Apex Level Standards & Industrial Metrology

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शीर्ष स्तरीय मानक एवं औद्योगिक मापिकी

शीर्ष स्तर मानक एवं औद्योगिक मापिकी विभाग में भौतिक, यात्रिक, इलेक्ट्रिकल एवं इलेक्ट्रॉनिक्स, प्रकाशीय एवं ध्वनि
मापन गतिविधियों सहित 12 समूह (श्रृद्धु) हैं। विभाग मापन के राष्ट्रीय मानकों को स्थापित करने, उनका अनुसरण और उनके
निर्देश उनके अंतर्गत संबंधित कार्य करता है। विभाग द्वारा देश के उद्योगों और संस्थाओं को उच्च स्तरीय अन्तर्राष्ट्रीय स्वीकृति
प्राप्त अशक्तांश से उल्लंघन कार्य करायी जाती है और इस प्रकार उन पैरामीटरों के आधार पर किए गए मापन के अनुरूप (द्वीसेरविलिटी) को सुनिश्चित किया जाता है। विभाग में निम्नलिखित श्रृद्धु हैं :-

1. द्रव्यमान मानक
2. विमा मानक
3. लाभ एवं आर्थिक मानक
4. प्रकाशीय विकिरण मानक
5. बल एवं कठोरता मानक
6. दाब एवं निर्वांत मानक
7. ध्वनिक, परा ध्वनिक, आधार और कंपन मानक
8. द्रव प्रवाह मानक
9. LF & HF प्रतिबाध एवं धी सी मानक
10. LF & HF वोल्टेज, धारा एवं माइक्रोवेव मानक
11. AC उच्च वोल्टेज एवं उच्च धारा मानक
12. AC पावर एवं ऊर्जा मानक

इस विभाग के कई श्रृद्धु BIPM, APMP जैसे अन्तर्राष्ट्रीय निकायों द्वारा आयोजित अन्तरराष्ट्रीय इंटर-कॉपीरिजन में कार्यरत हैं।
कुछ द्विपक्षीय इंटर-कॉपीरिजन भी संचालित किए जाते हैं। यह विभाग देश की अंतर्गत और परीक्षण प्रयोगशालाओं को उनके मापन
प्रामाणीकता (assurance) कार्यक्रम के अनुरूप के लिए विभिन्न पैरामीटरों में उनके परीक्षण देकर और दक्षता प्रशिक्षण कार्यक्रम
संचालित करके उनकी मदद कर रहा है।
Apex Level Standards and Industrial Metrology

The division constitutes of Physical, Mechanical, Electrical & Electronics, Optical and Thermal measurement activities involving twelve groups. The division is responsible to establish, maintain and continually upgrade the National Standards of measurements. Provides the apex level internationally accepted calibration services to the industry and institutions of the country and thus ensures the traceability to measurements made by these parameters. The groups are:

1. Mass Standards
2. Standards of Dimensions
3. Temperature and humidity Standards
4. Optical Radiation Standards
5. Force and Hardness Standards
6. Pressure and Vacuum Standards
7. Acoustics, Ultrasonic, Shock and Vibration Standards
8. Fluid Flow Measurements
9. LF & HF Impedance & DC Standards
10. LF & HF Voltage, Current & Microwave Standards
11. AC High Voltage and AC High Current Standards
12. AC Power & Energy Standards

Many areas of this division are engaged in international inter-comparisons organized by international bodies like BIPM, APMP etc. Some bilateral comparisons are also conducted. This group is also helping calibration and testing labs of country to maintain there measurement assurance programme by proving training and conducting proficiency testing programme in different parameters.

The calibration and measurement capabilities of most of the parameters in the division are internationally accepted and appear on the BIPM website.
Mass Standards

Final report of APMP.M.M-K2.1 - bilateral comparison of four stainless steel mass standards (500 g, 20 g, 2 g and 100 mg) between KRISS and NPLI had published in Metrologia. The results of KRISS and NPLI were consistent with each other for all four nominal values. The NPLI results were also within the agreement of KCRV of CCM.M-K2 within their uncertainties ($k = 2$).

(Results were published in *Metrologia*, 48, Tech. Suppl., 07008, 2011)

Interim results of inter-comparison of 1 kg platinum-iridium mass standard as APMP pilot study were presented in Asia Pacific Symposium on Measurement on Mass, Force, Torque (APMF-2011). NPLI was one of the participating laboratories in this inter-comparison. This inter-comparison was carried out among 10 laboratories from January 2009 to January 2010.

**Equivalence among participants is as follows:**

See, 2 kg in figure 5.1, 200 g in figure 5.2, 50 g in figure 5.3, 1 g in figure 5.4 and 200 mg in figure 5.5.

(Results were published in *Metrologia*, 48, Tech. Suppl., 07008, 2011)
located at fluid flow laboratory. Carried out characterization of 225 liters, 525 litres and 2000 liters vessels on this balance.

Completed the Proficiency Testing (PT) Program on Mass measurement (No. NPL-NABL/M/1/2010) among twenty seven NABL accredited laboratories in two loops. Results are in progress.

This section has provided apex level calibration facilities for the mass, density, volume and viscosity to number of organization belong to Govt. and private sectors. We are specializing in catering for pharmaceutical industries.

The Mass Standards group is strongly supporting SAARC countries (Pakistan, Bangladesh, Nepal, Sri Lanka, Bhutan, Maldives and Afghanistan) under PTB program for the activities like inter-comparison, training, traceability etc.

Well in advance, we have submitted our National Prototype Kilogram (copy No. 57) at BIPM for re-calibration after successful planning.

**Major facilities established :**

AX 206 mass comparator was established in the group. This comparator is provided by M/s Mettler Toledo. Its technical features are as follows:

- **Maximum load :** 211 g
- **Readability :** 1 µg
- **Repeatability :** 4 µg
- **Linearity :** ±8 µg

It will enhance our technical capability with more precision.

**Extraordinary research highlights:**

Our 27 CMCs entered in Appendix ‘C’ of BIPM database on 24th May 2011. Previously we had six CMCs in Appendix ‘C’. First time, viscosity with six CMCs came in Appendix ‘C’. We got CMC of ±28 µg; k=2 in 1 kg, comparable to other NMIs.

<table>
<thead>
<tr>
<th>No</th>
<th>Country</th>
<th>Name</th>
<th>Exp. uncertainty (k=2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Austria</td>
<td>CWM</td>
<td>±10 µg</td>
</tr>
<tr>
<td>2</td>
<td>China</td>
<td>NIM</td>
<td>±15 µg</td>
</tr>
<tr>
<td>3</td>
<td>Canada</td>
<td>NRC</td>
<td>±20 µg</td>
</tr>
<tr>
<td>4</td>
<td>France</td>
<td>BIPM</td>
<td>±25 µg</td>
</tr>
<tr>
<td>5</td>
<td>Germany</td>
<td>PTB</td>
<td>±30 µg</td>
</tr>
<tr>
<td>6</td>
<td>Italy</td>
<td>NRIM</td>
<td>±35 µg</td>
</tr>
<tr>
<td>7</td>
<td>Japan</td>
<td>NII</td>
<td>±40 µg</td>
</tr>
<tr>
<td>8</td>
<td>Korea</td>
<td>KRI</td>
<td>±45 µg</td>
</tr>
<tr>
<td>9</td>
<td>Russia</td>
<td>VNIIM</td>
<td>±50 µg</td>
</tr>
<tr>
<td>10</td>
<td>Sweden</td>
<td>SFM</td>
<td>±55 µg</td>
</tr>
<tr>
<td>11</td>
<td>Switzerland</td>
<td>THM</td>
<td>±60 µg</td>
</tr>
<tr>
<td>12</td>
<td>U.K.</td>
<td>NPL</td>
<td>±65 µg</td>
</tr>
<tr>
<td>13</td>
<td>U.S.A.</td>
<td>NIST</td>
<td>±70 µg</td>
</tr>
</tbody>
</table>

First time, NPL Mass Standards took consultancy project for characterization of the weighing balances up 20 t at M/s ABB, Faridabad and completed successfully the same. M/s ABB
is one of the leading flow meters manufacturing industries.

Standards of Dimensions

1) New technique developed:

In Dimension Standard, a new method is developed to calibrate flick standard using laser interferometer. A Laser retro-reflector is fitted with a linear displacement probe. A Moore’s indexing table and laser interferometer are arranged on a three dimensional Length Measuring Machine. The flick standard is aligned at the centre of index table. The flick depth is measured using laser interferometer to establish traceability through laser wavelengths. The uncertainty of measurement is improved from 170 to 60 nm. This technique will leads to obtain patent/copyright.
2) **New facility established:**

A new facility for measurement of Long Gauge Blocks up to 4-meter has been established using Laser Interferometer. This newly established facility will not only serve Indian Industries but SAARC countries also.

**Specification of facility:**

- **Nominal Range**: 0-4000 mm
- **Working Range**: 0-3700 mm
- **Resolution**: 0.01 µm
- **Maximum Error**: 1.5 µm
- **Repeatability**: 0.1 µm
- **Temperature**: (20 ±1)°C
- **Relative Humidity**: (50 ±10) %
- **Uncertainty of measurement**: ± (0.3 µm + (L/1200)×10⁻⁶), L in mm
  
  (At k = 2 i.e. at 95% confidence level)

**Laser used**: He-Ne Laser

**Wavelength**: 632.8 nm

**Photograph of facility**:

![Photograph of facility](Fig. 5.18 : 4 m Length measuring machine using laser interferometer)

2. **High precision roundness measuring machine**:

Purchase order has been placed to establish the Form and Roundness Measurement Facility and this machine is expected to be commissioned in August 2012.

3. **SAARC - PTB Project**:

International Inter-comparison was conducted in gauge blocks and its report was submitted/presented in SAARC Co-ordination committee workshop at Dhaka, Bangladesh during March 2012 with NPL as pilot Laboratory and MUSSD, Sri Lanka as the participating Laboratory. The other SAARC countries will also participate in the International Inter-comparison of gauge Blocks as and when they will have the traceability. The final protocol has already been circulated to all the member SAARC countries.

4. **Coordination of the proficiency testing program (PT - Project) under NABL sponsorship**:

Coordinated proficiency testing in Pressure, Length, Mass and Temperature. In Dimension Standards, one loop of the proficiency testing has been completed for the Dial Gauges in the ranges 0-25 µm and 0 to 10 mm. The least count of the dial testers is 0.5 µm and 10 µm.

**Temperature and Humidity Standards**

**APMP key comparisons** - This year our Group has developed the experimental facilities to participate in two APMP key comparisons, one in LIGT (-40 °C to 250 °C) and the other in Pt/Pd thermocouple on Co-C eutectic fixed point (1324 °C). Set of Pt/Pd thermocouples has been received from KRISS Korea (Pilot Lab) and measurements are under process.

We are establishing the primary standard in high temperature by realizing the Silver and Copper blackbody fixed points by linear photoelectric pyrometer (LP4). The LP4 pyrometer procured from K.E. Technologies, Stuttgart, Germany has been received and will be installed very shortly. Presently two of our tungsten strip lamps are the standards for high temperature and both of these standard lamps were calibrated in PTB Germany during Feb-March 2012.

For the XIIth Five Year plan, we have formulated an innovative project entitled “Determination of Boltzmann constant and realization of thermodynamic temperature by acoustic gas thermometry”. We are working on the preliminary experimental requirements for this project.

**National collaboration with NABL**

Our group was associated with NABL activities by organizing
proficiency testing programs in LIGT and TC comparison among accredited calibration laboratories in order to support quality assurance in temperature metrology. PT Programs in LIGT and TC are under process. Expertise was provided to NABL for laboratory accreditation in the field of thermal calibration. Expertise was also provided by attending the meetings of Supplementary and Core Accreditation Committees relating to thermal calibration area.

**International collaboration with SAARC-PTB project in Temperature Metrology**

Under the 2nd Phase of SAARC-PTB Project in metrology, Temperature & Humidity Standards is associated as one of the teams in the project. A preparatory workshop was attended during 6-8 June 2011 held and organized by MUSSD, Sri Lanka. The workshop was attended by the participants from BSTI Bangladesh, NBSM Nepal, NPL India, MUSSD Sri Lanka, Afghanistan, Bhutan and Maldives.

A 1st SAARC-PTB Coordination Meeting was held recently at BSTI, Dhaka during 13-14 June 2012. The meeting was attended by the participants from NPL India, BSTI Bangladesh, NBSM Nepal, MUSSD Sri Lanka and Bhutan. Temperature metrology is one of the areas of the above project in which the inter-laboratory comparison is to be organized by our group among the four SAARC countries (Bangladesh, Nepal, Pakistan and Sri Lanka).

**Major facilities**

**Establishment of high temperature blackbody source**

We have established the high temperature variable temperature blackbody source (Model M390 of M/s MIKRON Infrared Inc. USA) for the calibration of infrared total radiation pyrometers in the range from 600 to 3000 °C. The blackbody source has an emissivity of 0.997 and the overall uncertainty of measurement using this source is ±1.5 °C to ±7.8 °C for the calibrated range from 660 to 2700 °C. We have calibrated infrared radiation pyrometer, MINOLTA/LAND Cyclops 152, with spectral response of 0.8 to 1.1 µm on the above blackbody radiation source in the temperature range from 660 to 2700 °C with the estimated uncertainties of measurement ±1.8 °C to ±7.9 °C, as shown in Fig 5.19. The facility will be useful for comparison calibration of IR-total radiation pyrometers in the above mentioned range to the accredited laboratories, user industries and temperature metrology community in the country. The facility has been introduced in the Quality system documents as per ISO/IEC: 17025(2005) for calibration of IR-total radiation pyrometers.

The fixed point of Silver (961.78 °C) has been established using a new silver cell procured from HART Scientific, USA and realized by SPRT with an uncertainty of 4 mK. The fixed point is to be used for international comparisons and also to provide traceability to user industries and accredited laboratories.

The humidity standard has been upgraded with addition of a new humidity generator Model 2500 of Thunder Scientific, USA based on two pressure technique. The traceability of temperature and pressure transducers has been achieved from in-house at NPL, India. The measurements have been performed in the range of humidity from 10 % to 95 % RH & in the temperature range from 15°C to 70°C with uncertainty of ±0.3% RH & ±0.02 °C. The facility has been introduced in the Quality System Documents as per ISO/IEC: 17025(2005) as reference humidity standard for calibration of hygrometers,
Calibration procedure No.: Sub-Div.#D5.03/THS/Doc.3/HS/CP#02.

Extraordinary research highlights

We are developing the in-house fixed point realization facility for the new Co-C and Fe-C metal carbon eutectics using vertical three zone heating furnace from CARBOLITE, TZF 16/610 with bottom end closed. We have fabricated the graphite cell for Co-C from NPL workshop. For accurate realization of the fixed point, it is desired that the zone of the furnace where fixed point cell is placed should be highly stable and uniform to provide homogeneous heating to the fixed point cell. Therefore, it was required to measure the vertical thermal profile measurements of the said furnace, using a Type-S thermocouple and is shown in Fig 5.20. A stability of ±1°C has been achieved at the middle zone of about 200 mm (100 mm from center), which is adequate to place melting cell of 110 mm height.

Optical Radiation Standards

This section is providing world class calibration facilities for lamp and lighting industries, laboratories and institutes. The calibration facility is available for photometric parameters namely luminous intensity, luminous flux, luminance, illuminance, illuminance responsivity, color coordinates and color temperature. A number of Polystyrene films are calibrated for different pharmaceutical industries and R&D organizations using Fourier transform infrared spectrophotometer (FT-IR). FT-IR and FT-Raman Spectroscopic testing facilities are provided to various groups of NPL and outside agencies. A significant mount as ECF is generated through these calibration activities.

The scales for illuminance and illuminance responsivity are maintained through luminous intensity standard and standard illuminance meters, (which have cosine corrected $V(\lambda)$ matched silicon photodiode). The illuminance meters are also traceable to international standards. Absolute scales of luminous flux are prepared using a Gonio-photometer. The traceability of luminance comes from the luminous flux scales and the scales of colour temperature and colour coordinates are measured through luminous intensity standard lamps.

Spectral switching is now a well-known phenomenon. Recently, its potential applications have been explored for information encoding and transmission in free-space. In our recent work, we demonstrated a novel type scheme to encode and process information at multiple levels through spectral switching. A new
In recent years the group has established new force and hardness standard facilities with a view to provide to the users the national traceability in measurement of these parameters with lower uncertainty and international compatibility. The new force standard machine (GTM make) of capacity 1 MN commissioned and established with CMCs showing equivalence with PTB, Germany, was introduced as the national standard of force into the quality management system for force calibration. With the availability of this facility, option has been made available to the users to get the calibration of their lower uncertainty class force instruments such as class '00' up to 1 MN following the latest international standards ISO 376-2011. Further, the new force standard was used to recalibrate all the force transfer standards which in turn were used to calibrate/determine the CMC of the secondary standard force machines, so that the users get traceability of calibration of their force devices against the new national standard having lower uncertainty (± 0.002% up to 100 kN and ± 0.009% up to 1000 kN).

The existing 50 kN dead weight primary standard (Morehouse Instruments make) was compared with the new force standard machine to establish its equivalence. It was shown that the force values realized by the two machines have normalized error less than unity. The new 100 kN force comparator machine, designed and fabricated earlier to explore the feasibility of developing a force calibrator in this range, was evaluated for its CMC from 10 to 100 kN using the NPL force transfer standards. Its expanded uncertainty was evaluated to be within 0.05% (Fig. 5.23). Further work to improve its performance for stability in force application is in progress.

The force calibration facility for 2000 kN was upgraded using a 2.1 MN build-up system in the hydraulic force machine. The individual force transducers of the build-up system were

Fig. 5.22. Spectral switching based FSO link

Fig. 5.23. The relative repeatability, reproducibility and mean value deviation of force transfer standard output in 100 kN comparator machine
calibrated in the 1 MN force standard (GTM) and the curve fit of their calibrated output were used to determine the reference equation of the build-up system. The expanded uncertainty of the hydraulic force machine with the build-up system was evaluated using a class ‘00’ 3 MN force transducer as 0.05%. This facility has been put into operation to provide to users the calibration of their 2000 kN force transducers.

In-house comparison of torque standards

A comparison of the NPL primary and secondary torque machines, as a supported lever machine and an unsupported lever torque machine respectively, was carried out with a view to study the bending effect of the lever in the unsupported case. The bending effect due to the unsupported lever appears as an asymmetric deviation in the transducer output when mounted at different angular positions around its axis (Fig. 5.24). Taking into account the bending effect, the secondary torque machine was shown to agree in the realized torque values with the primary standard.

Key comparison in Rockwell Hardness A and B

Draft B of the APMP key comparison in Rockwell Hardness scales HRA and HRB, carried out by NPL during 2010-11, was received from the pilot laboratory, NIMT, Thailand. The key comparison measurement results of NPL(I) are within the claimed CMC values of the HRA and HRB scales, which is reflected in normalized error between the HRA and HRB values of the NPL(I) and the key comparison reference values as shown in the Fig. 5.25.

The group is engaged in a major way in providing support to industry and other user organizations in calibration of their reference devices, providing training, etc. About 450 calibration reports in force, hardness and torque parameters were issued to different users during the year. The ECF realized was approximately Rs 50 lakh. Force calibration as per the latest international standards ISO 376-2011 and ASTM E74-2006 have also been accepted to meet demand from user organizations.

Major facilities established

The hardness calibration facility was augmented by adding secondary hardness standard machines of Brinell, Rockwell (including superficial Rockwell), Vickers and micro-Vickers hardness (Fig. 5.26) to the existing primary hardness standard machines so as maintain in-house traceability of hardness calibration machines, which shall be used to provide the necessary traceability in hardness scale to the users. The secondary hardness machines conform to the requirement of the international standard ISO 6507 – 3 for calibration of standard hardness blocks. The work to establish the CMC of the secondary hardness machines is in progress.

Pressure and Vacuum Standards

The pneumatic pressure standards lab provides traceability in pneumatic pressure range from 0.4 to 400 bar. The measurements made are world class and traceable to the...
primary standards of mass and length that offer the potential for reduced uncertainties. The system is basically consisting of three parts: (i) a pressure generation device, (ii) an automatic weight loading / unloading unit, and (iii) a controlled clearance piston cylinder assembly having nominal diameter of 3.5 mm. The diameter of the piston measured with the help of NPLI Reference Standard Reference Gauge Blocks within the measurement uncertainty of + 0.07 mm (k = 2), is 3.56777 mm. The inner and outer diameters of the cylinder measured by Precision 3D Coordinate Measuring Machine within the uncertainty limit + (0.5 + L / 900) mm (k = 2), are 3.7668 mm and 26.0222 mm, respectively. The piston is in floating position when it is located 3.4 mm above its rest position in the cylinder. The total engagement length is 18.9 mm. We have carried out also studied under high pressures. The detailed analysis of results is underway.

PrO$_2$, which is found to be cubic at ambient, was seen to undergo a phase transition to the orthorhombic type, and the phase transition was observed at 33.9 GPa at room temperature (Fig. 5.27).

In addition, finite element simulations were also carried out on our 20 MPa piston cylinder assembly using ANSYS package as a part of an M.Tech. project and excellent agreement between the experimental and simulated results were achieved. The effective area, the distortion coefficient and the strain profiles were simulated and gap profiles obtained.

A 500 MPa controlled clearance piston gauge (CCPG) type primary pressure standard has been characterized with its parameters traceable to NPLI international standards. The primary as well as the secondary standards dead weight testers which are characterized against each other as well as are traceable through a continuous chain of overlapping pressures to the ultrasonic interferometer manometer. The latter is the low pressure primary standard of the Vacuum Standards. The secondary standards provide traceability to Indian industries through calibration services.

In addition to the above mentioned activities, the group is also engaged in research into the behaviour of rare earth sesquioxides under high pressures and a number of papers have been published in international reputed journals. The group also collaborates with groups within and outside NPL for Raman characterization of strategic materials. This work is being carried out as a part of a DST sponsored project.

A proficiency testing program in pneumatic pressure range up to 50 bar was also completed in which seven labs all over India participated. This program was started in November 2010 and was completed in October 2011.

In continuation of our research on high pressure behaviour of rare earth oxides, data analysis was completed for Ho$_2$O$_3$ and Yb$_2$O$_3$ and the results have been communicated for publication. Er$_2$O$_3$, Tb$_4$O$_7$, and PrO$_2$ were

![Fig. 5.27. Raman spectra of PrO$_2$ at increasing pressures](image)
2. Participation in APMP. M.P. K13

The NPLI is participating in this comparison, identified as APMP.M.P-K13 by BIPM and APMP, being piloted by NMIJ, Japan. The objective of the project is to compare the performance of hydraulic pressure standards in participating institutes, in the pressure range 50 to 500 MPa in gauge mode to essentially support the objective evidence for high pressure CMCs of the participating institutes. The results of this comparison will also be linked to the corresponding CCM key comparison, CCM.P-K13. The number of participating institutes is 13 including the pilot institute. These institutes are NMIJ/AIST, Japan; NPLI, India; NML/SIRIM, Malaysia; NMC/AIDS, Singapore; NIM, Thailand; NIMIA, Australia; NIM, China; CMS/ITRI, Chinese Taipei; KIM-LIPI, Indonesia; NIS, Egypt; KazInMetr, Kazakhstan; NBSM, Nepal; KRISS, Korea. The comparison started during November, 2010 and is expected to be completed during December, 2012. In this comparison, a piston-cylinder assembly of 2 mm² nominal effective area is being circulated as the transfer standard (TS). It is built in hydraulic pressure balance PG7302 equipped with a mass loading bell, a mass set, all parts having been manufactured by Fluke Corporation, DH Instruments Division, USA. The NPLI has completed the measurements and submitted their results to pilot laboratory during period under report. The evaluation of measurement results is under process.

3. Establishment of new Hydraulic Pressure Standards

A new controlled clearance type piston-cylinder assembly to measure hydraulic pressure up to 100 MPa has been procured (Fig. 5.29). The system is being characterised which would enable us to trace our secondary standards to primary pressure standard up to 100 MPa within improved relative measurement uncertainty of 35 x 10⁻⁶ at k = 2 in pressure measurements. Also established a secondary reentrant type piston cylinder assembly to give services to Indian industries up to 20 MPa. Two digital reference pressure...
monitors (RPMs) have also been procured in the range 100 MPa and 200 MPa, respectively (Fig. 5.29). These RPMs will be used to calibrate low accuracy industrial gauges and also monitoring jacket and line pressure in our experiments.

4. Studies on industrial pressure balances

The studies on stability of effective area were carried out on industrial pressure balances (PBs) which were characterized at NPL. The first industrial PB studied was Ruska Model 2485-530D, procured during 2004 (manufacturer supplied data) being used in Delhi, a northern part of India. It was first calibrated during 2007 and recently during 2011. Therefore, the stability data of the effective area was available for the period of 7 years for the analysis. The plots showing the stability of effective area (Ae) as a function of applied pressure (p) are depicted in Fig. 5.30 (a). As expected, the similar trends of the effective area (Ae) is observed during all these years except some drift in the values between 2009 and 2011. The data obtained during 2009 is much closer to the values reported by the manufacturer during 2004. When 2009 data is compared with manufacturer data of 2004, it is found that the values of 2009 are slightly higher up to 60 MPa and lower beyond that pressure. It is evident from the plots that there is no unidirectional drift in the values to assign some correction factors.

Therefore, it was considered appropriate to plot the average of all these values and determine the deviations from the average values for each year’s data as shown in Fig. 5.30(b). It is clearly evident from Fig. 5.30(b) that 2004, 2009 and 2011 data are well within 20 x 10^{-6}, 14 x 10^{-6} and 28 x 10^{-6}, respectively form the average values which is in excellent agreement with the estimated measurement uncertainty of this gauge as 72 x 10^{-6} at a coverage factor of k = 2. There is an agreement of 20 x 10^{-6} between 2004 and 2009 data while it is 45 x 10^{-6} in case of 2009 and 2011 data. It is mentioned here that these agreement values are the worst case values, generally obtained at the lowest pressure point of 5 MPa which is 5 % of the full scale pressure due to obvious reason that best performance of any PB is obtained in between (10-100) % of full scale pressure. Therefore, it is concluded from these studies that the gauge under test remained very stable during all these years and is properly handled by the operators.

Further studies were carried out on the two other PBs, one being used at the extreme southern part of India and another extreme eastern part of India. These two PBs studied were the identical Ruska Model 2485-5586 as previously described in Figs. 5.30(a) and (b) but slightly
varying dimensions of piston cylinder assemblies. The motive behind studying identical PBs was to investigate the behavior of effective area when used at different locations, organizations and operators. The behaviors of effective area for these PBs along with average effective area of previously described PB are shown in Fig. 5.30 (c). Interestingly, the similar trends of effective areas were observed for all the 3 three locations. It is observed that there is a small change in the short term stability but the change is prominent in case of long term stability. However, such changes are well within the estimated measurement uncertainty of the instrument. The reported maximum difference in the effective areas is less than $180 \times 10^{-6}$, $140 \times 10^{-6}$ and $60 \times 10^{-6}$, between PBs of Chennai and Guwahati, Chennai and Delhi and Delhi and Guwahati, respectively due to obvious reasons of varying form geometry of the piston cylinder assemblies. It is concluded from the studies that all the PBs remained very stable within their estimated measurement uncertainties. Compilation of such data creates the history of the instrument’s usage which would be helpful for the users to decide the frequency of their next calibrations.

### Acoustics, Ultrasonic, Shock and Vibration Standards

The theoretical computational for sound transmission loss (TL) have computed by developing software through Statistical Energy Analysis approach. The program is written in Visual Basic (VB) and the coding. Some of the aspects of Statistical Energy modeling procedures adopted in developing the program are explained subsequently. Figures 5.31 and 5.32 show the comparison for 12 mm thick gypsum board panel with cavity and panel with insulation. With cavity the sound reduction index at low frequencies is higher.

The AUV Section organized the one day workshop on ‘Noise and Vibration Control (WNVC-2012) on January 27, 2012.

### Advancement in Vibration and Acoustic Metrology

The new facility of primary vibration calibration standard in extended frequency range of 0.1 Hz to 20 kHz had been established last year. Although this facility, being a commercial system, yet there are numerous investigations carried out for improvement in the signal processing part especially the non-linearity’s arising in Homodyne interferometer and drift compensation in charge amplifier at low frequencies. The ongoing investigations have been fruitful in analysis of the behavior of shakers at high frequencies and certain deviations at 20 kHz have been observed, which are validated by FEM investigations for understanding the vibration modes excited especially in low and high frequencies.

The new microphone calibration standard facility using insert voltage technique was also established this year for the calibration of acoustic calibrators and microphones, which has reduced the uncertainty in calibration to a level at par with other NMIs of APMP region.
**Inclusion of NPL Vibration CMCs in KCDB website & Successful completion of Peer Review in October, 2011**

The CMCs for vibration have been appended in KCDB website in January, 2012. The section had successfully got peer-reviewed in October, 2011 and 36 CMC were approved by Technical and Quality expert in field of Acoustics, Vibration and Ultrasonic.

**Results of APMP.AUV.A-S1 comparison**

The recent APMP.AUV.A-S1 comparison for multifunction acoustic calibrator (B&K 4226) initiated in 2009 with NIMT, Thailand as pilot laboratory and 13 participating laboratories validated NPL CMCs for sound pressure level determination of multifunction acoustic calibrator (Fig.5.33). The maximum deviation in sound pressure level determination by NPL in comparison to NMI Japan was 0.12 dB at 16 kHz while 0.19 dB at 8 kHz as compared to NMI Australia which lies within the domains of the uncertainty value realized for multifunction calibrators calibration.

**Bilateral Inter-comparison**

Bilateral inter-comparison of Ultrasonic power measurement between NIST, USA and NPL India was carried out. Artefact designed and developed by NIST received by NPL. Measurement taken at three different frequencies in the range of 2 to 15 MHz for each frequencies at three different in put voltage, 10 sets of observations carried out following the procedure in the protocol. Results were sent to Dr. Fick, NIST. As per statement of Dr. Fick results were very encouraging and comparison shows variation with in uncertainty limits of NIST even without taking the attenuation correction.

**International PEER Review of Primary Standard of Ultrasonic Power Measurement**

NPL maintains Primary Standard of ultrasonic power using radiation force balance, developed indigenously in the laboratory. The Lab participated in the international Peer Review during 8-10, Nov. 2011. For this purpose, the radiation force balance was modified for providing variation of distance between the transducer face and float. It allowed uplift of water tank by an arrangement designed and developed for smooth functioning of vertical motion of tank and for a precision measurement of separation in 0.01 mm.

**EMAT System**

The EMAT (Electromagnetic Acoustic Transducer) system, designed and developed at NPL (Fig. 5.34, 5.35) was tried on aluminium sample to study the effect of external force for evaluation of residual stress measurement. Measurement of velocity by EMAT could be done with a precision of 0.1 m/s. Samples were exerted force in the range from 20 to 500 kN using the UTM machine of Force Standards at NPL.

The EMAT system has also been used to evaluate variation in wall thickness of a pipe with a precision of 0.1 micron.

**Fig. 5.34 Snapshot Showing the entire setup**

**Fig. 5.35 EMAT applied on 3cm thick aluminum alloy**

**Ultrasonic object detection system**

To help the divers operating in deep sea, the transmitter and receiver parts of the object detection system have been...
developed was tested in Chennai NIOT tank. The system worked well up to a range of 25 meters.

**Research Highlights**

Appreciable deviation in microphone calibration by Reciprocity technique and calibration by actuator technique was investigated for working standard microphones. The actuator response is compared with the pressure response measured on a reciprocity set up for a one-inch B&K 4144 (S. No. 1304815) microphone (Fig 5.36). The actuator response deviates from the pressure response because the radiation impedance loads the front of the diaphragm. If this impedance could be significantly reduced during the calibration, then the actuator could be used to measure accurately the pressure response.

**Establishment of new Secondary Microphone Calibration facility**

The secondary microphone calibration standard of NPL was commissioned in October this year. The system is capable of calibrating the microphones and acoustic calibrators as per IEC 60942. The system has been procured from B&K, Denmark. (Fig 5.37)

**Fluid Flow Measurements**

The Fluid Flow Measurement Standards group has the mandate to provide apex level testing and calibration services for the different types of domestic and industrial water flowmeters. The group has a Water Flow Calibration Facility (i.e. Primary Standard of Flow) comprising of two Test Rigs of sizes DN50 and DN200 for calibration of different types of water flowmeters as per ISO 4185 standard. The facility has the problems related to its traceability and also it has become obsolete now. Therefore, upgradation of this facility using latest instrumentation and controls has been planned to make it operational and traceable and also of NMI level.

The group also has a Water Meter Testing Facility (i.e. Secondary Standard of Flow), for testing of domestic/industrial water meters of sizes 15 mm to 50 mm as per IS 779, IS 6784 and ISO 4064 standards. The quality system has been implemented in the Water Meter Testing Facility. During this period, total 06 test reports were issued and an ECF of Rs. 4,32,369/- was generated for NPL.

The renovation work of the Fluid Flow Laboratory is almost finished. It took about 1½ years to complete.

**Major facilities to be established**

Presently, a Water Flow Calibration Standard (i.e. Primary Standard of Flow) of size DN100 is being developed in technical collaboration with M/s. Bharti Automation Pvt. Ltd., New Delhi. The different parts of this system have been installed and integrated. Now automation...
work of this prototype system is in progress. Our development work was severely affected due to renovation of our laboratory. Figure 5.38 shows the photograph of this new system.

**LF & HF Impedance & DC Standards**

This activity is maintaining the LF & HF impedance standards, DC standards and DC High Voltage standards.

**LF & HF Impedance Standard:** This activity is maintaining the primary standards of capacitance, inductance and ac resistance. Value to the 10 pF capacitor is assigned through primary standard, calculable cross capacitor, with an uncertainty of 0.6 ppm using precision ac bridges. Scale of capacitance is build up from 10 pF to 1 F using transformer ratio bridges. The unit of inductance, Henry, is realized from capacitance and resistance using Maxwell-Wien bridge. Value to 100 µH to 10 H is assigned through this bridge. The unit of ac resistance, Ohm, is also realized from capacitance, using Quadrature Bridge and other precision ac bridges at 1 kΩ. The scale of resistance from 1 Ω to 1 MΩ builds up with Kelvin double arms ac bridge. Precision reference airlines are being used as primary standards of HF impedance in frequency range of 10 kHz to 250 MHz.

**DC standards:** This activity is maintaining National Standards of DC voltage, DC current and DC resistance. The apex level calibration facilities have been provided to the ERTLs, ETDCs, Defence and other government organizations for dissemination of traceability.

**DC High Voltage Standards:** This group is providing calibration facility for High Voltage DC equipments ie. DC High Voltage probe, DC High Voltage divider, DC High Voltage Power Supplies and DC Volt meter, upto 100 kV. Primary standard of DC High Voltage is the Resistive Divider, which is traceable to Josephson Voltage Standard.

**An automation program using LabVIEW for the study of Standard Inductor**

This group has recently developed measurement automation program for the study of standard inductor over the required temperature range using LabVIEW Platform. This measurement automation program simultaneously controls LCR Meter and Air Bath. The high precision LCR Meter has superior measurement stability and air bath has the temperature stability of ± 0.03 °C over 24 hours, which provides a stable environment for the study of standard inductors.

Measurements have been taken for Standard Inductors of nominal values of 10 mH and 100 mH using the measurement automation. It is observed that air bath is providing very stable temperature for the study of standard inductor over the temperature range as shown in the Fig. 5.39. The inductance and resistance have been measured at different frequencies and plotted simultaneously for 10 mH as shown in Figs. 5.40 & 5.41.

Measurement automation program is providing the excellent platform for the study of standard inductor with better estimation of uncertainty parameters. Measurement automation also improves the reliability and efficiency of measurements.

![Temperature stability of air bath](image1)

![Inductance of 10 mH at 1 kHz](image2)

![Resistance of 10 mH at 1 kHz & 20 Hz](image3)
Bilateral comparison of low dc current with KRISS, Korea

This group is carrying out a bilateral comparison with KRISS, Korea for low dc current under Asia Pacific Metrology Programme (P1-APMP.EM.S-11). NPL is pilot lab for this comparison. Under this comparison, the measurements were carried out for low dc currents of 1 pA, 10 pA and 100 pA at NPL. The measurement setup consists of the calibrated Calibrator (as voltage source-traceable to JVS), Standard resistor (traceable to QHR) and electrometer (as current meter), all connected in series. Standard resistor of 1 GΩ and 100 GΩ were used, suitable voltage was taken from the calibrator to obtain the current of 1 pA, 10 pA and 100 pA. The artefact (electrometer) was then hand carried to KRISS and measurements were taken for about a week. The measurement setup at KRISS comprises of linear voltage ramp generator of 10 mV/s charging a capacitor and measuring the charging current. In this set-up, the non-linearity of a capacitor located in the integrator circuit is compensated by an analog feedback network. The diminution of the voltage slope was carried out by a Kelvin Varley divider. In order to calculate the generated current, the voltage output of the divider was measured by a high precision digital voltmeter (DVM), which was triggered by a precision external time base. The reference frequency of 10 MHz of the time base was monitored by a frequency counter. Using air capacitors in the range of 1 to 1000 pF, the set up can generate 100 aA to 100 pA. The reading of the DUT (electrometer) was recorded simultaneously with the output of the DVM by a computer. The ramping sequence was controlled by a computer through a relay controller via an optocoupler, which was used for galvanic isolation between the computer and ramp generator. All instruments were calibrated against KRISS Standards for the units of volt, capacitance and time/frequency.

Repeat measurements are being carried out at NPL as per the technical protocol. After measurements, the report will be sent to APMP for approval.

APMP Inter-comparison of 6½ Digit Precision Multimeter

This group along with LF, HF Voltage, current and Microwave Standards group is coordinating inter-comparison of 6½ Digit Multimeter (DMM) under Asia Pacific Metrology Programme (P1-APMP.EM-S8). For the first time, NPL is the Pilot laboratory for this inter-comparison, in which 16 countries are participating. The participating countries are Australia, Hong Kong, Sri Lanka, Kazakhstan, Egypt, South Africa, Thailand, New Papua Guinea, Vietnam, Jordan, Mongolia, Philippines, Malaysia, Indonesia, Syria and India.

The comparison will take about two years time for completion.

The measurement parameters are given in Table 1.

The DC measurements are taken by this group and ac measurements by LF, HF Voltage, current and Microwave standards group.

Out of 16 countries, only 8 countries are covered under ATA Carnet System. The inter-comparison is being carried out in two circulation schemes for countries covered under ATA Carnet system and for countries not covered under ATA Carnet system. Both circulation schemes have two loops.

### Table 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Nominal value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC Voltage</td>
<td>100 mV, 1 V, 10 V, –10 V, 100 V and 1000 V</td>
</tr>
<tr>
<td>DC Current</td>
<td>10 mA and 1 A</td>
</tr>
<tr>
<td>DC Resistance</td>
<td>100 Ω, 1 kΩ and 10 kΩ (using 4-wire)</td>
</tr>
<tr>
<td>AC Voltage</td>
<td>100 mV, 1 V, 10 V, 100 V and 700 V at 40 Hz and 1 kHz</td>
</tr>
<tr>
<td>AC Current</td>
<td>10 mA and 1 A at 40 Hz and 1 kHz</td>
</tr>
</tbody>
</table>
First loop of the countries covered under ATA Carnet for Australia, South Africa and Mangolia was completed during May to Nov, 2011. Similarly, the first loop for countries not covered under ATA Carnet system (i.e. Vietnam, Philippines, Papua New Guinea, Indonesia) is also in progress.

The second loop for countries covered under ATA Carnet started in Jan 2012 and is progressing as per the schedule.

**Comparative study of temperature influence on thick film and wire wound precision HV resistive divider.**

The study focused on determination of temperature influence of thick film and wire wound High voltage resistive divider. The deviation in resistance value depends upon the material used in resistance, type of construction and its coefficients. The temperature coefficient play vital role in calibration. The construction of HV divider reduces the temperature coefficient minimum by choosing some resistance with positive and other negative temperature coefficient. When these resistances are arranged in series, the total resistance changes for lower than that of individual but influenced with the working temperature of HV divider.

The study of deviation due to environment temperature from 20 to 30°C of Thick film divider and Wire wound divider up to 100 kV dc under stable condition of source traceable from National Standard. The nominal scale factor of both dividers are 10000:1, the comparative study investigate the influence of temperature in wire wound resistive divider is 5 ppm /°C where as thick film resistive divider have 1 ppm /°C

**Comparative study of voltage dependence and self heating in precision HV resistive divider**

The study focused to determination of voltage dependence of precision high voltage divider and self heating of HV resistance. High voltage resistive divider is a Primary Standard of DC High Voltage measurements. The traceability of HV measurements is directly related to divider’s traceability, to scale the voltage from Josephson voltage standard, which is primary standard of DC voltage. The change in effective resistance ratio with voltage depends upon self heating of resistance, electrostatic stress and leakage current. The design of divider and precision source minimize the above factor. The relative ratio change due to high voltage of HV divider in both positive and negative polarity is about 0.1 ppm /kV.

**LF & HF Voltage, Current and Microwave Standards:**

The activity has the responsibility for the establishment, maintenance, updating the Primary Standards and calibration facilities for the LF & HF Voltage, Current, Microwave Power, Attenuation and Impedance parameters, which are compatible to International Standards through continuous research and development. We are providing national traceability in the above parameters through apex level calibration to ISRO, DRDO, Naval Dockyard, Air Force, BEL, STQC labs, regional laboratories and the other user organizations. We regularly participate in international and bilateral comparisons (BIPM, APMP, EURAMAT) to establish a close degree of equivalence in measurements among the participating NMIs.

Traceability of the Low Frequency Voltage at 2 V, 10 Hz to 1 MHz and Current Standard at 5 mA, 40 Hz to 10 kHz have been re-established from the recently procured Multijunction Thermal Converter (MJTC). The established standards have better uncertainty ranging from 5 ppm to 20 ppm and will be used to calibrate the transfer standards of the user organizations.

We have participated in a EURAMAT Intercomparison for Low Frequency Voltage recently and the results are at par with the well established NMIs are very close to the reference line as shown in the Fig. 5.42.

An APMP Intercomparison P1-APMP.EM-S8 of 6½ digit DMM is being piloted by NPLI. Sixteen countries had participated.
We had provided an exclusive training in Low frequency voltage and current to Mr. Joe Panga from NISIT, (NMI) of Papua New Guinea in June 2011 at NPLI.

Broadband attenuation measurement facility based on the procured attenuator & signal calibrator system (8852/VM7) has been established. It will be used for the calibration of coaxial fixed & variable step attenuators in the frequency range from 10 MHz to 18 GHz. The complete measurement setup and the results are shown in Fig. 5.43 & Fig. 5.44.

Saood Ahmad, Bijendra Pal and A. K. Govil (Team – NPLI), have been awarded NPLI Technology Award 2011 comprising of Certificate & Cash Prize for the R&D invention based on Software Development for the Advancement in Measurements, which was registered by Copyright Office, Govt. of India for their contributions and innovation in the field of Electrical Metrology (Fig. 5.45). The developed softwares are of great use in calibration and maintaining the traceability chain of reference and transfer standards of LF & HF Voltage, Current and Microwave power. The award was presented during the National Technology Day Celebrations on 20 May, 2011 held at NPLI, New Delhi, India. Dr. Srikumar Banerjee, Chairman, Atomic Energy Commission & Secretary Department of Atomic Energy, Govt. of India, who was the Chief Guest at the said function, presented the awards.

This group has established a Vector network analyzer (VNA) based measurement facility in the frequency range of 1 MHz to 2 GHz for the characterization of RF power reference standards, power sensors and power mounts. We are working on establishing the in house measurement traceability for the one port broadband S-parameter measurements of VNA, from Dimensional Metrology and DC Resistance Standard. The measurement setup and the calibration kit are shown in Fig. 5.46 & Fig. 5.47. The established traceability will be used in assigning the VSWR/ reflection coefficient measurement and estimating...
the mismatch uncertainty for the microwave power measurement.

NPLI had piloted an APMP supplementary comparison for reflection coefficient magnitude and phase on coaxial a few years back. The Draft A report on the APMP supplementary comparison (P1-APMP.EM.RF-S3), Reflection coefficient magnitude and phase on coaxial have been prepared, compiled and submitted to APMP TCEM chair: Dr. Ilya Budovsky. The report was presented by him to all CCEM members presented at CCEM, BIPM meeting, Paris- France in March 2011. Subsequently, Draft A report have been circulated among the participating NMIs for their comments/suggestions.

The National Standard of AC High Current Ratio Measuring System up to 5000A/1A, 5A is shown in Fig. 5.48.

The National Standard of AC High Voltage Ratio up to 100 kV/100 V comprising of the Compressed Gas Capacitor, Air Capacitor & the Electronic Voltage Divider (EVD) is shown in Fig. 5.49.

Establishment of the National Standard for AC High Voltage Capacitance and Tangent Delta Measurement at NPL

AC High Voltage & High Current Standards

This section is maintaining National Standards for AC High Voltage and High Current Ratios at power frequencies (50Hz) by using Reference Standard High Voltage Ratio Measuring System and Reference Standard Current Transformers. Accordingly calibration services were provided for the calibration of Current Transformers, Current Transformer Testing Sets, Clamp Meters, CT Burdens, Voltage Transformers, Voltage Transformer Testing Sets, HV Probes, Electrostatic Voltmeters (ESVMs), HV Break Down Test Sets and Voltage Transformer Burdens etc. As many as 69 calibration certificates were issued to the electrical manufacturers and utilities in the country.

The National Standard of AC High Current Ratio Measuring System up to 5000A/1A, 5A is shown in Fig. 5.48.

Inputs and the feedback received from the participants have been incorporated in Draft A report. Preparation for the Draft B report will follow after the final approval from TCEM Chair.

AC High Voltage & High Current Standards

Fig. 5.47. Calibration kit of VNA

Fig. 5.48 The National Standard of AC High Current Ratio Measuring System up to 5000A/1A, 5A.

Fig. 5.49 National Standards for AC High Voltage
The uncertainties claimed in peer review in 2009 have been published in JCRB of BIPM. Minimum value is 70 ppm for active power, 90 ppm for reactive power and 80 ppm for apparent power.

Final report of Key comparison EURAMET.EM-K5.1, EURAMET Project 687 “comparison of 50/60 Hz power” has been published in KCDB. Pilot lab was UMM Turkey. We had taken part on normal test points, 120 V/5 A, PF = 1, 0.5 i/c and 0i/c, so at additional no power points: 120 V/0 A, 0 V/5 A & 0 V/0 A for DC offsets and for DC reference voltage measurement. Our results at every point are very close to the pilot laboratory. The results at 120 V/5 A, PF = 1, 0.5 i/c are given in Fig. 1, 2, 3 below:

### National Standard for AC High Voltage Capacitance and Tan δ

**Extraordinary Research Highlights**

Making use of the expertise and experiences available with the division, an innovative idea of using the recently installed C and Tan delta facility as kV meter for measurement of voltages as high as up to 200 kV has been implemented in addition to the C and Tan delta measurement and calibration services. This idea has added a new dimension in our measurement capability by adding one more parameter of AC high voltage measurement services from existing 100 kV to 200 kV for High Voltage Sources, kV Meters and High Voltage probes. This has been made possible by the induction of C and Tan Delta high precision measuring system.

### AC Power and Energy

PPCS primary power calibration system as shown in fig. 5.51, has been established traceable to DC voltage, resistance and time. We have calibrated our 3 phase and 1 phase reference standard against this PPCS. The uncertainties are established to within 30 ppm with respect to apparent power.
ECF earned during the financial year 2011-12 is 28 lakhs with 157 calibration & test reports

(NPLI is at 31st month)