NATIONAL ACCREDITATION BOARD FOR TESTING AND CALIBRATION LABORATORIES

SPECIFIC CRITERIA for CALIBRATION LABORATORIES IN MECHANICAL DISCIPLINE : Mobile Force Measuring System (Push Pull Gauge)

ISSUE No. : 05 AMENDMENT No. : 00
ISSUE DATE: 12.08.2014 AMENDMENT DATE:

AMENDMENT SHEET

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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 in Push Pull Gauge calibration under mechanical discipline. This part of the document thus amplifies the generic requirements for calibration of Push Pull Gauge and supplements the requirements of ISO/IEC 17025:2005.

1.2 Calibration and Measurement Capability (CMC)

1.2.1 CMC is one of 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 shall 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 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 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 Force Metrology.

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

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

1.3.1.2 Training and experience required:

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

b) Training in force calibration and in Uncertainty Measurements, CMC including statistical analysis for Technical Manager.

c) Experience and competence in Force 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.

1.3.2 Authorised Signatory

1.3.2.1 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 in Force Metrology.

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

1.3.2.2 Training and experience required:

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

b) Training, Experience and Competence in Force metrology 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

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 and onsite 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 ± 2.5 Hz 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 Push Pull Gauge

2.1. Scope: Calibration of Push Pull Gauge

Specific requirements for the calibration of Mobile Force Measuring System:

Sl. No.	Mobile Force Measuring System	Relevant Standard/ Guidelines	Permanent Facility	On-site Calibration
1	Push Pull Gauge (Analog and Digital), Force Gauge	VDI/VDE 2624 Part 2.1 (December 2008)	√	X

Note: 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 Guideline

- VDI/VDE 2624 Part 2.1 (December 2008) - Instructions for calibration of mobile force measuring system.
- OIML R 111-1 Metrological and technical requirement of weights.
- OIML - D28- Conventional value of the result of weighing in air.

2.3. Metrological Requirement

2.3.1. For Each weight, the expanded uncertainty, U, for k=2, of the true mass.

2.3.2. All weights used for verification of force shall be in Newton. The applied Newton force can be converted to other units like kgf, lbf etc., depending on the unit of pushpull gauges.

2.3.3. All Newtonian weights preferably equivalent or better than F_2 standard shall be used as per OIML R-111-1.

2.3.4. 'g' value shall be known with sufficient accuracy either by Geological Survey of India or any other relevant source for finer CMC.

2.3.5. Laboratory may also calculate 'g' value knowing latitude and height as per the formula.

2.3.6. Since mass has to be calibrated in true mass basis, the air buoyancy correction shall be applied.

2.3.7. Knowing the true mass and 'g' value, Newtonian value will be determined after applying buoyancy correction.

2.3.8. The material construction of the weights is preferably of stainless steel. If other materials like mild steel, cast iron, brass etc is used, additional uncertainty to be added because of the effect of environmental condition.

2.4. Terms & Definitions

2.4.1. Primary Force Standard

- A dead weight force applied directly without intervening mechanisms such as lever, hydraulic multiplier, or the like whose mass has been determined by comparison with reference standards traceable to national standards of mass. This is called Dead weight force standard machine.

2.4.2. Load Cell

- A load cell is a transducer that is used to convert a force into electrical signal. A load cell usually consists of four strain gauges in a Wheatstone bridge configuration.

2.4.3. Mobile Force Measuring System (Push Pull Gauge)

- It is basically a handheld instrument that contains a load cell, electronic part, software and display. For measurement of force during a push or pull test. It is also called as push pull gauge or force gauge. There are two kinds of force gauges i.e. mechanical and digital type.

Symbols Used

Symbol	Unit	Designation
a_{in}	%	Relative resolution of calibration item
a_0	%	Relative resolution of calibration item in unloaded state
b_n	%	Relative repeatability of calibration item
$b_{0.5}$	%	Relative repeatability of calibration item for force step $F_{0.5}$
f_0	%	Relative zero error of calibration item
F	N	Force
M	kg	Mass
F_{sn}	N	Force indicated on calibration item at increasing test load
F'_{sn}	N	Force indicated on calibration item at decreasing test load
F_{in}	N	Constant force realized at increasing test load through reference standards
F_{nom}	N	Nominal force of calibration item
F_{s0}	N	Zero shift of calibration item after removal of nominal force
F_t	N	Tare force applied to test zero filter
$\bar{F}_{nom}$	N	Mean value of all measured values of a force step at increasing test load
$F_{0.5}$	N	Force step at approx. 50% of F_{nom}
V_n	%	Hysteresis error
G	m/s^2	Local acceleration due to gravity
q_n	%	Relative error of indication
r_n	N	Resolution of the calibration item
W_n	%	Relative expanded uncertainty of measurement
W_{cmc}	%	Calibration measurement capability
X_i	%	Evaluation quantity (auxiliary quantity)
K		Expansion factor for a specified confidence interval (for a confidence interval at 95% contribution to 2σ, *k*=2
N		Index giving the force component related to the nominal value (eg for force step 50% F_{nom} is n=0.5)

2.5. Selection of Reference Standard

2.5.1. The rigid system shall be capable of calibrating the force gauge in compression and tension mode. Application of force in both increasing and decreasing steps and a suitable holder must be available to ensure vertical alignment of the measurement axis.

2.5.2 The reference standards employed must have been tracked back and their uncertainty of measurement shall not exceed 1/3 of the uncertainty of measurement aimed at. The best measurement capability of the reference / working standard measuring system must be known and have been determined by approved methods.

2.5.3 The calibration shall be performed based on SI units and generally carried out with constant force using calibrated Newton weights. Newton weights are made using the following formula for generation of force.

$F = m*g$

Where, 'F' is generated force, 'm' is mass in kg and 'g' is the local acceleration due to gravity.

2.5.4 Laboratory has to demonstrate proper holding fixture for holding the DUC and the application of load vertically without cosine error. Since force is a vector quantity it plays very important role.

2.5.5 Loading frame or hanger used in calibration system shall be treated as first step weight or fraction of the first step and needs calibration in terms of Newton to avoid shift in initial zero position. Hence laboratory has to demonstrate calibration using calibrated loading frames for both tension and compression having valid traceability.

2.5.6 Number of different capacity loading frames or hangers are required to cover the entire range for both tension and compression.

2.5.7 All Weights shall be in Newton as per SI unit. Number of different denominations may be required to cover the entire range.

2.6. Calibration Interval

Reference Equipment	Recommended Interval
Dead weight push pull force gauge calibration machine with stainless steel weights	5 years
Dead weight push pull force gauge calibration machine with alloy steel weights	4 years

2.7. Environmental conditions required for calibration and requirement of Environmental Monitoring System

2.7.1 Calibration shall be performed at a temperature between 18°C to 28°C. During calibration the measuring arrangement must be in thermal equilibrium and the ambient temperature shall not vary more than ± 1°C.

2.7.2 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 below. For better than 50 ppm 'g' value shall be measured by appropriate authority.

2.7.3 Recommended resolution for environmental monitoring equipment

- Temperature with a resolution of 0.1°C.
- Humidity with a resolution of 1% RH
- Barometer with a resolution of 1 mbar

However, laboratory may evaluate the requirement of accuracy, resolution and uncertainty of monitoring equipment depending on the CMC claimed.

2.7.4 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

2.7.5 Weight Consideration

- Weights should be calibrated in terms of Newton. If the weight is in terms of kg and converted in terms of force using the formula [F= m*g].
- For example: for m = 1 kg the generated force =1*9.80665= 9.80665 N.

  For Force of 10N, we require denomination of weights 1 kg, 10 g, 5 g, 2 g, 2 g, 500 mg, 200 mg, 10 mg & 1 mg to get 1.019716 kg.
- The shape of the weights used in the calibration machine should be such that, it doesn't affect verticality of the measuring axis and concentric to the applied force. Otherwise, the magnitude of error of applied force will be more and hence the uncertainty since, force is a vector quantity.

2.8. Calibration Procedures

2.8.1. Determination of resolution:

The relative resolution a_n of the force measuring device is calculated as follows:

$$\mathbf{a_n = r_n/F_{sn} * 100}$$

The resolution r of the calibration item having to be determined in each calibration point. If, the display in the unloaded state varies by more than the value previously determined for the resolution, the resolution r_n is to be taken as half the extent of the variation plus one additional increment.

2.8.2. Preloading:

Calibration item must be loaded at least once with the maximum force of the range to be calibrated. The number of pre loadings must be documented.

2.8.3. Loading of calibration item:

The calibration item is calibrated in only one mounting position, one series of measurements being carried out at increasing and one series at decreasing test loads. The minimum of five force steps lie between 10% to 100% of the nominal force F_{nom}. The force steps chosen should be approx. 10%, 20 %, 50%, 70% and 100% of the nominal force. The increasing and decreasing series are each to be realized at the same force steps. For calibration, the duration of test force application are to be selected in such a way that stabilization of the system is ensured.

For repeatability b_n force step $F_{0.5}$ (i.e. at 50% of the nominal force range) is additionally determined by three further measurements.

2.8.4. Determination of Errors:

2.8.4.1. Relative error of indication:

The relative error of indication q_n of the force displayed on the calibration item is calculated using the measurement values F_{sn} from the increasing series as follows:

Relative error of indication 'q_n'= $((F_{sn}-F_{in})/F_{in})*100$

2.8.4.2. Relative repeatability:

The relative repeatability b_n can be calculated only for $F_{0.5}$ and thus referred to as $b_{0.5}$

$b_{0.5}$ = (max $F_{s0.5}$ - min $F_{s0.5}$ /$F_{Avg.\ s0.5}$) * 100

2.8.4.3. Hysteresis error:

The hysteresis error v_n gives the difference between the values measured in the increasing series F_{sn} and in the decreasing series F'_{sn} and is calculated using the following formula:

$v_n = (F'_{sn} - F_{sn}/F_{sn})*100$

2.8.4.4. Relative zero error (zero shift):

The relative zero error can be determined in two ways taking into account of zero filtering:

a) **Without zero filtering**

In this variant, the zero shift F_{s0} is read after the decreasing series of measurements Reading of the zero shift is made 30s after complete removal of test load.

$f_0 = F_{s0}/F_{nom} *100$

b) **With zero filtering**

IF the calibration item has a zero filter, first the necessary tare force is to be determined. It is to be selected such that the upper limit of the filter is exceeded slightly. After application of this tare force Ft, the calibration item is no longer tared. Now the nominal force is applied to the calibration item and removed again after approx.30 s Then after another 30 S the zero shift is read.

$f_0 = F_{s0} - F_t /F_{nom} *100$

2.9. Measurement Uncertainty

2.9.1. Estimation of relative expanded uncertainty of measurement

$W_n = k * \sqrt{^2\left(W_{cmc}/2\right) + w^2_{a0} + w^2_{an} + w^2_{bn} + w^2_{qn} + w^2_{vn}}$, with k=2

W_{cmc} = Relative expanded uncertainty of measurement of the calibration force given in the calibration force for the reference standard (k=2).

w_{a0} = Relative expanded uncertainty of measurement of the resolution in the zero point or of the magnitude of the zero filter, $w_{a0} = a_o/2\sqrt{3}$.

w_{an} = Relative expanded uncertainty of measurement of the resolution in measuring point n.

$w_{an} = a_n/2\sqrt{3}$.

w_{bn} = Relative uncertainty of measurement of the repeatability. It is determined at 50% of the F_{nom} and applied in all force steps taking into account of an adjustment factor (factor 2).

$w_{bn}=2*wb_{0.5}=2*b_{0.5}/2\sqrt{3}$.

w_{qn} = Relative uncertainty of measurement of the error of indication in measuring point.

$w_{qn} = q_n / 2\sqrt{6}$.

w_{vn} = Relative uncertainty of measurement of the hysteresis in measuring point n.

$w_{vn} = v_n/2\sqrt{6}$.

Note: The known error of indication is accounted for in the uncertainty budget as in normal use of mobile force measuring systems it is not used for the correction of the measurement result.

2.9.2. Evaluation

Due to the simplified calibration procedure, no statement can be made as to a classification of the force measuring devices. Comparability can be ensured, using the following characteristics:

- X_q is the maximum of all absolute values of q_n
- X_b is the maximum of all absolute values of b_n
- X_v is the maximum of all absolute values of $v_n*2/3$
- X_a is the maximum of a_n
- X_{f0} is the maximum of all absolute values of f_0*10
- The maximum of all X_i values are stated for the overall evaluation

2.9.3. Recommended Calibration Interval for Push Pull gauge - 12 months.

2.10. Evaluation of CMC

2.10.1 Refer NABL 143 for CMC evaluation.

2.10.2 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).

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

- Uncertainty of the applied force.
- Repeatability of the artifact (5 readings with minimum and maximum).
- Uncertainty due to resolution.

2.11. Sample Scope

An illustrative example: Correct Presentation of Scope

Laboratory: XYZ							Date(s) of Visit:
Discipline: Mechanical							
Sl	**Parameter*/ Device under calibration**	**Master equipment used**	**Range(s) of measurement**	**Calibration and Measurement Capability****			**Remarks[+]/ Method used**
				Claimed by Laboratory	**Observed by Assessor**	**Recommended by Assessor**	
1	Force Push Pull gauge	Dead Weights (0.01 %), Push Pull calibration system (0 to 1000 N) with different denominations of Newton weight and different loading frame	0 to 100 N	0.06 %	0.08 %	0.08 %	Calibration of Push Pull gauge in push and pull mode as per VDI/VDE 2624

* *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.*

Signature, Date & Name of Lab Representative	Signature, Date & Name of Assessor(s)	Signature, Date & Name of Lead Assessor

2.12. Key Points

2.12.1. Most of the push pull gauges manufactured are better than 1% accuracy. The maximum uncertainty of this shall be 1/3rd i.e. 0.3%. Hence the applied force uncertainty shall be 1/3rd of 0.3 i.e. 0.1%. Accordingly lab shall demonstrate CMC values minimum of 0.3% which is approximately 1/3rd of the accuracy.

2.12.2. Laboratory has to demonstrate proper holding fixture for holding the DUC and the application of load vertically. Since force is a vector quantity it plays very important role.

2.12.3. Number of different capacity loading frame or hanger used in calibration system shall be treated as first step weight or fraction of the first step and needs calibration in terms of Newton to avoid shift in initial zero position. Hence laboratory has to demonstrate calibration using calibrated loading frames for both tension and compression having valid traceability.

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

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