

METHOD

Calibration of Gas Detectors

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Revision: 1.0

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1. Purpose and Scope

1.1 Purpose

This Standard Operating Procedure (SOP) describes the method for calibrating gas detectors to ensure accurate measurement of specific gas concentrations in accordance with ISO/IEC 17025:2017 requirements.

1.2 Scope

This procedure applies to the calibration of portable gas detectors used for the detection and measurement of gases in the below table. The calibration process involves both zero calibration using fresh air or nitrogen, and span calibration using NIST-traceable reference gases as listed in the below table.

Target Gas Name	Chemical Symbol	Gas Range
Acetylene	C ₂ H ₂	0 - 50 ppm
Oxygen	O ₂	0% - 21%
Ethylene	C ₂ H ₄	0 - 80 ppm
Chlorine	Cl ₂	0 - 10 ppm
Carbon Monoxide	CO	0 - 5000 ppm
Carbon Dioxide	CO ₂	0 - 100 %vol
Ethylene Oxide	ETO	0 - 10 ppm
Methane	CH ₄	0 - 50 %LEL
Hydrogen	H ₂	0 - 5,000 ppm
Hydrogen Sulfide	H ₂ S	0 - 100 ppm
Formaldehyde	CH ₂ O	0 - 10 ppm
Hydrogen Chloride	HCl	0 - 10 ppm
Hydrogen Cyanide	HCN	0 - 20 ppm
Nitrogen	N ₂	0 - 100 %vol
Ammonia	NH ₃	0 - 50 ppm
Nitrous Oxide	N ₂ O	0 - 200 ppm
Nitrogen Dioxide	NO ₂	0 - 200 ppm
Phosphine	PH ₃	0-10 ppm
Sulfur Dioxide	SO ₂	0 - 10 ppm
Isobutylene	C ₄ H ₈	0 - 50 ppm
Argon	Ar	0-100 %vol
Helium	He	0-100 %vol
Nitric Oxide	NO	0-1000 ppm
Ethanol	C ₂ H ₆ O	0-500 ppm

2. References

- ISO/IEC 17025:2017 - General requirements for the competence of testing and calibration laboratories
- Manufacturer's operation manual for the specific gas detector model being calibrated
- NIST - Certificates of Analysis for reference gases used in calibration

3. Definitions

- **Zero Calibration:** The process of setting the gas detector to read zero in an environment free of the target gas.
- **Span Calibration:** The process of calibrating the gas detector to a known concentration of the target gas.
- **Reference Gas:** A gas with a known concentration that is NIST-traceable and used as a standard for calibration.

- **LPM:** Liters Per Minute, a unit of flow rate.
- **ppm:** Parts Per Million, a unit of concentration.
- **%vol:** percentage of volume, a unit of concentration.

4. Responsibilities

4.1 Calibration Technician

- Perform calibrations according to this SOP
- Document all calibration activities
- Verify that all equipment is functioning properly
- Report any anomalies or issues encountered during calibration

4.2 Quality Manager

- Ensure that this SOP is implemented correctly
- Review calibration records
- Approve any deviations from this SOP
- Ensure traceability of reference standards

5. Equipment and Materials

5.1 Equipment

- Gas detector to be calibrated
- Calibration cap (as required per gas detector model)
- Flow regulator capable of delivering 0.5 LPM
- Timer or stopwatch
- Thermometer and humidity for recording environmental conditions

5.2 Materials

- NIST-traceable reference gas cylinders with appropriate concentrations for the target gas
- Zero air or nitrogen cylinder (if fresh air is not suitable for zero calibration)
- Connecting tubing compatible with the calibration gas

6. Environmental Conditions

6.1 Required Conditions

- Temperature: $20^{\circ}\text{C} \pm 5^{\circ}\text{C}$ ($68^{\circ}\text{F} \pm 9^{\circ}\text{F}$)
- Relative Humidity: 40% to 60%

6.2 Documentation

Record the environmental conditions at the beginning and end of each calibration procedure. If conditions fall outside the specified ranges, document this as a deviation and assess the impact on calibration results.

7. Calibration Procedure

7.1 Pre-Calibration Checks

1. Verify that the gas detector is in good working condition with no physical damage.
2. Check battery level to ensure adequate power for calibration.
3. Inspect all calibration equipment, including tubing and all connections.
4. Verify that reference gas cylinders are within their validity period.
5. Record the serial number of the gas detector and the certificate numbers of reference gases.
6. Record environmental conditions.

7.2 Zero Calibration Procedure

1. Power on the gas detector and allow 2 minutes for stabilization in fresh air.
2. If using fresh air for zero calibration: a. Ensure the calibration area is free from target gas contamination. b. Allow the detector to stabilize in fresh air for at least 2 minutes.
3. If using nitrogen for zero calibration: a. Connect the nitrogen cylinder to the gas detector using the appropriate calibration cap. b. Set the flow rate to 0.5 LPM. c. Allow nitrogen to flow for at least 2 minutes.
4. The gas detector reading may not read precisely 0 ppm. Depending on the model, it may display 0.0 or 0.00 ppm. Depending on the scale it may also read in %vol.
5. Save the zero calibration point to the detector per the gas detector model instructions.
6. Verify that the real-time display reading shows 0 ppm (or 0.0/0.00 ppm according to the detector's display precision or scale %vol).
7. Record the pre- and post-calibration zero readings.

7.3 Span Calibration Procedure

1. Ensure that zero calibration has been completed successfully before proceeding.
2. Connect the reference gas cylinder to the gas detector using a calibration cap or equivalent.
3. Set the flow rate to 0.5 LPM.
4. Expose the gas analyzer to the reference gas for 1 minute or until the reading has stabilized. Document any deviation from the standard exposure time.
5. Verify that the displayed gas value has stabilized.
6. Save this span calibration point to the gas detector per instructions of the gas detector model.
7. Record the following:
 - Pre-calibration reading (before adjusting)
 - Span gas concentration from the Certificate of Analysis

- Post-calibration reading
- 8. Allow the detector to return to fresh air and verify that the reading returns to zero.

7.4 Multi-Sensor Gas Calibration

For gas detectors with more than one gas sensor that require calibration to more than one target gas:

1. Repeat the zero and span calibration procedure (Section 7.2 and 7.3) for each target gas.
2. A mixed reference gas can be used to expose a multi-sensor gas detector. Undertake zero and span calibration simultaneously for each gas sensor within the multi-gas detector.
3. If a mixed reference gas is not available, treat each gas sensor separately and following Section 7.2 and 7.3.
4. Document the calibration results for each sensor separately (but on the same gas detector calibration certificate).

7.5 Calibration Verification

1. After completing all calibration steps, verify the calibration by exposing the detector to the reference gas again.
2. Record the verification reading.
3. The reading should be within $\pm 4\%$ of the reference gas concentration.
4. If verification fails, repeat the calibration procedure.

8. Documentation and Records

8.1 Required Documentation

For each calibration performed, record the following information:

1. Date and time of calibration
2. Calibration technician name
3. Gas detector information:
 - Manufacturer and model
 - Serial number
4. Reference gas information:
 - Gas type and concentration
 - Cylinder number
 - Certificate number
 - Expiration date
5. Environmental conditions:
 - Temperature
 - Relative humidity
6. Calibration results:
 - Pre-calibration zero reading

- Post-calibration zero reading
 - Pre-calibration span reading
 - Reference gas concentration used
 - Post-calibration span reading
7. Any deviations from this SOP
 8. Any observations or comments

8.2 Calibration Certificate

Upon successful completion of calibration, issue a calibration certificate that includes:

1. Title: "Certificate of Calibration"
2. Laboratory name and address
3. Unique identification of the certificate
4. Identification of the calibration method used
5. Description and identification of the gas detector
6. Date of calibration
7. Calibration results
8. Environmental conditions
9. Signature of the person authorizing the certificate
10. Statement that results relate only to the items calibrated
11. Statement on measurement uncertainty
12. Reference to the traceability of measurements to NIST standards

9. Uncertainty Analysis

Calculate and report the measurement uncertainty for each calibration according to the laboratory's uncertainty estimation procedure. The uncertainty is calculated as 95% confidence of the final calibration reading with a K factor equaling to 2. Items considered includes:

1. Reference gas uncertainty (from Certificate of Analysis)
2. Environmental conditions
3. Equipment resolution
4. Repeatability
5. Detector Drift during Calibration
6. Effect of gas flow rate

10. Quality Control

10.1 Regular Checks

1. Perform regular checks of reference gases using secondary standards.
2. Perform regular quality control checks on calibration equipment (as required).

10.2 Non-conforming Work

If any part of the calibration process does not conform to this SOP:

1. Document the non-conformance.
2. Evaluate the impact on calibration results.
3. Take corrective action as necessary.
4. Notify the customer if results are affected.

11. Revision History

Revision	Date	Description of Changes	Approved By
1.0	May 16, 2025	Initial Release	Quality Manager

12. Approvals

Role	Name	Signature	Date
Author	Dr. Koz Galatsis	Dr. Koz Galatsis	08/25/2025
Technical Reviewer	Dr. Koz Galatsis	Dr. Koz Galatsis	08/25/2025
Quality Manager	Dr. Koz Galatsis	Dr. Koz Galatsis	08/25/2025

APPENDIX 1

Example Certificate of Calibration - for a Single Gas Detector.



Certificate of Calibration

USA NIST Traceability Calibration

Calibration Location:

777 Silver Spur Road, Suite #130
Rolling Hills Estates, CA, 90274, USA

Test Conditions: Temperature: 70F \pm 1%, Humidity: 52% RH \pm 1%

Calibration Method ID: SOP-CAL-001

Certificate Number: 4567

Manufacturer: Forensics Detectors

Detector Model Number: FD-90A-CO

Reference Gas(s): CO

Detector Serial Number: 245686867

Cylinder Lot Number: 304-403306989-1

Reference Gas Expiration: 04/05/2029

INSPECTION RESULTS

Visual Inspection? Normal, no anomalies

PASS

Detector Functionality? Normal, no anomalies

PASS

Alarm Functionality? Normal, no anomalies

PASS

CALIBRATION TEST RESULTS

Gas Name

CO

Reference Gas Concentration

200 ppm

Expanded Uncertainty 5%
(k=2, 95% confidence level)

\pm 10 ppm

Pre Zero Calibration (As Found)

0 ppm

Post Zero Calibration (As Left)

0 ppm

PASS

Pre Span Calibration (As Found)

189 ppm

Post Span Calibration (As Left)

200 ppm

PASS

Other Comments: N/A

Calibration Technician Name and Signature:

Austin Jun

Date of Calibration: 05/23/2025

Certificate Issue Date: 05/23/2025

Next Cal Due Date: 05/23/2026

The calibration results reported in this certificate relate only to the specific instrument / reference gas identified herein and are valid only for the conditions under which the calibration was performed. The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%. All measurements performed during this calibration are traceable to the International System of Units (SI) through the National Institute of Standards and Technology (NIST). This certificate shall not be reproduced except in full, without written approval from Forensics Detectors.

APPENDIX 2

Example Certificate of Calibration - for a Multi-Gas Detector with 4 gas sensors.



Certificate of Calibration

USA NIST Traceability Calibration

	Calibration Location: Forensics Detectors, 777 Silver Spur Road, Suite #130 Rolling Hills Estates, CA, 90274, USA
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Test Conditions:	Temperature: 70F \pm 1%, Humidity: 52% RH \pm 1%		
Calibration Method ID:	SOP-CAL-001	Certificate Number:	4567
Manufacturer:	Forensics Detectors	Model Number:	FD-4S
Reference Gas(s):	O ₂ , CO, H ₂ S, CH ₄	Serial Number:	245686867
Cylinder Lot Number:	304-403306989-1	Reference Gas Expiration:	04/05/2029

INSPECTION RESULTS

Visual Inspection?	Normal, no anomalies	<u>PASS</u>
Detector Functionality?	Normal, no anomalies	<u>PASS</u>
Alarm Functionality?	Normal, no anomalies	<u>PASS</u>

CALIBRATION TEST RESULTS

Gas Name	CH ₄	O ₂	CO	H ₂ S	
Reference Gas Concentration	50%LEL	20.9%vol	200 ppm	25 ppm	
Expanded Uncertainty 5% (k=2, 95% confidence level)	\pm 3 %LEL	\pm 1%vol	\pm 10 ppm	\pm 1 ppm	
Pre Zero Calibration (As Found)	0% LEL	0.0%	0 ppm	0 ppm	
Post Zero Calibration (As Left)	0% LEL	0.0%	0 ppm	0 ppm	<u>PASS</u>
Pre Span Calibration (As Found)	40% LEL	20.9%	200 ppm	25 ppm	
Post Span Calibration (As Left)	50% LEL	20.9%	200 ppm	25 ppm	<u>PASS</u>

Other Comments: N/A

Calibration Technician Name and Signature:

Mr. Austin Jun

Austin Jun

Date of Calibration: 05/23/2025

Certificate Issue Date: 05/23/2025

Next Cal Due Date: 05/23/2026

The calibration results reported in this certificate relate only to the specific instrument / reference gas identified herein and are valid only for the conditions under which the calibration was performed. The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%. All measurements performed during this calibration are traceable to the International System of Units (SI) through the National Institute of Standards and Technology (NIST). This certificate shall not be reproduced except in full, without written approval from Forensics Detectors.