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Flow Calibration Essentials for the OEHS Professional

Maintaining Sample Integrity and Avoiding Costly Invalidations

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Your Presenters Today

Ram Parameshwar

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Ram Parameshwar is a Staff Product Manager at Mesa Labs, overseeing product strategy and market development for the Instrumentation portfolio.

His background in industrial instrumentation, calibration, and diagnostic technologies supports his work leading commercial, product management, and marketing initiatives that drive growth, adoption, and improved customer outcomes.

Laurence R. Durio, M.S., CIH

Laurence Durio is a Certified Industrial Hygienist with more than 50 years of experience spanning OSHA enforcement, chemical manufacturing, large-scale remediation projects, and industrial hygiene program development.

As Principal of Durio Consulting Services, he has supported clients across the U.S. on complex exposure assessments, hazardous materials management, and expert testimony.

Laurence also teaches EPA/HUD/DEQ certification courses and brings deep practical insight into sampling integrity, regulatory expectations, and real-world IH challenges.

WHAT YOU WILL HEAR FROM US TODAY!

Agenda

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Mesa Labs Businesses

Protecting the Vulnerable®

Our Divisions

Calibration Solutions

Calibration Solutions provides products used to measure or calibrate temperature, pressure, pH, humidity, or other chemical or physical parameters for health and safety purposes in various settings.

Sterilization and Disinfection Control

Sterilization and Disinfection Control provides Mesa biological and chemical indicators that assess the effectiveness of sterilization and disinfection processes for hospital, medical device, and pharmaceutical industries.

Biopharmaceutical Development

Gyros Protein Technologies provides automated systems for protein analysis and peptide synthesis solutions that accelerate the discovery, development, and manufacture of biotherapeutic drugs.

Clinical Genomics

Agena Bioscience® offers highly sensitive and affordable genomic analysis testing solutions for clinical laboratories.

Calibration Solutions Business Unit

Calibration Solutions offers products & services used to measure or calibrate temperature, pressure, pH, humidity, flow, torque, and other chemical or physical parameters for health and safety purposes in various settings.

Renal Care

90XL™ & IBP Technician Meter & Modules

pHoenix XL Clinician Meters

Standard Reference Solutions

Continuous Monitoring

ViewPoint™ Sensors & SaaS

INSTRUMENTS

DataTrace™

MPIII & MPRF Data Loggers

DryCal™

Defender™ Series Flow Calibrators

Metrology Series Flow Calibrators

BGI

PQ200 & PQ100 Air Particulate Samplers

Torque

SureTorque™ & Torquo™ Cap Torque Testers

What is calibration?

And why does it matter for IH/OEHS professionals?

What is Calibration?

Calibration is the comparison of an instrument being tested to a known standard.

In our world, measuring air flow with a device of known accuracy (a calibrator).

Doing so usually involves setting the airflow to a desired value.

What Purpose does Calibration Serve in Our World?

It tells us how much air has been drawn through sample media.

In some cases, it ensures proper operation of sampling devices.

Bottom line, it helps ensure the accuracy of our results.

Evolution of Gas Flow Calibration

From Soap Bubbles to Piston Provers

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Evolution of Gas Flow Calibration

From Soap Bubbles to Piston Provers

Soap Bubble Meters *(Early 20th Century)*

- One of the earliest methods for gas flow measurement.
- Used a liquid soap film to track volumetric displacement over time.
- Simple and cost-effective but limited in accuracy, repeatability, and automation.

Rotameters *(Mid-20th Century)*

- A variable area flowmeter using a floating ball or float in a tapered tube.
- Commonly used in laboratories and industrial settings for visual flow indication.
- Accuracy was highly dependent on fluid properties and required frequent calibration.

Evolution of Gas Flow Calibration

From Soap Bubbles to Piston Provers

Bell Provers *(Mid-20th Century - Present)*

- Used a sealed, counterweighted bell that rises and falls in a liquid medium to measure gas displacement.
- Provided better accuracy than soap bubble meters but required large, cumbersome setups.
- Still used today as a primary standard in some laboratory environments due to its direct volumetric measurement.

Piston Provers *(Late 20th Century - Present)*

- Introduced as a more precise, portable, and automated alternative to bell provers.
- Uses a precision-machined piston moving through a known volume, providing direct, primary gas flow measurement – early provers were mercury sealed (liquid O-ring).
- Eliminates issues with fluid contamination, temperature fluctuations, and operator variability.

Primary Standards

The Foundation of Defensible Measurements

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What are Primary Standards?

A primary standard is defined as a device or object used as the reference in a calibration that is acknowledged to be of the highest metrological quality and that derives its measurement without reference to another standard of the same quantity.

The attributes of a primary standard is based on fundamental measurements such as time, length, temperature and pressure.

Primary vs. Secondary Standards

What is the difference?

Primary Standard

- Standards based on physically measurable parameters
  - Volume or the dimensions defining it
  - Time
- Piston prover principle is volume/time = flow rate. This is a fixed, linear relationship unaffected by flow. For standardized flow, this is compensated for temperature and absolute pressure, also measurable parameters.
- Primary standard calibrators are traceable to recognized national and international standards; thus, their calibrations are legally defensible.

Secondary Standard

- Standards based on analogies to physically measurable parameters not directly related to air/gas flow
  - Change of resistance of a hot wire when cooled by airflow
  - Change of thickness of an aneroid when deformed by airflow/pressure changes
  - Change in angle of a vane subjected to airflow, etc.
- These are indirect, usually non-linear, relationships assuming all hot wires/aneroids/vanes, etc. behave the same, with the results displayed based on the input of the analogous parameter to an algorithm of unknown and generally non-linear accuracy.
- What could possibly go wrong? Hint: lots, including lack of legal defensibility.

Ideal Piston Prover

Example of Primary Standard

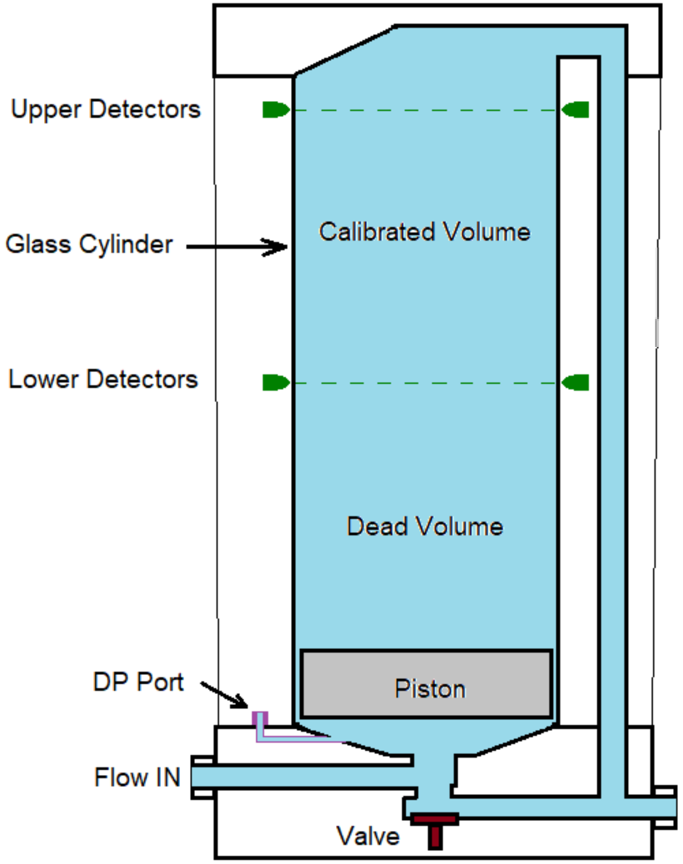
Design Concept

- Volume Displacement
  - Time
  - Length & diameter
- Frictionless

Components

High Precision Sensors

- Timing crystal
- Infrared light emitters/detectors
- Accurate calibrated volume
- Multiple pressure sensors
- Temperature sensor

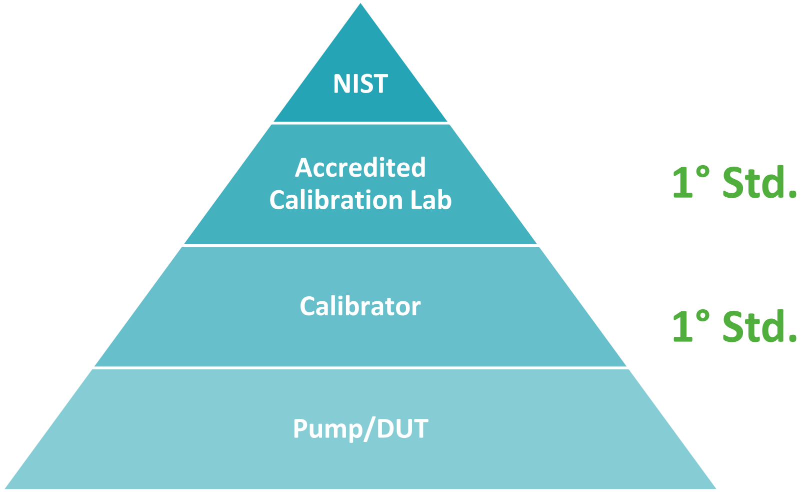


Achieving NIST Traceability

With a Primary Standard

Measurement of fundamental quantities achieved NIST traceability

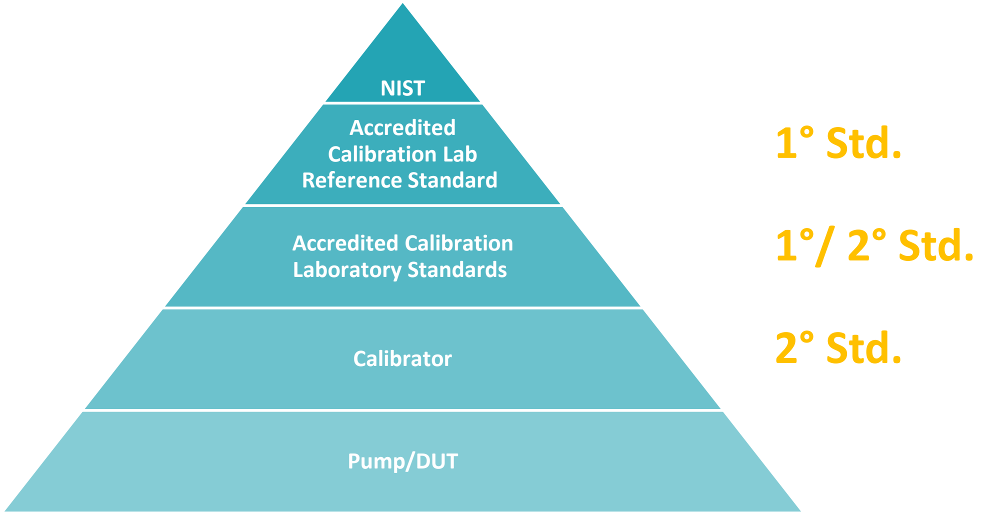
- Volume is defined by the piston's actual physical dimensions
- Time is measured by a high-precision clock
- Pressure and temperature are measured with sensors traceable to NIST fundamental quantities



Achieves NIST traceability as fundamental quantities are measured with lower uncertainty.

With a Secondary Standard

- Do not directly measure a fundamental quantity
- Must be calibrated against a primary standard
- If removed from calibration for too long, traceability is broken



A secondary std. can be calibrated with a NIST traceable device as it does not measure fundamental quantities and usually with higher uncertainties.

Applications and Key Characteristics

Applications of Calibrators

Industrial hygiene sampling | Environmental sampling |
Calibration/verification of process instrumentation | Specialty applications

Industrial Hygiene Sampling

Primary determines employee/worker exposures, limited area sampling. Contaminants are either particulates or gasses/vapors.

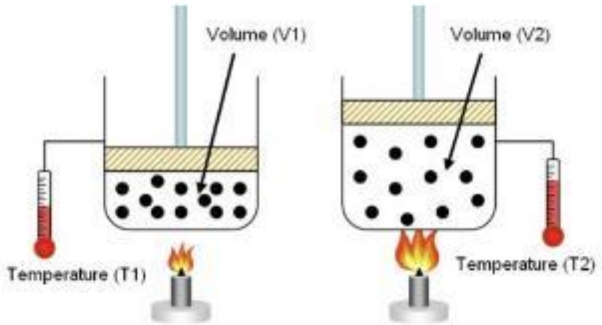
- Particulate limits are in mass or count/volume, sampled at medium flow
  - Mass and count are measured directly, so temp and pressure don't matter
- Gas/vapor limits are in ppm or ppb by volume, sampled at low flow
  - ppm/ppb are measured indirectly based on mass/standard volume, so temperature and pressure must be compensated for ("standardized")
- By regulatory and professional practice, standardizing for temperature and pressure invalidates particulate samples while failure to standardize invalidates gas/vapor samples.

Why Standardize for Gasses & Vapors

The body responds to the mass of contaminant, not its concentration

Charles Law *(Temperature-Volume Relationship)*

As temperature increases, volume expands
(proportional relationship)



Boyles Law *(Pressure-Volume Relationship)*

When pressure increases, volume decreases
(inverse relationship)

Volume (V) of a fixed mass of gas or vapor is directly proportional to absolute temperature (T) and inversely proportional to absolute pressure (P)

From the combined gas law, $\mathbf{V \propto T \div P}$

Industrial hygiene standardizes to 25° C and 760 mm Hg, environmental to 20° C and 760 mm Hg

Standardizing (Or Not) Is Not Trivial

- Temperature change of ≈ 27∘ F (15∘ C) → 5% change
- Altitude change of ≈ 1,400 feet (425 meters) → 5% change
- Effects can be additive or offsetting
- Standardizing must be based on the temperature and pressure of the area to be sampled, not the area where the calibration is performed unless they are the same.

Professional and Regulatory Guidance

Professional Practice

- As professionals, we want our work to be accurate
- Absent a regulatory requirement, standard practice is +/- 5%

Required by Regulations

- OSHA/NIOSH methods generally based on +/- 5% pre-sampling to actual and pre- to post-sampling flows
- EPA methods vary, generally +/- 5% but some are as low as +/- 1% and asbestos (a common application) is + 0/- 5%

Guidance from OSHA/NIOSH and Implications for Calibrator Choices

Organization	Relevant Section / Text	Key take-aways for IH/OEHS
OSHA	OTM Section II, Chapter 1 – Appendix D: Sampling Pump Calibration “Pump flow calibrators … should have a certified accuracy that is ±1 % …… have an annual calibration traceable to the National Institute of Standards and Technology (NIST) where a traceable calibration back to time and volume standards are performed.” Section C: “….. sampling pump should maintain its constant flow rate to within ±5% or 3 mL/min of its calibrated set flow rate….”	• Calibration equipment must be checked and traceable to NIST. • Accuracy requirement of ±1 % is met by primary standards due to design and physics. Ensure this is the case if not using primary standards.
NIOSH	NMAM 5th Edition – Chapter D “General Considerations for Sampling Airborne Contaminants” “For laboratory use, primary standards, such as a spirometer or soap-bubble meter, are recommended.”	• Use of primary standards is explicitly advised for pump calibration.

As a result, organizations like OSHA utilize primary standards to minimize uncertainty and increase defensibility in exposure monitoring.

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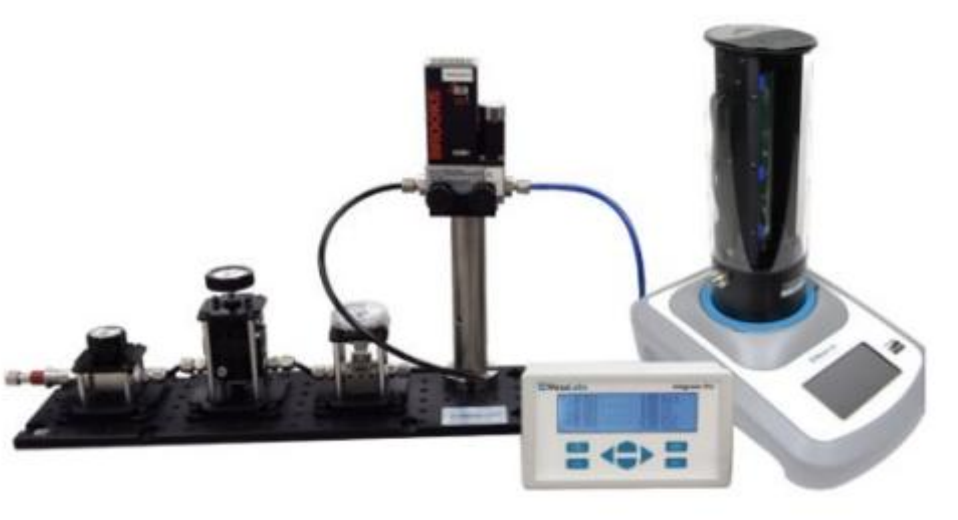
Environmental Sampling

- Done with area or emission source samples.
- Flow rates depend on method, often higher than for industrial hygiene sampling.
- Some particulate sampling methods call for temperature and pressure standardization.
- Selection of the proper calibrator depends upon the contaminant/method of interest.
- In all cases, a condensing atmosphere contraindicates use of a piston prover

Calibration/Verification Of Process Gas Flow Instrumentation

- Mass flow meters and rotameters
- Must be done within pressure and temperature limits of the calibrators
- Accuracy requirements may dictate more sophisticated calibrators than normally used for industrial hygiene and environmental sampling
- Only compatible with non-condensing gasses
- Corrosive and flammable gasses are concerns which must be evaluated



Specialty Applications

- In-line installation on laboratory equipment.
- Tank/vessel sampling.
- Corrosive, radioactive and flammable applications must be evaluated.
- No set guidelines on suitability/functionality - evaluate on a case-by-case basis.

Avoiding Common Sampling Pitfalls That Lead to Invalidations

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Why Calibrate?

False Results Are Expensive

- False high results can cause institution of unnecessary controls and their associated costs.
- False low results can jeopardize health and the environment, and lead to regulatory violations.
- Any false result in process instrumentation can result in sub-optimal production or worse.
- Any false result reflects badly on the party generating it.

Good Calibration Practices

Use The Appropriate Calibrator

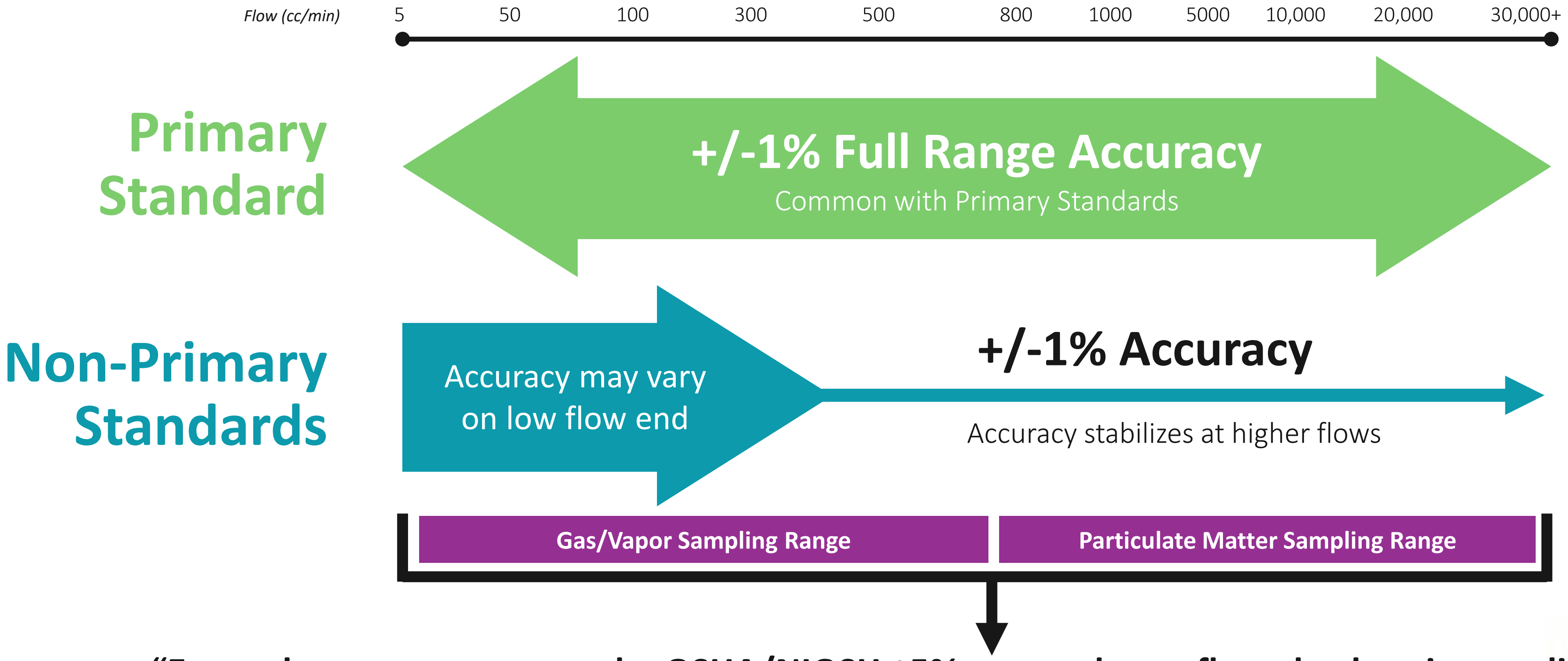
Stay within the flow range of the calibrator

- *Over-range is VERY limited*
- *Under-range is slow and accuracy suffers*

Some calibrators are ± a certain % or a fixed flow - whichever is greater.

Confirm that the calibrator you are using does not lose so much accuracy at low flows that the fixed flow tolerance exceeds the method accuracy tolerance.

Calibrator Accuracy Impacts System Uncertainty



"Even when a pump passes the OSHA/NIOSH ±5% pre- and post-flow check, using a calibrator with accuracy worse than the ±1% recommended in OSHA OTM can still raise total system uncertainty."

Good Calibration Practices

Continued

Stay within the range and requirements of the sampling method(s) utilized

- Particulates NORMALLY medium flow volumetric
- Gasses/vapors NORMALLY low flow standardized
- If in doubt, check the method

For particulate sampling, a volumetric calibrator is appropriate

For gas/vapor sampling, a calibrator such which provides needed information or performs standardization calculations is helpful

Good Calibration Practices

Continued

Calibrate With Sampling Train In Line

Use the same train as samples will be collected with.

Document Calibrations

Date, time, location, device, calibrated flow, temperature and pressure if standardizing, and person doing the calibration.

Can be on sample documentation or separate calibration log.

Common Calibration Errors

- Not allowing the calibrator to temperature-equilibrate before use.
  - Cold to warm can cause condensation in the cylinder.
  - Any difference can interfere with both volumetric and standard flow.
- Connecting a suction pump to the pressure fitting and vice versa.
- Not calibrating at the same temperature and/or pressure as will be sampled at.
- Not charging the calibrator.
- Standardizing particulate samples and not standardizing gas/vapor samples.

Good Calibration Practices

Problems?

- Verify battery is charged/charge as necessary
- Reset the Instrument if not responding
- Follow troubleshooting guide from OEM
- Call tech support

Risks of Relying on "Calibrated Pumps" from Third Parties

What to look out for

Unknown Calibration Quality

1

- Who calibrated the pump?
- With what standard? At what accuracy?
- Is documentation complete enough for defensibility?

Calibration Gaps During Actual Use

2

- Pumps must be calibrated before and after every sampling event.
- A pump calibrated "before shipping" does not cover multi-day field use.
- Supplier conditions (temperature, pressure) rarely match the sampling site.
- Supplier does not know—or calibrate with—your specific sampling train.

Shipping may affect calibration

3

- Transport through multiple depots, trucks, rough handling.
- Temperature and pressure swings, especially air transport.
- All can shift calibration outside tolerance.

Consequences if Post-Sampling Calibration Fails

4

- Pump no longer available for resampling.
- Samples may already be analyzed → laboratory fees lost.
- The operation or process sampled may no longer be running → rescheduling required.

Case Studies

01 — **Case Study One**
Insecticide Poisoning

02 — **Case Study Two**
No Exposure Leads to Supreme Court

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Keeping Your Calibrations and Pumps Reliable

The Role of OEM Service

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Why Send to OEMs for Service

It is more than just a **flow check**

Full Service from OEM

- Cleaning
- Troubleshooting
- Parts replacement
- Conditioning
- Full functional checks
- Multi point calibrations
- Adjustments where necessary
- Added warranty

Full Sensor Calibration/Check

- Temperature
- Differential Pressure
- Infrared light emitters/detectors

Volumetric Dimensional Calibration

- Piston OD
- Cylinder ID
- Stroke Length

Flow Calibration and Adjustments

Trust the source that built your unit!

OEMs have original parts, proprietary diagnostics, and expertise to ensure your equipment performs to spec.

ISO/IEC 17025 Accredited Calibration Labs

What is means for IH/OEHS Flow Calibration

Defines how calibration labs demonstrate competence

ISO/IEC 17025 sets the international requirements that a lab must meet to prove it can generate reliable, scientifically valid calibration results.

Calibration Gaps During Actual Use

Critical for IH: pump's flow rate—and therefore the sample volume—is defensible only when the calibration uncertainty and method are clearly stated.

Accreditation assures the lab follows a validated, audited quality system

Labs accredited to ISO/IEC 17025 operate under strict controls for methods, equipment, personnel training, and documentation—so users can trust the calibration data.

Independent auditors verify traceability to national standards (e.g., NIST)

Third-party assessors review the lab's entire traceability chain to ensure results are linked back to National Metrological Institute standards and recognized globally.

When calibrated by a 17025-accredited lab, your sampling decisions are backed by validated methods and national metrology standards.

Thank you!

Q&A

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