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NATIONAL ACCREDITATION BOARD FOR TESTING AND CALIBRATION LABORATORIES

SPECIFIC CRITERIA for CALIBRATION LABORATORIES IN MECHANICAL DISCIPLINE : Torque Measuring Devices

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Sl no	Page No.	Clause No.	Date of Amendment	Amendment made	Reasons	Signature QO	Signature Director
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Sl. No.	Contents	Page No.

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 calibration of Torque Measuring Devices under mechanical discipline. This part of the document thus amplifies the specific requirements for calibration of Torque Measuring Devices 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 be based on 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 Torque Calibration.

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

c) ITI with 1 year of experience in Basics of Torque Calibration.

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 torque calibration and in Uncertainty Measurements, CMC including statistical analysis for Technical Manager.

c) Experience and competence in toque calibration.

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 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 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 torque calibration.

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

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 torque calibration 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 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 Torque Measuring Devices

2.1 Scope: Calibration of Torque Measuring Devices (Torque meters, Torque Calibrators, Torque Transducer/Sensor)

Specific requirements for the calibration of Torque Measuring Devices:

Sl. No	Description	Relevant Standard/ Guidelines	Permanent facility	Onsite calibration
1	Torque Measuring Devices (Electrical, Mechanical, Hydraulic, Optical torque measuring device)	BS 7882	√	X

Note 1: Torque measuring devices can also be calibrated as per ASTM E2428-08 which is used for calibration of Torque Testing Machines as per ASTM E2624-09.

Note 2: This technical requirement is based on **BS 7882:2008.** 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

- BS 7882:2008: Method for calibration and classification of torque measuring devices.
- EURAMET cg 14: Static Torque measuring devices.
- ASTM E 2428-08 Practice for calibration of torque measuring instruments for verifying Torque indication of Torque testing machines.
- ASTM E 2624-09 Standard procedure for torque calibration of testing machines and devices.
- OIML R111-1-2004 Metrological and technical requirement of weights Classes E_1, E_2, F_1, F_2, M_1, M_2, M_3.
- OIML D28 2004: Conventional value of the result of weighing in air.

2.3 Metrological Requirement for the calibration Torque Measuring Devices

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.

2.3.3 Preferably all weights will be equivalent or better than F2 standard as per OIML R-111.

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. However, same shall be validated. (8.8.3.1 / 8.8.3.2).

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, value in newon will be determined after applying buoyancy correction.

2.4 Terms & Definitions

Torque

- Torque is the vector product of tangential force and length applied about a known center of rotation.

Torque Measuring Device

- A system comprising of an Electrical, Mechanical, Hydraulic or Optical Torque Transducers with associated instrumentation including the automated logging of data when part of the device Instrumentation can be a electronic instrument, a mechanical device is a scale and pointer system or a bourdon tube instrument.

Relative Reversibility

- Difference between the deflection obtain from the last given torque series applied in an increasing mode and the deflection obtained from the same given torque applied in decreasing mode.

Relative Residual Deflection

- Maximum residual deflection obtained from all the series of torque.

Acceleration due to Gravity 'g'

- It is the acceleration of a body due to the influence of the pull of gravity alone, usually denoted as 'g' and unit of measurement is m/s2.

2.5 Selection of Reference Standard Torque Calibration Machine

Calibration of torque measuring devices in the torque calibration machines will generally be carried out in accordance with a documented procedure such as BS 7882:2008 and the uncertainty of the calibration results will be dependent on the calibration machine uncertainty (maximum permissible uncertainty of calibration torque applied), as well as on the performance of the instrument during calibration.

The machine shall be capable of calibrating the instruments in clockwise/anti-clockwise, application of torque in both increasing and decreasing steps. It shall ensure axial application of torque.

2.5.1 Types of Torque calibration Machine

Reference standard calibration machine is required for application of Torque to calibrate Torque measuring device. The calibration machine shall be sturdy enough to receive reaction forces without any deformation and shall have the ability to hold the torque transducer or device at the correct alignment with its measuring axis axial and concentric to the applied torque - at each applied torque will have an effect on the magnitude of the force vector applied to the transducer measuring axis. Machine shall have proper couplings without any side force generation which otherwise may affect torque transducer output.

2.5.1.1 Dead Weight Torque Calibration Machine with calibrated beam (lever arm) supported with antifriction bearing:

For achieving uncertainty of torque applied in the range of ± 0.01% to ± 0.04% it is practically possible with dead weight torque calibration machine with calibrated beam (lever arm) supported with antifriction bearing, Calibrated Newton weights (preferably stainless steel). Local 'g' shall also be known with sufficient accuracy and uncertainty of measurement.

Torque is a product of tangential force and length applied about a known centre of rotation. Since Force is a vector quantity when a beam and weights are used as a calibration equipment, appropriate steps to be taken shall be to ensure that, there is no misalignment of the unit under test which could generate parasitic forces and cause a bias on the system.

The Torque Calibration machine with beam and weights should have provision so that UUT can be mounted in a position such that can be rotated through 360° in 90° increments or 120° increments in both clockwise and anti-clockwise directions about its principal axis of rotation between measurement series. When the design or specification of the UUT does not accommodate for rotation it shall be physically disconnected and removed from the calibration equipment and reconnected between measurement series.

Applied torque depends on following factors:

- Mounting of UUT without any misalignment between the arm and the reaction gearbox used to rotate about its principal axis.
- Quality of the gearbox used for rotation.
- Effect due to bearing friction.
- Class of accuracy and material of the Newton weights used.
- Cosine error, which depends on maintaining the horizontal position of the beam which changes in each step of a series when Newton weight is applied to create torque.
- Maintaining the verticality of the load applied to the horizontal beam which affects the repeatability of measurements.
- Oscillation effect on the hanging weights.
- Local acceleration of gravity.
- Buoyancy correction.
- Operator skill in applying the load slowly and gradually.
- Maintaining the stability of the temperature during calibration.
- Magnitude of vibration, shock or other disturbing conditions during calibration.

To achieve above condition, the torque calibration machine shall have torsionally rigid couplings between the UUC and the beam on one side and UUC and High ratio Gear box (used for rotation) on the other side along with sturdy high quality bed which can accommodate various sizes of UUC.

While applying Torque, beam shall be maintained horizontal to the axis using spirit level or any other method to minimize cosine error to the applied Torque.

The calibration machine shall be designed in such a way that, the load is applied exactly at a known distance of beam precisely and vertically.

Weights used shall be preferably of stainless steel and calibrated to F_2 or better class of accuracy as per OIML-R-111-1 in Newton. Local value of acceleration due to gravity "g" should be known to sufficient accuracy along with uncertainty and buoyancy correction needs to be applied.

2.5.1.2 Torque calibration machine with unsupported beam:

- It is generally accepted that a bearing supported beam is used for measurements of the highest accuracy in order to minimize bending effects on the test transducer. The weight of the beam is most significant in relation to the torque being measured. Suitability of a particular beam is also relative to the stiffness of the transducer under calibration. The distance between the beam and the transducer shall be kept minimum. Wherever it is possible, it is always best to connect the beam directly to the transducer in order to minimize any slack in the coupling of the square drives and the transducer itself shall be held as rigidly as possible in the calibration fixture.

- While applying Torque, beam shall be maintained horizontal to the axis using spirit level or any other method to minimize cosine error to the applied Torque.

- The calibration machine shall be designed in such a way that, the load is applied exactly at a known distance of beam precisely and vertically.

- Unsupported calibration beams coupled directly to a transducer is used in industry for verification of low torque applications.

- Un-supported beams generate additional bending moment and side force which makes the calibration conditions very different from pure torque conditions.

- The characteristics of a transducer, its behavior, its output and the way it is mounted are important factors to be considered.

- Sensitivity and bending effects should be considered as part of the uncertainty calculations

2.5.1.2.1 Method to determine bending effects for unsupported beam:

- The magnitude of bending effect depends on the design and structure of the transducer which may not be known to the calibration lab. The calibration process may damage the torque transducer due to bending effect. Lab has to identify the bending effect before starting the calibration as per below procedure.
- Example for verifying the bending effect of 100 Nm Torque Transducer.
- Apply load in steps of 10% (i.e. 10 Nm) of the full scale value in clockwise direction and note down the torque value T1.
- Apply additional load of 5 Nm (50% of 10 Nm) on both clockwise and counterclockwise directions i.e. at the end there will be 15 Nm (150% of 10Nm) on clockwise and 5 Nm (50% of 10 Nm) value on counterclockwise direction, but net nominal torque will be same. Now, note down the torque value T2.

- Bending effect = [(T2-T1)/T1)*100], where T1 and T2 are torque display values.
- If the component of bending effect is significant for the limit of accuracy of the transducer, to proceed with the calibration may cause damage to it. Hence, do not proceed with the calibration process.
- Same shall be repeated for full load in steps of 10 %. If, found linear then.
- It need not be repeated for all calibration steps. Otherwise, it has to be checked at each calibration step. Maximum effect should be taken for uncertainty calculation.

2.5.1.3 Comparator type torque calibration machine using several reference torque transducers

- Instead of Dead weight torque calibration machine, where a calibrated reference Transducer with indicating device is used for measurement of Torque generated by suitable means either manually or with power , steps shall be taken to ensure that there is no misalignment between the torque generator, UUC, reference torque transducer and the torque absorber.
- These machines are based on a number of torque transducers, individually calibrated in a dead weight torque standard machine and then loaded in parallel.
- The torque calibration machine shall have torsionally rigid couplings between the UUC and High ratio Gear box (used for rotation) on the other side along with sturdy high quality bed which can accommodate various sizes of UUC.
- Torque transducer or device shall be kept at the correct alignment with its measuring axis axial and concentric to the applied torque - at each applied torque.

For this type of machine, the uncertainty contributions that need to be considered will include, but are not limited to, the following:

- Uncertainty of Reference Transducers.
- Uncertainty due to Repeatability (3 rotational positions at minimum and maximum of the range to take into account coupling and misalignment effects).
- Uncertainty due to resolution.

2.5.1.4 Secondary standard Torque calibration Machine

This torque calibration machine is similar to primary torque standard machine having calibrated lever arm, except the load is applied through hydraulic system or motorized system using force proving instrument instead of dead weights. This system is normally used for calibrating torque transducers of high capacity where, dead weight system is not feasible.

For this type of machine, the uncertainty contributions that need to be considered will include, but are not limited to, the following:

- Uncertainty of reference force transducers.

- Uncertainty due to Repeatability (3 rotational positions at minimum and maximum of the range to take into account coupling and misalignment effects).
- Uncertainty of lever arm length.
- Uncertainty due to resolution of indicator.

2.5.2 Traceability Paths

There are two distinct traceability path for the torque generated by the torque calibration machine and the method of estimation of the associated uncertainty and evaluation of CMC depend on the following method.

1. **Traceability Path A:** The torque calibration machine directly from transfer standards calibrated in national force standard machine.
2. **Traceability Path B:** The torque calibration machine has independent traceability to the base SI units of Mass, Length and 'g' value.

2.5.2.1 Traceability of measurement:

All definitive measurements such as mass, 'g' value, length, temperature, humidity, atmospheric pressure which are used for realization of torque shall have traceability certificate.

Sl. No.	Type of force generating machine	Traceability certificates required for
1	Dead Weight	True Mass value, `g' value, lever length, temperature, Humidity and atmospheric pressure
2	Comparator type with reference torque/ force transducers	Reference Torque/ Force Transducers.

2.5.3 Components of uncertainty for Applied Torque of Calibration Machine

Dead Weight Torque Calibration Machine:

2.5.3.1 Equation for realization of Torque using Dead weight and Beam

Torque = Force x Distance x (cos α)

$$T = F \times D \times \cos\alpha$$

$$F = m_t \times g_L \times [1-\rho_a/\rho_m]$$

Where,

T= Torque in Newton- meter
F = Force in N
D = Nominal Length of the Lever Arm in metre
α = Angle
m_t = True Mass used for generating the force
g = Local acceleration due to gravity in m/sec^2
ρ_a = Density of Air in kg/m^3
ρ_m = Density of Mass in kg/m^3

2.5.3.2 Formula for applying Temperature correction to the length

L=	$l_0 *(1+\beta_T*\delta_T)$
l_0 =	length at calibration temperature, T_0=20ºC
β_T =	Coefficient of linear expansion for the material of arm length
δ_T =	Difference between the temperature at calibration and during calibration

Major sources of Uncertainty of Applied Torque

Uncertainty contribution of Force:

- Uncertainty of Mass, error in Mass, drift or stability in Mass and Mass stack.
- Uncertainty due to gravity and Uncertainty of gravity due to height of the mass stack.
- Uncertainty due to Air Density.
- Uncertainty due to Density of Mass.

Note: ILC may be recommended for the parameters like mass stack, cos α, and uncertainty due to height of mass stack.

2.5.3.3 Formula for calculation of uncertainty contribution of generated force

$$[\sigma(F)/F]^2 = [\sigma(m_t)/m_t]^2 + [\sigma(g)/g]^2 + [(\rho_a/\rho_m)^2 * ((\sigma(\rho_m)/\rho_m)^2 + (\sigma(\rho_a)/\rho_a)^2)]$$

Uncertainty contribution of Beam Length:

- Uncertainty of beam length $u(l_0)$.
- Uncertainty due to angle measurement $u(\alpha)$.
- Uncertainty due to thermal expansion coefficient $u(\beta_T)$.
- Difference in temperature of the beam between calibration and usage at lab (θ).
- Uncertainty in temperature measurement u(θ).

2.5.3.4 Formula for calculation of uncertainty contribution of Beam length:

$$\left((u(l)/l)^2\right) = \left((ul_0/l_0)^2\right) + \left(u^2(\alpha)\right) + \left((\beta_T\theta/(1+\beta_T\theta))^2\right) * \left\{(u\beta_T/\beta_T)^2 + (u\theta/\theta)^2\right\}$$

2.5.3.5 Uncertainty of applied Torque is calculated as below:

$$\left((u(T)/T)^2\right) = \left((u(F)/F)^2\right) + \left((u(l)/l)^2\right) + \left(u^2(\alpha)\right)$$

Where, uT is uncertainty of Torque, uF is uncertainty of Force, ul is the uncertainty of length of the beam and $u(\alpha)$ is uncertainty of cosine error.

2.5.4 Effect of Weight, Gravity, Buoyancy and Temperature on Generated Force

2.5.4.1 Weight Consideration:

Weights should be calibrated in terms of Newton. If the weight is in terms of kgs 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.

2.5.4.2 Gravitational Effects Consideration:

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 Force calibration laboratory establishes local value of gravity (g) and use weights that have been calibrated at that gravitational constant.

2.5.4.3 Buoyancy Effect Consideration:

The weights are used to generate a downward force in air during force calibration (not in Vacuum). This means that, Archimedes's principle applies i.e. air pressure under the weights causes an upward force. This reduces the effective force generated by the weights and therefore the mass must be increased to allow for this. If the weights are calibrated on conventional mass basis under standard conditions of air density of 1.2 kg/m^3 at 20°C and density of weight 8000 kg/m^3. The increase is required by a factor of 0.012% to 0.015%. Because, realization of force is a product of true mass local g and local air density.

2.5.4.4 Effect of Change in Temperature on Calibration Results:

- The weights and the hanger used are of steel material. The variation of temperature changes the volume of the material due thermal expansion and affects the value of mass as it is a function of density and volume.
- The variation of temperature affects the air density, which is used in buoyancy correction. Hence, change in temperature affects in realization of force values.
- Apart from the above, it affects change in length also in a lever multiplication system and there by uncertainty due to thermal expansion depending on the material used.
- In a hydraulic multiplication system, the piston and cylinder area is affected due to change in temperature and it is very sensitive to temperature and changes the generated pressure significantly.
- The change in temperature also affects the electronic systems used during calibration either as a control system, reference system or UUT and will contribute to uncertainty.
- Correction may not be required for the level applied torque uncertainty more than 0.05%.

2.6 Calibration Interval

Reference Equipment	Recommended Interval
Dead weight Torque calibration machine Stainless steel weights (both for supported & Unsupported beam)	5 years
Dead weight Torque calibration machine Alloy steel weights (both for supported & Unsupported beam)	4 years
Comparator type with force Transducer with calibrated arm	26 Months
Comparator type with torque Transducer	1 year

2.7 Legal Aspects

Calibration of torque measuring device done by any accredited laboratories is meant for scientific and industrial purpose only. However, if torque measuring device is used for commercial trading, additional recognition/ approval shall be complied as required by Dept. of Legal Metrology, Regulatory bodies, etc.

2.8 Environmental Conditions

Lab is advised to follow Manufacturer's recommendation for environmental conditions, operations and maintenance. Laboratory shall fulfill the following conditions for realization of applied torque.

2.8.1 The temperature shall be maintained in the range of 18°C to 28°C. The temperature shall not vary more than ± 1°C throughout a measurement series.

2.8.2 The relative humidity shall be maintained at 50% RH ± 15% RH.

2.8.3 For measurement uncertainty of applied force, 'g' value shall be known.

2.8.4 To achieve applied Force uncertainty better than 0.01%, lab to have the local acceleration due to gravity measured at the site of calibration.

2.8.4.1 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:

$$g = 9.780\,327\,(1 + A \sin^2 L - B \sin^2 2L) - 3.086 \times 10^{-6}\, H\ m \cdot s^{-2}$$

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.
- From the google 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 google maps and click on location of the lab and find out the latitude and height of the place as per google (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 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 (page No. 76**)**

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

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 ºC<t<30 º C and rh< 80%.

2.8.6 The Magnitude of vibration, Shock or other disturbing conditions shall be such that, they will have a negligible effect on the reading of standard equipment.

2.8.7 Recommended Environment monitoring equipments at calibration laboratory

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

However, laboratory shall evaluate the requirement of accuracy, resolution and uncertainty depending on the CMC aimed at.

2.9 Calibration Methods

Torque Measuring Devices can be calibrated as per BS 7882:2008 either with error of indication or with error of interpolation.

2.10 Calibration Procedures

2.10.1 Resolution of the Torque Indicator:

To ensure that the classification is consistent with the resolution of the torque indicator, a lower limit of calibration shall be determined. The calibration shall not be performed below the lower limits given by the equation T_{min} = ar   where 'a' has following values and 'r' is the resolution of the indicator.

Class	Value of a
0.05	≥ 4000 x r
0.1	≥ 2000 x r
0.2	≥ 1000 x r
0.5	≥ 400 x r
1.0	≥ 200 x r
2.0	≥ 100 x r
5.0	≥ 40 x r
Where r is the resolution	

2.10.2 Uncertainty of Applied Torque

Values for the maximum permissible uncertainty of the calibration Torque applied for the determination of different classifications of the torque measuring device shall not exceed the values given in table 1 as per BS 7882:2008. Where a reference standard is used to determine a calibration Torque it shall conform to table 1.

Table-1: Uncertainty of Calibration Torques (applied Torque)

Class of Torque measuring device to be Calibrated	Maximum permissible uncertainty of Calibration Torque applied (A) %
0.05	± 0.01
0.1	± 0.02
0.2	± 0.04
0.5	± 0.10
1.0	± 0.20
2.0	± 0.40
5.0	± 1.00

(A) Using a coverage factor of k=2 to give a confidence level of approximately 95%.

2.10.3 Classification of the Torque Measuring Device:

- Minimum range of measurement for a selected classification shall be 20% to 100% of the calibration range.

- Where calibration torques have been applied below 20% of maximum applied torque and all of the results meet the requirement, then the range of classification of the selected classification can be extended.

- A second classification of lower class and of an extended range can be awarded, provided that all of the requirements are met in respect of lower class.

Criteria for classification of torque measuring devices as per BS7882:2008 Table-2 (Permissible values in %)								Resolution required to satisfy Minimum torque criteria (Resolution ' r ' = 1)	
Class	Relative repeatability	Relative reproducibility	Relative error of interpolation	Relative residual deflection	Relative reversibility	Relative error of indication	Maximum Applied Torque uncertainty		
	R_1±	R_2	E_{it}	R_0	R_3	E_i	with k=2	Criteria	value in %
0.05	± 0.025	± 0.05	± 0.025	± 0.01	± 0.062	± 0.025	± 0.01	4000*r	0.025
0.1	± 0.05	± 0.10	± 0.05	± 0.02	± 0.125	± 0.050	± 0.02	2000*r	0.05
0.2	± 0.10	± 0.20	± 0.10	± 0.04	± 0.250	± 0.10	± 0.04	1000*r	0.1
0.5	± 0.25	± 0.50	± 0.25	± 0.10	± 0.625	± 0.25	± 0.10	400*r	0.25
1.0	±0.50	± 1.00	± 0.50	± 0.20	± 1.250	± 0.50	± 0.20	200*r	0.5
2.0	± 1.0	± 2.00	±1.00	± 0.40	± 2.50	± 1.00	± 0.40	100*r	1.0
5.0	± 2.50	± 5.00	± 2.50	± 1.00	± 6.250	±2.50	± 1.00	40*r	2.5

Note 1: The relative error of indication shall only be determined where the deflection is expressed in units of Torque i.e. Nm, cNm etc.

Note 2: The error of interpolation shall only be determined where the deflection is expressed in the units other than those of Torque i.e. mV, V or mV/V.

For the uncertainty calculation any one component from the above has to be considered.

2.10.4 Calibration Interval for Device under Calibration

As recommended in the standard - Not exceeding 12 months or approximately 5000 cycles of operation.

2.11 Measurement Uncertainty

2.11.1 Uncertainty components for Calibration of UUC

- Uncertainty due to applied torque depending upon the type of machine used for calibration.
- Relative repeatability error (R_1).
- Relative reproducibility error (R_2).
- Relative interpolation error (E_{it}).
- Relative zero error (residual deflection) (R_0).
- Relative reversibility error (R_3).
- Relative error of indication (E_i) where interpolation is not used.
- Uncertainty due to bending effect (only for unsupported beam).

Note:

a) The error of interpolation shall only be determined where the deflection is expressed in units other than those of torque (eg in units of Volts or mV).

b) The error indication shall only be determined where the deflection is expressed in units of torque.

2.11.2 Overall Accuracy of the Device (Oa)

Overall accuracy of the device can be obtained by combining the classification accuracy with the expanded uncertainty in quadrature.

$$\mathbf{O_a = \sqrt{[(E_i/\sqrt{3})^2 + (U/2)^2]}}$$

Then, overall accuracy O_a is multiplied by coverage factor k=2 to give U_{Oa} the classification accuracy is obtained by Ei column in the table 2 of BS 7882.

Note: This applies to the calibration device having deflection in Torque units like Nm, cNm etc.

2.12 Evaluation of CMC

2.12.1 Refer NABL 143 for CMC evaluation.

2.12.2 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).

2.12.3 For the purpose of CMC evaluation the following components shall be considered.

- Uncertainty of the applied torque.
- Repeatability of the artifact (10 reading at 3 rotation of position for minimum and maximum value of the range).

2.13 Sample Scope

An illustrative example for 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	Torque Measuring Devices	Dead Weight Torque Calibration Machine 0 to 2000 Nm with Newton weights	2 to 2000 Nm	0.008 %	0.01 %	0.01 %	Calibration of Torque Measuring Devices for accuracy class 0.05 and Coarser As per BS 7882

* *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

2.14 Key Points

2.14.1 Laboratory has to demonstrate the expanded uncertainty applied calibration force (at 95% confidence level) as per table below:

Class	Maximum permissible calibration Torque uncertainty With k=2 in %	Combined uncertainty with reversibility including error in %	Combined uncertainty with reversibility without error in %	Combined uncertainty without reversibility including error in %	Combined uncertainty without reversibility without error in %
0.05	0.01	0.031	0.029	0.025	0.023
0.1	0.02	0.061	0.058	0.049	0.045
0.2	0.04	0.122	0.115	0.098	0.090
0.5	0.1	0.305	0.288	0.246	0.244
1	0.2	0.610	0.575	0.492	0.448
2	0.4	1.221	1.151	0.985	0.896
5	1.0	3.052	2.877	2.462	2.241

Note1: Laboratory shall comply with the applied toque uncertainty required for different class as per the table above.

Note 2: The cut off CMC value for class 0.5 or better, for the applied torque of 0.1% beyond this accreditation shall not be granted to qualify as a reference standard for the calibration of torque generating devices.

Note 3: The Torque measuring device using for calibration of torque Tools as per IS 6789 & ISO 5393 requires 1 % accuracy including uncertainty (0.33 %). As per the above table the lab which can calibrate for 0.5 class or better of the torque measuring device with applied uncertainty 0.1 % or better can only qualify to carry out the calibration of Torque Tools as per the standard.

2.14.2 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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