in the verification and calibration activities listed in Table 1 and VC 2-A and VC 2-B for each analyzer.*
- VC 11-B *For the verifications and calibrations in Table 1 and VC 2-A and VC 2-B, the person responsible must:*
(a) record stored electronic factor(s) with the calibration results; and
(b) enter all data relevant to the verification or calibration on the analyzer's verification and calibration record.
- VC 11-C *For gas analyzer verifications and calibrations in Table 1, the person responsible must graph analyzer output data to demonstrate the stability of each measurement point.*

Additional requirements for documentation and the maintenance of records are set out in the Quality System Chapter (Chapter 5) of the AMD.

11.1 Verification and Calibration Reports

- VC 11-D *Written reports must be submitted to the Regulator for all gas analyzer verifications or calibrations in Table 1, including, at a minimum, all of the following:*
- (a) reason for the verification, calibration, or both, and whether the verification was routine or non-routine;*
 - (b) identification of gas analyzer verified or calibrated including:*
 - (i) its location;*
 - (ii) date of verification or calibration;*
 - (iii) make/model;*
 - (iv) serial number;*
 - (v) date last verified or calibrated; and*
 - (vi) inlet flow;*
 - (c) which verification or calibration method was used;*
 - (d) calibrator make/model;*
 - (e) calibrator serial number;*
 - (f) calibration standard certificate expiration date;*
 - (g) conditions under which verification or calibration is conducted:*
 - (i) temperature; and*
 - (ii) barometric pressure;*
 - (h) verification or calibration results including:*
 - (i) total flow;*
 - (ii) gas flow;*
 - (iii) expected concentration or calculated concentration;*
 - (iv) actual response as-found for all required points; and*
 - (v) indicated responses for all required points;*

- (i) *high point response error and, for a verification only, mid and low point response errors;*
- (j) *correction factors from the current verification or calibration ;*
- (k) *correction factors from the previous verification or calibration ;*
- (l) *percent difference of the correction factors of mid- and low-point from the indicated high point;*
- (m) *linear regression analysis including slope, y-intercept, and correlation coefficient;*
- (n) *calibration curve;*
- (o) *graph of analyzer output; and*
- (p) *identification of person who conducted the verification or calibration.*

VC 11-E *Calibration reports must be submitted to the Regulator for all particulate monitor audits, including, at a minimum, all of the following:*

(a) *identification of particulate monitor audited including:*

- (i) *its location;*
- (ii) *date of audit;*
- (iii) *make/model;*
- (iv) *serial number; and*
- (v) *date last audited;*

(b) *flow device make/model;*

(c) *flow device serial number;*

(d) *conditions under which audit is conducted:*

- (i) *temperature; and*
- (ii) *barometric pressure;*

(e) *audit results including:*

- (i) *flow;*
- (ii) *temperature;*
- (iii) *pressure;*
- (iv) *leak check; and*
- (v) *zero check as indicated by manufacturer; and*

(f) *identification of person who conducted the calibration.*

VC 11-F *The person responsible must have verification or calibration reports in VC 11-D and VC 11-E accessible from the continuous ambient air monitoring station.*

See section 6.0 for requirements to provide wind sensor calibration records.

Refer to Appendix G for an example of a calibration report.

The Reporting Chapter (Chapter 9) of the AMD provides detailed reporting requirements.

Appendix A Procedure for Purging a Regulator

The following procedure should be used for purging (sometimes referred to as evacuating) a regulator to remove oxygen and other contaminants from the pressure regulator and delivery system prior to use:

1. Allow the regulator to warm up to room temperature if exposed to cold.
2. Connect the regulator to the cylinder. With the cylinder valve closed, connect a vacuum pump to the outlet on the regulator and start the pump.
3. Open the outlet port, purge for a minimum of 5 minutes, then close the outlet port.
4. Slowly open and close the cylinder valve to charge the regulator.
5. Repeat steps 3 and 4 a minimum of 3 more times to be sure all oxygen or other impurities are removed from the regulator.

After purging a regulator:

1. Connect the transfer line to the gas inlet of the calibrator.
2. Open the cylinder main valve.
3. Set the regulator outlet pressure as required by the calibrator.
4. Open the regulator valve.

Valves should be opened slowly to mitigate the risk of damage to the regulator.

Appendix B Calculations: Verification or Calibration Acceptance Criteria

There are a number of different criteria established to determine if a verification or calibration is acceptable. How to calculate these is summarized in this appendix.

Example data and results for the calculations for the high-, mid-, and low-points are provided in the following table, with the example calculations following below.

Table of Sample H₂S As Found Verification Data
(Taken from sample calibration report in Appendix G)

Point	Total Flow (sccm)	Cyl. Gas Flow (sccm)	Calculated Concentration ^a (C _c) (ppb)	Analyzer Response (C _i or Z) (ppb)	Correction Factor (CF)	CF Tolerance ^b	% Error	% Error Tolerance
Zero	5000.0	0.0	0.0	-0.6 ^c				
High Span	5000.0	40.0	78.8	73.3	1.0663	n/a	6.22%	-10% - 10%
Mid	5000.0	20.0	39.4	36.3	1.0678	1.0130 - 1.1196	6.35%	-10% - 10%
Low	5000.0	10.0	19.7	17.7	1.0765	1.0130 - 1.1196	7.11%	-10% - 10%

- a: H₂S calibration cylinder gas concentration at 9.85 ppm.
 b: ± 5% of high point CF
 c: Note – this is different from the y-intercept calculated by regression analysis

High Point Error Calculation

To calculate the as found high point deviation, as per VC 9-A, the following equation is used:

$$\% \text{ error} = \frac{C_c - (C_i - Z)}{C_c} \times 100$$

Where:

- C_c = diluted calibration gas concentration (calculated concentration)
 C_i = indicated concentration (analyzer response)
 Z = analyzer zero response

Using the sample H₂S data above:

$$\begin{aligned} \% \text{ error}_{\text{High}} &= \frac{78.8 - (73.3 - (-0.6))}{78.8} \times 100 \\ &= 6.22\% \end{aligned}$$

This is within the -10% to 10% tolerance and is acceptable.

The % error for the low-point would be:

$$\begin{aligned} \% \text{ error}_{\text{Low}} &= \frac{19.7 - (17.7 - (-0.6))}{19.7} \times 100 \\ &= 7.11\% \end{aligned}$$

This is also within the 10% criteria, however the mid- and low-points only have to satisfy this criteria following a verification, not following a calibration. At all times, though, the mid- and low- points have an additional acceptance criteria, based on the correction factor, as shown below.

Correction Factor Calculation

The standard correction factor calculation is C_c/C_i (section 9.0). When an analyzer has been adjusted to read 0.0 at zero then this works fine. In a multi-point as found verification or field audit where the analyzer zero value is a little above or below zero, the zero reading needs to be considered in the correction factor calculation.

One reason for calculating correction factors using the zero response is that the routine data is treated in this manner already; during the baseline correction process, the daily zero value is subtracted from or added to the averaged data. Therefore, if an H₂S analyzer is responding with -0.6 ppb during the daily zero, then 0.6 ppb is added to the hourly averages for the day.

If an H₂S analyzer responds with -0.6 ppb to zero air during an as found verification, then 0.6 ppb is added to the up-scale indicated concentration values during the correction factor calculation. Additionally, this zero value must be taken into account when calculating the percent error in analyzer response to high point calibration gas.

The correction factor equation is:

$$CF = \frac{C_c}{C_i - Z}$$

Where:

CF = correction factor

C_c = diluted calibration gas concentration (calculated concentration)

C_i = indicated concentration (analyzer response)

Z = analyzer zero response

High-, Mid-, and Low-Point Correction Factor Calculation

First, you must perform the high point correction factor calculation:

$$\begin{aligned} CF_{\text{High}} &= \frac{78.8 \text{ ppb}}{73.3 \text{ ppb} - (-0.6\text{ppb})} \\ &= 1.0663 \end{aligned}$$

In the example above the zero is accounted for in the correction factor calculation.

The acceptable range for the mid and low point correction factors is within 5% of the high point correction factor, or 0.950 times the high-point correction factor to 1.050 times the high point correction factor. Checking that the correction factors are similar in this manner ensures that the analyzer response is linear.

In this example the high point correction factor is 1.0663 so the acceptable range is $0.950 \times 1.0663 = 1.0130$ to $1.050 \times 1.0663 = 1.1196$.

The mid- and low-point correction factors are calculated as follows:

$$\begin{aligned} CF_{\text{Mid}} &= \frac{39.4 \text{ ppb}}{36.3 \text{ ppb} - (-0.6\text{ppb})} \\ &= 1.0678 \end{aligned}$$

$$CF_{\text{Low}} = \frac{19.7 \text{ ppb}}{17.7 \text{ ppb} - (-0.6 \text{ ppb})}$$
$$= 1.0765$$

As such, even though the mid and low point responses are not within 5% of expected (the percent error is greater than 5%), they are within 5% of the high point correction factor (therefore demonstrating linear response) and would be acceptable.

Least Square Regression Analysis

A regression analysis is performed on the calibration results to provide a quantitative assessment of the analyzer performance. Most calculators/spreadsheets are able to perform this analysis and produce the slope, intercept and coefficient of correlation. The following procedures summarize the steps involved in this calculation.

The following procedure may be used to perform a least square regression.

It is necessary to define the dependent and independent variables in the analysis. The two variables involved are (i) the true or calculated values used in the calibration or audit of the analyzer (calculated concentration) and (ii) the values indicated by the analyzer (analyzer response).

The regression coefficients are calculated by designating the calculated concentration ($\mu\text{g}/\text{m}^3$ or ppm) as the abscissa (x variable) and the analyzer response ($\mu\text{g}/\text{m}^3$ or ppm) as the ordinate (y variable). See the graph in the sample calibration report in Appendix G. The resultant equation is in the form of:

$$y = mx + b$$

Where:

- y = analyzer response (indicated concentration)
- m = slope
- x = calculated/audit concentration
- b = the intercept

The slope is the parameter used to assess the accuracy of the analyzer response with respect to the calibration value. The correlation coefficient is an indication of the degree of linearity. The intercept shows the offset of the analyzer response with respect to the calibration zero.

The slope in this equation, m, gives the amount and direction of the analyzer response deviation from the calibration value. For example, a slope of 1.10 indicates that the reading of the analyzer is 10% high whereas a slope of 0.95 indicates that the analyzer reading is 5% low. The intercept, b is related directly to the zero offset of the analyzer. For example, an intercept of 0.05 indicates that the analyzer has a zero offset of +0.05.

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The slope, intercept, and correlation coefficient can all be calculated by most spreadsheet software, for example with the SLOPE, INTERCEPT, and CORREL functions in Microsoft Excel. However, these parameters can be calculated manually if necessary by using the following equations.

Note, the zero point should be included in the regression. The formulas for slope (m) and intercept (b) are as follows (see sample calibration report in Appendix G):

$$m = \frac{n \sum_{i=1}^n X_i Y_i - \sum_{i=1}^n X_i \sum_{i=1}^n Y_i}{n \sum_{i=1}^n X_i^2 - \left(\sum_{i=1}^n X_i \right)^2}$$
$$b = \bar{Y} - m\bar{X}$$

Where:

- Y_i = i^{th} reading of the analyzer
- X_i = i^{th} calibration value (true value)
- n = number of calibration points
- \bar{X} = mean of x values
- \bar{Y} = mean of y values

The formula for the correlation coefficient r is:

$$r = \frac{n \sum_{i=1}^n X_i Y_i - \sum_{i=1}^n X_i \sum_{i=1}^n Y_i}{\sqrt{\left(n \sum_{i=1}^n X_i^2 - \left(\sum_{i=1}^n X_i \right)^2 \right) \left(n \sum_{i=1}^n Y_i^2 - \left(\sum_{i=1}^n Y_i \right)^2 \right)}}$$

Linear regression calibration acceptance criteria are shown in the sample calibration report in Appendix G.

Appendix C Calculations: Daily Span Test Using a Permeation Device

Permeation rate in nanograms/minute is calculated using the following expression:

$$P_T = \frac{FC}{K_m}$$

Where:

P_T = permeation rate in nanograms/minute at temperature T in °C

F = flow rate in cubic centimetres/minute at STP

C = concentration in ppm (Volume)

K_m = molar constant = $\frac{\text{molar volume}}{\text{molecular weight}}$

The molar volume for an ideal gas at STP is 24.46 litres.

This can be rearranged as follows to obtain concentration in ppm:

$$C = \frac{P_T K_m}{F}$$

Table of Molecular Weights and Constants at STP

Gas	Formula	Molecular Weight	K_m
hydrogen sulphide	H ₂ S	34.08	0.719
nitrogen dioxide	NO ₂	46.01	0.532
sulphur dioxide	SO ₂	64.07	0.382

Appendix D Calculations: Dilution Calibration and Gas Phase Titration

In order to determine the concentration of calibration gas after dilution, the following relationship is used:

$$C_F = \frac{F_C \times C_S}{F_T} = \frac{F_C \times C_S}{(F_C + F_D)}$$

Where:

- C_F = output concentration (ppm)
- C_S = concentration of compressed gas being diluted (ppm)
- F_C = flow of compressed gas corrected to STP
- F_D = flow of zero gas (dilution air) corrected to STP
- F_t = total flow ($F_C + F_D$)

For determination of the NO concentration for a gas phase titration, use the dilution calculation:

$$C_F = \frac{F_C \times C_S}{F_T} = \frac{F_C \times C_S}{(F_C + F_D)}$$

Where:

- C_F = output concentration (ppm)
- C_S = NO concentration of compressed gas being diluted (ppm)
- F_C = NO flow at STP
- F_D = flow of zero gas (dilution air) corrected to STP
- F_t = total flow ($F_C + F_D$)

For determination of the O₃ concentration:

$$O_3 = NO_I - NO_{II}$$

Where:

- NO_I = NO concentration before introduction of O₃
- NO_{II} = NO concentration after introduction of O₃

For determination of the NO₂ concentration when the O₃ concentration is known:

$$NO_2 = NO_I - NO_{II}$$

Or

$$NO_2 = O_3$$

Since the NO_x converter in all analyzers is never 100% efficient, a calculation of converter efficiency must be performed.

$$\text{converter efficiency} = \frac{\text{NO}_2 \text{ increase}}{\text{NO decrease}} \times 100\%$$

Appendix E Calculations: Flow Measurements and Corrections

Bubble Flow Meter

The bubble flow meter technique is an absolute method of measuring the mass flow of gases. In order to measure mass flow in standard cubic centimeters per minute, the volume flow must be corrected for temperature, atmospheric pressure, and the vapour pressure of water.

The correction is made using the following equation:

$$\text{Mass Flow (sccm)} = \frac{\text{Volume (cc)}}{\text{Time (min)}} \times \frac{(P - P_v)}{760} \times \frac{298}{(273 + T)}$$

Where:

P = atmospheric pressure (mm of Hg)

P_v = vapour pressure of water (mm of Hg) at temperature T (°C), see table below

T = temperature of gas (°C)

Table of Vapour Pressure of Water (P_v)

Temp. (°C)	Press. (in Hg)	Press. (mm Hg)	Temp. (°C)	Press. (in Hg)	Press. (mm Hg)
15	0.50	12.79	24	0.88	22.38
16	0.54	13.63	25	0.94	23.76
17	0.57	14.53	26	0.99	25.51
18	0.61	15.48	27	1.05	26.74
19	0.65	16.48	28	1.12	28.35
20	0.69	17.54	29	1.18	30.04
21	0.73	18.65	30	1.25	31.82
22	0.78	19.83	31	1.33	33.70
23	0.83	21.07	32	1.40	35.66

Linear Mass Flow Meters

Although linear mass flow meters are generally very stable, it is desirable that calibration checks be performed periodically. The unit should be checked at several points over its full range using a bubble flow meter. Particulates carried into the flow meter by the gas stream will result in inaccuracy, or at worst, clogging of the sensor. Therefore, the best method of ensuring that the flow meter remains stable and accurate is to provide good flow filtration.

Rotameter

In order to measure mass flow using a rotameter, the volumetric flow must be corrected for both temperature and atmospheric pressure. The equation for correction of volumetric to mass flow is:

$$F_{STP} = F_{AMB} \times \sqrt{\frac{P_A}{760} \times \frac{298}{T_A}}$$

Where:

F_{STP} = mass flow at STP, which is ambient volumetric flow corrected for temperature and pressure

F_{AMB} = flow, for a given float ball position, as read from the manufacturer's curve

P_A = ambient barometric pressure (mm of Hg)

T_A = ambient temperature (°K)

The rotameter is a moderately accurate, rugged, field portable measuring device. Since air density will affect the accuracy of the unit, it is essential that STP corrections be applied to all flow measurements.

Accuracy is affected by build-up of contaminants on both the walls of the tube and the indicator ball. Therefore, some effort should be made to eliminate particles from the air stream. Rotameters can be cleaned by running methanol through the unit. Rotameters should be cross-checked using a bubble flow meter or mass flow meter approximately every 6 months.

Capillary and Orifice Systems

Capillary and orifice based calibration systems use a set of flow restrictors and a corresponding set of pressure differential versus flow curves to give a predetermined flow. Because of the high sensitivity to the diameter of the restrictor (proportional to the 4th power), and variances in the repeatability of pressure gauges, accuracy of these systems generally leaves much to be desired. Therefore, flows should be cross-checked more frequently than with other systems. If this system is used to generate a calibration standard, the flow system should be used only to maintain a constant flow. The flow measurement should be done with either a bubble flow meter or a mass flow meter.

Appendix F Calculations: Methane Equivalent

Methane equivalent is obtained from the following expression:

$$\text{methane equivalent} = \frac{\text{molecular weight of hydrocarbon gas (in calibration mixture)}}{\text{molecular weight of methane}}$$

Example

If the calibration mixture is 1.40 ppm propane (C₃H₈) and 5.00 ppm methane (CH₄) with the balance being zero air, then the total hydrocarbon content in methane equivalent is:

$$\begin{aligned} \text{methane equivalent} &= \left(\frac{\text{molecular weight of C}_3\text{H}_8}{\text{molecular weight of CH}_4} \times 1.40 \text{ ppm} \right) + 5.00 \text{ ppm} \\ &= \left(\frac{(3 \times 12.01) + (8 \times 1.008)}{(1 \times 12.01) + (4 \times 1.008)} \times 1.40 \text{ ppm} \right) + 5.00 \text{ ppm} \\ &= \left(\frac{44.09}{16.04} \times 1.40 \text{ ppm} \right) + 5.00 \text{ ppm} \\ &= (2.749 \times 1.40 \text{ ppm}) + 5.00 \text{ ppm} \\ &= 3.85 \text{ ppm} + 5.00 \text{ ppm} \\ &= 8.85 \text{ ppm} \end{aligned}$$

Appendix G Example Reports

Example report for a multi-point as found verification:

H₂S Analyzer Multi-point As Found Verification

Required elements of VC 11-D are noted in red text Acceptance criteria are noted in blue text

Date: 12-May-23 Location: TVMU Performed by: AB
VC 11-D(b)(ii) VC 11-D(b)(i) VC 11-D(p)

Temperature: 20.0 °C Barometric Pressure: 770 mmHg
VC 11-D(g)(i) VC 11-D(g)(ii)

Verification routine or non-routine: Routine
 Reason for Verification: - Routine 3-month verification.

Monitor: Make/Model: Thermo 450i Serial # 123456789
VC 11-D(b)(iii) VC 11-D(b)(iv)
 Inlet flow (sccm): 989 Range ppm: 0.1
 Last Cal./Ver. Date: 17-Feb-23 As Found Cc/Ci: 1.022
VC 11-D(b)(v) VC 11-D(b)(v)

Verification Method: Dilution VC 11-D(e)
 Calibrator: Make/Model: Sabio 2010 VC 11-D(d) H₂S cylinder #: FF51720
 Calibrator Serial #: 1234 VC 11-D(e) Cylinder Expiry : 17-Dec-23
 Calibrator Verification Date: 13-Mar-23 VC 11-D(f) H₂S Conc. (ppm): 9.85
 Flow Device: Bios 530+ SN:2345 Zero Air ID #: Pump Pack
 Flow Device Expiry: 20-Jul-23

Calibrator Reference Settings:

Flows	Zero	High	Mid	Low
Dilution	5000	4960	4980	4990
Gas		40	20	10

Verification:

Calibrator Measured Flow (sccm)			Calculated Conc. (ppm)	Indicated Concentration (ppm)		Cc/Ci Ratio		
Air	Gas	Total		Initial	Final	Previous	Initial	Final
5000	0.000	5000.0	0.0000	0.0004	-0.0006			
4960	40.000	5000.0	0.0788	0.0765	0.0733	1.018	1.036	1.066
4980	20.000	5000.0	0.0394	0.0380		1.024	1.048	
4990	10.000	5000.0	0.0197	0.0186		1.044	1.082	
Average Correction Factor (CF) =						1.029	1.055	

VC 11-D(m) Slope, Y-intercept, and Correlation coefficient of calibration curves. VC 11-D(i); High, Mid, and Low point response accuracy VC 11-D(j) and VC 11-D(k)

Linear Regression Analysis:
 $y=mx+b$ (x =calculated conc., y =indicated conc.)

	VC 11-D(m)	Criteria
r (Correl. Coeff.) =	1.000	≥ 0.995
m (Slope) =	0.969	0.90-1.10
b (Icpt. as % of f.s.) =	0.0%	± 3% F.S.

Accuracy Analysis
 (% Error Cc vs. Ci):

Criteria	± 10%
High Pt. =	3.43 %
Mid Pt. =	4.57 %
Low Pt. =	7.61 %

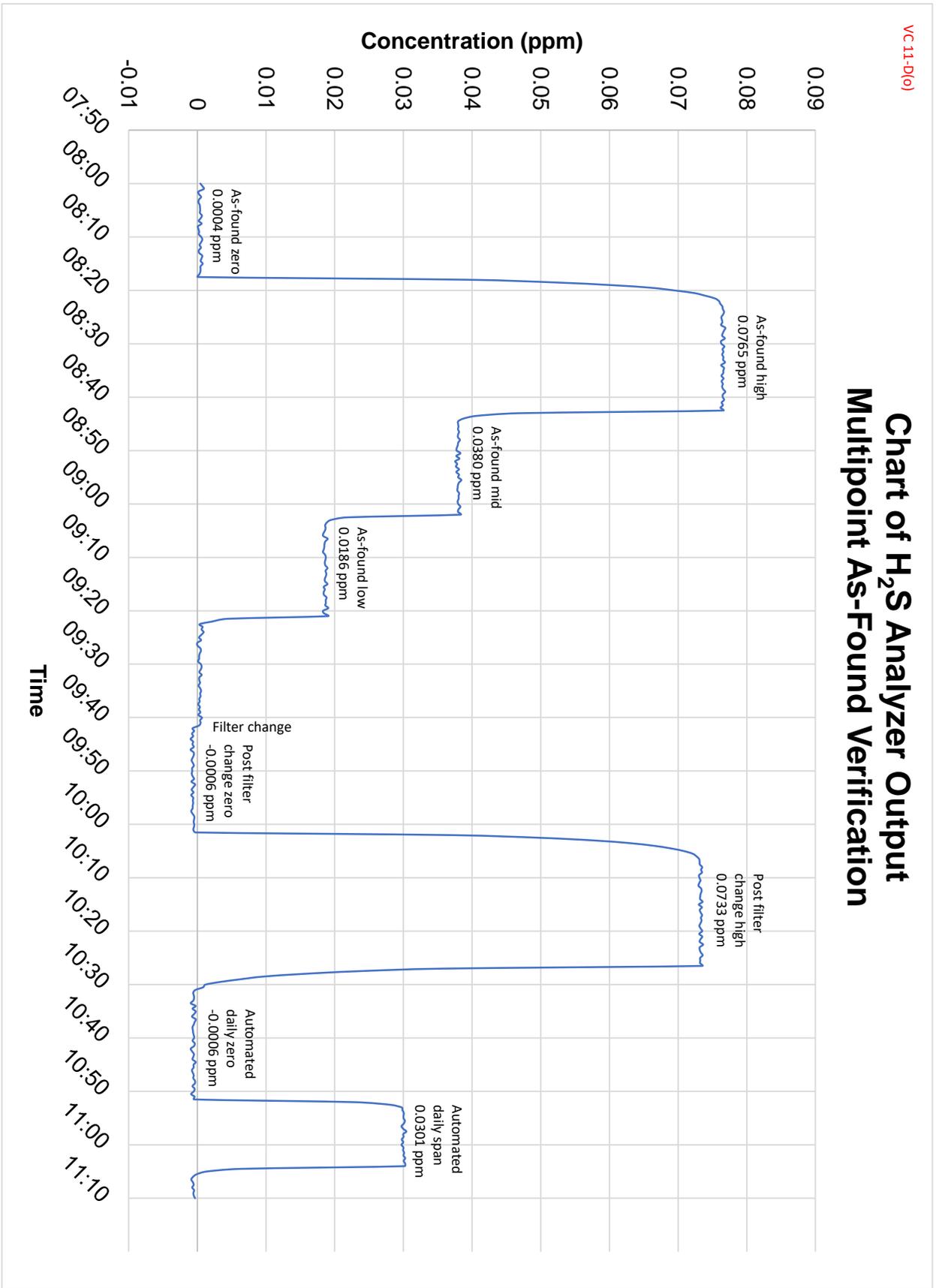
Linearity Analysis
 (% Diff. Corr. Factors):

Criteria	± 5%
Mid Pt. =	1.20%
Low Pt. =	4.53%

Notes: - Provided as an example of an MAFV only.
- No changes, repairs, or adjustments made; only filter changed.
- SO₂ scrubber challenged with ~380 ppb SO₂ following MAFV. No observable response.

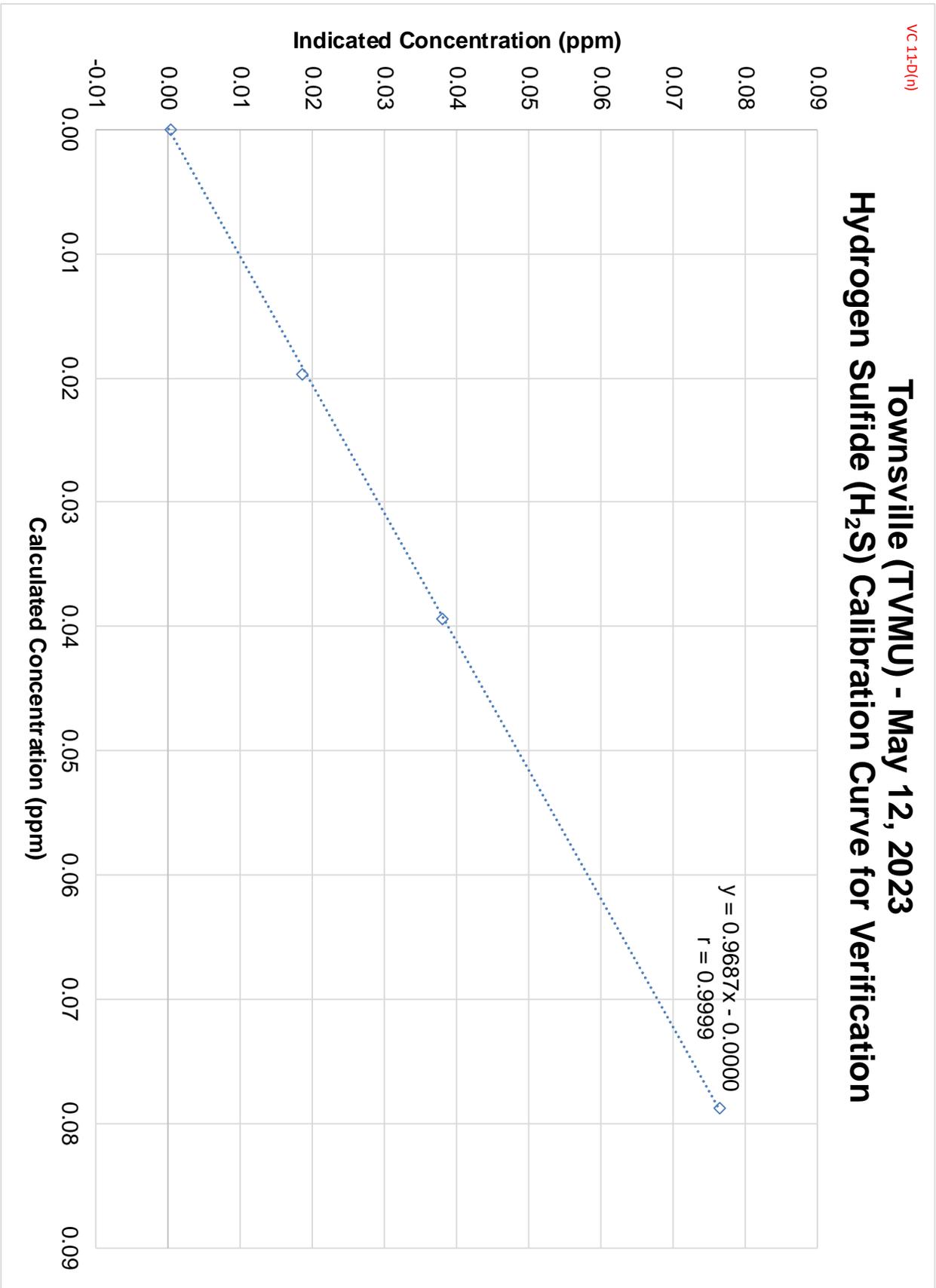
Reviewed by: Jane Doe

Chart of H₂S Analyzer Output Multipoint As-Found Verification



VC 11-D(n)

Townsville (TVMU) - May 12, 2023 Hydrogen Sulfide (H₂S) Calibration Curve for Verification



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Example report of verification and adjustment:

H₂S Analyzer Multi-point As Found Verification and Adjustment

Required elements of VC 11-D are noted in red text
Acceptance criteria are noted in blue text

Date: 12-May-23 **Location:** TVMU **Performed by:** AB
VC 11-D(b)(i) VC 11-D(b)(i) VC 11-D(p)

Temperature: 20.0 °C **Barometric Pressure:** 770 mmHg
VC 11-D(g)(i) VC 11-D(g)(i)

Verification routine or non-routine: Routine
VC 11-D(a) VC 11-D(a)

Reason for Verification and Adjustment: - Routine 3-month verification.
- Adjustment performed due to as-found low-point being outside 8% criteria defined in QAP.

Monitor: Make/Model: Thermo 450i VC 11-D(b)(iii) Serial # 123456789 VC 11-D(b)(iv)
 Inlet flow (sccm): 989 VC 11-D(b)(vi) Range ppm: 0.1
 Last Cal./Ver. Date: 17-Feb-23 VC 11-D(b)(v) As Found Cc/Ci: 1.030

Verification Method: Dilution VC 11-D (e)
Calibrator: Make/Model: Sabio 2010 VC 11-D (d) H₂S cylinder #: FF51720
 Calibrator Serial #: 1234 VC 11-D (e) Cylinder Expiry : 17-Dec-23
 Calibrator Verification Date: 13-Mar-23 VC 11-D (f) H₂S Conc. (ppm): 9.85
 Flow Device: Bios 530+ SN:2345 Zero Air ID #: Pump Pack
 Flow Device Expiry: 20-Jul-23

Calibrator Reference Settings:

Flows	Zero	High	Mid	Low
Dilution	5000	4960	4980	4990
Gas	X	40	20	10

Verification and Adjustment:

VC 11-D(h)(i) and VC 11-D(h)(ii)			VC 11-D(h)(iii)	VC 11-D(h)(iv) and VC 11-D(h)(v)		VC 11-D(j) and VC 11-D(k)		
Calibrator Measured Flow (sccm)			Calculated Conc. (ppm)	Indicated Concentration (ppm)		Cc/Ci Ratio		
Air	Gas	Total	(ppm)	Initial	Final	Previous	Initial	Final
5000	0.000	5000.0	0.0000	0.0004	0.0000	X	X	X
4960	40.000	5000.0	0.0788	0.0765	0.0787	1.0184	1.0355	1.0013
4980	20.000	5000.0	0.0394	0.0380	0.0394	1.0240	1.0479	1.0000
4990	10.000	5000.0	0.0197	0.0186	0.0196	1.0438	1.0824	1.0051
Average Correction Factor (CF) =						1.0287	1.0553	1.0021

VC 11-D(m) Slope, Y-intercept, and Correlation coefficient of calibration curves. VC 11-D(i); High, Mid, and Low point response accuracy VC 11-D(i); Mid and Low point response linearity

Linear Regression Analysis:
 $y=mx+b$ (x =calculated conc., y =indicated conc.)

	Initial	Final	Criteria
r (Correl. Coeff.) =	1.000	1.000	≥ 0.995
m (Slope) =	0.969	0.999	0.90-1.10
b (lcpt. as % of f.s.) =	-0.020%	-0.020%	± 3% F.S.

Accuracy Analysis (% Error Cc vs. Ci):

Criteria	± 10%	
	Initial	Final
High Pt. =	3.43 %	0.13 %
Mid Pt. =	4.57 %	X
Low Pt. =	7.61 %	X

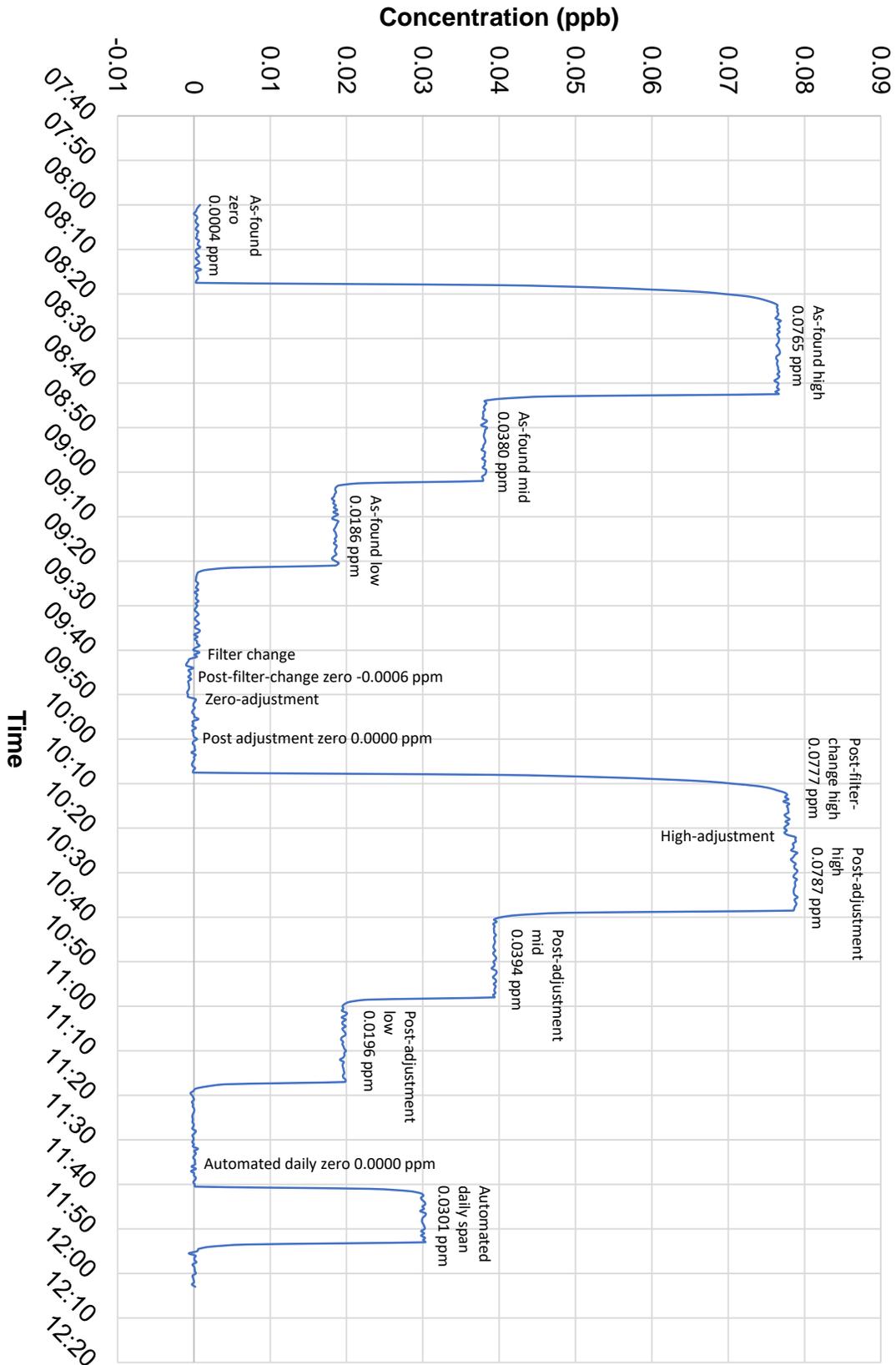
Linearity Analysis (% Diff. Corr. Factors):

Criteria	± 5%	
	Initial	Final
Mid Pt. =	1.20%	-0.13%
Low Pt. =	4.53%	0.38%

Notes: - Provided as an example of result of option to specify additional criteria in operator QAP as to when to perform adjustment.
- No changes, repairs, or adjustments made prior to MAFV; adjustment performed after MAFV.
- SO2 scrubber challenged with ~380 ppb SO2 following adjustment. No observable response.

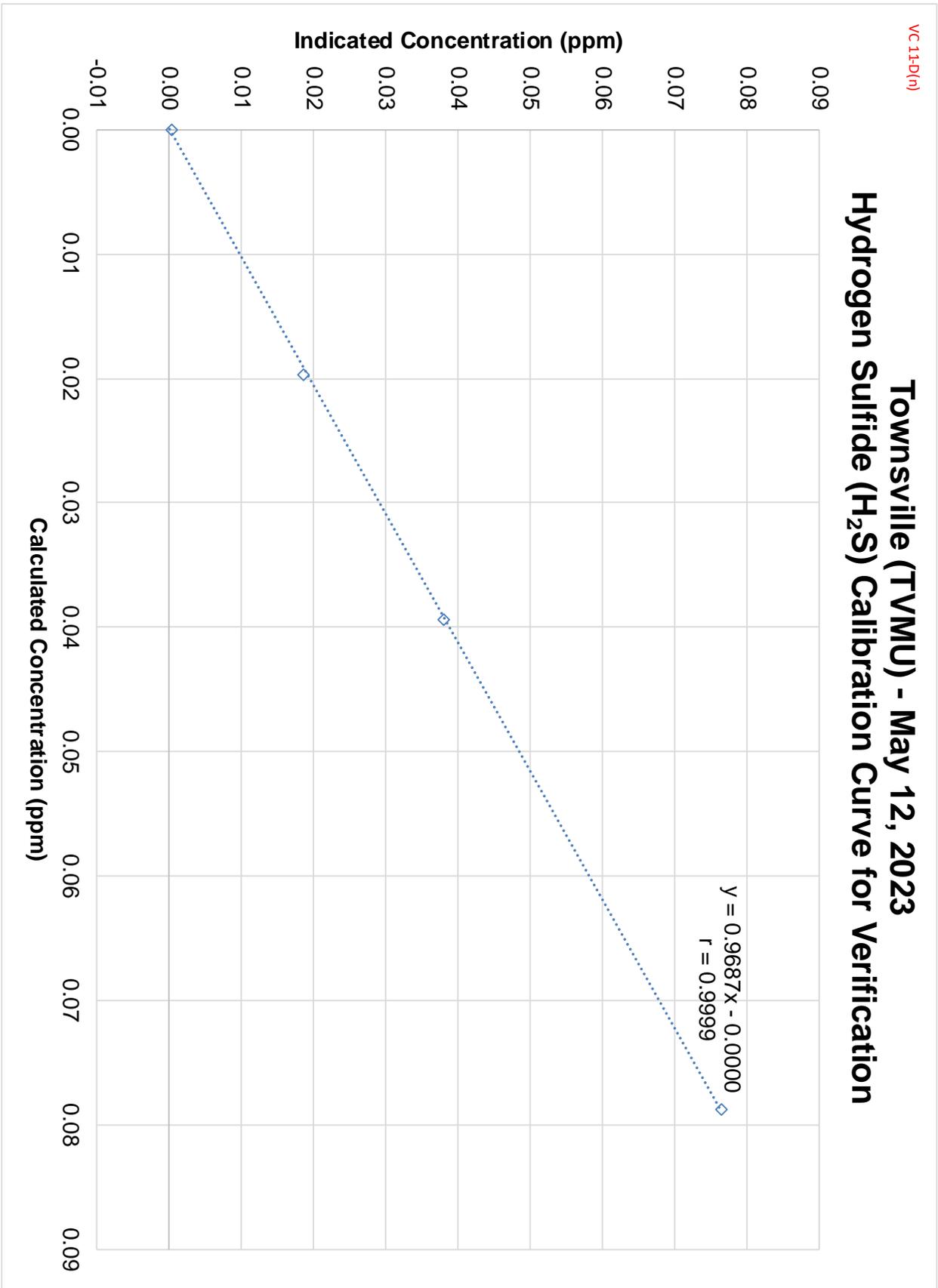
Reviewed by: Jane Doe

Chart of H₂S Analyzer Output Multipoint As-Found Verification and Adjustment



VC 11-D(n)

Townsville (TVMU) - May 12, 2023 Hydrogen Sulfide (H₂S) Calibration Curve for Verification



VC 11-D(n)

Townsville (TVMU) - May 12, 2023 Hydrogen Sulfide (H₂S) Calibration Curve for Adjustment

