Metrology Society Of Australasia

MSA Test Method 2

Calibration of Mechanical Pressure Gauges

Version: 2.1 (02/2022)

Guidance on the use of Metrology Society of Australasia (MSA) Publications:

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This version replaces all previous versions of MSA Test Method 2

Table of Contents

Metrology Society of Australasia
Pressure Measurement Technical Group
www.metrology.asn.au
secretary@metrology.asn.au

1. Introduction

This is a Test Method for the calibration of pressure gauges. It is intended that this document be referenced instead of the Australian Standard AS1349-1986 for the testing of mechanical pressure gauges.

This document has been prepared in consultation with members of the Metrology Society of Australasia (MSA) – Pressure Measurement Technical Group, representing people from manufacturers, laboratories and users of calibration services. It is to be used in conjunction with ISO/IEC 17025, General and Supplementary Requirements for Calibration Laboratories.

2. Scope

This document describes testing of mechanical pressure gauges designed for measuring gauge pressure, vacuum, differential pressure or absolute pressure which utilise a dial and pointer or chart and pen indication.

The gauges may utilise a bourdon tube, capsule, diaphragm or other sensitive mechanical element.

This document is not a standard for the manufacture of pressure gauges or the testing of digital/electronic instruments.

3. Accuracy Classes

Reference shall be made to the accuracy class indicated on the dial, or to the manufacturer's specification unless the user has requested a specific accuracy class.

Gauges are manufactured to many standards and hence to many classes. Some typical accuracy classes include: 0.1, 0.25, 0.3, 0.6, 1.0, 1.6, 2.5, 3, and 4. The accuracy class represents the maximum allowable correction in % of range.

In instances where the user has specified or accepted an accuracy specification that is different than the manufacturer's specification or typical accuracy for the size/type of gauge, the gauge shall be clearly labelled with the accepted specification.

The typical accuracy classes to adopt for various gauge types are as follows:

3.1 Test Gauges

Mechanical gauges of accuracy class 0.25 or less are referred to in this Test Method as 'Test Gauges'. Test Gauges should be labelled 'Test Gauge' and shall be considered accuracy class 0.25 unless marked otherwise.

3.2 Industrial Gauges

Gauges with accuracy class ≥0.3 are referred to as 'Industrial Gauges' in this Test Method.

If the accuracy class is not marked on the gauge and the manufacturer's specification is unknown, the following rule shall apply:-

Industrial gauges will be class 1.0, except for gauges less than 70 mm nominal dial diameter, which shall be class 3.0.

3.3 Chart Recorders

Chart recorders are a class of instrument that typically use a pen to indicate and plot pressure on a moving paper chart.

If no user and/or manufacturer accuracy specification can be determined, it may be appropriate to adopt a specification of 1% of range.

3.4 Backflow Test Kits

Backflow Test Kits are used for verifying the performance of water backflow prevention valves. Mechanical types consist of a differential pressure gauge, typically using a convoluted diaphragm between the high and low channels and series of connected valves. Digital types are also available but are not within the scope of this test method.

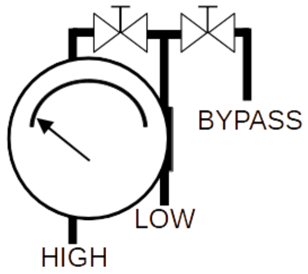

Figure 1. Typical Mechanical Backflow Test Kit

Mechanical backflow test kits are generally ranged 0 to 100 kPa (or equivalent) with an accuracy specification of 2% of range (±2 kPa).

4. Reference Instrument

Reference instruments shall be certified by an accredited laboratory and be traceable to the International System of Units via national or international standards.

The uncertainty of the reference instrument shall be less than or equal to ¼ of the accuracy specification of the gauge under test at all test points, except when Test Gauges are used as below (see notes)

When Test Gauges are used as the reference instrument for calibrating Industrial Gauges, the Test Gauge shall have a range not more than 1.5 times that of the Industrial Gauge.

Corrections for reference instruments shall be applied whenever they are significant to the calibration.

5. Gauges for Oxygen and Oil-Free Service

The laboratory shall have procedures for the safe handling of gauges for use on oxygen or marked oil-free, where contamination with oil can present substantial risk to the end user of the gauge.

The safe-handling procedure shall include identification of oxygen and oil-free gauges immediately on receipt so that they can be isolated or prevented from being contaminated. If the laboratory cannot provide a suitable oil free calibration, the procedure for safe handling shall include isolating the gauge, notifying the customer and returning the untested gauge.

6. Test Procedure

6.1 Overload Testing

Overload testing is not specified in this procedure.

6.2 Environment

The temperature of the laboratory shall be maintained in the range 18 °C to 22 °C for the calibration of test gauges only.

Gauges under test shall be given adequate time to come to room temperature.

6.3 Orientation

Unless otherwise specified, gauges shall be tested with the dial vertical and the mid-scale point in the 12 o'clock position.

Gauges tested in another orientation shall have the position marked on the dial or a label on the gauge case.

6.4 Test Fluid

The test fluid shall be suitable for the gauge. Test Gauges with ranges of 2500 kPa or less shall be tested on liquid or gas depending on which fluid they will be used on.

If a gauge of range ≤2500 kPa is intended to be used on gas and is instead tested on liquid, or vice versa, a significant error may occur because of the increased weight of the bourdon tube when filled with liquid.

6.5 Test Points

The minimum number of test points is dependent on the gauge accuracy class:

Minimum Number of Test Points	
Accuracy class < 0.3 *(i.e. Test Gauges)*	8 points
Accuracy class ≥ 0.3 *(i.e. Industrial Gauges)*	5 points

Table 1 - Minimum Number of Test Points

Unless requested otherwise by the user:

- Where possible, gauges shall be tested in SI units.
- Test points shall be spread over the range of the gauge and shall include the minimum and maximum scale values.
- Zero shall be included unless it is either not free (pointer stop) or not well defined (broad zero band).
- Each test point shall be tested on a rising and falling pressure direction where possible.

For gauges measuring negative gauge pressure (i.e. vacuum or compound gauges) with a minimum reading of -100 kPa (or equivalent), it may not always be possible to test at the minimum reading and it may be acceptable to test the nearest practical point, such as the nearest minor division.

Differential Gauges may be tested with one port open to atmosphere.

Specific requirements and exceptions for Backflow Test Kits:

Unless specified by the user and/or manufacturer:

- Backflow test kits shall be assessed to an accuracy specification of ±2 kPa (or equivalent) in a falling pressure direction.
- Testing in a rising pressure direction is not mandatory but if tested, reported results are not required to fall within the gauge's specified accuracy specification.
- Backflow test kit calibration shall be performed at a number of test points consistent with section 6.5 and shall include 7 kPa, 14 kPa, and 35 kPa or the nearest marked divisions within 1 kPa of these pressures. Additional recommended test points are 50 kPa, 70 kPa and 100 kPa.
- Calibration may be performed by closing the valve between the high and low sides, venting the low side to atmosphere and applying test pressures to the high port using water or non-toxic gas.

Note: 7 kPa, 14 kPa and 35 kPa are prescribed test limits featured in Australian and New Zealand backflow prevention standards, and therefore calibration to assess performance at or near these pressures is required.

6.6 Gauge Readings

Care should be taken to read the gauge with the finest possible resolution to ensure the best performance of the gauge can be discriminated, and uncertainty due to readability minimised.

It is common for a resolution to be adopted between one-quarter and one-tenth of a scale division, depending on the distance between scale markings, width of the pointer/pen and an assessment of parallax error.

The gauge shall be exercised to the scale limits and back to zero before testing.

Gauge readings shall then be taken at each of the test points as described in section 6.5. The gauge shall be tapped lightly before each reading. Chart recorders shall have the paper/chart rotated slightly in the normal direction of travel before recording each reading.

A minimum of two sets of readings are required for gauges of accuracy class <0.3 (i.e. Test Gauges).

Readings may be made by applying a pressure which will bring the gauge to the mark (pointer aligned with the nominal value) and observing the true pressure from a reference instrument, such as a digital pressure calibrator.

Alternatively, a pressure near to the nominal value may be applied, such as the closest value produced by a dead weight tester or pressure controller, and the gauge read.

In cases where the applied pressure is significantly deviant from the nominal value (by more than 1/8th of the resolution), it is considered "off-nominal". When "off-nominal" testing is performed, additional rounding uncertainty may be required if subsequent rounding of results relative to the nominal pressure is performed.

If any adjustments (or other changes which may impact performance) are to be made to the gauge, an initial 'As Found' test shall be performed before adjustment. It is acceptable to perform the 'As Found' test by taking readings at each test point in one direction only (rising or falling pressure).

7. Reporting of Results

The report shall include the following:

- Date of test.
- Test report number.
- Serial number of the gauge.
- Description of the gauge including nominal dial/chart diameter.
- Orientation of the gauge during testing.
- The test fluid used during testing.
- Room temperature and range.
- Table of results including the pressure of each test point and corresponding mean readings and/or corrections for all tested directions (typically rising and falling pressure except for backflow test kits).
- Statement detailing whether the gauge was adjusted and if so, the maximum 'As Found' correction. Reporting the 'As Found' readings is recommended but not mandatory.
- The uncertainty shall be calculated for at least one pressure point, at the 95% confidence level, and in the units of the gauge readings.
- Conversion factor used if not SI units.
- The model of chart used for chart recorders.
- Any other information important to the performance of the gauge.

The report shall also contain a statement of compliance to this Test Method. The compliance statement shall include a description of the accuracy specification to which it conforms (see notes, section 8 regarding the compliance decision rule).

8. Notes

8.1 Compliance Decision Rule

It is normal to accept a gauge as complying only if the measurement uncertainty added to the correction are within the tolerance.

However, this would put this test method out of step with other current standards for manufacture and calibration of pressure gauges. Therefore, unless specified by the user, the gauge is deemed to comply with this test method if both the correction and uncertainty (not added) are not larger than the accuracy tolerance at all test points.

As an example, a Class 0.25 test gauge may have a correction as large as 0.2% of range and an uncertainty of measurement equal to 0.25% of range. Theoretically, this means a reading could be in error by a maximum of 0.45%. But, while the provisions of section 4 are followed this is consistent with the implied position of other standards including manufacturing standards.

8.2 Uncertainty Estimates

Uncertainty estimation is a subject on its own covered in other texts. Reference can be made to *MSL Technical Guide 13* or *NMI Monograph 1 – Uncertainty in Measurement: The ISO Guide.* While these guides are useful, they should be used in conjunction with the current BIPM JCGM 100 Evaluation of measurement data – Guide to the expression of uncertainty in measurement.

The following principal terms to include in the uncertainty estimate are:

Reference Instrument Uncertainty:

The reference instrument uncertainty should consider the uncertainty from its calibration report and any contributions from the environment (uncertainty in temperature, local gravity), test set-up (uncertainty in head height measurement), and an allowance for drift since calibration.

For digital reference instruments, the manufacturer's one year accuracy specification should be used as a drift allowance in the absence of other data. When a digital reference instrument is used with a resolution or pressure unit other than it how it was calibrated, any impacts on the associated reference uncertainty shall be accounted for.

Readability:

Standard uncertainty due to readability may be estimated using:

$u_{READ} = Resolution/\sqrt{3}$

where *resolution* is the discrimination of the gauge under test that was used during calibration. In the testing mode where the gauge is taken to the nominal division and readings are instead taken from a finer resolution reference instrument, the resolution term should remain based on the minimum discrimination of the gauge that could reasonably be expected for a user to discriminate.

It is recommended to either include both readability and repeatability, or the maximum of readability and repeatability in the total uncertainty.

Repeatability:

Repeatability shall be estimated using a statistically valid method that is appropriate for the type of instrument. Be guided by the recommended approaches in the above texts.

9. Definitions

Corrections: The value to be added to a test instrument reading to indicate the true pressure. They are opposite in sign to reading errors.

Gauge pressure: Pressure that is relative to atmospheric pressure.

Absolute pressure: Pressure that is relative to full vacuum such as that measured by a barometer.

Hysteresis: For the purposes of calibration, hysteresis is the maximum difference in the instrument reading, at a supplied pressure when approached from below and above that pressure during a full range pressure cycle.

Range: The span between bottom and full scale of measured values.

Resolution: The minimum discrimination that the gauge under test can be read to.

Repeatability: The variation in readings at a given test point observed during the time of testing.

10. References

AS 1349 (1986) - *Bourdon Tube Pressure and Vacuum Gauges*

BS EN 837-1: 1998 *Bourdon Tube Pressure Gauges*

M P Fitzgerald, D J Jack & M T Clarkson, *MSL Technical Guide 13 - Pressure Gauge Calibration,* Measurement Standards Laboratory of New Zealand, 2006

Robin E. Bentley, *NMI Monograph 1 – Uncertainty in Measurement: The ISO Guide, Eleventh Ed.* National Measurement Institute, Australia, 2005