A Practical Guide to Calibration for GMP Regulated Teams

An educational guide

PHARMAGRAPH

Contents

Why calibration matters in GMP

In GMP-regulated environments, calibration is not a technical detail, it is a foundation of product quality, patient safety, and regulatory confidence.

At its simplest, calibration is the comparison of a measuring device against a known reference standard. In practice, it is how organisations demonstrate that the data they rely on, such as temperature, pressure, airflow, CO_2, particles, is accurate, reliable, and defensible.

Regulators expect every critical measurement to be traceable back to internationally recognised standards. Without this traceability, data integrity is compromised, audit readiness is weakened, and patient risk increases.

Poor calibration does not just affect a single instrument. It undermines:

- Environmental monitoring data
- Process control decisions
- Batch release confidence
- Regulatory inspections

Every calibrated device forms part of a wider traceability chain, linking shop-floor measurements back to the International System of Units (SI) through recognised national measurement institutes. This chain, and the evidence supporting it, is routinely examined during GMP audits.

Calibration fundamentals

What calibration is *(and is not)*

Calibration is the process of determining the relationship between a measuring instrument and a reference standard.

It is important to clarify a common misconception:

> *Calibration does not automatically involve adjustment.*

A device can be calibrated and found to be:

- Within tolerance
- Out of tolerance

Adjustment, repair, or replacement may follow, but these are separate actions.

Why SI units and traceability matter

SI units provide a globally consistent measurement framework. Whether a sensor is installed in the UK, Europe, or the US, traceability to SI ensures results are comparable, auditable, and defensible.

In the UK, SI standards are maintained by the National Physical Laboratory (NPL). Calibration providers establish traceability by linking their reference equipment back through an unbroken chain to these national standards.

The three branches of metrology

Calibration sits within the broader discipline of metrology, which has three recognised branches:

Scientific Metrology
Establishes and maintains SI standards

Industrial Metrology
Applies these standards to manufacturing and process control

Legal Metrology
Ensures compliance where measurement affects regulation or trade

GMP environments primarily rely on industrial metrology, underpinned by scientific metrology and governed by regulatory expectations.

Calibration types - When to choose what

Not all calibration activities require the same level of accreditation.
The appropriate approach depends on how the measurement is used,
its impact on GMP decisions, and the associated risk profile.

ISO/IEC 17025 Accredited Calibration*

ISO/IEC 17025 represents the highest level of calibration assurance and is typically expected where measurement data plays a direct role in GMP-critical decisions.

This level of calibration is generally required when:

- Measurement results directly influence product quality or patient safety
- Data is used to support batch release, regulatory submission, or formal compliance evidence
- Instruments are classified as critical through GMP risk assessment

In these cases, formal control of measurement uncertainty and accreditation of the calibration process are key to audit defensibility.

Traceable Calibration

Traceable calibration is appropriate where instruments support monitoring, trending, or early warning, rather than direct control or release decisions.

This approach is commonly used when:

- Measurements provide operational insight rather than GMP decision authority
- The associated risk is lower, but accuracy and consistency remain important
- Data is used to identify trends, deviations, or developing issues

Traceable calibration still relies on reference equipment that is itself calibrated against accredited standards, maintaining a clear and defensible link to SI units.

A Risk-Based Calibration Strategy

Accredited and traceable calibration are not competing approaches. Both play a valid role within a compliant, risk-based metrological control strategy.

The key is applying the right level of calibration to the right measurement, based on documented risk, regulatory expectations, and intended use of the data.

**ISO/IEC 17025 accredited calibration is applicable where it is offered within a calibration provider's accredited scope, which defines the specific measurement types, ranges and uncertainties covered by accreditation.*

Calibration decision matrix

Use this matrix to determine whether ISO/IEC 17025 accredited calibration or traceable calibration is appropriate for your application.

Decision Factor	ISO/IEC 17025 Accredited Calibration*	Traceable Calibration
Impact on product quality	Direct impact on product quality or batch release	Indirect or supportive monitoring only
Patient safety risk	Measurement failure could impact patient safety	Low patient safety risk
Use of data	Data used for release decisions, compliance evidence or regulatory submission	Data used for trending, awareness or operational insight
GMP criticality	Classified as critical under GMP risk assessment	Classified as non-critical or low risk
Regulatory scrutiny	Likely to be examined in detail during inspection	Reviewed as part of overall system
Measurement uncertainty required	Uncertainty must be formally stated and controlled	Uncertainty understood but less tightly constrained
Instrument examples	Particle counters, DP transmitters, critical temperature probes	CO_2 sensors, general environmental monitors
Calibration evidence	UKAS-accredited certificate required	Traceable certificate required
Audit defensibility	Highest level of audit confidence	Acceptable when justified by risk

**Availability of ISO/IEC 17025 accredited calibration is dependent on a provider's accredited scope. Not all instrument types or calibration activities are offered or available under current accreditation.*

Quick guidance

1. If a measurement influences batch release, patient safety or compliance decisions, choose ISO/IEC 17025 accredited calibration.

2. If a measurement supports monitoring, trending or early warning, traceable calibration may be appropriate, provided the risk assessment supports it.

Both approaches rely on calibration equipment that is itself calibrated using accredited standards, maintaining an unbroken traceability chain to SI units.

Accredited and traceable calibration are not competing approaches. Both form part of a compliant, risk-based metrological control strategy in GMP environments.

What good calibration looks like

A calibration certificate should provide clear, complete, and auditable evidence.

Certificate Essentials

A compliant certificate should include:

- Unique instrument identification
- Calibration equipment used (ID, serial number, calibration status)
- As-found and as-left readings
- Defined tolerances
- Measurement uncertainty (where applicable)
- Calibration date and next due date
- Technician identification
- Notes, remarks, or deviations

What GMP Adds

GMP environments require more than technical accuracy. They demand:

- Full traceability to SI
- Document control
- SOP alignment
- ALCOA+ compliant records
- CAPA and deviation handling
- Internal audit readiness

Missing or incomplete calibration data is a common audit finding, and an avoidable one.

Calibration certificate review checklist

Use this checklist to review calibration certificates for completeness, traceability, and audit readiness. A YES should be supported by clear, documented evidence.

1 INSTRUMENT IDENTIFICATION

- ☐ Instrument ID is clearly stated
- ☐ Serial number is included
- ☐ Instrument location or system is identified
- ☐ Instrument application (e.g. temperature, pressure, CO_2) is clear

The instrument on the certificate must be unmistakably identifiable.

2 CALIBRATION DETAILS

- ☐ Calibration date is stated
- ☐ Next due date is defined
- ☐ Calibration method or procedure is referenced
- ☐ Environmental conditions (if relevant) are recorded

3 AS-FOUND / AS-LEFT RESULTS

- ☐ As-found results are recorded (not just pass/fail)
- ☐ As-left results are recorded
- ☐ Any adjustments made are clearly stated
- ☐ Evidence exists if no adjustment was required

Absence of as-found data is a common GMP finding.

4 TOLERANCES & ACCEPTANCE CRITERIA

- ☐ Acceptance tolerances are clearly defined
- ☐ Tolerances align with SOP or URS requirements
- ☐ Results are clearly assessed against those tolerances

5 TRACEABILITY & REFERENCE EQUIPMENT

- ☐ Traceability to SI units is explicitly stated
- ☐ Reference equipment used is identified
- ☐ Reference equipment calibration status was valid at time of use
- ☐ Accreditation or traceability status is documented

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MEASUREMENT UNCERTAINTY (WHERE REQUIRED)

- ☐ Measurement uncertainty is stated (if applicable)
- ☐ Uncertainty is appropriate for the application
- ☐ Uncertainty does not invalidate acceptance decisions

7

PERSONNEL & AUTHORISATION

- ☐ Technician performing calibration is identified
- ☐ Authorisation or approval is recorded
- ☐ Training requirements are met (per SOP)

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DEVIATIONS & FOLLOW-UP (IF APPLICABLE)

- ☐ Out-of-tolerance results are clearly flagged
- ☐ Deviation or non-conformance is referenced
- ☐ Impact assessment has been initiated if required
- ☐ CAPA or corrective action is documented

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GMP DOCUMENT CONTROL

- ☐ Certificate is controlled and versioned
- ☐ Stored in approved document management system
- ☐ Record is legible, complete, and permanent
- ☐ ALCOA+ principles are met

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FINAL REVIEW QUESTION

- ☐ Could this certificate be confidently presented during a GMP inspection without explanation?

If the answer is no, the certificate represents a compliance risk, even if the calibration itself was technically correct.

In GMP environments, calibration evidence must be technically accurate, fully traceable, and retrospectively defensible.

Key terms you need to know

Accuracy
Closeness to the true value

Tolerance
Acceptable limits of variation

Uncertainty
Quantified doubt in a measurement

Repeatability
Consistency under the same conditions

Reproducibility
Consistency across different conditions

Linearity
Accuracy across the measurement range

Hysteresis
Difference in readings depending on direction of change

Resolution
Smallest detectable change

As-found / As-left
Condition before and after calibration

Zero / Span Adjustment
Corrections at baseline or full scale

All measurements exist within uncertainty. Understanding this is key to intelligent GMP decision-making.

The operational risks of poor calibration

Poor calibration rarely fails loudly. More often, it introduces small, compounding inaccuracies that quietly undermine control, data integrity, and confidence.

In GMP environments, these risks extend far beyond a single instrument.

1. Data Integrity and Decision Risk

When instruments drift or calibration evidence is incomplete, the data generated becomes unreliable.

This affects:

- Environmental monitoring trends
- Process control decisions
- Alarm thresholds and alerting
- Historical data used during investigations

Once confidence in the data is lost, every downstream decision is questioned.

Regulators do not only assess results, they assess whether those results can be trusted.

2. Product Quality and Batch Impact

Inaccurate measurements can directly affect product quality without being immediately detected.

Examples include:

> Temperature probes reading within limits while actual conditions exceed stability thresholds
>
> Differential pressure sensors masking airflow imbalances
>
> CO_2 sensors under-reporting levels in controlled environments

These issues often surface after the fact, triggering:

- Retrospective impact assessments
- Batch disposition delays
- Increased QA workload

3. Patient Safety Implications

Calibration failures ultimately translate into patient risk.

Poorly calibrated monitoring can lead to:

1. Inadequate environmental control
2. Increased contamination risk
3. Compromised sterility assurance

While the failure may appear operational, the regulatory concern is always patient safety.

4. Audit and Inspection Findings

Calibration is a frequent focus during GMP inspections because it links directly to data integrity.

Common findings include:

- Missing as-found results
- Unclear traceability statements
- Expired reference equipment
- Inconsistent calibration intervals
- Certificates that do not support acceptance decisions

These findings can escalate quickly from minor observations to major deficiencies.

5. Operational Disruption and Cost

Calibration issues create avoidable operational strain:

- Equipment taken out of service unexpectedly
- Emergency recalibration or replacement
- Rework of documentation and investigations
- Unplanned downtime

The cost is not just financial, it is lost time and lost confidence.

6. Device Drift and False Confidence

One of the most dangerous risks is false confidence.

Instruments may:

- Remain within tolerance on paper
- Drift gradually between calibration intervals
- Produce stable but inaccurate readings

Without robust calibration and trend review, drift can go unnoticed for months.

Practical Examples

Example 1 – Temperature Monitoring

> A freezer consistently read 2 °C lower than actual temperature. Stability samples remained in use for weeks before the discrepancy was identified during routine review.

Example 2 – Differential Pressure

> A DP transmitter masked a gradual airflow imbalance, delaying detection of containment issues during production.

Why this is a system problem, not a single failure

Poor calibration is rarely about one missed event. It usually indicates:

- Weak metrological control
- Inadequate documentation
- Poor visibility of calibration status
- Lack of ownership

GMP compliance depends on systems that detect, correct, and prevent drift, not just pass audits.

Pharmagraph mitigates calibration risk by treating calibration as a GMP control, not a tick-box task. Through validated equipment, trained engineers, full traceability, and audit-ready documentation, calibration data remains reliable, defensible, and fit for regulatory scrutiny.

Effective calibration is about maintaining trust, in your data, your systems, and your decisions.

How Pharmagraph ensures compliant calibration

Pharmagraph provides calibration services designed specifically for GMP-regulated environments, where accuracy, traceability and documentation are as critical as the measurement itself.

Calibration is treated not as a standalone technical task, but as an integral part of GMP control, supporting data integrity, audit readiness, and patient safety.

Our Approach

Pharmagraph's calibration approach is built around risk-based metrology, regulatory expectations, and operational reality.

Accredited and Traceable Calibration Equipment

Where ISO/IEC 17025 accredited calibration is not available or not required, Pharmagraph provides traceable calibration using equipment that is itself calibrated against accredited standards where applicable, maintaining a defensible SI traceability chain.

Calibration is performed using appropriately accredited or traceable equipment, selected based on instrument criticality and GMP risk assessment. This ensures an unbroken traceability chain back to SI units, supporting global consistency and audit defensibility.

GMP-Trained Engineers

Pharmagraph engineers are trained not only in calibration techniques, but in GMP principles, including:

- ALCOA+ data integrity
- Deviation awareness and escalation
- Documentation discipline
- Inspection-ready behaviour on site

This ensures calibration activities align with quality systems, not just technical standards.

Fully Compliant Calibration Certificates

Calibration certificates are issued as controlled GMP records, providing clear, complete, and auditable evidence. Certificates include all essential information required to support acceptance decisions, retrospective review, and regulatory inspection.

Clear Communication When Tolerances are Exceeded

If an instrument is found outside tolerance, Pharmagraph provides transparent, timely communication, ensuring issues are identified early and managed appropriately, before they escalate into compliance or product risk.

Support with Investigation and Corrective Action

Where required, Pharmagraph supports customers with:

- Initial impact assessment
- Investigation input
- Corrective action and follow-up calibration
- Guidance on replacement or requalification

This reduces operational disruption and QA burden.

Integration with End-to-End Monitoring Solutions

Calibration services are fully aligned with Pharmagraph's wider environmental monitoring capabilities, ensuring consistency across installation, operation, calibration, and ongoing compliance.

Calibration Tools Used

To support accurate, repeatable and reliable calibration, Pharmagraph utilises industry-recognised calibration equipment, including:

Fluke
Temperature and electrical calibration

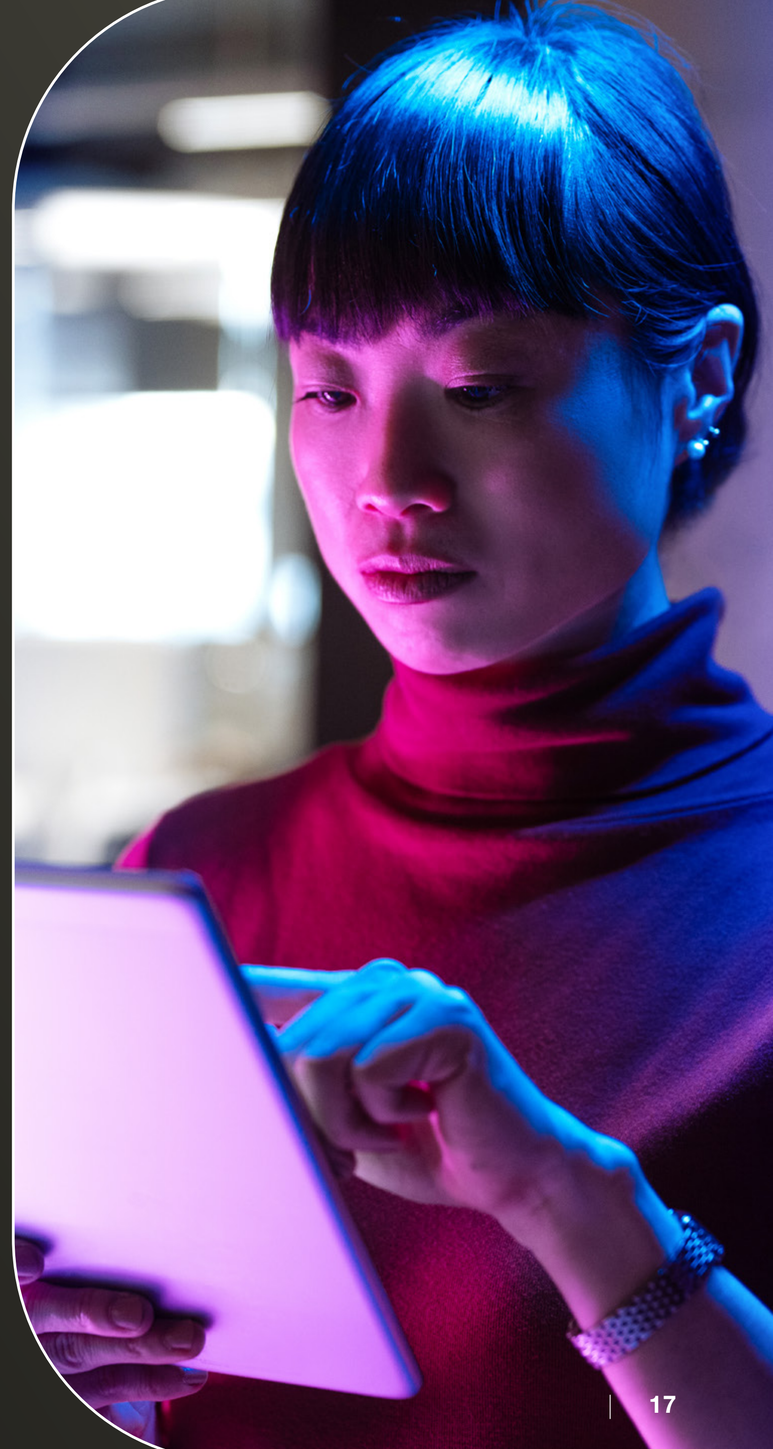
Ametek
Temperature calibration

Furness Controls
Differential pressure measurement

Vaisala
CO_2 measurement

These tools are selected for their proven performance, stability, and suitability for GMP applications, reinforcing confidence in both the calibration process and the resulting data.

Reliable calibration starts with reliable reference equipment.



Calibration readiness checklist

Use this checklist to assess whether your current calibration programme is fit for GMP inspection:

- [ ] Are all calibration certificates traceable to SI units?
- [ ] Are instruments labelled with calibration status and next due date?
- [ ] Do certificates include as-found and as-left readings?
- [ ] Is calibration documentation ALCOA+ compliant?
- [ ] Are acceptance tolerances clearly defined and justified?
- [ ] Is ISO/IEC 17025 accredited calibration used where required by risk?

Gaps in any of these areas increase audit exposure, even when calibration has been technically performed.

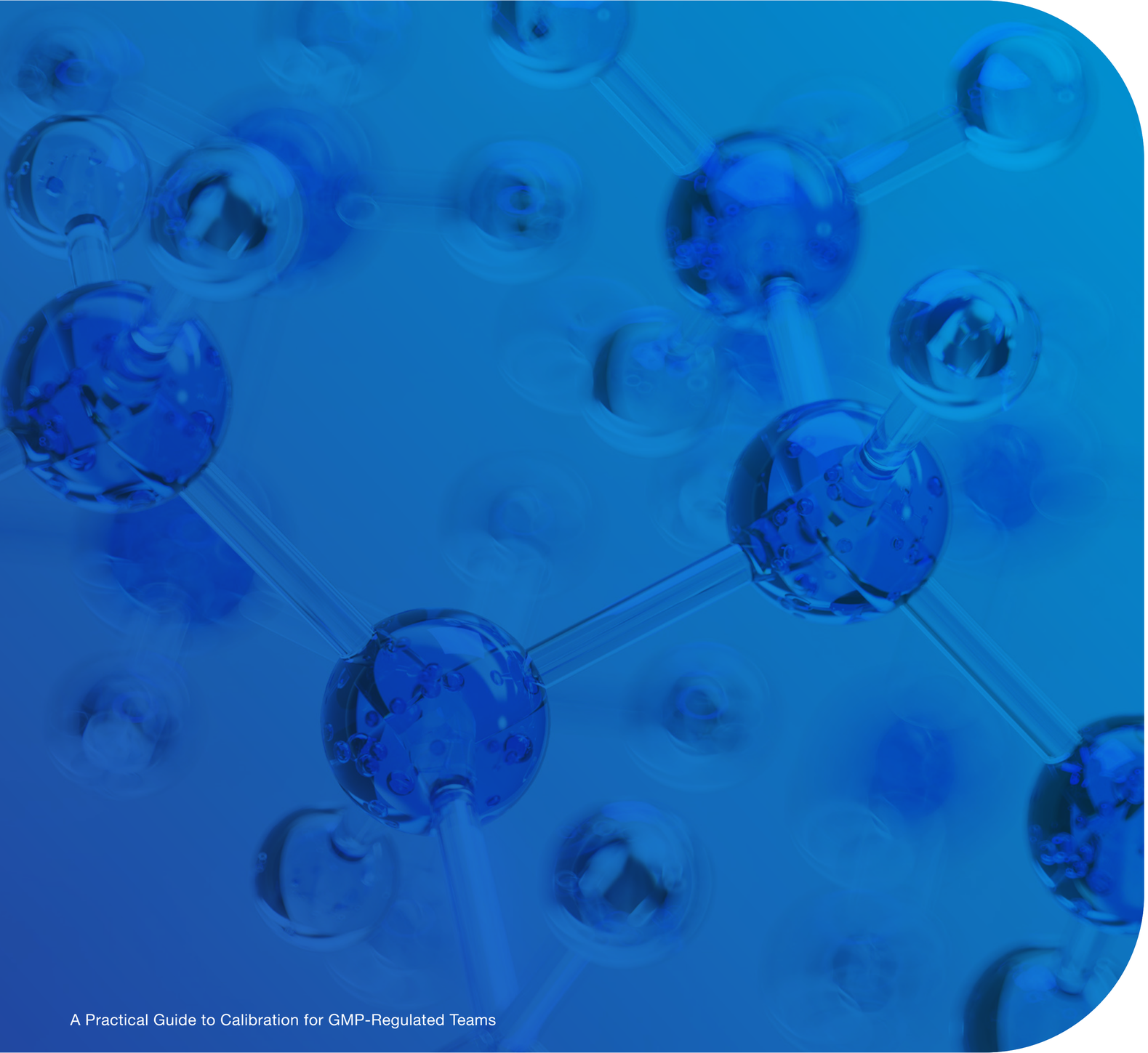
Compliant calibration is not just about meeting standards; it is about maintaining confidence in every measurement you rely on.

Need support with calibration?

Need help ensuring your monitoring equipment meets GMP calibration standards?

Speak to our calibration specialists.

Contact us



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PHARMAGRAPH

Pharmagraph is a specialist provider of environmental monitoring, calibration, and compliance solutions for GMP-regulated industries. We help organisations maintain data integrity, regulatory confidence, and patient safety, every day.

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