Metrology Lab

The National Metrology Institute (NMI).

(Traditionally referred to as 'the national laboratory').

Metrology - The science of measurement.

Lord Kelvin, the renowned scientist, had the following to say about metrology:-

"When you can measure what you are speaking about and express it in numbers, you know something about it, but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind".

Measurements have been carried out by humans for as long as civilization has existed. From the primitive population who lived in caves to modern man, the need has always been there to measure and know. Of course, all these measurements were approximate. With the development of civilization the need for more acceptable measurement grew. This led to the evolution of the standards of measures. For example, the standard of length evolved from the foot of the "King", to the Egyptian cubit, to the metallic metre and finally to the monochromatic, highly stabilized light source. Interestingly enough, even though we can now measure with much greater precision, the measurements are still "approximate" and will always have an element of "uncertainty".

Today, reliable measurements are required over a much wider range of activities. As industry undergoes major new developments with new materials, techniques and the miniaturization of products, measurements become more critical. The increasing trend to sub-contract assembly or sub-systems means that each location needs to have the same measurement system; otherwise the various parts would not fit together. New areas in metrology, such as nanotechnology, optical techniques, material sciences, and metrology in chemistry, healthcare, food safety and testing have developed rapidly. And today the requirements of law enforcement, fraud, forensics and environmental sciences also need accurate and traceable measurements to be able to function properly.

The further globalization of trade needs traceable, comparable and mutually acceptable measurements across the world, not only in the trade of manufactured products and raw materials but in all aspects of international trade. Society now demands that it can have confidence in the results of measurements. Decisions based on the data that comes from measurements are increasingly seen to have a direct influence on the economy, human safety and welfare. The only way for this to be assured is for measurements in all areas of science to be made in terms of a well defined system of units and verified measurement procedures.

The SI (Systeme International d'Unites) is a globally agreed system of units based on the metric system. There are seven base measurement units from which all other measurement units are derived. These base units are the metre (length), the second (time), the mole (amount of substance), the candela (light intensity), the ampere (current), the kelvin (thermodynamic temperature), and the kilogram (mass).

Measurement science is vital for trade and commerce and is the basis of modern science and technology. (See references made in the Accreditation section to the World Trade Organisation (WTO) and technical barriers to trade (TBTs)). Reliable and traceable measurements are required by every country to ensure that they remain a player in the world market, whether they are selling goods and services or buying them. It is the responsibility of all the countries of the world to ensure they have a practical system to provide their markets with the appropriate levels of traceable metrology to underpin their trade activities. This does not mean that they need to be able to realise the base units of the SI system. What they need is to be able to provide a practical traceable solution, one level higher than the industry is generally operating at.

Several countries have fallen into the trap of planning a national laboratory at the highest level and then finding that they are unable to provide for the requirements of their own industry and academia. The correct way to establish the appropriate level for the national laboratory is to survey the industry and to cater for the general requirements. There will always be one customer who needs an above-average traceable calibration but these should be treated as special and sent to another laboratory that can provide the service, even if it is in another country.

To cater for the demands of its country, the national laboratory also needs to evaluate the cost-effectiveness of maintaining the required level in each discipline of metrology. In Europe, the various countries have recognised that, even in their environment, not every national laboratory can be everything to everybody and they have agreed to have different areas of speciality while maintaining the general requirements for their industry. In some developing counties, the national laboratory is no more than a "post office" which co-ordinates the flow of work to suitable, accredited laboratories in other countries or even economies. The national laboratory also ensures that the work being performed is what is required by their customers and is recognised by the various regulating bodies of their country.

The biggest challenge that faces all metrology laboratories is the availability of suitably qualified staff. It is often said that the head of a national laboratory should at least have a PhD but this is clearly not correct. The staff level needs to be such that they can provide consistently good measurement results and be competent to know what is required to achieve this. So, if the country only has a "post office", it does not need much more than a clerical person with a good understanding of how the international traceability and accredited facilities work. On the other hand, if the organisation is of national research institute level, it will need to have people with suitable qualifications to manage the complicated mathematics and system requirements.

Similarly, if the workload at the national laboratory is such that it does not require specialist staff for every discipline, it is quite easy to combine several of the disciplines under one or two fields. Many high level laboratories group the electro-magnetic and mechanical fields simply as two sections with appropriate cross-trained staff in each group.

Three factors of great importance to metrology laboratories are environmental control, work and storage space, and electrical power supply. Good care must be given to these as the best equipment in the world will not function correctly at the required uncertainties if these are not correctly maintained.

Environmental control is not difficult if it is correctly planned and installed but is a nightmare to fix if you try to patch it up after the main installation is complete. Most of the laboratories will require a temperature control of 23 °C ± 2 °C for high level work and ± 5 °C for general purpose work. Traditionally, the dimensional laboratories have worked at 20 °C and sometimes require a tighter spec of ± 1 °C. It is, however, better to have a good stable temperature than the ideal set point. What is of equal importance is the temperature profile of the whole laboratory. The correct use of diffusers will spread the conditioned air evenly around the laboratory so that there are no direct draughts over any specific work space. Humidity control is of less importance but needs to be maintained at around 45% ± 10% RH.

Normally, environmental control requires two stages with an interlocked system to maintain these conditions well. The first stage is that the general building air conditioning provides a comfortable working environment, and the second is that the laboratory is controlled within that zone. This means that the laboratory conditioning unit only has to contend with the small variances of the building environmental system and not the full fluctuations of the external weather conditions. In this case it generally not necessary to have an airlock between the general building and the laboratory. The laboratory should also have a small amount of positive pressure (through a dust filter system) to keep the outside air and dust out of the laboratory.

Having the correct workspace makes the job much easier. Care must be given to having stable, non-static and deep work surfaces at a convenient level above the floor (this varies depending on the country and the average height of the staff). The metrologists will frequently need to stand and sit, so the right chairs or stools are also required. It is very useful to have the external work brought into the laboratory on a trolley that is at the same height as the work surface so that the work can be left on the trolley while being calibrated. This is obviously not possible in all cases but, where it is, it can save a great deal of time and physical effort.

The pre-calibration storage area needs to be at the same temperature as the laboratory and preferably have power available on the storage racks so that equipment due to be calibrated is allowed to soak at the laboratory temperature under power.

The electrical supply and lighting is frequently overlooked when establishing a laboratory. The lighting in the laboratory needs to be >500 Lux over the work surfaces and about 300 Lux in the storage areas. Some laboratories like to have a combination of fluorescent and incandescent lights so that, if they are doing an electrical noise sensitive measurement, they can turn off the fluorescent lights (they generate a great deal of electrical noise).

The power must be checked to ensure that all the plug points per workstation are fed from the same phase of the electrical supply. Various phases can cause earth loops, which will result in erratic readings and are difficult to find. The mains voltage should be at the normal supply level (e.g. 230 Vac) ± 10% and have sufficient power available to supply all the equipment without causing any voltage drops. Care must also be taken to keep items such as air conditioners and other heavy equipment on a different circuit from the laboratory equipment. It is also essential to test and confirm the earth bonding of the laboratory supply and, if it is not sufficient, then an additional "earth" system must be installed. This is particularly so in high-level electrical and temperature laboratories.

There are several books on the market which relate to all sorts of general laboratory requirements and procedures. It would be well worth the expense of getting some of these books before you finalise the plans for the laboratory. Two that are commonly used are a) Calibration: Philosophy in Practice - ISBN 0-9638650-0-5 b) The Metrology Handbook - ISBN 978-0-87389-620-7

So, the real industry requirements need to be established in each discipline of metrology and then people, equipment and facilities chosen that can cater appropriately to industry. As the industry grows in competence, the national laboratory may need to upgrade its facilities to cater for the new demands, but this is generally not an overnight requirement. The most important issue is that the national laboratory is capable of producing traceable calibration with competence and efficiency at the level required by its market. Establishing a national facility with the highest level of accuracy and then being unable to calibrate basic products will mean that industry will lose faith in the national laboratory and seek traceable calibrations from another source.

1. **Mass Metrology**
2. **Volume Metrology**
3. **Pressure Metrology**
4. **Length & Dimensional Metrology**
5. **Thermometry**
6. **Definitions of the frequently used Metrology Terms**
7. **Accommodation and environmental conditions**
8. **Calibration procedure for calibration of External micrometer**
9. **Metrology Lab Layout**
10. **ElectricalMetrology**

1.Mass Metrology

1. Introduction
2. Definition
3. Scope
4. Equipment Required
5. Environmental conditions in the laboratory
6. Manpower required
7. Space required

1. Introduction

Mass is one of the most important quantities of the physico-mechanical system. The concept of mass constitutes a universal characteristic of bodies. Newton described mass as a physical quantity that could be determined in relationship with other physical quantities. Experimentally, it was found that if the same force was applied to different bodies, they showed different acceleration directly proportional to their mass. As a result, we see traceablity related to mass in the fields of force and pressure as well.

Mass is a key measurement in the world of trade, so much so that there is an organization known as OIML, the International Organisation of Legal Metrology, which is focusesd on lLegal mMetrology, or that metrology which effects the daily trade of goods. Obviously this also applies to the trade between Countriescountries, and as a result, the OIML hasve been party to defining certain regulations and guidelines related to mass standards and measurements. The most important for the mass industry is the R 111, which is available from the OIML.

2. Definition

Mass is defined as the mass of the iInternational pPrototype of the kilogram kept under the custody of the International Bureau of Weights & Measures (BIPM) at Paris in France. It is a right circular cylinder of height 39 mm and equal diameter. It is made of single-phase alloy of platinum-iridium with 10% iridium by weight. Currently the prototype kilogram is the last remaining artifact that forms part of the SI units. Work is currently underway to redefine the kilogram in terms of an invariant of nature. Till then, many cCountries have copies of the prototype that are regularly inter-compared with the standard artifact at the BIPM. The SI unit of mass is known as the kilogram (kg).

3. Scope

This document covers the establishment of a mass metrology laboratory for calibration of weights generally required by Industrial level laboratories and the industry.

Classes of Weights:

The OIML has defined certain classes of weights and given a brief description of each. In summary, they are the following
Class E1 - Inter-comparison between international mass standards & calibration of class E2 weights.
Class E2 - Typical laboratory standards to be used to calibrate class F1 weights
Class F1 - Used to calibrate class F2 weights & class 1 accuracy instruments
Class F2 - Used to calibrate class M1 & M2 weights & class 2 accuracy instruments
Class M1 - General work with class 2 accuracy weighing instruments
Class M2 - General work with class 3 accuracy weighing instruments
Class M3 - General work with class 3 & 4 accuracy weighing instruments

Range of weights: 5000 kg to 1 mg.

4. Equipment Required
4.a. Balances and Mass Comparators

Mass comparators and balances are used to inter-compare the various levels of mass pieces and so the traceablity chain is maintained. Lower accuracy devices are typically referred to as weighing instruments, and these range from tiny scales right through to heavy vehicle weigh bridges. The laboratory needs to select the correct instruments to calibrate the requirements from industry and then the class of mass pieces chosen to be the laboratory standards. They need to be at least one class above the industry requirements.

Sl. No.	**Capacity**	**Readability**	**Range**
1.	5000 kg	10 g	5000, 2000, 1000 kg
2.	500 kg	0.1 g	500, 200, 100 kg
3.	50 kg	2 mg	50, 20 10, 5 kg
4.	10 kg	0.1 mg	10, 5, 2 kg
5.	1 kg	0.001 mg	1000, 500, 200, 100, 50 g
6.	20 g	0.001 mg	20, 10, 5 g
7.	2 g	0.0001 mg	2g to 1 mg

4.b. Standard weights required

Normally all weights are made in compliance with the OIML International Recommendation R111, which prescribes constructional requirements and specified materials, tolerances, surface conditions, density and markings. The highest precision weights, Classes E1 and E2, are solid stainless steel, with a prescribed density. These have no weight markings as the marking would itself attract dirt. Lower grade weights are usually adjustable and may be of materials other than stainless steel, including chrome-plated brass, brass or painted cast iron. Except for the lowest grade of weights, stainless steel is the preferred material because of its several advantages as given below:-

(i) Stability
(ii) Ability to be polished during manufacture
(iii) Density

Smaller weights may be of stainless steel, germanium, nickel, silver or aluminium. Because of its density and softness, aluminium is only used for weights up to 10 mg. In an ideal case a calibration laboratory should have a minimum of two sets of standards, to ensure that there is no dependence on a single standard weight whose value may change between calibrations without the knowledge of the laboratory.

For higher accuracy work, a simple one-to-one calibration is sufficient, with calibration in groups using a restraint or check standard (usually 1, 10 or 100 level). When a large number of low accuracy weights are calibrated, it may be necessary to have other low grade weights to avoid wear on the laboratory's main standards

Sl. No.	**Range**	**No. of sets/weights**
1.	1 mg to 20 kg	2 sets
2.	20 kg	20 weights
3.	50 kg	10 weights
4.	500 kg	2 weights

4.c. Tolerance limits

Maximum possible errors on verification for conventional measures

Maximum permissible errors for weights (± dm in mg)

NominalValue	**ClassE1**	**ClassE2**	**ClassF1**	**ClassF2**	**ClassM1**	**ClassM1-2**	**ClassM2**	**ClassM2-3**	**ClassM3**
5 000 kg			25 000	80 000	250 000	500 000	800 000	1 600 000	2 500 000
2 000 kg			10 000	30 000	100 000	200 000	300 000	600 000	1 000 000
1 000 kg		1 600	5 000	16 000	50 000	100 000	160 000	300 000	500 000
500 kg		800	2 500	8 000	25 000	50 000	80 000	160 000	250 000
200 kg		300	1 000	3 000	10 000	20 000	30 000	60 000	100 000
100 kg		160	500	1 600	5 000	10 000	16 000	30 000	50 000
50 kg	25	80	250	800	2 500	5 000	8 000	16 000	25 000
20 kg	10	30	100	300	1 000		3 000		10 000
10 kg	5.0	16	50	160	500		1 600		5 000
5 kg	2.5	8.0	25	80	250		800		2 500
2 kg	1.0	3.0	10	30	100		300		1 000
1 kg	0.5	1.6	5.0	16	50		160		500
500 g	0.25	0.8	2.5	8.0	25		80		250
200 g	250	0.3	1.0	3.0	10		30		100
100 g	0.05	0.16	0.5	1.6	5.0	&bsp;	16		50
50 g	0.03	0.10	0.3	1.0	3.0		10		30

20 g	0.025	0.08	0.25	0.8	2.5		8.0		25
10 g	0.020	0.06	0.20	0.6	2.0		6.0		20
5 g	0.016	0.05	0.16	0.5	1.6		5.0		16
2 g	0.012	0.04	0.12	0.4	1.2		4.0		12
1 g	0.010	0.03	0.10	0.3	1.0		3.0		10
500 mg	0.008	0.025	0.08	0.25	0.8		2.5		
200 mg	0.006	0.020	0.06	0.20	0.6		2.0		
100 mg	0.005	0.016	0.05	0.16	0.5		1.6		
50 mg	0.004	0.012	0.04	0.12	0.4				
20 mg	0.003	0.010	0.03	0.10	0.3				
10 mg	0.003	0.008	0.025	0.08	0.25				
5 mg	0.003	0.006	0.20	0.06	0.20				
2 mg	0.003	0.006	0.20	0.06	0.20				
1 mg	0.003	0.006	0.20	0.06	0.20				

The nominal weight values in the table specify the smallest and largest weight permitted in any class of R 111 and the maximum permissible errors and denominations shall not be extrapolated to higher or lower values. For example, the smallest nominal value for a weight in class M2 is 100 mg while the largest is 5 000 kg. A 50 mg weight would not be accepted as an R 111 class M2 weight and instead should meet class M1 maximum permissible errors and other requirements (e.g. shape or markings) for that class of weight. Otherwise the weight cannot be described as complying with R 111.

5.a. Environmental conditions in the laboratory

Level of Calibration	**Temperature**	**Relative humidity**	**Air Pressure**
Class E1 and E2	(20 to 25)°C at a set point ± 1 °C maximum rate of change of temperature: 0.5 °C/hour	40 to 60% ± 5% per 4 hour	10 Pa
Class F1 and f2	(20 to 25)°C at a set point ± 2 °C maximum rate of change of temperature: 1.0 °C/hour	40 to 60% ± 10% per 4 hour	10 Pa
Class M1, M2, M3	(18 to 27)°C maximum rate of change of temperature 2.0°C/hour	40 to 60% ± 15% per hour	Normal atmospheric pressure

5.b. The instruments required to measure the barometric air pressure, air temperature and relative humidity

Level of calibration	**Barometric pressure**	**Temperature device**	**RH**
Class E1 and E2	± 65 Pa (± 0.5 mmHg)	± 0.1 °C	± 5 %
Class F1 and F2	± 135 Pa (± 1.0 mmHg)	± 0.5 °CC	± 10 %
Class M1, M2, M3	The laborator y maintains documented uncertainty measurements results		

6. Manpower required

Metrologist/ Head	:	M Sc/ BE/ B Tech degree in Physics or in any branch of Engineering	ONE
Technical officer	:	Diploma in Mechanical/ Instrumentation engineering	TWO
Technician	:	ITI	ONE

7. Space required

The approximate area of about 90 sq meters may be adequate for housing the mass and volume metrology laboratory

2.Volume Metrology

1. Introduction
2. Scope
3. Equipment required
4. Environmental conditions in the laboratory
5. Man power

1. Introduction

Volumetric measurements are obtained from mass measurement of known density materials. The volume calibrations are either by a gravimetric method (weighing procedure) or by a volume transfer (comparative) method. For precise determination of the capacity of volumetric measures, the gravimetric method is used. In this method the capacity is determined by weighing the volume of distilled water that the vessel contains. We already know from mass metrology that, as the measurements are made in air, corrections will need to be made for air buoyancy, etc. In addition, the effects of temperature, local gravity and atmospheric pressure will also need to be applied.

The uncertainty of measurement will vary depending upon the balance used, the purity of the water, the ability to make accurate temperature measurements, the nominal value of the volume standard being calibrated/tested and the ability to make adequately accurate mass measurements.

There is a good book that covers in detail the various aspects of volume and capacity measurements, titled - Comprehensive Volume and Capacity Measurements - ISBN 81-224-1819-8, 9788122418194.

2. Scope

Facility for volume measurements and calibration of metallic measures .

Range:	2000 litre (l) to 10 millilitre (ml)
	2 litre (l) to 1 millilitre (ml)

3.Equipment required

For volume measurements by the gravimetric method, standard weights and balances are needed. The working standard weights, balances and mass comparators from a standard mass metrology laboratory are typically used until such time as the workload requires a separate set just for this purpose.

4. Environmental conditions in the laboratory

The environmental conditions required in the volume metrology laboratory will also be the same as suggested for the mass metrology laboratory.

5. Man power

Initially the manpower deployed for mass metrology may also be sufficient for organizing the calibration of volume measures.

3.Pressure Metrology

1. Preamble
2. Pressure standards requirement
3. Scope
4. Items which can be calibrated
5. Instruments required for the laboratory
6. Space required
7. Environmental conditions required
8. Man power required

1. Preamble

In view of globalization and international competitiveness in trade and commerce and the introduction of ISO 9000, the quality of products and services has emerged as the forerunner of all activities in industries. Measurement and calibration play an important role in fulfilling the requirements of industries to produce quality products. Measurement is the technical basis for development of the economy and trade. Uniform and internationally compatible measurements are beneficial in eliminating technical barriers to trade and promoting international cooperation.The validity of precise and accurate pressure measurements is essential in trade, efficiency, quality and safety. The role of pressure measurements is now well established in many industries. These applications are found in industries as diverse as nuclear, power, gas, fertilizer, pesticide, chemical, petrochemical, biological, hot and cold forging of steel, pharmaceutical and drugs, synthesis of super hard materials like diamond, optimization of domestic appliances like pressure cookers and filling cooking gas cylinders, assessment of health like blood pressure monitors, optical, aerospatial, defense, meteorological, automotive, semiconductor, environmental, ventilation, filtration and process control in general.The introduction of quality systems stipulates that all the critical instruments and apparatus being employed for calibration and testing activities should be periodically checked, calibrated and inter-compared against each other to establish and build up mutual confidence and to estimate the uncertainty associated with the measurements. In order to achieve the goals defined above, the new industrial pressure calibration laboratory should be established, keeping in view the following technical requirements.

2. Pressure standards requirement

Most of the industrial pressure calibration requirements are up to 200MPa in the hydraulic pressure region and up to 10MPA in the pneumatic pressure region. In the first phase, a calibration laboratory may be established at up to 140MPa, the most critical range, in the hydraulic, and 10MPa in the pneumatic range . The hydraulic range may be further extended up to 200MPa in the second phase. The national metrology laboratory should be equipped with primary pressure standards. However, the laboratory can be established using high precision dead weight secondary pressure balances in the first phase and the controlled clearance type pressure balances in the second phase. The following instruments are proposed to be procured as laboratory standards.

3. Scope

The proposal covers the measurement of pressure and calibration of pressure measuring devices.

Sl. No.	**Item**	**Range**	**Measurement uncertainty**
1	Absolute pressure	1 kPa to 1 MPa	±0.01%
2	Gauge pressure - gas	-100 kPa to 10 MPa	±0.01%
3	Gauge pressure - oil	-1 kPa to 140 MPa	±0.01%

4. Items which can be calibrated

Sl. No.	**Item**
Range	**Accuracy**
1.	Dead weight tester
140 MPa ± 80 ppm	± 0.1%
2.	Bourden gauges (pressure dial gauges)
upto 140 Mpa	± 0.1%
3.	Pressure transducers
upto 140 MPa	± 0.1%
4.	Pressure transducers
upto 140 MPa	± 0.1%
5.	U-tube manometers
upto 130 kPa	± 0.2%
6.	Blood pressure instruments
0 to 50 kPa	± 0.2%
7.	Capacitance diaphragm gauges
upto 1 MPa	± 0.2%

5. Instruments required for the laboratory

a. Primary standard (National Standard)

Sl. No.	**Item**
Range	**Measurement uncertainty**
1.	Simple re-entrant type hydraulic dead weight pressure balance
140 MPa	80 ppm (k=1)
2.	Simple re-entrant type pneumatic dead weight pressure balance
10 MPa	80 ppm (k=1)
3.	Hydraulic digital pressure clibrator
140 MPa	100 ppm (k=1)

4.	Pneumatic digital pressure clibrator
10 MPa	100 ppm (k=1)

b. Accessories

Sl. No.	**Item**
Quantity	
1.	Office tables (1800*1200) mm
3	
2.	Office chairs
10	
3.	Working tables (2400*1200) mm with non magnetic stainless steel top for isolation of vibrations
3	
4.	Computer table 1500*1000) mm
1	
5.	Office almirah standard size
2	
6.	Books self
2	
7.	Computer with printer and peripherals (latest)
1 set	
8.	Hydraulic screw pump (capacity 2500 bar or more)
2	
9.	Constant volume valve (CVV) for cross floating of pressure balances
1	
10.	Pressure dial gauges (upto 2500 bar) working pressure gauges
4	
11.	High pressure tubing (capacity 2500bar)
50m	
12.	Tube fittings (Cross, elbow, tee, union reducers)
3 each	
13.	One way needle valve
4	
14.	Two ways needle valve
4	
15.	Color, gland nuts, dummy plugs
50 each	
16.	Adopters (different sizes)
2 sets	
17.	Pneumatic pressure controller
1	
18.	Nitrogen gas cylinders
2	
19.	Pressure regulators and filters
2 each	
20.	Copper tubing

50m	
21.	Pressure transmitting fluid (preferably sebacate oil)
25 liters	
22.	Digital barometer
1	
23.	Digital humidity measuring device
1	
24.	Digital temperature measuring device
1	
25.	6-1/2 digit multimeter
2	
26.	DC power supply (0-30 V)
27.	On-line UPS (1 kVA), 48 V
28.	Glass thermometers
2	
29.	Threading tools, conning tools, spanner set, copper tube cutter, cleaning agents such as methyl alcohol, ethyl alcohol, acetone, cotton, cotton clothes, lens, tissue papers, ordinary tissue papers etc.
As per requirements	
30.	Temperature indicators with data logger, recorder etc.
3	

Procurement of these instruments would enable the pressure calibration laboratory to provide the industries of the country with national traceability and apex level pressure calibration in the specified pressure range and also to take part in the future international/ national and bilateral inter-comparisons.

New Technology

It should also be noted that there are some modern pressure controllers/calibrators available for both hydraulic and pneumatic systems. These controllers allow the operator to "dial up" the pressure required through an electronic controller and display unit. This makes day-to-day calibrations much simpler at accuracies very similar or better than the traditional working standards.

6. Space required

The approximate space or area required for the pressure calibration laboratory is estimated to be about 90 sq meters, including laboratory space, storage and handling of instruments received for calibration, and office space.

7. Environmental conditions required

The room temperature and humidity in the calibration laboratory should be controlled within 23 ± 2° C and relative humidity within 50 ± 10 %, using air conditioners and de/humidifiers. The barometric pressure in the laboratory should be recorded. The value of local acceleration due to gravity (g) local should be measured/ known to the best possible measurement uncertainty.

8. Man power required

Man power:

The laboratory requires adequate managerial and technical personnel and resources to maintain and upgrade national standards and provide calibration services to industry. All the personnel involved in the calibration and testing work should be professionally qualified and trained and experienced in the use and application of the instruments and standards and the latest technology and measurement techniques in pressure metrology. They should also be trained in evaluating the errors and measurement uncertainty. The suggested qualifications are given below:

Metrologist/ Head	:	M Sc/ BE/ B Tech degree in Physics or in any branchofEngineering	ONE
Technical officer	:	Diploma in Mechanical/ Instrumentation engineering	TWO
Technician	:	B Sc with some experience in measurement and calibration	ONE

4.Length & Dimensional Metrology

1. Preamble
2. Instruments and artifacts required to be calibrated
3. Instruments/Artifacts recommended for Length laboratory
4. Space required
5. Manpower required

1. Preamble

In the Introduction to Metrology section we made reference to the development of the unit of length, the metre, and of the massive advances required by industry, especially because of International trade and the sub-contracting of manufacturing and assembly. Dimensional metrology has become critical to the success of these processes and continues to drive the uncertainties lower and lower.

The current standard for length is based on the speed of light. By using frequency stabilized lasers, a system of traceable length measurements has been developed. The instruments are known as laser interferometers. There are various grades of interferometers, with the highest being used in national research institutes, and many others down the accuracy scale. There are also three-dimensional machines known as coordinate measuring machines (CMMs).

However, the bulk of length and dimensional measurements are done using a vernier caliper and/or a micrometer. Laboratory-type vernier calipers incorporate a main scale and a sliding vernier scale which allow readings to the nearest 0.02 mm. This type of vernier can be used to measure outer dimensions of objects using the main jaws, and the inside dimensions using the smaller inverted jaws, and depth by using the stem.

The micrometer uses a screw gauge principle and is used to measure smaller dimensions than the vernier calipers. They also have two scales and are able to measure to a resolution of 0.001 mm. Both verniers and micrometers need special care when using them in high precision applications, as it is easy to make mistakes.

Verniers and micrometers are calibrated using gauge (sometimes referred to as gage) blocks and ring gauges, which, in turn, are calibrated by interferometers. There are many other instruments involved in dimensional metrology (analogue and digital) all working on basically the same systems but measuring other things, such as angle, screw threads etc.

Critical to dimensional metrology is an absolutely flat surface to work on, as close to zero vibration as possible and good temperature control. As usual, procedures play an important part, as it is easy for two metrologists to get two different results even when using the same equipment.

2. Instruments and artifacts required to be calibrated

Sl. No.	Item	Range (mm)	Uncertainty/Accuracy/ Resolution (mm)
1.	External micrometers	0-25 25-50 50-75 75-100 100-400 in steps of 25 mm	0.001/0.01 0.001/0.01 0.001/0.01 0.001/0.01 0.001/0.01
2.	Vernier caliper, vernier depth gauges, digital vernier caliper, digimatic vernier caliper	0-600 mm 150, 200, 300, 600 mm Least count:	0.01 mm/ 0.02 mm
3.	Dial Gauges (plunger type, Lever type)	0-2 mm 0-10 mm 0-25 mm ±100 µm ±50 µm	0.001 mm, 0.01 mm, 0.0002 mm
4.	Gauge blocks (End standards)	All setsM10 to M125	Grade '0', I, and II
5.	Long gauge blocks (Length bars)	125 mm to 1000 mm in steps of 25 mm	Grade '0', I, and II
6.	(a) Angle gauges and (b) Polygons	3` to 90 µ 6, 8, 12 and 72 face	±1 sec to ±3 sec
7.	Line standards (a) Steel scale (b) Glass scales (c) Glass graticules (d) Tape measures (e) Standard metre bars	 0-1000 mm 0-300 mm 0-10 mm 0-50 m 1 m	 ±0.050 mm 0.01 mm 0.003 mm 0.100 mm 0.010 mm/ 0.005 mm

8.	Precision Levels	All ranges	Sensitivity: 0.2 " to 2 "
9.	Surface Roughness	Ra, Rmax, Rz, Rt	±5%
10.	Roundness	200 mm diameter component	±0.05 μm, 0.1 μm
11.	Length & dimensional measuring instruments (a) Dial gauge tester (b) Caliper checker (c) Height gauge (d) Auto-collimator (e) Sine Bar (f) Sine Centre (g) NC/CNC machines (h) Length measuring machines (i) CMMs		

3. Instruments/Artifacts recommended for Length laboratory

Sl. No.	Name of the measuring instrument	Quantity	Priority
1.	Long Gauge Blocks (steel) Range: 125-1000 mm Calibration grade as per ISO 3650	1 Set (125, 150, 200, 250, 300, 400, 500, 600, 800 and 1000 mm)	I
2.	Gauge Blocks Set	M122 (Set of 122	I

	(steel) Grade 'K' or 'OO' as per ISO 3650	pieces)	
3.	Mike Check Set Steel/ WC2 Grade 'O'	M10 (1 Set) (2.5, 5.1, 9.7, 10.3, 12.9, 15, 17.6, 20, 22.8 and 25 mm)	I
4.	Monochromatic Light Unit 200 mm diameter surface plate with spare lamp (sodium)	1 Set Complete	I
5.	Dial Gauge Tester (a) Range : 0-25 mm Least count : 0.001 mm Accuracy : ?0.001 mm (b) Range : 0-5 mm Least count : 0.0002 mm Accuracy : ?0.2 ?m	1 Set	I
6.	Computerized Gauge Block Comparator Model: 826 E Make: Mahr or equivalent Measuring Range : 0-175/250 mm Range of Scale : 2000 Âµm x 1.0 µm 200 Âµm x 0.1µm 20 Âµm x 0.01µm	1 Set Complete with temperature sensor, accessories, shield etc.	I
7.	Mike Check Gauge Block set holder	1	I
8.	Optical Parallels 12.00, 12.12, 12.25, 12.37 mm diameter	1 set	I
9.	Optical Flats	1 set	I
10	Check Master Range : 0-1000 mm 10 mm blocks Block pitch : 20 mm Accuracy of block pitch : ± 0.0012 mm Parallelism of block	1 Set	I

	pitch : 0.001 mm		
11.	Caliper Checker Range : 0-600 mm Accuracy of block pitch : ±0.005 mm Parallelism of block pitch : 0.005 mm	1 Set	I
12	Digital Micro Height Gauge with facility of squareness measurement Range : 0-600 mm / 0-900 mm / 0-1000 mm Resolution : 0.0005 mm	1	I
13.	Comparator Stand - Chrome plated column - Column with 8mm diameter clamping device DIN 876 T, grade 'OO'	1	I
14.	Slip Gauge Accessories 0-300 mm/0-600 mm	1 Set	I
15.	Surface Roughness measuring instrument with (i) Roughness standard (ii)Groove depth standard Model: S8P Make: Perthen or equivalent Capable to measure all parameters as per IS/ISO/DIN/JIS	1 Complete	I
16.	Angle Gauge Blocks (steel) 9 x 50 mm measuring face Accuracy : ±1 sec of arc or better	1 Set of 13 pcs and a square block and straight edge	II

17.	Auto-Collimator Model: Elcomet : 2000 Resolution: 0.05"	1 Set	II
18	Optical Computerized Moore Index Table 0-360° with stand and accessories Accuracy : 0.1/0.05"	1 Complete	II
19.	12 face Polygon Steel/Glass	1 Set	III
20.	Laser Interferometer with -Linear optics -Angular optics -Flatness optics -Squareness optics	1 Set complete (material temperature sensor, air sensor)	II
21	Sine table 500 mm Lifting resolution equivalent to 0.1 sec	1	II
22.	Electronic Level Range: ±2000 counts ±200 counts Sensitivity : 1 sec per m (5 counts) 0.2 sec per m (1 count) Base length : 150 mm/100 mm	1 Set	II
23.	Roundness Measuring Instrument Mahr MMQ40/ or equivalent/or latest	1 Set	III
24.	Horizontal Metroscope Measuring Range: 0-1000 mm Resolution: 0.2 Âµm with facility for inside and external measurements, screw thread measurements	1 set complete	II
25.	Accessories	3 nos.	

	(i) Granite Surface Plate 1000 x 1000 mm Grade 1 (ii) Aids like V Blocks, Magnifying glass, Clamps, Level, Scale, Vernier caliper, Dial gauge etc.		

4. Space required

The size of the laboratory will vary greatly, depending on the amount of work that it is required to do and how many workstations it has. It is likely to vary from 45 m2 up to 90 m2

5. Manpower required

Metrologist/ Head	:	M Sc/ BE/ B Tech degree in Physics or in any branch of Engineering	ONE
Technical officer	:	Diploma in Mechanical/ Instrumentation engineering	THREE
Technician	:	B Sc with some experience in measurement and calibration	ONE

Please refer to the Introduction to the metrology section for more information

5.Thermometry

1. Preamble
2. Scope
3. User Industries requiring calibration of temperature measuring devices

1. Preamble

Temperature is the state, which determines the direction of flow of heat from one body to another. In other words temperature is the measure of hotness or coldness of a given body and the thermometer is the device to measure this. Temperature is not directly measurable by comparison with a standard, as in the case of length or mass. We can infer the temperature of a body by measuring
(i) length of mercury column in a capillary tube
(ii) the electric resistance of a platinium wire
(iii) the pressure of an ideal or non-ideal gas
(iv) the equilibrium pressure of a gas above a boiling liquid
(v) the thermoelectric emf between the dissimilar metals
(vi) the speed of a sound in a gas and
(vii) the magnetic susceptibility of a paramagnetic salt
The International Temperature Scale ITS-90 is the reference scale for the range of temperature. The practical implementation of ITS-90 requires the ability to transfer the scale from standard instruments to other secondary instruments either by comparison calibration or by using fixed points.

2. Scope

Temperature measurement and calibration of temperature measuring devices/instruments in the over all range of –50 °C to 1200 °C

2.1 Liquid filled glass thermometry:

Range : -50 °C to 300 °C

2.2 Thermocouple thermometry

Range: 0 °C to 1200 °C
Accuracy: ±0.5 ºC to 1 ºC

2.1. Liquid filled glass thermometry:

2.1(a). Items which need to be calibrated for most industrial needs, their range and accuracy of temperature measurement:

Sl. No.	**Item**	**Range (mm)**	**Accuracy**

1.	Liquid-in-glass thermometer	-50 °C to 300 °C	± 5 °C to 1 °C
(i)	Industrial (Hg) mercury and Alcohol glass thermometers		
(ii)	Low range thermocouples		
(iii)	Digital thermometers with thermocouple sensors or RTD	-50 °C to 1200 °C	
(iv)	Dial gauge (analogue) thermometers with bi-metal sensors	--50 °C to 300 °C	
(v)	Liquid calibration bath	--50 °C to 300 °C	
2.	Thermocouples R, S and K type	-50 °C to 1600 °C	
(i)	Type S & R thermocouples	-0 – 1600 °C	± 1 °C to 3 °C (Pt/Pt 50% Rh and
(ii)	Type K thermocouples	-0 – 1200 °C	Cr, Al alloys
3.	T, C Indicators	-50 °C to 1200 °C	
4.	Resistance, Temperature devices RTDs	-50 °C to 600 °C	

2.2. Standards/Instruments required for laboratory:

2.2(a). Liquid filled glass thermometry:

(a) Standards:

Sl. No.	**Item**	**Range**	**Resolution**	**Quantity**	**Approximate cost (Rs. in lakh)**
1	Glass thermometers	--50°C to 20 °C	0.1 °C	1	0.02
2		0°C to 25°C	0.05 °C	1	0.05
3		25°C to 50°C	0.05 °C	1	0.05
4		50°C to 75 °C	0.05 °C	1	0.05
5		75°C to 100 °C	0.05 °C	1	0.05
6		100°C to 200 °C in span of 10°C	0.02 °C	1 0	0.50
7		100°C to 200 °C in span of 25°C	0.05 °C	4	0.12
8		200°C to 300 °C in	0.1 °C	2	0.06

		span of 50°C			

(b) Constant Temperature Source:

Sl. No.	Item	Range (mm)	Stability	Approximate Cost (Rs. in lakh)
1	Ice point cell	0.000 °C	± 0.005 °C	0.10
2	Low Temperature bath	-50°C to 100°C	± 0.005 °C	6.00
3	Water bathl	20°C to 95°C	± 0.002 °C	6.50
4	Oil bathl	50°C to 300°C	± 0.005 °C	7.50
5	Fluidized bath	300°C to 600°C	± 0.10 °C	15.00
6	Dry Block calibrator	50°C to 600°C	± 0.10 °C	

(c) Medium for constant temperature source:

Sl. No.	Item	Range (mm)	Stability	Approximate Cost (Rs. in lakh)
1	Alcohol for low temperature bath	-80°C to 20°C	25 litres	0.20
2	Distilled water for water bath	-5°C to 95°C	25 litres	--
3	Silicon oil for Oil bath	-50°C to 300°C	25 litres	3.00
4	Aluminium Powder for fluidized bath	100°C to 600°C	20 kg	0.20

(d) Accessories required:

Sl. No.	Item	Quantity	Approximate Cost (Rs. in lakh)
1	Reading telescope for measurement in calibration of glass thermometers, magnification not lesser than 10 X	1	0.30
2	Exhaust Chimney	1 set	0.50
3	Cub boards, almirahs	as	0.20

		required	
4	Computer, printer, UPS and other peripherals	as required	1.00

(e) Manpower required:

Metrologist/ Head	:	M Sc/ BE/ B Tech degree in Physics or in any branch of Engineering	ONE
Technical officer	:	Diploma in Mechanical/ Instrumentation engineering	TWO
Technician	:	B Sc with some experience in measurement and calibration	ONE

2.2(b). Thermocouple thermometry:

2.2(b-1) Standards required:

Sl. No.	**Item**	**Range**	**Resolution**	**Quantity**	**ApproximateCost (Rs. in lakh)**
1	Type ‘S’ Thermocouple	0°C to 1200 °C	0.1 °C	1	2.50
2	Type ‘S’ Thermocouple	0°C to 1200 °C	0.1 °C	1	2.50

2.2(b-2) Constant temperature source and measuring device:

Sl. No.	**Item**	**Range**	**Resolution**	**Stability**	**ApproximateCost (Rs. in lakh)**
1	Ice Point cell	0.000 °C	--	±0.005 °C	0.10
2	Annealing Furnace	1200°C	--	±2 °C	10.00
3	High temperature tubular furnace	100°C to 1200°C	--	±0.5°C	16.00
4	61/2 Digit Voltmeter	0 to 50 mV	0.1 µV or 1 µV	±0.5°C	5.00

2.2(b-3) Accessories required:

Sl. No.	Item	Quantity	Approximate cost (Rs. in lakh)
1	High temperature insulating material (fiber fax or kawool)	1 kg	0.50
2	Exhaust chimney	1 set	
3	Almirah for storage	as required	0.20
4	Computer, printer, UPS and other peripherals	1 set	1.00

2.2(b-4) Manpower required:

Metrologist/ Head	:	M Sc/ BE/ B Tech degree in Physics or in any branch of Engineering	ONE
Technical officer	:	Diploma in Mechanical/ Instrumentation engineering	TWO
Technician	:	B Sc with some experience in measurement and calibration	ONE

3. User Industries requiring calibration of temperature measuring devices:

Petrochemicals and petroleum products
Oil refining
Plastics
Iron and Steel
Metallurgical related
Cement manufacturing
Food Research Institute
Automobile
Aerospace
Textile
Electrical and Electronics
Thermal power plants
Heavy and medium engineering
Medical laboratories and hospitals
Temperature instrument manufacturer
Oceanographic studies
Pollution boards
Fluid flow measurements
Defense laboratories

6.Definitions of the frequently used Metrology Terms

The BIPM Joint Committee for Guides in Metrology (JCGM) has the responsibility for the following two documents:

a) Guide to Expression of Uncertainty in Measurement (known as the GUM) and

b) International Vocabulary of Metrology - Basics and General Concepts and Associated Terms (known as the VIM)

The JCGM-WG1 has recently completed its first supplement to the GUM and a revised edition of the VIM, prepared by JCGM-WG2, are now both available on the BIPM website.

We recommend that readers use these two documents as the definitive source for uncertainty calculations and statements and for general metrology vocabulary.

The full copy of the GUM is available on the ISO website and a free copy of the VIM on the BIPM website.

The definitions below are an extract from the VIM and are placed here for convenience.

1. Quantity
2. Measurement unit, unit of measurement, unit
3. Base unit
4. Derived unit
5. International System of Units SI
6. Quantity value, value of a quantity, value
7. Measurement
8. Metrology
9. Measurand
10. Measurement method, Method of measurement
11. Measurement procedure
12. Reference measurement procedure
13. Measurement result, result of measurement
14. Measured quantity value, measured value of a quantity, measured value
15. True quantity value, true value of a quantity , true value
16. Conventional quantity value, conventional value of a quantity, conventional value
17. Measurement accuracy, accuracy of measurement, accuracy
18. Measurement trueness, trueness of measurement, trueness
19. Measurement precision, precision
20. Measurement error, error of measurement , error
21. Systematic measurement error, systematic error of measurement , systematic error
22. Measurement bias, bias

23. Random measurement error, random error of measurement , random error
24. Repeatability condition of measurement, repeatability condition
25. Measurement repeatability, repeatability
26. Reproducibility condition of measurement , reproducibility condition
27. Measurement reproducibility, reproducibility
28. Measurement uncertainty, uncertainty of measurement , uncertainty
29. Type A evaluation of measurement uncertainty, Type A evaluation
30. Type B evaluation of measurement uncertainty, Type B evaluation
31. Standard measurement uncertainty, standard uncertainty of measurement, standard uncertainty
32. Combined standard measurement uncertainty, combined standard uncertainty
33. Uncertainty budget
34. Expanded measurement uncertainty, expanded undertainty
35. Coverage factor
36. Calibration
37. Calibration hierarchy
38. Metrological traceability
39. Verification
40. Validation
41. Input quantity in a measurement model, input quantity
42. Output quantity in a measurement model, output quantity
43. Influence quantity
44. Correction
45. Measuring instrument
46. Measuring system
47. Indicating measuring instrument
48. Material measure
49. Measuring transducer
50. Sensor
51. Detector
52. Reference condition
53. Sensitivity
54. Discrimination threshold
55. Stability
56. Instrumental drift
57. Instrumental uncertainty
58. Maximum permissible error, limit of error
59. Measurement standard, etalon
60. Internal measurement standard
61. National measurement standard, national standard
62. Primary measurement standard, primary standard
63. Secondary measurement standard, secondary standard
64. Reference measurement standard, reference standard
65. Working measurement standard, working standard
66. Traveling measurement standard, traveling standard

1 Quantity
Property of a phenomenon , body, or substance, to which a number can be assigned with respect to a reference.

2 Measurement unit, unit of measurement, unit

It is a scalar quantity, defined and adopted by convention, with which any other quantity of the same kind can be compared to express the ratio of the two quantities as a number.

3 Base unit

Measurement unit that is adopted by convention for a base quantity.

4 Derived unit

Measurement unit for a derived quantity.
Examples
The metre per second , symbol m/s, and the centimeter per second, symbol cm/s, are derived units of speed in the SI. The kilometre per hour, symbol km/h, is a unit of speed outside the SI but accepted for use with the SI. The knot, equal to one nautical mile per hour, is a unit of speed outside the SI.

5 International System of Units SI

Coherent system of units based on the International System of Quantities, their names and symbols, and a series of prefixes and their names and symbols, together with rules for their use, adopted by the General Conference on Weights and Measures (CGPM). The SI is founded on the seven base quantities of the ISO and the base units contained in the following table.

Base Quantity	**Base unit**	
Name	**Name**	**Sumbol**
length	metre	m
mass	kilogram	kg
time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
luminous intensity	candela	cd

6 Quantity value, value of a quantity, value

Number and reference together expressing magnitude of a quantity Examples

a)	Length of given rod	5.34 m or 534 cm
b)	Mass of a given body	0.152 kg of 152 g
c)	Celcius temperature of a given sample	-5º C
d)	refractive index of given	1.32 sample of glass

7 Measurement

Process of experimentally obtaining one or more quantity that can reasonably be attributed to quantity
Measurement implies comparison of quantities or counting of entities
Measurement presupposes description of the quantity commensurate with the intended use of the measurement result, a measurement procedure, and a calibrated measuring system operating according to a specified measurement procedure.

8 Metrology

Field of knowledge concerned with measurement

9 Measurand

Quantity intended to be measured
The application of a measurand requires description of the state of the phenomenon, body, or substance carrying the quantity, including any relevant component and the chemical entities involved.

10 Measurement method, Method of measurement

Generic description of a logical organization of operations used in a measurement
measurement methods may be qualified in various ways such as:
a) substitution measurement method
b) differential measurement method, and
c) null measurement method
or
d) direct measurement method, and
e) indirect measurement method

11 Measurement procedure

Detailed description of a measurement according to one or more measurement principles and to a given measurement method, based on a measurement model and including any calculation to obtain a measurement result.
a) A measurement procedure is usually documented in sufficient detail to enable an operator to perform a measurement.
b) A measurement procedure can include a target measurement uncertainty.

c) A measurement procedure is sometimes called a standard operating procedure, abbreviated SOP.

12 Reference measurement procedure

Measurement procedure accepted as providing measurement results fit for their intended use in assessing measurement trueness quantity values obtained from other measurement procedure for quantities of the same kind, or in characterizing reference materials

13 Measurement result, result of measurement

Set of quantity values being attributed to a measurand together with any other available relevant information

a) A measurement generally provides information about the set of quantity values, such that some may be more representative of the measurand than others.This may be demonstrated in the form of a probability density function (PDF).

b) A measurement result is generally expressed as a single measured quantity value and a measurement uncertainty. If the measurement uncertainty is considered to be negligible for some purpose, the measurement result may be expressed as a single measured quantity value. In many fields this is the common way of expressing a measurement result.

14 Measured quantity value, measured value of a quantity, measured value

Quantity value representing a measurement result

15 True quantity value, true value of a quantity , true value

Quantity value consistent with the definition of a quantity

16 Conventional quantity value, conventional value of a quantity, conventional value

Quantity value attributed by agreement to a quantity for a given purpose

Examples

a) standard acceleration of free fall (formerly called standard acceleration due to gravity) is g= 9.80665 m s-2

b) the conventional quantity value of the Josephson constant, Kj-90=483597.9 GHz V-1

c) the conventional quantity value of a given mass standard, m=100.00347 g.

17 Measurement accuracy, accuracy of measurement, accuracy

Closeness of agreement between a measured quantity value and a true quantity value of the measurand

18 Measurement trueness, trueness of measurement, trueness

Closeness of agreement between the average of an infinite number of replicate measured quantity values and a reference quantity value

Notes

A reference quantity value can be a true quantity value of the measurand or an assigned quantity value of a measurement standard with negligible measurement uncertainty.

The term “measurement trueness” should not be used for ‘measurement accuracy’ and vice versa.

19 Measurement precision, precision

Closeness of agreement between indications obtained by replicate measurements on the same or similar objects under specified conditions

Notes

a) Measurement precision is usually expressed numerically by measures of imprecision, such as standard deviation, variance, or coefficient of variation under the specified conditions of measurement.
b) The specified conditions can be repeatability conditions of measurement, intermediate precision conditions of measurement, or reproducibilityconditions of measurement (see ISO 5725-5:1998).
c) Measurement precision is used to define measurement repeatability, intermediate measurement precision, and measurement reproducibility.
d) Sometimes “precision” is erroneously used to mean ‘measurement accuracy(b)’

20 Measurement error, error of measurement , error

Difference of measured quantity value and reference quantity value

- The sign of the difference must be noted
- Measurement error should not be confused with production error or mistake.

21 Systematic measurement error, systematic error of measurement , systematic error

Component of measurement error that in replicate measurements remains constant or varies in a predictable manner

22 Measurement bias, bias

Systematic measurement error or its estimate, with respect to a reference quantity value

23 Random measurement error, random error of measurement , random error

Component of measurement error that in replicate measurements varies in an unpredictable manner

24 Repeatability condition of measurement, repeatability condition

Condition of measurement in a set of conditions that includes the same measurement procedure, same operators, same measuring system, same operation conditions and same location, and replicate measurements on the same or similar objects over a short period of time

25 Measurement repeatability, repeatability

Measurement precision under a set of repeatability conditions of measurement

26 Reproducibility condition of measurement , reproducibility condition

Condition of measurement in a set of conditions that includes different locations, operators, measuring systems, and replicate measurements on the same or similar objects

27 Measurement reproducibility, reproducibility

Measurement precision under reproducibility conditions of measurement

28 Measurement uncertainty, uncertainty of measurement , uncertainty

Parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used.
Notes
Measurement uncertainty includes components arising from systematic effects, such as components associated with corrections and the assigned quantity values of measurement standards, as well as the definitional uncertainty. Sometimes known systematic effects are not corrected for but are instead treated as uncertainty components.
The parameter may be, for example, a standard deviation called standard measurement uncertainty (or a specified multiple of it), or half width of an interval, having a stated coverage probability.
Measurement uncertainty comprises, in general, many components. Some of these may be evaluated by Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from series of measurements and can be characterized by experimental standard deviations. The other components, which may be evaluated by Type B evaluation of measurement uncertainty, can also be characterized by standard deviations, evaluated from probability density functions based on experience or other information.

29 Type A evaluation of measurement uncertainty, Type A evaluation

Evaluation of a component of measurement uncertainty by a statistical analysis of quantity values obtained under defined measurement conditions

30 Type B evaluation of measurement uncertainty, Type B evaluation

Evaluation of a component of measurement uncertainty determined by means other than a Type A evaluation of measurement uncertainty
Example
Evaluation based on information
- associated with authoritative published quantity values
- associated with the quantity value of a certified reference material
- obtained from a calibration certificate and incorporation of drift
- obtained from the accuracy class of a verified measuring instrument
- obtained from limits deduced through personal experience

31 Standard measurement uncertainty, standard uncertainty of measurement, standard uncertainty

Measurement uncertainty expressed as a standard deviation

32 Combined standard measurement uncertainty, combined standard uncertainty

Standard measurement uncertainty that is obtained from the measurement results of the input quantities in measurement model

33 Uncertainty budget

Statement of a measurement uncertainty, of the components of that measurement uncertainty, and of their calculation and combination

34 Expanded measurement uncertainty, expanded undertainty

Product of a combined standard measurement uncertainty and a factor larger than the number one
Expanded measurement uncertainty is termed “overall uncertainty”
The term ‘factor’ in this definition refers to a coverage factor.

35 Coverage factor

Number larger than one by which a combined standard measurement uncertainty is multiplied to obtain an expanded measurement uncertainty

36 Calibration

Operation that, under specified conditions, in a first step establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

37 Calibration hierarchy

Sequence of calibrations from a stated reference to the final measuring instrument or measuring system, where the outcome of each calibration depends on the outcome of the previous calibration

38 Metrological traceability

Property of measurement result whereby the result can be related to a stated reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty

39 Verification

Provision of objective evidence that a given item fulfils specified requirements, taking any measurement uncertainty into consideration
Examples
Confirmation that a given reference material as claimed is homogeneous for the quantity and measurement procedure concerned , down to test portion having a mass of 10 mg
Confirmation that stated performance properties or legal requirements of a measuring system are achieved.

40 Validation

Verification, where the specified requirements are adequate for a stated use
Example
A measurement procedure, ordinarily used for the measurement of nitrogen concentration in water may be validated also for the measurement of nitrogen concentration in human serum.

41 Input quantity in a measurement model, input quantity

Quantity that must be measured, or a quantity, the value of which can be otherwise obtained in order to calculate a measured quantity value of a measurand
Example
When the length of a rod is being measured, temperature, length, and the linear thermal expansion coefficient of the rod are input quantities in a measurement model.

42 Output quantity in a measurement model, output quantity

Quantity, that the measured value of which is calculated using the values of input quantities in a measurement model

43 Influence quantity

Quantity that, in a direct measurement, does not affect the quantity that is actually measured, but affects the relation between the indication and the measurement result

44 Correction

Modification, applied to a measured quantity value, to compensate for a known systematic effect

45 Measuring instrument

Device used for making measurements, alone or in conjunction with supplementary device(s)
A measuring instrument alone may be considered to fbe ameasuring system
A measuring instrument may be an indicating measuring instrument or a material measure

46 Measuring system

Set of one or more measuring instruments and often other devices, including any reagent and supply, assembled and adapted to give measured quantity values within specified intervals for quantities of specified kinds (a measuring system may consist of only one measuring instrument)

47 Indicating measuring instrument

Measuring instrument providing an output signal carrying information about the value of the quantity being measured
For example
Ammeter, micrometer , thermometer, electronic balance

48 Material measure

Measuring instrument reproducing or supplying, in a permanent manner during the use, quantities of one or more given kinds, each with an assigned value (weight piece, volume measure, standard electric resistor, line scale, gauge block, standard signal generator)

49 Measuring transducer

Device, used in measurement, that provides an output quantity having a specified relation to the input quantity (thermocouple, current transformer, strain gauge, pH electrode, Bourden tube, bimetal strip)

50 Sensor

Element of a measuring system that is directly affected by the phenomenon, body, or substance carrying the quantity to be measured

Examples

a) Sensing coil of a platinum resistance thermometer
b) rotor of turbine flow meter
c) Bourden tube of a pressure gauge
d) Float of a level-measuring instrument
e) Photocell of a spectrometer
f) Thermotropic liquid crystal which changes color as a function of temperature

51 Detector

Device or substance that indicates the presence of a phenomenon, body, or substance when a threshold value of an associated quantity is exceeded

a) a halogen detector
b) a litmus paper

52 Reference condition

Performanceevaluation condition of use prescribed for evaluation the performance of a measuring instrument or measuring system or for comparison of measurement results

53 Sensitivity

Quotient of the change in the indication and the corresponding change in the value of the quantity being measured

54 Discrimination threshold

Largest change in the value of a quantity being measured that causes no detectable change in the corresponding indication

55 Stability

Ability of a measuring instrument or measuring system to maintain its metrological properties constant with time

56 Instrumental drift

Continuous change in an indication, related neither to a change in the quantity being measured nor to a change of any recognized influence quantity

57 Instrumental uncertainty

Component of measurement uncertainty arising from the measuring instrument of measuring system in use, and obtained by its calibration

58 Maximum permissible error, limit of error

Extreme value of the measurement error, with respect to a known reference quantity value, permitted by specifications or regulations for a given measurement, measuring instrument, or measuring system

59 Measurement standard, etalon

Realization of the definition of a given quantity, with stated quantity value and measurement uncertainty, used as a reference

Example

a) 1 kg mass standard
b) 100 ohm standard resistor
c) Cesium frequency standard
d) Reference material

60 Internal measurement standard

Measurement standard recognized by signatories to an international agreement and intended to serve worldwide

61 National measurement standard, national standard

Measurement standard recognized by national authority to serve in the country

62 Primary measurement standard, primary standard

Measurement standard whose quantity value and measurement uncertainty are established using a primary procedure

63 Secondary measurement standard, secondary standard

Measurement standard whose quantity value and measurement uncertainty are assigned though calibration with respect to a primary measurement standard for a quantity of the same kind

64 Reference measurement standard, reference standard

Measurement standard designated for the calibration of working measurement standards for quantities of a given kind in a given organization or at a given location

65 Working measurement standard, working standard

Measurement standard that is used routinely to calibrate or verify measuring instruments or measuring systems

66 Traveling measurement standard, traveling standard

Measurement standard , sometimes of special construction, intended for transport between different locations

7.Accommodation and environmental conditions

1. Laboratory rooms
2. Suggested environmental conditions
3. General Precautions
4. Electric Power and Compressed Air
5. Laboratory Accessories and Furniture

On the basis of the findings and suggestion to procure the various measuring instruments and standards for

Mass standards laboratory
Volume standards laboratory
Pressure standards laboratory
Length and Dimensional standards laboratory
Thermometry laboratory

1. Laboratory rooms

Emphasis is laid on the infrastructure such as appropriate accommodation and the measuring rooms in which the various laboratories are housed and the precision instruments will be installed and the standards artifacts are proposed to be stored. All the rooms must have controlled environmental conditions, such as given in the following table:

2. Suggested environmental conditions

Sl. No.	**Condition**	**Mass**	**Volume**	**Length**	**Pressure**	**Temperat-ure**
1	Temperature	23 ± 0.5	23 ± 0.5	23 ± 0.5	23 ± 0.5	23 ± 0.5
2	Max Temperature change	per day : 1°C per hour : 0.5°C	per day : 1°C per hour : 0.5°C	per day : 0.5°C per hour : 0.2°C	per day : 1°C per hour : 0.5°C	per day : 1°C per hour : 0.5°C
3	Temperature gradient	1°C	1°C	1°C	1°C	1°C
4	Uncertainty in measurement of temperature	± 0.1C	± 0.1C	± 0.1C	± 0.1C	± 0.1C
5	Permissible ground vibration	0.3 to 1.0 µm 0.0035 mm/s velocity over any 1	0.3 to 1.0 µm 0.0035 mm/s velocity over any 1	0.3 to 1.0 µm 0.0035 mm/s velocity over any 1	0.3 to 1.0 µm 0.0035 mm/s velocity over any 1	0.3 to 1.0 µm 0.0035 mm/s velocity over any 1

		hour0.0025 mm/s velocity over any 8 hour	hour0.0025 mm/s velocity over any 8 hour	hour0.0025 mm/s velocity over any 8 hour	hour0.0025 mm/s velocity over any 8 hour	hour0.0025 mm/s velocity over any 8 hour
6	Humidity	50 ± 5 %	50 ± 5 %	50 ± 5 %	50 ± 5 %	50 ± 5 %
7	Cleanliness	better than Class 100000	better than Class 100000	better than Class 100000	better than Class 100000	better than Class 100000
8	Differential air pressure	> 10 Pa	> 10 Pa	> 10 Pa	> 10 Pa	> 10 Pa
9	Air velocity	~ 0.2m/sec	~ 0.2m/sec	~ 0.2m/sec	~ 0.2m/sec	~ 0.2m/sec
10	Illumination	~ 400 lux (400 ± 50 lux	~ 400 lux (400 ± 50 lux	~ 400 lux (400 ± 50 lux	~ 400 lux (400 ± 50 lux	~ 400 lux (400 ± 50 lux
11	Noise level	< 45 dBA	< 45 dBA	< 45 dBA	< 45 dBA	< 45 dBA
12	Head rooml	3.5 to 4 m	3.5 to 4 m	3.5 to 4 m	3.5 to 4 m	3.5 to 4 m
13	Power supply	± 10% regulated	± 10% regulated	± 10% regulated	± 10% regulated	± 10% regulated
14	Frequency fluctuation	± 3%	± 3%	± 3%	± 3%	± 3%

3. General Precautions

Measures are needed for vibrational insulation and influences from temperature fluctuations. Separate air-conditioning system may be installed in all the measuring rooms. Alternately the location of the laboratories may be organized/restructured in such a way so that a composite air-conditioning system with separate Air Handling Units (AHUs) exhausting the air at different temperatures for the different parameters could be installed.
Additional insulation of the walls, roof and flooring of rooms is desired.
Shielding of the rooms against temperature radiation form the rooms walls, windows by means of an enclosure of the instruments, which could be made from simple insulating and transportable wall elements. This chamber simultaneous serves the purpose of shielding the instruments from direct air current when doors are open.
The air stream from the air-conditioning system may be directed from the ceiling to the floor (or as advised by air-conditioning expert)
Cold light sources with filters against thermal and infrared radiation may be used to minimize the heating by the luminaries.
Lights/luminaries may be located in the areas close to the outgoing air outlets.
All major instruments generating large heat may be equipped with the hot air exhaust pipe.

Lights in the measuring room should be just sufficient to provide prescribed illumination and should not be switched on and switched off in order to guarantee a maximum consistency of room's climate
Installation of easy to service dust filters in the air-conditioning system and generating of a slight over pressure in the measuring rooms is desirable
Automatic shoe cleaning machine, and using overshoes, and dust adhesive mats at the entry door may also be installed. Entry to the measuring rooms should be restricted.
Measuring rooms should have air-locks at the entry door
Preparation of job for calibration (measurement, e.g. dispatching, cleaning etc. should be done outside the measuring rooms/anterooms maintained at a reasonably comfort temperature (say 0 to +2°C over and above the temperature in the measuring room)

4. Electric Power and Compressed Air

Supply of electric power to measuring rooms and to the measuring instruments should be made through a separate feeder line and processing units, in order to avoid voltage drops and voltage surges. Additionally, a voltage conditioner/uninterrupted power supply system is recommended.
A separate air compressor with appropriate ratings and all the required accessories to separate, water, dust may be installed so that dry, clean and controlled pressure air can be supplied to the pneumatic systems of the instruments (if there are any in the measuring rooms). However a dedicated air supply line may be provided in each measuring rooms for air cleaning.

5. Laboratory Accessories and Furniture

Inventory Tables	:	1200 x 800 mm approx. (wooden iron) with granite stone and covered with PVC as per requirements
Data acquisition system	:	Latest model computer and printer for keeping records of inventory control, calibration certificates and other miscellaneous office jobs viz. challans, bills, accounting etc. as per requirements
IDigital indicating temperature and humidity recording system	:	For all labs
Consumables	:	Fibre free cleaning cloth Wooden tweezers

		Plastic/wooden trays Cleaning reagent like acetone benzene etc. for degreasing the instruments and standards before calibration Rust preventing wraping paper Silicon grease/petroleum jelly for coating the instruments and standards after calibration Cotton for pre-cleaning Oil and dust free air supply for pre-cleaning Dust free coats for personnel Hand gloves
Office furniture	:	As per requirements

8.Calibration procedure for calibration of External micrometer

1. Scope
2. Purpose
3. Calibration Procedure
4. Methodology
5. Staff Authorized to Perform Calibration
6. Location
7. Calibration Certificate
8. List of Supporting Documents

1. Scope

The calibration procedure is applicable to calibration of external micrometer 0-25 mm, 25-50 mm, 50-75 mm and 75-100 mm.

The Procedure is applicable to micrometers based on screw gauge principle for measurement of external dimensions of least count.

i) 10 µm		
a)	Linear scale 0.5 mm	(pitch of screw)
	Circular scale 10 µm	(50 div)
	Linear scale 0.5 mm	(pitch of screw)
	Digital display 10 µm	
ii) 2 µm		
a)	Linear scale 0.5 mm	(pitch of screw)
	Circular scale 2 µm	(250 div)
b)	Linear scale 0.5 mm	(pitch of screw)
	Digital display 2 µm	
iii) 1 µm		
a)	Linear scale 0.5 mm	(pitch of screw)
		Circular scale 10 µm (50 div)
	Vernier scale 1 µm	(10 div)

b)	Linear scale 0.5 mm	(pitch of screw)
	Digital display 1 µm	
iii) 2 µm		
a)	Linear scale 0.5 mm	(pitch of screw)
	Circular scale 2 µm	(250 div)
b)	Linear scale 0.5 mm	(pitch of screw)
	Digital display 2 µm	

2.Purpose

To ensure that the micrometer produces consistently repeated specific measurement results and associated measurement uncertainty.

3.Calibration Procedure

3.1 Principle

Accuracy is determined by comparison with calibrated slip gauges and wires. Flatness and parallelism of anvils is determined by calibrated optical flats (flatness l/10).

3.2 Following tests are recommended to be performed

Visual inspection
Ratchet functioning
Zero error
Repeatability
Flatness and parallelism of anvils
Accuracy of scale

After visual inspection the micrometer under calibration is clamped in micrometer clamping stand to prevent temperature changes on account of handling of micrometer during calibration.

The micrometer anvil, slip gauges (mike-check set), standard wires and optical flat are degreased, cleaned with benzene and lint free cloth and left on the surface plate for about two hours so that the temperature of all these is nearly the same.

3.3 Standards required

The measurement standards required for calibration of micrometer are given in table 1.

Table 1

Equipment/Standard	Specification
Calibrated Slip gauge set	a. Grade '1', tungsten carbide/Steel 122 pieces (M122)
	b. Mike Check set 10 pieces (M10)
Optical flat	Flatness λ/10
	Parallelism (λ/4)

3.4 Support Equipment

The support equipments required for calibration are given in table 2.

Table 2

Support equipment	Specification
Micrometer clamping stand	
Thermometer	10-30 °C Least count 0.1 °C or better
Granite surface plate (Grade-1)	Appropriate size
Cleaning Materials	Lint free cloth, white petrol/acetone

3.5 Environmental Conditions

The laboratory has a controlled/uncontrolled environment given below:

Temperature (controlled) : 20 ± 2 °C
Relative Humidity (uncontrolled) : 50 ± 10%

4. Methodology

4.1 Preliminary Operations

a) Physical condition of micrometer is visually examined for

Ratchet function
Zero error

(scratch marks, dents etc.)
Status of markings of linear and circular scales

Ratchet functioning is checked by moving the ratchet and seeing that it does so smoothly. Zero check is done by moving the movable anvil close to the fixed anvil in contact position and seeing that zero reading is correct or, if not so, zero error is noted (setting of zero is recommended).

b) Acceptability for calibration:

The micrometer having smooth wratchet function lapped & flat anvils, free of scratches, dents and chipped edges can be calibrated by this calibration procedure.
The micrometer with only slightly damaged anvils can also be calibrated.

In such cases (ii) The micrometer can be calibrated by using standard wires instead of slip gauges and optical flat.

c) Criteria for rejection

Any malfunctioning of wratchet and too much visual damage of anvils if any.

4.2 Measurement Procedure

After receiving the micrometer, clean it with benzene/methane or any other cleaning reagent which do not leave any residue. Keep the micrometer for temperature stabilization. Standard slip gauges and optical flat which are used for the calibration of micrometer are also cleaned and kept for temperature stabilization.

Following points are considered

Zero setting of the micrometer
Error in reading
Flatness of anvils
Parallelism between anvils
Error in scale

(a) Zero error

The zero error of micrometer is checked and if zero error is observed the same may be adjusted by adjusting the barrel to zero of the thimble if possible, zero error should be indicated in the calibration results and compensated for in the final report.

The error in scale is determined by measuring the slips of the following sizes: 2.5, 5.1, 7.7, 10.3, 12.9, 15.0, 20.0, 17.6, 20.2, 22.8 and 25 mm (IS 2967:1983)

(b) Flatness

The flatness error is checked by keeping the optical flat on each anvil under monochromatic light. A number of coloured interference fringes will be seen on their surfaces. The flat is adjusted in such a way so that minimum number of bands are obtained. For the specified tolerance on faltness, maximum four bands should be formed .Flatness is determined as n x l/2, where n is number of bands and l is the wavelength of the light used.

© Parallelism

Parallelism error between two anvils is tested by gripping optical parallels of three different thickness covering different positions of circular scale.
In each case the total number of fringes appearing on both anvils are counted together. Out of three cases, the parallelism assessment is done on the basis of maximum number of fringes.

The flat is placed between the measuring faces and adjusted in a way so that number of interference bands visible on one face are minimum. The number of bands on other face are counted which in general should not exceed 8, for 0-25 mm. The thickness of optical flats recommended are 12.5, 12.625, 12.750 and 12.875 mm.

Parallelism error between the anvils = N x $\lambda/2$

Where 'N' is the maximum number of fringes appearing on both anvils and λ is the wavelength of light used.

(d) The micrometer is mounted in the micrometer clamping stand.

(e) The temperature before starting the calibration is recorded on data sheet.

(f) The slip gauges are measured one by one in increasing order and then in the corresponding readings of micrometer (estimated to 1/5th division of circular scale are recorded on the data sheet. The same procedure is followed in the decreasing order and readings of micrometer are recorded on the data sheet. This forms one set of measurement. Two such sets of measurements are taken making total of four observations on each slip gauge.

(g) The temperature after completion of measurement is recorded.

4.3 Observations sheet

Description of instrument and work assignment
Name and address of customer
Letter number and date
File No. of case allotted
Purpose (i.e. calibration of micrometer at 20°C)
Standards and measuring equipment used
Date on which the calibration was commenced
Date on which the calibration was completed
Calibration Report No………

Date on which calibration report sent to dispatch section
Date of return of instrument to the concerned section/customer

4.4 Results with uncertainty

PRACTICAL EXAMPLE FOR CALIBRATION OF EXTERNAL MICROMETER and EVALUATIONMEASUREMENT UNCERTAINTY

DATA SHEET

Observations:

	Beginning	25.2 °C
1. Room temperature……………………………. ..	Mean	24.6 °C
	End	24.0 °C

2. Zero error………………………………………………………………..Nil
3. Optical flat……………………………………………. 1 fringe on each anvil.
4. Ten readings against 12.9 mm slip gauge

12.9004
12.9000
12.8998
12.8998
12.9000
12.9006
12.9000
12.9000
12.9002
12.9000

Note:-

Reading upto 4 decimal is observed by eye estimation.

5. Readings with 10 slip gauges of size as specified in IS:2967-1983 as indicated in table below are observed in increasing and decreasing order.

Nominal size of slip gauge (mm)	Reading of micrometer		Mean (mm)	Error (mm)
	Increasing order (mm)	Decreasing order (mm)		
2.5	2.5000	2.4992	2.4996	-0.4
5.1	5.1006	5.0998	5.1004	+0.4
7.7	7.7002	7.7006	7.7004	+0.4
10.3	10.2994	10.2994	10.2994	-0.6
12.9	12.8998	12.8990	12.8994	-0.6
15.0	15.0010	15.0004	15.0007	+0.7
17.6	17.6006	17.6008	17.6007	+0.7
20.2	20.1992	20.1990	20.1991	-0.9
22.8	22.8008	22.8008	22.8008	+0.8
25.0	25.0000	25.0004	25.0002	+0.2

7. Difference of temperature between micrometer and slip gauge on account

of handling: Say 2 °C (for example)

EVALUATION of MEASUREMENT UNCERTAINTY

4.4.1 Type A measurement uncertainty (UA)

(mm)			$\sigma = \sqrt{1/(n-1)\sum_{i=1}^{n}(x_i - \bar{x})^2}$ (μm)
12.9004	+0.3	0.09	
12.9000	-0.1	0.01	
12.8998	-0.3	0.09	
12.8998	-0.3	0.09	
12.9000	-0.1	0.01	
12.9006	+0.5	0.25	
12.9000	-0.1	0.01	
12.9000	-0.1	0.01	
12.9002	+0.1	0.01	
12.9000	-0.1	0.01	

Where = 12.9001

Type A Measurement Uncertainty UA

$$= \frac{\sigma}{\sqrt{n}}$$

$$= \frac{0.254}{\sqrt{10}}$$

$$Ua = 0.159$$

$$\approx 0.16\,\mu m$$

4.4.2 Type B Measurement Uncertainty UB

(i)Error due to deviation of mean calibration temperature from 20ºC on account of different coefficients of linear expansions (α) of slip gauges and micrometer for the entire range

(ii) Error due to variation in temperature (± 0.6 ºC) for the entire range

(iii) Error due to standard slip gauges

as reported in the calibration certificate of slip gauges

(iv) Error due to flatness and parallelism of anvils

(v)Error due to difference of temperature (2 ºC) between slip gauge and micrometer for the entire range,

Total Type B Uncertainty

$$= \sqrt{1/3\sum_{i=1}^{5} a_i^{\,2}}$$

$$= \sqrt{1/3(0.23^2 + 0.17^2 + 0.2^2 + 0.6^2 + 0.6^2)}$$

$$= 0.5297$$

$$= 0.53\,\mu m$$

Combined Uncertainty U

Expanded uncertainty at approximately 95% confidence level (k=2)

Results of calibration:

Maximum error in the entire range of micrometer

Uncertainty of measurement at 95% confidence level

4.5 Traceability

Slip gauges used for calibration of micrometer are traceable to National Standard

Mike check slip gauge set and optical flats are calibrated periodically. (Every two years) Against wavelength of light recommended for the realization of flatness parallelism and length of gauge blocks using interferometric method Or by comparison against interferometric calibrated slip gauges using gauge block comparator.

International traceability is ensured through participating in international intercomparison for measurement of slip gauges by interferometreic method.

4.6 Precautions

The micrometer and slip gauges and other aids should be thoroughly cleaned and wiped off with silk/linen cloth

The system should be thermally soaked for sufficient time to ensure equalization of temperature

Avoid rapid movement of wratchet while measuring the slip gauges

Slip gauges and optical flat should be handled carefully to avoid scratches on these

All the items should be stored properly after calibration.

The items should not be handled with bare hands.

5. Staff Authorized to Perform Calibration

As per authorization list

6. Location

The measurement set up is located in Room No. ………..

7. Calibration Certificate

As per document No…………

8. List of Supporting Documents

IS:2967-1983 or ISO…………or BS…………DIN……………JIS…………..

9.Metrology Lab Layout

The following links will provide the layout designs for a metrology lab,

Close Temperature Control Lab

Typical Metrology Lab Layout

10.ElectricalMetrology

Electrical Metrology (DCLF)

An electrical metrology is usually the first to be set up in a country. It is relatively simple to establish, and in general the demand from industry is relatively high. In addition, several other metrology disciplines require the backing of the electrical standards to derive their traceability, especially those organisations that will be sending their standards for calibration to the national laboratory·

This section has been limited to what is commonly known as DCLF, which stands for dc to low frequency (≤ = 1MHz) electrical metrology and excludes the more specialist and complicated sections that use higher frequencies·

Like several other disciplines in metrology, the pinnacle of the dc traceability chain is based on a physical phenomenon known as the Josephson Effect, which in turn is traceable to frequency. There are only a few Josephson junction systems operational in the world, and they are very costly to purchase and even more costly to run. The Josephson junction apparatus is typically only activated, by the few national research institutes that have them, a few times a year to transfer 10 Vdc (the characteristic voltage for most systems), to very stable, zener-based, reference sources.

In turn, the users then maintain a group of zener references and, by periodic inter-comparison of them, maintain their laboratory standard for dc voltage. Some laboratories prefer to use the absolute value of one of the zeners, while most use the mean value of the group of zeners. If a laboratory wants to improve its dc capability, it simply increases the number of zener references in the group·

To put this in perspective, the Josephson junction apparatus can deliver approximately 0.1 ppm, while a group of about 8 zener references will be able to maintain 0.3 ppm, and a group of only 4 about 0.8 ppm per year. In contrast, it is relatively easy to maintain the groups of zener references, while establishing the transfer value of the Josephson junction is very difficult and requires a great deal of equipment and experience·

In practice, very few national laboratories actually need to have a Josephson junction system, and a group of zener references is usually sufficient. From this group, one zener reference is sent once a year to a laboratory that has a Josephson system to import traceability to the group·

However the zener references only have an output voltage fixed at a nominal 10 Vdc, and they need to be treated well and not loaded with low impedance measuring devices. This means that, in most cases, the zener references are used to transfer the 10 Vdc standard into a more robust electrical multifunction calibrator which will then source any voltage (ac or dc) from zero up to approximately 1100 V. These calibrators have a one-year specification of 3.5 ppm on their basic Vdc function·

Resistance capability, at this level, is maintained by having a series of standard resistors. In some very high-accuracy cases, special standard resistors are placed in a stirred oil bath, but the more modern "air resistors" are quite stable enough at <3 ppm per year. One or two of the set (1, 10, 100, 1k, 10k, 100k, 1M & 10MΩ) are then sent to a high-level laboratory once a year to import traceability, and the imported value is compared against the rest of the set in the laboratory, by inter-comparison. Once again, the standard resistors are of a fixed value and their value is also transferred into a multifunction calibrator to allow general high-level calibration over a wide range·

The calibration of a multifunction calibrator is done using a procedure known as artifact calibration. Using only one calibrated 10 Vdc zener reference, a 1Ωand a 10kΩ standard resistor as it's source traceability, the calibrator is able to deliver a very wide range of Volts (ac and dc), resistance, and current (ac and dc), all of which are traceable to international standards. Multifunction calibrators, together with a null detector or a good long scale digital multimeter (DMM), can then be used to calibrate most 8½ digit multimeters and other industrial level calibrators·

Following down the calibration chain, there is another step before the general purpose test equipment level is reached. For example, a simple 3½ digit multimeter used by the thousands in industry is difficult (almost impossible) to calibrate using only a multifunction calibrator because the multifunction calibrator is not designed to do this level of work. Even though the multifunction calibrator is very accurate, it lacks the range and additional functions required by the typical multimeter, such as 20 amps, thermocouple simulation, capacitance, frequency etc. To calibrate all of these functions on a DMM, a multi-product calibrator is used·

The multi-product calibrator has a Vdc specification of about 12 ppm per year and is thus suitable for calibrating most DMMs up to 6½ digits, as well as many of the other lower level calibrators, DMMs, panel meters etc. typically seen in industry·

There are many countries that simply use a multi-product calibrator with a few accessories as their national standard and, invariably, even the highest-level laboratory requires the lower level equipment to be able to perform their tasks adequately. So the decision about what to install is usually based from the bottom up, starting with a multi-product calibrator and then, if the market requires the laboratory to calibrate other laboratory's multi-product calibrators, installing a multifunction calibrator with a few accessories. In limited cases, the national laboratory will need to go to fixed values such as zener references and standard resistors and, very rarely, a Josephson junction system· The tables below show how traceability is derived and the typical equipment and workload associated with each level of laboratory. *Do not be misled by the terminology used that a national laboratory has to be a primary level laboratory. The most important issue is that the national laboratory is capable of producing traceable calibration at the level required by its market, with competence and efficiency·*

Laboratory Level	**Typical Workload**
National research institute(Vdc±0.1ppm/year) Josephson Junction System, Quantum Hall devices	Zener references Fixed resistors etc.
Primary level .aboratories (Vdc ± 0.5ppm/year) Zener reference group/s Fixed standard resistors, capacitors etc Thermal transfer standards Reference dividers Null detector / 8½ DMM	Multifunction calibrators Reference DMMs
Secondary level laboratory (Vdc ± 3.5ppm/year) Multifunction calibrator 6½ to 8½ Digit multimeter	Multi-product calibrators Laboratory DMMs
Tertiary level laboratory (Vdc ± 12ppm/year) Multi-product calibrator 6½ Digit multimeter 50 Turn coil	Bench & handheld DMMs Panel meters, thermometers Clamp meters, process tools Oscilloscopes

The equipment that would normally be in a typical high-level laboratory (mixture of laboratory levels) which could cater for most industrial and laboratory work loads would include the following:-

Lab standards
2 x Reference standards (8 zener reference cells)
1 x External battery and charger (required for inter-comparison journeys)
1 x Transit case (to hold one zener and one ext battery for inter-comparison)
1 x Set standard resistors (1, 10, 100, 1k, 10k, 100k, 1M & 10MΩ)
1 x Transit case (to hold two/three standard resistors for inter-comparison)

High-level station
1 x Reference DMM (8½) with Ratio function
1 x Multifunction calibrator

General work station
1 x Multi-product calibrator with scope cal opt. (600MHz)
1 x 6½ Digit DMM
1 x 50 Turn coil
2 x Set low thermal leads
1 x Set thermocouple test leads
1 x Hand held DMM

Other useful items

1 x Dual bench power supply (0-30V >2 amps)
1 x Decade resistance box (1Ω to 10MΩ)
1 x Decade inductance box (100µH to 11H)
1 x High voltage probe (40kV)
1 x LCR Meter
1 x 25Ω Resistance standard (for temperature calibration work)
1 x Hand held thermometer with selection of probes
1 x PC, Printer & met/cal software etc.
1 x Cal Book (Philosophy of Calibration in Practice)

If required to calibrate insulation and installation testers
1 x Multifunction electrical tester calibrator or 1 x Set high voltage resistors
1 x Set low Ω , high current resistors