DIVISION OF STANDARDS

AREA COORDINATORS

ELECTRICAL & ELECTRONIC STANDARDS

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THERMAL MECHANICAL & OPTICAL STANDARDS

Dr. D. Sen

INTRODUCTION

The Division of Standards has the responsibility of realising the units of physical measurements at internationally accepted level of accuracies and of dissemination of the units through calibration of measuring instruments of various agencies engaged in consumer protection, industrial quality control and scientific and technological advancement. Primary and transfer standards of six of the seven base S.I. units and for many of its derived units have been established at NPL. The international traceability of these standards is established through periodic calibrations/international intercomparisons with other countries. Since, all calibrations in the country should be traceable to the standards maintained at NPL, a large part of the activity of the Division of Standards is directed towards the development and maintenance of transfer standards, measurement systems and techniques and to provide calibration to user agencies.

During the last few years intensive R&D work has been carried out to update our primary standards in order to realise the units through their quantum phenomena based definitions. This has been successfully implemented for the units of time, length, electromotive force and electrical capacitance. The fundamental physical constants play a vital role in realisation of the system of units from phenomena based definitions. Measurement of these constants through different paths provides a test of our understanding of the physical phenomena and establishes the consistency of the units, realised through these phenomena. In view of the capability which has been generated at NPL in quantum metrology, we propose to begin work in the near future on determination of a few fundamental constants which are important for realisation of the system of units.

The total activity of the Division of Standards is divided into different projects. In each project a team of scientists is engaged in maintenance and updating the standards and calibration facilities related to a single or a group of closely related parameters. These projects are:

1. Standards of Length and Angle
2. Standards of Mass, Volume and Density
3. Standards of Force and Hardness
4. Standards of Pressure
5. Standards of Vacuum
6. Standards of Temperature
7. Standards of Radiometric and Photometric quantities
8. Standards of Acoustical Parameters
9. Standards of Time and Frequency
10. Standards of D.C. Electromotive Force, Resistance and Current
11. Standards of Capacitance and Inductance
STANDARDS OF LENGTH AND ANGLE

1. SCOPE AND OBJECTIVES
To establish, maintain and update the standards of length and angle and the facilities of measurement and calibration in terms of those standards.

2. STATUS AS ON 1.4.1981
The standards maintained were Hg$^{198}$ lamp, national prototype metre for length and a pair of 12 sided polygons for angle. The uncertainties of the standards are respectively $5 \times 10^{-8}$, 0.2 $\mu$m and 5 $\mu$ rad. Calibrations made were traceable to these standards. The accuracies of transfer were respectively 0.03 $\mu$m, 0.5 $\mu$m and 20 $\mu$ rad. During the last few years R&D work was carried out to establish the wavelength standard and laser measurement systems. The Kr$^{86}$ standard was installed and frequency stabilized He-Ne lasers were developed.

The dimensional calibration and testing service was continued. Measurement and testing facilities were updated by installation of a laser interferometer and other digital measuring instruments and by the development of a laser interferometer and of improved measurement techniques. Particular mention may be made of the work done on holographic interferometry and multiplexing.

Basic studies were made on the instabilities and collisional energy transfer in the He-Ne laser plasma and on the polarization properties of internal mirror He-Ne laser radiation. These studies enabled us to make improvements to the techniques of laser frequency stabilization. Theoretical studies were made on the coherence properties of laser radiation and on the thermal properties of gases.

3. PROGRESS IN THE YEAR
3.1 Standard of Length
Improvements have been made to the laser frequency comparator to be able to measure optical beat frequency by direct counting. The iodine stabilized He-Ne laser along with this frequency comparator has been installed and is being maintained as the primary standard of length. The frequency stability obtained is 5 part in $10^{10}$. Frequency of He-Ne laser of NPL calculable capacitor has been calibrated by comparison with the iodine stabilized laser.

The uncertainty in this frequency intercomparison was 2 parts in $10^9$.

3.2 Measurement System and Technique
A technique has been developed for frequency stabilization of the two mode randomly polarized He-Ne laser using a passive cavity. The method is useful for very small displacement measurement by heterodyning interferometry. We are now getting $2 \times 10^8$ resolving power (1/rd). Work is being carried out to increase the resolving power to $10^{10}$ or better in order to make this technique suitable for earth strain and similar geophysical measurements.

A servo-controlled Fabry-Perot interferometer has been fabricated. It can be locked for maximum transmission of radiation from a single frequency stabilized laser and also on the mean radiation frequency of a two mode stabilized laser. The performance of the Fabry-Perot interferometer is being evaluated for use in laser wavelength measurement. A scanning Fabry-Perot interferometer (optical spectrum analyser) has been fabricated to study spectrum of multimode lasers.

The resolution of the laser interferometer developed earlier has been improved from $\lambda/16$ to $\lambda/80$. An automatic switching control system has been designed and built for the interferometer for registration of data. It operates through relay controls actuated by zero crossing pulses and can be used also for automatic control in thin film coating and in frequency locking of lasers. A measurement system for block gauges based on this laser interferometer has been designed and is under fabrication [1].

An optical scanner has been designed and set up for testing parabolic trough solar collectors of size 1m x 1m. Data generated by the scanner has been useful in improving the collection efficiency of parabolic trough collectors designed at NPL.

3.3 Calibration
Calibration service to the industry and other organizations has been continued. A gauge block comparator of 0.02 $\mu$m resolution and digital readout has been installed. Developmental tests have been carried out on bearing rollers (straightness) for HMT Bearings Ltd. and on blood cell counting slide for ISI. 766 calibration and test certificates have been issued and Rs.42,890/- have been realised as calibration fee.
4. PROJECT TEAM:
D. Sen — Project Leader.
P.C. Jain, V.D. Dandawate, P.N. Puntambekar,
V.T. Chitnis, Mrs. Kousalya, Mahesh Chander,
V.G. Kulkarni, H.S. Dahiya, R.K. Khanna,
Mrs. V. Roonwal, L.M. Bhatia, B.K. Roy, A.K.
Kanjilal, N.K. Aggarwal, Ram Narain, V.D.
Sharma, M.K. Balchandani.

STANDARDS OF MASS, VOLUME AND DENSITY

1. SCOPE AND OBJECTIVES
To maintain the national prototype kilogram
and to build up and calibrate the transfer standards
of mass.
To test and calibrate the standards of
mass, volume, density and related parameters
for legal metrology and other applications.
To carry out Research and Development
in the areas needed for standardisation of mass,
volume and density.

2. STATUS AS ON 1.4.1981
2.1 Standard of mass
The unit of mass, its multiple and sub-multiples
have been realised through sets of calibrated
transfer standards of accuracies of 1 part in 10^7
in the range of 10g to 10kg and ± 1 mg in the
range of 1 mg and 5 g. These standards have
been maintained by regular intercomparison by
the method of group weighing, using balances
of required capacities and sensitivities. Recently
two of our 1 kg transfer standards were got
calibrated from PTB, West Germany. This was
done after a small change in the mass of one of
the standards was detected during intercom-
parison. The values given by PTB and those
obtained by us show excellent agreement.
Work has been started on development of
transfer standard masses from indigenous materi-
al and of 1 kg standard balances for intercom-
parison of our transfer standard with the nation-
al prototype kilogram. The standard mass pieces
were made with the required precision and sur-
face finish from nickel free stainless steel and
Ni-Cr alloy supplied respectively by NML,
Jamshedpur and DMRL, Hyderabad. The stabili-
ity of these standards is being studied.

References:
   1577
4. V.G. Kulkarni and P.N. Puntambekar,
For development of the standard 1 kg balance two alternatives were chosen. An existing 2 kg balance was modified for completely remote operation and its performance evaluated by installing it in a specially designed chamber with 0.001°C temperature uniformity and stability. At the expected sensitivity of 50 μg the performance of the balance was not satisfactory. The remote weight changing mechanism has been redesigned. The second balance being developed is a three knife edge interchangeable pan balance based on NPL, Teddington design. Most of the parts of the balance have been fabricated and the balance partly assembled. However the progress of this work has been delayed due to our inability to get the high precision knife edges either from Indian or from Foreign manufacturers.

2.2 Calibration

High sensitivity balances of capacity ranging from 3g to 10 kg have been installed in stable environmental conditions to provide calibration in term of our transfer standard masses. The accuracies of calibration are 2 prts in $10^7$ in the range 10g to 10 kg and ± 2 μg in the range 1 mg to 5 g. Facilities have been established also for calibration of hydrometers and of volumetric measures in terms of our standard masses. The accuracies of both density and volume measurements are 1 part in $10^4$. 25 litre automatic pipettes of accuracy 1 part in $10^4$ were designed and fabricated for calibration of still higher capacity measures. These pipettes have been supplied to BHEL and Central Water and Power Commission.

3. PROGRESS IN THE YEAR

3.1 Two Pan Interchangeable 1 kg Balance

The blanks of the bearing planes and knife edges were got fabricated by an Indian firm in Varanasi. The final polishing of these knife edges and bearing planes have been completed and found to be satisfactory for the purpose of using these in the subsidiary suspensions. To get an overall idea of the straightness and the thickness of the edge of the knife edge, the microphotograph with magnification 202 were taken. The width of the edge of the knife is found to be of the order of 5 μm. On close scrutiny, it has been seen that there are chippings at various places which may not matter when the knife edges are used only as a suspension device. Further efforts are being made to avoid the chippings and to decrease the width of the edge for obtaining the knife edges for the beam.

3.2 Standard of mass

The further fabrication work of 200 g weights was taken up during the year. Four weights of 200g each of the Nickel-Chromium alloy which was manufactured by the DMRL, Hyderabad have been made. Out of four, two have been finally polished which are awaiting their calibration.

A new 10 kg balance with optical read out has been set up. The balance has a magnetic damping and is able to read up to 0.2mg in 10kg.

3.3 Density standards

The work regarding the setting up of temperature bath with a stability of 0.02°C has been initiated. This hydrostatic bath will be used for calibration of the density hydrometers and later on for realising the artifacts as standards of density.

3.4 Prototype testing for a baby weighing scale

A small scale industry in Tamil Nadu, through the Controller of Weights & Measures, Tamil Nadu, has approached us for the prototype testing of a steeple type baby weighing scale. This is a new instrument, though based on the existing principle, is supposed to be used in the villages. We have laid down the specific tests, test procedures and the criterion for acceptance for such machines. The machine has been tested and the report has been sent to the manufacturers with a copy to the Controller, Weights and Measures.

3.5 Calibration

Besides the calibration of secondary standards of mass and the capacity, measures for States Departments of Legal Metrology, a number of precision weights, volumetric glassware like automatic mercury pipettes, butyrometers etc., and large number of hydrometers of various types have been calibrated for the research and industry. 353 calibration certificates, with Rs.29,696/- as test fee, have been issued this year.

Calibration of travelling standards, received under the Asia/Pacific Metrology Programme
in which several countries like Malaysia, and Australia are taking part, have been completed. Calibration scheme of the two travelling standards together with one standard of our own have been worked out for double substitution method. Necessary arithmetic for calculations of the variances and different statistical tests was also carried out. A random uncertainty of 0.08 mg has been achieved in these measurements.

4. PROJECT TEAM
S.V. Gupta — Project leader.

STANDARDS OF FORCE AND HARDNESS

1. SCOPE AND OBJECTIVES
To establish the standards of force and hardness and to provide calibration facilities to the users.

2. STATUS AS ON 31.3.1981
Standard of force is maintained through a dead weight cum lever multiplication machine. It has dead weight capacity of 100 kN with 0.002% accuracy and lever multiplied capacity up to 1 MN with 0.01% accuracy. This machine has been in use for calibration since last year. Earlier the standard of force was maintained by means of a NPL designed and fabricated dead weight machine of 30 kN capacity and 0.004% accuracy.

3. PROGRESS IN THE YEAR

3.1 Standard of force and hardness
A hydraulic multiplication system has been designed and installed for calibration of force measuring devices up to 500 kN. The capacity of the machine is being extended up to 1 MN with 0.02% accuracy.

Developmental work on load cells for use as transfer standard has been started and two load cells respectively of 5 kN and 50 N capacity have been made.

Design has been started for a standard hardness machine.

3.2 Calibration
530 force measuring devices were calibrated for various users and the calibration fee of Rs. 1,00,075/- was realised.

4. PROJECT TEAM
M.K. Das Gupta — Project leader

STANDARDS OF PRESSURE

1. SCOPE AND OBJECTIVES
To establish pressure standards and facilities for the calibration of high pressure measuring instruments and to improve the quality of Indian instruments to satisfy international standards.

To set up primary and transfer standards and facilities for calibration of pressure measuring instruments. The primary standards will be used by the NPL to calibrate transfer standards of the user industry. The calibration facilities will be used to calibrate pressure gauges extensively used by the Indian industry in chemical and petrochemical plants, boilers, and the manufacture of compressors etc. A pressure range from 1 bar to 10 K bar will be covered.

2. STATUS AS ON 1.4.1981
A detailed study of the equipment and the problems related to pressure standards had been made and the measurement of uncertainties and the limitations of the equipment used in the relevant areas were also studied in detail. The necessary equipment for the establishment of pressure standards up to 10 K bar had been procured. The calibration facilities will be used by the Indian industry in chemical and petrochemical plants, boilers and the manufacture of compressors etc.

3. PROGRESS IN THE YEAR
Work for the erection and commissioning of equipment related to primary and transfer standards for measurement of pressure i.e. controlled clearance piston gauge and dead weight testers up to 10 K bar has been undertaken.

Effect of pressure and temperature on the dielectric and electrical properties has been studied on a series of copolymers. A high pressure dielectric cell has been designed and fabri-
eated to measure the various electrical and dielectrical properties over a wide range of temperatute and pressure. The results obtained have been published in international journals [1].

References

4. PROJECT TEAM
J.K.N. Sharma — Project leader.
K.K. Jain.

STANDARDS OF VACUUM

1. SCOPE AND OBJECTIVES

To establish vacuum standards and facilities for the calibration of vacuum gauges and testing characteristics and performance of vacuum pumps and vacuum instruments for improving the quality of Indian instruments to meet the international standards and to develop the indigenous capability for the design of vacuum equipments.

To set up primary and transfer standards facilities for calibration of vacuum gauges, testing of vacuum pumps and vacuum equipments. The primary standards will be used by the National Physical Laboratory to calibrate transfer standards of the user industry. The calibration facilities will be used to calibrate pressure gauges including altimeters, transducers, vacuum valves, vacuum systems, and fittings. A pressure range of 1 atmos. down to the $10^{-7}$ torr will be covered.

To establish ultra high vacuum facilities of the order of $10^{-11}$ torr and to develop the UHV techniques for use in scientific research to surface sciences and in the allied fields with-in the country.

Development of vacuum instrumentation.

2. STATUS AS ON 1.4.1981

A standard McLeod gauge [1] using variable compression techniques used as a primary standard of pressure in the range of $10^{-2} - 10^{-5}$ torr with an accuracy of 2-3% has been established. Vacuum standard from $10^{-3}$ to $10^{-6}$ torr using orifice techniques has also been established. A special oil manometer for measuring pressure from 10 torr to $10^{-2}$ torr has been developed and is being successfully used for calibration in this region.

Calibration of gauges: The standards maintained by the NPL as described above are used for precise calibration of the vacuum gauges as per accuracy of the standard used.

Performance characteristics of rotary pumps: An equipment for measuring characteristics of rotary vacuum pumps has been satisfactorily designed, fabricated and tested as per ISO and ISI specifications.

The apparatus for measuring the characteristics of high vacuum diffusion pumps has been designed and fabricated and the comparative study of the various characteristics of diffusion pump with conductance method and flowmeter under different conditions are going on.

The Penning and Pirani gauges to measure vacuum down to $10^{-5}$ torr have been satisfactorily designed and developed. Penning and Pirani controllers have been successfully designed and developed for system automation. Automatic electronic sequence control system has also been designed and developed for the vacuum system.

Vacuum Leak Detector based on thermal conductivity principle suitable for vacuum coating, vacuum metallurgy, vacuum drying, vacuum impregnation etc. has been successfully designed and is being commercialised by the local industry through National Research Development Corporation.

A special McLeod gauge using piston and cylinder assembly and a Vacuometer have been developed for industrial use.

The infra-structure in vacuum technology has been used to develop silver impregnated graphite contacts and different types of vacuum valves such as (1) A bakeable glass-isolation valve
(2) A two way metal vacuum valve
(3) Extra fine control needle valve both line mounting and panel mounting
(4) the quarter swing valves of 2”, 4” and 6” sizes; and (5) Gate valves.

Ultra high vacuum of $3 \times 10^{-9}$ torr has been produced by using oil diffusion pump system.

Designed and developed the complete automatic as well as semi-automatic vacuum sys-
tems for the first indigenous scanning electron microscope made in the country.

3. PROGRESS IN THE YEAR

The dynamic method of calibration of vacuum gauges from $10^{-2}$ - $10^{-7}$ torr using diffusion pump has been designed and various components are being assembled. This is to improve the accuracy of the existing dynamic system for gauge calibration for the above range.

The work on the study of power consumption of rotary pumps at varying pressure is currently going on.

While studying the performance characteristics of the oil vapour pumps, a fundamental study of molecular flow inside a test dome has been undertaken in great detail resulting in revision of earlier work.

Comparison of two pumping speed measuring methods of oil diffusion pumps has been done to standardise the position of conductance tube.

The vacuum group has received the NPL Merit Award of 1981 for development and establishment of vacuum standards and related techniques for generation and measurement of high vacuum.

References


4. PROJECT TEAM

J.K.N. Sharma — Project leader.
A.C. Gupta, P.K. Ahwini Kumar, D.R. Sharma, Pradip Mohan.

STANDARDS OF TEMPERATURE

1. SCOPE AND OBJECTIVES

To establish, maintain and update the primary standard of temperature. To realise the International Practical Temperature Scale by development and maintenance of the fixed points on that scale and the transfer standard instrument and to provide the associated calibration service.

To provide the service for measurement of thermal properties of materials.

2. STATUS AS ON 1.4.1981

The unit of temperature has been realised with the accuracy of $\pm 0.5$ m K by establishing and maintaining the cell for triple point of water. Periodic improvements and re-evaluation of the triple point cell have been carried out. A number of fixed points of the IPTS over the range 90.188K to 1337.58K have been established and are maintained. The accuracy of their realisation is 1m K to 2m K upto 693.72 K and 0.1 K for higher temperatures. Platinum resistance thermometers, platinum-iridium thermocouple and optical pyrometer are used as transfer standard instruments for measurement of temperatures. The accuracy of calibration is 0.001°C to 0.005°C over 183°C to 630°C by platinum resistance thermometry, 0.3°C to 0.5°C over 630°C to 1064°C by thermocouple thermometry and 0.5°C to 2°C over 1064°C to 1800°C by optical pyrometry. The standard platinum resistance thermometers used have been designed and fabricated at NPL. Industrial type platinum resistance thermometers have been developed and supplied to other organisa-
tion. Various methods for measurements of thermal conductivity and thermal expansion have been established [1,2].

3. PROGRESS IN THE YEAR

3.1 Standard of Temperature

The fixed points established earlier and transfer standard instruments have been maintained and reevaluated. Improvements have been made to the triple point of water cell. The fixed points of indium, tin and zinc have been established for calibration of thermocouples.

Work has been carried out to develop a platinum resistance standard thermometer suitable up to 962°C (silver point) in order to replace the thermocouple standard in that range. Improvements are being made in the construction technique for ceramic enclosed platinum resistance thermometer.

3.2 Calibration and Testing

The service for calibration of temperature sensors and testing of materials for thermal properties have been continued. During the year 300 calibration and test reports have been issued and Rs.26,888/- were realised as calibration and test fees. Two stem type platinum resistance thermometers have been fabricated and supplied with calibration to BHEL. A fee of Rs.11,000/- has been realised for this service.

References


5. PROJECT TEAM

K.D. Baveja — Project leader.

STANDARDS OF RADIOMETRIC AND PHOTOMETRIC QUANTITIES

1. SCOPE AND OBJECTIVES

To maintain and update the national standards of luminous intensity, luminous flux, illuminance, luminance and other associated parameters and to provide calibration traceable to these standards. To develop and instal an absolute radiometer for realisation of the unit of radiant intensity. To provide service for measurement of optical and calorimetric properties of materials.

2. STATUS AS ON 31.3.1981

The units of luminous intensity (candela), luminous flux (lumen), colour temperature and spectral irradiance have been realised by means of sets of standard lamps, calibrated by BIPM, NPL, UK, PTB, West Germany and NBS, USA. These standards are maintained by mutual and international intercomparisons. Transfer standards for calibration have been derived from these national standards. The accuracies of calibration is 1% to 2% for luminous intensity and flux and ± 5 K to ± 10 K for colour temperature.

Facilities have been established for life testing of lamps, goniophotometric test of luminaires, colorimetric measurement, spectral and luminous transmittance and reflectance measurements and refractive index measurement.

3. PROGRESS IN THE YEAR

3.1 Standards of Radiometry and Photometry

A set of four travelling standard lamps have been calibrated under the Asia Pacific Metrology Programme. For three of these lamps our values agree within 0.8% of the value assigned by the Australian Standards Laboratory. The fourth lamp is showing a difference of 1.7% which is larger than the uncertainty of our measurement. Further measurements are being made on this lamp.

Work is continuing on the design of an electrically compensated thermopile radiometer for absolute measurement of radiant intensity.

3.2 Calibration and Testing

Calibration and testing of lamps, luminaires and optical instruments and components have been
continued. During the year 252 calibration and test certificates were issued and Rs.1,23,020/— were realised as calibration fees.

4. PROJECT TEAM
S.R. Das — Project leader.
K.S. Sharma, K.C. Joshi, Om Prakash, Mrs. S. Manrai, O.P. Bholo, Mrs. S. Mallela, Madan Mohan, Kailash Chand.

2.3 Testing
Acoustics and electro-acoustic devices, instruments and materials received from outside parties have been evaluated for performance requirements.

2.4 Consultancy
Advice has been rendered to outside parties on various problems in acoustics.

3. PROGRESS IN THE YEAR
3.1 Standards of Acoustical Parameters
Primary calibration of laboratory standard microphones by reciprocity method in a coupler cavity and an accuracy of + 0.2 dB was achieved. Factors contributing to inaccuracy have been identified and efforts are under way to improve the accuracy to better than ± 0.1 dB. In an international round-robin comparison of transfer standard microphones and piston-phone among national standards laboratories of Australia, China, India, Indonesia and New Zealand under the Asia-Pacific Metrology Programme, transfer standard microphones and pistonphone received from Australia were calibrated.

3.2 Calibration
14 items received from outside parties were calibrated. Calibration fees realised amounted to Rs.1205/—.

3.3 Testing
Performance evaluation of 133 items received from outside parties was carried out and test fees amounting to Rs.11,786/- were realised.

3.4 Investigations
Suitability of some toy guns, pistons and balloons as sound sources for investigations of room acoustics, reverberations and echoes was studied.

4. PROJECT TEAM
A.F. Chhapgar — Project leader
STANDARDS OF TIME AND FREQUENCY

1. SCOPE AND OBJECTIVES

To realise the base units of time and frequency and to disseminate standard time and frequency signals to the nation and the neighbouring countries.

2. STATUS AS ON 1.4.1981

The time standard at NPL is maintained with the help of two Atomic Cesium Standards - one kept at NPL and the other at ATA (Standard Time Broadcast station). Other secondary standards at NPL include one Rubidium Vapour Frequency Standard and three crystal Oscillators. The accuracy maintained at NPL with regard to frequency or time intervals is $5 \times 10^{-12}$. The uncertainty of "Epoch" or "Time Instant" is less than 50 microseconds (upper limit). At present, there is no direct accurate time (Epoch) link between India and other established international laboratories. However, with the help of NNSS satellite receiver at NPL, Epoch can be monitored to about $25 \mu$ seconds. This combined with the monitoring of GBR (16 kHz) signals (NNSS monitoring help in cycle identification of 16 kHz) gives an Epoch accuracy of a few $\mu$ seconds. VLF monitoring facilities have also been established [1,2].

The standard Time Broadcast continue to be made on three carrier frequencies viz. 5,10 and 15 MHz [3].

3. PROGRESS IN THE YEAR

3.1 Time Transfer and Time Dissemination Experiments via APPLE

During early 1982, time transfer and time dissemination experiments using Indian Experimental Satellite APPLE were started in collaboration with ISRO. The technique of time comparison via TV, developed at NPL, was tried over long distances, between New Delhi and Madras, taking advantage of broadcast of cricket matches over P & T lines and the results were cross-checked using the same technique via satellite APPLE.

3.2 Rubidium Vapour Frequency Standard

Development work on Rubidium Vapour Frequency Standard is in Progress. Hyperfine resonance and initial locking of crystal oscillator have been observed for the first time [4].

3.3 Contribution to CCIR Volume VII

Two documents, "Time and Frequency Comparisons via 6 kHz Transmissions from GBR,UK" and "Time Dissemination and Time Comparison by means of French-German Satellite Symphonic-1" based on the work done at NPL [5,6] were presented to final meeting of CCIR held in Geneva in September 1981 and were accepted for inclusion in CCIR volume VII.

3.4 Time Dissemination Service via INSAT

Time Dissemination Service via Indian Satellite INSAT, a project submitted to INSAT Coordinating Committee, was discussed at Technical Advisory Group of INSAT. Preparatory work in this direction has already been initiated at NPL.

3.5 Calibration of Clocks using NPL Portable Clocks

NPL Portable clock was used to calibrate clocks at SHAR, Sriharikota and Laser Station (STARS) at Kavalur, Madras.

3.6 Installation of NNSS-Satellite Receiver

A NNSS (Navy Navigation Satellite System) Satellite receiver was installed and timing accuracies of 25 microseconds order were achieved.

References

2. A. Sen Gupta, G.K. Goel and B.S. Mathur, JIETE 27 (1981), 403

Fig.3: Atomic Standards of Time & Frequency at NPL


4. PROJECT TEAM
B.S. Mathur — Project leader.

STANDARDS OF DC ELECTROMOTIVE FORCE, RESISTANCE AND CURRENT

1. SCOPE AND OBJECTIVES
To realize the units of dc voltage (volt),resistance (ohm) and current (ampere) and to establish physical standards of these parameters at international levels of accuracy.
To establish techniques of measurements of ratios of voltage, resistance and current.
To provide apex level calibration service to user organizations.

2. STATUS AS ON 1.4.1981
2.1 Standard of E.M.F.
The primary standard of dc voltage is maintained in the form of a bank of one ohm standard resistors kept in constant temperature oil bath. Mutual intercomparison technique is employed to assign values to each resistor using direct current comparator (precision 1 part in 10^7).

Standard resistors of lower and higher denominations covering the range 10^{-5} to 10^5 ohm are also maintained at constant temperature and assigned values against 1 ohm standard. Facilities have been created for measurement of resistance, in the range of 10^{-5} to 10^{16} ohm.

2.3 Facilities have been created for the calibration of various dc standards and measuring instruments e.g. standard cells, potentiometers, standard resistors, constant current and voltage sources, calibrators, voltage, current and resistance measuring instruments etc.

3. PROGRESS IN THE YEAR
3.1 The as-maintained “ohm” was compared with the absolute “ohm” derived from calculable capacitor. New values have been assigned to the one ohm standard resistors traceable to the calculable capacitor (uncertainty ± 0.62 ppm).

3.2 E.M.F. Standard
Work on development of dc transfer standard based on Zener diode and that of temperature-controlled air-enclosure for it, was continued.

3.3 Measurement of Low Voltages
Facilities for precision measurement of small voltages (nanovolt) were established.

3.4 Intercomparison of E.M.F. Standards
NPL India acted as the pilot laboratory for intercomparison of dc voltage standard among the countries under the Asia/Pacific Metrology Programme: Intercomparison with Australia based on (i) “Transvolt” and (ii) Zener diode voltage standard “Cropico”, has shown that Indian and Australian standard of emf (one volt level) agree with each other within 0.5 μV.

Intercomparison of VNIIIM (USSR) Standard Cells with those of NPL (India) was also carried out.

3.5 Calibration Service Rendered
Calibration work for a large number of agencies e.g. Regional Calibration Centres, Defence
Establishments, various Government Departments, Research Institutes, Public Sector Undertakings and Private Industries was carried out.

4. PROJECT TEAM
V.K. Batra – Project leader.
S.K. Mahajan, T.V. Ganapathy, P.K. Mittal
B. Sircar, Amreek Singh.
K.Chandra

STANDARDS OF CAPACITANCE AND INDUCTANCE

1. SCOPE AND OBJECTIVES
To set up primary standard of capacitance based on calculable capacitor and to realize the units Farad, Henry, Ohm and Weber through it and to set up the scales of capacitance, inductance and a.c. resistance. To provide apex level calibration service to user organisations.

2. STATUS AS ON 1.4.1981
2.1 Primary Standard of Capacitance
The vertical model of calculable capacitor based on Thompson-Lampard principle was set up. The accuracy obtained in the realization of the absolute value of capacitance is 5 parts in 10^7. The technique to calibrate a 10 pF quartz capacitor against the calculable capacitor using a specialized transformer bridge was perfected and a 10 pF capacitor was calibrated with an accuracy of 5 parts in 10^7. The setting up of this facility has put NPL on par with major standards laboratories in the world.

2.2 Primary Standard of Inductance
The Maxwell-Wien bridge for capacitance-inductance transfer was evaluated. Preliminary experiments on the realization of inductance from capacitance using Maxwell-Wien bridge and Resonance Technique were completed. Further work to improve the accuracy of inductance transfer is in progress.

2.3 Scale of Capacitance and Inductance was partially built up and calibration facilities for capacitance and inductance standards and impedance bridges were set up.

Fig4: Set up for realization of "Absolute ohm" from calculable capacitor.

3. PROGRESS IN THE YEAR
3.1 Primary Standard of Capacitance : [1]
Based on the calculable capacitor the scale of capacitance was built up from 0.001 pF to 10 µF with enhanced accuracies varying from 0.5 ppm to 100 ppm. The present accuracies of standards and calibration facilities are given in the following table.

3.2 Primary Standard of Inductance : [2]
The unit of inductance, Henry has been realised from the unit of capacitance with the help of Maxwell-Wien bridge and Resonance Technique. The uncertainty in the realization of a 10 mH inductor at 1 KHz by both the techniques is about 10 ppm. This has brought the standard of inductance on par with other standards laboratories in the world.

The scale of inductance has been built up from 10 µH to 10 H with uncertainties varying from 10 ppm to 500 ppm. The present accuracies of the standards and calibration facilities are given in the following Table.

3.3 Absolute "Ohm" Determination
The unit of resistance "Ohm" has been realized through the calculable capacitor with the help of precision bridges using four terminal-pair techniques and intermediate standards of 1000 pF capacitors, 100 kΩ and 1 kΩ resistors. The components of these bridges and the standards are kept at a steady temperature in an oil bath with a temperature stability of a few milli-degrees. The absolute Ohm was determined with an uncertainty of ± 0.62 ppm. The value of absolute ohm thus determined is
### TABLE 1

<table>
<thead>
<tr>
<th>Standard</th>
<th>Uncertainty</th>
<th>Calibration Facilities</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Model of Calculable Capacitor</td>
<td>5 parts in (10^7)</td>
<td>10 pF and 100 pF quartz capacitors</td>
<td>1 part in (10^6)</td>
</tr>
<tr>
<td>10 pF and 100 pF quartz capacitor</td>
<td>5 parts in (10^7)</td>
<td>10 pF, 100 pF and 1000 pF air capacitors</td>
<td>5-10 parts in (10^6)</td>
</tr>
<tr>
<td>10 pF, 100 pF and 1000 pF air capacitors</td>
<td>1-2 parts in (10^6)</td>
<td>0.001 (\mu F - 1 \mu F)</td>
<td>5-10 parts in (10^5)</td>
</tr>
<tr>
<td>0.001 (\mu F - 1 \mu F)</td>
<td>1-5 parts in (10^5)</td>
<td>10 (\mu F - 100 \mu F)</td>
<td>1-2 parts in (10^4)</td>
</tr>
<tr>
<td>10 (\mu F)</td>
<td>1 part in (10^4)</td>
<td>0.001 pF - 1 pF</td>
<td>2-5 parts in (10^3)</td>
</tr>
<tr>
<td>0.001 pF - 1 pF</td>
<td>1 part in (10^4)</td>
<td>10 aF - 0.001 pF</td>
<td>5 parts in (10^3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standard</th>
<th>Uncertainty</th>
<th>Range</th>
<th>Calibration Facilities</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 mH, realized from 100 mH capacitance</td>
<td>1 part in (10^5)</td>
<td>10 mH, 100 mH</td>
<td>1 part in (10^4)</td>
<td></td>
</tr>
<tr>
<td>1 mH, 1 H</td>
<td>5 parts in (10^5)</td>
<td>1 m H, 1 H</td>
<td>1 part in (10^4)</td>
<td></td>
</tr>
<tr>
<td>10 H</td>
<td>1 part in (10^3)</td>
<td>10 H, 100 H</td>
<td>5 parts in (10^3)</td>
<td></td>
</tr>
<tr>
<td>100 (\mu H)</td>
<td>1 part in (10^4)</td>
<td>100 (\mu H)</td>
<td>5 parts in (10^4)</td>
<td></td>
</tr>
<tr>
<td>10 (\mu H)</td>
<td>1 part in (10^3)</td>
<td>10 (\mu H)</td>
<td>1-2 parts in (10^3)</td>
<td></td>
</tr>
</tbody>
</table>

\(\Omega_{abs} = (\Omega_{BIPM} + 1.0 \mu\Omega) + 0.62 \mu\Omega\)

### 3.4 Development of Inductive Voltage Divider

Design and fabrication of 4-dial and 6-dial inductive voltage dividers was completed. The technique to calibrate these IVDs with suitable accuracies was also established.

### 3.5 Calibration Service Rendered

Calibration of Capacitance and Inductance Standards and impedance bridges from various organisations and laboratories at Echelon I level is carried out.

### References


### 4. PROJECT TEAM

S.L. Dahake – Project leader.
K.Chandra
STANDARDS OF LOW & HIGH FREQUENCY VOLTAGE, CURRENT, POWER, ENERGY, ATTENUATION, IMPEDANCE AND NOISE

1. SCOPE AND OBJECTIVES

The project is aimed to establish, maintain and update the primary and transfer standards for measurement of: Voltage, current, power ratio (20 Hz - 30 KHz) and energy (50 Hz); Voltage, current, power, attenuation noise, frequency and impedance (30 KHz - 1 GHz), and to establish calibration facilities for these parameters.

2. STATUS AS ON 1.4.1981

2.1 A.C. & L.F. Voltage, Current, Power and Energy

Primary standard for A.C. power based on Electrodynamic Watt meters and transfer standard for single and three-phase power and energy based on electronic multiplication circuit have been established.

AC and LF voltage and current standards at transfer level based on thermoelectric comparator, r.f. micropotentiometer and thermal converters have also been established.

2.2 H.F. Voltage

Transfer standards of H.F. voltage based on R.F. micropots, thermal voltage converters and ATVM have been established.

2.3 H.F. Attenuation

Primary standard of HF attenuation based on WBCO is being established (10 - 100 MHz) to aim an accuracy of 0.001 dB/10 dB. Transfer standard based on IF and RF techniques has been established.

2.4 Frequency Measurement upto 1 GHz

Facilities for frequency measurement upto 1 GHz based on frequency counter locked to cesium clock have been established. Standard frequency signals from 0.1 Hz to 500 MHz have been generated from 1 MHz signal obtained from cesium atomic clock.

2.5 H.F. Impedance

Facilities for lumped circuit impedance parameters based on precision LCR bridge, trans-
former ratio arm bridge, Twin-tee bridge and RX meter are being established upto 300 MHz.

3. PROGRESS IN THE YEAR

3.1 Primary Standards of AC, LF Voltage and Power [1]

Primary standards of AC and LF voltage and current measurement at 1 KHz based on multi-junction thermal converters have been established with AC/DC transfer uncertainty of $2 \times 10^{-6}$ upto 3 V and 10 mA.

L.F. power measurement facility based on voltage and current measurement and absorption power meter (100 W upto 30 KHz, uncertainty ± 0.1%) have been established.

3.2 Standards of H.F. Voltage [2]

Compatibility amongst various transfer standards of HF voltage has been established.

Work on primary standard of HF voltage based on calorimeter power head has been started.

3.3 Extension of Calibration Facilities

Calibration facilities have been extended in the following ranges:

a) AC & LF voltage - upto 1000 volts (20 Hz to 100 KHz)
b) AC & LF current - upto 20 Amp. (20 Hz to 5 KHz)
c) AC power and energy - 50 Amp. to 500 Amp, single phase
d) HF voltage - upto 30 volt (1 MHz to 220 MHz) [3]

3.4 International Intercomparison

International intercomparison of thermal converters of VNIM, USSR with NPL thermal transfer standards has been carried out at NPL at 1 KHz, 2KHz, 10 KHz, 20 KHz, 100 KHz and 1 MHz and 1 volt, 3 V, 10 V, 30 V and 100 V levels.

3.5 Calibration Services

Using the above-mentioned facilities, a large number of instruments e.g. Precision A.C. Voltmeters, A.C. Ammeters, power meters, power factor meters, rotatory sub-standard type energy meters (Single Phase and 3-Phase both), precision calibrators, digital multimeter, signal generators, frequency counters, selective microvoltmeters, attenuators etc. have been calibrated for various user agencies.
References

4. PROJECT TEAM
Sharwan Kumar — Project leader (Abroad on Special leave)
K. Chandra

STANDARDS OF POWER, ATTENUATION FREQUENCY, IMPEDANCE AND NOISE AT MICROWAVE FREQUENCIES

1. SCOPE AND OBJECTIVES
To establish, maintain and update the primary and transfer standards of power, attenuation, impedance, frequency and noise in the microwave frequency range from 1 GHz to 40 GHz at internationally accepted accuracies.

To establish apex level calibration facilities at microwave frequencies (1 GHz – 40 GHz) in order to meet the calibration requirements of various Government departments, Defence, Establishment, Regional Calibration Laboratories, Research and Academic Institutes and Public and Private Sector Industries.

2. STATUS AS ON 1.4.1981
2.1 Using thin film bolometer mount as transfer standard of microwave power with ± 0.37% uncertainty in effective efficiency, a feed through power measuring standard was established with an uncertainty of ± 0.8% at 10.0 GHz. Work on micro calorimetric technique was in progress.

2.2 Facilities for measurement of microwave frequencies from 1 GHz to 18.0 GHz have been established. Study of Frequency and Power Stability of different phase locked sources was completed. Standard Microwave Signals had been generated in X and XN bands.

2.3 Parallel IF substitution technique for attenuation measurement up to 100 dB was established in coaxial and waveguide systems with a total uncertainty of ± 0.05 dB/10 dB (± 1.0 dB in 100 dB) in 1–24 GHz range.

2.4 Coupled sliding load technique for VSWR measurement in 2-12.4 GHz range was established with an uncertainty of ± 0.005 in minimum VSWR of 1.02. Tuned reflectometer is being used for measurement of reflection coefficient in X-band.

Precision microwave components such as quarterwave short, moveable precision short circuit have also been developed in X-band.
3. PROGRESS IN THE YEAR

3.1 Microwave Power Standard
Standard bolometer mounts using thin film elements fabricated with the assistance of NPL's thin film group have been developed for use as microwave power standards. These bolometer mounts have been compared and assigned values for their effective efficiencies at 10 GHz by the Electro Technical Laboratory, Japan. Preliminary measurements on these mounts by microcalorimetric technique showed encouraging results [2,1].

3.2 Microwave Attenuation
The audio substitution technique has been established with an uncertainty of 0.02 dB/10 dB with a single step measurement of 30 dB. The total range of the technique is 60 dB with total uncertainty of 0.05 dB/10 dB. The frequency range for both the measurements is 1 to 12.4 GHz in coaxial and waveguide systems [1].

3.3 Microwave Frequency Standard
Power and frequency stability study of the phase locked microwave sources (BWO) was carried out using spectrum analyser, microwave counter and digital power meter with output connected to strip chart recorder [3,4,1].

3.4 Microwave Impedance
A standard mismatch of VSWR $1.10 \pm 0.005$ has been developed.

3.5 Microwave Noise Standards
Transverse level (Echelon II) equipment for measuring noise parameters, such as noise factor, noise figure, excess noise ratio and equivalent noise temperature, in the frequency range 0.01 GHz to 18.0 GHz has been procured and is being set up.

References

4. PROJECT TEAM
V.K. Agarwal – Project leader.
K. Chandra,