NATIONAL ACCREDITATION BOARD FOR TESTING AND CALIBRATION LABORATORIES

SPECIFIC CRITERIA for CALIBRATION LABORATORIES IN MECHANICAL DISCIPLINE : Pressure Indicating Devices

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1. General Requirement:

- The purpose of this document is to specify requirements with which a laboratory has to operate and demonstrate its competency to carry out calibration in accordance with ISO/IEC 17025:2005.

- To achieve uniformity between the laboratories, assessors and assessment process in terms of maximum permissible error, CMC, measurement uncertainty etc in line with National/International standards.

- To achieve uniformity in selection of equipment's, calibration methods, maintaining required environmental conditions, personnel with relevant qualification and experience.

1.1 Scope

This specific criteria lays down the specific requirements for calibration of pressure indicating devices under mechanical discipline. This part of the document thus amplifies the specific requirements for calibration of pressure indicating devices and supplements the requirements of ISO/IEC 17025:2005.

1.2 Calibration and Measurement Capability (CMC)

1.2.1 CMC is one the parameters that is used by NABL to define the scope of an accredited calibration laboratory, the others being parameter/quantity measured, standard/master used, calibration method used and measurement range. The CMC is expressed as "the smallest uncertainty that a laboratory can achieve when calibrating the best existing device". It is an expanded uncertainty estimated at a confidence level of approximately 95% corresponding to a coverage factor k=2.

1.2.2 For evaluation of CMC laboratories should follow NABL 143 - Policy on Calibration and Measurement Capability (CMC) and Uncertainty in Calibration.

1.3 Personnel, Qualification and Training

1.3.1 Technical Personnel

1.3.1.1 Qualification required for carrying out calibration activity:

The following are the specific requirements. However, qualification and experience will not be the only criteria for the required activity. They have to prove their skill, knowledge and competency in their specific field of calibration activity.

a) B.E / B.Tech or M.Sc. (having Physics as one of the subject) degree with 3 months experience in Basics of Pressure Metrology.

b) B.Sc (with Physics as one of the subject) or Diploma with 6 months experience in Basics of Pressure Metrology.

c) ITI with 1 year of experience in Basics of Pressure Metrology.

1.3.2 Training and experience required:

a) Training may be external / internal depending on the expertise available in the field.

b) Training in calibration of pressure indicating devices and in Uncertainty Measurements, CMC including statistical analysis for Technical Manager.

c) Experience and competence in Pressure Metrology.

d) Sufficient knowledge about handling of reference equipment, maintenance, traceability, calibration procedure and effect of environmental conditions on the results of calibration.

e) During training calibration activity should be done under supervision.

1.3.3 Authorised Signatory

1.3.3.1 Qualification required for interpretation of results and signing the calibration certificates:

The following are only guidelines. However, qualification and experience will not be the only criteria for the required activity. They have to prove their skill, knowledge and competency in analysis and interpretation of calibration results.

a) B.E / B.Tech or M.Sc. (with having Physics as one of the subject) degree with 6 months experience Pressure Metrology.

b) B.Sc. (with Physics as one of the subject) or Diploma with 1 year experience in Pressure Metrology.

1.3.3.2 Training and experience required:

a) Training may be external / internal depending on the expertise available in the field.

b) Training, Experience and Competence in calibration of Pressure indicating devices and training in Uncertainty Measurements, CMC including statistical analysis for Technical Manager.

c) Sufficient knowledge and competence in effective implementation of ISO/IEC 17025, specific criteria and NABL guidelines.

d) Competency in reviewing of results, giving opinion and interpretations.

e) During training the relevant activity has to be done under supervision.

1.4 Accommodation and Environmental Conditions

A Laboratory may be offering calibration services under different categories:

i. Permanent laboratory service

ii. Onsite service

iii. Mobile service

The above category of laboratories may provide following types of services:

a) Service that intended primarily for measurement standards, reference equipments which are further used for calibration purposes or high accuracy measurements which requires high degree of accuracy and better CMC.

b) Service that intended primarily for calibration and adjustment of test, measurement and diagnostic equipments to use in such areas as product testing, manufacturing and servicing.

Accommodation and environmental conditions adversely affect the results of calibration and measurement accuracy unless they are controlled and monitored. Hence, they play a very important role.

The influencing parameters may be one or more of the following i. e. temperature, relative humidity, atmospheric pressure, vibration, acoustic noise, dust particle, air currents/draft, illumination(wherever applicable), voltage fluctuations, electrical earthing and direct sunlight etc., depending on the nature of calibration services provided. The variables described above can play a major factor on calibration results.

The main difference between the permanent laboratory, onsite and mobile calibration services has to do with environmental conditions only. Since the onsite calibration relies on where the service is provided, it affects the results of calibration. (Refer NABL 130).

The laboratories are advised to follow the requirement of accommodation and environment depending on the types of services provided as recommended:

- By the manufacturers of the reference equipment
- By the manufacturers of the Unit under calibration
- As specified in the National/ International Standards or guidelines followed for the calibration

The environmental monitoring equipments used should also meet the requirement of manufacturers' recommendations and specifications as per the relevant standards followed.

If, accommodation and environmental conditions are not specified either by manufacturer or by National/International standards / guidelines, the laboratory shall follow the below recommendations.

1.4.1 Vibration

The calibration area shall be free from vibrations generated by central air-conditioning plants, vehicular traffic and other sources to ensure consistent and uniform operational conditions. The laboratory shall take all special/ protective precautions like mounting of sensitive apparatus on vibration free tables and pillars etc., isolated from the floor, if necessary.

1.4.2 Acoustic Noise

Acoustic noise level in the laboratory shall be maintained to facilitate proper performance of calibration work. Noise level shall be maintained less than 60 dBA, wherever it affects adversely the required accuracy of measurement.

1.4.3 Illumination

The calibration area shall have adequate level of illumination. Where permissible, fluorescent lighting is preferred to avoid localized heating and temperature drift. The recommended level of illumination is 250-500 lux on the working table.

1.4.4 Environmental Conditions and Monitoring

The environmental conditions for the activity of the laboratory shall be such as not to adversely affect the required accuracy of measurement. Facilities shall be provided whenever necessary for recording temperature, pressure and humidity values prevailing during calibration. The atmospheric conditions maintained in the laboratory during calibration shall be reported in the calibration report/ certificate.

1.5 Special Requirements of Laboratory

1.5.1 The calibration laboratory shall make arrangements for regulated and uninterrupted power supply of proper rating. The recommended voltage regulation level is ± 2% or better, and Frequency variation ± 2.5Hz or better on the calibration bench.

1.5.2 The reference standards shall be maintained at temperatures specified for their maintenance on order to ensure their conformance to the required level of operation.

1.5.3 The laboratory shall take adequate measures against dust and external air pressure.

1.6 Safety Precautions

1.6.1 Relevant fire extinguishing equipment for possible fire hazards, shall be available in the corridors or convenient places in the laboratory. Adequate safety measures against electrical, chemical fire hazards must be available at the work place. Laboratory rooms/ areas where highly inflammable.

1.7 Other Important Points

1.7.1 **Entry to the Calibration Area:** As far as possible, only the staff engaged in the calibration activity shall be permitted entry inside the calibration area.

1.7.2 **Space in Calibration Area**: The calibration Laboratory shall ensure adequate space for calibration activity without adversely affecting the results.

1.8 Proficiency Testing

To give further assurance to the accuracy or Uncertainty of measurements, a laboratory will be required to participate, from time to time, in Proficiency Testing Program. The laboratory shall remain prepared to participate in the Proficiency Testing Program through inter-laboratory, inter-comparison schemes wherever it is technically feasible. (Ref. NABL 162, 163 and 164 for further details)

2. Specific Requirements: Calibration of Pressure Indicating Devices

2.1. Scope: Calibration of Pressure Indicating Devices:

Sl. No	Description	Relevant Standard/ Reference	Permanent Facility	Onsite Calibration	Mobile Facility
1	Precision Pressure Calibrator with pump (digital and Analog)	OIML R-101 OIML R-97 (Barometer) EURAMET Cg-17, Version 2.0 (03/2011) / DKD R-6-1 IS 3624	√	√	√
2	Pressure transducer with digital pressure indicator		√	√	√
3	Pressure transducer with Voltage, current or frequency output		√	√	√
4	Pressure transmitters with Voltage (5 V,10V….) , Current (4-20mA,0-20mA,…) Frequency Digital format (RS232,……..)		√	√	√
5	Industrial Pressure gauges with analog/digital indication.		√	√	√
6	Barometer		√	√	√
7	Oxygen Pressure gauges*		√*	X	X
8	Pressure Switches		√	√	√
9	Magnahelic Gauge, Pirani Gauge		√	√	√
10	Vacuum Gauge	ISO 3567 ISO 27893	√	√	√

*** Special separate arrangements shall be required when calibrating oxygen pressure gauge.**

Note 1: Onsite and Mobile calibration with Dead weight testers as a master is not recommended.

Note 2: This technical requirement is based on the above mentioned guideline. Lab may follow any relevant standard, however care shall be taken to follow the requirements in totality.

2.2. National/ International Standards, References and Guidelines

- IS: 3624-1987 (Reaffirmed 2004) " Specifications for Pressure and Vacuum gauges"
- OIML R 101 :1991 Indicating and recording pressure gauges, vacuum gauges and pressure- Vacuum gauges with elastic sensing elements (ordinary instruments)
- EURAMET Cg-17, Version 2.0 (03/2011) "Guidelines on the calibration of Electromechanical Manometers"
- DKD R-6-1 Guidelines on Calibration of Pressure Gauge
- DKD R-6-2 Guidelines on Calibration of measuring devices for Vacuum
- ISO 3567:2011 Vacuum Gauges- Calibration by direct comparison with a reference gauge
- ISO 27893:2011Vacuum Technology-Vacuum gauges-Evaluation of results of calibrations by direct comparison with reference gauge
- OIML R-97:1990 Barometers (International Recommendation)

2.3. Metrological Requirement

- **Pressure Gauges to use with oxygen & Acetylene**
  Oxygen under pressure forms an explosive mixture with oil or grease, and a serious explosion may result if the two are brought together. When Oxygen gauges are calibrated Oil and grease should not be allowed to touch or enter the gauge. They should be tested only with dry and clean air and used for that purpose alone, and no other gauges should be calibrated on this equipment to avoid the risk of oil contamination (refer appendix C clause 9.1.5 of IS 3624: 1987, RA 2004).
- Acetylene in conjunction with copper form an explosive compound .Care shall be taken during calibration.
- SI Unit of measurement of pressure is Pascal, (Pa).
- Pressure gauges, vacuum gauges, Pressure-Vacuum gauges are to be calibrated in Pa, kPa, MPa, GPa, as per SI units. However, Units like bar and mbar, may also be used.
- 'g' value shall be known with sufficient accuracy either by Geological Survey of India or any other relevant source for finer CMC.
- Laboratory may also calculate 'g' value knowing latitude and height as per the formula in annexure A. However, same shall be validated.
- A suitable air buoyancy correction shall be applied if the weights are calibrated either by conventional basis or by true mass basis.
- Knowing the true mass, piston cylinder area value and 'g' value, Pressure value will be determined after applying buoyancy correction.
- The reference equipment used for calibration of pressure gauges or electro manometer should be such that, its accuracy including uncertainty better than 1/3 of the accuracy class of the device under calibration.
- The laboratory is not recommended to calibrate the higher accuracy DUC with lower accuracy reference equipment.

2.4. Terms and Definitions

Pressure Gauge
- A Gauge to measure and indicate pressure greater than ambient using ambient pressure as the datum point

Pressure Switch
- A pressure switch is a form of switch that closes an electrical contact when a certain set pressure has been reached on its input. The switch may be designed to make contact either on pressure rise or on pressure fall.

Ambient Pressure
- Ambient pressure is the pressure surrounding the measuring element.

Gauge Pressure
- Gauge pressure is zero reference at ambient pressure which is equal to absolute pressure minus atmospheric pressure.

Absolute Pressure
- Absolute pressure is zero reference against a perfect vacuum. It is equal to gauge pressure+ atmospheric pressure.

Differential Pressure

- It is the difference in pressure between two points.

Vacuum Gauge

- A gauge to measure and indicate pressure less than ambient using ambient pressure as the datum point

Compound Gauge

- A gauge to measure and indicate pressure greater than and less than ambient using ambient pressure as datum point.

Differential Gauge

- A gauge having two connections and a means to measure and indicate the difference between the two pressures.

Barometer

- A gauge to measure and indicate Atmospheric pressure.

Pressure Transducer

- Converts the measured pressure into analog electrical signal proportional to the applied pressure.

Pressure Transmitter

- Pressure transmitter is a unit that consists of a pressure transducer and a module for conditioning and amplifying the transducer signal.

Digital Pressure Gauge or Manometer

- Is a complete measuring instrument that measures and indicates the unit of pressure proportional to the applied pressure.

Dead Weight Pressure Tester (Also called as Dead weight piston gauge or Pressure balance**)**

- One of the fundamental method – Force/ unit area of the piston. Consists of an accurately machined piston of known weight which is inserted into a closed fitting cylinder (clearance between the piston and cylinder will be few microns), both of known cross sectional area. Weights of known mass loaded on one end the piston and the fluid pressure applied to the other end of the piston until enough force is developed to lift the piston-weight combination, When piston is floating freely within the cylinder (between limit stops), piston is in equilibrium with the unknown system pressure. So the applied pressure is equal to the ratio of force due to the weight-piston and the area of cross section of the piston cylinder.

Effective Area

- The area determined for a given piston-cylinder assembly which is used in conversion equation for the calculation of the measured pressure.

Free Rotation Time of the Piston

- The time during which the piston rotates freely after spinning to a specified rotation rate, until it stops

Upper limit of the measuring range	Free rotation time (min) for accuracy class					
	0.005	0.02	0.02	0.05	0.1	0.2
from 0.1 to 6 included	4	4	3	2	2	2
over 6 to 500 included	6	6	5	3	3	3

Rate of fall of Piston

- The speed of fall of the piston at its operating level at 100% pressure value by loading related quantity of masses.

Pressure medium in clearance	Upper limit of the measuring	Maximum piston fall rate (mm/min) for accuracy class					
		0.005	0.01	0.02	0.05	0.2	0.1
Gas	0.1 to 1 included	1	1	1	2	2	–
Gas	more than 1	2	2	2	3	3	–
Liquid	0.6 to 6 included from	0.4	0.4	0.4	1	2	3
Liquid	6 to 500 included	1.5	1.5	1.5	1.5	3	3

Datum Levels

- Operating level of the piston: level of the piston, with respect to a clearly defined part of the support column or the base of a pressure balance.
- Pressure reference level: The vertical level, with respect to a clearly defined part of the support column or the base of the pressure balance, to which a measured pressure is related when the piston is at a specific operating level

2.5. Selection of Reference Equipment

2.5.1. Make sure that the reference equipment used for calibration of pressure gauges or electro manometer should be such that, its accuracy including uncertainty better than 1/3 of the accuracy class of the device under calibration.

2.5.2. The following table gives the accuracy class of **Industrial Pressure Gauges (Dial type)**

Nominal size [overall diameter or length of the dial in mm]	Accuracy Class as per IS:3624-1987 reaffirmed 2004							
	0.1	0.25	0.5	1	1.6	2.5	4	5
40 and 50					x	x	x	x
63				x	x	x	x	x
80				x	x	x	x	
100				x	x	x		
160		x	x	x	x			
200	x	x	x	x	x			
Note: Accuracy class also denotes the limits of permissible error (percentage of error span) including hysteresis								

2.5.3. The reference equipment for calibration can be selected from below based on the required accuracy class of the DUC.

2.5.3.1. Hydraulic or Pneumatic Dead Weight Tester

2.5.3.2. Digital Pressure calibrators with built-in hydraulic/pneumatic/vacuum pressure generating pump.

2.5.3.3. Analog Master gauge or Pressure transducer with Digital display along with hydraulic/ pneumatic/vacuum pressure generating pump.

Note: Transmitter /Transducers shall be calibrated as a whole unit with indicator and power supply

2.6. Calibration Interval

Recommended Calibration interval to be in line with standards/ guidelines.

2.7. Legal Aspects

Calibration of Pressure gauge done by any accredited laboratories is meant for scientific and industrial purpose only. However, if used for commercial trading, additional recognition/ approval shall be complied as required by Dept. of Legal metrology, Regulatory bodies, etc. This should be clearly mentioned in the calibration certificate issued to the customer.

2.8. Environmental Conditions

2.8.1. For Pneumatic and Hydraulic Pressure Measurements

During calibration temperature shall be 18°C to 28°C. Preferably 23°C ±1.5°C should not change more than 1°C during calibration.

2.8.2. For Vacuum Pressure (as per Standard ISO 27893:2011):

During calibration temperature shall be 20°C to 26°C. Preferably 23°C ±1.5°C should not change more than 1°C during calibration.

2.8.3. Temperature measuring instrument shall have an expanded uncertainty ≤ 0.5°C at k=2.

2.8.4. ‘g’ value should be known to sufficient accuracy.

2.8.4.1. Effect of gravity "g" on calibration when Dead weight testers are used.

- It is very important to establish the gravitational value of the laboratory since it is one of the major quantity during realization of force. The effect of not doing this could be a variation in force produced by the weight perhaps 0.5% of the force. It is therefore recommended that, the Pressure calibration laboratory establishes local value of gravity (g) and use weights that have been calibrated at that gravitational constant.

- For measurement uncertainty of applied force, ‘g’ value shall be known. For realization of applied force more than 0.01%, ‘g’ value shall be calculated using the formula given in below For better than 0.005%, ‘g’ value shall be measured by appropriate authority.

- **Validation of local ‘g’ and its uncertainty**
  Formula for calculation of Acceleration due to gravity

  An approximate value for *g*, at given latitude and height above sea level, may be calculated from the formula:

$g =$	$9.780\,7\,(1 + A \sin^2 L - B \sin^2 2L) - 3.086 \times 10^{-6}\, H\ m{\cdot}s^{-2}$

Where, A = 0.005 302 4, B = 0.000 005 8, L = latitude, H = height in meter above sea level

2.8.4.2. To validate this calculated 'g' value the simple steps given below can be followed:

- Find out the actual 'g' value of NMI from the certificate issued by them or by any other source.
- Find out the actual 'g' value of NMI from the certificate issued by them or by any other source.
- From the maps click on the location of NMI, find out latitude and height above sea level. (you can know the 'g' value).
- Calculate the 'g' value using the above formula with these latitude and height. The difference between the calculated value of 'g' and the actual value of the NMI should be within 20 to 30 ppm.
- Now, go to the maps and click on location of the lab and find out the latitude and height of the place as per the location (you can know the 'g' value also).
- Calculate the 'g' value for this latitude and height. The value obtained should be within 20 to 30 ppm.
- Then this value can be taken as 'g' value of the lab and uncertainty of 'g' can be assumed to be within ± 50 ppm.

2.8.5. Estimation of Air Density

Air density should be known to sufficient accuracy depending on the required uncertainty of the applied force by measuring temperature, RH & barometric pressure.

(Approximation formula as per OIML R-111-1: 2004 pg. No. 76)

$$\rho_a = \frac{0.34848p - 0.009*h*e\wedge(0.061*t)}{273.15+t} \qquad \text{(E-3.1 OIML)}$$

Where, Pressure (P) in mbar, temperature (t) in° C and humidity (h) in % Equation(E-3.1) has a relative uncertainty of 2×10^{-4} in the range 900hPa < p<1100hPa, 10 ° C<t<30 ° C and rh< 80%

2.9. Calibration Methods

Pressure gauges can be calibrated with one of the following methods:

2.9.1. Using Dead weight tester by calculating the actual pressure generated with the help of area of the piston, local 'g' and applied known mass while comparing.

2.9.2. Using Dead weight tester by comparison method using the nominal pressure values mentioned on the pressure weights of the Dead weight tester.

2.9.3. Using Digital Pressure Calibrator.

2.9.4. By comparison method using a Digital /analog pressure gauge and pressure generating system.

Method I: Reading as per set on DUC

Method II: Reading as per set on standard

2.10. Calibration Procedure & Measurement Uncertainty

2.10.1. Recommended calibration sequences based on their accuracy:

Calibration Sequence	Measurement Uncertainty aimed at in % of the meas. Span (*)	Number of meas. Points with zero up/down	Number of press. loadings	Load change +waiting time sec. (**)	Wafting time at upper limit of meas. Range minutes (***)	Number of meas. Series Up	Down
A	< 0.1	9	3	>30	2	2	2
B	0.1…..0.6	9	2	>30	2	2	1
C	> 0.6	5	1	>30	2	1	1

(*) Reference to span is used to allow the sequence to be selected from the table as the accuracy specifications of the manufacturers are usually related to the measurement span.

(**) One has to wait in any case until steady-state conditions are reached.

(***) For the bourdon pressure gauges, a waiting time of five minutes is to be observed. For quasi-static calibrations (piezoelectric sensor principle) the wafting time reduced.

2.10.2. Calibration of Industrial Pressure Gauges by using Dead Weight Tester and calculating the actual pressure generated at each point

2.10.2.1. After noting down the applied mass, temperature at 5 calibration point of the steps and series as per the above referred table (8.10.1), the pressure generated to balance the UUT can be calculated using the pressure formula given below:

2.10.2.2. Equation to calculate the Generated Pressure from a Dead Weight Tester:

$$P_e = \frac{[\Sigma_i m_i *(1-\rho_a/\rho_{mi})] *g+ \sigma c}{A_0(1+ \lambda * p)*[1+(\alpha_p+\alpha_{c)} *(t-t_r)]} \quad (+)\ \rho_f.g.\Delta h \qquad \text{(A-1)}$$

Where,

g = Local acceleration due to gravity in m/s^2

ρ_a = Density of Air in kg/m^3

ρ_m = Density of mass in kg/m^3

ρ_{m1} = Density of mass of PCU in kg/m^3

A_0 = Effective area of the Piston Cylinder Assembly (PCU) at reference temperature and zero pressure in m^2

λ = Pressure distortion co-efficient of Piston Cylinder Assembly (PCU) in /pa

α= Linear thermal expansion coefficient of the piston in/ °C

σ = Surface tension of the oil in N/m

c = Circumference of emergent piston in m

ρ_f = Density of Hydraulic Fluid in kg/m^3

p = Applied Nominal Pressure in pa

Note 1: In case of Pressure generated from a pneumatic dead weight tester, Fluid head correction factor ($\rho_f.g.\Delta h$) may be considered negligible and pressure distortion correction ($1+ \lambda * p$) may be considered negligible if not reported in the certificate

Note 2: In case of absolute pressure measurements, the atmospheric pressure should be added to the generated pressure. The uncertainty component of atmospheric pressure measuring device should also be included while estimating the measurement uncertainty of calibration.

2.10.3. Calibration of Industrial pressure gauges by using Dead Weight Tester and Reference Pressure Value

2.10.3.1. Check the calibration certificate of the Dead weight tester whether pressure value is given for standard 'g' value 9.80665 m/s^2 or local 'g' value (corrected to the lab 'g' value). If the pressure values mentioned is for standard 'g' value then convert them to the local 'g' value using the following equation for accurate measurements.

2.10.3.2. Also add the uncertainty components of temperature and 'g' value in terms of pressure to the uncertainty given in the certificate.

2.10.3.3. The pressure corrected to the local 'g' value and temperature at which calibration is performed using the following equation.

$$P_e = \frac{P_s * g_L * [1+(t-20)*\alpha]}{9.80665}$$

Where, 't' is the temperature during calibration and gravity 'g_L' local acceleration due to gravity (g' value of the lab) and 'α' is the linear thermal expansion coefficient of the Piston / °C.

2.10.3.4. After noting down the applied pressure at each calibration point of the steps and series as per the above referred table (2.10.1) error and uncertainties are estimated.

2.10.3.5. Uncertainty components of the calibration to be considered but not limited to:

- Applied pressure uncertainty (after correction if required) (u_1)

Uncertainties associated with DUC
- Repeatability (u_2)
- Reproducibility(u_3) - Optional
- Resolution (u_4)
- Zero error (u_5)
- Hysteresis (u_6)

2.10.3.6. Equation for combined uncertainty calculation:

$$\mathbf{u_c = \sqrt{(u_1^2+ u_2^2+ u_3^2+ u_4^2+ u_5^2+ u_6^2)}}$$

2.10.3.7. **Expanded uncertainty U = *k* x u_c**

where, k= coverage factor corresponding to the effective degree of freedom.

2.10.4. Calibration of Pressure Gauges using Digital Pressure Calibrator or Reference Pressure Gauge and Pressure Generating Pump

2.10.4.1. After noting down the applied pressure at each calibration point of the steps and series as per the above referred table (11.10.1) error and uncertainties are estimated.

2.10.4.2. Uncertainty components of the calibration to be considered but not limited to

- Applied pressure as per the calibration certificate of digital pressure calibrator (u_1)

Uncertainties associated with DUC

- Repeatability (u_2)
- Reproducibility(u_3) -Optional
- Resolution (u_4)
- Zero error (u_5)
- Hysteresis (u_6)

If Digital multi meter when used to record values in units other than pressure the associated uncertainty should also be added to the above.

2.10.4.3. Equation for combined uncertainty calculation

$$u_c = \sqrt{(u_1^2 + u_2^2 + u_3^2 + u_4^2 + u_5^2 + u_6^2)}$$

2.10.4.4. Expanded uncertainty U = *k* x u_c

Where, k= coverage factor corresponding to the effective degree of freedom.

2.10.5. Calibration Procedure for Vacuum Gauges

- Follow ISO 27893:2011 & DKD R-6-1.

2.11. Evaluation of CMC

2.11.1. Refer NABL 143 for CMC evaluation.

2.11.2. CMC value is not the same as expanded uncertainty reported in the calibration Certificate/Report. CMC values exclude the uncertainties which are attributed to the UUT (Unit Under Test/Calibration).

2.11.3. For the purpose of CMC evaluation the following components should be considered.

- Uncertainty of the applied pressure.
- Repeatability from 3 cycles (up and down 6 readings) at five equally distributed points. over the range to be calibrated (10% to 100 %).

- Uncertainty due to resolution of DUC 50% contribution to be taken.
- Uncertainty due to input and output electrical voltage or current measurements (normally in pressure transducers or transmitters)$.

  $ Optional if there is pressure display provided and shall be covered in the resolution.

2.12. Sample Scope

An illustrative example: Correct presentation of scope

<table>
<tr><td colspan="6">Laboratory: XYZ</td><td colspan="2">Date(s) of Visit:</td></tr>
<tr><td colspan="8">Discipline: Mechanical</td></tr>
<tr><th rowspan="2">Sl</th><th rowspan="2">Parameter* / Device under calibration</th><th rowspan="2">Master equipment used</th><th rowspan="2">Range(s) of measurement</th><th colspan="3">Calibration and Measurement Capability **</th><th rowspan="2">Remarks+/ Method used</th></tr>
<tr><th>Claimed by Laboratory</th><th>Observed by Assessor</th><th>Recommended by Assessor</th></tr>
<tr><td colspan="8"></td></tr>
<tr><td>1</td><td>Pressure Indicating Devices</td><td>Dead Weight tester / Pressure Balance of uncertainty 0.006 %</td><td>600 kPa to 6000 kPa</td><td>0.1 % rdg</td><td>0.08 % rdg</td><td>0.1 % rdg</td><td>By comparison method as per Euramet cg-17</td></tr>
<tr><td>2</td><td>Vacuum Gauge</td><td>Digital Pressure Indicator With uncertainty of 0.05 %</td><td>-900 mbar to 0 mbar</td><td>0.2 mbar</td><td>0.15 mbar</td><td>0.2 mbar</td><td>By comparison method as per ISO 27893</td></tr>
<tr><td colspan="8">* Only for Electro-technical discipline; scope shall be recommended parameter wise (where applicable) and the ranges may be mentioned frequency wise.
** NABL 143 shall be referred for the recommendation of CMC
+ Remarks shall also include whether the same scope is applicable for site calibration as well. NABL 130 shall be referred while recommending the scope for site calibration.</td></tr>
<tr><td colspan="3">Signature, Date & Name of Lab Representative</td><td colspan="3">Signature, Date & Name of Assessor(s)</td><td colspan="2">Signature, Date & Name of Lead Assessor</td></tr>
</table>

2.13. Key Points

2.13.1. The laboratory has to demonstrate the CMC values of 1/3rd or better of the maximum permissible error (MPE) as per relevant standard for grant of accreditation.

Note: For calibration of Pressure Gauges of accuracy 2.5 % class, the master equipment shall have accuracy 1/3rd or better i.e. (0.83 %). Hence, master equipment uncertainty shall be 1/3 rd of accuracy (0.83 %) i.e. 0.28 %.

2.13.2. Demonstration of any CMC values doesn't automatically qualify for granting accreditation until the lab satisfies the stipulated requirement given in this document.

2.14. Important Technical Information

2.14.1. Other Important Points:

- For pressure gauge calibration pressure is applied till set value is achieved in DUC and the corresponding applied pressure shall read on the master gauge accordingly.

- For the purpose of recommending CMC the laboratories shall claim/ report uncertainty either in % of reading or absolute value only.

- Laboratory shall report CMC value either in % of reading or in absolute value.

2.14.2. Uncertainty of the Equipment

There are two ways of stating measurement error and uncertainty for the entire range of measuring instrument.

- Percent of full scale deflection or FSD

- Percent of reading or indicated value

The difference between the two concepts becomes highly significant when an instrument is operating near the bottom of its turn down range. The following example will show the difference between the two.

Assume you have a 100 bar pressure gauge (Maximum), and that the stated uncertainty as:

Case-1: At 100 bar ± 0.5%FSD uncertainty is = 0.5 bar for the entire range. This represents the "best case" uncertainty of the measurement. However, when a lower range is utilized this 0.5 bar becomes more significant.

Case-2: At 100 bar ± 0.5% of reading the uncertainty is = 0.5 bar.

The following table explains the difference

Value	Case -1 (%FSD)		Case-2 (%rdg)	
	uncertainty	uncertainty in % for the indicated value (% of reading)	Uncertainty	uncertainty in % for the indicated value (% of reading)
100 bar	± 0.5 bar	0.50	± 0.5 bar	0.5
90 bar	± 0.5 bar	0.55	± 0.45 bar	0.5
80 bar	± 0.5 bar	0.62	± 0.40 bar	0.5
70 bar	± 0.5 bar	0.71	± 0.35 bar	0.5
60 bar	± 0.5 bar	0.83	± 0.30 bar	0.5
50 bar	± 0.5 bar	1.00	± 0.25 bar	0.5
40 bar	± 0.5 bar	1.25	± 0.20 bar	0.5
30 bar	± 0.5 bar	1.67	± 0.15 bar	0.5
20 bar	± 0.5 bar	2.50	± 0.10 bar	0.5
10 bar	± 0.5 bar	5.00	± 0.05 bar	0.5

Therefore, what looks to be a good uncertainty reading at full scale actually translates into substantially more % uncertainty at the lower range of the tester with case-1.

As can be seen by the above cases, uncertainty as related to full scale value increases significantly as you go lower in the range, while % uncertainty related to indicated value stays constant throughout the useful range of the UUT.

The above explanation holds good for the error of the equipment expressed in % of reading and % FSD also.

Hence, care to be taken in selecting the right equipment used for calibration in the laboratory and also while issuing calibration report for the calibrated equipment.

2.14.3. Equipments with %FSD

Generally, when manufacturer declares % FSD, their useful range will be from zero to full scale i.e. for example ± 0.5% FSD from 0 to 100 bar, this is interesting because at 0 bar the system is only accurate to within ± 0.5 bar. Basically the error goes to infinity at zero.

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