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NATIONAL PHYSICAL LABORATORY
NEW DELHI

CONTENTS

PREFACE

DIVISION OF STANDARDS

PHYSICO MECHANICAL STANDARDS

Standards of Length & Angle	1
Dimensional Metrology	1
Standards of Mass, Volume & Density	1
Standards of Force & Hardness	2
Standards of Pressure	2
Standards of Vacuum	3
Standards of Temperature	3
Optical Radiation Standards	4
Infra Red Radiation Standards	4
Standards of Acoustics	4
Ultrasonic Standards	4

ELECTRICAL & ELECTRONIC STANDARDS

Standards of Time & Frequency	6
Standards of DC, EMF, Resistance & Current	6
Capacitance, Inductance & AC Resistance Standards	6
AC, LF & HF Standards	7
Microwave Standards of Power, Frequency, Noise Attenuation & Impedance	8
Josephson Voltage Standards	8
Low Dimensional Coulomb Systems	8
Calibration Service Programme	9
Testing & Calibration Activities at NPL	9

MATERIALS CHARACTERIZATION DIVISION

Characterization of Materials by Chemical Methods	13
Characterization of Materials by Spectroscopic Methods	13
Characterization of Materials by EPR Spectroscopy	14
Characterization of Materials by X-Ray Diffraction and Fluorescence Techniques	15
Characterization of Materials Regarding Microstructure by Transmission & Scanning Electron Microscopy and Electron Diffraction Techniques.	16
Characterization of Single crystals regarding Perfection and relevant Instrumentation	17
Growth and Characterization of single crystals	21
Characterization of Materials regarding Surface Area and Porosity	21

CRYOGENICS & SUPERCONDUCTIVITY

Cryogenic Plants & Facilities	23
Superconductivity & Superconducting Materials	23
A-15 Superconductors through in-situ Technique	24
Theoretical Investigations in Condensed Matter Physics	25

APPLIED PHYSICS PROJECTS

Utilization of Solar Energy-Thermal Conversion	27
Studies on Polycrystalline Silicon	27
Electrostatics & Electrophotography	27
Thin Film and Amorphous Materials	28
Display Devices	29
High Pressure Technology	30
Microelectronics	31

DIVISION OF MATERIALS

Development of Solid Electrolyte Grade Beta Alumina tubes for Sodium Sulfur Battery	32
Ultrasonic Transducers, Materials & Devices	32
Development of Carbon Products	34
Aviation Grade Brushes, High Purity Carbon Pitches	34
Carbon Fibre, Carbon-Carbon Composites & Glassy Carbon	34
Luminescent Materials & Devices	36

RADIO SCIENCE DIVISION

Ground Based Facility for Environment Monitoring	37
Sodar Studies	37
Indian Middle Atmosphere Programme (IMAP)	37
Satellite Radio Beacon Studies	39
SROSS Aeronomy Satellite	40
Planetary Ionospheres	40
Tropospheric & Ionospheric Communications	41
Ionospheric & Neutral Atmosphere Modelling	46
Atmospheric Science	47

SERVICE SECTIONS

Workshop	49
Glass Technology workshop	49
Works & Services Division	49
Library	49
	50

APPENDICES

Papers Published	51
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Technical Reports	56
Ph.D.'s Awarded	57
Symposia/Workshop/Training Courses	58
Advice/Consultancy/Calibration	58
Visits Abroad	59
Patents Filed/Accepted	62
Receipts on Account of Testing/Calibration/Glass Fabrication & Other Charges.	63
Premia and Royalties of the Processes Released earlier and in Production	63
Personnel	64
Membership of Research Advisory Council	67
Membership of Executive Committee	68
Honours & Awards	68
Staff Strength	68
Technological Nursery for Optical Components	69
Expedition to Antarctica	69
International Activities in Metrology	69
Collaboration with Other Institutions/Agencies	70
Processes Released to Industry for Commercialization	70

PREFACE

In this report we present a short summary of research activities carried out during the period April 1, 1984 to March 31, 1985. The major activities of the laboratory continue to be the following: Measurements Standards (Mechanical, Thermal Optical, Electrical and Electronic), Materials, Components and devices and their characterization, Radio & Atmospheric Sciences, Solar Energy, Cryogenics and Applied Projects of contemporary interest.

Measurements, Standards & Calibration

NPL's primary responsibility is the custody, maintenance and updating of the standards of measurements and establishment and operation of the calibration service programme. In general terms:—

- Accuracies of the base and derived parameters have been brought to the required Echelon I level.
- International intercomparisons have been carried out either through bilateral exchange programmes (India-USSR, India-FRG) or through Asia-Pacific Metrology Programme (involvement of 18 countries).
- Gradual shift to the concept of fundamental constants.

In particular, significant contributions made in the area of measurement standards are:—

- (1) Accuracy of time & frequency standards has been improved to 1 part in 10^{12} . Clock synchronization accuracy of 10 micro-seconds has been achieved.
- (2) DC. voltage standard is now traceable to Josephson effect with uncertainty of 5 parts in 10^7 . AC Josephson effect has been used to generate quantised voltage at 1 mV level.
- (3) Intercomparison of dc voltage/standard with Australia, China, New Zealand and USSR has confirmed an agreement within 1 ppm.
- (4) Accuracy of 'farad' has been improved to 2 parts in 10^7 .
- (5) Frequency Calibration accuracy of 1 part in 10^{10} has been achieved from 0.001 Hz to 1 GHz and a few parts in 10^{10} upto 26 GHz for calibrating frequency counters, signal generators etc.
- (6) A dead weight of 100 KN has been established with an uncertainty of 2 parts in 10^5 .
- (7) Iodine stabilized He-Ne Lasers emitting 633 nm radiation has been established. This is one of the recommended radiations for the realization of the "Metre" in terms of the 1983 definition of metre.
- (8) An accuracy of 5 parts in 10^3 has been achieved in the measurement of luminous intensity.
- (9) A confidence in temperature measurement to an accuracy of 0.1°C , in the range 0°C to 1000°C has been established through international intercomparisons.
- (10) Primary standards for measurement of pressure upto 10 K bar with 150 ppm accuracy have been established; similarly vacuum standards measurement range has been extended down to 10^{-7} mbar.
- (11) Mass measurement capability has been improved from 1 part in 10^6 to 1 part in 10^7 .
- (12) A hydrostatic (absolute) method has improved the accuracy of calibration of reference standard hydrometers from 1 part in 10^4 to 1 part in 10^5 .
- (13) Ultrasonics output power measurement facility has been established with overall uncertainty of $+5\%$. Techniques have been developed to estimate vibration amplitude down to 50Å.

A major conceptual advance was the linking of electrical parameters such as volt, farad, ohm and ampere with second and metre (He-Ne laser: 1 part in 10^{10}) through Josephson effect (5 parts in 10^7) and calculable capacitor.

Materials, Components and Devices

NPL has a long and distinguished record of research and development activity on materials. Those specially studied during 1984-85 included (i) Carbon Fibres, Carbon-carbon composites and glassy carbons, (ii) piezoelectric materials for high power ultrasonic applications, (iii) electro-optic materials, (iv) cast silicon ingots for photo-voltaic applications, (v) super-conducting materials, (vi) super-hard materials.

New devices and components investigated during 1984-85 include (i) photovoltaic and photoconductive cells (polycrystalline silicon solar cells, screen printed CdS/Cu₂S solar cells, CdS photoconducting cells), (ii) β -alumina tubes for Na-S batteries a joint effort of NPL, CECRI and RRC, Kalapakkam, (iii) Ultrasonic and piezoelectric devices, (iv) Thin film devices (space-qualified interference filters for Earth Resources Satellite, gun-sight reflector glass components for defence applications) (v) feasibility studies on Xero-radiography.

For both materials and devices development, a first rate facility for characterization of materials including electronic materials is needed. The main emphasis in this area has been on the development of a variety of locally constructed high-quality X-ray diffractometers for different types enabling the studies on micro-structural changes in single crystals.

Radio & Atmospheric Sciences

In the Radio and Atmospheric Sciences, major activities during 1984-85 included (i) Activities relating to Indian Middle Atmosphere Programme (IMAP) (ii) Fabrication of payloads for SROSS Aeronomy Satellite-one of the two scientific mission satellites expected to be launched during the seventh five-year plan period, and (iii) a major radar and communication service programme serving Defence Establishments, OCS, P&T, Railways and ISRO.

Under IMAP, 2 balloon flights have been conducted for the measurement of stratospheric ionization and 5 rocket experiments were conducted for the measurement of ozone. A laser-heterodyne system for measuring atmospheric minor species has also been made operational. An UV-B photometer continues to be operational since IMAP beginning in January 1982, a gas chromatograph facility for atmospheric minor species has also been commissioned and several special IMAP documents have been prepared.

Antarctica

On Antarctica, NPL has successfully carried out, through all four expeditions, a vigorous programme on the study of Upper Atmosphere, Ionosphere and Radio Communication. An entirely new concept has been introduced through simultaneous observations in Dakshin Gangotri and in India.

In the area of Cryogenics & Superconductivity both the liquid air & liquid nitrogen plants were in production. The operation of a 7T superconducting magnet, fabricated in the laboratory, was a significant development.

Sponsored Projects

The new sponsored projects in progress which are supported by outside agencies are (i) investigations on hydrogenated amorphous silicon films, supported by DNES and (ii) Development of High Density Carbon-Carbon Composites, sponsored by DRDL, Hyderabad.

The emphasis during the period had been on (a) automation in measurements and other experiments wherever possible, (b) micro-processor based systems (c) establishment of a major computer facility and (d) improvement of environmental conditions (new clean room facilities) for special experiments.

The modernization steps taken for better management were introduction of word processors for administration, accounts and stores, in-house training for computer programming and training of helpers to ITI level in the workshop. The following processes were released to industry:—

- (i) Ceramic enclosed sensors for Platinum resistance Thermometers.
- (ii) Flat plate solar collectors.
- (iii) Silver impregnated graphite contacts.

The scientists of the laboratory also rendered consultancy services to various organisations in different fields, such as noise reduction, acoustic treatment, designing of auditoria, designing of quality control laboratories for lamps and luminaire industry, radio communication etc. More than 100 papers were published in national and international journals and 50 were presented in national conferences and symposia.

NPL has undertaken calibration of a large number of reference standards and measuring instruments from outside agencies. The calibration revenue realised (at very normal calibration fee) during the period amounted to Rs. 8.814 lakhs and the number of calibration reports issued were 2831.

A. P. Mitra

(A.P. MITRA)
Director

DIVISION OF STANDARDS

PHYSICO-MECHANICAL STANDARDS

STANDARD OF LENGTH AND ANGLE

1. Standard of Length

As a part of international comparison of standards, the stabilised laser of NPL was intercompared with those of other nine laboratories of the world through a similar laser of PEL New Zealand. The intercomparison experiment was carried out at NPL.

The analysis of the experimental data, confirmed the stability and reproducibility values of NPL laser which is within the limits prescribed by CGPM'83. The mean frequency offset of NPL laser with respect to that of PEL as zero, is found to be 5.2 KHz; whereas the largest deviation of this value for some other laboratory was found to be 78.5 KHz. A comparison of the standard deviation (S.D.) in the frequencies of the lasers of various laboratories showed that the S.D. for NPL laser is 10 KHz, whereas the average value of the S.D. for rest of the lasers is 3 KHz. A bit of higher value of the S.D. of NPL laser realised in this experiment has made us to take some effective measures to reduce it.

1.1 Measurement Systems and Techniques

Laser measurement system for the calibration of slip gauges has been fabricated and is under performance evaluation. A micro-processor control for the linear movement of the bed for the line gauge measurement system has been designed and is under fabrication.

An interferometer which gives approximately constant radial and azimuthal shears has been developed. It gives the partial derivatives $\partial u/\partial r$ and $(\partial u/\partial \phi)/r$ which are used to determine the complex amplitude u of a wavefront in polar coordinates.

1.2 Basic Studies

Research work on the polarization properties of gas laser with and without magnetic field is being continued. Studies on the stability of Fabry-Perot etalons with cemented parts has been carried out.

DIMENSIONAL METROLOGY

1. Calibration

Calibration facilities have been fully utilised by industry and other organisations. Two large size surface plates and a profile projector were calibrated at site for Bharat Electronics Ltd. Ghaziabad and BHEL, Bhopal, respectively.

Photoelectric autocollimator of Rank organisations, U.K. has been installed. It is useful for precision measurement of small angles and for calibration of angle gauges, polygons, rotary tables, straightedges, and surfaces plates, etc. Its readability is 0.2 seconds of arc.

1.1 International inter-comparison of standards

From the results of international intercomparison of ten slip gauges, in which seven countries participated, it was established by the Malaysian coordinator that the accuracies of NPL calibrations were equivalent to those of Australia and New Zealand.

STANDARDS OF MASS VOLUME AND DENSITY

1. Calibration and Testing

1.1 Mass

A number of NPL standards as well as several sets

of reference and secondary standards of mass for the weights and Measures Enforcement Departments of the State Governments of the country have been calibrated. Several sets of analytical weights for research organisations have also been calibrated.

1.2 Density

A large number of glass hydrometers of various types for sugar, petroleum and other industries have been calibrated. A few reference grade hydrometers used as NPL standards have been calibrated by hydrostatic weighing method. Glassware like Burettes, Pipettes, Butyrometers used in Dairy Industry have been calibrated. A number of secondary standard capacity measures for Weights and Measures Enforcement Departments of State Governments of the country have been calibrated and recalibrated.

1.3 Viscosity measurement

Quite a few viscometers from Oil companies have been calibrated. Viscosity of several oils have been measured both for in house work and for Pressure and Vacuum Standards group.

2. Developmental Work

2.1 Mass

An equi-arm, interchangeable pan, mechanically remote controlled 1 kg. balance has been assembled and initial evaluation has been carried out. It has a sensitivity of $50 \mu\text{g}$ and a stability, in terms of standard deviation, of the same order.

2.2 Density

With the help of a solid cylinder whose volume was established in terms of the density of water, density of xylene has been determined with a precision of better than one part in one hundred thousand. A very short range but with open scale (1 scale division 0.00001 g/cm^3) to be used as master hydrometer in xylene has been calibrated at several points by using hydrostatic method.

2.3 Viscosity

Starting with water, the primary standard of kinematic viscosity, two master viscometers have been calibrated which are then used to measure the viscosity of an oil of kinematic viscosity of approximately $3 \text{ mm}^2/\text{s}$. This oil has then been used to calibrate another set of viscometers having higher range (3 to $9 \text{ mm}^2/\text{s}$). Hence a viscosity scale up to $9 \text{ mm}^2/\text{s}$ has been established by the primary method.

STANDARDS OF FORCE AND HARDNESS

To have dead weight or lever multiplication machine of capacity more than 1 MN is difficult because of their prohibitive cost and unwieldy size. For higher capacity normally hydraulic multiplication system was designed of capacity 1 MN. In this system a small force in the form of dead weight is applied on the piston of a small piston-cylinder assembly and is connected hydraulically to a bigger piston-cylinder assembly. Both the cylinders are rotated around their pistons to minimize friction. Force obtained on the piston of the bigger piston cylinder assembly is equal to the dead weight force applied on the small piston multiplied by the ratio of area of the bigger to smaller piston. In the present case the ratio of areas is 320. Accuracy obtained is of the order of ± 0.03 per cent. Accuracy can be increased in the subsequent design.

The facility of force calibration is used by all the steel manufacturers both in private and public sector including Railways, Defence, ISRO and fabricators of a large variety of jobs.

STANDARDS OF PRESSURE

In order to ascertain the total uncertainty of measurement comparable at the international level, an intercomparison exercise of standards through the transfer standards has been taken up with IMGCI, Italy using strain gauge transducer and establishing the secondary standard upto 5 K bar.

High pressure viscometer based on rolling ball principle has been set up for studying the viscosity

of pressure transmitting fluids upto 7 K bar. The range is being extended upto 14 K bar. This would help the steel industry for the proper selection of the lubricant used in hot and cold forging steel processes and also to improve the overall measurement accuracy of the primary pressure standard. These facilities have been used for the calibration of pressure measuring equipment used by different industries such as BHEL, Rashtriya Chemical and Fertilisers Ltd, Defence Organisations, Steel Authority of India Ltd. and other private industries.

A comprehensive study of the relaxation and transport properties of long chain heavy molecular weight organic materials in pure as well as in impurity doped form under high hydrostatic pressure and in different ambient conditions by the newly developed piezo-stimulated discharge current technique has helped in characterizing these materials at the microscopic level. The results thus obtained have been confirmed theoretically and these have helped in removal of certain anomalies existing in the literature regarding the behaviour of different processes such as molecular/electric/ionic associated with the observed transport properties in these materials.

STANDARDS OF VACUUM

Facilities for the study of the characteristics of rotary vacuum pump and oil diffusion pump have been established. This has resulted in carrying out the detailed study on the molecular flow inside the test dome and the theoretical analysis has been given of the gas beaming effect for both the orifice type and tubulated ionization gauges. This study has brought the tubulated gauge again in the field as earlier, the gas beaming effect inside these gauges was not as clear as the theory and experiments conducted have shown. This has enabled to define the position of inlet gauge and air-admittance used in the conductance method for the measurement of speed of oil diffusion.

The Ultra High Vacuum facilities upto 10^{-11} m bar have been created and would be used for the surface analysis. An automatic and semi-automatic vacuum system for the indigenous scanning electron microscope (SEM) with va-

rious safety devices and interlockings has been designed and fabricated.

Process know-how for the manufacture of silver impregnated graphite contacts has since been commercialised. These contacts are widely used by Indian Railways as contact material in signalling which are imported at present. This know-how would be able to meet the country's demand of relays contacts. The demand for such contacts is increasing with introduction of more modern signalling techniques.

STANDARDS OF TEMPERATURE

A Photoelectric Linear Pyrometer purchased from West Germany was set-up. The pyrometer was stabilised by providing 24 hours air conditioning during summer. A bank of tungsten filament lamps were calibrated. One high stability tungsten strip lamp was sent for calibration to the National Measurement Laboratory for intercompare calibrations. Black body furnace has been designed for check-ups at freezing points of Aluminium, Silver and Copper.

Sag method of linear expansion was used for determination of α for Platinum, Gold and Palladium in the Temperature range of 30°C to 500°C, using resistance variation for temperature measurement.

A study was conducted on the speed of calibration of clinical thermometers with a continuous system developed at NPL. A maximum speed of 1000 thermometers per hour could be achieved by manual operation.

Low Temperature

In the low temperature side, experimental set up for the realization of BP of Oxygen at Tripel Point was established for the first time. Results obtained from trial runs were encouraging.

Two SPRTs for the range —183 to 450°C and a triple point of water cell were constructed and supplied to industry. Apart from this several SPRTs were calibrated at triple point of water, tin and zinc points to determine R_0 and α & δ , the constants of thermometers. Calibration of Industrial Platinum Resistance Thermometers

(RTDs) for various outside parties was taken up and study of RTDs as secondary standards for the range 0–500°C was continued.

OPTICAL RADIATION STANDARDS

An absolute radiometer has been partially set up. Using the above radiometer, the conversion factor between the photometric and radiometric units has been obtained. The value obtained, though differs from the internationally agreed (statistical) value, is well within the expected limits. It is expected that a better agreement between our values and the internationally agreed values would be obtained with further improvements in the NPL radiometer. Testing and Calibration of Reference standard lamps and luminaires, light measuring instruments to lamps and lighting industry, research institutions is continued. Lighting designs were made and supplied to PSLV Centre, SHAR, ISRO. Advice on the establishment of Quality Control Laboratories were given.

INFRARED RADIATION STANDARDS

Work on irradiance measurement of light sources in the spectral region of 0.8 to 1.6 microns has been started. Also spectral irradiance of tubular fluorescent lamps of GLS type was determined in the spectral region of 280 nm to 380 nm. Feasibility for absolute measurement of absorption coefficient using photoacoustic spectrophotometer was made. It was established that it would be possible by measuring the phase of the photoacoustic signal.

A facility for absolute measurement of reflectance has been taken up. Initially a set-up for relative measurement of specular reflectance in the spectral region of 0.7 to 3 microns was completed. The optical schematic for absolute measurement of specular reflectance has been completed and the fabrication is in progress.

Work on the indigenous development of Hot Axle Box Detection System and a system for temperature rise measurement in armature conductor of 165 M DC traction motor sponsored by

Department of Science and Technology and Bharat Heavy Electricals Ltd. is continued. Fabrication of preproduction model of Hot Axle Box Detection System has been undertaken in cooperation with CEL. Remote detection of temperature of commutator riser part of DC traction motor—sponsored by BHEL—was completed. The contact temperature measurement of armature conductor is taken up.

Design of a grating double monochromator for the spectral regions of UV, visible and near IR has been completed and fabrication of the instrument is in progress. Testing of optical elements as per relevant IS and other specifications, measurements in infrared and photoacoustics spectroscopy for industry and research institutions is continued.

STANDARDS OF ACOUSTICS

Participated in International Round Robin Calibration of Vibration measuring system (accelerometers) under the initiative of NBS, USA. The system consisted of amplifier and power supply unit, accelerometer and connecting cable and the calibration was done by noting the output voltage of the accelerometer, mounted on a shaker table and the corresponding displacement amplitude. The sensitivity of the system was measured at 3 nominal frequencies (80, 100 & 160 Hz) against nominal acceleration of 20, 20 and 30 'g' respectively with an overall accuracy of $\pm 0.5\%$.

Completed a project 'Feasibility Studies on Noise from domestic Electrical Appliances' sponsored by Deptt. of Electronics. Investigations into the augmented absorption characteristics of Conical Sound Absorbers was completed.

All components for absolute calibration of vibration accelerometers using laser interferometry were acquired and experimental system was set up. Testing of electro-acoustical devices and acoustic products for industry and research institutes is continued. Consultancy services for acoustical treatment of auditoria etc. is provided.

ULTRASONIC STANDARDS

For housing the facilities created for ultrasonic

standards, a clean room has been established during this year. Measurement on particle count in the clean room, clean benches and the typical laboratory room have been done using a particle monitor, model, 218, Royee Inst. Inc., California. The relative measurements show that the clean room has a significant reduction of particle count 326 (at rate of .01 cfm) than in air in the adjoining environment, which has a particle count of 9000. The clean benches have a particle count of 8 which is better than class 10,000.

An extensive work for the characterisation of materials to be used for lining in the water tank has been carried out using pulse technique in the frequency range 0.5–5 MHz. The reflection and transmission properties of the rubbers and other materials were studied and in some cases also the transmission at various angles of incidence. The experimental results reveal that neoprene/steam

rubber having an echo reduction >20 dB and attenuation 45 dB/cm are suitable for making the anechoic lining in the tank.

A miniature piezoelectric ceramic hydrophone (dia-2 mm) has been calibrated using the two transducer reciprocity technique at frequencies, 1.17 MHz, 1.88 MHz, 2.58 MHz and 3.8 MHz. The work has been carried out using indigenously made reciprocal transducers and in a perspex tank of low reflection coefficient. The sensitivity of the hydrophone by reciprocity has been estimated to be $0.1 \mu\text{Pa}$ between 2 to 4 MHz and is in good agreement with the value obtained by comparison against a standard PVDF hydrophone. The accuracy has been estimated to be ± 3 dB. A significant improvement in accuracy and precision is expected when the anechoic tank with micropositioning unit which is under construction is installed.

ELECTRICAL & ELECTRONIC STANDARDS

STANDARDS OF TIME AND FREQUENCY

The monitoring of "Epoch" or "Time Instant" has been continued through reception of NNSS (TRANSIT) signals and continuous phase comparison of GBR (16 KHz) signals with that of NPL Standard. VLF studies have been conducted at Antarctica during Fourth Expedition.

After feasibility experiments for Standard Time and Frequency Signal (STFS) dissemination via Satellite INSAT-1B, the necessary instrumentation for STFS service via C/S band has been finalised.

ATA—the HF time service has been made round-the-clock on 10 MHz with additional service at 5 MHz during night and 15 MHz during day. Time of emission of ATA time pulse is advanced by 50 milliseconds with respect to UTC to avoid interference with similar transmissions.

An automatic 8 channel data—logging system has been developed. An automatic "TV Time transfer data recording system" has been developed.

The indigenously developed Rubidium Atomic frequency standard has been found to have medium term stability of the order of 1×10^{-11} . The first experimental model, developed in 1983, was quite bulky and occupied three standard 19" bins. The frequency standard has since been miniaturized with necessary modifications in electronic circuits and mechanical design. The overall size has been reduced to one third.

STANDARDS OF DC ELECTROMOTIVE FORCE, RESISTANCE AND CURRENT

1. Standard of E.M.F.

The 'as-maintained' standard of dc voltage in the form of standard cells was compared against the Josephson Voltage Standard (at 1 mV level using Nb-Nb point contact junction and highly stable

microwave frequency of 9.8479 GHz) using 'TRANSVOLT' as the transfer standard. The agreement has been found to be within 0.5 to 0.6 μ V.

For introducing automation in the material intercomparison of standard cells, experiments using manually operated mechanical switching system gave thermo-emf's of the order of 3 to 4 μ V. Therefore, an electronic multiplexer scanner (HP 3495A) and a micro-computer (desk-top HP 9836B) has been tried for the intercomparison.

A new system using a Lindeck potentiometer for calibration of standard voltage sources was established with a precision of 1×10^{-7} .

A feasibility report on Quantum Hall Resistance Standard was prepared.

1.1 International Intercomparison of Standards

Final measurements on the intercomparison of d.c. voltage standards with USSR (based on travelling standard cells) were carried out and report of this intercomparison has been compiled. Final report on the intercomparison of dc voltage standard under Asia Pacific Metrology Programme (APMP) was completed.

The second round of intercomparison of d.c. voltage standards under Asia Pacific Metrology Programme in which China, India and Thailand are participating, was started by NPL as the pilot laboratory.

CAPACITANCE, INDUCTANCE AND AC RESISTANCE STANDARDS

1. Variable Ratio Inductance Bridge

A variable ratio inductance bridge to compare any two inductances with accuracies in the range 10–50 ppm has been developed and evaluated. This bridge is used for comparing standard inductances in the range 10 μ H to 10 H and for

calibration of odd value inductances, for which requisite standards are not available.

1.1 Measurement of High Value Capacitances

The range of the bridge to measure high value capacitances has been extended from $10\ \mu\text{F}$ to 1 Farad with accuracies of 0.1% to a few per cent at 120 Hz. The calibration facilities have been established.

High value capacitors from 1 mF to 1 Farad, based on the transformer principle have been designed, fabricated and evaluated. These capacitors are being used as standards for calibration of high value capacitors.

1.2 Precision 8-decade Inductive Voltage Dividers

Development work on precision 8-decade Inductive Voltage Dividers has been completed and inphase ratio accuracies of a few parts in 10^8 have been obtained.

1.3 International Intercomparison of Standards

Final report on the intercomparison of Capacitance and Inductance Standards with USSR has been completed and sent to USSR. Preliminary work on international intercomparison of 10 pF and 1000 pF capacitance standards under Asia Pacific Metrology Programme has been completed. NPL is acting as a pilot laboratory.

1.4 Calibration Services

Calibration of Capacitance & Inductance Standards and Impedance Bridges from various Govt. organizations, Defence Establishments, Regional Laboratories, Industries etc. was carried out.

A.C., L.F. & H.F. STANDARDS

A.C. & L.F. Voltage

The mutual intercomparison of multijunction thermal convertors has been extended upto 30 KHz. AC/DC transfer error assigned at 30 KHz is 15 ppm.

Under the Indo-Soviet Programme of Cooperation thermal voltage convertors have

been designed and fabricated at NPL using thermoelements supplied by USSR. The aimed voltage and frequency ranges are 250 mV to 300 V and 10 Hz to 1 MHz respectively. These thermal convertors are under evaluation.

1.1 A.C. Power, Energy & Ratio

The frequency range of power measurement using comparator technique has been extended from 50 Hz to 400 Hz. The current range in power and energy measurement has been extended from 200 A to 500 A at 2 kV and 0.25 to unity power factor.

Facility has been set up to calibrate current transformers for both ratio and phase angle with ratio error less than 0.01% and phase angle error less than 3 minutes.

A.C. Power and energy calibration facility has been set up to provide calibration accuracy better than 0.05% at power factor from 0.1 p.f. to 1.0 p.f. both leading and lagging.

1.2 H.F. Voltage & Power

In order to improve the accuracy of HF voltage and power measurements using calorimetric techniques, a temperature stabilisation system has been incorporated in the calorimetric mount. The transfer standard thermal convertors have been assigned AC/DC transfer error upto 4 Volts and upto 1 GHz. The accuracy in assigning these values has been improved to $\pm 0.02\%$ to $\pm 0.75\%$. Work is in progress to extend the voltage range upto 10 V and also to establish compatibility between Attenuator Thermal Voltmeter and Calorimetric standard.

1.3 H.F. Attenuation

Power ratio technique for measurement of H.F. attenuation with a precision of 0.005 dB/10 dB in the dynamic range 0-20 dB upto 1 GHz has been established.

Feed through HF power standards have been linked to the calorimetric standards of HF power at frequencies 100 MHz, 200 MHz, 400 MHz and 1 GHz.

1.4 H.F. Impedance

The standard capacitance values of the precision

reference air-lines have been computed from their dimensional measurements in the frequency range of (1-1000 MHz). The measured capacitance values at 1 KHz agree within $\pm .02\%$ with the computed values.

Prototype 10 pF coaxial standard capacitor (with GR 900 type connector) has been developed and is under evaluation.

1.5 Calibration Services

Precision instruments and standards have been calibrated for a large number of user organisations. These include various public and private undertakings including defence, space etc.

MICROWAVE STANDARDS OF POWER, FREQUENCY, NOISE ATTENUATION & IMPEDANCE

1. Microwave Power Measurement

Broad band calorimetric loads of a novel design with a maximum VSWR of 1.08 over the entire X-band have been fabricated. These are under evaluation for the effective efficiency by two techniques viz. the single load micro-calorimetric technique and the twin load microcalorimetric technique. Preliminary measurements have shown very high effective efficiency, of the order of 99.9% of these mounts. These will be used for precise measurement of microwave power. The estimated uncertainty in the power measurement is below $+0.25\%$.

1.1 Microwave Attenuation Measurement

Two water cooling jackets for the reflex klystrons X-13 (8.2 to 12.4 GHz) and X-12 (12.4 to 18.0 GHz) have been designed and fabricated for improved frequency and power stability at maximum power level of the klystrons. The facilities for calibrating the Rotary Vane Attenuators at Ku-band (12.4 to 18.0 GHz) incorporating the water cooled klystrons are being established.

1.2 Microwave Impedance Measurement

Three standard quarter wave short circuits of nominal unity reflection coefficient (i.e. $|\Gamma| = 1$) at

XN band (6.0, 7.0 & 8.0 GHz) have been designed and fabricated. Three broad band mismatches of VSWR 1.10, 1.20 and 1.30 at XN-band frequencies have been designed and are under fabrication. The fabrication work of the mismatch of VSWR 1.10 is complete. Two multistub tuners have been designed and fabricated at XN-band frequencies.

1.3 Six Port Measurement System

A six port system comprising of a directional coupler and a slotted line has been assembled for the measurement of impedance at X-band frequencies. The calibration constants of the system were computed using computer software programming. The analysis of the theoretical and experimental results is in progress.

1.4 Calibration Services

Calibration of power-meters, attenuators, frequency meters etc. was carried out for Defence Establishments, Indian Railways and Private Industry.

JOSEPHSON VOLTAGE STANDARDS

The standard of voltage based on a.c. Josephson effect has been realized at 1 mV level using a Niobium-Niobium point contact junction. The junction, when irradiated with highly stabilised microwave radiations in the X-band, generates current steps at constant voltage interval in its d.c. I-V characteristic. The cumulative Josephson step voltage corresponding to 50th step is used to assign value to one of the cells of a GUILDLINE Transvolt which serves as a transfer standard. The same cell is also assigned value by intercomparison with the as maintained Volt based on a bank of standard cells. The two values are found to agree within 0.5 ppm. The overall uncertainty (99 per cent CL) in assignment of emf value to a standard cell against the Josephson voltage standard is 1.2 ppm.

LOW DIMENSIONAL COULOMB SYSTEMS

A project proposal was prepared for submission

to D.S.T. to set up a milli-Kevin temperature facility and conduct experiments on an electron system suspended on a liquid helium substrate. It has been proposed to control the motion of electrons in one of the two available dimensions experimentally and thus change the dimensionality of the system continuously towards one from two. The crossover phenomena, nature of the electron gas, liquid and solid, etc., can thus be studied as a continuous function of dimensionality.

Theoretical work was done and published on possible explanations for the density dependent mobility of a 2D electron system by considering correlations between electrons. Theoretical work was also started on finding analytical expressions for various properties of a transmission line formed by a 2D electron sheet on liquid helium. This would help in better and accurate analyses of experiments. This work was undertaken in collaboration with Case Western Reserve University, U.S.A. A theoretical calculation of the viscosity of a 2D electron liquid was continued and some preliminary results obtained.

Work on studying the density profile and dynamic capacitance of a 2D electron layer by computer solutions of the Laplace's equation was started.

Computer simulations of a 2D array of Josephson junctions driven by an external field were set up. It is proposed to study the dynamics and statistical properties of vortices and their relation to chaos in such a system in collaboration with the University of Hyderabad.

CALIBRATION SERVICE PROGRAMME

1. Introduction

To ensure compatibility and traceability in measurements throughout the country, Government of India has approved a scheme entitled 'National Coordination of Testing and Calibration Facilities' (NCTCF) which is being implemented by the Dept. of Science & Technology. In this programme, the responsibility of coordination of the entire calibration activities in the country has been entrusted to NPL through the

'Calibration Service Programme' a Calibration Service Cell has been established at NPL.

1.1 Objectives

To establish the calibration hierarchy, to coordinate the calibration activity among various laboratories and to ensure traceability of all measuring instruments to National Standards of measurement by periodic calibration at appropriate level.

To make recommendations on the level of accuracies for calibration laboratories at various echelons as well as at industrial level and to assist in identifying measurement results carried out at various calibration laboratories.

To lay down uniform calibration procedures and to ensure uniformity in reporting of measurement results carried out at various calibration laboratories.

To work out the criteria for assessment and accreditation of Echelon I, Echelon II and Echelon III Laboratories.

To monitor the functioning of calibration laboratories and to make recommendations for their accreditation.

To establish information system on measurement standards and calibration and to arrange training programmes, seminar/symposia, exhibitions, audio-visual programmes related to this activity.

To ensure compatibility in calibration through 'measurement Assurance Programme' and coordinate the intercomparison of standards amongst various laboratories using travelling standards.

To work out guidelines for calibration charges at various levels to ensure uniformity.

To assist in formulation of Acts & Statues for 'National Coordination of Testing & Calibration Facilities.

Under the Calibration Service Programme, the calibration laboratories throughout the country are to be categorized into three Echelons depending upon the level of accuracy.

1.2 Echelon I Laboratories

In the calibration hierarchy, the National Physical Laboratory is at the apex because it has been

entrusted with the responsibility of realizing the 'units' of physical measurements according to the international system and of custody, maintenance and updating of the National standards of measurements.

The National standards of Ionizing Radiations required for protection and therapeutic purposes are maintained by the Bhabha Atomic Research Centre, Bombay.

1.3 Echelon II Laboratories

Several Regional Calibration Centres have already been established or are being established under various Government Departments (Deptt. of Electronics, Deptt. of Weights & Measures, Defence etc.) in various parts of the country. These Regional Centres are to be categorized as Echelon II Laboratories. In addition to these Regional Centres, many R&D Laboratories and several public sector undertakings which have established in-house calibration facilities and are also comparable in accuracy to the Regional Centres will also be approved in this category. Echelon II Laboratories, whose reference standards are calibrated at NPL, will undertake calibration of standards maintained by Echelon II laboratories and of other user agencies requiring such accuracies.

1.4 Echelon III Laboratories

In some states of the country, State Testing & Calibration Centres have been established by Government Departments (Deptt. of Weights & Measures, Dept. of Electronics etc.) and other agencies. These laboratories are to be categorized as Echelon III. Many other R&D establishments, teaching institutions and some industries will also be approved in this category.

1.5 Steering Committee for Calibration

The Calibration Service Programme works under the guidance of the 'Steering Committee for

Calibration' which consists of members from Govt. Departments, Public Sector Undertakings, Academic Institutions and Private Industries. To assist the Steering Committee, six Expert Panels have been constituted for Electrical Measurements, Mechanical Measurements, Electronic Measurements, Thermal & Optical Measurements, Flow Measurements and Radiological measurements. These Panels, with the help of their sub-committees, have prepared the specific criteria for approval of Laboratories including levels of accuracies for Echelon I, II, & III Laboratories. The following documents were finalized during the year:—

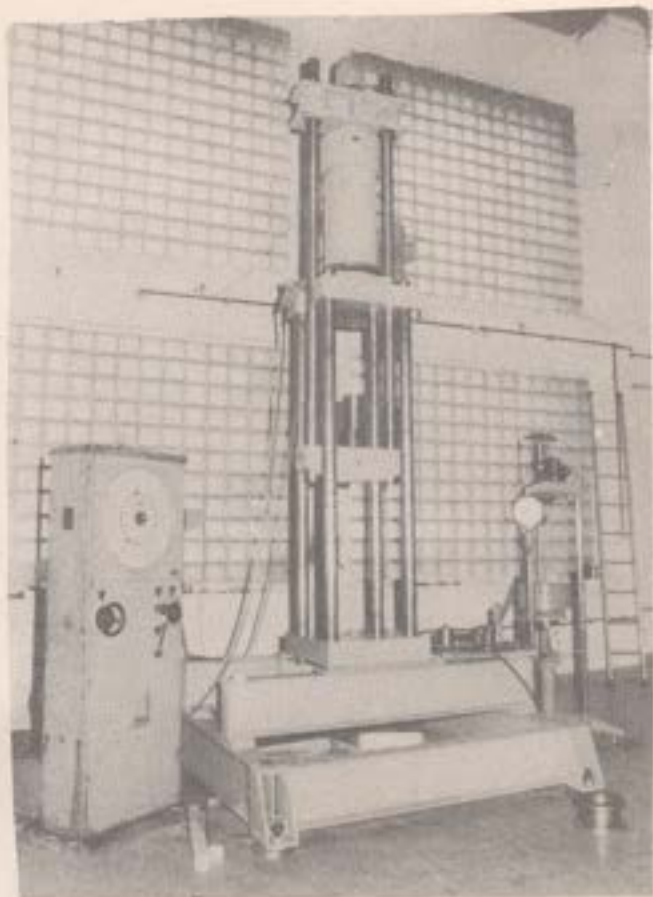
1. General guidelines for approval of Calibration Laboratories.
2. Specific criteria including levels of accuracies required at various Echelons related to four fields viz. Electrical, Mechanical, Thermal and Optical and Radiological Measurements.
3. Compendium of Laboratories, Institutions and Industries having Calibration/Measurement Facilities.
4. Format of application for approval of Calibration Laboratories.
5. Report of the Ad-hoc Panel for Standard Atmospheric Conditions for Calibration.

To prepare a Directory of Calibration Facilities in India, proformae were sent to a large number of agencies to collect information on calibration facilities available in various Laboratories/Institutions. Replies from more than 80 institutions have been received.

1.6 New Facilities

A micro computer facility has been established to assist in various activities of the Calibration Service Programme.

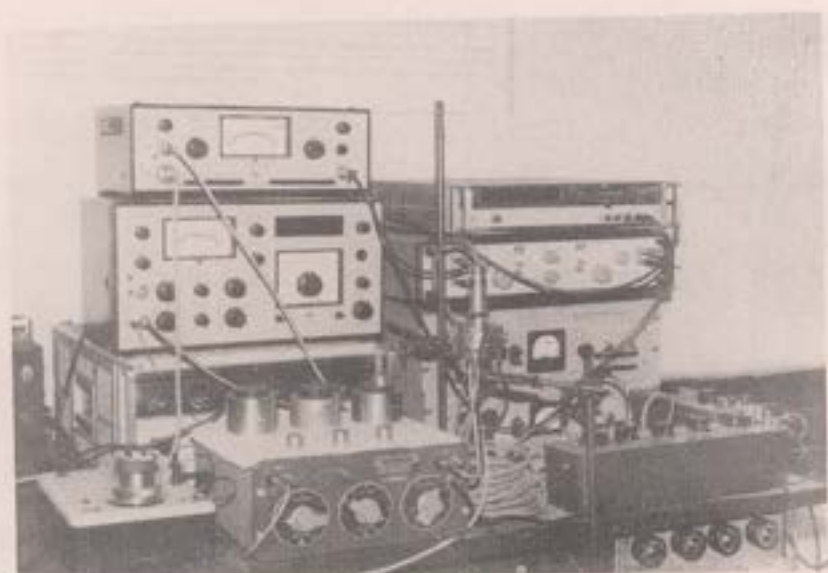
TESTING & CALIBRATION
ACTIVITIES AT NPL



Force Measurement



Light Intensity Measurement



Acoustic Vibration Measurement



*Calibration of Slip Gauges by
Interferometric Method*

MATERIALS CHARACTERIZATION DIVISION

CHARACTERIZATION OF MATERIALS BY CHEMICAL METHODS

Research & Development work has been done to develop new methods of determining sulphur dioxide gas in the environment without using any hazardous material. Method has been developed to trap sulphur dioxide in morpholine solution as morpholine forms a stable adduct with sulphur dioxide. Sulphur dioxide in the morpholine is estimated using bleached pararosaniline hydrochloride which forms a violet complex. Other methods developed for the determination of sulphur dioxide depend on the reduction of Fe^{3+} to Fe^{2+} Cr^{6+} to Cr^{3+} by sulphur dioxide and determination of the excess of Fe^{3+} or Cr^{6+} by complex formation.

Permeation of sulphur dioxide has been studied through teflon. Stainless steel container with teflon window has been designed to fill SO_2 at high pressure for permeation at constant temperature, ppm concentration standards of sulphur dioxide can be made for calibrating sulphur dioxide monitoring devices.

Commercial activated carbons, molecular sieves, silica gel, alumina powders and activated carbon prepared from almond shells have been studied for their adsorption characteristics of methane for its detection in the environment with the existing gas chromatograph which has limited sensitivity. It is found that the activated carbon prepared from almond shell and maintained at dry ice temperature is quite suitable. More than 95% of the methane present in the gas sample can be recovered for detection at higher concentration by the present gas chromatograph (Toshniwal model ELO4). Methane is found to undergo decomposition reactions on copper surface at low temperature. The reaction products yield four new peaks in the gas chromatograph. The nature of the species responsible for new peaks are being investigated.

Characterization of chemical composition of various materials has been carried out using classical and instrumental methods of analysis. Samples analysed for various projects of NPL and outside agencies/institutions included nitrogen gas for benzene vapour concentration, toluene for adulteration, fish tissues for mercury content, election ink for silver nitrate content, various steels and alloys for composition, high purity graphite for trace impurities and minerals.

CHARACTERISATION OF MATERIALS BY SPECTROSCOPIC METHODS

1. Fourier Transform Infrared Spectrophotometer (FTIR)

Helium gas recovery line was laid from FTIR instrument to Helium plant and tested for leakage and continuity. Liquid helium dewar and transfer line were installed and tested. Cryostat along with its temperature regulator and measurement system was installed and tested. With FZ silicon windows in crystal, infrared absorption and transmission measurements were performed at liquid helium temperature.

Reflection measurements at ambient temperature were carried out of different black coated surface. From this emissivity of these surfaces in the wavelength region 2.5 to 25 micron could be measured.

Determination of oxygen and carbon impurities in different samples received from Materials Division and BHEL, were carried out. ASTM F-121 and F-123 specifications were used to estimate oxygen and carbon impurities. Fortran programme of auto subtraction was used through NOVA-4 minicomputer, to eliminate interference from other absorption bands and precise estimation of impurities.

Spectra computation and subtraction capabilities of NOVA 4 computer of FTIR were utilised

for accurate estimation of (i) interstitial oxygen, (ii) oxygen aggregates and (iii) carbon, in silicon.

Estimation of aggregate oxygen has been done by annealing the sample and measuring the enhancement of absorption coefficient.

Substitutional carbon impurity band is observed at 607 cm^{-1} and a two phonon silicon lattice band occurs at 610 cm^{-1} . Under high resolution of FTIR, these two bands are separated and the interference of two phonon band is eliminated by auto subtraction method.

Theoretical and experimental studies of metallic meshes were carried out to estimate diffraction losses in the region defined by $\lambda < g(1 + \sin\alpha)$ in reradiation theory. Measurements at collimated, converging and diverging beams were taken and the transmission difference (ΔT) was estimated for various wave lengths. High value of ΔT and the difference in the peak position of transmission were explained on the basis of diffraction losses.

1.1 Pyroelectric and Ferroelectric Properties and Growth of Single Crystals from Solution

Work on growth of single crystals from solution both in ferroelectric and paraelectric phases was

continued. Doped crystals of TGS, LATGS and mixed crystals of KDP and ADP were grown. Characterization of these crystals for their ferroelectric and paraelectric properties was done.

Biased hysteresis loops have been observed in certain doped TGS crystals. Theoretical and experimental studies are being conducted in respect of domain wall motion and to explain the biased loops on the basis of unsymmetrical double bottom potential well.

CHARACTERIZATION OF MATERIALS BY ELECTRON PARAMAGNETIC RESONANCE SPECTROSCOPY

A new X-band EPR spectrometer (Varian make, E-line Century series, model E-112) has recently been commissioned. Alongwith this MMR gaussmeter and liquid nitrogen variable temperature accessories were also installed. The performance of the spectrometer was tested using different kinds of samples at different temperatures and the verification of its different specifications was done by using strong pitch and weak pitch samples.



Fig. 1 X-band EPR Spectrometer (Varian E. Line Century Series)

Detailed analysis of the EPR results of the monotropic liquid crystal HBT indicated the presence of smectic B phase in the heating cycle also. Similar studies on this liquid crystal using nitroxide probe is in progress.

An exhaustive survey/abstracting of the last ten years work on EPR studies of paramagnetic defect centres in silicon crystals has been undertaken.

CHARACTERIZATION OF MATERIALS BY X-RAY DIFFRACTION AND FLUORESCENCE TECHNIQUES

1. Study of Crystal Structure of Chalcogenides

In continuation of single crystal x-ray diffraction on Ga_2Te_3 , stationary crystal photographs were recorded in cylindrical camera using graphite monochromated $\text{CuK}\alpha$ beam. The wavelength of modulated structure when calculated either by the method suggested by Daniel and Lipson or by Guinier, from the position of the side bands, did not give consistent results. It was interesting to observe that the satellites with 111 & 444 reflections were along the equatorial direction ([110] as goniometer axis); and 222 or 333 exhibited satellites along the lateral direction. The reciprocal lattice angular range for all these satellite were found to be 0.7° on either side of the main reflection.

The long annealing of Ga_2Te_3 material for 500 hours at 660°C produced no changes in powder pattern, though single crystal studies revealed small deviations, such as, di-pyramidal-like shape of satellites around 113 has been resolved into eight satellite spots, otherwise, the general character of satellite reflections remaining same as before.

In continuation of the work $\text{CuGa}_x\text{In}_{1-x}\text{Se}_2$ the crystal data for compounds $x = 0.25, 0.5$ and 0.75 have been finalised. A few more compositions for $x = 0.0, 0.4, 0.6$ and 1.0 have been synthesized.

For better understanding of the Ga_2Te_3 single crystals, an investigation of the system $\text{Ga}_2\text{Te}_3 - \text{In}_2\text{Se}_3$ was undertaken. Five different stoichiometric preparations of composition $(\text{Ga}_2\text{Te}_3)_x(\text{In}_2\text{Se}_3)_{1-x}$, with $x = 0.1, 0.2, 0.3, 0.4$

and 0.5 were synthesized by quenching method and studied by x-ray diffractometer. The preliminary results obtained suggest that Ga_2Te_3 lattice is found to play a dominant role in forming a solid solution and the degree of perfection of the Ga_2Te_3 lattice is found to decrease as the amount of In_2Se_3 is increased.

1.1 X-ray Analysis of Materials

A large number and wide variety of samples have been tested for various divisions of NPL, industry, research institutions etc. for crystalline phase analysis, elemental analysis, crystallite size and lattice parameter measurements etc. X-ray diffraction/fluorescence studies on Nb_3Sn formed in multifilamentary samples after short durations of diffusion reactions have been carried out. The results show that compound layer formed in the beginning is considerably tin deficient and the lattice parameter is smaller than the reported ideal value. As annealing progresses both the tin concentration and the lattice parameter rapidly approach the optimum values. This is correlated by Te measurements carried out on the samples. X-rays measurements on α_1, α_2 separation and maximal height of the peaks and width and shape of the rocking curves of annealed and unannealed quartz crystals were studied by powder diffractometer and results correlated with their physical characteristics such as resistivity, frequency stability etc.

1.2 Study of In doped films and manganese oxide

The dependence of In doped ZnO film thickness on grain size and orientation has been studied. The changes in electrical parameters, density of trap states have been correlated with these parameters.

Supplementary characterization, by x-ray diffraction, was done on decomposition of hydrogen peroxide carried out on oxide of Manganese by thermal decomposition of manganese carbonate under different reaction conditions.

1.3 Study of Cotton Fibres, Carbon Fibres and Graphite Fibres

In collaboration with IARI, New Delhi, x-ray diffraction studies have been extended to Go-

ssypium Herbaccum and Gossypium Barbadense species of cotton. For 25 varieties of each species orientation angle and percentage crystallinity measurements have been completed.

Experimental data on Carbon fibres collected in the recent past was finalised for the change in degree of orientation and 'apparent crystallite size' of modified PAN precursor fibres.

X-rays diffraction studies on the graphite flakes (Dia 75μ) untreated as well as treated with conc. H_2SO_4 for various durations have been undertaken. Almost 50 percent decrease in crystallite size values, L_a and L_c of flakes have been found with 10 hour treatment time. Another variety of graphite flakes obtained from entirely different sources shows complete absence of (100) and (110) reflections, suggesting only two dimensional ordering of structure.

CHARACTERIZATION OF MATERIALS REGARDING MICROSTRUCTURE BY TRANSMISSION AND SCANNING ELECTRON MICROSCOPY AND ELECTRON DIFFRACTION TECHNIQUES

Silver films prepared on to quartz and carbon layers under very high vacuum conditions (4×10^{-7} Torr) were examined by T.E.M. The detailed study of the films using defocus contrast technique did not show the presence of void contrary to earlier observations that Ag films prepared by cathodic sputtering or thermal evaporation at a relatively poor vacuum conditions had a high density of voids. These observations threw morelight on the origin and nature of voids and their growth.

Thin films of silver prepared by sputtering or thermal evaporation at a relatively poor vacuum conditions have a high density ($10^{10} - 10^{12} \text{ cm}^{-2}$) of small voids (15Å) and these voids could be observed by defocus contrast technique in T.E.M. Intrinsic void formation in the films occurs due to the trapped gas atoms. No stable voids could be nucleated and further grown without the presence of gas atoms in the voids.

The growth of voids occurs only due to the diffusion of excess vacancies quenched in the film

during film formation process. Thin films of silver prepared under V.H.V. condition do not show the presence of void because intrinsic stable voids are not formed due to relatively lesser number of gas atoms trapped in the film during their deposition.

1.1 Microstructure of the sputtered Cr-C films

The microstructure of thick films of Cr-C prepared on to well polished stainless steel substrates by activated reactive sputtering using planar magnetron has been investigated. The sputtering was carried out in a mixture of argon and methane (CH_4) atmospheres and the temperature of substrates was varied upto 500°C during deposition. The composition of the films has been carried out by electron microprobe analysis (EPMA) and energy dispersive spectrometer (EDS). The presence of low atomic number impurities such as carbon and oxygen has been detected by electron energy loss spectroscopy (EELS). The study has led to interesting results and some of the data on EELS and micro micro diffraction is still being analysed.

1.2 Study of optical properties and morphology of selective coatings (black nickel-cobalt)

More than one hundred samples of black Nickel-Cobalt selective coatings were prepared on Aluminium sheets by chemical deposition techniques by varying deposition parameters. The optical and thermal constants i.e. absorptance (α) and emittance (ϵ) were evaluated from U.V. and I.R. reflection measurements. By varying various deposition parameters the best values of α and ϵ were obtained as 0.94 and 0.07 respectively. All the samples were examined with SEM for morphology and the composition of Nickel-Cobalt coatings was determined with E.D.S. Some samples have also been examined by TEM to study the structure of the coatings. The thermal stability of these coatings was also investigated by observing changes in surface structure and optical constants as a function of annealing temperature from room temperature to 300°C . The study showed little change in morphology and optical constants of the coatings in annealing upto 350°C .



Fig. 2 The figure shows a SEM micrograph of selective coating of Nickel + cobalt on Aluminium magnification X 7500

1.3 Microstructure and analysis of sintered Beta-Alumina

The microstructure and composition of sintered Beta-Alumina was studied by SEM and EDS. The study carried out on a large number of samples revealed that the grains have platelet like morphology and there are two phases present in the material viz the one showing lighter contrast and the other dark. The elemental analysis of both the phases was carried out with EDS. The study showed the light grain had Na and Al elements present in the ratio of 18:82 while the dark grains showed 7.8:92.2 indicating that the light grain Beta-Alumina $\text{Na}_2\text{O} \cdot 5\text{Al}_2\text{O}_3$ phase as a major constituent while the dark grain was Beta Alumina $\text{Na}_2\text{O} \cdot 11\text{Al}_2\text{O}_3$ phase as a minor constituent.

1.4 Failure analysis of a transistor for SAC/ISRO, Ahmedabad

One transistor type 2N3019 used in a sub-system was brought from ISRO Ahmedabad for failure

analysis. The transistor had failed in a functional test. The transistor was decapped and was examined by SEM at various magnifications in different orientation. The examination of the transistor revealed that the bond wire had a discontinuity near the bonded point with a bead at the end and the pad showed thin hair like cracks. It appears that it failed due to overheating at the bonded point.

CHARACTERIZATION OF SINGLE CRYSTALS REGARDING PERFECTION AND RELEVANT INSTRUMENTATION

1. High Resolution X-ray Diffraction Studies of Electric Field Induced Microstructural Defects in Silicon and Study of Dynamical Phenomenon and Precise Determination of Lattice Parameter of Silicon Single Crystals.

For testing and commissioning of the quadruple crystal X-ray diffractometer designed and de-

veloped at the NPL, silicon single crystals were used at the third and the fourth crystal stages. The first two crystals of the diffractometer are plane monochromators set in (+, -) configurations and have diffracting surfaces parallel to (111) lattice planes. The source is a fine focus X-ray tube (size $0.4 \times 0.4 \text{ mm}^2$ after foreshortening). A combination of special collimator and slits developed in the laboratory and the monochromators gives us a highly collimated and monochromated $K\alpha_1$ beam of X-rays, with a width in the horizontal plane of 0.2 mm. The vertical dimension can be continuously varied with the help of a special slit. The maximum height is about 40 mm at the third crystal stage. The third crystal can be aligned in Bragg or Laue geometries and can be set in dispersive or non-dispersive settings. A traversing device with a least movement of 0.01 mm has been incorporated at the third crystal stage. This permits recording of high resolution traverse topographs even when the exploring radiation is highly collimated $K\alpha_1$ beam. This unique technique permits recording of topographs even when diffraction curves have half width of less than 10 sec arc. Several traverse topographs have been recorded with crystal showing diffraction curves of half width of 3 seconds of arc only. The special fine angular movement unit successfully developed and incorporated at the third and the fourth crystal stages, permits least angular movement of 0.4 sec of arc. The fourth crystal is generally aligned in Bragg geometry and acts as an analyser crystal. Both dispersive and non-dispersive settings are used. Changes in lattice parameter of the third crystal can be easily monitored by the fourth crystal with a sensitivity of $\Delta d/d = 10^{-5}$. As a part of testing of the system, the following experiments were performed on dislocation free silicon single crystals specimen:

- (i) diffraction curves were recorded;
- (ii) high resolution traverse topographs were recorded; and
- (iii) radius of curvature were measured.

The diffraction curves showed a half width of ≈ 3 sec of arc for (220) diffracted planes in Laue geometry and (+, -, +, -) setting. $\text{MoK}\alpha_1$ was the exploring beam. Such a sharp curve is very



Fig. 3(a). A high resolution traverse topograph of a dislocation free (111) silicon single crystal recorded on the Quadruple Crystal X-ray Diffractometer: 220 relp; $\text{MoK}\alpha_1$; (+, -, +, -) setting; Circular contours are the electrode boundaries.



Fig. 3(b). A high resolution traverse topograph of a dislocation free (111) silicon single crystal (specimen same as in 3(a)) recorded on Quadruple Crystal X-ray Diffractometer during the application of an electric field to the specimen: $p = 0.01 \text{ Wmm}^{-2}$, 220, relp; $\text{MoK}\alpha_1$; (+, -, +, -) setting; electric field induced changes clearly visible in the circular electrode region.

satisfying and showed that very small deviation from ideal perfect state of a crystal can be detected and measured with the help of the present diffractometer. Traverse topographs of about 15 mm in scan can be recorded in a few hours time. Images of defects can be clearly seen. These high resolution traverse topographs have much more sensitivity compared to the standard projection (Lang) topographs.

The radius of curvature is typically about 100 m or more for most of the nearly perfect crystals. In case of some crystals, the values are in the range of 400—500 m.

This diffractometer has been used for the following investigations:—

1.1 Study of Electric Field Induced Microstructural Defects in silicon

Experiments were performed to study microstructural defects generated by dc electric fields in silicon single crystal discs which had their surfaces parallel to (111) planes and thickness of about 1 mm. 5 mm dia, 2 μ m thick aluminium electrodes were coated with vacuum evaporated on the two larger surfaces of the specimen. The specimen was placed at the third crystal stage. The diffractometer was set in (+, -, +, -) configuration. (220), (333) and (555) diffracting lattice planes were used. Diffraction curves, high resolution traverse topographs and radius of curvature were recorded before, during and after the application of the dc field. The diffraction curves had a half width in the range of 3–5 sec of arc, before any field was applied. The shapes of diffraction curves did not show any strong change on application of the dc fields up to power densities of 0.01 W m⁻². The radii of curvature of the specimen were in the range of 100–200 m before the field was applied. After a few applications of the dc fields, the radius of curvature showed an increase to about 400 m. Images of filaments could be observed in high resolution topographs at a power density of about 0.01 W mm⁻². With the limited experiments performed so far, this is the threshold value. It was observed that the images of the filaments do not disappear immediately on switching off the field. The decay characteristics of the filaments are under in-

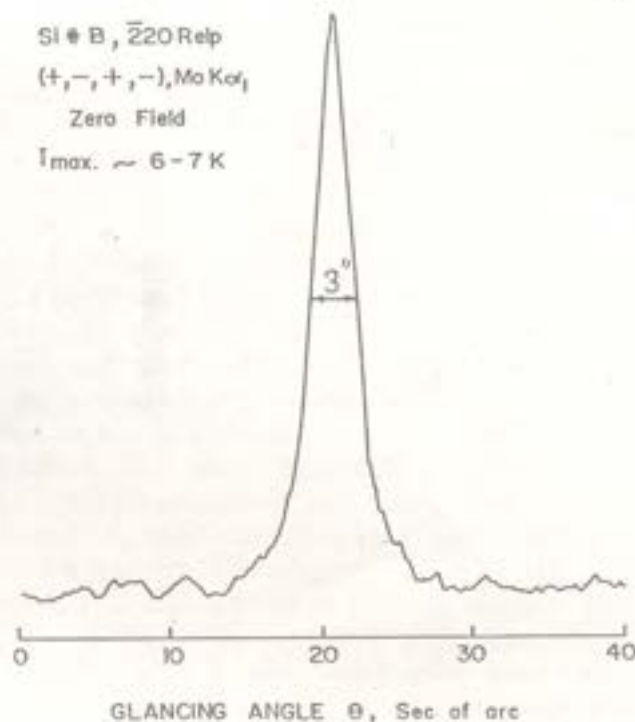


Fig. 4. A typical diffraction curve of a nearly perfect (111) silicon single crystal recorded in symmetrical *h*ve (transmission) geometry on the Quadruple Crystal X-ray Diffractometer; 220 rlp; MoK α_1 , (+, -, +, -) setting.

vestigation. The images of the filaments are not due to surface features as revealed by experiments performed in Bragg geometry by using (333) and (555) diffracting lattice planes. In this case, topographs were recorded by traversing the crystal across the beam in Bragg geometry. No filaments were observed. Experiments on the study of decay and gradual emergence of filaments images are in progress.

1.2 Measurement of Absolute value of Lattice Parameter of Silicon Single crystals

Fz grown crystals were chosen as specimen for lattice parameter measurement. DXS measurements had been made earlier on this crystal. The specimen was introduced as the fourth crystal of the diffractometer. It was aligned for diffraction from (111) lattice planes in (+, -, +, -) and (+, -, +, +) configurations. The angular separation between the two orientations of the specimen was determined experimentally. Since the

diffraction curves have a half width of a few seconds of arc, the value of $(180 - 2\theta_n)$ can be determined with a high precision. From the Bragg angle θ_n , determined by experiment, the value of lattice parameter was determined to be $a = 5.4313 \text{ \AA}$ at 29°C . At present the precision attained is about 10 ppm. This can be further improved if the temperature and vibrations in the ambient are controlled. A simple experiment was performed to check the sensitivity of these measurements as well as for checking the overall sensitivity of the diffractometer. An electric bulb of 200 W power was placed at a distance of 200 mm from the analyser crystal. After the bulb is switched on for about 20 seconds the intensity of the X-ray beam diffracted from the fourth crystal starts showing a decrease due to a shift in the angular position of the specimen for diffraction. A change in the temperature of about $2-3^\circ\text{C}$ can cause measurable effect in the diffracted intensity due to shift in the peak position.

1.3 Study of anomalous transmission and absorption in nearly perfect single crystals

Anomalous transmission and absorption of X-rays is expected to take place when nearly perfect crystals are aligned for diffraction in the Laue geometry. We have used silicon single crystals specimens having thicknesses 0.26, 0.92, 1.62, 3.12 and 4.57 mm. The specimen is the third crystal of the diffractometer and $\text{Mo K}\alpha_1$ exploring beam was employed. Two scintillation counters are used to simultaneously measure the intensities of the diffracted and the direct beams. One timer is used to control the time interval set for accumulating the output counts. Dynamical effects can be observed even when the value of the absorption coefficient is less than 1 (equal to 0.36). Strong anomalous transmission and absorption are observed at a μt value of about 1.3. Here μ is the absorption coefficient. Anomalous transmission is dominant when the μt values are about 2.2 and above. We have succeeded in obtaining two intense, highly collimated, monochromated and coherent beams of X-rays having comparable intensities.

An accurate value of the absorption coefficient of silicon for $\text{Mo K}\alpha_1$ radiation has been

determined. It was observed that anomalous transmission and absorption strongly influence transmitted X-ray intensities in the vicinity of the diffraction peaks. Therefore, value of absorption coefficient was determined by rotating the specimen by about $(10^\circ \approx \theta_n)$ on either side of the diffraction maximum. The accurate value of the absorption coefficient for silicon has been determined as 1.395 mm^{-1} for 0.70926 \AA ($\text{Mo K}\alpha_1$).

2. Diffuse X-ray scattering Measurements

The triple crystal X-ray diffractometer earlier developed in our group for measurement of diffuse X-ray scattering was modified for use with a high power fine focus source in place of earlier low power microfocus source. Since the source size in the new set up is larger than that in the microfocus source, one more monochromator crystal was added to the earlier two crystal set of Bonse-Hart type. The new monochromator crystal was prepared out of a (111) silicon single crystal boule with its diffracting planes parallel to (111). Its surface was prepared by careful grinding, lapping, polishing and etching. The three crystal monochromator assembly is aligned in (+, -, -) configuration. This dispersive set up (at the last stage) gives high spectral resolution.

A new microprocessor controlled electronic counting and stepping motor control unit has been commissioned. To suite the input impedance of this system, a new scintillation counter was developed. The stepping motor was attached to find angular movement assembly used for specimen crystal. With this arrangement angular rotations of 0.5 sec of arc can be provided to the specimen crystal.

Diffuse X-rays scattering measurements have been made on CZ grown silicon crystals for calibration of the new system. Measurements have also been performed on silicon crystal grown by the Float Zone method. On this set up also nearly perfect crystals give very sharp diffraction curves (half widths 10 sec of arc). The scattering vector was chosen along four different directions. No significant scattering was observed when the crystal was rotated by about 1 minute from the diffraction maximum.

(3) Evaluation of Strain Field in Silicon Single Crystals Wafers having Polysilicon Deposits on Silicon Dioxide Films by Double Crystal X-ray Topography

A double crystal X-ray diffractometer developed at the NPL was used for evaluation of perfection of silicon single crystal wafers having polysilicon deposits on SiO_2 films. Also, it was aimed to determine the strain generated by the films at the interface with the wafer. The films were grown by chemical vapour deposition on silicon single crystals in collaboration with CEERI, Pilani. Diffraction curves and high resolution topographs were recorded with $(\bar{2}20)$ and (111) lattice planes. The specimen had their larger surfaces parallel to (111) . Curvature measurements were also made. The planes parallel to the surface of the specimen were found to be quite strained. The strain was anisotropically distributed in the body of the crystals. The planes perpendicular of the surface such as $(\bar{2}20)$ planes were found to be much less strained. The diffraction curve half width for (111) and $(\bar{2}20)$ planes were in the range of 270 to 430sec and in the range of 45 to 65 seconds of arc. For comparison, measurements were also made on a nearly perfect dislocation free crystal of silicon which was taken as a reference diffraction curve of this crystal had a half width of 14 sec of arc. The radius of curvature of the specimen were in the range of 4-5 m. This is very small compared to that of the reference crystals. The value of strain has been quantitatively estimated and found to be 5.5×10^{-5} .

In the double crystal X-ray diffractometer developed last year, only one asymmetrically cut silicon single crystal monochromator was used. The experiments performed with this set up showed that the spectral quality of the exploring beam was not very high. To overcome this drawback another plane crystal monochromator was added to the system. It is a symmetrically cut silicon single crystal which allows only very small wave band around $K\alpha_1$ characteristic radiation to be diffracted. The specimen could now be used in dispersive as well as non-dispersive settings. The quality of the topograph was found to improve.

GROWTH AND CHARACTERIZATION OF SINGLE CRYSTALS

The crystal growth system employing resistive heating was made more versatile by adding an induction heating system. A RF generator has been commissioned and crystal growth experiments have been performed by using nickel crucible.

A vacuum chamber has been developed for growth of crystals under controlled environment by using induction heating. The quartz envelope, water cooled top and bottom attachments have been designed, developed and fabricated and assembly work is in progress.

Study of effect of growth conditions on strain at the seed-melt interface was carried out. KCl crystals were prepared with different rates of pulling (10 mm per hour, 15 mm per hour and 29 mm per hour) and different rates of rotation (30 rpm, 60 rpm). Wafers were prepared from these boules with growth direction parallel as well as perpendicular to their surfaces. Their perfection has been evaluated by using X-ray diffraction topography. Double crystal topography has also been used.

Crystals of LiF, KBr, KCl, NaCl were grown by CZ method and supplied to several institutions on request.

CHARACTERIZATION OF MATERIALS REGARDING SURFACE AREA AND POROSITY

1. Research & Development of Adsorptive Carbon Fibres

Several samples (17) of carbon fibres were prepared using viscose rayon yarn precursor. The carbonization was carried out in a vertical furnace. Adsorption properties of these samples were compared with those prepared in a horizontal furnace. Scattering in the values of yield and specific surface has been observed. Effect of ageing on the carbonized rayon yarn samples, prepared during 1977, was studied. R—

emarkable decrease in the uptake of nitrogen at 77K has been observed.

1.1 Testing and Standards

One sample of activated carbon was tested regarding BET-surface area and open porosity.

Draft standard for the adsorption apparatus and the procedure for the measurement of specific surface using low temperature gas adsorption method has been put into wide circulation. Prototype of BET-apparatus, proposed for ISI, has been got fabricated and will be installed very shortly.

CRYOGENICS AND SUPERCONDUCTIVITY

CRYOGENIC PLANTS & FACILITIES

1. Liquid Air Plant

The liquid air plant developed, based on Stirling Cycle, had begun production. During the year, extensive efforts have been made to make the plant more efficient and reliable. Various control valves in the machine were studied and improvised. The water flow in the machine was inadequate, which was increased for better efficiency and more output of the plant, by the installation of a new water pump. The plant consists of about 1000 components of which some are of critical nature, like water-cooled heat exchanger, regenerator, shaft sealing optically flat special bush etc. Efforts have been continued for the development and perfection of heat exchangers. Another important critical parameter for the efficient working of the plant is the difference in filling pressure and average working pressure in the machine, which should be about 4 to 5 kg/cm². By modifying various seals and the working of valves it is now obtained to about 3 kg/cm² pressure difference. The plant is at present delivering about 3 litres liquid air per hour. The problem faced at the moment is overheating, of the plant which can be minimised by coupling a chilling plant with the machine to cool water flowing in oil-cooler and water cooled heat exchanger.

2. Development of Low Temperature Cooling Systems (77-80°K) for Infrared Detectors

The miniature cooling system consists of various sub-systems viz. (a) intensifier (high pressure booster) (b) high pressure gas accumulator (c) various control valves (d) Purifier (e) J.T. Heat exchanger & flow nozzle and (f) glass dewar. Efforts have been made to develop and fabricate all the above sub-systems. The intensifier and bottles were fabricated from a local firm. Both have been tested at high pressures. By the use of

intensifier, gas bottles have been filled upto 4000 psi. Various J.T. heat exchangers based on the heat transfer calculation have been designed and developed. The mini-coolers have been tested for their performance at different input pressures of nitrogen gas. Liquid nitrogen temperatures have been obtained on the cooler tip in about 2-3 minutes at about 2000 psi input pressure. The design of mandrel and flow nozzles are being modified. A solenoid valve has also been designed and developed. It has been tested upto 4000 psi pneumatically preliminarily at Defence Science Centre, New Delhi.

3. Liquid Nitrogen

The liquid nitrogen plant PLN-430 was operated successfully and produced 7120 litres. It was supplied to various research groups within the laboratory and Delhi University, All India Institute of Medical Sciences, Institute of Communicable Diseases, Delhi etc.

SUPERCONDUCTIVITY AND SUPERCONDUCTING MATERIALS

1. Mechanism of Superconductivity

A comparative study of CESR was made on various simple elements like Nb, Al, Re etc. and also alloys and compounds and the presence of strong exchange interactions in the conduction band was confirmed. Previous findings and conclusions about the mechanism of superconductivity are thereby further consolidated. A preliminary analysis of the isotope effect which is generally taken in strong support of the conventional phonon mechanism revealed the paramount role of hyperfine interaction in the observation of the effect.

1.1 Superconducting Materials

Characterization of Superconducting parameters

for various binary and ternary systems formed using magnetic elements have revealed the presence of composite phases, with T_c values ranging from 4.2 K to 10.3 K. These phases will be further studied. Multifilamentary Nb-CuSn systems containing Nb-filaments of various sizes and numbers ranging from 2600 to 10,000 were investigated. Nb₃Sn layers of A-15 crystal structure formed by solid state diffusion were studied and characterised. The growth kinetics studies made were explained in terms of previously developed models involving grain growth kinetics.



Figure showing Nb₃Sn grains in the bronze processed layer. Magnification 3,30,000.

1.2 Development of Josephson tunnel junctions and SQUIDS

Mask alignment facility has been established. Expertise have been developed to make Pb and Pb-In alloy films upto 5 micron line width on glass and silicon substrates using photolithographic lift-off technique. The technique uses only a single layer of a positive photoresist (Shipley 1350 J) which is treated in chlorobenzene to get an undercut in the photoresist stencil. An array of 20 tunnel junctions has been successfully patterned using this technique.

1.3 Study of nonequilibrium superconductivity using weak links

The resistive superconducting state with low differential resistance (LDR) which was observed

earlier in suitably prepared solder blob junctions (SLUGs) has been further studied. It is found that the transition from the LDR to the normal region is hysteretic. A detailed analysis of the variation in the values of the hysteretic parameters reveals that the hysteresis arises mainly due to net trapping of self induced flux in the superconducting loop formed in the SLUG between London penetration regions in the individual superconductors and the pair of the weak links. Thus the hysteretic behaviour of I-V curves support the superconducting nature of the LDR region formed due to nonequilibrium superconductivity in accordance with Aslamazon-Larkin model.

Preliminary studies of Josephson tunnel junctions (Pb-Pb₃O₇-Pb) with thin uniform barriers show two types of self induced step structure in their I-V curves. In one case extrapolated differential resistance regions converge to a common current value in the pair current region. There is homogeneous nucleation of phase slip centres each having a maximum pair current 0.30 I₀. In the other case the nucleation of these centres is heterogeneous since they differ in their critical currents. This indicates creation of a new inhomogeneous nonequilibrium superconducting state.

A-15 SUPERCONDUCTORS THROUGH INSITU TECHNIQUE

1. Cu-Nb composites

The composites of Cu-Nb, the base material to Cu-Nb₃Sn were thoroughly characterized. The microstructure of the composite wires has been found very satisfactory in so far as they have high density fine ribbon shaped filaments.

A significant development has been the operation of a 7T superconducting magnet, fabricated in the laboratory. Critical current density (J_c) measurements have been carried out on all Cu-Nb composites (1 to 30 at.% Nb). Below the percolation threshold concentration (15 at.%) composite wires show a drastic reduction of J_c with temperature and magnetic field. Cu-Nb (20, 25, 30 at.%) composites carry an overall J_c of 2.5×10^9 A. cm⁻² in zero field and at 4.2 K. Very interestingly the upper critical field H_{c2} of the



Fig. 1. The SEM picture of a typical Nb-dendrite in a Cu-Nb (5 at.%) composite (as cast).

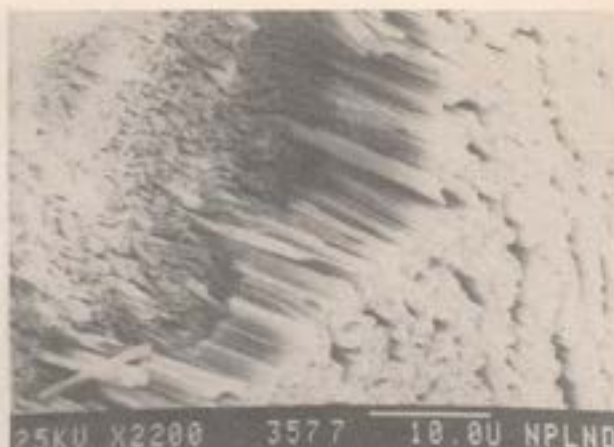


Fig. 2. The drawn (Cu-Nb) and (Cu-V) composite wires have a large density of very fine ribbon shaped filaments. Above is a typical SEM picture of a Cu-V (35 at.%) 0.44 mm dia wire.

composite wires as computed from the Kramers plots is about 1.1 T significantly higher than 0.2 T, the value observed for pure Nb wire. This increase is attributed to the increase of normal resistivity of Nb-filaments caused by a dissolution of about 2 wt.% of Cu in Nb during the quench of the alloy and also by an increase in dislocation density due to cold working. Interesting results have been obtained on the variation of H_{c2} with annealing.

Cu-Nb tapes show anisotropy of J_c in magnetic fields. The large values of J_c in fields parallel to the wider side of the tape strongly indicate the dominance of surface flux pinning in these materials. The peak in volume pinning force versus reduced magnetic field plots at 0.25 also supports this contention. Further work is in progress.

1.1 Cu-Nb₃Sn composites

Cu-Nb composites with Nb 15 to 30 at.% were coated with varying amounts of Sn (2.7 to 36 V%) through electroplating technique using an alkaline bath and heat treated in a series of steps to accomplish the conversion of Nb-filaments into Nb₃Sn. Highest T_c value of 17.5 K (midpoint) has been obtained for composites with Sn in excess of the stoichiometric values and heat treated for 70 to 100 hrs at 550°C. Overall J_c values as high as 3×10^5 A cm⁻² (6T, 4.2 K) have been obtained for a number of specimens. These values compare well with the best values reported in the literature. Fresh materials with preheating and improved reaction procedures are being

prepared for further studies. Efforts are being made to prepare larger quantities of ingots (80–90 gms) by modifying the arc melting procedure and to install facilities for drawing wire in larger lengths. Facilities are also being created for the measurement of the upper critical field H_{c2} .

THEORETICAL INVESTIGATIONS IN CONDENSED MATTER PHYSICS

1. Non-equilibrium superconductivity

Detailed studies on the soliton-bearing scalar fields were done with a view to get an insight into the soliton solution obtained earlier in the problem of non-equilibrium superconductivity.

1.1 Bethe ansatz and its applications

A general class of problems amenable for a Bethe-ansatz treatment were taken up for investigation. A possible connection between the S-matrix theory of the Kondo problem and the Bethe ansatz solution of the strong coupling region of the Kondo problem is expected to be revealed from these studies.

1.2 Jahn-Teller interaction in solids

The theoretical formulation to the optical (Ra-

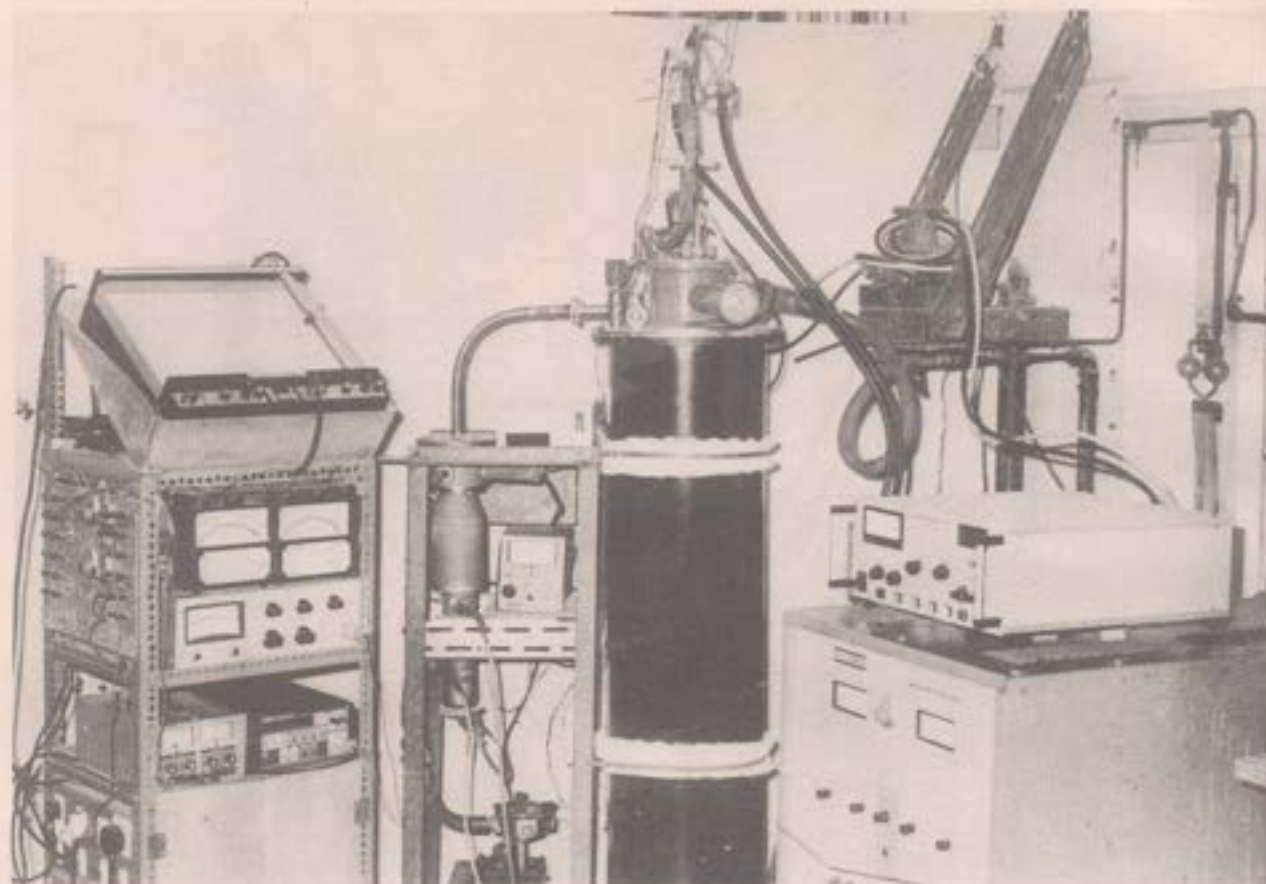


Fig. 3. A 7T magnet system used for critical current measurements on insitu superconductors. The superconducting magnet has been fabricated in the laboratory.

man spectroscopy) and magnetic behaviour of chromocene Cr (C_5H_5)₂. Large reduction in the values of Racah parameter, the spin-orbit coupling and the orbital contribution to magnetic moment from their free ion values had required the introduction of Jahn-Teller induced vibronic coupling in the complex. The method of canonical transformation and variational approach, re-

cently developed for cobaltocene was found applicable to this case too.

1.3 Theoretical studies in ESR Analysis

The expression developed last year for the ESR line shape in liquid crystals specially valid for the slow tumbling region of the probe, was tested on the basis of existing ESR results.

APPLIED PHYSICS PROJECTS

UTILIZATION OF SOLAR ENERGY — THERMAL CONVERSION

1. Test Facilities for Solar Flat Plate Collectors

In order to bring the measurement accuracies of thermal performance efficiency of flat plate collectors under transient/steady state conditions at par with internationally reported values, a specially designed micro-computer based multi-channel data logger has been installed as a part of the National Test Facility for Solar Collectors with support from the DNES.

1.1 Development of Copper Disc Pyrheliometer

A copper disc pyrheliometer based on transient principle has been developed. The salient features of this method are that the solar radiation is determined in terms of heat capacity of the sensor, sensor area and its heating and cooling rates. The heat loss coefficient which is difficult to determine accurately has been eliminated. As these parameters could be measured accurately, this type of pyrheliometer is highly accurate and is well suited for bench standard for radiation measurement. The accuracy obtained at present is 0.61%. In the present system an imported tracking unit has been used and could be made indigenously. Work is in progress as to consistency and over-all accuracy.

1.2 Size optimisation of Solar Hot Water Systems

Theoretical calculations of thermal energy collection using flat plate collectors are being made utilizing actual data on average solar insolation, ambient temperature, collector tilt and collector thermal performance test results for a few cities in India.

1.3 Device for Optimum Heat Transfer

A novel device for better heat transfer to the desired place/heat extraction tank has been de-

veloped and a unit fabricated. This unit uses the principle of upward flow of the hot liquid and gravity flow of cold part to convert the unit into a heat concentrator.

STUDIES ON POLYCRYSTALLINE SILICON

Ingots with circular section having 45 and 75 mm dia were cast. Polysilicon wafers of 38 mm dia, were sent to Central Electronics Ltd., for evaluation of photovoltaic properties using CEL process. Solar cells fabricated on these wafers with POCl_3 diffusion and screen printed front and back metallization and spin on AR coating gave AM1 total area efficiency of 8.5%.

The facilities have been augmented to process solar cells upto 50 mm in diameter. Image analyser has been made fully operational and measurements of grain size, grain size distribution, each pit density, and dislocation density & distribution are being carried out with it. EBIC setup has been fabricated. DLTS apparatus is made functional and measurements for the study of deep level impurities in silicon are being carried out.

Surface photovoltage measurement set up has been improved and it is possible to obtain measurable SPV signal and determine diffusion length.

An Oriel Solar Simulator has been fully commissioned for operation at AM1 & AM 1.5 and a new lock-in-amplifier has been procured & put into SPV assembly.

ELECTROSTATICS & ELECTRO PHOTOGRAPHY

1. Electrostatic Dust Collectors

Efficiency measurements of dust collects both on qualitative and quantitative basis is being carried

out using ASHRAE test bench. From the results of these studies optimization of the geometry and design parameters of the ionizer and collecting systems of the dust collectors is being done.

2. Xeroradiography

2.1 Photoreceptors

Towards the improvement in X-ray sensitivity for reducing the X-ray dosage to patients, efforts have been made to increase the thickness of selenium photoreceptors. Photoreceptors upto a thickness of 300μ have been developed. Efforts have also been made to increase X-ray sensitivity by doping the Selenium with Te and As. Te concentration of about 200 ppm was found to have good X-ray sensitivity.

2.2 Toners

Efforts are being made to further improve the contrast and resolution of toners. New materials are being studied to develop resinless toners and resin coated paper to improve the transfer of the Xeroradiographic images.

2.3 Cloud Chamber Development

The cloud chamber developing system is being modified to improve the xeroradiographic efficiency by giving better development for lower X-ray dosages. To control the flow of aerosol the arrangement like pressure regulator valves, timers etc., are being incorporated in the design of cloud chamber. The effect of development electrode is being studied to obtain defect free full tone image.

2.4 Newer Material

With a view to reduce the X-ray dosage, efforts are being made to develop more X-ray sensitive photoreceptors using newer materials like PVK, CdS with suitable dopents. CdS doped with copper and chlorine has been found to have photoconductivity comparable to that of selenium and fabrication of photoreceptors using this material is being tried.

THIN FILM AND AMORPHOUS MATERIALS

1. Thin film optical coatings

Multicavity (four) broad band (HbW 800–1000 Å) all dielectric interference filters suitable for use in Multispectral scanning of earth resources through IRS series of satellites by ISRO have been developed under a sponsored programme. Representative optical design of such a filter is

$$\text{air/H 2L HLH 2L HLH 2LH/Glass}$$

where L and H correspond to respectively low and high index quarter wave thick layers. These filters to be qualified for space application for extended period are required to meet the following specifications.

MIL-0-13830—A, MIL-C-675 A, MIL-M-13508 C, MIL-E-12397 B, MIL-675 and MIL-E-12397

Optical characteristics of such filter has since been approved by ISRO. A set of sixteen filters peaking at 4850 Å, 5500 Å, 6500 Å and 8150 Å have been supplied to ISRO for conducting environmental testing and their comments were received. Various mechanisms for failure of these filters at very low temperature have since been conceived and changes incorporated in the design of such filters. Such remedial measures appear to be quiet optimistic as evidenced by environmental studies carried on a batch of 6 filters by-Electronics Regional Test Laboratory, OKHLA.

Meanwhile a large number such multicavity filters for ground based radiometric work has been supplied to ISRO has since shown great interest in transfer of the related knowhow to a third party.

Computer assisted design capability of broad band (0.4μ to 1μ) antireflection coating has been achieved.

Theoretical studies have shown that thin-film multilayer

$$\begin{matrix} 1.0 & L & & L^p & & 1.52 \\ \text{(air)} & \frac{1}{2} & | & \text{HL} & | & \frac{1}{2} & \text{(Substrate)} \end{matrix}$$

where p is an integer ≥ 5 and L, I, H are quarter-wave layers of three different materials of indices

n_L , n_s and n_H respectively has interesting spectral characteristics (high transmission in visible and high reflectance in the near IR) which make it suitable for a heat-reflecting mirror. Efforts are continuing to improve the characteristics and to fabricate this structure.

1.1 Entire development work related to optical coatings for optical systems of MIG series of fighters under sponsored programme from HAL, Nasik has been completed. These are:—

- (i) Collimating sight glass (hard coatings)
- (ii) Gun sight reflector glass (hard coating)
- (iii) Elliptical mirrors (hard coating)
- (iv) Rear view prism (hard coating)

NPL has since been type approved for supply of 1-3 coatings listed above while approval for item no. 4 is awaited. The group has since undertaken a large amount of recoating job according to their own developed process for HAL, Nasik.

2. Amorphous Silicon Films

Amorphous hydrogenated silicon (a-Si:H) films being produced in a single zone and cascaded double zone reactors designed and fabricated in the laboratory, were characterised for density of gap states by three different techniques i.e. ESR, field effect and by space charge limited current studies. An average values of $5 \times 10^{16}/\text{cm}^3 \text{eV}$ was arrived at by this characterisation study for amorphous silicon films produced in our single zone reactor which is considered to be satisfactory for application of such films in p-i-n solar cell fabrication. However, the gap state density reduces in the films grown in IIInd reactor (down the line) of a cascaded system.

Detailed study of light induced conductivity changes in the films grown in a cascaded reactors system indicated that films grown down the line are almost immune to such changes.

2.1 Small area Schottky diodes were fabricated using the a-Si material to ascertain the suitability of this material for photovoltaic application. A typical Schottky diode (without the use of a n⁺

layer and antireflection coating) has the following parameters;

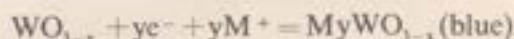
- | | |
|------------------------------------|-----------------------------|
| (1) rectification ratio at 1 Volt, | $- 10^5$ |
| (2) Open circuit voltage, V_{oc} | $- 0.5$ volt |
| (3) Short circuit current I_{sc} | $- 2 \text{mA}/\text{cm}^2$ |
| (4) Fill factor | $- 0.7$ |
| (5) Diode quality factor | $- 1.2$ |

2.2 A novel scheme of transfer of substrate under vacuum from one chamber to other, for design of a low cost multichamber plasma CVD reactor was envisaged. Detailed engineering drawing has since been completed for fabrication of a prototype in collaboration with central workshop.

DISPLAY DEVICES

1. Electrochromic Materials & devices

Electrochromic thin film devices are in advance stage of development for display applications. Transition metal oxides exhibit electrochromism by reversible ion insertion mechanism. Substoichiometric tungsten trioxide, WO_{3-x} , has been studied in detail and is found to be promising material, when employed as an electrode in an electrochemical type cell colours cathodically by a reduction process:—



where $x \leq 0.3$ and $y \leq 0.35$ and $M = \text{H, Li and Na}$. Various process parameters of the device technology have been worked out. A number of innovations have been simultaneously introduced through continuing basic and applied research, these include (i) "Oblique" evaporation of WO_3 films for relatively faster electro-optical response speed (ii) special electrodes configuration design for uniform contrast and (iii) introduction of both charge transfer and ion insertion/extraction mechanism in coloration and bleaching of the display segments. The challenging problems of reversibility and operational life of these devices are being actively looked into.

1.1 Electron-beam evaporated transparent conductive coatings

Electron beam evaporation technique is further

optimised to prepare repeatedly In_2O_3 films with and without Sn doping on larger glass substrates. No post deposition treatment is needed and highly transparent and conducting films have been obtained. The characteristic feature of such films is their high carrier density and high infrared reflectivity. The lowest resistivity is found to be $2.4 \times 10^{-4} \Omega \text{cm}$ with a carrier concentration of $8 \times 10^{20} \text{cm}^{-3}$ and mobility of about $30 \text{cm}^2 \text{V}^{-1} \text{S}^{-1}$ at the doping level of 4 mol % SnO_2 . These polycrystalline films show a highly preferred orientation in X-ray diffraction pattern. On the basis of Hall measurements and structural data, sources of scattering in these films have been suggested.

In collaboration with Delhi University, indium tin oxide films have also been grown by r.f. Sputtering at various Ar- O_2 mixtures, at substrate temperatures (200°C), and deposition rates (25 Å/min) followed by post deposition annealing (at 350°C) in different ambients (O_2 , N_2 and cracked ammonia). Post deposition annealing in cracked ammonia (reducing atmosphere) has been found to be very effective and resulted in films of high quality (electrical & optical) with good structural properties.

2. Properties of heterocyclic conducting polymers

A great deal of progress has been made in the preparation and characterization of thin conducting polymeric films. Simultaneous electrochemical polymerization and doping technique has been further adopted to obtain chemically stable (upto 100°C) conducting films of polypyrrole as well as polypyrrole—phenol (doped with ClO_2). These films are found to be p-type semiconductors, with activation energy of $\sim 0.02 \text{eV}$; thermoelectric power $\sim +30 \mu\text{V/k}$, electrical conductivity $\sim 4 \Omega^{-1} \text{cm}^{-1}$. A change in electrocolouration has been observed on doping and undoping of films made on transparent conductive coatings of indium tin oxide on glass substrates.

3. Multiplexing limits of dual frequency addressed twisted nematic—liquid crystal displays

In order to address a large density information

display, multiplexing (time sharing) techniques are generally employed. The multiplexing limits of a root-mean-square responding TN-LC cell are essentially determined by the sharpness of its electro-optical transmission characteristics which in turn are governed by the various physical properties of the LC mixture used and the cell fabrication parameters. Even with the best adjustment of the material properties and the cell fabrication parameters, the maximum number of multiplexible lines N_{max} could not be more than 30 or so without the use of extra non-linear elements. However, through a recently proposed novel dual frequency addressing scheme the multiplexing limit of TN-LCD's has increased considerably and thus the possibility of realizing a high information density display has been further explored. Our present investigations have shown that the multiplexing limits of dual frequency addressed TN-LCD's are also very sensitive to the surface alignment condition, i.e. the tilt bias angle of the LC molecules at the bounding surfaces and the temperature of the cell. The temperature effects depend mainly upon the variation of $\Delta\epsilon_{\text{H}}/\Delta\epsilon_{\text{L}}$ with temperature, where $\Delta\epsilon_{\text{H}}$ and $\Delta\epsilon_{\text{L}}$ are high and low frequency dielectric anisotropies respectively. This ratio can be made small depending upon a proper choice of liquid crystal mixture. Hence an optimum selection of the tilt bias and the temperature would be necessary to maximize the multiplexing limits.

HIGH PRESSURE TECHNOLOGY

Work on the development of cBN compacts without a substrate was taken up and encouraging results obtained. Some compacts were sent to BHEL for the evaluation of mechanical performance. Pending their report, efforts were made to optimise the process parameters, such as the temperature and pressure of reaction, the ratio of binder to cBN crystals and the reaction time to obtain acceptable values of toughness and hardness in the compacts.

Work on the pressure and temperature calibration of the newly erected and commissioned 1000 ton vertical press was also undertaken.

On the hot extrusion press in the extrusion of

tube hollows, the operational problems of the availability of a retracting mandrel, the leakage of nitrogen and the requirement of an additional accumulator are still pending. After these drawbacks in the equipment are rectified the development of tubes can be undertaken in a more comprehensive way.

Trials on the development of composite tubes (stainless steel/mild steel) were undertaken. The mechanical properties were evaluated. Designs for the use of short mandrel in place of long mandrels were also completed.

As a consequence of the development of copper-nickel tube by hot extrusion technology, a project on "Techno-Economic Feasibility Report for setting up/rennovating a copper-nickel tube plant in India" was undertaken.

MICROELECTRONICS

1. Fabrication of thin film lines with small line-width

The principle of single resist layer has been adopted to form the stencils for the fabrication of the fine lines of aluminium. The selection has been based primarily on the availability of facilities resources and need.

Using this principle, we have succeeded recently to demonstrate the feasibility of a repeat-

able photo-resist lift-off process for the fabrication of about 2.6 micron wide thin film metal lines with 5.6 micron centre-to-centre spacing. The process was developed using primarily the facilities of the Centre of Applied Research in Electronics, IIT, New Delhi.

The process appears adequate for the study of material structures and advanced experimental devices that require fine line geometry and has a considerable potential for the fabrication of miniaturized devices such as, high frequency SAW oscillators and LSI/VLSI circuits. Additional work is required now using semiconductor grade clean room conditions, facilities and chemicals to investigate and evaluate the process for large scale device manufacturing applications.

2. High sensitivity thermistor

Manganese oxide powders made by freeze drying & spray drying technique was sintered and some of its physical & electrical properties were determined for the characterization of the thermistor. The thermistor has shown some improved properties compared to other known thermistors.

3. Design of atmospheric pressure chemical vapour deposition unit

An atmospheric pressure chemical vapour deposition unit (A.P.C.V.D.) has been designed and fabricated.

DIVISION OF MATERIALS

DEVELOPMENT OF SOLID ELECTROLYTE GRADE BETA ALUMINA TUBES FOR SODIUM SULPHUR BATTERY

1. Beta-Alumina

Seven different compositions of $\beta''\text{-Al}_2\text{O}_3$ having Na_2O content ranging from 8 to 9.5 weight per cent were investigated. After careful preparation of these powders, one end closed tubes were pressed isostatically. The pressed tubes were sintered in lanthanum chromite furnace at temperatures 1570°C and 1600°C with 10 minutes duration.

Resistivity of the sintered tubes was measured by using molten electrodes of $\text{NaNO}_3/\text{NaNO}_2$ mixture. The optimum composition gave the lowest resistivity at both these temperatures. The lowest resistivity obtained was ~ 3 ohm centimeter.

1.1 Nasicon

Nasicon is a superionic conductor having composition $\text{Na}_{1+x}\text{Zr}_2\text{Si}_x\text{P}_{3-x}\text{O}_{12}$. This material has relatively higher resistivity than $\beta''\text{-Al}_2\text{O}_3$ but sinters at much lower temperature. A composition $\text{Na}_3\text{Zr}_2\text{Si}_2\text{PO}_{12}$ was prepared. Grinding of the composition after calcination was standardised to yield desired particle size ($< 1\ \mu\text{m}$) for processing. The X-ray analysis of the powders and sintered discs were carried out. The analysis shows presence of Nasicon as well as free ZrO_2 . Free ZrO_2 is harmful to the product and efforts are being made to eliminate it.

During sintering study of this material, it has been observed that it is very sensitive to temperature changes. Although it sinters around 1200°C , its sintering range is narrow. Several difficulties like melting and decomposition were faced. However, few samples have been prepared by sintering at 1180°C and density measured. Density has

been found to be 3.1 g/cc which is approx. 93 per cent of the theoretical density.

1.2 High Purity High Density α Alumina Headers

High purity high density $\alpha\text{-Al}_2\text{O}_3$ headers are used in conjunction with $\beta''\text{-Al}_2\text{O}_3$ tubes to be used as solid electrolyte in sodium sulphur battery. These headers were prepared isostatically by pressing $\alpha\text{-Al}_2\text{O}_3$ powder in the shape of a solid cylinder, machining to exact dimensions and sintering at high temperature ($\sim 1500^\circ\text{C}$) to suit 10 mm diameter $\beta''\text{-Al}_2\text{O}_3$ tubes. A die was also fabricated and $\alpha\text{-Al}_2\text{O}_3$ headers were prepared by uniaxial compaction and sintering. Few such headers prepared were joined with $\beta''\text{-Al}_2\text{O}_3$ tubes using a glass seal and were supplied to CECRI, Karaikudi.

1.3 Glass for sealing $\beta''\text{-Al}_2\text{O}_3$ tubes with $\alpha\text{-Al}_2\text{O}_3$ headers

This sealing glass is of a special type, which should match its expansion properties with those of $\beta''\text{-Al}_2\text{O}_3$ and $\alpha\text{-Al}_2\text{O}_3$. One such composition has been developed. Glass was prepared by melting the ingredients in their mixed form at 1250°C and then powdered by grinding. Powdered glass was applied to the joint in the form of a paste and gently heated to 1200°C to make a permanent joint. The joint was found to be satisfactory.

ULTRASONIC TRANSDUCER MATERIALS AND DEVICES

1. High power piezoelectric ceramic materials

Studies have been made to reduce the loss factor of the lead zirconate titanate material developed for high power applications. The tan value for this material designated as NPL-ZT-4B has been brought down to 0.004. Tubular transducers of

dimensions upto (70 mm) have been fabricated of this material using conventional as well as isostatic pressing technique. The material has a dielectric constant of 1250, charge constant d_{33} of 450×10^{-12} C/m and mechanical quality factor of 500.

1.1 Transducers & Devices

Transducers for Pingers: Transducers have been made using the tubular elements developed at NPL and were mounted in rubber encapsulations. The frequency response, directional response in X-Y plane, acoustic source level, electric impedance and efficiency has been experimentally obtained. Typical value for a 62 mm diameter transducer are:

Freq. band	-9-12 kHz.
Source level	-115 dB re 1 Pa per volt at 1 meter, Electrical impedance 20 K.

Transducers for primary sources for parametric sonar: The requirement of the transducer for the 200 m operational range parametric sonar has been studied values of SPL obtained for a transducer of frequency 15.8 kHz at 13.5 Nm. Tension was 167 dB re $1 \mu P_a$.

1.2 Parametric acoustic arrays in air

Experiments have been conducted to study the feasibility of narrow beam speech transmission. To meet the demand for a wide band primary source for this purpose, an electrostatic transducer with biasing of 1.5 kV and SPL of 124 dB re 0.0002 $\mu b/ft$ was used. Investigations were conducted using self demodulation as well as two transducer mode. The ultrasonic carrier to the transducer was modulated by a speech or music signal. In the case of speech signal, severe distortions were observed in listening by unaided ears, as well as in the recorded waveform on the oscilloscope. In case of music, sensible perception could be observed, however with aided ears only.

1.3 VLF Transducers

National Institute of Oceanography is interested in the development of very low frequency transducers for work in ocean acoustic tomography.

Design consideration for the VLF transducers and for its driving element has been studied.

2. Characterisation for power handling capacity

Ceramic high power rings of (NPL-ZT-4) material and sandwich transducers, indigenous and imported, have been examined for the acoustic output for different levels of excitation over different time intervals.

Low power examination based on the comparison of motional impedance characteristic has also been made on the indigenously developed and imported ceramic rings and transducers. Further work is in progress.

3. Ultrasonic NDT

A method has been developed with the help of which experimental data has been obtained on the variation of reflection coefficient with angle of incidence of the ultrasonic waves on solid-solid interface. The reproducibility of the setup has been brought to ± 3 dB in the range of 60° angle of incidence.

On the request of Archeological Survey of India for the ultrasonic nondestructive testing of Tajmahal, feasibility study was carried out. A number of stones, including Markana White Marble (used in Tajmahal), with and without defects, were examined. It has been established that ultrasonic NDT methods can be used for detection of cracks in the stones with suitably modified transducer systems. Further work on the study of effect of environment on the stones using ultrasonic NDT methods is in progress.

4. Biomedical Ultrasonics

Four prototype models of the ultrasonic A-scan ophthalmoscope were further modified to meet the requirements of the clinicians (hospitals) for their routine use. The present models give better resolution to diagnose the eye structure even upto sclera and in normal & diseased eyes. Resolution of the probe and complete system was improved for achieving tissue differentiation. Identification of hospitals has been done for clinical testing of the systems.

4.1 Focussed Transducers

Ultrasonic lenses and a few shaped crystals having frequency upto 1 MHz and 25 mm diameter have been made as first step towards achieving focussed transducers. The relative gain in intensity produced using these has also been measured.

DEVELOPMENT OF CARBON PRODUCTS

Moulded Products

A new grade of clutch carbon of size I.D. 52 mm & O.D. 75 mm has been developed and the sample has been sent to industry for tests and report. The use of resinous binders has been experimented. The die for carbon brick work, fabricated in the workshop, was used for moulding. The 100 ton press was modified for use. The punch and the bottom plate were scratched needing modification for use.

1.1 Extruded products

A no. of batches were processed regarding extrusion of carbon electrodes of 25 mm dia. The development of electrodes used in Sac batteries was taken up. These are used by the Railway Deptt. One grade of electrode was processed & baked. The samples were sent to industry for user-tests & report.

AVIATION GRADE BRUSHES, HIGH PURITY CARBON AND PITCHES

1. Two varieties of carbon brushes corresponding to PR-72-008 and PR-072-0021 were made by judicious combination of metal and graphite constituents followed by compression moulding and thermal treatment resulting in composite blocks. The blocks were tested for bulk properties and submitted to HAL, Nasik. The brushes were found to give satisfactory performance under high altitude conditions, besides meeting other requirements. Type approvals for two varieties have since been received. The remaining variety of the brush corresponding to PR-72-006 (split type

brush) was directly made by molding with pig tails and arrestor strip fixed in proper position. The die for split type brush was fabricated with provision of pig tail fixing and arrestor strip. The samples have been sent to HAL, Nasik for thorough test and performance evaluation.

1.1 DST constituted project profile committees to consider the application of pitch developed at NPL for use in graphite electrodes as an import substitute. It was suggested that the NPL process be developed to productionize impregnating pitches in the country.

Solvent fractionization of coal tar was carried out and pitches were made from the fractions. The rheological behaviour of the pitches, so made, was studied at temperature around 200°C. The preliminary work relating to the separation of solvents for reuse and chemicals based on boiling point cuts was done to assess the reuse of solvents in the extraction process.

1.2 The behaviour of cokes in presence of metal catalysts was investigated with a view to study catalytic graphitization making use of X-ray diffraction. The degree of graphitization was found to increase at lower temperature in presence of metal catalysts.

CARBON FIBRE, CARBON-CARBON COMPOSITES AND GLASSY CARBON

1. Carbon Fibres

A continuous set-up for processing 20 gms of carbon fibres per day, has since been designed and fabricated and the properties of carbon fibres achieved so far (at 1000°C HTT) are as follows:

$$\sigma = 375-400 \times 10^3 \text{ psi}$$

$$Y = 26-20 \times 10^6 \text{ psi}$$

The complete set up has following salient features.

1.1 Furnaces

These are specially designed to give specific temperature profile over a length of 1.80 metres. These can be operated through a single line

supply so that the temperature profile is controlled through out the length by a single temperature controller.

1.2 Drive System

Oxidation of PAN fibres require definite stretching in certain temperature regions and this is achieved by differential speed trips. All these trips are driven by a single motor to ensure constant stretch ratio in each temperature zone.

The facility thus ensures uniform properties of resulting carbon fibres and is capable of running for weeks together without human handling at any state of processing, including fibres unwinding and winding systems. Studies have also been undertaken to characterize the modified PAN fibres using X-ray diffraction technique. It has been established that the improvement in carbon fibre properties results due to improvement of crystalline structure of modified PAN.

2. Carbon Carbon Composites

Under the VSSC sponsored project on development of carbon-carbon composites for ablative applications, studies were undertaken to develop 2D composites using phenolic resin as matrix precursor and impregnating coal tar pitch as densifying material. Composites were made with 8H satin rayon based as well as PAN based high modulus carbon cloth. Composites were characterised both at polymer stage and after pyrolysis. These composites were further densified with coal tar pitch followed by carbonisation. This process was repeated till end properties were achieved. Effect of various processing conditions during impregnation was studied in detail. From these studies it was concluded that PAN based carbon cloth result in composites with higher density and mechanical properties than with rayon based carbon cloth. These composites were further heat treated to 2200°C and were evaluated for mechanical properties. These studies have resulted in the development of 2D carbon carbon composites with following properties:

Density: 1.6–1 g/cc, Flexural strength 250–320 MN/M², Flexural density 50–60 GM/M² and ILSS 12–14 MN/M².

Under the DRDL sponsored project on C/C composites CFRP composites developed at NPL as well as supplied by DRDL were analysed by TGA, DSC and TMA for their thermal behaviour. From this analysis three critical temperatures were selected which correspond to HDT, temperature of onset of pyrolysis and charring temperature. Mechanical properties of these composites were evaluated at these selected temperatures. These results were correlated with the thermal degradation behaviour of composites.

Studies were carried out on indigenously developed furan resin to find its suitability as matrix for making carbon-carbon composites. Resulting carbonised composites were impregnated under normal conditions. Comparison of c/c composites made with furan resin and phenolic resin as matrix showed that composites made with furan resin as matrix result in better mechanical properties than those made with phenolic resin.

3. Glassy Carbon

The efforts have been made to produce glassy carbon from mixtures of resins. It has been found that a mixture of phenol formaldehyde and catechol formaldehyde resins in 4:1 ratio improves greatly the density and strength of resulting carbon, along with causing improvement in other characteristics. The preliminary experiments have been carried on animals (rabbit and monkey) and human beings by the Army Hospital, Delhi. The results of NPL glassy carbon resistor plates for thin film applications and tubular crucibles for silicon processing have been quite successful.

Extensive work has been done on the development of special pitches, preforming as well as impregnating, for their use in the process of carbon-carbon composites. A large number of experiments involving the distillation, condensation, and polymerisation of coal tar, both under vacuum and in nitrogen atmosphere, have been carried out and the resulting pitches have been characterised with respect to the important properties such as softening point, quinoline insolubles, benzene insolubles, coking value etc.

Regarding the development of QI free impregnating pitch, a simpler solvent extraction process has been found. Besides this, efforts are being made to improve the efficiency of the hot filtration of coal tars and pitches by replacing the ceramic filters with metallic ones and using filter aids as well as employing high pressure instead of vacuum.

LUMINESCENT MATERIALS AND DEVICES

1. TV Phosphor

Some laboratory batches of zinc sulphide were prepared using LR grade ammonia solution and zinc oxide. The results indicated that LR grade ammonia solution can be used for pilot-plant production to further reduce the cost of manufacture. A detailed design of mechanised dry roller grinding mill which forms an important part of the plant was undertaken and completed. This mill is under fabrication.

1.1 Calcium-Sulphide phosphors

Samples of CaS: Ce were prepared using sodium carbonate flux and incremental increase in Ce concentration. Samples were also prepared using sodium sulphate flux when phosphors emitting in the blue under U.V. excitation were obtained by firing the material in a silica container. Various samples obtained by the use of these fluxes were characterised for their chemical composition by chemical analysis. X-ray diffraction studies confirmed above test results. It was inferred that silica or Si might have a role in this blue-emitting photoluminescent CaS: Ce phosphor. An x-ray TSL peak at 470 k in CaS: Ce has been detected under specific preparation conditions and interest to X-ray radiologist for dosimetry application. The unique feature is that it appears at a particular concentration of Ce. This has been interpreted as being due to a sulfur vacancy (VS^{2+}) and calcium (or Ce) interstitial aggregate.

2. Gas-liquid Reaction and, Spray Reactor Cum Dryer

In gas liquid reaction, problem of formation of crust of precipitates on the reacting surface was

identified. It affected mass transfer and led to erratic results. This was solved by reducing the liquid concentration by one fifth. Experimental parameters of gas composition and absorption time were also modified to meet the assumptions made in gas-liquid reaction theory.

The regime (category) of the reaction has been identified and found to be belonging to very fast reaction. Stainless steel nozzle and cyclone separator for spray reactor has been designed and got fabricated and assembly of the system has been started.

3. Alkaline earth sulphides for AC thin Film Electroluminescent (TFEL) devices

Work was done on Thin Film Electroluminescence which is the latest technology for flat panel displays. It was the first attempt to introduce alkaline earth sulphides for ACTFEL device applications and an extensive investigation on CaS, SrS and BaS in the form of thin film, was carried out to overcome the problem of obtaining multicoloring in these types of devices. Since the structure, crystallinity and perfection of the films dominate the properties of the films and control their life, the growth behaviour of these films were studied and also the dependence of EL characteristics on film deposition conditions were investigated. Using rare earth ions like Ce^{3+} and Eu^{2+} ions, EL phosphor films for three primary colors, namely, CaS: Eu, Cl (red) CaS: Ce, Cl (green) and SrS: Ce, Cl (Greenish-blue) with luminances of 100, 650 and 350 cd/m^2 , respectively, were achieved.

3.1 $CuInS_2$ Thin Films

$CuInS_2$ thin films prepared by chemical deposition technique were characterised by energy dispersive spectrometer (EDS) and spectrochemical method for composition, X-ray powder and transmission electron diffraction (TED) for crystal structure, SEM for surface morphology and electrical measurements. The effect of compositional variation on the structural and electrical properties have been measured. These studies show that single phase p-type polycrystalline $CuInS_2$ thin films with sphalerite structure were obtained.

RADIO SCIENCE DIVISION

GROUND BASED FACILITY FOR ENVIRONMENT MONITORING

1. Monitoring of anomalous long distance TV signals

Monitoring of anomalous long distance TV signals at Delhi has been continued systematically. Various modes of propagation have been identified. An attempt has also been made to receive coloured TV signals during the last two years. In the Band-I (47–68 MHz), where Ionospheric propagation plays an important role, such coloured TV signals can be observed with very fine tuning and strong signals. However in Band-III (175–230 MHz), where Tropospheric propagation plays an important role, such coloured TV signals have been observed all the time whenever favourable conditions prevail.

The monthly sunspot number during the year has been significantly low. An almost absence of TV-DX in Band-I has been observed. However there has been substantial increase of TV-DX in Band-III from Indian stations. The absence of TV-DX in Band-I during these non-summer months is due to decrease in foF2 value and as such in MUF(4000) F2 in equatorial anomaly belt and also unfavourable condition for artificial ionospheric modification. The increase of TV-DX in Band-III is due substantial to the increase of number of Indian TV stations on various channels within Tropospheric paths during this period.

2. Antarctic Studies

Research activities continued in cyclone monitoring and high latitude-low latitude coupling making use of the microbarograph data from Indian Stations (Delhi, Calcutta, Hyderabad and Madras) and Antarctica.

SODAR STUDIES

A systematic classification of the observed structures on the monostatic sodar has been proposed to give information on the prevailing Pasquill Stability Category which determines pollution dispersion. The comparative studies have been based on the determination of stability categories from a knowledge of the fluctuations in the horizontal wind direction. The work leads to nowcasting of the atmospheric boundary layer with respect to air pollution hazards.

Effect of surface wind speed on the development of fine structural details of the shear echo structures have been studied. The studies have shown that:—

Effect of surface wind speed on the development of fine structural details of the shear echo structures have been studied. The studies have shown that:—

- (i) stratified and smooth top layers occur more in the lower zone, short-spiky top layer structures have equal probability of occurrence at all levels while tall spiky layers occur more in the upper zone.
- (ii) Stable structures of flat top, short spiky top and stratified layers are generally formed when the wind speed in the surface layer is within 2.5 m S^{-1} while stable layer structures of tall spiky top are formed more often in the presence of moderate winds.

INDIAN MIDDLE ATMOSPHERE PROGRAMME

There are three major programmes in 1985 as a part of the national programme for the Indian Middle Atmosphere Programme:

- (i) ballon-borne measurements of stratospheric ionization,
- (ii) construction of six additionally UV-B

Photometers for IMAP-approved network in India and a comparative study of the UV-B dosages,

- (iii) installation and operation of laser heterodyne system for monitoring of minor species and
- (iv) modelling of middle atmospheric ionization.

Experimental work was carried out for the fabrication, testing and calibrations of rocket experiments including aerosols, Ozone, Lyman-alpha, Langmuir probe and propagation experiment. For Lyman-alpha experiment, a new sensor consisting of a combination of filter and a phototube has been designed for future rocket flight to replace conventional ionization chambers used earlier. This sensor has better efficiency than the previously used ion chamber and is more rugged.

A balloon-borne Langmuir probe was launched at 0120hrs IST on Feb. 16, 1985 from

Hyderabad. This was a part of an IMAP intercomparison experiment on stratospheric ionization in which the other participating organisations were Physical Research Laboratory, Ahmedabad and CESS, Trivandrum. Ionization derived from 19-27 km was roughly of order of 10^3 cm^{-3} (Fig. 1) and is in broad agreement with the other two sets of observations.

UV-B measurements, started several years ago at the NPL at 280, 290 and 310 nm, were continued and efforts were made to fabricate six additional UV-B systems as a part of IMAP network at the initiative of the Scientific Advisory Committee for IMAP. The Delhi observations which have now accumulated over a number of years showed that the observed values range from 0.035 to 0.09 $\text{Mj/m}^2/\text{month}$ with maximum around June-July period as against the calculated values which were higher by nearly a factor two; it appears that the assumed aerosol

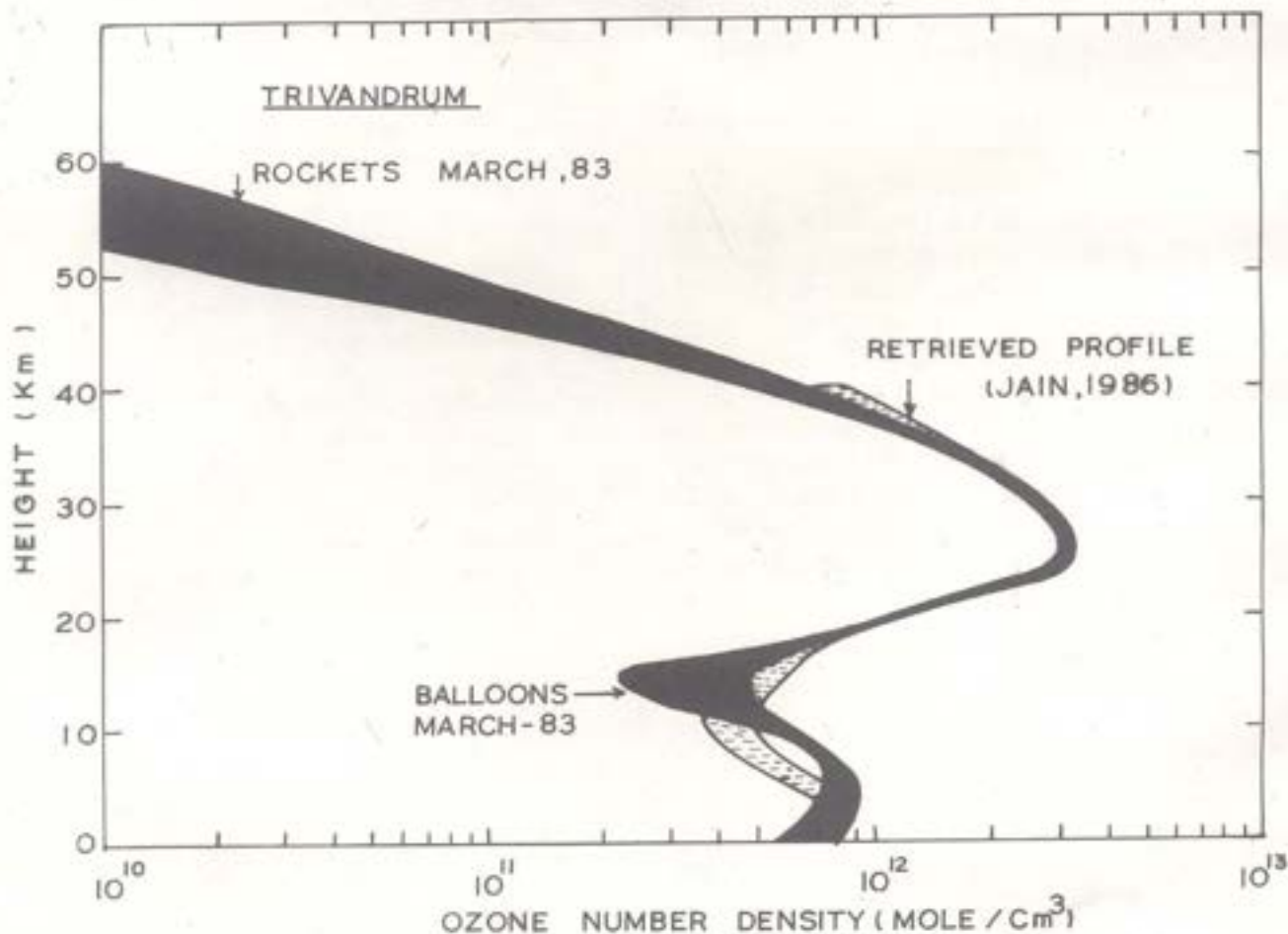


FIG.2 THE RETRIEVED OZONE HEIGHT PROFILE FROM INVERSION METHOD & INITIALLY ASSUMED MODEL FOR TRIVANDRUM

content has to be drastically modified. Absolute global UV fluxes measured around noon on 7 March 1984 gave the following values: 3.4 uw/nm/cm² at 280 nm, 6.3 uw/nm/cm² at 290 nm and 25 uw/nm/cm² at 310 nm. A decision was also taken regarding the location of the six newly built UV-B photometers.

The laser heterodyne system, designed, developed and fabricated at the NPL to monitor several trace species of the atmosphere, is now under final stages of installation. Currently the primary thrust is the measurement of ozone and water vapour. Detailed inversion programmes were undertaken for ozone for the ozone absorption line at 10.53.96 cm⁻¹. 16 channels, one at line center and 15 in the wings, were chosen to define the line profile and to get adequate highest resolution (estimated to be 1-3 kms). The result of a detailed intercomparison with an initially assumed model for Trivandrum shows that real time monitoring of the ozone profile is possible upto an height of about 35 km (Fig. 2).

Several modelling efforts were undertaken. One concerned the study of long-term trend of total ozone over India to look for changes due to

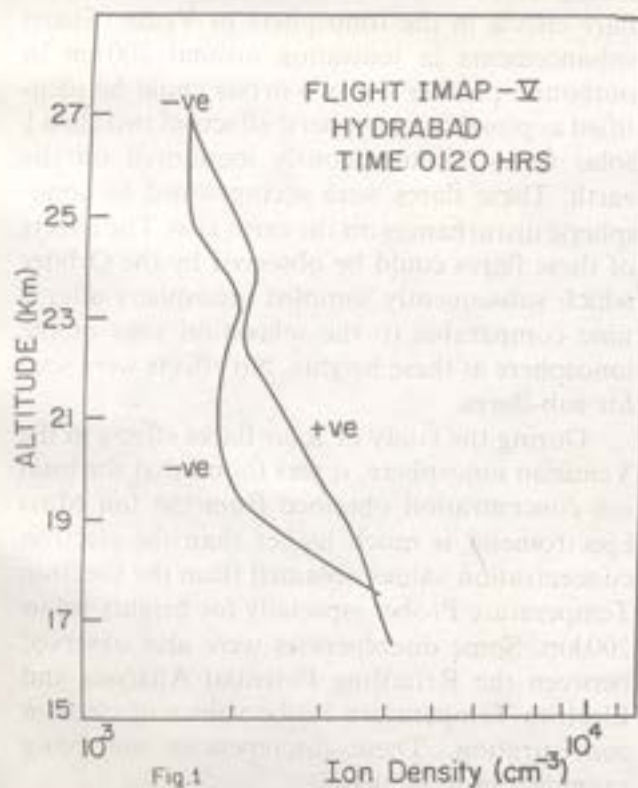
human activities and to effects due to the El Chicon volcanic eruption of 1982. Three stations were chosen: Srinagar (34°N), Delhi (28°N) and Kodaikanal (9°N) covering the total latitudinal extent of the country. While the quasi biennial oscillation were quite evident no other major effects were observed. A curious result was that the 12 months running mean value were less than those of northern stations and did not show any strong periodicity. Another modelling effort concerned the calculation of the ion production rates in the troposphere and the stratosphere using the primary cosmic ray spectrum above 20 km. This work was done jointly with scientists of the IMAP Programme Office.

SATELLITE RADIO BEACON STUDIES

1. Results on Ionospheric Electron Content

A semi empirical model of IEC at low latitudes for solar minimum has been developed based on a harmonic analysis approach for calculating the electron content at three locations in and around the Northern equatorial anomaly crest for solar minimum conditions using the data collected from ATS-6 observations. A set of twenty five coefficients comprising the mean, first and the second harmonic coefficients was found to be sufficient for calculating the electron content within ± 15 percent of the observed values under worst conditions. This model requires set of coefficients as inputs and enables first order correction to time delay (or refraction errors) with little demand on the computer.

Simultaneous observations of Faraday rotation angle of satellite signals from Symphonie II (0°, 49°E) and ETS-II (0,130°E) from Delhi have been utilised for obtaining special correlation of IEC for the period March-April 1979. The IEC correspond to the subionospheric points for the two satellites. Results indicate that IEC measured at the location close to the crest of the anomaly with the help of satellite at low elevation angle is constantly higher compared to that obtained away from the anomaly crest with a satellite at the higher elevation angle. The IEC responses to geomagnetic activity at the two locations separated by a horizontal distance of



900 km are uncorrelated. It has also been observed that the correlation is a function of local time and the correlation distance is shorter than in the mid latitudes.

In order to remove the ambiguities in the Faraday rotation angle measurements, it is important to know precisely the initial polarization (a system invariant for a given satellite and a receiver station) for various types of transmitting polarizations. A concise paper giving all the analytical expressions under various transformations has been published for the first time by the group.

The diurnal, seasonal, day-to-day and solar cycle variations of the ionospheric slab thickness for Delhi have been studied by analysing the electron content data obtained during the ascending phase of the present solar cycle. The results show that the seasonal variations of slab thickness depend on local time and sunspot activity. While there is a linear increase in daytime slab thickness with 10.7 cm solar flux, no correlation is observed with geomagnetic activity. The diurnal variation is characterized by daytime plateau and occasional peaks of varying magnitude in pre sun-rise and pre-midnight time.

1.1 Results of Scintillation Studies

Multi-station study of nighttime scintillations in low latitudes have been thoroughly investigated and following results have been obtained. The stations were located along the 78°E meridian extending from 3° to 21°N magnetic latitudes. The occurrence of post-sunset saturated VHF scintillations (or scintillation producing irregularities) in the entire low latitude belt during a high solar activity period is essentially controlled by the generation of ESF (equatorial spread F) irregularities over the equator. The latitude extent of the post sunset scintillation phenomenon is dependent upon the maximum height to which plasma bubbles develop over the magnetic equator, and the onset, duration and decay of scintillations at different latitudes would depend upon the growth, shape and dynamics of the equatorial plasma bubbles. These results establish the equatorial control on the generation of scintillation producing irregularities in a meridian plane, but

more co-ordinated and exhaustive measurements are required to understand the meridional propagation mechanism of these irregularities.

SROSS AERONOMY SATELLITE

This project was approved in principle in April, 1984. The details of the experiments (RPA & EPS) were sent to ISAC, Bangalore. In order to work out the details of various experiments and telemetry interface etc., the first meeting of the Experimenters and Engineers from Project Team and ISAC Engineers was held in Bangalore. The paper design work of various units comprising the satellite payload have been finalized. The working model of the payload will be demonstrated.

PLANETARY IONOSPHERES

1. Solar Flares Effects

A large number of dayside passes of Pioneer Venus Orbiter were examined to look for solar flare effects in the Ionosphere of Venus. Sharp enhancements in ionisation around 200 km in outbound profiles for two orbits could be identified as possible ionospheric effects of two class 1 solar flares, simultaneously monitored on the earth. These flares were accompanied by Ionospheric disturbances on the earth also. The effects of these flares could be observed by the Orbiter which subsequently sampled ionosphere after a time comparable to the relaxation time of the ionosphere at these heights. No effects were seen for sub-flares.

During the study of solar flares effects in the Venusian ionosphere, it was found that the total ion concentration obtained from the Ion Mass Spectrometer is much higher than the electron concentration values obtained from the Electron Temperature Probe, especially for heights below 200 km. Some discrepancies were also observed between the Retarding Potential Analyser and Electron Temperature Probe values of electron concentration. These discrepancies are being examined in more detail.

1.1 Exploratory Study of VLBI Observations of Venus Zondes During VEGA Mission to Comet Halley

During discussions between the Indian and the Soviet experts in Moscow for various collaborative programmes for the VEGA Mission to Comet Halley, it was agreed that 'Indian side would explore the possibility of making VLBI observations to track balloon zondes floating in the venus atmosphere'. However, when engineers at ISRO's Space Application Centre, Ahmedabad were consulted about the antenna availability and its sensitivity, it was found that the antenna would have only marginal sensitivity to record the VLBI observations. In addition, there were difficulties about construction of Back End at Ooty, design and construction of Frong End at Ahmedabad, importing of amplifier and limitation of time. Thus the Soviets were informed in November, 1984 that it would not be possible to make VLBI observations in India during the VEGA mission.

2. In-coherent Scatter Studies

Incoherent Scatter Data available in our data bank was mainly used to study the Ionospheric and Upper Atmospheric Dynamics. Ion drifts parallel and perpendicular to the magnetic field lines were deduced from the line of site velocities measured with the Arecibo Radar. These ion drifts are now being analysed to study possible effects of ion drifts on neutral temperature.

Ion temperatures at a height of 260 km were studied for diurnal and long term variations. Sudden changes in the ion temperature from one observation to the next were observed on several days. These are now being examined in the light of ion drift data available.

3. MST Radar Data Interpretation

The magnetic tape containing sample MST data for four days from the Pocker Flat radar was received. From the line of site velocities, meridional zonal and vertical winds have been derived. These have been compared with the results supplied by Dr. Balsley and there seem to be good agreement between the two. The

sample data is now being used for studying middle atmosphere dynamics.

TROPOSPHERIC AND IONOSPHERIC COMMUNICATIONS

1. Long-term Ionospheric Predictions

1.1 Direct approach to Ionospheric Predictions

The prediction of foF2 for HF circuit planning is usually done by predicting the sunspot number and then using its correlation with foF2. The single most advantage of using the sunspot number as an intermediary is the fact that it has a long series of observations; however, this method also has the disadvantage of introducing additional inaccuracies due to the problems that exist in predicting the sunspot number itself. Good world-wide foF2 data is now available for more than 3 solar cycles and it is considered appropriate to attempt a direct prediction of foF2 using statistical techniques. The multiple regression curve of the form

$$Y = A_0 + \sum_{i=1}^{12} a_i x_i$$

where the dependent variable represents foF2 values to be predicted for a particular month. The independent X_1, X_2 etc. are the foF2 values for the 12 calendar months. This method has been employed to predict foF2 values, six months in advance, for several Indian stations and a comparison of these predicted values with the observed values demonstrated well the efficacy of this technique (Fig. 1).

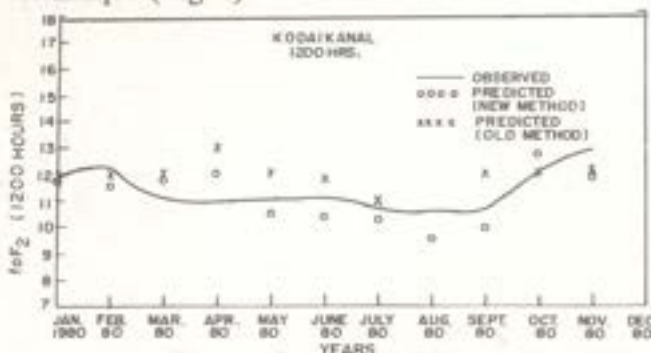


Fig. 1. Comparison of predicted foF2 values using the new technique with observed values for Kodaikanal.

1.2 Quantification of day-to-day variability factor

Conventional HF communication predictions are usually based on the monthly median values of ionospheric parameters predicted 6 months in advance. It has been appreciated for quite some time that large day-to-day variability factor at low latitudes poses serious problems in point-to-point communications in two ways. Firstly, a very conservative and a fail-safe estimate will push the operating frequency too far below; crowding the lower spectrum and increasing the power levels. Secondly, a modest estimate may reduce the reliability in certain seasons and local times to very low levels because the predicted frequency is higher. Elaborate calculations were attempted to quantify this factor for different latitudes, solar activities and seasons so that the long-term predictions will also include these factors to enable the user to scale down the predicted MUF appropriately depending upon the reliability criteria. Fig. 2 shows a sample distribution of this

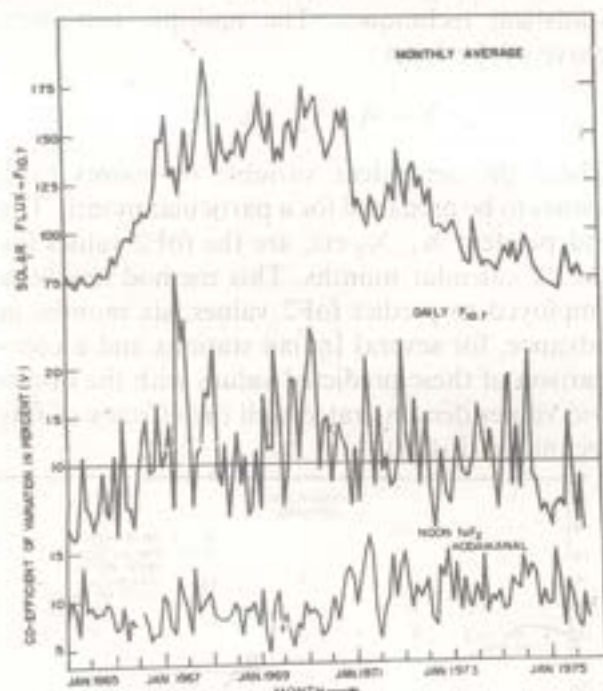


Fig. 2. Plots of monthly average solar flux at 10.7 cm for the period January 1965 to December 1975. Coefficient of variation for daily flux values from monthly means and noon foF2 values from monthly median values for the corresponding months.

factor at Kodaikanal for local noon over a solar cycle.

2. Short-term forecasting

2.1 IEC variability and foF2 variations

The possibility of using IEC values to predict foF2 variations was explored. These variations were studied separately for both magnetically disturbed and quiet periods. It has been observed in general that deviations in foF2 and IEC do not always follow similar pattern during magnetically disturbed days. However, certain groups of days which are usually characterised by very low magnetic activity exhibit similar patterns in foF2 and IEC departures (Fig. 3). One conclusion with possible application is that deviations in foF2 and IEC departures are well correlated during daytime hours especially at locations away from the equatorial anomaly peak.

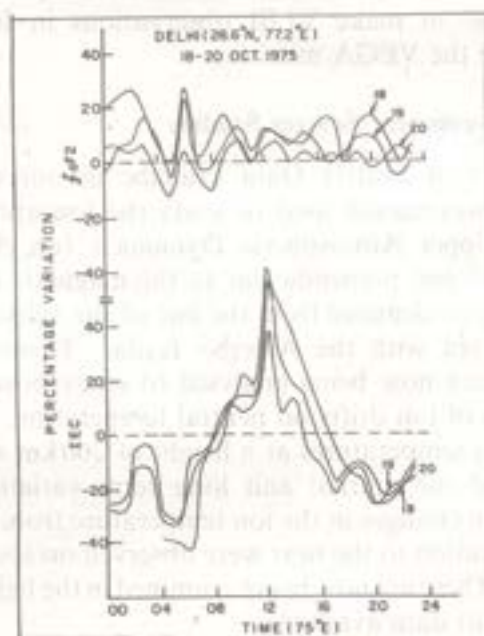


Fig. 3. Percentage deviations in foF2 and IEC from their monthly medians at Delhi for a group of consecutive quiet days in October 1975.

2.2 Augmentation of ARWC activities

A flux-gate magnetometer has been set up to monitor magnetic field variations. The establishment of this in-house facility has enhanced the utility of the country's only Warning Centre.

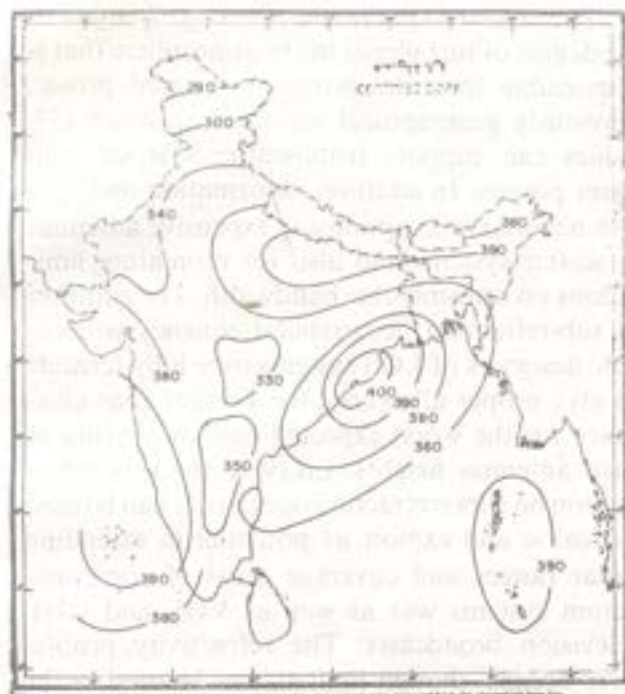


Fig. 4. Distribution of surface refractivity in June (0000 GMT).

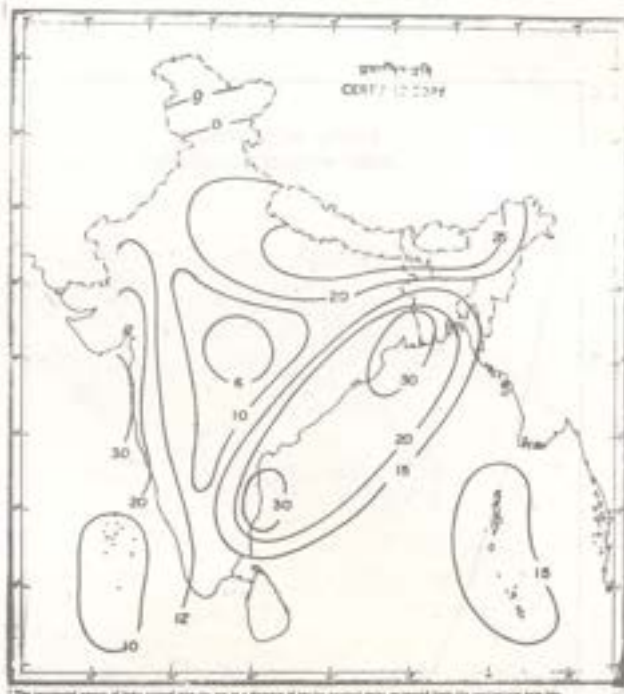


Fig. 6. Surface duct occurrence probability in April (0000 GMT).

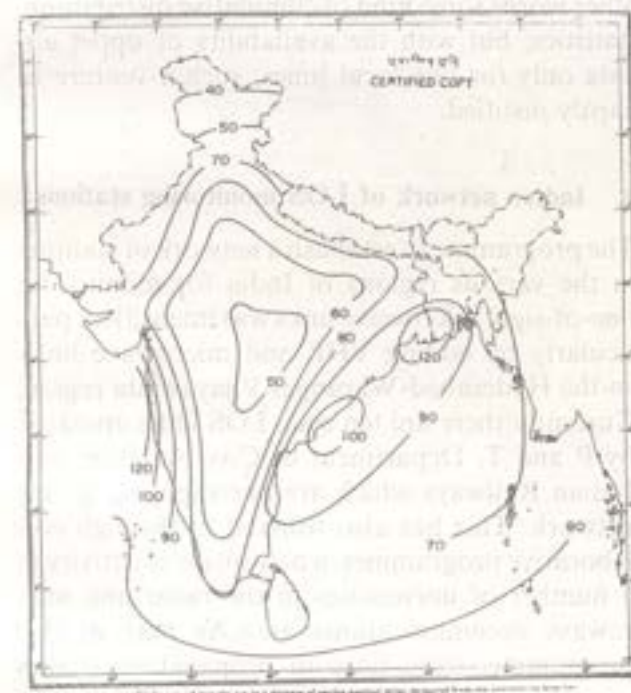


Fig. 5. Initial refractivity lapse rate in May (0000 GMT).

Solar flare reports and magnetic storm forecasts are received daily from other centres around the

world and the local magnetic field observations have added to the confidence of forecasting storm departures in HF communications.

3. Tropospheric radio refractivity atlas

This atlas is the revised version of the atlas of tropospheric radio refractivity. The maps and diagrams on surface refractivity, initial refractivity gradient, effective earth's radius factor, subrefraction, superrefraction, duct occurrence frequency, refractivity profiles over Indian Ocean, structure intensity parameter (Figs. 4-7), present adequate details of the distribution and are representative of the various zones of the subcontinent.

Tropospheric radio refractivity data required for this atlas were obtained from the India Meteorological Department. Refractivity Profiles were calculated from radiosonde data collected from 32 stations twice a day (0000 GMT and 1200 GMT) for a period of 5 years (1975-79), using the fixed pressure level data at intervals of 50 mb from 1000 mb level to 50 mb level. Refractivity over the sea areas has been calculated from Monex-79 data. The initial gradient across

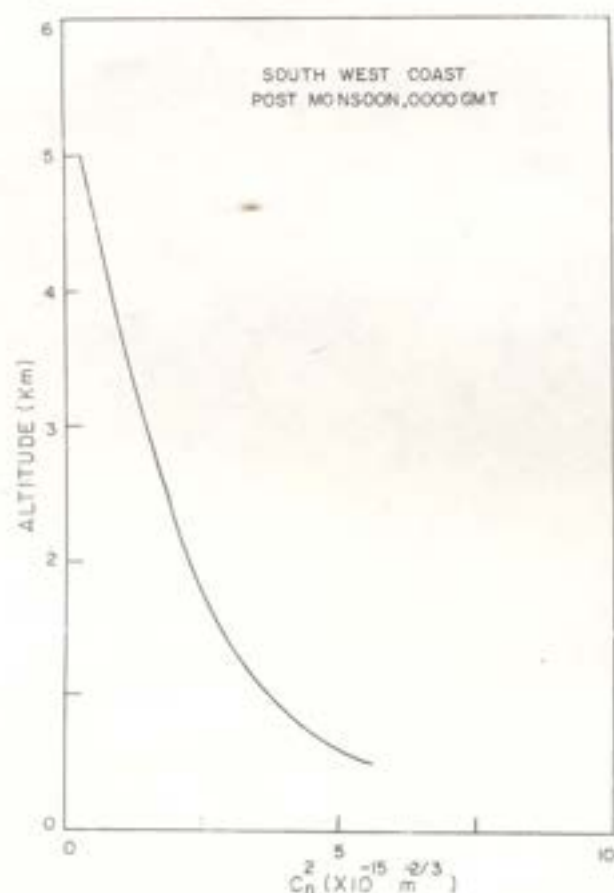


Fig. 7. Structure parameter over south west coast in postmonsoon (0000 GMT).

250 metres was obtained by interpolation from fixed pressure level data.

Information on radio refractivity characteristics as presented in this atlas can be of value in link design and Radar performance estimation (including range and elevation angle errors for airborne targets) but the data are to be used with considerable engineering judgement because of certain inherent limitation.

The morphological parameterisation documented here indicates average values essentially at two local times. They should serve well to estimate the median path loss in LOS and Troposcatter systems. The desired system performance however can be achieved in terms of the reliability of information transfer such as maximum permissible bit-error rate etc. only from cumulative distribution statistics for high reliability links.

The structure parameter C_n^2 (Fig. 7) signifies the degree of turbulence in the atmosphere that is responsible for trans-horizon scattered power. Obviously geographical regions with larger C_n^2 values can support troposcatter systems with lesser powers. In addition, information on C_n^2 is also necessary for optimising expensive antennas in scatter systems and also for estimating limitations on transmissible bandwidth. The addition of sub-refraction occurrence frequency will enable designers of LOS systems over hilly terrains to give proper allowance for Fresnel zone clearance for the worst expected case in arriving at their antennas heights. Likewise the new information on superrefraction occurrence can be used to realise and exploit its potential in extending radar ranges and coverage areas of communication systems as well as VHF and UHF television broadcasts. The refractivity profiles over oceans, though limited, can be used in the area of Marine communications. The single lapse of this Atlas is the lack of information on the extent of diurnal variability in refractivity or in other words some kind of cumulative distribution statistics; but with the availability of upper air data only for two local times, such a venture is hardly justified.

4. Indian network of LOS monitoring stations

The programme to establish a network of stations in the various regions of India for monitoring line-of-sight microwave links was intensified, particularly by adding VHF and microwave links in the Hyderabad-Warangal-Vijayawada region. Currently there are ten such LOS links operated by P and T, Department of Civil Aviation and Indian Railways which are participating in this network. This has also ushered in through collaborative programmes, a new phase of activity in a number of universities in the radar and microwave communications area. As part of this programme, trans-horizon propagation studies over Hyderabad-Warangal TV path at VHF were completed. Fig. 8 shows the results of the comparison of field strengths expected under various initial refractivity gradient conditions (a) by the diffraction mode using CCIR nomograms, (b) by diffraction using Fock's method, (c) through

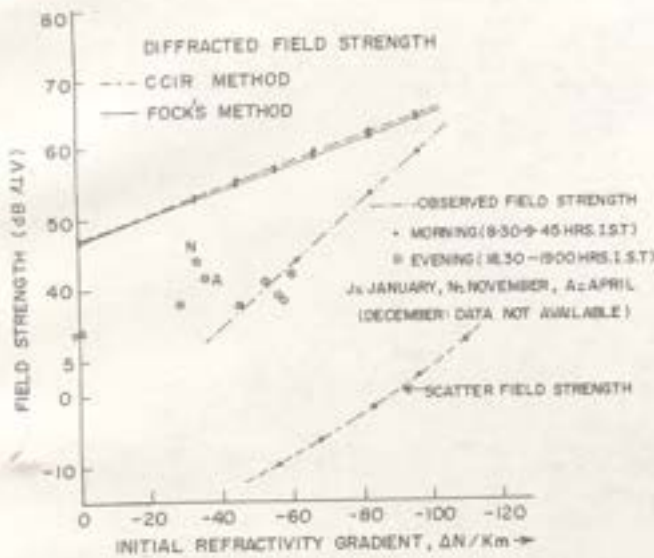


Fig. 8. Variation of field strength with initial refractivity gradient.

tropospheric scattering and (d) the actual observed monthly median values in the morning and evening hours. It has been concluded that scatter is dominant mode of propagation though it will be expedient to bring in possible contributions due to reflections from elevated layers and large-scale irregularities to explain the very high field strengths that were occasionally observed.

5. Solid State Digital Microwave Refractometer

A Solid State Digital Microwave Refractometer was designed and fabricated in collaboration with DEAL (Fig. 9) and the first instrument was flight-tested in June 1983. A second instrument was flown in January 1985 over Kanpur and Lucknow and simultaneous radiosonde refractivity profiles were used for comparison. Fig. 10 show typical radio refractivity profiles obtained from microwave refractometer flights. The atmospheric turbulence parameters were derived from the fine structure obtained from the radio refractivity profiles of the microwave refractometer. Fig. 11 shows height profiles the variance ($\langle \Delta n^2 \rangle$) and C_n^2 of the refractive index fluctuations measured with the refractometer for typical summer and winter conditions. The mean height profiles of C_n^2 were calculated from these INSITU measurements for the first time in India.

6. Consultancy Services

An extensive study was undertaken on groundwave propagation of radiowaves to evolve prediction charts for groundwave field strengths at various frequencies in the medium and higher frequency ranges. Ready to read charts and tables for ground-wave field strength were developed for different terrain conditions relevant to zones of army operations.

7. Solar-Terrestrial Prediction and Data Services

The group is responsible for providing solar and Ionospheric predictions to various communication and research organizations in the country. Some of the major responsibilities include the following:—

- 1) Ionospheric Communication parameters are predicted six months in advance to aid in planning of HF communication networks by various Defence and Civilian organizations in the country. Predictions are published every month in the form of easy to read contour maps.
- 2) Special monthly ionospheric predictions are provided to Defence one month in advance for planning of HF operations in certain strategic areas.
- 3) Long-term solar activity variations are predicted to aid in planning of ionospheric communications and for planning of ground-based, rocket and satellite experiments.
- 4) The group also discharges the responsibilities of Associate Regional Warning Centre under IUWDS and disseminates solar and geophysical data on near-real-time basis and also issues daily warning messages on solar, magnetic and ionospheric conditions through the Time and Frequency transmitter of NPL at 3 p.m. daily on 5, 10 and 15 MHz. These warnings are based on the observational data obtained from India and the data received from other Warning Centres in the World.
- 5) Short-term prediction activity includes prediction of weekly average solar index (Fig. 10.7) to aid ISRO in their satellite.

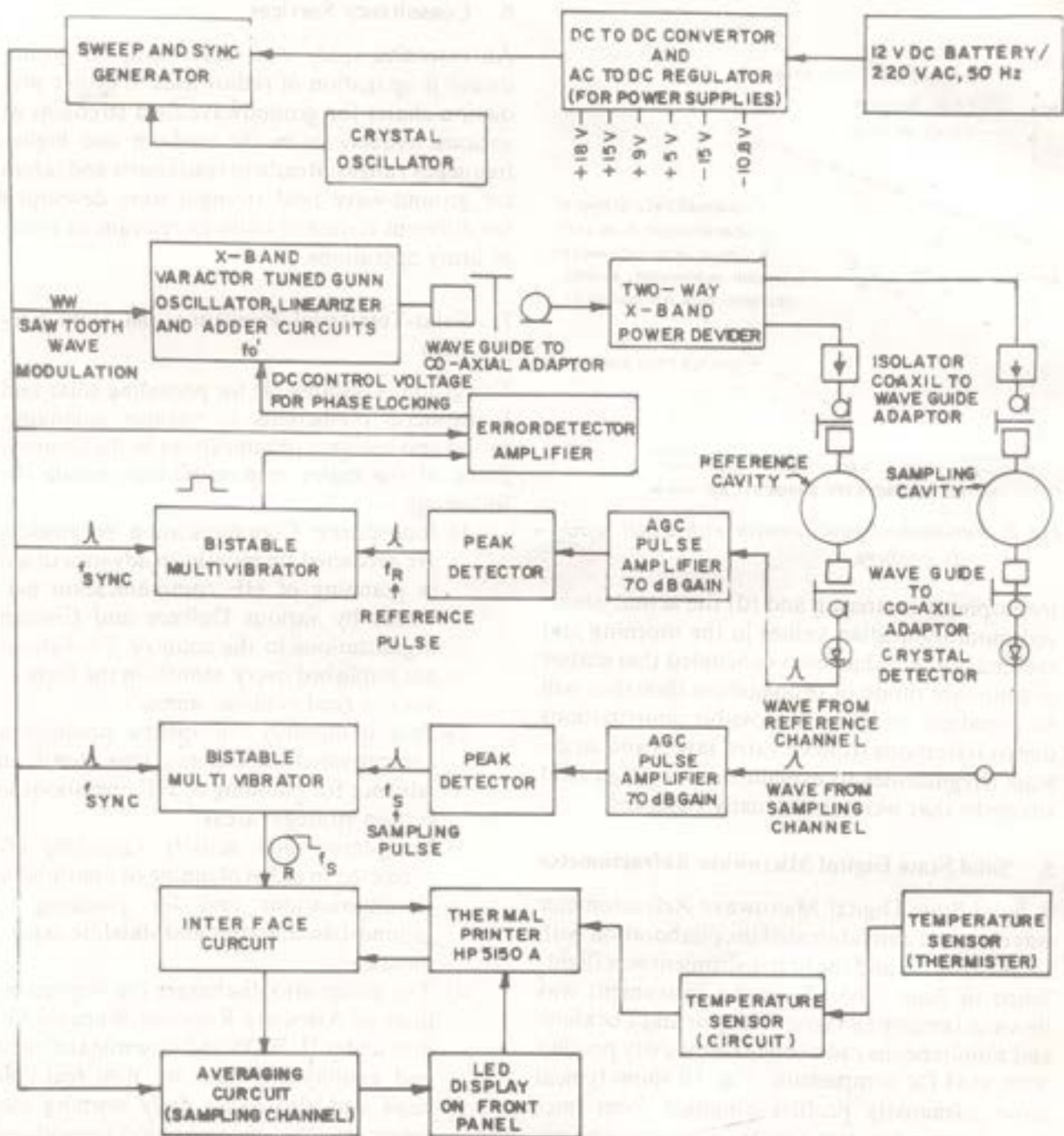


Fig. 9. Block diagram of solid state digital microwave Refractometer.

orbital parameter computations and also prediction of short-term variations in ionospheric communication parameters over the Indian zone.

IONOSPHERIC & NEUTRAL ATMOSPHERIC MODELLING

Ion composition variation in the equatorial zone

showed anomalous behaviour in the transition of (O_3 to H_5) height in the post sunset period during high solar activity period.

Neutral winds derived from MSIS atmospheric model are found to be generally in good agreement with the observations from St. Santin particularly in daytime.

ATMOSPHERIC SCIENCES

1. Microwave Radiometer

For water vapour height profiling, a single frequency inversion technique developed by us earlier was being used by interpreting antenna temperature values using an album of temperature, pressure and humidity profile based on those actually observed with radiosonde's flown over New Delhi and using theoretical equation of water vapour absorption. Recently, we have developed a simple inversion technique using two frequency radiometric observations at New Delhi by selecting proper frequencies from the nature of weighting functions. The technique introduces 0.5% to 2% error in the determination of integrated water vapour as compared to 2 to 7% error from single frequency inversion.

An algorithm was developed for determining cloud liquid by using observations at X and K-bands. Cloud liquid is found to be highly variable on time scale, varying shows poor correlation with water vapour content. For more accurate determination of cloud liquid existing facilities are being improved to add channels above the K-band.

Radiometric observations at 18 and 22.235 GHz have been used to estimate earth space path rain attenuation values upto 50 GHz. As the radiometric observations cannot be obtained due to Saturation above 14dB, this method can be useful in finding earth space path rain attenuation for values above the saturation limit.

1.1 Simultaneous foF₂ and IEC observations were used to study Ionosphere-Magnetosphere interaction processes at different latitudes. Delhi showed positive changes (Winter) during disturbed days both in foF₂ and IEC at all local times while Ahmedabad showed positive changes during day and negative changes during night in both the parameters (Figure). This rapid transition from midlatitude character to low latitude character between Delhi and Ahmedabad seems to be consistent. The night time magnetospheric convection which intensifies during night time is expected to squeeze the plasma from outer to inner field tubes. Since the low latitude field tube plasma content is low, the charged particles at low

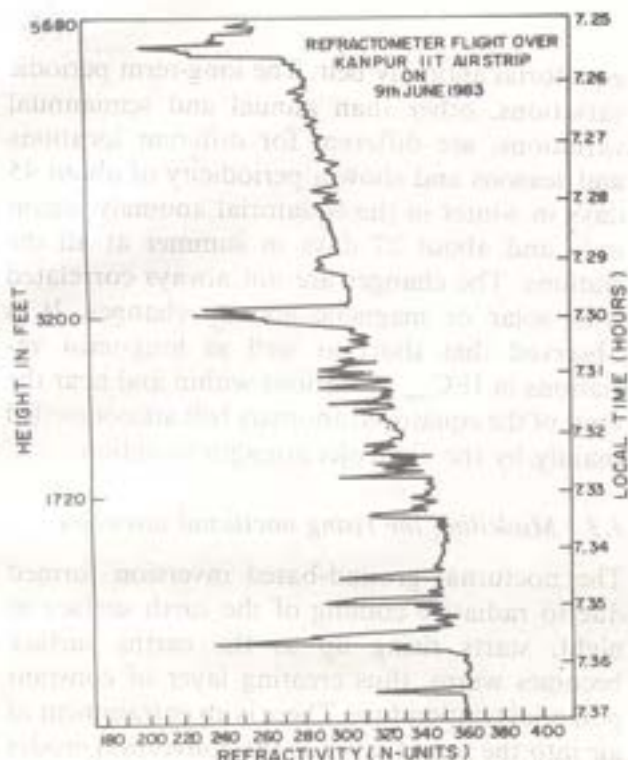


Fig. 10. A typical refractivity profile obtained by refractometer.

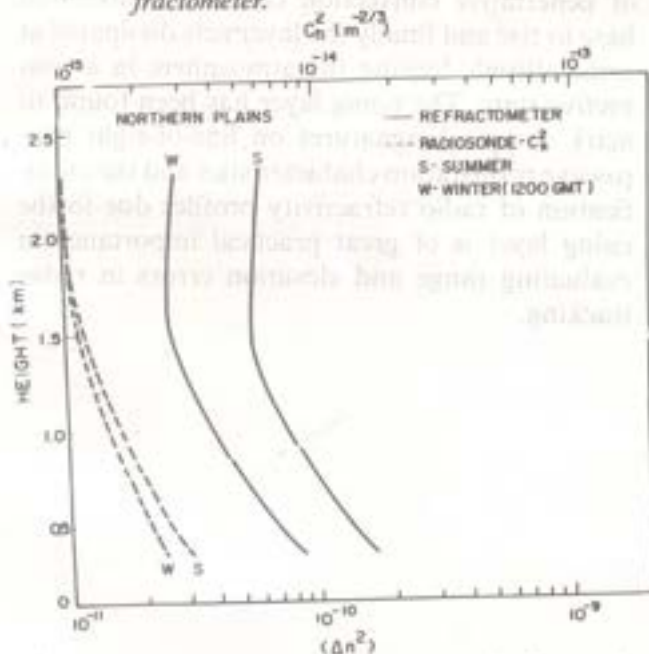
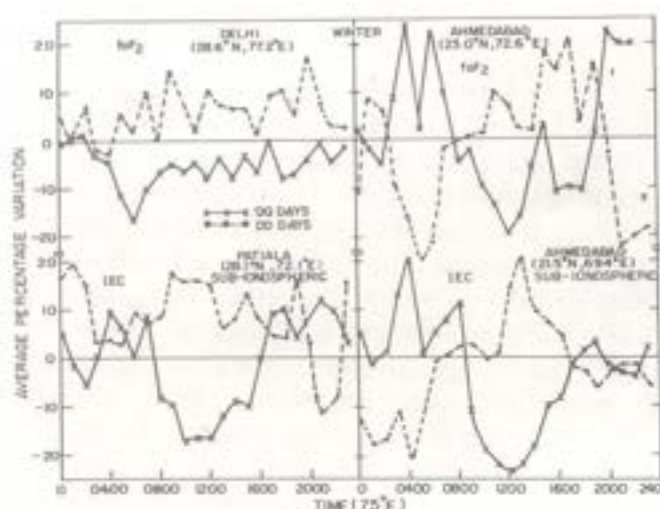


Fig. 11. Height profile of refractive index fluctuation.

Geomagnetic storm effects at low latitude are found to be smaller than at mid latitudes in the TEC variations.

The use of the Epstein functions for representing the electron density profile in the lower ionosphere is discussed with a few samples.



latitudes are consumed as they are pushed to low altitudes and the night time ionosphere is depleted followed by rapid increase after sunrise.

1.2 The day-to-day variability in ionospheric electron content (IEC) is studied using the diurnal IEC maximum data obtained from multistations located in the latitude range between 15.0°N and 30.0°N in the Indian zone during solar minimum. Depending on the location of the observation station, the changes in IEC_{max} values, of about $+20$ to 40% , are found to occur in the form of single day abnormality, alternate day abnormality, and long-term periodic fluctuations. The magnitude of fluctuations is found to be maximum at a station which is near the crest of the

equatorial anomaly belt. The long-term periodic variations, other than annual and semiannual variations, are different for different locations and seasons and show a periodicity of about 45 days in winter in the equatorial anomaly region only and about 27 days in summer at all the stations. The changes are not always correlated with solar or magnetic activity changes. It is observed that short as well as long-term variations in IEC_{max} at stations within and near the crest of the equatorial anomaly belt are controlled mainly by the electrojet strength variation.

1.3 Modelling the rising nocturnal inversion

The nocturnal ground-based inversion formed due to radiative cooling of the earth surface at night, starts rising up as the earth's surface becomes warm, thus creating layer of constant potential temperature. There is an entrainment of air into the mixed layer as the convection erodes away at the overlying inversion base. This process of penetrative convection causes the inversion base to rise and finally the layer gets dissipated at some altitude leaving the atmosphere in a convective state. The rising layer has been found to mark a typical signatures on line-of-sight microwave propagation characteristics and the modification of radio refractivity profiles due to the rising layer is of great practical importance in evaluating range and elevation errors in radar tracking.

SERVICE SECTIONS

WORKSHOP

1. The design and fabrication of instruments, apparatus, gadgets etc., for various projects of the laboratory was continued. A no. of new machines were added during the period. About 2400 job orders were completed valued at Rs. 20 Lakhs approximately. The major jobs were:—

1. Gear boxes.
2. Components for tank for Ultrasonics.
3. Radio-meters for R.S.D.
4. Kn Band Wave Guides for Microwave Section.
5. Fabrication of boss heads for Low Temperature Section.
6. Prisms for L.C.G.
7. Making of R.P.A.s, for R.S.D.
8. Gear box for Force Standards.
9. Vibrating apparatus.
10. Flanges for Microwave Section.
11. Metallic oxide brackets for R.S.D.
12. Colimeter Slit for L.C.G.

1.1 Drawing & Design Section

The section assisted scientists in their Research and Development work with Mechanical Design and Drawing, writing charts for their Seminars etc., and making graphs/curves for their Publication work. The section assisted Central Workshop as required. About 460 jobs were completed during this year. Some of important jobs were:—

1. SROSS Project.
2. Reciprocity calibration Unit.

3. Special laser tube arrangement.
4. Vibrating reed internal apparatus, for Films and Foils.
5. Goniophotometer.
6. 2.6 GHz Feed Antenna.
7. Rotating system of Integrated Sphere.
8. Vertical output special Gear Reduction system.
9. Village Refrigerator etc.

GLASS TECHNOLOGY WORKSHOP

This unit helped various divisions of the laboratory with its glass technology expertise. This included vacuum system for SEM, reconditioning of mercury arc glass bulbs, rectifiers, sealing of highly inflammable liquids for different purposes, glass to metal seals, liquid purification apparatus etc.

This unit also assisted other organisations in design, fabrication and reconditioning of glass & silica equipment, like Kasturba Gandhi & LNJP Hospital, CRRI, NTPC, SSPL, of Delhi, ONGC & IIP Dehradun, Aligarh Muslim University, Punjab University, REC, Srinagar, HIL, Gurgoan. etc.

Training was provided to four persons of private and public sector for a period of 6 to 12 weeks. The receipts of the jobs done for outside parties amounted to Rs. 1.50 lakhs approximately.

WORKS & SERVICES DIVISION

1. Civil Engineering Section

Completed design, execution of the extension of the IInd floor, modernization of the Guest House,

time targetted works in connection with symposia/seminar. Provided facilities for the installation of the computer centre, various small clean rooms etc.

1.1 Electrical Section

Provided electrical services including telephone maintenance and operation of the diesel generator sets.

1.2 Air-conditioning Section

Completed design, tendering of the clean rooms at IIInd floor, maintenance of air-conditioning plants etc.

1.3 Horticulture Section, H.L.S., & Enquiry Office (colony)

Carried out routine maintenance and special repairs in the laboratory and N.P. L. colony.

In addition to the above a number of projects on the application of Micro-Processor like micro-stepping of stepper Motors and control of a diesel generator were completed.

LIBRARY

The library continued to meet educational, research, and informational needs of its scientists

through its library and documentation services. Its other activities included collection development, collection organisation and technical processing.

Under the collection development activities the library acquired 533 books, subscribed 311 journals, and received about 100 journals as gratis and exchange.

Under the collection organisation activities the periodical section was reorganised to improve conditions for document storage and retrieval and to remove the less used journals to secondary collection.

The library issued a total of 5240 publications to its scientists and 836 to libraries of institutions such as DESIDOC, INSA, INSDOC, IOC, EIL, IMD, IIT, Delhi University.

In addition to the library service the library is providing documentation services. Under this programme a total of 2164 references were provided. In addition six bibliographies were supplied. The technical section did the cataloging of 546 books and monographs. In addition 530 bound volumes of periodicals were added and 1486 standard specifications cataloged.

The library is an inspection center for Indian patents. Under this arrangement it continued to receive Indian patents from the Indian Patent Office, Calcutta.

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DIVISION OF MATERIALS

1. Preparation and characterisation of β' - Al_2O_3 ; H.S. Kalsi, R.P. Tandon, Balbir Singh, R.C. Goel and B.K. Das, *Bull. Mater. Sci. Vol. 6, No. 6, Dec. 1984 pp.* 979-989.
2. Preparation of high density solid electrolyte Grade β' - Al_2O_3 Tubes by isostatic pressing and sintering; H.S. Kalsi, Balbir Singh, S.K. Sharda, R.C. Goel and B.K. Das, *Bull. of Electro Chemistry* **1(1)**, Jan-Feb. 1985 pp. 65-67.
3. A Broad Band Capacitive Transducer for Characterising Pulsed Ultrasonic System; V.N. Bindal, T.K. Saksena and S.K. Jain, *Indian J. Tech.*, **22** (10), 397-400 (1984).
4. A Simple Method for Designing of a Half Wave Resonator Transducer Assembly; V.N. Bindal, T.K. Saksena and S.K. Singhal, *Indian J. Pure & Appl. Phys.* **22** (11), 642-646 (1984).
5. Testing of Underwater Offshore Structures V.N. Bindal, (i) *Science Reporter*, **21** (7), 318-323 (1984); (ii) *Chemical Age of India*, **35** (10), 721-725 (1984).
6. On the Feasibility of Narrow Beam Speech Transmission in Air Using Nonlinear Interaction of Ultrasonic Waves; V.N. Bindal, T.K. Saksena and Mukesh Chandra, *Proceedings 10th International Symposium on Nonlinear Acoustics (10th ISNA)* Kobe, Japan, 141-145 (1984).
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10. Viscosity measurements in reacting fluids upto 600°C G. Bhatia, B. Komaglik, *High Temp. High Pres.*, **16** (1984), 435.
11. 'Electroluminescence in Thin Film Cas; Ce,' V. Shanker, S. Tanaka, M. Shiiki, H. Deguchi, H. Kobayashi and H. Sasakura; *Appl. Phys. Lett.* **45**, 960 (1984).
12. 'Electroluminescence due to allowed 5d-4f transition of CeSt in a ZnS Thin Film', S. Tanaka, H. Kobayashi, M. Shiiki, T. Kunou, V. Shanker and H. Sasakura, *J. Luminescence* **31/32**, 945 (1984).

RADIO SCIENCE DIVISION

1. S.P. Singal, D.R. Pahwa, S.K. Aggarwal and B.S. Gera, "Sodar structures in relation to characterisation of atmospheric stability", *Environmental Physics and Atmospheric Planetary Boundary Layer News Letter IITM Pune*, **2(1)**, June 1984, pp. 8-9.
2. S.P. Singal, B.S. Gera and S.K. Aggarwal, "Nowcasting by Acoustic Remote Sensing—Experiences with the NPL Systems", *Jour. Sci. Industr. Res. (India)*, **43**, 1984, pp. 469-488.
3. S.P. Singal, D.R. Pahwa, S.K. Aggarwal and B.S. Gera, "Studies of sodar shear echo structures in relation to wind speed at New Delhi", *New Letter Environmental Physics and Atmospheric Boundary Layer, IITM, Pune*, **2(2)**, Dec. 1984, pp. 2-3.

4. S.P. Singal, S.K. Aggarwal, D.R. Pahwa and B.S. Gera. "Stability studies with the help of acoustic sounding". *Atmospheric Environment*, 19, Feb. 1985, pp. 221-228.
5. S.P. Singal, "Status report on atmospheric acoustics", *J. Acoust. Soc. India*, 13, Jan. 1985, pp. 10-16.
6. 'Day-to-day changes in IEC...' *Radio Science*, 19, p. 749-756. (1984) R.S. Dabas, R.K. Bharadwaj, J.B. Lal, Tuhi Ram Tyagi.
7. 'A semi-empirical model of IEC... Solar minimum', *Ind. J. Radio Space Phys.*, 13, p. 63-68. (1984). P.K. Bhuyan and Tuhi Ram Tyagi.
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- ture with Experimental Measurements During Low Solar Activity" *Adv. Space Res.* 4, Vol. 97, 1984.
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 27. Infrasonic observation at Antarctica, *Indian Journal of Radio and Space Physics*, Vol. 13, p. 109 (1984) by R. Venkatachari & A.K. Saha.
 28. Physics Research in Israel—A Preliminary Bibliometric Analysis, S. Arunachalam, M.K. Dharendra Rao and Parveen K. Shrivastava North Holland. *Journal of Information Science* Vol. 8 (1984) 185–195.

TECHNICAL REPORTS

1. A Pilot Noise Survey in Delhi-1983, A.F. Chhappgar and V. Mohanan.
2. A hollow vibrating cone to measure internal damping in metals, V. Mohanan.
3. Calibration of half-inch condenser microphone.
4. Inter-comparison of Iodine-Stabilized Ne-Ne Laser at 633 nm-R.B. Hurst, V.D. Dandawade and NPL Team, PEL (NZ) and NPL (India), June, 1984.
5. "The Dissemination Service of the National Physical Laboratory, New Delhi (Part I—ATA, the High Frequency Standard Time Broadcast)"—Technical Note 1984.
6. "Standard Time and Frequency Signal Dissemination via INSAT-1B (Part I—Preliminary experiments via INTELSAT IV)"—Technical Note 1984.
7. "Standard Time & Frequency Signal Dissemination via INSAT 1B (Part II—Preliminary Experiments via INSAT 1B)" Technical Note 1984.
8. Report on the Intercomparison of capacitance, Inductance and Resistance Standards under Indo-Soviet Cooperation in Standardization & Metrology.
9. Feasibility Report on Quantum Hall Effect.
10. Report on the intercomparison of DC Voltage under Indo-Soviet Cooperation in Standardization & Metrology.
11. "Design, Development and Evaluation of Precision type N connectors."
12. Report on the Intercomparison of D.C. Voltage Standard under Asia Pacific Metrology Programme using 'Transvolt' as Travelling Standard.
13. AC Power Measurement using Electrodynamic Comparator Technique NPL—Technical Bulletin—July 1984.
14. Report on Metrology in Maldives (*Unesco Consultancy Report*)—Dr. K. Chandra (April 1984).
15. Final report on the project 'Development of solid electrolyte grade beta alumina tubes for sodium sulphur battery. Report No. NPL-II-Bal-FR-84, B.K. Das, Balbir Singh, R.P. Tandon, S.M. Khullar, H.S. Kalsi, R.C. Goel and S.K. Sharda.
16. Technical Report No. NPL-85-0005 'Development of solid electrolyte grade beta alumina tubes for sodium sulphur battery'. B.K. Das, Balbir Singh, R.P. Tandon, H.S. Kalsi, S.M. Khullar, R.C. Goel and S.K. Sharda.
17. "Rocket Measurements of k.e.v. range protons over a low latitude station, SHAR" M.N.M. rao, B.C.N. Rao, C.B. Tandel, T.S.R. Murali Krishna and M.S. Tripathi RSD-129, Aug. 1984.
18. A self absorbing gas cell uV radiometer for the measurement of nitric oxide concentrations in the middle atmosphere' N-Iwagami and K.S. Zalpuri—RSD Sci. Report No. 128.
19. Banerjee P.K. Mahendra Mohan and Reddy B.M.,

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25. V.K. Pandey, K.K. Mahajan & V.C. Jain "An Improved Empirical Model for Electron Temperature in the F2-Region" *Indian Journal of Radio & Space Physics*, 13, 42, 1984.
 26. K.K. Mahajan and V.K. Pandey, "Electron Temperature modelling in the F-region and Topside of the Ionosphere A proposal for improving the IRI", Report UAG-90, (ed. K. Rawer and C.M. Miunis) World Data Center A, Boulder, Colorado, U.S.A., May, 1984.
 27. Infrasonic observation at Antarctica, *Indian Journal of Radio and Space Physics*, Vol. 13, p. 109 (1984) by R. Venkatachari & A.K. Saha.
 28. Physics Research in Israel—A Preliminary Bibliometric Analysis, S. Arunachalam, M.K. Dharendra Rao and Parveen K. Shrivastava North Holland. *Journal of Information Science* Vol. 8 (1984) 185–195.

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1. A Pilot Noise Survey in Delhi-1983, A.F. Chhappgar and V. Mohanan.
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11. "Design, Development and Evaluation of Precision type N connectors."
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16. Technical Report No. NPL-85-0005 'Development of solid electrolyte grade beta alumina tubes for sodium sulphur battery'. B.K. Das, Balbir Singh, R.P. Tandon, H.S. Kalsi, S.M. Khullar, R.C. Goel and S.K. Sharda.
17. "Rocket Measurements of k.e.v. range protons over a low latitude station, SHAR" M.N.M. rao, B.C.N. Rao, C.B. Tandel, T.S.R. Murali Krishna and M.S. Tripathi RSD-129, Aug. 1984.
18. A self absorbing gas cell uV radiometer for the measurement of nitric oxide concentrations in the middle atmosphere' N-Iwagami and K.S. Zalpuri—RSD Sci. Report No. 128.
19. Banerjee P.K. Mahendra Mohan and Reddy B.M.,

- 'Gegahertz scintillation experiment using INSAT-1B', Technical Report No. NPL-85-0002, Feb. 1985.
20. Lakshmi D.R. Jain A.R., Dua M.K., and Jagdish Singh, 'Flux gate magnetometer facility at NPL to aid HF Communication Predictions', Technical Report No. NPL-85-0015, April, 1985.
21. Report No. NPL-85-0042. 'Report on Second Antarctic Expedition (1982-83) compiled by A.K. Saha.'
22. Report No. NPL-85-0037. 'Differential absorption measurement of atmospheric minor constituents with a laser—water vapour by S.L. Jain, B.C. Arya, D.R. Nakra & A.K. Saha'.
23. Lakshmi D.R., Aggarwal S., Shastri S., Shiv Kumari and Reddy B.M., 'Major consultancy services for defence operations during 1983-1984 on HF Communications', Technical Report No. NPL-85-0003, March 1985.

Ph.D's Awarded

Awardee	Title of Thesis	University
G.S.N. Murty	Some Upper Atmospheric studies using the ground-based night air glow measurement.	Andhra
M.P.S. Chauhan	Nonequilibrium effects in Josephson junctions.	Delhi
V.D. Dandawate	Development of He-Ne lasers and study of their characteristics in single and multimode operation.	Delhi
V.T. Chitnis	Laser metrology applied in super precision fabrication technology.	Nagoya, Japan
V.G. Kulkarni	Studies on hologram interferometry and its applications to precision measurements	Delhi
S.K. Singhal	Synthesis of superhard materials with special reference to single crystal diamond and cubic boron nitride compacts.	Delhi

SYMPOSIA/WORKSHOP/TRAINING COURSES

A one day workshop on "Current Status of High Pressure Technology in India" was organised. NML, Jemshedpur, NGRI, Hyderabad and University of Delhi have participated in this workshop besides NPL. Collaborative proposals with NGRI and NML were made.

An advance course on "Precision Measurements" was given from 15th to 31st. January 1985.

A national seminar on "Temperature Measurement" took place from 26th to 28th Feb. 1985 at NPL.

Fifteen lectures were conducted on BASIC programming at NPL.

A workshop on "Ionospheric Communication"

was organised from 4th to 7th December 1984. The workshop dealt with various aspects of low latitude Ionospheric Radio Communications and was attended by participants representing various Defence and Civilian organizations.

Practical training in Metrology was imparted to trainees from Malaysia, Nepal and Karnataka.

A symposium on Optics was held from 6th and 8th February 1985.

A one day national seminar on 'Carbon Industry' was conducted on 15th March 1985. It was well attended by people from industry and research organizations.

ADVICE/CONSULTANCY/CALIBRATION

The Acoustics Standards project has provided consultancy regarding noise reduction, acoustical treatment of auditoriums etc. and testing of electro-acoustical devices & acoustic products for industry and research institutes.

The Optical Radiation standard project has rendered advice regarding the establishment of Quality Control Laboratories for the lamp and lighting units.

Ready to read charts and tables for groundwave field strength were developed for different terrain conditions relevant to Zones of Army Operations by the Troposphere and Ionosphere communications group.

Advice was provided to M/s Britelite Carbons Ltd, Holol (Gujarat) regarding pollution reduction in the plant during baking of carbon products.

The Capacitance & Inductance Standards project has provided calibration services to various Govt. & Defence Establishments, Regional Laboratories, Industries etc.

The AC, LF & HF Standards project rendered calibration facilities for precision instruments and standards to various public & private undertakings including Defence & Space.

Calibration services are rendered also by Microwave Standards group for Railways, Private Industry etc. regarding powermeters, attenuators, frequency meters etc.

The Mass, Volume & Density Standards project has provided calibration facilities to the Weights & Measure Enforcement Departments of the State Governments. Services were rendered to Sugar, Petroleum and other Industries regarding the calibration of glass hydrometers, burettes, pipettes, butyrometers, vicometers etc.

The calibration facilities of Force and Hardness Standards project were used by the steel manufacturers in private and Public sector including Indian Railways, Defence, ISRO etc.

VISITS ABROAD (BETWEEN APRIL 1984 AND MARCH, 1985)

Name of Scientist	Country(s) visited	Month(s)	Purpose
1	2	3	4
Dr. S.V. Gupta	Vietnam	April-May	Under UNIDO Assignment as an Consultant in Metrology.
Dr. Kailash Chandra	Mal Dives	April	For the consultant services for the establishment of Metrology facilities sponsored by UNESCO.
Dr. M.M. Bindal	U.S.A.	August	To familiarize with the activities at N.B.S. Under UNDP Project.
Dr. A.K. Gupta	FRG, Austria, Switzerland, France, U.K., S. Korea & Japan	April, May, Aug. & Sept.	Under UNDP Project.
Dr. A.K. Gupta	S. Korea & Japan	June & Aug. to Sept.	Under UNDP Project.
Sh. Mohinder Nath	USA	May	For training with M/s Volend Corpn. USA.
Dr. K.K. Mahajan	USSR	April	As a member Indian Team sponsored by INSA.
Dr. Omkar Sharma	Australia	June	For advanced training in the area of acoustics at the Division of Applied Physics at CSIRO, Sydney.
Dr. A.P. Mitra	USSR, U.K., Austria	May, June & July	To attend ICSU meeting at Moscow. To discuss and finalise the details of course on Troposphere, Mesosphere and Stratosphere and to attend the COSPAR meeting in Austria.
Dr. V.N. Bindal	Japan	July	To attend and present a paper at the 10th International Symposium on Non-linear Acoustics at Kobe.

1	2	3	4
Dr. Ravi Mehrotra,	W. Germany	August	To participate in the 17th International Conference on Low Temperature Physics.
Dr. K.S. Zalpuri & Dr. Venkatachari	Italy	Sept.	To attend the Autumn College on the Troposphere, Stratosphere and Mesosphere Course at ICTP.
Dr. V.D.P. Sastry	France	Oct.	Under CSIR-CNRS Exchange Programme.
Dr. S.R. Das	U.S.A.	Aug.	NBS—activities & collaboration.
Dr. A.V. Narlikar	W. Germany, U.K.	August	To act as a Chairman of the Superconducting Session in the 17th Intl. Conference on Low Temp. Physics. Lt-17.
Dr. P. Banerjee	Italy	Aug.-Sept.	To attend the URSI General Assembly at Florence.
Dr. A.P. Jain	USA	Sept.-Oct.	To visit various laboratories on the project entitled "Development of Low Temperature."
Dr. Kailash Chandra,	Bangkok, Malasia and Phillipines	Oct.	To discuss at the ESCAP the Regional Office and their land Institute and Industrial Research and to discuss at the Asia Pacific Instt. for Broadcasting—to attend and Chair the Steering Committee at Phillipines.
Dr. J.K.N. Sharma	Japan, USA, France and Austria	Sept.-Oct.	Under UNDP Project.
Dr. P.C. Mohendru	Japan	Nov.	To participate in the 2nd Intl. Conference on Electrostatic Precipitation at Kyoto.

1	2	3	4
Dr. R.B. Tripathi	USA	Oct.-Nov.	To attend the 4th Intl. Conference on the Measurement of Domain Wall Energy Parameters in Doped Ni-Zn at San Francisco.
Dr. M.M. Pradhan	Japan	Oct.	To attend the Intl. Conference on Infrared and Milimetre Waves at Osaka.
Dr. Subhash Chandra	USA	Nov.-Dec.	Under CSIR-NSF Exchange Programme.
Dr. S.K. Lahiri	USA	Oct.	To visit NBS Laboratories, USA.
Dr. B.K. Das	UK and France	Oct.	For training in Quantimet 900 Image Analyser at Cambridge Uni. U.K., and to visit CNRS laboratories.
Dr. N.K. Arora	U.K.	Oct.	-Do-
Dr. O.P. Bahl	Japan	Nov.	To deliver lectures on Carbon Fibres' Development in India.
Dr. M.K. Raina	U.K.	Dec. to Feb.	Under CSIR-British Council Exchange Prog.
Dr. K. Lal	Japan	Dec.	For the Familiarization Training on the Maintenance of High Power X-ray Generator of rotating Type & Microprocessor Controlled Diffractometer with M/s Rigaku Corporation.
Dr. B.M. Reddy	France	June	International Workshop on Solar Terrestrial Predictions.
	Australia	Feb.	To give a Review Talk on the Inaugural Session on the "future of Ionospheric Physics and Radio Propagation."
Dr. A.K. Bandyopadhyaya	W. Germany	March	To avail UN Fellowship Training in the field of

1	2	3	4
			Pressure Standards and for the establishment of Primary & Transfer Pressure Sds. under UNDP Project.
Dr. Gopal Bhatia	W. Germany	Aug. 1983 to Dec. 1984	Alexander von Humboldt Foundation at the Institute of Chemical Technology Karlsruhe.
Dr. S.S. Bawa	Czechoslovakia	April to July	Under CSIR—CSAV to work on Ferroelectric liquid crystals at the Institute of Physics, Praha.
Dr. M.M. Pradhan, R.K. Garg	USA	April	To attend a course on Fourier Transform Infrared Spectrometer.
Dr. (Mrs) Vsantha Raman	Stokholm	August	To attend III International conference on Indoor Air Quality and climate.

PATENTS FILED/ACCEPTED

Patents Filed. No.	Title	Inventors
245/DEL/85	Recovery of Silver from waste hypo solution by chemical process.	A.K. Sarkar
271/DEL/85	An improved process for the production of Glassy Carbon.	Gopal Bhatia, R.K. Aggarwal
272/DEL/85	Improved process for making transparent electrically conducting pattern in glass substrates for electro-optical display devices.	Subhash Chandra S.S. Bawa
278/DEL/85	The improved solar cooker	R.H. Bhawalkar
Patent Accepted		
155150	A process for making duplicating ink with rice bran oil	P.K. Gupta, J. Rai, Hari Singh.

**RECEIPTS ON ACCOUNT OF TESTING/CALIBRATION/GLASS FABRICATION & OTHER
CHARGES REALISED DURING APRIL 1984 TO MARCH 1985**

Divisions	No. of Reports Issued	Amount (Rs.)
Optical Standard	298	2,32,052
Force Standard	463	1,51,050
Length Metrology	950	1,80,040
Length Standard	1	2,000
Chemical Testing	66	12,695
Mass Standard	581	76,200
EL/ES STANDARD		
a) A.C. Standard	48	55,975
b) D.C. Standard	69	31,838
c) M.W. Attenuation	9	3,300
d) M.W. Equipment	2	650
e) Cap. & Ind. Standard	16	8,600
f) Time & Freq. Standard	1	500
g) T.V. Picture Tube Testing	9	900
Accoustic Standard	50	17,630
Thermometry Standard	185	40,350
Material Analysis	20	18,960
High Vacuum Standard	9	2,150
Ref. Tech. & Pt. Thermometry	10	27,525
Pressure Standard	44	19,000
Glass Fabrication	—	1,46,357
Carbon Products	—	693
Total	2831	10,28,465

**PREMIA & ROYALTIES OF THE PROCESSES RELEASED EARLIER AND IN PRODUCTION
(Upto 31.12.1984)**

Process	Party	Royalty (Rs.)
Photocopying machine	M/s Macneill & Magor Ltd., Ghaziabad	19,079.55
Cinama Arc Carbon	M/s Isocarbon Co., Visakhapatnam	5,927.55
Microwave Component	M/s Scientific Instruments Co. Ltd., Ghaziabad	4,794.25
Soft Ferrites	M/s Ferrites India Ltd. M/s Morris Electronics, Pune	13,000.00 1,04,824.89
Indelible Ink	M/s Mysore Lac & Paints Ltd.,	1,10,000.00
TV Picture Tube	M/s Video Electronics	672.00
Reconditioning		1354.48
He-Ne Gas Laser	M/s Thermometer & Thermomatic, New Delhi	4000.00

PERSONNEL

DIRECTOR MITRA, A.P.

SCIENTISTS & OFFICERS

DIVISION OF STANDARDS

Aggarwal, N.K.	Jain, K.K.	Pradeep Mohan
Aggarwal, R.	Jain, P.K.	Prabhakar, A.C.
Aggarwal, V.K.	Jha, P.P.	Puntambekar, P.N.
Arora, T.R.	John, P.C.	Rajput, S.S.
Ashwani Kumar, P.K.	Joshi, K.C.	Ram Narain
Bahl, M. (Mrs)	Juneja, S.L.	Ram, R.S.
Bahl, P.P.	Kailash Chand	Ram Sarup
Balsara, A.N.	Kailash Chandra	Roy, B.K.
Bandopadhyay, A.K.	Kandpal, H.C.	Rustogi, V.K.
Banerjee, P.	Kanji Lal, A.K.	Saksena, A.K.
Batra, V.K.	Karfa, M.	Sarkar, S.K.
Baveja, K.D.	Kaushik, A.R. (Mrs)	Sarma, K.S.
Bhaskar, H.L.B.	Kewal Krishan	Saxena, G.M.
Bhatia, L.M.	Khandekar, R.	Saxena, M. (Mrs)
Bhatnagar, H.M.	Khanna, O.N.	Sen Gupta, A.
Bhatnagar, K.N.	Khanna, P.K.	Sharma, D.R.
Bhola, O.P.	Kohli, N.K.	Sharma, J.K.N.
Chakraborty, B.R.	Kowsalya (Mrs)	Sharma, R.S.
Chatterjee, A. (Mrs)	Kothari, P.C.	Sharwan Kumar
Choudhry, M.K.	Kulkarni, V.G.	Singal, S.P.
Chitnis, V.T.	Kulshreshtra, R.K.	Singhal, R.P.
Dahake, S.L.	Lahari, S.K.	Singh, C.P.
Dahiya, H.S.	Lakshmi Kumar, S.T.	Singh, G.
Dandavate, V.D.	Luthra, R.K.	Singh Joginder (S/o Mr. Bachan Singh)
Das Gupta, M.K.	Mahajan, S.K.	Singh Joginder
Das, M.L.	Mahesh Chander	Singh, S.
Das, S.R.	Maini, H.K.	Singh, S.K.
Dhar, R.N.	Mallela, S.B. (Mrs)	Singh, Y.P.
Dhawan, J.K.	Manrai, S. (Mrs)	Sood, P.C.
Dutta, P.K.	Mathur, B.G.	Srivastava, N.K.
Ganapathy, T.V.	Mathur, B.S.	Suri, S.P.
Gautam, C.B.L.	Mathur, S.P. (Mrs)	Taneja, K.C.
Goel, G.K.	Mehrotra, R.	Taneja, P.N.
Govil, A.K.	Mithan Lal	Tanwar, L.S.
Gumber, V.K.	Mittal, M.K.	Thadani, H.K.
Gupta, A.C.	Mittal, P.K.	Tripurari Lal
Gupta, A.K.	Mohanani, V.	Veena Roonwal (Mrs)
Gupta, D.	Nagar, M.R.	Verma, S.P.
Gupta, S.C.	Nangia, S.N.	Wasan, V.P.
Gupta, S.R.	Nath, M.	Yadav, R.S.
Gupta, S.V.	Negi, P.S.	
Gurmej Ram	Ojha, V.N.	
Hanjura, A.K.	Omkar Sharma	
Inderjeet, B.	Om Prakash	

MATERIALS CHARACTERIZATION DIVISION

Amar, V.K.

Ananthamurthy, R.V.
 Bhagavannarayana, G.
 Bohra, J.N.
 Dhar Rakesh (JRF)
 Dhawan, U. (Mrs)
 Garg, R.K.
 Goswami, S.N.N. (Mrs.)
 (Res. Assoc.)
 Gupta, P.K.
 Gupta Prabhat Kumar
 Gupta, S.K.
 Haldar, S.K.
 Krishan Lal
 Kundra, K.D.
 Malhotra, G.L.
 Malik Alpina (Mrs) (JRF)
 Nagpal, K.C.
 Narendra Kumar
 Parashar, D.C.
 Parthasarathy, S.
 Pradhan, M.M.
 Rai Jitendra
 Ramachandram, R. (Mrs)
 Rao, S.U.M.
 Sarkar, A.K.
 Sharma, S.D.
 Sharma, S.K.
 Singh Mewa
 Suri, D.K.
 Trehan, J.C.
 Vasantharaman (Mrs)
 Vijay Kumar

CRYOGENICS & SUPERCONDUCTIVITY

Babbar, N.K.
 Ekbote, S.N.
 Gera, S.C.
 Gupta, A.K.
 Jain, A.P.
 Jayaram, B.
 Kasturi Lal
 Kataria, N.D.
 Krishan, H.
 Krishan, M.M.
 Narlikar, A.V.
 Reddy, Y.S.
 Samanta, S.B.
 Sankaranatarajan, N.
 Saxena, R.B.
 Sharma, R.G.

Tomar, V.S.
 Vahishta, S.C.

APPLIED PHYSICS PROJECTS

Aggarwal, A.K.
 (S/O Mr. Dharam Pal)
 Aggarwal, A.K.
 Agnihotri, S.A. (Mrs)
 Anandan, C.
 Anandani, R.C.
 Bahl, S.D.
 Basu, A.
 Bawa, S.S.
 Bhatara, R.C.
 Bhattacharya, R.
 Bhawalkar, R.H.
 Bindal, M.M.
 Biradar, A.M.
 Chakraborty, T.K.
 Chopra Rajeev
 Dhar Ajay
 Dixit, P.N.
 Gupta, A.K.
 Gupta, S.K.
 Hagde, M.S.
 Jain, S.C.
 Kamalasanan, M.N.
 Kumaraswami, B.V.
 Longanathan, B.N.
 Mahendru, P.C.
 Malik, I.A.
 Meenakshi Kar (Mrs)
 Misra, S.C.K.
 Nayyar, R.K.
 Panwar, O.S.
 Panwar, V.S.
 Parshad Ganga
 Ramji Rai
 Ram Prasad
 Rastogi, A.C.
 Saini, K.K.
 Shah, V.V.
 Sharma, C.P.
 Sharma, D.C.
 Sharma Sham Lal
 Singhal, S.K.
 Singh Bachan
 Singh, B.P.
 Singh Devendra
 Singh Ramadhar
 Singh Ved

Sootha, G.D.
 Subhash Chandra
 Sundaram, R.
 Suresh Chand
 Tagra, O.P.
 Tripathi, T.C.
 Vaishya, J.S.
 Verma, B.S.
 Verma, N.S.
 Verma, S.S.
 Virendra Babu

DIVISION OF MATERIALS

Aggarwal, R.K.
 Ahmed Aftab
 Arora, N.K.
 Ashok Kumar
 Avasthy, B.R.
 Bahl, O.P.
 Bangari, N.S.
 Bhatia Gopal
 Bindal, V.N.
 Chakravarty, B.C.
 Chottey Lal
 Das, B.K.
 Datta, K.K.
 Ghosh, P.K.
 Goel, R.C.
 Gogia, V.K.
 Govindaswami, G.
 Hanspal, S.S.
 Harish Chand
 Jain Kiran (Mrs)
 Jain, S.K.
 Kalsi, H.S.
 Kapur, S.K.
 Khullar, S.M.
 Khurana, B.S.
 Kotnala, R.K.
 Manmohan, S.B.
 Manocha, L.M.
 Mathur, R.B.
 Mohan Lal
 Mukesh Chandra
 Narang, H.P.
 Narayanaswamy, N.
 Ramanathan, P.V.N.
 Ramanathan, S.
 Ram Kishore
 Saksena, T.K.

Santosh Kumari (Mrs)
Sastri, V.D.P.
Seth, R.L.
Shanker, V.
Sharda, S.K.
Singh Balbir
Singh Janardan
Singh, N.P.
Singh, P.K.
Singh Satbir
Singh, S.N.
Singh, V.R.
Siva Ram, P.
Som, J.N.
Subhash Chandra
Tandon, R.P.
Tarsen Lal
Tripathi, R.B.
Verma, C.L.

RADIO SCIENCE DIVISION

Aggarwal, S. (Mrs)
Arya, B.C.
Banerjee, A.
Banerjee, P.K.
Bhattacharya, K.
Chopra, P. (Mrs)
Dabas, R.S.
Dua, M.K.
Dutta, H.N.
Garg, S.C.
Gera, B.C.
Ghosh, A.B.
Goel, M.K.
Gupta, J.K.
Jain, A.R.
Jain, S.L.
John Thomas
Khanna, R.M.
Kundu, N. (Mrs)
Lakshmi, D.R. (Mrs)
Mahajan, K.K.
Mahendra Mohan
Malhotra, P.L.
Mitra, A.P.
Murty, Y.V.R.
Nakra, D.R.
Pahwa, D.R.
Pandey, V.K.
Pasricha, P.K.
Prasad, M.V.S.N.
Raina, M.K.

Ramakrishna, M.
Rao, B.C.N.
Rao, M.N.M.
Reddy, B.M.
Sachdeva, V.P.
Saha, A.K.
Sarkar, S.K.
Sarma, S.B.S.S.
Saxena, P.C.
Saxena, T.K.
Sethi, N.K.
Shakdhar, M.L.
Sharma, M.C.
Sharma, V.N.
Shastri, S. (Mrs)
Singal, S.P.
Singh, L.
Somayajulu, Y.V.
Srivastava, B.N.
Subrahmanyam, C.V.
Subrahmanyam, P.
Tandel, C.B.
Tewari, D.K.
Tyagi, T.R.
Uppal, G.S.
Upreti, U.C.
Vashisht, A.R.S.
Venkatachari, R.
Vijay Kumar, P.N.
Vohra, V.K.
Zalpuri, K.S.

SERVICE SECTIONS

Workshop

Anand, J.R.
Chhibber, M.K.
Dua, C.S.
Harish Chand
Khanna, R.
Nagpal, M.L.
Ojha, J.N.
Poddar, H.N.P.
Sarkar, M.L.
Shgal, M.G.

Glass Technology Workshop

Biswas, M.K.
Hans, G.S.
Jusht, M.C.
Ram Kani

Razdan, D.N.
Sen Gupta, S.K.
Sen, S.S.
Shashi Bhushan
Singh Chandan
Singh Karnail
Vashisht, J.P.
Verma, M.L.
Verma, V.P.

Works & Services

Kapur, S.S.
Krishna Murty, K.V.
Kumar, C.S.P.
Makloga, K.S.
Singh Raj
Tomar, T.R.

Library

Ashok Kumar
Dhawan, S.M.
Phull, S.K.
Srivastava, G.S.
Sundarshan Kumar

P & L

Arora, G.K.
Balchandani, M.K.
Bhakri, S.S.
Dwivedi, S.
Khanduja, R.S.
Khullar, F.C.
Kohli, P.K.
Malik, M.K.
Mandal, S. (Mrs)
Rao, M.K.D.
Sharma, S.K.

Others

Dhawan, R.C.
Shankar, R.
Sharma, J.C.

Singh Dewan

Administration

Meni, O.P.

Accounts

Bhasin, R.K.

Pandey, S.S.

Bansal, P.D.

Grover Harish

Pran Nath

Rajagopalan, K.M.

Gupta, S.L.

Sardana, J.M.

Singh Bijay

Joseph, S.A. (Mrs)

Sharma, M.C.

Soni, S.S.

Lal, R.B.

Singh Lakhpat

Mathur, H.M.

Singh, R.S.

Varma, O.P.

MEMBERSHIP OF RESEARCH ADVISORY COUNCIL
(w.e.f. 1.10.1984)

Prof. S. Chandrasekhar, Raman Research Institute, Bangalore-560 080.	Chairman	Prof. A.K. Barua, Director, Indian Institute of Cultivation of Science, Jadavpur, Calcutta-700 032.	Member
Prof. J.K. Choudhury, 23, Jadavpur North Road, Calcutta-700 032.	Member	Dr. R. Chidambaram, Director (Physics Group), Bhabha Atomic Research Centre, Trombay, Bombay-400 085.	Member
Dr. P. Krishna, Professor of Physics, Banaras Hindu University, Varanasi-221 003.	Member	Dr. R.G. Kumble, Director, Department of Science & Tech., Technology Bhawan, New Delhi-110 016.	Member
Prof. S.K. Joshi, Department of Physics, University of Roorkee, Roorkee-247 672.	Member	Shri B.K. Sinha, Director General, Indian Standards Institution, 9, Bahadur Shah Zafar Marg, New Delhi-110 002.	Member
Dr. G. Venkataraman, Jawaharlal Nehru Fellow, Reactor Research Centre, Kalapakkam, Madras-603 102.	Member	Dr. R. Vijayaraghavan, Tata Institute of Fundamental Re- search, Colaba, Bombay-400 005.	Member
Prof. (Mrs) Sulochana Gadgil, Centre for Atmospheric Physics, Indian Institute of Science, Bangalore-560 012.	Member	Dr. S. Varadarajan, Director General (SIR), CSIR, New Delhi-110 001.	Member (Ex-Officio)
Prof. K.P. Sinha, Chairman, Centre for Theoretical Studies, Indian Institute of Science, Bangalore-560 012.	Member	Dr. A.P. Mitra, Director, NPL, New Delhi-110 012.	Member (Ex-Officio)
Dr. A.K. Sreedhar, Director, Defence Science Centre, Metcalfe House, Delhi-110 054.	Member		

Prof. V.K. Gaur,
Chairman, Coordination,
Council for Physical and Earth Sciences Group,
N.G.R.I., Hyderabad-500 007.

Member
(Ex-Officio)

Dr. B.S. Mathur,
Scientist,
National Physical Laboratory,
New Delhi-110 012.

Member
Secretary

MEMBERSHIP OF EXECUTIVE COMMITTEE
(w.e.f. 1.10.1984)

Dr. A.P. Mitra, Director, National Physical Laboratory, New Delhi-110 012.	Chairman	Dr. B.S. Mathur, Scientist, NPL, New Delhi-110 012.	Member
Prof. J.K. Choudhury, 23, Jadavpur North Road, Calcutta-700 032.	Member	Dr. S.K. Sharma, Scientist, NPL, New Delhi-110 012.	Member
Prof. S.K. Joshi, Department of Physics, University of Roorkee, Roorkee-247 672.	Member	Sr. Finance & Accounts Officer, NPL, New Delhi-110 012.	Member
Dr. A.K. Sreedhar, Director, Defence Science Centre, Metcalfe House, Delhi-110 054.	Member	Chairman, Coordination Council for Physical & Earth Sciences, Group of CSIR.	Permanent Invitee
Dr. B.M. Reddy, Scientist, NPL, New Delhi-110 012.	Member	Director General, SIR CSIR, New Delhi-110 001 OR His Nominee	Permanent Invitee
		Administrative Officer, NPL, New Delhi-110 012.	Member Secretary

HONOURS & AWARDS

Dr. A.P. Mitra was elected as the President of the International Union of Radio Science (URSI) for the next 3 years (1984-87). He is the second Asian to hold this office. The URSI is one of the oldest scientific organisations under the International Council of Scientific Union (ICSU) and was established in 1919.

Dr. K. Chandra was awarded the Lal C. Verman Award 1984 conferred by the Institute of Electronics and Telecommunication Engineers for his distinguished contributions in the area of Standardization and Precision Measurements in Electronics & Telecommunication Field.

Dr. V.N. Bindal was elected President of Ultrasonic Society of India.

STAFF STRENGTH
(As on 1.9.85)

Category	Nos.
<i>Scientific</i>	
Scientists	303
Technical Officers	108
Establishment	529
Group D	147
<i>Others</i>	
Officers	18
Establishment	161
Group D	51
Total	1317

TECHNOLOGICAL NURSERY FOR OPTICAL COMPONENTS

The setting up of a Technological Nursery for Optical Components in U.P. Hills is planned as a joint project of CSIR & the Hill Development Department of U.P. Government with NPL & Garhwal Mandal Vikas Nigam Limited, Dehra Dun as principal executive agencies. The nursery is conceived as a camp for generation, development & transfer of optical technology. It will employ retired technologists and guest scientists from different R&D centres.

EXPEDITION TO ANTARCTICA

Mr. A.K. Suri participated in the IVth Antarctic Expedition. During this expedition, the scientific programme as carried out by N.P.L. during previous three expeditions was continued. The experiments included study of ionosphere through VLF studies and using riometers tuned to different frequencies. The experiments also included the study of ground wave pressure fluctuations using microbarographs. The aerosole sampling was done enroute to Antarctica in collaboration with N.I.O.

INTERNATIONAL ACTIVITIES IN METROLOGY

(a) Asia Pacific Metrology Programme (APMP)

The Steering Committee of Asia Pacific Metrology programme was held at Manila, Philippines in Oct., 1984 under the Chairmanship of Dr. K. Chandra, the present Regional Coordinator. The information on the training, calibration and consultancy requirements of developing countries in the Asia Pacific Region have been collected and steps been taken to provide assistance to these countries through Unesco, CSC and Australia Development Assistance Bureau.

Intercomparison of capacitance standards (10 pF) amongst Australia, India, China & Singapore and 2nd round of Intercomparison of D.C. Voltage Standard (Transvolt) amongst China, India, Thailand and Philippines has been started (NPL is the Pilot Laboratory for the Intercomparison).

Dr. K. Chandra, acting as Unesco Consultant to Maldives, prepared a Project Plan in Metrology for Maldives. Based on this report, a 'Model Metrological System for Small Island States' has been prepared.

The following documents have been prepared for APMP:

1. Report on the APMP Steering Committee Meeting held at Manila, Philippines.
2. Report on the Regional Workshop on Metrology & Standardization for Developing Countries and Small Island States—Vol. I & II.

3. Manuscript of the Document 'Asia Pacific Metrology Programme—Aims, Objectives & Activities'.

(b) Indo-Soviet Collaboration in Metrology and Standardization

The meeting of the Indo-Soviet Working Group on Metrology and Standardization was held at New Delhi in July, 1984 in which the programme for the year 1984-85 and 1985-86 were finalized.

Two Reports on Intercomparison of Standards between NPL (India) and VNIIM(USSR) were prepared to send to USSR.

(c) Cooperation Amongst Countries of Non-Aligned Movement in the Sphere of Standardization & Metrology

As members of the Indian Delegation, NPL Scientists attended the Meeting of the Countries of the Non-Aligned Movement (NAM) in the Sphere of Standardization, Measurement and Quality Control, held at New Delhi in Jan. 1985. In the Second Meeting of the Functional Group 3—Metrology, a paper on 'Cooperation in Metrology Amongst NAM Countries' was presented.

COLLABORATION WITH OTHER INSTITUTIONS/AGENCIES

The Materials characterization Division had international collaborative programme with (i) Department of Metallurgy Centre for Nuclear Research (AEC) Grenoble, France regarding study of microstructure of chromium film prepared by sputtering techniques, (ii) PTB-FRG regarding microstructural changes in semiconductor and insulator subject to high electric fields by triple and quadruple crystal X-ray diffractometer, (iii) Institute of Metrology, Gosstandart-Moscow (USSR) regarding properties of materials and

physical constants being coordinated by ISI, New Delhi and (iv) Institute of Crystallography, Moscow (USSR) on crystal growth and lattice imperfections being coordinated by INSA, New Delhi.

The Radio Science Division had active and useful collaboration with the India Meteorological Department, P&T, Civil Aviation, Indian Railways & Space. The prediction of Ionospheric Communication parameters helps in the planning of HF communication network of Defence & Civilian Organisations.

PROCESSES RELEASED TO INDUSTRY FOR COMMERCIALIZATION

Title	Party	Premium	Royalty	Nature
Flat Plate Solar Collector	1. M/s Mech & Fab Industries, Bhopal 2. M/s Dimy Enterprises, New Delhi 3. M/s Bharat Bobins Ltd., Ahmedabad 4. M/s Industrial Boilers Pvt., Ltd., N. Delhi	Rs. 3000/-	2%	Non-exclusive
Ceramic enclosed Censors (sponsored)	M/s Ohio Parameters, Calcutta.	Rs. 3500/-	—	—
Silver impregnated Graphite contacts	M/s Weldon SIG Contacts New Delhi	Rs. 15000/-	5%	Non-exclusive