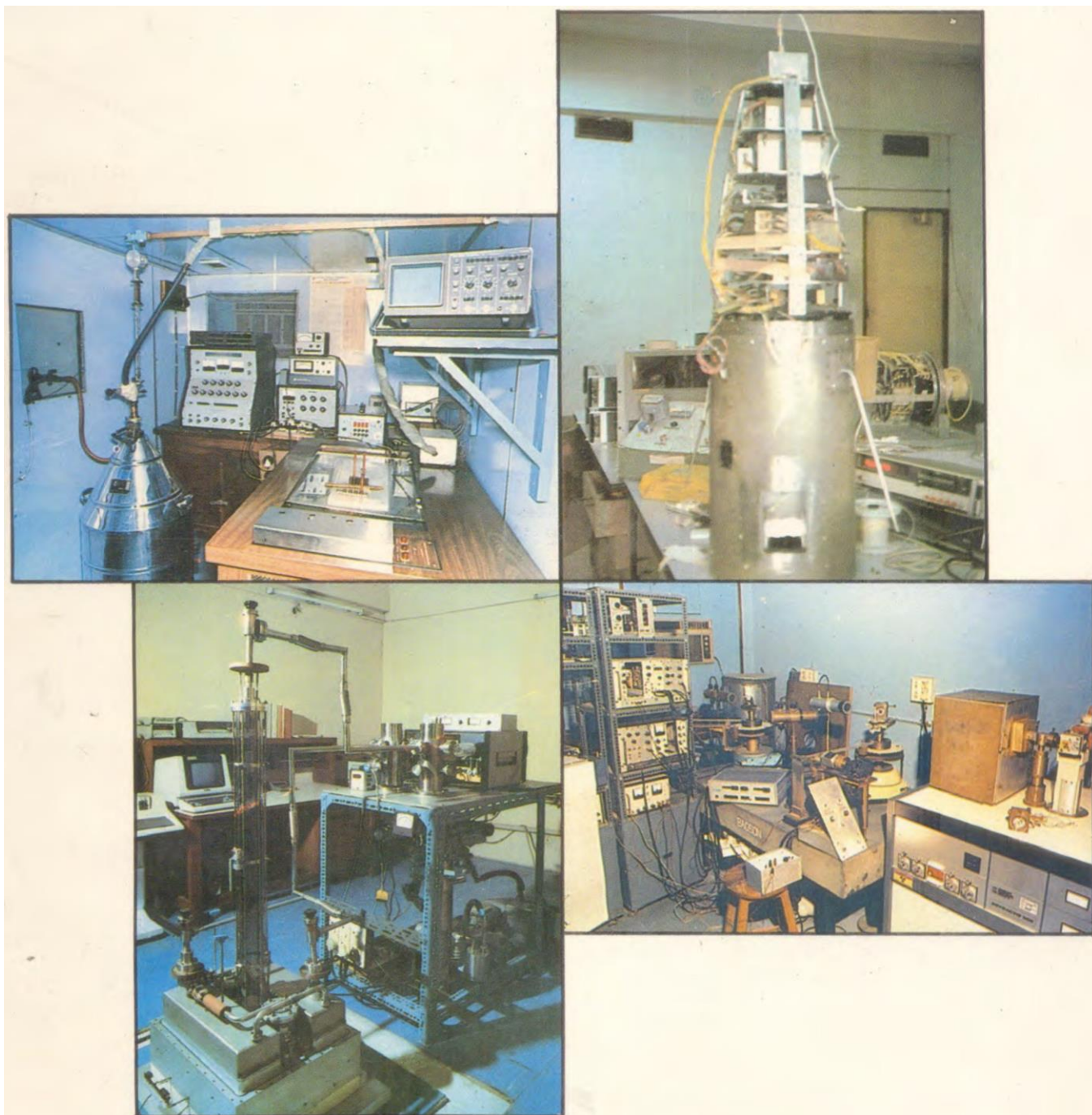


ANNUAL REPORT

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NATIONAL PHYSICAL LABORATORY
NEW DELHI

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PREFACE

The Laboratory has completed yet one more year of its fruitful activities in the area of Standards, Materials Development & Characterization, Radio Sciences & Atmospheric Physics and several Applied Physics Projects. A summary of the activities are presented here in this report.

Measurement Standards & Calibration

The laboratory has the responsibility of realising the 'units' of physical measurements and of development, custody & maintenance of the national standards of measurements. Efforts were continued towards improving the accuracies wherever needed & establishing the international compatibility and traceability through intercomparisons amongst various countries. Some of the significant achievements in the area of Standards & Calibration are summarized below:--

- Due to improvements made in the laser cavity and electronic servo control system, the stability of the I₂ stabilised He-Ne laser has improved to 5×10^{-12} with a reproducibility of 5×10^{-11} . A new technique of frequency stabilization of internal mode He-Ne laser operation at 633 nm using polarization modulation has also been developed.
- Methods for the measurement of horizontality of flat surfaces have been developed using (i) opto-pneumatic level, based on free mercury pool method & (ii) liquid paraffin cavity serving as a precision horizontal reference.
- The National Kilogram (Copy No. 57 of the International Prototype) was recalibrated by the International Bureau of Weights & Measures, France. A new facility for calibrating weights upto 500 kg has been established.
- Intercomparison of Ultra-19w expansion glass density standard from **CSIRO**, Australia and our own density standards has been carried out.
- Accurate "Time Instant" and Standard Frequency were provided through portable clocks (checked against NPL's master clock) to long Baseline Interferometry Experiment carried out at Radio Astronomy Centre, Ooty in collaboration with several international laboratories.
- Time intercomparison was carried out using direct TV broadcast from the Russian satellite "Stationer-6" between **NPL** and **VNIIFTRI (USSR)** and through portable clocks.
- Improved versions of the prototypes of industrial platinum resistance thermometers to be used as secondary standards, capsule thermometers and tungsten resistance thermometers were designed and fabricated. The photoelectric pyrometer was evaluated for linearity and is now ready for use in calibration.
- The design of a standard machine for Rockwell hardness scales has been completed and is under fabrication.
- International intercomparison of pressure transducers with **IMGC** (Italy) and of vacuum standards amongst FRG, France, U.K., U.S.A., Japan and other countries was carried out

the aegis of **BIPM**. The range of the primary standards of pressure (controlled clearance piston gauge) has been extended to 1.0 GPa.

- An automatic goniophotometer used for the measurement of directional light distribution characteristics of light sources has been designed & fabricated. This will assist in the evaluation of total lumen output of lamps more accurately.
- NPL participated in the International Round Robin Intercomparison of standard accelerometers and vibration measuring systems with NBS, USA & of standard condenser microphones with CSIRO, Australia.
- A technique for the calibration of miniature probe hydrophones in the ultrasonic frequency range of 0.5MHz-7 MHz has been established.
- The "as maintained volt" has been intercompared against the Josephson voltage standard (already established at NPL) with an overall uncertainty of 1 ppm.
- Automation has been introduced in d.c. measurements using a desk-top computer, scanner and digital nanovoltmeter. This system is used for intercomparison of standard cells and calibration of standard voltage sources. Second round of intercomparison of dc voltage standards amongst India, China & Thailand has also been completed.
- The frequency range of mutual intercomparison of individual members of the group of multijunction thermal convertors serving as the primary standards of AC & LF voltage and current has been extended from 30 KHz to 100 KHz. Intercomparison of AC/DC travelling thermal transfer standard has been carried out under Asia Pacific Metrology Programme.
- The standard of AC resistance (1 K Ω at 592 Hz) has now been realized with an uncertainty of 3 parts in 10⁷ and facilities for measurement of AC resistance upto 100 K Ω have been established.
- A constant temperature portable oil bath of 0.002cc temperature stability within a working range of 20°C to 30°C has been designed and developed. Two units have been fabricated for a Defence Establishment.
- An X-band pure calorimetric load of novel design has been perfected and evaluated for its effective efficiency by single load calorimetric technique covering the entire band (8.2 to 12.4 GHz).
- As in the past, the calibration of a large number of reference standards and precision measuring instruments from outside agencies was undertaken. The various beneficiaries were the Deptt. of Weights & Measures, Deptt. of Electronics, Deptt. of Telecommunication, Civil Aviation, Indian Railways, **ISRO**, Defence Establishment, **ISI**, various Public Sector Undertakings, Private Industries etc.

Materials Development

In the area of Materials Development, the main achievements were:-

- Polycrystalline silicon ingots of 50 x 50mm have been cast and evaluated for use in photovoltaic solar cells.
- Beta-alumina tubes have been processed and supplied to CECRJ, Karaikudi and IGCAR, Kalpakkam to be used in a prototype of sodium-sulphur battery under development.

- Black & White **TV** phosphor samples have been prepared and supplied to an industry for use in **TV** picture tubes to obtain field trials.
- Clinical trials on ultrasonic ophthalmoscope and of glassy carbon dental implants have been made on actual patients.
- A project on the development of carbon-carbon composites sponsored by Vikram Sarabhai Space Centre, Trivandrum has been completed.
- The NOT of archival materials has been undertaken.
- Work on establishment of intensity measurements, with studies on development of high power ultrasonic systems for oceanographic studies and development of parametric systems for detection of objects in the sea bottom has been continued.

Materials Characterization

Important studies carried out by the Materials Characterization Division are summarized below:-

- High resolution **X-ray** diffractometric and topographic methods and the Quadruple Crystal **X-ray** Diffractometer, developed in the laboratory were used successfully, for the first time for observation of a small but measurable interaction in Si Mosfets (Klitzing elements). Studies on charge carrier- lattice interaction during two-dimensional conduction in devices have been undertaken.
- The electron microscopic studies of thin silver films have successfully explained the mechanism of void formation.
- A method has been developed for the determination of sulphur and phosphorous in different materials by using atomic absorption spectrophotometer.

The following new facilities were added:-

- A portable gas chromatograph with flame ionization detector and thermal conductivity detector for analysing the atmosphere in factories and fields.
- A rotating anode X-ray source of high power and high brilliance has been commissioned. A triple crystal X-ray diffractometer has been setup with this source.

Radio & Atmospheric Sciences

In the area of Radio and Atmospheric Sciences the following significant contributions have been made:-

- As a part of **IMAP**, a number of different payloads were fabricated, tested and three rocket flights with several experiments were successfully conducted in March 1986.
- There was considerable progress in **SROSS**. Laser Heterodyne and Solar **UV-B** network experiments.
- Comprehensive results were published including some new techniques in **HF**, **VHF** and microwave communications and there was increasing demand from Defence Services for advice on communications.

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- Ionospheric modelling efforts have yielded parameters that would be inputs for International Reference Ionosphere.
- The gas chromatograph facility for atmospheric minor species was developed.
- A number of young scientists from abroad were trained in advanced radio communications.
- Some of the new areas, initiated recently, such as Planetary Ionospheres and Antarctic Research have yielded valuable results.

The work on ferroelectric liquid crystals has been initiated in the laboratory for developing past memory display devices. The electro-optical display devices which 500 μ sec. response time, working at high temperature were developed.

A number of sets of filters, peaked at different wavelength in the visible & near infra-red region, were fabricated and supplied to **ISRO** for ground based radiometric work. A set of neutral density filters with different transmittance values were supplied to **SAC**, Ahmedabad.

Various new series of minicoolers, with modified design of mandrel and flow-. nozzles, have been developed for obtaining efficiency and very small cool-down time.

The scientists of the laboratory have given advice and consultancy to various organisations in the public and private sector. The different fields were-acoustical treatment of auditoria; processing of laser plasma; desert cooler testing; antenna and radar operational problems and **HF** & microwave communications.

The third Review Committee Meeting and the Training Workshop of the **APMP** was held in Dec. 1985 and the **IMAP** Workshop in April 1985.

The calibration revenue realised during the period amounted to Rs. 10.612 lakhs. and the no. of calibration reports issued were 3052. More than 135 papers were published in national & international journals & a good number of research reports were produced.

vffoa.,
(Kailash Chandra)
Acting Director

DIVISION OF STANDARDS

PHYSICO-MECHANICAL STANDARDS

STANDARDS OF LENGTH

1. Iodine Stabilised He-Ne laser

As an outcome of the intercomparison of our iodine stabilised He-Ne laser at 633 nm, improvements were conceived and made in the mechanical stability of the laser cavity and in the electronic servocontrol system.

It is found that as a result of these improvements the standard deviation (**S.D.**) of the beat frequency of our laser has improved from the earlier value of ± 10 kHz to 2 kHz. This value is less than the average value of the **S.D.** of the lasers of other nine laboratories which took part in the last years international intercomparison.

The effect of these improvements is also noticed on the stability value of the laser which now is $\pm 5 \times 10^{-12}$ with a reproducibility of $\pm 5 \times 10^{-11}$.

All this very clearly supports our claim of having developed, and set-up, the primary standard of length in the form of I₂ stabilised He-Ne laser with performance comparable to those developed in other standards laboratories of the world.

1.1 Calibration of other stabilised laser

Experiment was carried out to determine the frequency of radiation of a H.P. laser transducer system No. 5501 A, being used in NPL calculable capacitor standard against stabilized He-Ne laser. This illustrates the importance of the developed primary standard in the absence of which, the laser had to be sent to some foreign standards laboratory for calibration.

1.2 Frequency Stabilization of He-Ne laser

A new technique of frequency stabilization of internal mode He-Ne laser operating at 633 nm-

using polarization modulation has been developed. The frequency stability achieved is 5×10^{-9} for an integration time of 10 sec. This gives a polarization modulated stabilized source useful in polarimetric measurements and eliminates the need of an electro-optic modulator.

1.3 Optogalvanic Effect with Dye Laser

Initial experiments carried out to detect the Optogalvanic signal in a He-Ne discharge cell using dye laser were successful giving a very strong optogalvanic signal with a high **S/N**. Experiments are planned to use this technique for calibrating the wavelength of the tunable dye-laser.

1.4 Laser Polarimeter

A technique for polarimetric measurements using the polarization modulated stabilised laser source has been developed. Initial results are encouraging and further work is in progress. A simple conventional polarimeter using two detector system was tried out and gave an measurement sensitivity of 10 sec. It is useful in bi-refringence studies and other such measurements.

1.5 Laser measurement system for line gauge calibration

A heavy base for holding the interferometer and the linear dividing machine has been fabricated and installed and interferometric system is being tried out.

Studies on the polarization flipping of He-Ne, gas lasers with and without axial magnetic field is being done. Preliminary results have been obtained and are being analysed.

DIMENSIONAL METROLOGY

1. Calibration

Calibration facilities have been used by industry and other organisations for measuring instruments or gauges used by Echelon II or Echelon III laboratories.

Items calibrated include slip gauges, length measures & bars measuring tapes, screw and plain plug and ring gauges, micrometers, calipers, surface plates, setting discs and rods, precision levels, angle gauges, cylindrical squares etc.

Calibration of length bars upto 500mm size by comparison method with an accuracy of $0.7\mu\text{m}$ & Calibration of angle gauges, polygons and circular tables with an accuracy of ± 3 seconds of arc were done.

2. Development of techniques

Two methods have been developed for measurement of horizontality of a flat surface. In one method, an opto-pneumatic level based on free mercury pool and moire effect is used which gives a resolution of the order of 10^{-5} radian. In the other method, a liquid paraffin cavity is used as a precision horizontal reference. Deviations of the order of 0.1 second of arc can be detected by an autocollimator.

An instrument for interferometric measurement of small ball diameters has been designed.

MICROSCIENCE METROLOGY

A varian ultra high vacuum thin film deposition system with a base pressure of 1.5×10^{-9} m bar provided with two e-beam guns and a substrate cleaning device has been installed for the deposition of thin films of refractory metals and their silicides. The performance of the equipment has been tested by depositing thin films of Ti and Si at room temperature and at 75°C . For the measurement of stress in thin film deposited substrates, some arrangements have been made to measure the stress in thin films, both statically and dynamically.

$2.8\mu\text{m}$ linewidth Al metallisation lines have

been delineated on St-X quartz substrate by lift off process for Surface Acoustics Wave (SAW) device.

A plasma CVD system has been designed and built for making silicides. Mass flow controller, purge assemblies are required before the system can be tested. Some furnaces have been designed and built for the annealing and sintering of refractory metals and silicides and studying the surface tension of phosphosilicate and boro phosphosilicate glasses which are used as passivation layers in MOS devices.

Some theoretical work has been done on migration of atomic silver in amorphous chalcogenides. Based on the informations available in the literature, a model has been proposed to explain the formation of a heterojunction at the silver doped-undoped interface of inorganic photoresist.

The work on 'thermistors' started earlier using freeze dried and spray dried NiO and Mn_3O_4 and also Mn_3O_4 has been completed.

STANDARDS OF MASS, VOLUME & DENSITY

1. Developmental Work

1.1 Mass

A 1 kg transfer standards of mass received from Mauritius has been calibrated against our transfer standard using our newly constructed equi-arm two pan balance by double transposition weighing method. Standard deviation of mean of the mass value obtained for this standard has been found to be $10\mu\text{g}$. The same transfer standard has also been calibrated with the help of single pan balance by substitution weighing method. The standard deviation of the mean value on this balance has been found to be $\pm 30\mu\text{g}$. The mass values obtained from the two weighing systems agree within $20\mu\text{g}$.

The national prototype in platinum iridium, Copy No. 57 of the International Prototype Kilogram has been hand carried to **BIPM**, France for recalibration by one of our scientists. The

prototype has been received back after due calibration. The new mass value is about 32 μg more than the previously assigned mass value.

Two pan equi-arm, magnetically damped 500 kg capacity balance with electronic null detection system has been installed and performance evaluated. Standard deviation of single weighing has been found to be about 200 $\cdot\text{mg}$. Thus a new facility of calibrating the weights upto 500 kg has been established.

1.2 Density

Another 1 kg single pan Mettler's balance has been installed and is being used for calibration of high precision measurement of density by hydrostatic weighing.

An ultra-low-expansion glass cylindrical block was sent to us by CSIRO, Australia for the purpose of (a) comparing the measurement capabilities of the two laboratories and (b) examining the possibility of using this cylindrical block as travelling standards to calibrate density standards and reference grade hydrometers through hydrostatic weighing by various participating countries of Asia Pacific Metrology Programme. The volume of the cylindrical block has been determined using triple and double distilled water and intercompared its volume against our own glass cylindrical cylinder. The standard deviation of the mean of the volume has been found to be a few parts per million.

2. Calibration and Testing

2.1 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.

2.2 Density

A large number of glass hydrometers of various types 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.

2.3 Viscosity

Quite a few viscometers from Oil Companies have been calibrated. Special mention may be made regarding the calibration of a field viscosity comparator (Visgauge) containing four scales ranging from very low value of viscosity upto 400 mm^2/s (centistokes).

STANDARDS OF FORCE & HARDNESS

A standard machine for Rockwell hardness scales has been designed and is being fabricated and the assembly of the machine would be taken up.

A 100 kN dead weight machine which was designed earlier is being fabricated for calibration of force measuring devices. Strain-gauge type load cell of capacities starting from a few newtons to 100 kN have been fabricated as a part of the calibration programme.

The calibration of force measuring devices for the industry & the government departments was done.

STANDARDS OF PRESSURE

1. Transfer Pressure Standard

In order to facilitate the measurements of the pressure in the range 300 MPa and above where the transportation of the dead weight piston gauge is not possible. A great deal of research and development work has been done in this direction and as a result some resistive and the strain gauges have been identified. To make sure that they can be used as transfer standards an international intercomparison exercise has been started wherein these transfer gauges have been calibrated against our primary pressure standard and then against the primary pressure standard maintained by the other international standard laboratories. The computed data of the international intercomparison of pressure transducers (Manganin Resistance and Strain Gauge) between NPL (India) and IMGC (Italy) upto the pressure range of 500 MPa show that the strain gauge transducer

can be used as transfer standard if the accuracy in pressure measured is not required better than 1×10^{-3} whereas the manganin resistance gauge would give the better accuracy of the order of 5×10^{-4} .

1.1 Fixed Points-Melting Line of Mercury

In collaboration with Physikalisch-Technische Bundesanstalt, Braunschweig, West Germany, an experiment was performed to re-establish the mercury melting line at and around 0°C . The volumetric method has been used where the mercury is allowed to freeze completely and then changing the pressure by a little amount and allow the frozen mercury to come to a thermodynamically equilibrium state. The pressure vessel and the accessories were designed and developed in the laboratory. The obtained value at 0°C is $756.9 \pm 0.3 \text{ MPa}$.

1.2 Primary Pressure Standard

As a result of analysing the stall and jacket pressure curve obtained from the primary controlled clearance piston gauge upto 500 MPa in relation to the effect of speed of rotation, piston temperature and the viscosity of the pressure transmitting fluid have clearly defined the advantages of fixing the optimum values of these parameters over the arbitrarily fixed values. It is possible now that the pressure can be measured by this controlled clearance piston gauge within an overall uncertainty of 150 ppm at 500 MPa full scale. Now the range of this primary controlled clearance piston gauge has been extended to 1.0 GPa .

2. Service to Industry

A large number of different types of pressure gauges from industries, academic institutions and defence organizations were received for calibration during the period under review which were mostly of dead weight piston gauges and are calibrated by using cross float method.

STANDARDS OF VACUUM

1. Swire E.Ypmsion System

An international intercomparison was performed

for calibration of gauges in the 10^{-2} - 10^{-6} mbar range. on the newly established NPL series expansion apparatus by using 5 spinning-torque gauges and 3 measuring units. Two of the measuring units were provided by **PTB**, Berlin. This intercomparison exercise was performed under the aegies of the **BIPM**. France and the other participants are **PTB**, FRG; **LNE**, France; **IMGC**, Italy; **NPL**, UK; **CMU**, Czechoslovakia; **NBS**, USA; **ETL**, Japan and **NIM**, China.

The small volumes used on the system were determined at **PTB**, West Germany by the displacement method and later on cross-checked at the **NPL**. A quartz spiral gauge **DDR** 6000 and a capacitance manometer (1000 Torr **MKS** Baratron) were used for measuring the inlet pressure of the gas in the initial volume.

The data obtained during this intercomparison has since been analysed. The effective value of the tangential momentum transfer coefficient Go_{err} has been determined for each of the gauges by calibrating in the range 10^{-2} - 10^{-3} torr range and extrapolating the value at 10^{-4} torr pressure. The results obtained are realistic and comparable within the scattering of values obtained in international comparison measurements. for example, the Go_{err} for ball no. **IV** has the following value:

$$Go_{ctr} = 1.1516 \pm 0.10\% \quad \text{NPL}$$

$$Go_{err} = 1.1578 \pm 0.08\% \quad \text{PTB}$$

which shows that there is an agreement within 1% of the values obtained at **NPL** and at **PTB**.

1.1 Constant Pressure Flowmeter

It has been found that the errors associated with flow measurement and calibrations are rather high (1-8%) due to the use of diaphragm valves which have high outgassing rate and leak rate. To reduce the errors, a new flowmeter, consisting of stainless steel components and copper gaskets has been assembled. It has been found to be able to measure gas throughputs in the range 10^{-2} - 10^{-5} mbls^{-1} with much reduced errors (1-2.5%). Using the dynamic system with the newly assembled flowmeter, an ionization gauge and a **SRG** have been calibrated over the range 10^{-3} - 10^{-6} mb with uncertainties of $\pm 3.2\%$. The ion gauge

thus calibrated is proposed to be used. for measuring pressures in the chamber below the orifice. thereby further reducing the errors associated with gauge calibration.

1.2 Determination of the Volume of flowmeter and capillaries

While using a gas flowmeter (f.m.) in constant volume mode a knowledge of the f.m. inlet volume is needed and when it is used in constant pressure mode. the volume variation required to maintain the pressure constant needs to be known. A micrometer screw driven piston which is an essential part of f.m. is shown to be useful for determining the volume of the f.m. ($\approx 180 \text{ cm}^3$).

The piston in conjunction with a volume variation mechanism and a capacitance manometer (differential) has been used to determine capillary volume of $\approx 2 \text{ cm}^3$ with a high degree of accuracy.

A porous plug has been connected to the flowmeter to enable the latter to function in the constant volume mode. The leak conductance of the porous plug has been determined as a function of pressure of the gas reservoir. It has been found that the conductance in the pressure range 1-100 mbar can be expressed by a polynomial of sixth degree.

1.3 Ultrasonic Interferometer Manometer

The Ultrasonic Interferometer Manometer has been installed on a vibration free platform. The vacuum system for UIM has been designed and has been integrated with the manometer. The complete installation of UIM will help civil aviation industry in the calibration of aeroplane altimeters.

2. Surface studies in Ultra High Vacuum

Having established UHV facility. the pressures as low as $\approx 10^{-11}$ mbar in the VT-112 system (Varian Associates) are obtained. Further. we have upgraded the system into a Surface Analytical unit by incorporating (a) a four grid retarding field energy analyser. (b) a high precision sample manipulator (with multiple sample tray. and heating/cooling facilities). (c) a 3-KeV ion gun. etc. and their relevant electronic control units.

With these additions. we are able to work on (1) AES for both qualitative and quantitative elemental analysis and (2) LEED for surface structural analysis. The depth profiling of the sample is achieved by analysis after ion-milling surface layers with the ion gun scanning over an area.

We have developed computer programs in **BASIC** to identify the possible elements and to estimate their relative percentage composition in the surface layers under investigation. After the successful completion of the installation of the equipment we have standardised it for reliable and repeatable observations. We have undertaken an extensive study of oxygen Free High Conductivity Copper (OFHC-Cu). We have studied the impurity concentration as a function of depth into the material. and the effect of incident beam characteristics on the Auger intensities obtained.

2.1 Vacuum Leak Detector

A compact and miniaturized thermal conductivity type of vacuum leak detector using Integrated circuits, consisting of voltage controlled oscillator with visual indication as well as an audible alarm has been designed. The instrument can be used to determine leaks down to 10^{-3} mbar ls^{-1}

3. Electronic Module to satisfy the power requirements of rotary vacuum pump

The electronic module consists of a current transformer, precision rectifier and low pass active filter. The electronic module was calibrated against programmable **AC** calibrator and trans-conductance amplifier. Studies have been carried out on various direct driven and belt driven rotary pumps. Analysis on various parameter such as peak current, average current. peak pressure etc. has been made.

STANDARDS OF TEMPERATURE

A three-heater furnace fabricated at NPL was used for realization of freezing point of copper

Plateaus of half an hour could be obtained. This is being continued to collect more data.

The Photoelectric Pyrometer was given a linearity check using coated mirror of 50% transmission. The results showed that the linearity of the Photoelectric Pyrometer is satisfactory.

Temperature measuring instruments were calibrated for industries and departments & thermal tests were carried out on materials.

Several experimental runs were made for the realization of triple point of oxygen. Plateaus within 1 mK could be obtained for more than an hour. This has helped in extending of range of temperature standards down to 54K.

Improved versions of following prototypes were fabricated for study:

- i) Industrial PRTs for use as secondary standards in the range 0-500°C.
- ii) Glass sheath enclosed capsule thermometer.
- iii) Tungsten Resistance thermometers.

OPTICAL RADIATION STANDARDS

An automatic goniophotometer for the measurement of directional light distribution characteristics of light sources has been designed and fabricated. In this instrument, the light source is turned about its vertical axis and the detector scans the light source by rotating at constant speed around the light source. The luminous intensity at various positions is recorded at equal intervals of the polar angle and then integrated. The detector starts and ends at the nadir position while the light source turns about its vertical axis at specified intervals simultaneously.

A microprocessor based control circuit will catch the output of the photometer head and feed it to ADC (Analogue to Digital Converter) and to memory. From memory the output is fed back to DAC (Digital to Analogue Converter) and finally to visual display unit and printer. A provision is also made for automatic recording and printing of the photocell output. The automatic measurement will be made under control of the process computer, which allows:

- I. The automatic movement of the goniometer sub-assemblies.

2. The automatic requisition of angular and light technical values.
3. The automatic evaluation, calculation and format input of the measured values.

The goniophotometer will be particularly useful for very accurate evaluation of total lumen output of various types of lamps like **HPMV**, **HPSV** and **HALOGEN** lamps.

To establish the photometric scale of the laboratory to radiometric base, an absolute radiometer has been fabricated. This radiometer is based on the principle of electrical compensation of radiant power so as to make radiant power measurement in term of electrical watt, as per the new definition of candela.

Measurements so far made on the basis of the existing radiometer have yielded a tentative value of the maximum luminous efficacy of radiation (K_m) equal to 676 lm/watt as against the internationally accepted value of 683 lm/watt. Further modifications in the apparatus and with use of measuring instruments of better accuracy, a closer agreement between the expected value of K_m is expected to be obtained in the next stage of the programme.

INFRA-RED RADIATION STANDARDS

Feasibility studies for irradiance measurement of a lamp in the spectral region of 0.8 to 1.6 microns were completed. Spectral irradiance of fluorescent lamps in 280 nm to 380 nm and of a **BARC** lamp in 0.8 to 1.6 microns were measured.

Feasibility for absolute measurement of absorption coefficient using photoacoustic spectrophotometer was explored. For measurement of absolute reflectance, the optical schematic for specular reflectance measurement has been completed and the fabrication is in progress.

The fabrication of a grating double monochromator for the spectral region of UV, visible and near **IR** is in progress. Infrared study of polycrystalline silicon was carried out in 2 to 25 microns spectral region for a variety of samples: (a) different growth, and (b) annealing conditions. A variety of liquid and solid samples were studied

using custom built Photoacoustic spectrophotometer.

STANDARDS OF ACOUSTICS

1. International Calibration

Participated in International Round Robin Calibration of Standard one inch Condenser Microphones initiated by CSIRO, Australia. The microphones were calibrated at frequencies of 250 Hz and 1000 Hz to an accuracy of ± 0.1 dB.

Participated in International Round Robin Calibration of Standard Accelerometers and Vibration Measuring Systems initiated by NBS, USA. The calibration was carried out by Cathetometry method in the LF region and by back to back calibration method in the HF region using calibrated standard accelerometer. The overall accuracy attained was $\pm 1\%$.

Two one inch and two half inch standard condenser microphones were calibrated and recalibrated in the frequency range 50 Hz to 12.5 kHz to an accuracy of ± 0.1 dB by reciprocity method in a coupler cavity to participate in the International Inter-calibration being conducted by NPL, U.K.

1.1 Testing & Other Studies

Testing and calibration of electro-acoustic devices and acoustical products and materials continued as usual.

The project on Noise Feasibility Studies of domestic air coolers, air conditioners and refrigerators was completed. Components for setting up laser interferometer technique for vibration pick-up calibration were acquired and preliminary set up made for trial.

Work was initiated to carry out a systematic study of the acoustics of NPL auditorium due to consistent complaints of echoes on the dais. The defect was detected and remedial measures were suggested and got implemented. The P.A. system which was quite old, was also detected to have lost sensitivity in the high frequency range. A new P.A. system has been installed. The new projection/seminar room has also been internally equipped under our supervision for all sorts of audio-visual purposes.

2. Sodar

A monostatic sodar system similar to indigenously developed system at NPL has been installed at the Air Pollution Cell, Mukherjee Nagar, Delhi for boundary layer studies related to monitoring and nowcasting hazardous situations of air pollution.

An improved model of the facsimile recorder for sodar system was developed and fabricated. The sodar echograms recorded at Delhi for the period May 1977 to April 1982 have been further analysed for nowcasting the meso-scale phenomena. Studies of correlation features of the concentration of carbon monoxide released by petrol driven vehicles on road were made with the Pasquill Stability category derived from Sodar data and the potential of Sodar data to nowcast hazardous situations of air pollution was demonstrated.

Sodar and tower data acquired at Tarapur for the year 1982 have been studied for the potential capabilities of sodar to study land and sea breeze circulations and marine boundary layer. It has been seen that sodar can give precise information of the thermal structure of the marine boundary especially the time of starting and ending, height and width of the sea breeze.

ULTRASONIC STANDARDS

An anechoic synthetic paint coated steel water tank fitted with micromanipulators having precision movements of 0.1 mm in x,y,z directions and rotation of 0.1 in z plane has been constructed with a tiltable stainless steel reflector which can be moved for achieving desired transition region between the near and far field. The properties of unlined as well as lined tank with butyl rubber has been measured using pulse technique as well as by measuring the standing wave ratio using the continuous waves.

The electrical impedance and linearity of the auxiliary transducers, parametric type with nominal frequencies of 0.5, 1.0, 3.0, 5.0 and 10 MHz, have been studied and monitored. The open circuit voltage of the auxiliary transducer operated in self reciprocity mode has been monitored



at various distances from the water boundary, and provides information about the ultrasonic field conditions.

The calibration of piezoelectric ceramic hydrophone has been carried in the frequency range 0.5 MHz-7 MHz, by the two transducer reciprocity technique, with the precision of measurement as 0.7 dB. The accuracy of measurement is evaluated by comparing the sensitivity with that of a standard PVDF hydrophone by simple substitution and is seen to be ± 1.80 dB upto 6.5 MHz. The experimental set up for the radiation pressure float method for measuring total power has been improved by incorporating a tank fitted with manipulator to provide precise vertical movement to the side rods of various cross section. The rods can be moved up or down with a precision of 0.025 mm for precise power measurement.

A system for measuring vibration amplitude of high amplitude resonators has been set up using laser beam interferometer. The system is capable of measuring high vibration amplitude $8\mu\text{m}$ at 20KHz.

ELECTRICAL & ELECTRONIC STANDARDS

STANDARDS OF TIME AND FREQUENCY

A time intercomparison was carried out using direct TV broadcast from the Russian Satellite "Stationer-6" between NPL and VNIIFTRI, U.S.S.R. The facilities of Delhi Earth Station at Malcha Marg, New Delhi were used to receive the TV signals. The interface units were developed at NPL. The final analysis of data from USSR side is awaited.

Atomic cesium beam and atomic rubidium vapour time standards after initial synchronization with NPL's master clock were flown to Radio Astronomy Centre, Ooty to provide accurate 'Time Instant' and "Frequency" for a Very Long Baseline Interferometry experiment being carried out there between several international laboratories. 'Time Instant' accuracy provided by NPL was of the order of a few (less than 5) microseconds.

A portable atomic cesium clock was brought to NPL from VNIIFTRI U.S.S.R. for intercomparison of 'Time Scales' of NPL and VNIIFTRI. The two 'Time Scales' agreed to within a few (less than 5) microseconds.

Improvement and modification of the rubidium vapour frequency standard developed at NPL were carried out. A vacuum system to fill the Rubidium isotopic absorption cell, filter cell and lamps at NPL itself is being assembled in collaboration with Vacuum Standards section.

Improvement, modification and software development of various interface units developed for Standard Time and Frequency Signal (STFS) dissemination via Indian Satellite INSAT-IB were carried out. This experimental service is due to start shortly. The feasibility studies have already been carried out.

The reference cesium beam tube of the first atomic cesium clock (Hewlett-Packard) procur-



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red by NPL in 1974 was successfully replaced and evaluated. Normally it is done only in few selected Hewlett-Packard Companies around the world. This has given a new life span to the atomic cesium standard which otherwise had outlived its life.

STANDARDS OF DC ELECTROMOTIVE FORCE, RESISTANCE AND CURRENT

1. Automate DC Measurements

Automated measurements using a desk-top computer, scanner, digital nanovoltmeter etc. have been carried out in high precision dc. measurements such as intercomparison of standard cells of the national standards bank and calibration of unknown voltage sources, calibrators and computer interfaceable voltmeters etc. The precision is found to be of the order of 0.1 to 0.2 ppm.

1.1 Intercomparison of Standards of DC Voltage Under APMP

Intercomparison of standards of dc voltage using the travelling standard 'TRANSVOLT' comprising of four standard cells in temperature controlled air enclosure among NPL Thailand and China was completed under Asia Pacific Metrology Programme.

The national standard of dc voltage in the form of temperature controlled standard cells 'TRANSVOLT' were assigned values based on the Josephson effect at one millivolt level using the value of $2e/h = 483\,594.0 \text{ GHz/V}$.

CAPACITANCE, INDUCTANCE AND AC RESISTANCE STANDARDS

1. Reassignment of value to 10 pF Silica Capacitor against calculable capacitor

The absolute value of capacitance of the calculable capacitor was calculated in terms of the wavelength of the He-Ne laser which had been calibrated against iodine stabilized laser. A 10 pF silica dielectric capacitor was reassigned value against the calculable capacitor with an un-

certainty of 2 parts in 10⁶.

1.1 Realization of 1 KO. A.C. Resistance Standard of capacitance

The portable 1 KO. a.c. resistance was again realized from the 10 pF silica capacitor at 1591 Hz with an uncertainty of 3 parts in 10⁶. using quadrature bridge and equal power 100:1 resistance bridge.

1.2 Scale of A.C. Resistance Standards

Facilities have been set up for precision measurement of A.C. Resistances at 1 KHz and standards of a.c. resistance from 1n to 100 KO. have been realized against the portable 1 KO. a.c. resistance derived from the standard of capacitance. The accuracies obtained are of the order of 2 to 10 ppm.

1.3 International Intercomparison of Standards

Intercomparison of 10 pF and 17F capacitance standards under Asia Pacific Metrology Programme has been completed.

1.4 Development of Automatic Precision Capacitance Bridge

Modalities for development of precision automatic capacitance bridge in collaboration with Jadavpur University have been completed.

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

1. A.C. & L F Voltage

The frequency range of mutual intercomparison of individual member of the group of multijunction thermal converters serving as the national standard of AC & LF voltage and current has been extended from 30KHz to 100 KHz. The mean AC/DC transfer correction factor for the group is 15ppm of 100 KHz.

1.1 Transfer Standard of AC & LF voltage and current

An AC/DC travelling thermal transfer standard Fluke Model 540B along with three current

shunts belonging to **NML**, Australia has been intercompared against corresponding voltage and current standards of NPL, under Asia Pacific Metrology Programme. The intercomparison has been carried out at nominal voltage and current values of 0.5V, 5V, 50V and 500V; 10mA, 100 mA and 1 A respectively at frequencies 57 Hz, 400 Hz, 1 KHz. Mean AC/DC transfer correction factor of travelling standard w.r.t. thermal transfer standard varies between - 3.0 ppm to -10.0ppm in voltage and -4.0ppm to - 25.0ppm in current. The detailed report of intercomparison has been prepared and sent to *Pdor Laboratory (NML, Australia)* for the final Analysis.

Two thermal current convertors have been developed for nominal current values of 30mA and 50 mA using single junction thermo-elements and have been evaluated against primary standards (MJTC). These have been developed for the purpose of intercomparison of thermal current convertors of USSR at nominal values of 10mA, 30mA and 50mA at frequencies 1 KHz, 20KHz, 100 KHz and 1 MHz.

1.2 Standards of HF Voltage and Power

The attenuator thermal voltmeter and 7.0 volt thermal convertor have been linked to the primary standard **HF** voltage and power based on calorimetric power mount.

Feed through power mounts have been linked to the calorimetric lower standards in the entire frequency range of 100 MHz to 1 GHz. The mount (100MHz to 400MHz) had been detuned during transporting it from one room to another and had been behaving erratically. The matter was referred to M/s Wcinshell Engg. USA for its repairs and recalibration. The mount had been repaired, retuned and recalibrated.

The attenuation measurement range using power ratio technique has been extended from 20dBs to 30dBs in the frequency range of 10MHz to 1 Ghz.

2. Constant Temperature Oil Bath

A constant temperature portable oil bath of 0.002 C temperature stability within a working

range of 20°C-30°C has been designed & developed. Two units were fabricated for the Defence Deptt., New Delhi. The various parts like electronic circuit boards, regulated power supplies, tanks, frames & fixtures were made & assembled.

MICROWAVE STANDARDS OF POWER, FREQUENCY, NOISE ATTENUATION & IMPEDANCE

1. Microwave Power

An X-band pure calorimetric load of novel design has been perfected and evaluated for its effective efficiency by single load calorimetric technique. The salient features of the newly designed load are (1) it is extremely broad band covering the entire X-band (8.2 to 12.4GHz) with a maximum **VSWR** of 1.08. This will enable us to maintain *only* one load in the band instead of a set of thin film barretter mounts required so far. (2) It has a very high effective efficiency of 99.9% or more over the entire X-band. (3) It is, unlike thin film barretter mounts, rugged and invariable with time. (4) It can directly be used to measure medium power upto 200 mW or so. (5) The total uncertainty in the power measurement is only $\pm 0.17\%$ as against $\pm 0.58\%$ achieved earlier with thin film barretter mount.

Further work is in progress towards introducing the automation and reducing the uncertainty.

1.1 Microwave Attenuation and Impedance

Three standard mismatches of **VSWR** 1.10, 1.20 & 1.30 have been fabricated at XN band (5.85 to 8.2 GHz) microwave frequencies. The variation in **VSWR** of the standard mismatches about the nominal value is ± 0.01 in **VSWR** throughout the frequency band.

A two channel technique for insertion phase shift measurement was investigated for calibrating rotary vane phase shifters at X-band (8.2 to 12.4 GHz) microwave frequencies. The technique gave an uncertainty of 0.75° for a measurement of 90° insertion phase shift. The work was carried out by Major R.C. Balwada, M. Tech Student

under the guidance and supervision of Dr. K. Chandra and Dr. **R.S.** Yadava.

JOSEPHSON VOLTAGE STANDARDS

The as-maintained volt has been intercompared against the Josephson voltage standard using a **GUILDLINE** Transvolt as a transfer standard. The overall uncertainty in assignment of emf value to a standard cell against the Josephson voltage standard is 1 ppm. The as-maintained volt is found to agree with the Josephson Voltage Standard within overall uncertainty.

LOW DIMENSIONAL COULOMB SYSTEMS

A **He³** refrigerator has been designed to provide temperatures as low as 300 **mK** to conduct experiments on a single electron layer floating about 100 angstroms above a liquid helium surface.

Theoretical work was done on viscoelastic effects in a two dimensional classical electron liquid and propagating shear modes predicted to exist above a temperature dependent minimum frequency. Molecular dynamics simulations on a 2D electron system were also performed on a

desktop computer to study the transverse current correlations in the electron liquid. The results of the simulations were found to be in good agreement with the theoretical calculations mentioned above.

A theoretical analysis of the Sommer technique for the measurement of mobility of charges in two dimensions was carried out in collaboration with Case Western Reserve University, U.S.A. An exact solution of the transmission line equations was obtained for various geometries of experimental cells. This will help in more accurate analyses of experiments which have been more precise than the theory so far.

The dynamic capacitance and density profiles and edge effects in a 2D electron system on a liquid helium surface were studied by solving the Laplace's equation on a computer. An exact solution of the transmission line equations was obtained for the edge effects. This would help the experimentalists in this area to design the experiments and analyse them better.

The Quantum Hall Effect can be utilized in developing a quantum standard of electrical resistance. Preliminary experiments on a GaAs-(AlGaAs) heterojunction were conducted and the Quantum Hall Resistance plateaus observed. A precision of about 5 ppm was obtained. The accuracy was, however, limited to about 100 ppm due to the calibration of measuring instruments.

MATERIALS CHARACTERIZATION DIVISION

CHARACTERIZATION OF MATERIALS REGARDING PURITY AND COMPOSITION

Chemical Methods

A method for determination of sulphur in different materials indirectly by using atomic absorption spectrophotometer has been developed. Sulphur is converted into sulphate which is precipitated as lead sulphate with known excess of lead in alcoholic solution. Precipitated lead sulphate is centrifuged and the remaining lead is measured by atomic absorption spectrophotometer. The method has been successfully employed for the determination of sulphate in different samples of water including samples from power plant and Antarctica Glacier. The sensitivity of the method is 0.1 ppm with relative mean deviation of 1 percent.

A method has been developed for the determination of phosphorus indirectly, using atomic absorption spectrophotometer. Phosphorus is converted to bismuth phosphomolybdate, which is extracted into a suitable solvent. The absorbance due to bismuth is measured and correlated with the phosphorus as bismuth & phosphorus are present in stoichiometric ratio of 1:1. This method has been applied for the determination of phosphorus in steel and cast iron.

An experiment has been set up for the determination of oxygen in metals by reacting oxygen with hydrogen at 900 C to form water, which is absorbed into a weighed phosphorus pentoxide tube. This technique is useful for oxygen concentration of 0.1% and above. This technique has been applied for the evaluation of oxygen in copper and also copper oxide.

Facilities to characterize gases and volatile materials for their composition and impurity content by gas chromatography have been created. A portable gas chromatograph with flame ionisation detector and thermal conductivity detector has been procured and commissioned to

analyse atmosphere in factories and fields. Method has been developed to prepare gas mixture for calibration by dynamic dilution method. This facility has been used to measure the methane efflux in rice paddy fields.

Arsenic has been determined spectrophotometrically (upto 5 ppb) using silver diethyl-dithiocarbamate complex in morpholine chloroform system. Determination of iron in presence of copper as its thioglycolic acid has been carried out and the method applied in the analysis of brass. An improved method for determination of silica in high purity water (upto 10 ppb) has been worked out by using mixed reducing agent ascorbic acid and potassium antimony tartarate reagent. An apparatus for preparation of high purity water and acids by sub-boiling distillation has been designed and fabricated.

FTIR Absorption and UV-Visible Emission Spectroscopy

Measurement on silicon samples were done for estimation of oxygen and carbon impurities in as grown silicon and annealed silicon. Fortran programme of spectra subtraction was used to estimate concentration of diffused impurities in 200 ppb level. Measurement of certain samples were done at 1,000cm⁻¹ which is beyond the range of the instrument by block averaging and large number of scans in NOVA-4 computer of F.T.I.R. Emission measurements were done on Graphite and HgI₂ samples from outside agencies and CdS from NPL projects. Trace elemental impurities were estimated.

Using FT.I.R., measurements were done on optical properties of metallic meshes for diffraction region and calculations were carried out on the basis of radiation theory and factors contributing high T were obtained. Studies were conducted on domain wall motion of ferroelectric crystals and these were utilised in coupling a high frequency signal to a pyroelectric detector made

to investigate shallow donors and acceptor levels, deep impurities, irradiation induced defects and dangling bonds in semiconducting materials.

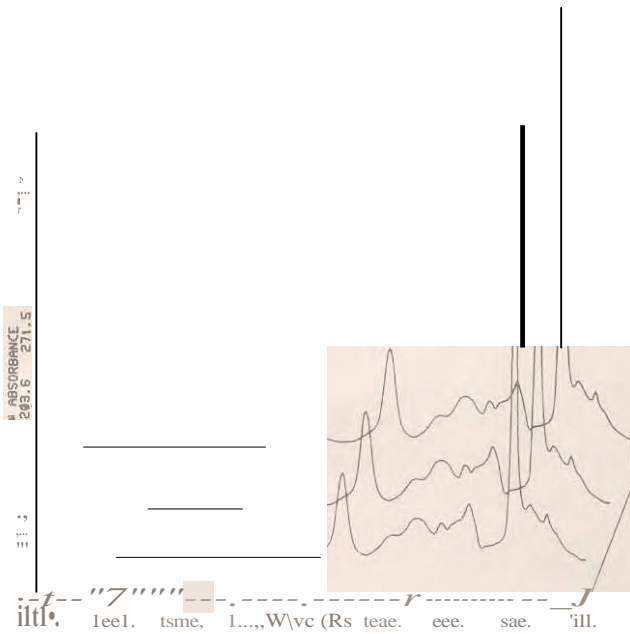
CHARACTERIZATION OF MATERIALS REGARDING CRYSTAL STRUCTURE

X-ray Diffraction Methods

X-ray diffraction studies on Beta alumina, Nasicon ($\text{Na}_3\text{Zr}_2\text{Si}_2\text{PO}_{12}$), BiNiCo, PbIn, Nb_3Sn , LiNbO_3 , CdS, $\text{Cu}_2\text{Se/SnO}_2$, CaS, pyrophyllite, intercalated carbon compounds, graphite flakes, carbon-carbon composites, carbon fibres, tantalum oxide coating, quartz crystals, AlMn, FeMn, Si etc. have been carried out for projects of the laboratory.

In collaboration with other agencies such as CAFS, IIT, New Delhi, environmental pollution studies of the metallic content of soil and suspended particulate matter have been quantitatively determined by XRF technique. The results have been correlated with the various aspects of the interaction of soil and suspended particulate matter.

Basic research on superlattice formation in Ga_2Te_3 was carried out. Though the superlattice phase (x-ray pattern indexible on orthorhombic cell) was produced, its reproducibility was not found to be hundred percent, and hence, in this collection, critical parameters involved in synthesis and annealing are being optimised. X-ray diffraction studies on the polycrystalline $(\text{Ga}_2\text{Te}_3)_1 \cdot (\text{In}_2\text{Se}_3)_x$ alloys have been completed. The composition with $x = 0.50$ mol In_2Se_3 gave x-ray pattern indexible on cubic zinc-blend unit cell of Ga_2Te_3 with lattice parameter decreasing linearly from 5.91 to 5.81 Å. The peak width at half height increased substantially with increase in In_2Se_3 content suggesting a gradual change to disordered state. Alloys in range $0.70 \leq x \leq 0.90$ crystallised in hexagonal lattice with c-parameters decreasing slightly as x increases, with no effect on sharpness of lines. Annealing of these alloy powders at 450°C for a period of two weeks indicated its decomposition in different crystalline phases.

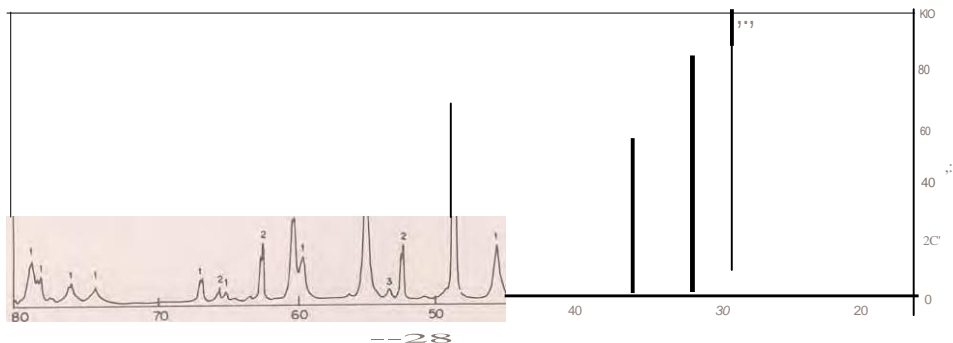


Infrared absorption spectra of polycrystalline silicon crystal plate by FTIR Measurements have been taken at 20°C, 30°C and 40°C and are represented in three dimensional format. Bands due to oxygen and carbon diffused impurities exist near 1100cm^{-1} and 600cm^{-1} respectively.

on the same crystal plate. Thus modulated signal was obtained which could be transmitted remotely. Coupling mechanism of two electronic circuits was studied on the basis of detector parameters. High frequency signal was coupled by a guarded electrode around the front electrode of the detector. Spectral reflectance measurements of chemically coated films on solar cells showed optimal absorption in 460-570nm solar radiation. Higher formation of Cu_2O compared to CuO in heat treated copper plates showed enhanced absorption upto 5.25 which makes it applicable for solar collectors.

EPR Spectroscopy

EPR measurements were made to monitor the spin density of dangling bonds in hydrogenated amorphous silicon. ESR signal due to these bonds was observed at $g = 2.0055$ having line width about 7.5gauss. Intensity of this signal was found to depend on visible light irradiations and annealing temperature of the sample. Detailed investigations of these thin films will be done in due course of time. Exploratory work was carried out



X-ray diffraction pattern of Barton Oxide taken on Siemen D-500 diffractometer indicating 1. PbO (Tetragonal), 2. Pb and 3. PbO (Orthorhombic) phases.

Electron Microscopy and Electron Diffraction Techniques

The work on the study of microstructure of carbon doped chromium films by TEM has been continued. It has been established that the carbon content in the film increases and the crystallite size of the chromium decreases with increase in the partial pressure on methane (CH_4). The films prepared at 250°C and 350°C showed strained structure. The films prepared at higher CH_4 pressure (2×10^{-3} Torr) showed the presence of amorphous regions and crystallites of chromium simultaneously. The formation of chromium carbide phase could not be detected/observed except in the films prepared at 500°C which showed some extra reflections.

Silver films prepared by thermal evaporation under V.H. Vacuum conditions (4×10^{-7} Torr) did not show the presence of voids on examination with T.E.M. using defocus contrast technique. However, similar study carried out with sputtered silver films revealed a high density (10^{10} to 10^{12}cm^{-2}) of voids (15-50Å) in diameter. These contradictory results have been explained on the basis of recent developments in the field. The mechanism of void formation and their growth is based on the fact that such small clusters of vacancies (voids) are not stable and hence voids do not consist of purely vacancies. Therefore, the gas atoms trapped in the film during preparation act as the nuclei for void formation.

The structural properties of thin films of

CuInS_2 prepared by chemical deposition technique have been investigated for the surface structure, morphology and composition using S.E.M. and E.D.S. The surface morphology and composition has also been studied.

The affect of thermal treatment on the surface structure and morphology of silver films prepared on the quartz by thermal evaporation technique has been investigated by S.E.M. The films showed hillock formation on annealing in vacuum while the films annealed in oxygen atmosphere/air showed complete agglomeration.



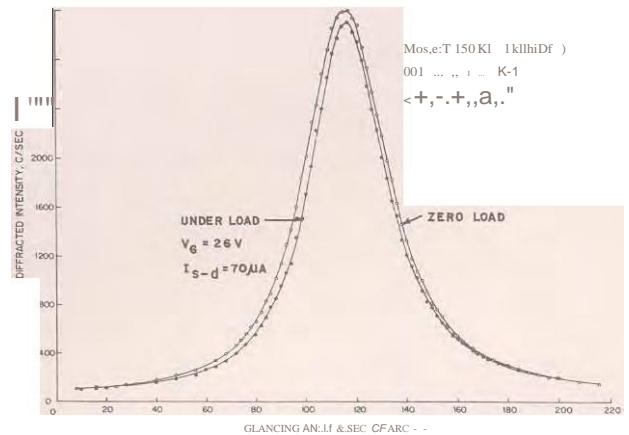
Bright field TEM micrograph of a typical Cr-C film grown at a partial pressure of 2×10^{-3} Torr of CH_4 . The film depicts crystallites of chromium and amorphous zones of Cr-C marked 'A' grown simultaneously.

CHARACTERIZATION OF MATERIALS REGARDING PERFECTION

High Resolution X-ray Diffractometric and Topographic Techniques

Using the high resolution X-ray diffractometric and topographic techniques and a quadruple crystal X-ray diffractometer developed at the **NPL**, the fading out characteristics of the field induced images in topographs were studied. The time taken for complete disappearance of the images when the specimen was stored at room temperature was found to be 6-8 weeks. The images were found to reappear again on the same spot when electric field is applied a second time after the complete fade out. This has established the link of the images with the material inhomogeneities. Also, the shapes of images in different crystals have been studied. These experiments have established for the first time that a strong charge carrier-lattice interaction during moderate electric currents (about 10 mA) and fields (about 100 V/mm) exists in the crystals.

To explore the feasibility of the application of high resolution X-ray diffractometry and topographic methods for the study of the electron-lattice interaction during two dimensional conduction in semiconductors, experiments were performed on Si MOSFETs and GaAs heterostructures. These devices were brought from Physikalisch-Technische Bundesanstalt, Braunschweig, **F.R.G.** for experiments. The diffraction curves show a small but measurable change in the shape when the electric field is applied. In the topographs, significant changes in the contrast could be observed. These results show that there is a strong coupling between the charge carriers and the lattice even when a small ($70 \mu\text{A}$) two-dimensional electric current flows through the device. Zero field and under field topographs were also recorded while maintaining the glancing angle of the crystal at the half intensity point of the diffraction curve. This leads to higher sensitivity and therefore, stronger changes in the contrast are observed. Some experiments have also been performed on GaAs heterostructures. Small changes could be detected in the topographs with current of $50 \mu\text{A}$.



Diffraction curves of a silicon MOSFET (Klitzing element) recorded before and during two-dimensional conduction ($V_G=26 \text{ V}$, $I_{s-d} = 70 \mu\text{A}$). A Quadruple Crystal X-ray Diffractometer developed at the NPL. 008 Relp, MoK α , exploring beam, Bragg configuration and (+, -, +) geometry were used

High resolution diffuse X-ray scattering (**DXS**) study of defects in magneto-optic films and their interface with substrate GGG crystals was completed. Remarkable differences in the DXS distribution patterns could be observed due to small compositional variations in the films. A comparative study of **DXS** distribution in Float Zone and Czochralski grown crystals of silicon was completed. A significant difference in the defect structure in the two cases has been observed. This is linked to the lower Oxygen content of the Float Zone Crystal. Deliberate heat treatment was given to Czochralski grown crystals under oxygen at various temperatures upto 1000°C . **DXS** intensity distribution in these crystals has been measured and is being analysed for understanding the kinetics of aggregation of oxygen in silicon.

High resolution X-ray diffractometric and topographic investigations on diamond crystals were carried out by using the quadruple crystal X-ray diffractometer (MoK α_1 radiation) and the triple crystal X-ray diffractometer (CuK α). Diamond crystals have shown anomalous X-ray diffraction features. The aim of these investigations is to understand the true nature of diffraction process in these crystals.

An **RF** generator is being coupled to the Crystal Growth system developed at the NPL. Preliminary heating experiments have already been initiated. The crystals grown have been characterized by the standard X-ray topography methods.

A rotating anode X-ray source of high power and high brilliance has been commissioned. A triple crystal X-ray diffractometer has been set up with this source. The source is operated in a very fine focus mode. The monochromators are two independent silicon crystals which can be set in dispersive or non-dispersive mode. This system has been successfully used for some studies on Si **MOSFETS** and diamond crystals.

Scientists from **BHEL**, Bangalore had approached **NPL** for diagnosis of some of the failures due to defects in their high voltage devices. The quadruple crystal X-ray diffractometer was used for topographic and diffractometric characterization of a number of wafers from **BHEL**. Also, the triple crystal X-ray diffractometer with rotating anode generator was used in

this work. Characterization of Cadmium Telluride crystals on request of the Solid State Physics Laboratory, Delhi, was carried out on the quadruple crystal X-ray diffractometer.

Surface Area and Porosity Measurements

Experiments were carried out for carbonization and activation of rayon yarn. Yield of char increased from 25 to 35 by refinements of processing conditions. On activation the specific surface area increased to $1100 \text{ m}^2\text{g}^{-1}$ (area developed during the carbonization was in the range $400\text{-}500\text{m}^2\text{g}^{-1}$). In some of the samples the increase in specific surface has reached to $1780 \text{ m}^2\text{g}^{-1}$. Such a high specific surface is rarely seen in the commercially available charcoal cloth. Work is being continued to establish the processing conditions for reproduction of such a high specific surface.

Samples of activated carbon and precipitated silica were tested for specific surface area and porosity measurements.



MATERIALS DIVISION

POLYCRYSTALLINE SILICON

1. Polycrystalline silicon ingots of both circular (50 mm diameter) and rectangular (50 x 50 mm) cross section were cast in graphite crucibles (Figs. 1 & 2). These ingots were characterised for grain size, resistivity and minority carrier life-time. Some of these were processed and n +p solar cells were made on them. The typical values of average grain size, mean resistivity and effective minority carrier lifetime were found to be 0.5-2 mm, 3-10ohm cm and 20-30 μ -sec ranges, respectively.

Processing and characterisation facilities were augmented with the addition of the following:

- A 18 mega ohm resistivity deionised water preparation facility (Millopore Lab Model Milli Q).
- A VDS-100 terminal for LSI-11/23 computer (provided with Quantimet 900 Image Analyser)
- An automatic solar cell tester for measurement of V_{oc} , I., FF and P_{max} for solar cell, capable of giving I", upto 6Amp.

Gold doped silicon diodes were prepared for preliminary investigations on deep levels using the DLTS set up made in the laboratory. A nondestructive method measurement of diffusion length of minority carriers in p-silicon wafers (without the need of junction fabrication) was evolved. Some theoretical and experimental investigations on photoconductivity of polycrystalline silicon were made. Nature and content of intragrain defects in polycrystalline silicon wafers produced in **NPL** were studied using Image Analysis and Electron Beam Induced Current Techniques. Small signal High Frequency Capacitance Measurements on Polycrystalline Silicon Solar Cells were made.

A SiO_2 layer on silicon wafers was grown thermally and then the properties of the SiO_2 layer & SiO_2 -Si interface were studied by C-V Technique. A few epitaxial solar cells on special poly-silicon were studied with aim to determine

the possible effects of **BSF** and surface texture of epi film on the performance of these cells.

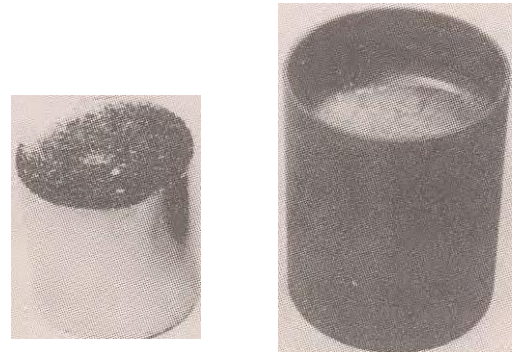


Fig. 1. Directionally solidified polycrystalline silicon ingot (50 mm diameter).

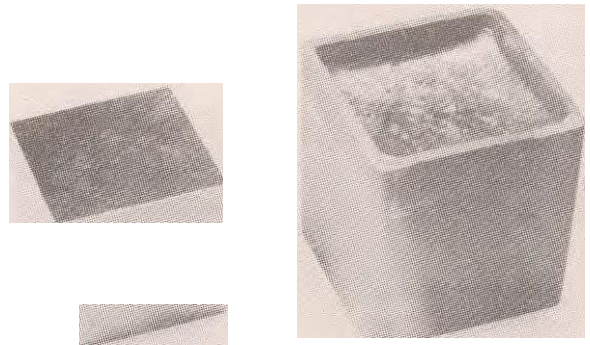


Fig. 2. Directionally solidified polycrystalline ingot (50mm x 50mm cross section).

1.1 Silicon Pilot Plant

Under the collaborative programme between NPL and NCL, efforts to design, fabricate and operate large CVD reactors for thermal decomposition of trichlorosilane to silicon were continued. Thirteen rods of silicon of 11 mm dia and six rods of silicon of 32 mm dia were grown. The larger silicon rods were grown in a six rod quartz domed CVD reactor fabricated at NPL. The problem of initial heating of the six rod reactor was solved without using very high voltage or external heating. To save energy, an aluminium reflector was used on the six rod CVD reactor

resulting in an energy saving of about 33%.

A stainless steel CVD reactor was fabricated and operated under a slightly higher pressure. Some difficulties in the material of construction and in the operation of the reactor were faced. Quality of silicon made in such reactor was also evaluated. An apparatus for generation of trichlorosilane in a fluidised bed was fabricated and a few experiments were conducted.

BETA ALUMINA TUBES FOR SODIUM SULPHUR BATTERY

Work was carried out to machine the beta alumina tubes (in green state) to achieve uniform wall thickness and smooth surface finish. Using techniques involving cold isostatic pressing and sintering more than 130 tubes of 10mm OD, 1-1.2mm wall thickness and 85 mm length were fabricated. Twenty of these tubes most of them fitted with alpha alumina headers were supplied to CECRI and IGCAR for use in prototype sodium sulphur batteries. Prototype batteries made therefrom show open circuit voltage of 2.1 V and a short circuit current of 80-100mA/cm².

Diametral fracture strength of these tubes were measured and found to be more than 150 MPa. The electrical resistivity of these tubes is consistently below 5 ohm-cm at 300°C. Corrosion behaviour and fracture under sodium ion conduction are being studied.

NASICON tubes of 10 mm OD and 1.5 mm wall thickness were prepared by isostatic pressing and sintering. Studies carried out on post sintering annealing resulted in lowering the resistivity (due to Na⁺ ion conduction) to less than 5ohm cm at 300°C. These tubes are being tried as replacements for beta alumina tubes in sodium sulphur batteries.

ULTRASONIC TRANSDUCER MATERIALS AND DEVICES

J. High Power Ultrasonic Systems for Oceanographic Studies

Measurements have been taken on the transmit-

ting response of transducers elements of pingers, encapsulated in I.T.U. rubber moulds. Steps have been taken for fabrication of suitable die-set for rubber moulding and modification of existing press incorporating electrical platen base.

A high pressure generation system for 300 p.s.i. using hand pump type generator in a pressure vessel of 5 litres has been installed for underwater measurements. Using this facility, studies have been made of motional impedance characteristics upto 300 p.s.i. of a 500 Hz transducer with different backing e.g. corprene, stacked paper, etc. Investigations have been made on the estimation of the freefield conditions in a tube of internal diameter of 3" in the frequency range of 5-10 KHz at normal pressures, using the method of active impedance termination.

High power primary sources have been developed using a sandwich transducers operating in multielement configuration. The performance of sandwich transducers as a function of mechanical bias has been studied. Studies of transmitting response, and directing patterns of the two sets (four transducers operating at frequency of 46KHz and three transducers operating at 48KHz) have been made in the pulsed mode. Strong intermodulation effects are seen and a rough estimate of the parametric level is obtained.

Investigations have been made on a method by which losses at high power can be studied using equivalent circuit analysis and using a high voltage resistor in series with the transducer. Measurements have been taken on 500KHz transducers with different values of tan δ and the predictions are qualitatively satisfactory.

1.1 Transducer Materials

Low loss piezoelectric ceramic material (PZT-4) has been standardised to reduce rejection rate and batch produced for consumers acceptability. Batch production of higher charge sensitivity ($d_{33} = 450 \times 10^{-12} \text{C/N}$) and high permittivity ($K_1 = 3000$) material NPLZT-5 H₂ has also been carried.

The work on special materials lead meta-niobate and oriented glass ceramics has been initiated. Preliminary investigations on glass ce-

ramie composite indicate that materials with high voltage sensitivity are achieved.

1.2 VLF. Transducer for Ocean Acoustic Tomography

The feasibility study of the development of transducer for the Ocean Acoustic Tomography System was undertaken. The design of a transducer working at 900 KHz was undertaken utilizing flexural mode vibration principle of a mosaic of 60 piezoelectric ceramic elements. The resonator is backed by a matching cavity and radiates acoustic waves through a Helmholtz resonator.

1.3 Ultrasonic NDT

To study the effect of environment particularly the sulphur content in the atmospheres, experiments have been conducted on marble stones treated with various concentration of sulphuric acid for various periods. It is observed that very little change in surface of marble produces appreciable change in the back scattered pulse pattern. Studies have also been made on the design of a transducer for reception of surface waves from any direction particularly for acoustic emission applications.

1.4 Biomedical Ultrasonics

Improvements have been made in the design of ophthalmic probe to reduce its background noise and clinical trials on ultrasonic A-scan ophthalmoscope have been made at AIIMS (Fig. 3). Studies have been made on some plane and shaped transducers, particularly of plano-concave and convexo concave type with acoustic lens as well as shaped crystals for ultrasonic focussing applications. Investigations on acoustic transmission in bones for differential diagnosis of fracture and its healing has been initiated. and studies on safety of ultrasound radiations have been planned.

CARBON-CARBON COMPOSITES

A systematic study was made on the effect of constituent materials i.e. type of carbon fibres and type of preforming pitch on the development of

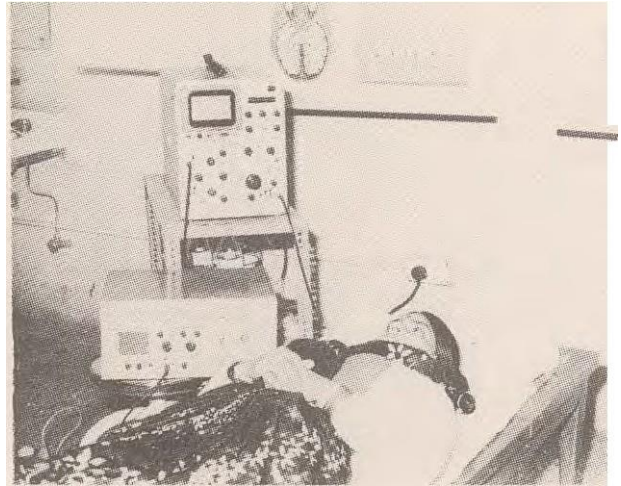


Fig. 3. Clinical trials on patients with ultrasonic A-scan ophthalmoscope AIIMS

carbon-carbon composites. By improving the processing conditions and using specially prepared CTP forming preforms, an improvement in skeleton density of 20% could be achieved.

By using normal technique of densification, a density of around 1.7g/cc could be achieved in 2D C/C composites only after twelve impregnation cycles. For making C/C composites of very high densities such as 1.8-1.9 g/cc, it involves pressure of the order of 1000 bars at 600°C. However, the laboratory has succeeded by working only at normal pressures, but by using a novel technique of intermediate graphitization have now succeeded in achieving 2 DC/C composites of density **1.84** g/cc. The importance of this intermediate graphitization was studied in detail with reference to open porosity, pore size distribution and subsequent densification of C/C composites. Composites made by using this technique have the following properties.

Density	1.8-1.85 g/cc
Flexural strength	250-280MN ²
Flexural modulus	60-65GN/M ²
1.L.S.S.	10-J3MN/M²
Specific heat	0.3Cal/gm°C
Coefficient of thermal expansion	-0.5 x 10⁻⁶°C

Oxidation resistance of carbon fibres as well as of *CJC* composites was studied. It is observed that the weight loss of C/C composites in Air (600' C for one hour) can vary from 5% to 75% for various type of C/C composites. To understand the factors responsible for such large difference in oxidation resistance. detailed studies are in hand.

Knowledge gained in the development of high density 2D C/C composites was applied to the development of high density 3D C/C composites. So far 3D C/C composites have been developed with density of 1.65g/cc.

As mentioned above, a very special class of pitch is required for making skeletons of *CJC* composites. Commercially available coal tars have been subjected to distillation under controlled conditions of temperature and partial vacuum to obtain preforming pitches possessing high softening point. coking value. resins, together with optimum contents of wetting and adhesive components. The Characteristics of Pre-forming Pitch are:-

Softening point (R&B)	165-175°C
Coking value	65-70%
Quinoline Insolubles	12-15%
Toluene Insolubles	50-55%
P-resins	35-40%

Besides this, complete thermal characterisation of carbon fibres reinforced plastics (development by **DRDL**, Hyderabad) was carried out. The project on the development of medium density C/C composites sponsored by **VSSC**, Trivandrum was completed in May 1985.

CARBON FIBRES

Using special grade (SAF) Polyacrylonitrile (**PAN**) precursor, carbon fibres possessing following mechanical properties have been developed on a semi-automatic continuous bench scale by keeping the High Temperature Treatment (**HTT**) only upto 1000°C.

Tensile' strength	2.0GPa
Young's modulus	200-210GPa
Strain to failure	1.4%

In order to optimize processing parameters

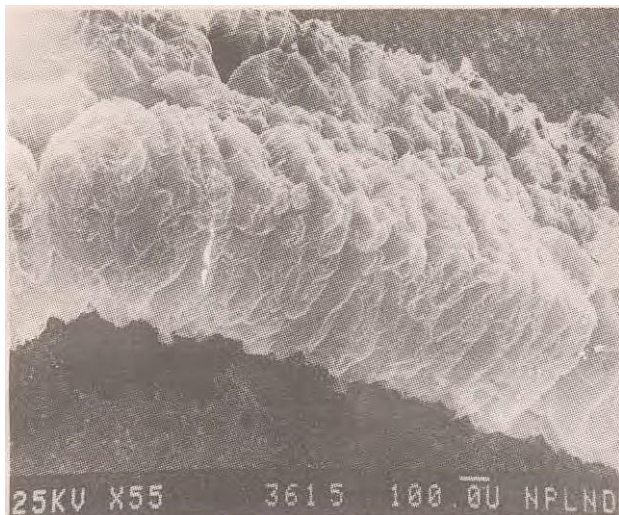
during carbonization, the modified **PAN** was characterised by employing thermal analysis, length changes and X-ray diffraction techniques. Whereas the orientation parameters for the molecular chains along the fibre axis was improved from, $Z = 30''$ lo $Z = 18''$, the activation energy could be reduced from 140 KJ/mol for unmodified **PAN** to only 107 KJ/mol. for modified **PAN**.

Systematic experiments were carried out and as a result. the carbonization speed could be increased by a factor of 3. Further, trial runs were undertaken successfully in which four parallel tows could be accommodated in the same system so as to increase the production rate by a factor of 4 without affecting the resulting carbon fibre properties. Based on the success of the above system, a completely automatic system for processing 150-200 grams of carbon fibre per day has been designed and tendered for fabrication.

Exploratory studies have been initiated to understand the intercalation and exfoliation mechanism of high purity natural graphite flakes. **A** novel technique has been evolved to achieve uniform degree of exfoliation (approx. 300). Figures sh w **SEM** micrographs of intercalated and exfoliated flakes respectively. The micrographs show how the basal planes of graphite open up during intercalation and lead to subsequent degree of exfoliation due to thermal treatment of these flakes.



SEM Micrograph of Inrrecalated Graphite Flake



SEM Micrograph of exfoliated Graphite flake (Degree of exfoliation = 300)

GLASSY CARBONS

Glassy carbon dental implants have shown successful results so far. The work is continuing to make more of such implants in different sizes.

Glassy carbon crucibles of different capacity varying from 10 to 100ml approx. have been made by the carbonization of a suitably synthesized phenol formaldehyde resin having formaldehyde to phenol molar ratio of 1.5. These crucibles, supplied to the silicon processing unit of laboratory, have been found to work very well.

A theoretical mechanism has been proposed

to explain the optimum molar ratio requirements of formaldehyde to phenol in different phenolic resin systems. The Characteristics of Glassy Carbons Obtained from Different Phenolic Resin Systems are tabulated:-

AVIATION GRADE BRUSHES

All the brush varieties passed on for development on evaluation including simulated tests for wear under high altitude conditions vis-a-vis the original imported brushes. Scale up work for 125 nos. per batch has been taken up and facilities for brush fabrication and material processing have been generated. One batch of brush variety PR-72-001 has been sent to HAL, Nasik for evaluation.

The impregnating pitch has been found to give comparative properties & the PST had recommended to design a prescale unit on 5 kg batch. The design work has been completed. The unit comprises extraction, desolventisation, distillation and polymerisation using stainless steel equipment. The process uses fractionisation of coal tar with organic solvents on the basis of molecular weight cuts.

Oxidation of Natural Graphite has been carried out at temperature 350-750°C in presence of boric acid, zinc chloride, potassium nitrate and sodium tungstate. Activation energy has been calculated. Formation of surface groups has been studied by IR.

Characteristics

Glassy Carbon from

	Glassy Carbon from		
	Phenol formaldehyde resin	Resorcinol formaldehyde resin	Catechol formaldehyde resin
1. Baked density (gcm ⁻³)	1.50	1.50	1.53
2. Carbonisation yield(%)	71.5	61.2	65.3
3. Volume shrinkage(%)	40.2	46.2	39.4
4. Transverse breaking strength (MPa)	140	256	326
5. Young's modulus (GPa)	29.0	25.7	
6. Open porosity(%)	1.0-1.1	Nil	
7. Electrical resistivity(mcm)	7.9-8.1	10.6	11.2

CARBON PRODUCTS

The processed material of earlier batches was used for the extrusion of electrodes, as the Dough Mixer & the Roll Mixer were shifted from the present location & disconnected from the steam-line. A new die was being fabricated for thick sizes of Midget Electrodes. The technical data of clutch carbon process was collected so that the product could be commercialised. The release of know-how of Cinema Arc Carbons on revised terms was being explored. The products were supplied to the industry.

LUMINESCENT MATERIALS AND DEVICES

The CEL indicated for establishing the commercial viability of the process and provided the commercially available cheaper raw materials which were experimented on a laboratory and subsequently on a pilot plant scale. Testing of the phosphors so produced was done for colour and brightness. The laboratory batch of 500gm of white-emitting **T.V.** phosphor was sent to M/s

Samtel (India) Ltd., Bhivadi for testing and simultaneously a 5 **Kg.** sample batch was prepared and tested for colour and brightness. After the colour matching was successfully achieved, this sample was found to be around 80 percent in screen brightness when compared with the imported phosphor presently in use. The raw material cost has been reduced by these experiments.

The kinetics of hydrogen sulfide gas absorption in ammoniacal zinc chloride solution has been studied using a stirred cell having a plane gas-liquid interface. The reaction is found to be first order with respect to gas and zero order with respect to liquid. The value of reaction rate constant is determined to be 10900sec^{-1} . The experimental facility for spray reaction cum drying has been set up and experiments conducted have established the feasibility of the technique. The reaction of gas with liquid before the spray is well formed and deposition of **ZnS** precipitates on nozzle arc the main problems affecting continuous running of experiments. The feed, reacting gas, **H₂S**, and drying air are to be suitably adjusted to get maximum conversion and smooth production of dry, powdered zinc sulfide.

RADIO SCIENCE DIVISION

INDIAN MIDDLE ATMOSPHERE PROGRAMME

J. Solar UV-B Measurement

During this period special efforts were given to complete the fabrication and testing of 6 units of solar **UV-B** photometer for establishment of a chain of **UV-B** measurement stations in India. These stations are New Delhi, Pune, Jodhpur (**IMD**), Shillong (**IMD**), Waltair, Mysore and Trivandrum. These **UV-B** photometers can measure the global solar radiation in four wavelength bands at 280, 290, 300 and 310 nm. The filters are rotated with the help of a motor at 1 rpm and 5 minutes are required to complete one full scan. The output of the filters is fed to a digital recorder through a **P.M.** tube. The system set up is shown in the photograph.

During this period the regular monitoring of solar UV-B for direct, diffuse and global radiation were undertaken by both **UV-B** photometers (old unit and automotive integrating type newly built unit). From the measurement of direct radiation, aerosol concentration over De-

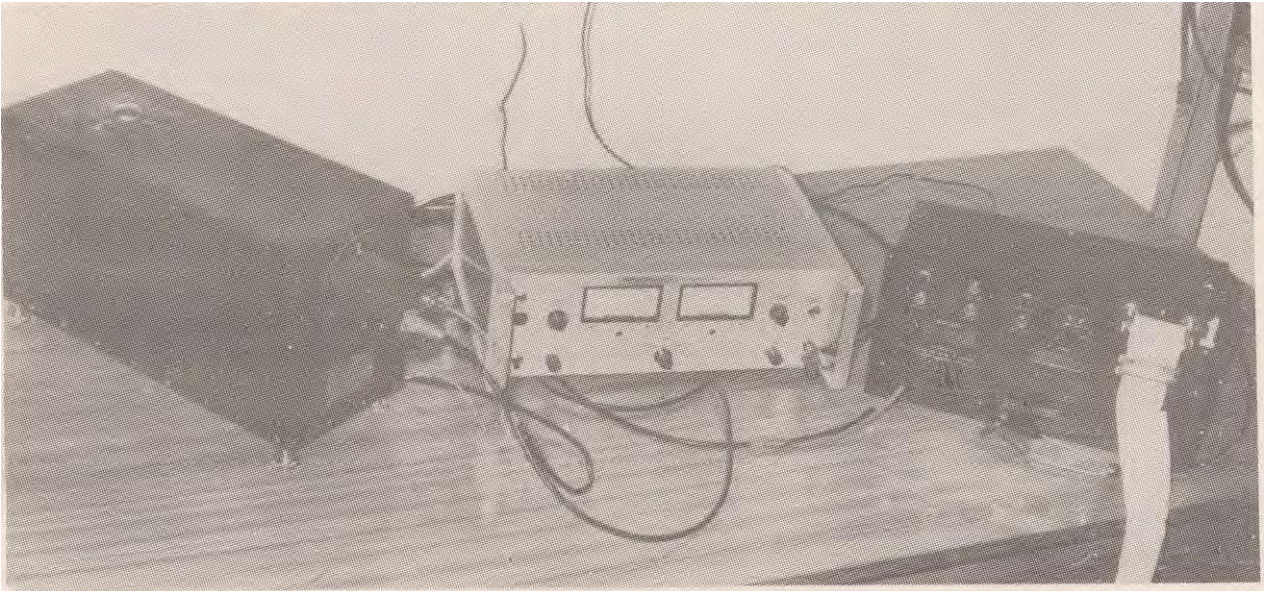
lhi during year 1984 were estimated. Also from the measurement of direct and diffuse radiation, the erythemal dose were calculated and compared with theoretical calculation. Throughout the year erythemal doses were lower than the calculated value. The diffuse radiation measured by the solar UV-B photometer were also correlated with daily ozone value measured by **I.M.D.** and semi empirical relation of Green et al.

Laser Heterodyne System

2. The software for obtaining height profiles of ozone and water vapour from the line profile measurement with the system has been developed and tested with model profiles. The system and the experimental arrangements are complete and can be fully operational as soon as a sensitive detector ordered from abroad arrives. A system for reconditioning of CO₂ laser with fresh gas filling has been designed and completed.

2.1 Global Ozone Trend Analysis

Long period and short period variabilities have been identified and work is in progress on detail



Solar UV-B Photometer for Measurement of Global Radiation.

examination of global ozone from **NIMBUS 7** Satellite **DATA**. Analysis has been carried out on ozone profile data obtained from balloon sonde over Trivandrum. Fluctuations in the profile shape in the upper troposphere were found to be associated with disturbed weather condition as evidenced by satellite cloud over pictures. The phenomena may be linked with flow of minor constituents including water vapour from troposphere to stratosphere in the tropical regions.

3. Rocket and Balloon Experiments

Twelve numbers of different payloads were fabricated, tested and calibrated for three rocket flights and two balloon flights. The payloads consisted of the propagation experiment operating at two frequencies viz. 1865 kHz and 2610 kHz; the Langmuir Probe and the Lyman-alpha experiments. All the payloads were fabricated as per guidelines and workmanship standards laid down by the Quality Assurance Division of **VSSC, ISRO** for space-borne experiments. All rocket payloads were subjected to Thermal, Shock and Vibration Tests for qualifying the 'GA TE' tests specified for **RH 300** and Centaure rocket payloads. Thermal and sine vibration tests were carried out at ERTL, New Delhi while Random Vibration, Shock and Spin tests were conducted at VSSC, Trivandrum. The balloon payloads were subjected to low temperature tests as per guidelines laid down for balloon-borne experiments.

In order to improve the height resolution, the concept of auto-gain ranging was introduced in the design and was successfully tested for the electrometer of the rocket borne Langmuir Probe experiment. This electrometer could measure currents from 5×10^{-12} amp to 5×10^{-6} amp. in 8 gain ranges in a linear scale.

IMAP-8 Balloon experiment was conducted on Dec. 6, 1985 at Hyderabad, in which we have participated by contributing the Gerdien Condenser for the measurement of positive ion density and conductivity, we obtained useful data in the altitude range of 8 to 17.5 km. The voltage on the field generating central electrode was swept from 0 to 13 volts and back 0 volts in about 30 seconds time. From the slope of the **I-V** characteristic and

conductivity of the medium was calculated and it was found to vary from 6×10^{-14} Mho/metre at 8 km to 8.6×10^{-14} Mho/metre at 17.5 km. Assuming the mobility from models the positive ion density has been calculated and it is found to vary from $1.55 \times 10^{-3} \text{cm}^{-3}$ at 8 km to $6.5 \times 10^2 \text{cm}^{-3}$ at 17.5 km.

A balloon-borne Langmuir Probe experiment was also flown under the conductivity campaign. The aim of the flight was to measure the stratospheric ionisation and their mobilities and intercomparison of results obtained from different techniques. Balloon reached a float altitude of about 33 kms. and good data was obtained. For our **LP** experiment analysis of the data is in progress.

3.1 D-Region Ionisation Campaign

Under the **IMAP** D-region Pre-Ionisation Campaign, two rocket flights were held from TERLS, Trivandrum on March 7th and 10th, 1986. The payloads in each of these flights from our group included Propagation Experiments and Langmuir Probe for measuring the D-region electron density, and Lyman-alpha experiment for the measurement of molecular oxygen concentration and collision frequency profile. All the payloads in both the flights worked satisfactorily and data was obtained. Data scaling and the analysis work is in progress.

Identical Gerdien Condenser Payloads were flown along with other experiments aboard Centaure-IIB on 7th March, 1986 and aboard RH-300 on 10th March, 1986 from Thumba. Both the experiments were successful and all channels were working throughout the flight and data were obtained. Analysis of the data was taken up.

One RH-300 rocket flight was carried out on March 6, 1986 from TERLS. The payload included a Langmuir Probe to measure the electron density. The payloads as a whole went through all the environmental tests successfully. But due to some malfunctions in the performance, the rocket could reach to peak altitude of about 10 kms only and therefore no useful data could be obtained.

TROPOSPHERIC AND IONOSPHERIC COMMUNICATIONS

1. Short-term Predictions to aid HF Communications

One of the most common causes of low reliability in HF communications including HF radar operation is the unpredictable day-to-day variability. This is further compounded at low latitudes because of large horizontal gradients associated with the equatorial anomaly. In order to use the available Ionospheric Electron Content (IEC) values from places without ionosonde facility, a comparison of IEC and foF2 values (Fig. 1) were made from several stations. It was concluded that the correlation is good only during daytime especially at locations away from the equatorial anomaly peak.

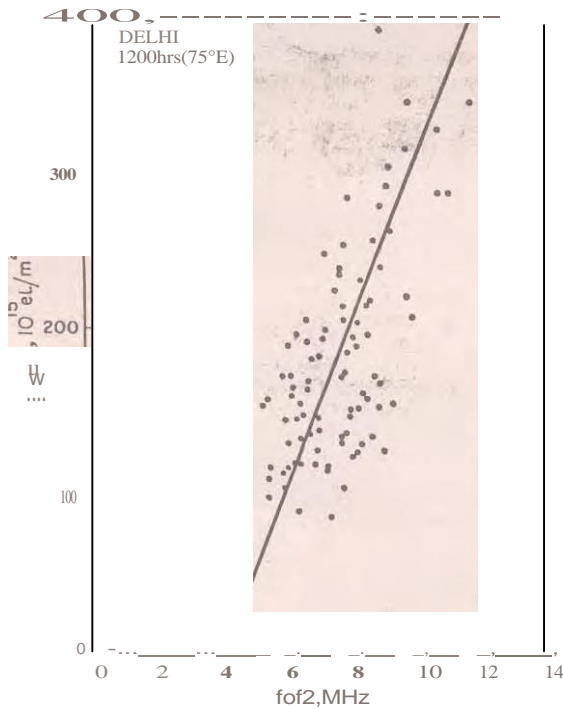


Fig. 1. A p/01 of daily noontime values of foF2 and IEC for Delhi during 1975-76.

The saturation effect of foF2 during high solar epoch does not justify the linear regression method of CCIR for ionospheric predictions. Auto-correlation analyses were performed on the deviations of foF2 from mean seasonal patterns separately for solar minimum and maximum

conditions and assuming a first order autoregressive process the predictability of monthly foF2 is estimated as the variance of the mean seasonal patterns. A Markov statistical model was used to estimate the persistence in the foF2 data and it was found that the prediction under disturbed conditions is more accurate. Coefficients of foF2 variations indicating the extent of random day-to-day variability were calculated for a few low latitude stations. It may be concluded that the decaying phase of the solar epoch is characterised by larger variability for these latitudes (Fig. 2).

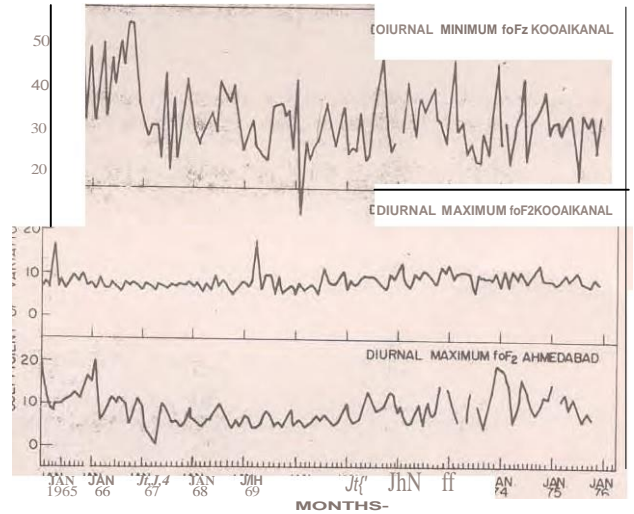


Fig. 2

2. Ionospheric Scintillations

An empirical model of equatorial ionospheric scintillations was evolved exclusively for Indian longitude zone using extensive observations at Ooty. Remarkable differences exist between this and the WBMOD model. Notable are the much weaker dependence on solar activity and the presence of a post-midnight peak at the Indian longitudes (Fig. 3). Studies on C-Band scintillations using INSAT-1B have yielded SI values of as high as 35%. This is much higher than expected at this frequency for low solar activity. The

equipment & the antenna are shown in the photographs.

3. *Anomalous VHF Propagation Phenomena*

Comprehensive VHF monitoring (TV signals) was carried out at Warangal and Delhi during the last two years. The Hyderabad-Warangal data show that superrefraction is the main cause of large field strengths, though reflections from elevated layers are responsible at certain times. Jalandhar-Delhi signals at 208 MHz on the other hand seem to propagate by scattering during y

and by scattering and reflection during night. The path losses calculated using NPL method and obtained from observations are 194db and 197 db respectively.

4. *Magnetic Activity and the Upper Atmosphere*

A flux gate magnetometer has been set up and pressed into service for providing short-term forecasting of ionospheric parameters during disturbed periods as well as for micropulsation studies. It should be emphasised that solar flare

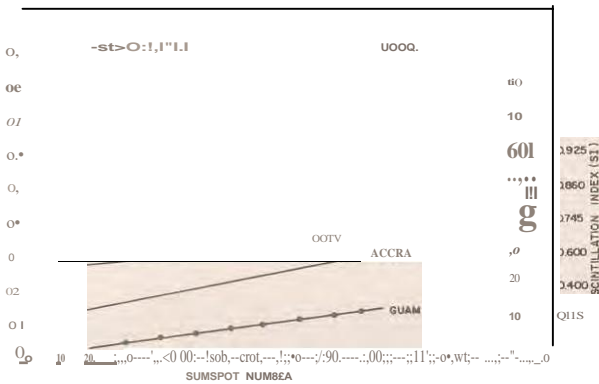
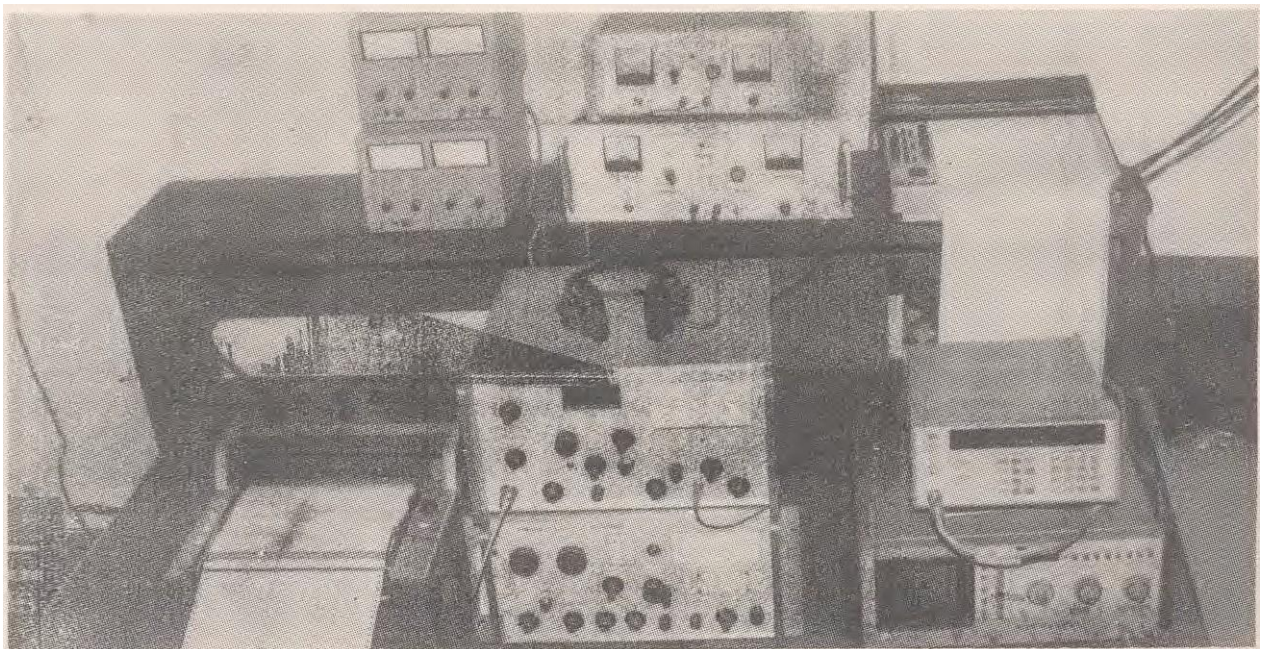


Fig. 3



reports through ARWC and in-house magnetic observations have enhanced the confidence in forecasting storm departures in HF communication parameters.

Storm-time departures in TEC at Ooty were analysed for five major storms along with data for four stations in the anomaly region. It was concluded that ionosphere-plasma sphere exchange and converging equatorward meridional winds also have significant effects at these latitudes though **EXB** drifts exercise the preponderant influence. Simultaneous measurements of electron and ion concentrations and their temperatures from AE-C satellite have shown anomalously large ion temperatures, far exceeding electron temperature in the so-called high latitude trough region. The results were explained in terms of enhanced Joule heating at the trough. The good correlation of the enhanced ion temperature with magnetic activity only proves the point.

5. LOS Microwave Propagation Studies

Microwave propagation phenomena associated with links in hilly terrain were studied to characterise the longterm median field strength morphology. Daytime signals suffer fast but low amplitude fluctuations of 2-3 db while during nighttime the amplitude is as high as 25 db. The fade rates are very high (150 per hour) during premonsoon. The subrefraction occurrence is identified as the major cause for total fadeout, not infrequently, due to inadequate Fresnel zone clearances.

6. Correlation Bandwidth and Dust-storm problems in Troposcatter/ Propagation

The uncorrelated fading in scatter links is responsible for the intermodulation distortion and limits severely the coherent bandwidth in transhorizon links. Special studies by the group show that the correlation band width problem is serious during low atmospheric stability conditions; the intermodulation problems are also severe when the stability is low. The influence of dust storms on Microwave propagation (Scatter) under typical Indian desert conditions was investigated for a

variety of particle sizes, concentrations and vertical distributions.

7. Turbulence

Lower Atmospheric Turbulence has a special significance in Radio Communication. The scattering efficiency and Antenna gain degradation in Tropo-systems are critically dependent on this parameter. A general expression was formulated to estimate medium-to-aperture coupling loss for unidentical antennas using C; values over selected Indian regions. The classical Parl's method was found to over estimate the antenna degradation. Proper use of these results will save antenna costs in scatter systems.

In order to collect fine structure variations in **R.R.I.** profiles over India, an air-borne solid state digital refractometer was designed and flight tested successfully. The variance of the refractive index $(\Delta n)^2$ was computed from 128 N values obtained by flying the instrument on board a **CESSNA** aircraft over Northern India. A typical distribution of power spectral density with spectral frequency is shown in Fig. 4. The scale sizes were estimated from a Gaussian description of turbulence-the microwave scatter power was

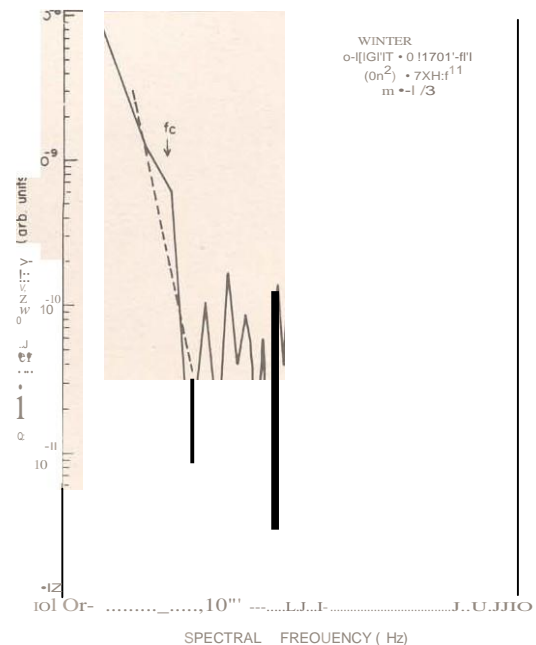


Fig. 4

observed to depend on the abundance of lower scale sizes comparable to operating wavelength.

8. Radar Tracking Errors

A comprehensive 3-dimensional ray-tracing programme was developed and utilised earlier for range and elevation angle corrections in radar operation. However, in view of the complexity of programming procedures, the utility was limited. During 1985-86, a simplified 2-dimensional ray tracing programme was designed for average refractivity conditions over a number of selected zones in India (Fig. 5). This programme can be readily used by the radar operator with the help of

average refractivity information for the relevant local time and season.

9. Consultancy Services

More than one hundred specific consultancy services were rendered on HF and Microwave communications. The organisations benefited include all the wings of the Defence Services, Border Security Force, Indian Space Research Organisation, Police wireless, P & T, Railways, India Met. Department among other Research and Communication Institutes. A number of classified jobs for Defence Services were also undertaken during the year.

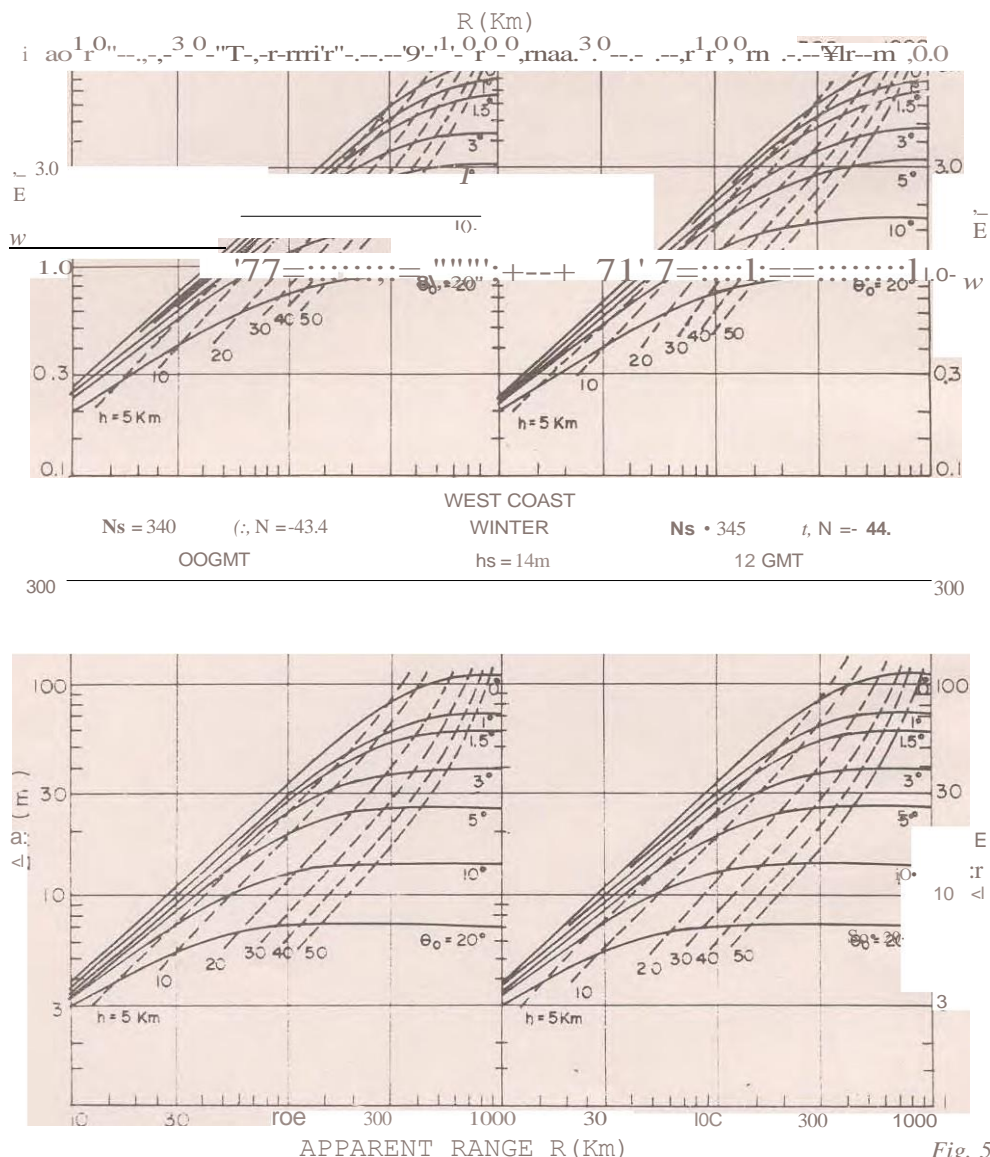


Fig. 5

SROSS AERONOMY SATELLITE

Laboratory models of the two NPL satellite payloads, the Retarding Potential Analyser (RPA) and the Energetic Particle Spectrometer (EPS) have been developed and their performance has been tested satisfactorily. Prototypes of the sensors and the electronic boxes for the two payloads have also been fabricated. Efforts are made to restrict the size, weight and the power of the payload electronics within specified limits.

1. *Retarding Potential Analyser*

A block diagram of the RPA experiment is shown in the figure. The two sensors, mounted on the top deck of the satellite, collect electrons and ions separately and cause currents in the range 10^{-12} amp. to 10^{-6} amp. The current from each sensor is separately measured by an eight stage auto-gain ranging linear electrometer amplifier. A staircase generator is used to generate the staircase voltage waveform which is applied to the retarding grid of the sensor. Depending on the magnitude of the retarding grid bias only those electrons or ions whose energies are greater than the applied potential reach the collector of the sensor to cause current in the sensor. The current voltage characteristics thus obtained are used to derive various ionospheric parameters of the bulk plasma.

The magnitude and the waveform of the staircase generator is kept programmable by ground telecommands. Thus experiment can be performed in several modes, such as thermal electron/ion modes, suprathreshold electron mode, duct mode etc.

The first derivative of the electrons/ion current with respect to the retarding grid bias (for the measurement of electrons/ion temperatures) is measured by an auto-gain ranging derivative amplifier. An ac wiggle is modulated over the retarding grid bias and then reflected wiggle in the current output is measured by synchronous detection technique to get the derivative information. The difference amplifier measures the fine structures in the electrons/ion densities along the orbital path of the satellite.

1.1 *Energetic Particle Spectrometer (EPS)*

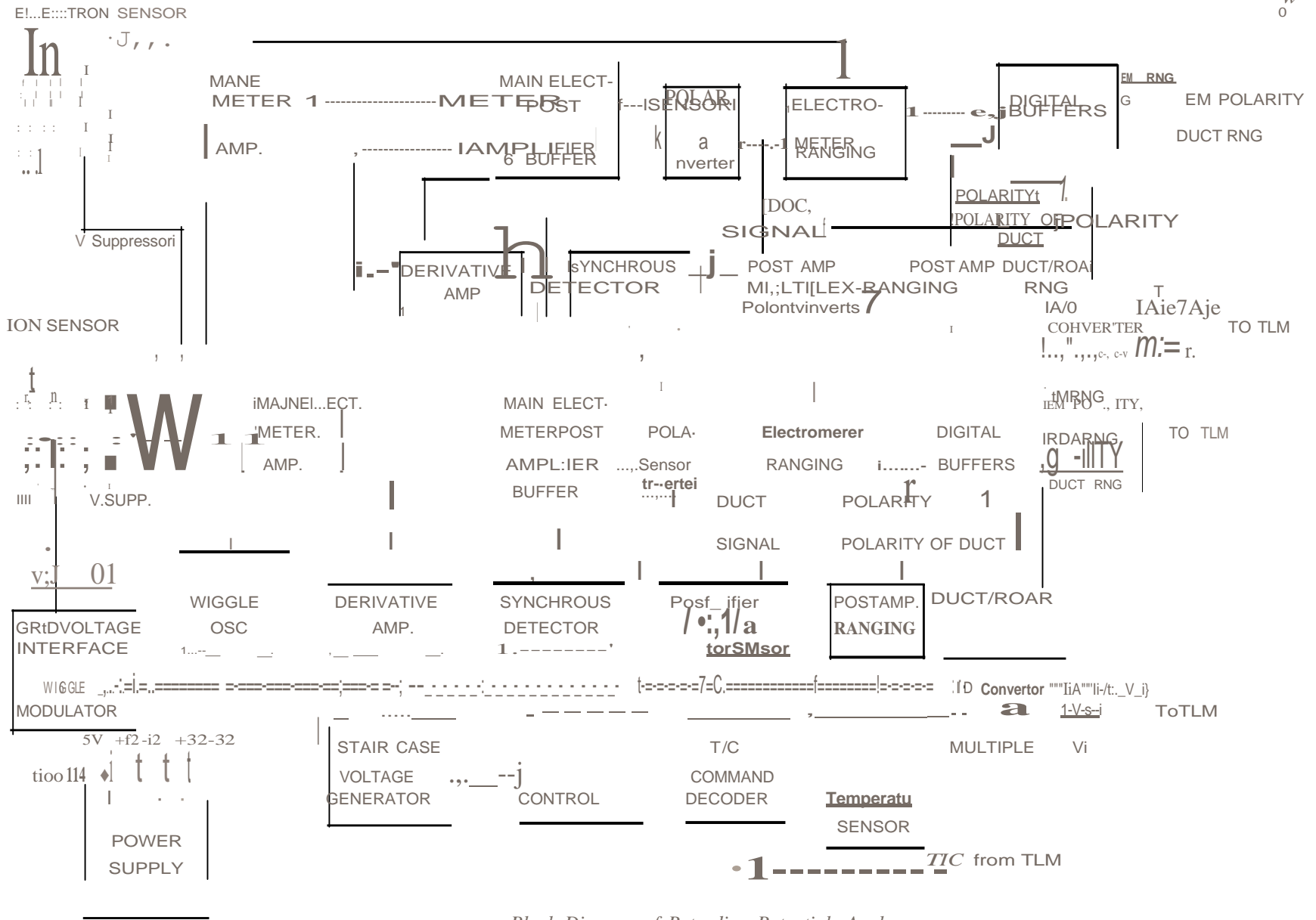
A block diagram of the energetic particle spectrometer is shown in Figure. This consists of two surface barrier detectors, the first one measures protons and electrons and the second one only electrons. Every energetic charged particle that hits the sensitive surface of the sensor produces a charged pulse whose amplitude is proportional to the energy of the particle. The purpose of the whole experiment is to count the number of charged particles incident on the sensitive surface of the detector during a given period and measure their energies and then to build their energy spectra. The detector is followed by a charge sensitive preamplifier with a capacitive feedback. The resulting charge pulse is shaped and amplified. Then these pulses are passed through a comparator with a staircase reference voltage. During each step the comparator allows a bunch of pulses, whose heights are greater than the threshold value, decided by the voltage of that step. Thus within a specified period, all the incoming pulses are graded. From the outputs of the two sensors, proton population in the energy range 20-120 KeV is computed.

RADIO AND ATMOSPHERIC PHYSICS

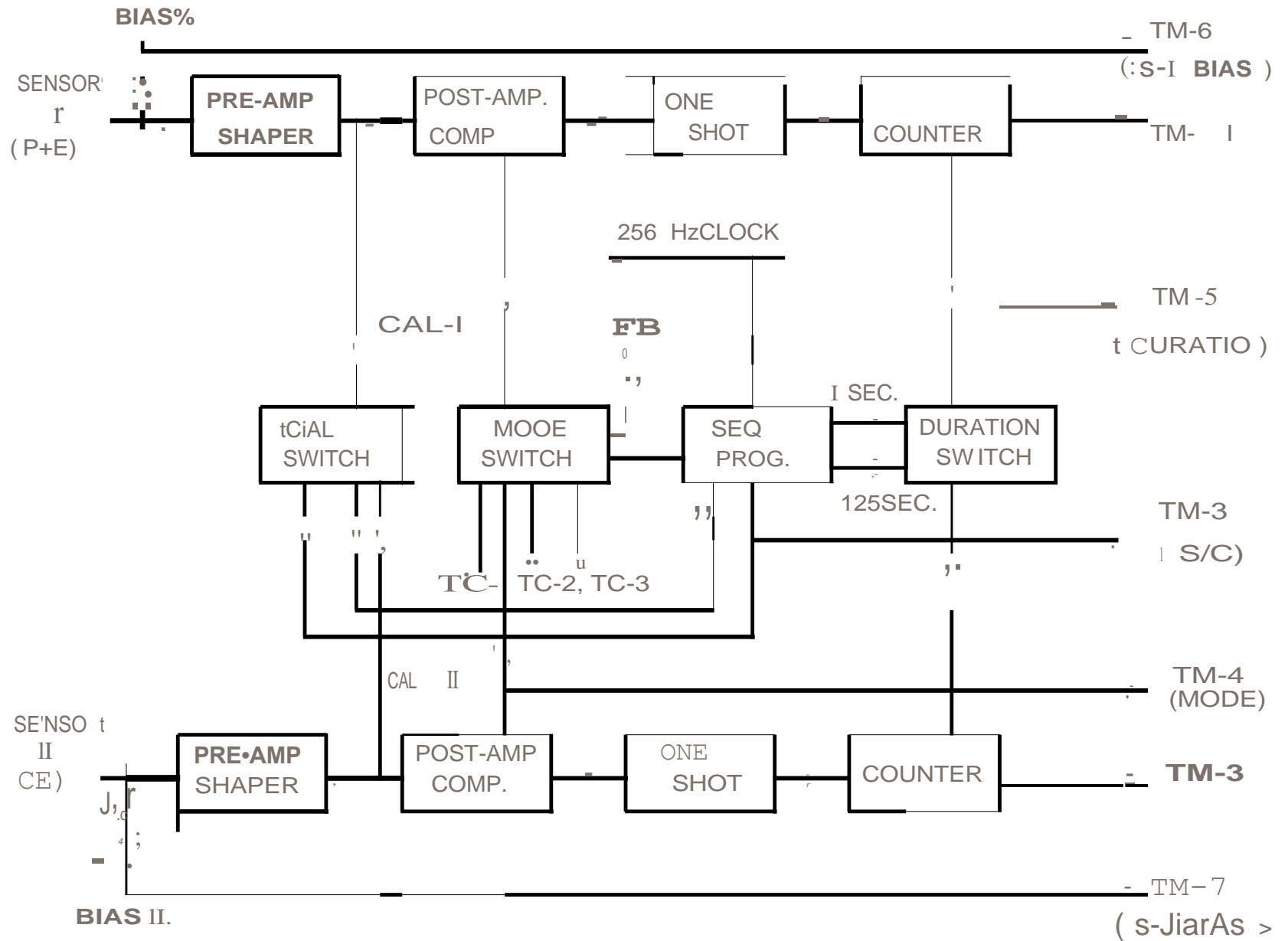
I. *Planetary Ionospheres*

II *Equatorial Anomaly in the Ionosphere of Saturn*

Electron density profiles obtained from radio science experiments on the Pioneer-11, Voyager-1 and Voyager-2 were analysed to look for equatorial anomaly in the ionosphere of Saturn. The Voyager 1 egress measurement near the morning terminator at 1°S showed an extremely depleted ionosphere with peak electron density about a factor of 10 smaller than that at low and mid latitudes as can be seen in Fig. 6.



Block Diagram of Retarding Potential Analyser



Block Diagram of EPS.

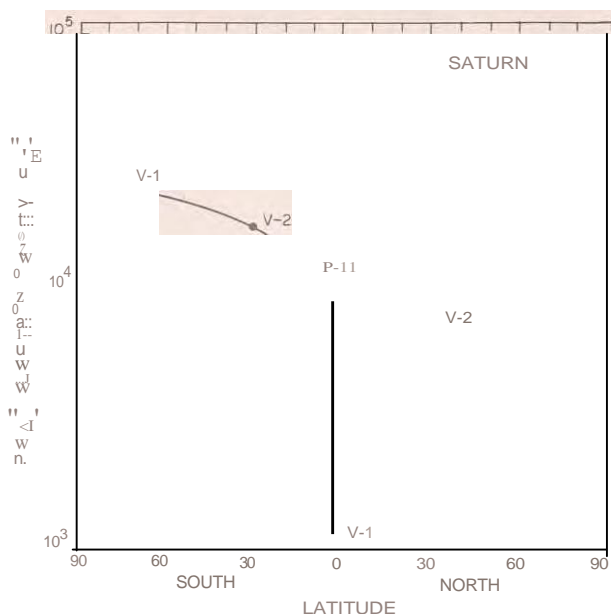


Fig. 6

1.2. A(fiven Wave Heming ofJupirer's Thermo.s-phere

An order-of-magnitude estimate of heating by the dissipation of Alfvén waves in Jupiter's thermosphere was made. The waves generated by the relative motion between Io and the co-rotating magnetospheric plasma move down the magnetic field lines into the Jovian ionosphere, where most of the wave energy is reflected back and only a small part transmitted. The rate of heating resulting from the dissipation of the transmitted wave energy by ion neutral collisions was calculated for the case when the wave period was much longer than the collision period between ions and neutrals. Using the Voyager observations for the amplitude of the Alfvén waves near Io, the rate of heating for characteristic low period waves (..... 1 sec) from Io, due to $H^+ - H_2$ collisions was found to be of the same order as the solar EUV heating. This heating would take place essentially near the feet of the Io flux tube and may have important implications locally.

1.3 Effects of large scale Magnetic Fields in the dayside ionosphere of Venus

In-situ measurements from various ionospheric experiments on Pioneer Venus Orbiter (PYO), as

available in the Unified Abstract Data System, were used to study the effects of large scale magnetic fields in the ionosphere of Venus. Orbiter data for the first three dayside periastron passes, covering the period from December 1978 to March 1980 were analysed for this purpose. The topside ionosphere, lying between the ionopause and chemical equilibrium regions, was found to be in a compressed state during high magnetic field conditions. However, the degree of this compression, as deduced from the layer thickness of O^+ ion density profiles, was found to be related to the parameter $B(SB/82)$, which is indicative of the magnetic field conditions in the ionosphere. Further, the peak value of O^+ ion density was, generally, found to increase during high magnetic field conditions. Contrary to earlier reports, these effects could be observed even at larger solar zenith angle.

2. Incoherent Scatter Studies

2.1 Solar Activity Control of F-region Electron Temperature

Incoherent-scatter radar measurements of electron temperature (T_e) and electron concentration (N_f at Millstone Hill ($42.6^\circ N$, $71.5^\circ W$) were analysed for the period 1968-74 (which covers a small part of rising and a major part of declining phase of sunspot cycle 20) to look for solar activity dependence of T_e in the F2-region of the ionosphere. As N_e is the major controlling parameter for the F2-region T_e , electron temperature for constant values of N_e were observed that there is a significant dependence of F2-region T_e on solar activity, both during the rising and the declining phase of the solar cycle.

2.2 Thickness Parameter for the Bottomside F-region

Electron density-height profiles from the Arecibo incoherent scatter radar were analysed, for the period August 1974 to May 1977, to look for a thickness parameter for the bottomside F-region of the ionosphere. These profiles were obtained using short pulse lengths of 7.4 μs resulting in high altitude resolution in electron density profiles. In

the analysis Gulyaeva's empirical relationship of 0.5 NmF to occur at 0.8 hmF. was tested. Arccibo profiles indicated this factor to be close to 0.85 hmF, for most of the cases.

2.3 Analysis of MST radar data

Two magnetic data tapes from two different MST radar stations were procured. These tapes contain radial velocities and these have been processed. From the radial velocities we derived the zonal and meridional velocities. From the study of the time series of these velocities at various heights in the lower atmosphere, short period fluctuations in this region were found.

3. Satellite Radio Beacon Studies

3.1 Annual and semi-annual periodicities in IEC abstract

The variations of the annual and semi-annual periodicities in ionospheric electron content (IEC) are investigated by harmonically analyzing the monthly median values for three Indian locations during the low solar activity period of 1975-76 and through half a solar cycle (1975-80) for Delhi. Results are presented as a function of local time. The phase and amplitude of the annual and semi-annual components exhibit geomagnetic, solar cycle and local time dependence. Semi-annual maxima occur in April and October at all the locations and irrespective of solar activity condition which may be attributed to similar changes in atomic oxygen concentration controlling the production of ionization. The annual maximum shows systematic changes in phase and amplitude as a function of latitude and local time. During low solar activity, the winter phase is evident only near the dip equator. Away from the equator, the occurrence of the annual maximum changes from summer to winter as the sunspot activity increases. Another feature observed is the near absence of these periodicities during nighttime. In addition to atmospheric composition changes, F-region plasma transport controlled by ExB drifts is likely to be the main contributor to those observed periodicities at low latitudes.

The diurnal variations of the annual and semi-annual periodicities in the F-region of the ionosphere over Lunping are investigated by analyzing the monthly mean value of ionospheric electron content (IEC) for a period of three consecutive years representing low, medium and high sunspot activity. Significant solar cycle variations in both amplitude and phase have been observed. The diurnal maximum in IEC occurs progressively later with increase in solar activity. The phase of the annual component shifts from winter in solar minimum to late autumn in solar maximum, whereas the phase of the semi-annual maxima is only in equinox conforming the global behaviour. The variations are mostly explained in terms of the ExB drifts and changes in the atmospheric composition.

3.2 Lunar and Solar daily variations of IEC at Delhi

Ionospheric electron content measurements obtained at Delhi during the period 1975-1980 have been analysed by the Chapman-Miller method to compute lunar and solar daily variations. The results show that the magnitude of the lunar harmonic components is about one-tenth that of the solar harmonic components. Significant seasonal and solar cycle variations were observed for both the lunar and the solar terms. The lunar semi-diurnal component, the most significant term, can be explained as due to the additional 'fountain' effect caused by the lunar semi-diurnal variation of the electric field at the equatorial region. The lunar semi-diurnal variations were found to have significant oceanic and ionospheric components.

3.3 Satellite Beacon TID Campaign

In order to study the characteristics and sources of gravity waves, a TID campaign was held from May 7, 1985 to June 3, 1985 by monitoring the FR of ETS-11 signals at Panipat, Meerut and Delhi. It has been observed that occurrence of TID's is 50 percent during the campaign period. They occur equally during day and night. The average speed of TIO is 120 m/sec and most of them move towards West. Another three station network

made operative at Hyderabad, Vikarabad and Shadnagar from Dec. 1985 have provided data up-to-date and the analysis of the same is in progress.

3.4 Faraday Polarisation Fluctuations Observed at Delhi

Low-latitude nighttime ionospheric scintillation phenomenon and the associated Faraday polarisation angle fluctuations (FPFs) observed on transionospheric satellite signals during the ascending phase of solar activity, reveal certain interesting morphological features. While the FPFs occur predominantly during the pre-midnight hours, the scintillations are observed throughout the night. Further, there is a marked difference between the scintillations observed in the pre-midnight period and those observed in the post-midnight period. Under the influence of high solar activity clear seasonal trends are present in the occurrence of FPFs while the same is not apparent in the occurrence of amplitude scintillations. The seasonal scintillations' occurrence trend shows minimum during the winter solstices and moderate activity in other periods. Hitherto, FPFs are supposed to be predominantly observed on transequatorial anomaly of occurrence (1ST) at Hyderabad (17.1°N; 78.3°E), a low-latitude station and Delhi (28.63°N; 77.22°E). It shows that the FPFs die down first at Delhi and then at Hyderabad. From this it is concluded that the FPFs are one of the important manifestations of the strong magnetic equator coupling with the higher latitudes in the Indian sector especially during high solar activity.

3.5 L-band Scintillation Project using MAR/SAT Signal

An L-band satellite receiver system is being aligned to receive **MARISAT F-II** (0°N, 72°E). A 10 feet chicken mesh dish with a helical feed at its prime focus has been installed and the satellite signal has been down converted using a low-noise amplifier front and together with a mixer. A carrier to noise of better than 15dB has been obtained by displaying the satellite signal around

1535 MHz. on a spectrum analyser. The receiver is to be commissioned shortly.

4. Ionospheric and Neutral Atmospheric Modelling

The causes for some of the reported discrepancies between the International Reference Ionospheric (IRI) description of the lower ionosphere electron density profile and the ground based radio measurements are examined. A careful study of the available experimental measurements showed that the peak height of the E-region during daytime should be lower than the value used in the IRI description.

During high solar activity period it is found that He⁺ ions, which are normally minor ions compared to H⁺ ions in the topside ionosphere, become major ions at mid-latitudes during night time. The relative abundance of these ions is an important parameter in ion composition modelling. The substorm effects of high latitude ionosphere are explained by using 'servo mode' in terms of equator-ward winds and changes in electric field and topside plasma flux.

5. Microwave Radiometric Measurements

Exploratory work was done to establish 37 GHz millimeter wave radiometer facility. To house this facility, a millimeter wave laboratory consisting of a clean room of the size 20' x 17' x 10' was designed, built and completed.

Work was continued for development of inversion techniques for integrated water vapour and height profiling using multifrequency observations by selecting proper frequencies from the nature of weighting functions. The antenna temperature obtained at 22.4 GHz and 19.85 GHz were inverted to get directly integrated water vapour and profile shape after estimating the surface water vapour density separately. However, it was found that when these two types of independent inversion techniques are appropriately combined it is possible to derive the profile shape independent of the surface water vapour density.

Analysis of the data at 11 GHz, 18 GHz and 22.235 GHz showed that at 11 GHz, attenuation

for the rain rate upto 100 mm/hr can be measured. whereas for 18 GHz and 22.235 GHz, the attenuation cannot be measured for rain rate exceeding more than '40-m ihr. This is because of the saturation of the radiometer in the emission mode which is not able to measure more than 12 dB.

Water vapour attenuation measurement at microwave frequencies have been obtained based on theoretical formulations. Sky noise temperature at 10.14, 18 and 22.235 GHz show that for water vapour content of 5 gm/m^3 , the variations are between 20 K and 46 K. Likewise variation for water vapour content at 10 gm/m^3 , 15 gm/m^3 and 20 gm/m^3 have been obtained. By interpolating and extrapolating the curves. Zenith sky noise temperature as low as below 10 GHz and as high as 26.5 GHz have been determined. Studies were initiated during the year to use Hankel transform as a technique for remote sensing of the refractivity spectrum. A computer programme has been evolved for this purpose.

6. *Monitoring of anomalous long distance TV Signals*

The data for anomalous long distance TV reception during 1978-86 has been collected systematically. The percentage of TV reception has been studied for summer, quinoxes and winter separately (Fig. 7). Various natural modes of

propagation mechanism have been considered and have been found that the percentage of **TV** signals is more than expected. The extra **TV** signals have been considered due to artificially modified ionosphere carried by high power short-wave transmitters operating in the neighbourhood.

ATMOSPHERIC CHEMISTRY

The project involves measurement and study of minor atmospheric gases, both in the troposphere and in the stratosphere of importance in long range environmental and climatic changes. During the period a portable gas chromatograph was procured and used to measure methane efflux from inundated rice paddy fields. Methane is a green house effect gas affecting the heat balance of the earth and is also of importance in stratospheric ozone chemistry. A new method for estimation of sulphur dioxide content has also been devised and successfully applied.

The Department of Science & Technology has sponsored a project for establishing a sophisticated gas Chromatograph facility for analysis of trace gases to levels of parts per billion or lower. Preparation of standard gas mixtures for calibration purposes for above has also been undertaken.



Measurement of methane efflux in the field

CRYOGENICS & SUPERCONDUCTIVITY

CRYOGENIC SYSTEMS AND DEVICES

1. *Liquid Air Plant Based on Stirling Cycle*

The liquid air plant developed in the laboratory, was in production. The lower rate of production was due to the various inefficiencies in the plant like, the difference in the average and working pressure, inadequate heat rejection from the compressed gas and absence of chilling plant for chilled water supply etc. During this year, a water chilling plant has been purchased and installed for the supply of chilled water to the liquid air plant. Various seals and gaskets have been modified and surface finish of components improved which have resulted in the increase of difference in average and working pressure of hydrogen gas. Considerable work in the development of water cooler (heat exchanger), has been carried out. Research on the designing of the regenerator is continued (on high efficiency heat exchanger). The plant is now producing about 5-5.5 litres of liquid air per hour. This development has implications for further developments in the area of Stirling cycle based power generating systems in small capacities range for rural villages and for high resolution (infrared sensing) Stirling Cycle based cryo-cooler for space and defence applications. Preliminary studies in this direction have been made.

1.1 *Development of Cryo Mini-Coolers for Infrared Detectors*

Some of the important developments in this area have been the intensifier (high pressure booster) to 6000 psi of nitrogen gas pressure; high pressure bottles, J.T. heat exchangers, solenoid valves, ultra-fine flow nozzles ($e^{-1} \approx 30 \mu$) and highly uniform inner bore. glass dewars etc. All these systems operate at very high pressures of 6000 psi which is an aerospace technology. The intensifier is working satisfactorily. The bottles have been filled successfully many times upto a pressure of

6000 psi, using our own indigenously developed intensifier. Various new series of minicoolers with modified design of mandrel and flownozzles have been developed for obtaining high efficiency and very small cooldown time. Liquid nitrogen temperatures have been achieved in less than $\frac{1}{2}$ minute at pressures between 3000-4000 psi. Glass dewars of very highly uniform inner diameter (10μ) which is an important requirement for the success of this minicooler development programme have been developed. Present system is a fixed orifice J.T. expansion system. Preliminary studies to test the feasibility of using a bellow for self regulating mini-cooler system have been made and promising results are obtained.

1.2 *Cryogenic Infrastructure*

The liquid nitrogen plant (PLN-430) is a central facility for producing and distributing liquid nitrogen in the entire laboratory. During the period, the plant has produced more than 9,000 litres of liquid nitrogen. Liquid nitrogen was supplied to some of the outside R&D institutions like, AIIMS, National Instt. of Malaria and Delhi University.

SUPERCONDUCTIVITY AND SUPER CONDUCTING MATERIALS

1. *Mechanism of Superconductivity*

The theoretical justifications for the exclusion of electron correlation in superconductivity have been studied in depth. Inadequacies of the assumptions for the screening of Coulomb interaction and experimental evidences for the dominance of exchange and correlation effects have been reported. In the above context CESR. Spin waves. T^2 behaviour of resistance, NMR etc. on a host of superconductors were analysed to strengthen the new mechanism of electron pairing. An alternative explanation based on the existence and effects of hyperfine interactions for the isotope

effects ($T_c \propto 1/m^*$) has been developed. The critical analysis shows the variation of Fermi contact term with ionic mass ($T_c \propto 1/\sqrt{m^*}$). This puts a question mark to the very existence and overemphasized role of virtual phonons in the electron pairing of BCS type.

1.1 Superconducting Materials

The ESR and resistivity studies of Bi and Ni ternary and binary compounds were carried down to liquid nitrogen and liquid helium temperatures respectively which shows the strong probability of enhanced electron-electron interaction. Growth kinetics of superconducting Nb_3Sn layers formed by solid state diffusion in different multifilamentary bronze composites have been studied. Both scanning and transmission electron microscopy have been used to reveal the grain structure of the layers. The inter-relation between the layer growth and the grain growth has been examined in terms of the theoretical models. The problem of ordering of Nb_3Sn layers which was not explored earlier, has been studied for the first time. Nb_3Sn layers formed after short duration of diffusion reaction have been investigated for their superconducting critical temperature T_c , lattice parameter and stoichiometry. Various possible mechanisms of ordering of the layers have been examined and the energetics of the processes have been worked out.

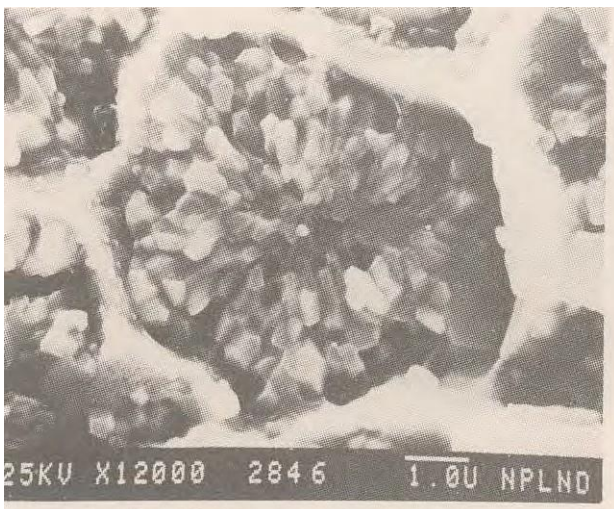


Figure showing Nb_3Sn grains in the bronze processed layer.

1.2 Josephson Tunnelling and Squids

The as-maintained volt of NPL has been intercompared against the Josephson voltage standard. The overall uncertainty in the intercomparison has been reduced to 1 ppm. D.C. SQUID's based in solder blob junctions having two well defined weak links have been locally fabricated and studied for detection of weak magnetic field signals. Well defined oscillation in the output voltage across the SQUID as a function of externally applied magnetic field have been observed. Design work of a planar thin film dc SQUID has been completed. Work is in progress to get the masks fabricated using mask making facility at CEERI, Pilani.

A-IS SUPERCONDUCTORS THROUGH IN SITU TECHNIQUE

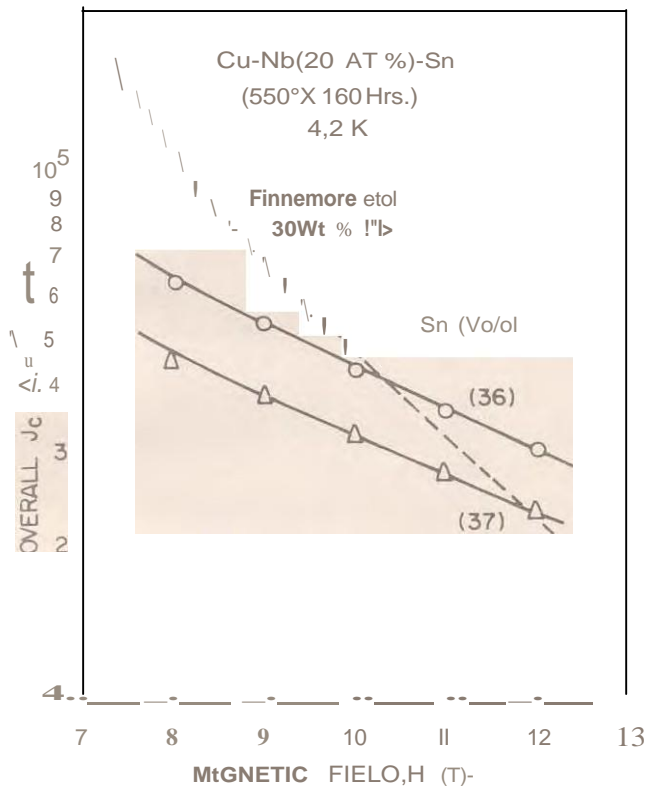
I. Sintered Cu-Nb Composites

A large number of Cu-Nb (15-30 at%) composite wires were characterized for their critical current density, J_c , which increases with area reduction ratio and Nb-concentration. Evidence of proximity effect in zero field was very convincing. The observed enhancement of H_n from 0.25T (for pure Nb) to 10 T for in situ filaments was explained in terms of an increase in normal state resistivity $\rho_n(H_c2 \propto Y\rho_n T_0)$. Annealing brings down H_n but improves proximity. Cu-Nb tapes with aspect ratio 16 and 20 show large J_c , anisotropy with respect to magnetic field. Tapes have significantly high J_c , when the magnetic field is applied parallel to the wider side of the surface indicating that the S-N boundaries are effective flux pinning sites in *in situ* superconductors.

I.1 Sintered Cu-Nb₃Sn Composites

Cu-Nb₃Sn composites were obtained by coating composite wires of Cu-Nb with varying amounts of tin and heat treating for varying periods in multiple steps. Stoichiometric Nb₃Sn was formed with as high a T_c as 17.5 K (midpoint) for 26 Y₂O₃ tin and 72 hours of reaction time. Typical J_c values measured for our best specimens are 3×10^5 A/cm² (6.5T, 4.2K) and 3×10^4 A/cm² (12T, 4.2K) which compare well with the published values. The J_c measurements at 12T were carried out by Dr. Tanaka of the **NRIM** Japan. Encouraged by these results fresh lot of specimens

were prepared with Nb (20-35 wt%). Various process parameters are now being optimized through characterization.



THEORETICAL INVESTIGATIONS IN CONDENSED MATTER PHYSICS (EXPLORATORY)

1. Non equilibrium Superconductivity

Detailed studies done on the soliton-bearing scalar fields have revealed that a superconductor driven by quasiparticle injection is similar to the ideal-gas phenomenology of Krumhansl & Schrieffer and other one-dimensional Kink-bearing systems like Sine-Gordon chain and ϕ^4 chain. The non-linear response of the Sine-Gordon Chain via Fokker-Planck approach, is dominated by soliton in the low-temperature limit. However, in the case of superconductor driven by quasiparticle injection, a similar response is not seen. Clearly, the damping terms need re-examination.

1.1 Bethe-Ansatz and its Applications

Although the connection between the S-matrix

theory of the Kondo Problem and the Bethe-Ansatz solution of the strong coupling region of the Kondo Problem could not be obtained rigorously, the calculation points to a significant modification of the self-energy of the impurity. **Work is in progress** to incorporate this modified expression for the impurity self-energy in predicting the behaviour of magnetic impurity in superconductors.

1.2 Jahn-Teller Interaction in Solids

Compared to octahedral and tetrahedral complexes the Jahn-Teller (JT) problem in metallocenes (symmetry group D_{5h}) is more complicated since the three interactions orthorhombic field (O.F.), spin-orbit (S.O.) and JT are all equally important. These are mutually competing interactions and over estimation of any one may result in to under estimation of the other two. Therefore for a correct assessment of the strength of these interactions, the three must be treated on equal footing. The previous work, which considers only SO and JT interaction on equal footing, is modified to include OF also.

The theory compares well with the ground level behaviour of JT-prone metallocenes. In particular it overcomes the difficulty so far felt in consistent interpretation of Raman spectroscopy, magnetic susceptibility and ESR results in chromocene.

1.3 Theoretical Studies in ESR Analysis

PBF theory of ESR line shape in liquid crystals is simplified. The simplification is based upon the fact that the equations of motion or orientational dependent spin density matrices responsible for microwave absorption are the equations of motion of coupled rotators moving in an anisotropic complex potential. In the slow tumbling region the rotators tend to librate about the extremum points of the potential. Total microwave absorption is the sum of contribution from each liberator. Detailed computation to compare the present theory with the experimental **ESR** results are in progress. Preliminary results are encouraging.

APPLIED PHYSICS PROJECTS

UTILIZATION OF SOLAR ENERGY-THERMAL CONVERSION

1. Test Facilities for Solar Collectors

Test facilities established earlier were used for determination and issue of test reports of solar transmittance and absorptance, normal emittance and UV transmittance of samples received from outside organizations. Work is being continued to modernize and upgrade test facilities so as to bring at par with international level. Action is being taken to acquire high accuracy matching field input/sensors/control sub-systems.

1.1 Development of Copper disc pyrheliometer

A proto-type, developed earlier was field tested and results compared with available Eppley pyrheliometer. Certain modifications with regard to sensor housing and its peripherals needed for achieving consistency in accuracy of measurement of solar radiation, were made and the unit is being reassembled.

1.2 Refrigeration Unit Working on Solar Energy

Based on a patent regarding better heat transfer to any desired gadget, a water ammonia absorption refrigeration system (having a capacity of 5 kg ice per day) working entirely on solar energy was designed and will be fabricated locally. Such a system would be of immense use for rural applications for preservation of vaccines, medicines etc.

increase sensitivity of the system and thereby reduce the dosage have been undertaken. Due to the electrostatic nature of the latent image, a screen in contact with the sensitized plate, like in conventional radiology, results in distortion of the charge pattern and the image. Efforts are being made to solve this problem by vacuum deposition of various materials which are sensitive to X-rays and it would result in the enhancement of the X-ray sensitivity of the photoreceptor plates. Materials which are highly photoconducting like copper doped cadmium sulphide are being examined for this purpose. Electropolishing/cleaning technique to polish metals like aluminium, chrome plated brass, stainless steel etc. is being developed to prepare mirror finish substrates for coating X-ray sensitive materials.

1.1 Development of Toners

Due to the amorphous nature, selenium photoreceptor plates have very high resolution, however, it is limited by the particle size of the toner used in development process. Therefore, in order to attain very high resolution and hence high degree of diagnostic accuracy, toner of the smallest possible particle size is required. Freeze drying technique is being tried to produce ultrafine particles and the preliminary experiments are in progress.

1.2 Development of Prototype of X-Ray Machine

A prototype of X-Ray Machine for hospital trials is now assembled & a corona charging unit has been procured. An aerosol generator with continuous toner feeding arrangement is being fabricated. Block drawing of machine has been made and its full specifications are being worked out

XERO RADIOGRAPHY

1. Photoreceptors

Feasibility studies of Xeroradiography (XR) have already been made and development of laboratory prototype of the xeroradiographic machine, for hospital trials, is in progress. Efforts to

THIN FILM & AMORPHOUS MATERIALS

1. Development of space qualified interference filters/or ISRO

Computer assisted design of multicavity interference filters have been worked out as per specifications laid down by **ISRO**. 8 sets of filters, peaked at different wavelength in the visible region, were fabricated and supplied to **ISRO** for ground based radiometric work. Theoretical analysis of multilayer structures with basic period consisting of three layers having low, intermediate and high refractive indices exhibit very interesting optical characteristics. Theoretical computations were carried out with a five layer stack of the form $L/2 I H I L/2$ where L, I & H denote quarter wave layers of low, intermediate and high refractive indices respectively. This structure was repeated N times where N varies from N = 1 to N = 6. The reflectance curve for a 6 period design shows vary high reflectance (>90%) in the wavelength region of 0.9μ to 1.25μ and high transmission in the visible region. Efforts are continuing to improve the characteristic and to fabricate the structure experimentally.

1.1 Fabrication of Thin Film Devices

Four sets of broad band all dielectric multicavity (4 cavities) interference filters for peak wavelengths 485 nm, 550 nm, 650 nm and 850 nm having half bandwidths of 70nm, 70nm, 60nm and 90nm respectively were fabricated. The optical characteristics of these filters have been approved by ISRO.

A set of 14 neutral density filters, with different transmittance values were fabricated & supplied to SAC Ahmedabad. A set of ION D filters (in the UV region) were fabricated for the Radio Science Division.

Under the sponsored programme on 'Hot Axle Detection System for Railways', Ge lenses were provided with special AR coatings to reduce the reflection losses. Elliptical glass blanks (18) received from HAL, Nasik were given highly reflecting (85%) and durable mirror coatings.

1.2 Metallisation of Ferrite Rods for Phase Shifters

The NPL has been approached to develop metallisation process for ferrite rods to be used in phase shifters by D.R.D.L., Hyderabad. This involves sequential coating of chromium, copper and gold by RF Magnetron sputtering and have near bulk conductivity and high peel strength. Large number of rods have since been coated and the process optimised. A value of 3×10^{-6} ohm-cm. has been obtained for the conductivity of copper layers as against value of bulk conductivity of Cu = 1.55×10^6 ohm-cm. NPL metallised ferrite rods for X and C bands have since been found to perform satisfactorily in phase shifters as reported by I.I.T., Delhi. A scheme for increasing the throughput of the process has been envisaged and is being implemented.

2. Thin Film Amorphous Silicon Solar Cells

The earlier stainless steel plasma CVD system has been modified for the preparation of p+i-n solar cells. The modified system comprises of S.S. Cross Glow Discharge Reactor, Safety interlocks, Upward deposition facility, Provision for biasing of the anode, Gas supply lines with valves and mass flow meter Vacuum pumping station and Scrubber to neutralise the exhaust gases.

Initially, individual p and n layers (using diborane and phosphine dopant gases) were fabricated and deposition parameters were optimised to yield films suitable for p-i-n solar cell fabrication.

Experiments have been conducted to fabricate three different structures of solar cells viz MIS, p+i-n, (small area 0.2 mm²) and Schottky barrier type. The results of preliminary measurements made on these structure are reported in the following:-

(a) MIS structure (Glass/NiCr/n +i-oxide/Au)	
Open circuit voltage	= 0.63V
Short circuit current	= 13.5mA/cm ²
Fill factor	= 00.40
Efficiency	= 6.8%
Input intensity	= 50mW/cm ²
	(52% transmission of gold layer)

- (b) Schottky Cells (Glass/ NiCr/n +-i/Pd)
- | | |
|--------------------------------|-------------------------|
| Open circuit voltage | = 0.45V |
| Short circuit current | = 15 mA/cm ² |
| Fill factor | = 0.28 |
| Efficiency | = 0.28 |
| Input intensity | = 50 mW/cm ² |
| (39% transmission of Pd layer) | |
- (c) p+-i-n + cells(Glass/SnO/p+-i-n +/Al)
- | | |
|-----------------------|---------------------------|
| Open circuit voltage | = 0.6 V |
| Short circuit current | = 7.25 mA/cm ² |
| Fill Factor | = 0.42 |
| Efficiency | = 3.5% |
| Input intensity | = 51.5 mW/cm ² |
| (AM 1.5 light) | |

DISPLAY DEVICES

1. Ferroelectric liquid crystals and their applications

The work on ferroelectric liquid crystals (FLC's) has been initiated in the laboratory with a view to develop fast memory display devices. FLC's can flow like a liquid and attain the shape of the container in which they are kept and simultaneously behave like solid ferroelectrics. These liquid crystalline materials exhibit a P vs E hysteresis (Fig. 1) and possess a temperature dependent spontaneous polarization (Fig. 2) similar to that of solid ferroelectrics.

Ferroelectric liquid crystals having permanent dipole moment perpendicular to their long mole-

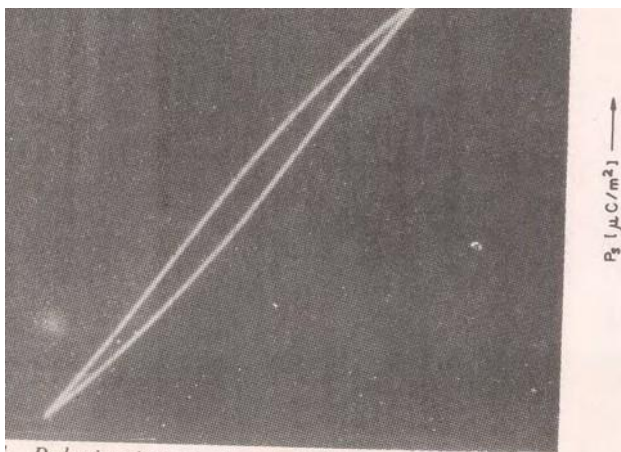


Fig. 1. Polarization vs electric field hysteresis of FLC DOBAMBC at 76 C

cular axis possess a spatially modulated structure characterized by a tilt of molecular direction from the normal to smectic layer which precesses around the normal in successive layers. The featuring characteristics of FLC's are tilt angle, pitch, spontaneous polarization, hysteresis effect and electro-optical switching. We have studied these parameters in DOBAMBC and its mixture with SmC. The dynamics of unwinding and winding processes in FLC's have been studied and analysed in detail the frequency dependence of polarization reversal and the molecular re-orientation processes involved during switching amongst uniform states.

FLC's have potential application in near future of display technology because of the occurrence of bistable states and their microsecond switching amongst them. The electro-optical display devices with 500 μ sec response time, working at higher temperature were developed. Effort to make room temperature fast switching memory display devices is in progress.

2. Development of Liquid Crystal Digital display devices

The positive contrast coloured liquid crystal displays based on guest-host principle in nematic liquid crystals along with suitable dyes were successfully developed. Salient features of these new type of displays include: (i) low voltage operation (3 V r.m.s), (ii) good pleasing contrast (C.R. 4:1) (iii) higher brightness and (iv)

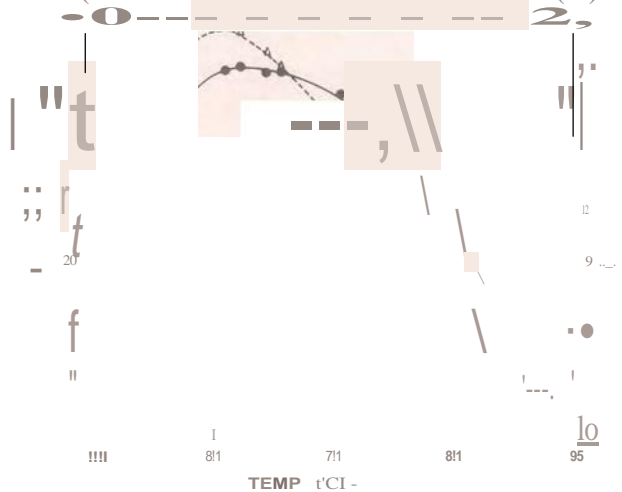


Fig. 2. Spontaneous polarization & effective bulk viscosity vs temperature of FLC DOBAMBC

wider viewing angle. The unique feature involved in the development of these displays has been to promote controlled tilted homeotropic alignment of the LC molecules at the two bounding glass substrates. New process techniques have been developed and stabilized to promote desired tilted homeotropic alignment for making good contrast displays. A number of 3½ digit display devices suitable for clocks, DMM etc. have been fabricated. The developed displays have been characterized for their electro-optic performance characteristics. Fig. 3 is a typical photograph of such a 3½ digit displays developed in the laboratory. The segments of the display have been energized by 3 V r.m.s signal. The display has a contrast ratio of 4:1.



Fig. 3. 3½ Digit LC Display using black dye mixture.

3. Development of Electrochromic Display Devices (ECDs)

Electrochromic thin film devices, based on transition metal oxide WO_3 are in advanced stage of development for display applications. WO_3 when employed as an electrode in an electrochemical cell (Fig. 4) colours cathodically by a reduction process. Stoichiometry, morphology, water content and porosity of WO_3 film. bye-beam technique and introduction of charge injection and extraction mechanism with a specially designed electrode pattern Fig. 5 (a,b) improved the speed colouration & bleaching times. With these innovative techniques and with an aprotic lithium based electrolyte 3½ digits, seven segmented ECDs (Fig. 6) have been successfully fabricated. Activated digits of such ECDs show pleasant blue colouration.

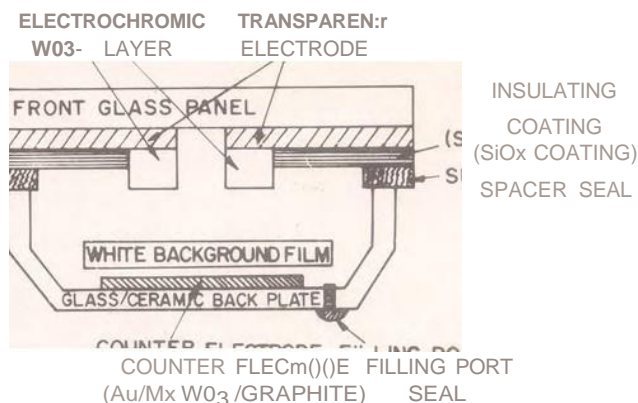


Fig. 4. Schematic diagram of an ECD with a liquid electrolyte

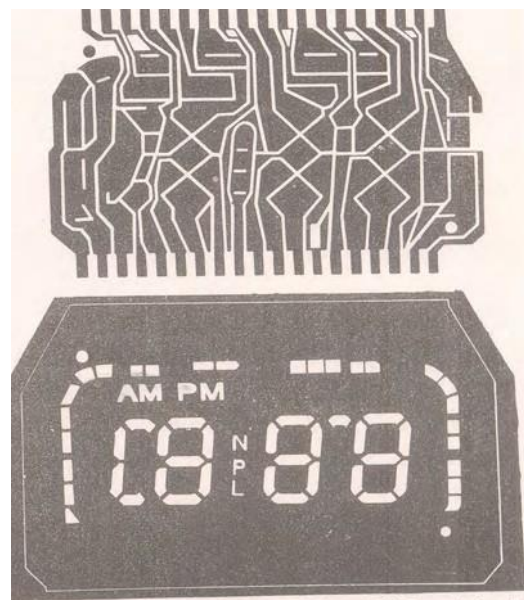


Fig. 5 a Electrode pattern for ECD with dummy segments on both sides of the display segments (b) the corresponding mask pattern

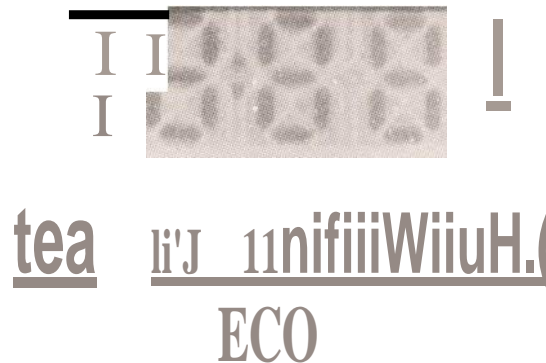


Fig. 6. Photograph of a 3½ digits, 7 segmented ECD. Activated digits show pleasant blue colouration

3.1 Poole-Frenkel Conduction Mechanism in Insulating Oxide Films

The current-voltage characteristics of insulating oxide films of tantalum with metallic film electrodes above and below have been observed to follow the relationship $I = aV \exp (b/A \sqrt{V})$.

The coefficients a and b have been found to depend upon the properties of the oxide film. Anodically oxidized films with b - the non-linearity coefficient - of about 4 could be achieved and resulted in resistivity transformation ratio R_{OFF}/R_{ON} in the range 10^2 to 10^4 .

4. Conducting P-polymers Simultaneous Electrochemically Initiated Polymerization and Doping

It has been experimentally ascertained that organic polymers such as polypyrrole, polythiophene, polyphenylene oxide, pyrrole & polyfuran when suitably doped become electrically conducting. The electrical conductivity of these newer materials - also termed as conducting polymers - can be controlled over several orders of magnitude (from insulator to semiconductor). Repeated experimental observations made on some of the polyheterocyclic and polyaromatic conductors (whose ground states are energetically non-degenerate) prepared in the laboratory by simultaneous electrochemical polymerization and doping methods have brought out that the mechanism of electrical conduction in these synthetic "molecular semiconductors" can neither be electronic nor ionic. It appears that it is the radical cations and di-cations which essentially transport the electrical charge. Our quest for a deeper understanding of the origin of electrical conduction in these materials has been further motivated by the recent revelation that the conductive polymeric films change their respective colour on switching and hence have possible applications in electro-optic displays.

HIGH PRESSURE PHYSICS AND TECHNOLOGY

1. Development of Superhard Materials

A new jig has been devised for mechanical characterisation of the strength of single crystal

diamond cBN under an impact loading. The strength of single crystal diamond has been found to be comparable with that of crystals marketed by standard commercial houses. Investigations were continued to optimise the process parameters to obtain satisfactory compacts of cBN. Ne₂ binders were tried in order to achieve an acceptable compromise between the toughness and the hardness of the compacts.

In high pressure investigations above 30 kbar, pyrophyllite is the usual material used as the pressure transmitting material. Efforts are being made to recycle the pyrophyllite powder obtained during the machining of the high pressure reaction cell and also to evolve an alternative mineral of indigenous origin which could be used in place of pyrophyllite.

2. Hot extrusion, cold forging and design

The hot extrusion technology for the manufacture of stainless steel 321, 316 using glass lubrication, Inconel 70/30, 90/10, aluminium brass has been developed. The report has now been completed and submitted to the Ministry of Industry for implementation. On the basis of experience gained in trial runs on hot extrusion, it was felt that some major modifications were required on the 500-tonne press.

A joint project has been initiated with NML for developing Magnetic alloy (Mn-Al-C) by hot extrusion process. NML will develop the casting of this alloy and will supply billets to NPL for hot extrusion. These will be used as permanent magnets for industrial applications. One billet was made available by NML but due to casting defects the billet broke into pieces and could not be extruded.

Initially, two steel components from Maruti Udyog Ltd. were identified, their sequence of operations and tool design finalised. In the meantime, lubricating and heat treatment techniques were optimised. Few trial runs for producing a copper sleeve cold forged to study the metal-flow characteristics were made.

3. Shear spinning

The shear spinning technology is particularly

useful for various **R&D** activities involving the applications of tubes in newer exotic materials and also, where IO production volumes are envisaged. A major effort has been directed towards developing short mandrel technology for processing tubes upto 4 metres in length.

Considerable R&D effort has been devoted to the

processing of special grade stainless steel tubes required by the Reactor Research Centre Kalpakkam for their project on sodium cooled fast breeder reactor. The tubes shear spun here met their six-cifled tolerances and the first batch of 110 tubes has already been delivered to them.

SERVICE SECTIONS

WORKSHOP

1. The fabrication of instruments, apparatus, gadgets etc., for various projects of the laboratory was continued. About 2360 job orders valued at Rs. 18.5 Lakhs approximately were completed. The major jobs were-Boss heads; goniophotometer; mirror mount; gear boxes; rocket & balloon ayloads; diffractometer, diesetc.

1.1 Drawing & Design Section

The section assisted scientists for Mechanical Design & Drawing, writing charts for their seminars etc. and making graphs/curves for their publication work. The section assisted central workshop as required. About 500 jobs were completed during the year. Some of the important jobs were:-

Precision **X-Ray** Diffractometer; microscope object table x-y movement system; SROSS project; microwave Antenna; constant Temp. oilbath; helican feed antenna; Gerdian condenser; rotating system of integrated sphere; simulating boiler; Goniophotometer and stand for weight hanger of primary standard etc.

GLASS TECHNOLOGY WORKSHOP

The unit assisted in the design, fabrication & reconditioning of glass and silica equipment to various **R&D** Projects of the laboratory. The jobs included high vacuum standard joints; stopcocks; mercury & oil diffusion pump; quartz & teflon stopcocks. discharge & laser tubes. glass to metal seals; dewar flask; liquid purification apparatus; quartz reaction chamber etc.

The unit also assisted various organisations & institutions in the fabrication of glass equipment as per their requirements such as graded glass seals; quartz cells; McLeod gauge; glass cryostat; var, us-tat and Older Shaw Column etc. Some of the beneficiaries are-IARI, BHEL, SSPL, IIP, Indian Oil Corp.. Universities of Chandigarh, Kur-

ukshetra. Aligarh & Hyderabad; M/s Dabur (P) Ltd. Ghaziabad, LNJP Hospital, Nuclear Research Lab. etc. The receipts of the jobs done for outside parties amounted to Rs. 2.1 lakhs approximately.

WORKS AND SERVICES

1. Air-Conditioning & Electrical Sections

Completed design & supervised the works of class 100.000 Clean Rooms at 11nd floor. Provided electrical services including telephone maintenance and operation of the diesel generator sets.

1.1 Civil Engineering, Honieulture, HLS Sections

Completed design, execution of the extension of the 11nd floor. estimates for Guest House and other time targetted works in connection with Symposia/Seminar. civil works in connection with Clean Rooms were under taken. Carried out routine maintenance and special repairs in the laboratory and NPL Colony.

LIBRARY

With the availability of a centralised computer facility the library initiated its computerisation activities. Consequent upon its efforts in this regard journal subscription records for 1986 have been taken on a computer file. The library has already prepared subscription lists in different formats using the data base developed for the purpose.

Under the collection development activities the library acquired 435 books, subscribed 302 journals, and received about 100 journals as gratis and in exchange. The emphasis in acquisition was once again on need-based literature in physics and related sciences. The expenditure ratio between journals and books was 86:14.

Its technical section diC: the cataloging of 426 books and monographs. In addition 1093 bound volumes of periodicals were added and 288 standard specifications catalogued. The library continued to maintain its status as an inspection centre for Indian patents. Under this arrangement it continued to receive Indian patents from the Indian Patent Office, Calcutta.

The library maintained its lending and consultation facilities. It issued a total of 5000 publications to its scientists, and 600 to libraries of other institutions such as DESIDOC, **INSA**, INSDOC, IOC, EIL, IMD, IIT, Delhi University. It borrowed 144 publications on inter-library loan.

In addition the library continued to provide documentation services which it had initiated in 1972. Under the **SDI** service a total of 1850 references were provided. Under its bibliographic services a total of six bibliographies were supplied. For improving the photocopying facilities the existing photocopying machine, Xerox 320, was replaced with a heavy duty machine, Modi xerox 1045. The library turned out a total of 1,26,770 photocopies during the year.

COMPUTER FACILITY

Computer Facility works as a central facility for all **NPL** staff. The following are the main areas of computer application in **N.P.L.**

Theoretical modelling; Process simulation; Design optimisation; Statistical analysis; Empirical modelling of geophysical parameters; Data processing of different measurements; Computer-aided design; Computer-aided measurements; Graphics and Office-automation.

The VAX-11/780 computer system, which was ordered during 1984, was finally cleared for export by the U.S. Govt. in the middle of 1985 and the main computer consisting of CPU, main memory, discdrives arrived in March 1986.

Due to the undue delay and uncertainty in the receipt of this, the Zenith SC computer system was procured and installed in June 1985. It consists of MC 68010 CPU, 1 MB memory, 40 MB disc drive, 2 floppy drives and 4 terminals. This system was made available for use to all **NPL** staff since August 1985.

A number of scientific programmes were developed for use by scientists. Payroll software was developed to suit the needs of **NPL** establishment. The necessary inputting of pay data of the staff has started. Training courses for **NPL** staff were conducted by the scientists of the Computer Facility in BASIC and FOR TRAN programming languages.

PHOTOGRAPHY SECTION

This section assisted the scientific and technical staff as well as various activities of the laboratory in the various types of photographic work such as scientific instruments, equipments, experimental set ups etc. Also about two dozen conferences, seminars, workshops, CSIR functions and exhibitions have been covered by this section. I.A.U. was one of the biggest coverage in which more than 800 exposures were taken. The section has completed more than 850 jobs which include about 12,000 prints and 2,500 colour slides. A process has been developed for toning B & W slides in various colours for projection.

APPENDICES

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54. Optical properties of black nickel selective surface by conversion coating process. J.S. Vaishya, J.C. Tripathi, No. 86-77.
55. Study of submicron Inorganic Photoresists: silver-Amorphous chalcogenide system. S.T. Lakshmi Kumar, No. 86-78.
56. Preparation and study of M_3O_4 thermistors. **S.K.** Sarkar, M.C. Sharma, **S.K.** Lahiri, No. 86-79.
57. A simplified two dimensional ray tracing programme for radar tracking errors in tropical troposphere. R.S. Dabas, B.M. Reddy, No. 86-80.
58. Macroscopic properties and electro-optical response of the mixture of ferroelectric liquid crystal and SmC. S.S. Bawa, **A.M.** Biradar, S. Chandra, No. 86-86.
59. An approach for collector area optimization for solar hot water system. J.S. Vaishya, T.C. Tripathi, No. 86-87.
60. Calibration/testing facilities provided to various organisations during year 1984-85. H.K. Thadani, No. 86-89.

**GENERAL LIST OF GOVT. DEPARTMENTS/PUBLIC SECTOR UNDERTAKINGS/PRIVATE
SECTOR ORGANISATIONS WHICH GOT ITEMS CALIBRATED/TESTED BY N.P.L.**

Government Departments

- | | |
|---|--|
| <p>1. Controller of Weights & Measures, Hyderabad, Madras, Tripura, New Delhi, Shimla, Chandigarh, Trivandrum, Gawahati, Ahmedabad, Kola & Jodhpur.</p> <p>2. Directorate General of Supplies & Disposals, New Delhi.</p> <p>3. Deptt. of Atomic Energy, Madras</p> <p>4. Deptt. of Weights & Measures, Kathmandu (Nepal)</p> <p>5. Election Commission, New Delhi</p> <p>6. Electronic Regional Test Laboratory, New Delhi and Calcutta.</p> <p>7. Electricity Boards of Gujarat, Kerala Rajasthan & Bombay</p> <p>8. Electrical Inspectorates of Uttar Pradesh, Tamil Nadu.</p> <p>9. New Delhi Municipal Committee.</p> <p>10. Nuclear Fuel Complex, Hyderabad.</p> <p>11. Public Works Departments of Jodhpur, Jaipur, Bikaner, Ajmer, Banswara, Bhilwara, Bharatpur & Delhi.</p> <p>12. Southern & Western Railways.</p> <p>13. Customs Department.</p> <p>14. Post & Telegraph Deptt. New Delhi</p> | <p>References & secondary standard weights, Reference and secondary standard length measure, thermometer.</p> <p>GLS lamps, HPMV lamps, air cooler.</p> <p>Proving ring.</p> <p>Secondary standard weights.</p> <p>Indelible ink.</p> <p>Fluke calibrator, spectrum analyser, standard cell, standard capacitors & inductors, DC voltmeter Q standard, millivoltmeter.</p> <p>RSS wattmeter, lamps, pressure gauge</p> <p>Wattmeter, current transformer, energy-meter, sub-standard wattmeter.</p> <p>Thermal conductivity.</p> <p>Proving ring</p> <p>Proving ring, pressure gauge.</p> <p>Proving ring</p> <p>Flash point apparatus, thermometer, lensc</p> <p>Telephone sets.</p> |
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Defence Departments

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|---|---|
| <p>15. Air Force Stations New Delhi, Kanpur, Chandigarh</p> <p>16. Controllerate of Inspection Electronics, Bangalore.</p> <p>17. Inspectorate of Armament & Vehicles Delhi, Pune & Madras</p> <p>18. Inspectorate of Military Explosives, Itarsi, Jabalpur & Pune.</p> | <p>Standard resistors, standard cell, standard inductors, standard capacitors, set of seedy weights, pressure gauge, surface plate, frequency, counter, attenuator.</p> <p>Standard resistor, standard voltage reference.</p> <p>Traction power tester, lenses head light, slipgauge & wheatstone bridge.</p> <p>Thermometer.</p> |
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R & D Academic Institutions

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|---|---|
| <p>19. B.A.R.C., Bombay.</p> <p>20. C.S.I.R. Laboratories and Institutes.</p> <p>21. Indian Standards Institution, New Delhi.</p> <p>22. I.I.T., Madras.</p> <p>23. V.S.S.C., Trivandrum.</p> <p>24. Cement Research Institute, New Delhi</p> <p>25. R.D.S.O.; Lucknow</p> | <p>Set of weights, proving ring.</p> <p>P.R.T., standard resistors, proving ring, X-ray, thermo-meter, thermocouple, P.F. Meter, wattmeter, standard lams and coal sample.</p> <p>Hearing aid, safety glass, insulation wool, hydrometer, GLS lamps, helmet, TFL lamp.</p> <p>Thermocouple.</p> <p>Thermocouple, weights.</p> <p>Noise measurement.</p> <p>Proving ring, sound level meter.</p> |
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Public-Sector Under-takings

- | | |
|---|---|
| <p>1. Abad Dairy, Ahmedabad</p> <p>2. Air India & Indian Air Lines.</p> | <p>Hydrometer, lactometer.</p> <p>Micrometer, ring gauge therm., couples and thermometer.</p> |
|---|---|

3. Bharat Heavy Electricals Ltd., Bangalore. Bhopal. Har-dwar, Hyderabad, Janshi and New Delhi.
4. Bhart Petroleum & Indian Oil Corporation, N. Delhi.
5. Bharat Electronics Ltd., Bangalore.
6. Cement Corporation of India. Bilaspur.
7. Electronic Corporation of India Ltd.. Hyderabad.
8. Export Inspection Agency. New Delhi
9. Hindustan Aeronautics Ltd., Bangalore, Hyderabad, Kan-pur, Koraput, Lucknow & Nasik.
10. Hindustan Photo & Films Ltd.. New Delhi, Madras.
11. Heavy Engg. Corporation Ranchi.
12. Indian Telephone Industries, Allahabad.
13. Instrumentation Ltd., Kota and Palghat.
14. Keltron, New Delhi.
15. National Thermal Power Corporation, New Delhi. Mir-zapur.

Private Organisations

- Assam Carbon Products Ltd.. Gauhati
K.G. Khosla Compressores Ltd. Faridabad
 Blue Star Ltd.. New Delhi
 Delhi Scientific Works. Delhi
 Dhingra Scientific Instrument Co. Delhi
 Fibre Glass Pvt. Ltd.. New Delhi
 Gcep Industrial Syndicate. Allahabad
 Horstmann India Pvt. Ltd.. Pune
 LEIMCO. Bombay
 Letape (1) Pvt. Ltd.. New Delhi
- Larsen & Toubro Ltd.. Bombay
- Metronic Instruments Co.. New Delhi
 Precision Balance. Calcutta
 Scientific Instrument Co. Ltd.. Ghaziabad
 Swastik Pipe Pvt. Ltd.. New Delhi
 Shankar Wire Products Industries. Dcoghat (Bihar)
 Temp-Tech. New Delhi
 T;Ita Engg. & Locomotive Co.. Punc
 Western Electronic Components Pvt. Ltd.. Delhi
- Auto Lamps Ltd.. New Delhi; Atlas Industries. Bombay; Ajay
 Electricals. New Delhi; Ciclmac (P) Ltd. Bombay; Abhay
 Electrical Lamp Industries. Ratlam; Apar Pvt. Ltd.. Pune;
 Bengal Lamps Ltd.. New Delhi; Bijlcc Products India. Punc;
 Crompton Greaves Ltd., New Delhi; Lamps & lighting Ltd..

Weights. measuring machine slip gauge, ring gauge, pressure gauge, dead weight tester, thermocouple, thermometer, phasemeter. wattmeter, sound Jevelmeter.
 Thermometer, hydrometer, pressure gauge.

Standard resistance inductance & capacitors.
 Proving ring.
 Standard capacitors. standard inductance, standard voltage cell, high megohm resis-tance.
 Head lamp fitting and Head lamp assembly.
 Pruving ring, potentiometer, thermocouple, slip gauge, attenuator, standard. capacitors, inductor, tensometer. **LCR** meter, standard resistance.
 Bulbs. audio tape.
 Technical compensator.
 AC/DC calibrator, standard capacitor & in-ductance.
 Pressure gauge, resistance and bridge box, dynamometer.
 Sound projector.
 Activated carbon. Rotary sub-standard, me-ter, **X-ray** sample, Trivectorrnmeter.

Carbon Blocks.
 Nozzles and Techometer.
 Dynamometers.
 Hydrometer and Polarimeter tubes.

Sound absorbing material.
MnO₂ Ores.
 Discs.
 Thermometer & Hydrometer.

Measuring tapes. thermocouple and micro-meter.
 Pressure gauge and slip gauge.
 Termometer. Weight box.
 Microwave components.
 Plug gauge.
 Weights
 RTD Thermocouple
 Slip gauge & auto lamp.

Magnetic tape.

Auto Lamps. GLS Lamps. Lamps. Tube fitting. Head lamps. wattmetcr & Elcctncal Fiuings.

Alwar; Prakash Tubes Ltd.. Nainital. New Delhi; Philips India. New Delhi; Sylvania & Laxman Ltd.. New Delhi; Electric construction & Equipment Co .. New Delhi; Lumcx Industries Ltd., New Delhi;.

Associated Instruments Mftg. Ltd .. New Delhi; Associated Scientific & Engg. Works, Delhi; Allied Scientific & Engg. Corporation. Delhi; Continental Soler Syndicate. Delhi; Hydraulic & Engg. Instrument Co., Delhi; IT Incorporate, Bombay; Lawrence & Mayo (I) Pvt. Ltd.. Delhi; Mctronik Instrument Co., New Delhi; Mallick Engg. works, Delhi; Precision Scientific Equipment Corporation. New Delhi; TISCO.Jamshedpur.

Pressure gauge. Proving ring. cylindrical cups. Flow cups. Flash point apparatus. Lead cell.

STAFF STRENGTH
(As on 1.6.1986)

Category	Nos.
<i>Scientific</i>	
Scientists	304
Technical Officers	90
Establishment	582
Group D	116
<i>Others</i>	
Officers	19
Establishment	158
Group D	69
Total	1338

PERSONNEL

(ason 31.3.1986)

DIRECTOR, MITRA, DR. A.P. (UPTO FEB. 25, 1986)
ACTING DIRECTOR, KAILASHCHANDRA, DR. (w.e.f. Feb. 26, 1986)

SCIENTISTS & OFFICERS

DIVISION OF STANDARDS

Aggarwal. **N.K.**
Aggarwal. Ritapder
Agrawal. Dr. **V.K.**
AnilKumar
Arora. T.R.
Ashwani Kumar. Dr. **P.K.**
Bahl, (Mrs.) Madhu
Bahl, P.P.
Banaudha. Inderjeet
Bandopadhyay, Dr. A.K.
Banerjee, Dr. **P.**
Batra. **V.K.**
Bhaskar. **H.L.B.**
Bhatnagar. **H.M.**
Bhatnagar, **K.N.**
Bhola, O.P.
Chakraborty. Dr. B.R.
Chatterjee. (Mrs.) A.
Chaudhuri, M.K.
Chitnis. Dr. V.T.
Dahake. Dr. S.L.
Dahiya, Dr. H.S.
Dandavate, Dr. V.D.
Das Gupta. M.K.
DasM.L.
Das, Dr. S.R.
Dhar, Dr. R.N.
Dhawan, J.K.
Dutta, P.K.
Ganapathy, T.V.
Gera. Dr. B.S.
Gautam. C.B.L.
Goel. G.K.
Govil. **A.K.**
Gumber. Dr. **V.K.**
Gupta. A.C.
Gupta. A.K.
Gupta. Dr. Dcvendra
Gupta, S.C.
Gupta. S.R.
Gupta. Dr. **S.V.**

Gurdial Singh
Gurmej Ram
Hanjura, Dr. A.K.
Jain. Dr. **K.K.**
Jain, Dr. P.C.
Joginder Singh
(S/o Mr. Bachan Singh)
Joginder Singh
John. P.C.
Joshi, Dr. K.C.
Kailash Chand
Kandpal, Dr. H.C.
Kanji Lal, **A.K.**
Karfa. **M.**
Kaushik, (Mrs.) **A.R.**
Kewal Krishan
Khandekar, R.S.
Khanna, Dr. O.N.
Khanna, **R.K.**
Khanna. **R.M.**
Kohli, N.K.
Kowsalya, (Mrs.)
Kothari, Dr. P.C.
Kulkarni, Dr. V.G.
Kulshreshtha, Dr. **R.K.**
Lakshmi Kumar Dr. S.T.
Luthra, **R.K.**
Mahajan, Dr. **S.K.**
Mahesh Chander
Maini, H.K.
Mallela, (Mrs.) S.B.
Manrai (Mrs.) S.
Mansha Ram
Mathur, B.G.
Mathur, Dr. B.S.
Mathur, (Mrs) S.P.
Mehrotra. Dr. Ravi.
Mithan Lal
Mittal. M.K.
Mittal. P.K.
Mohanan. Dr. V.
Mohinder Nath
Nagar. M.R.

Nangia, S.N.
Negi, P.S.
Ojha, V.N.
Om Prakash
Pahwa, D.R.
Prabhakar, A.C.
Pradeep Mohan.
Puntambekar, Dr. P.N.
Ram Narain.
Ram, Dr. R.S.
Ram Swarup.
Roonwal, (Mrs.) V.
Roy, B.K.
Rustogi **V.K.**
Sarkar, Dr. **S.K.**
Sarma. K.S.
Saxena, **A.K.**
Saxena, Dr. G.M.
Saxena, (Mrs.) **M.**
Sen Gupta, Dr. A.
Sharma, Dr. D.R.
Sharma, Dr. **J.K.N.**
Sharma Omkar
Sharma, **R.S.**
Singal, Dr. **S.P.**
Singha!, **R.P.**
Sing6, C.P.
Singh, S.K.
Singh, **Y.P.**
Sood, P.C.
Srivastava, **N.K.**

Surinder Singh
Suri. S.P.
Taneja. **K.C.**
Taneja. **P.N.**
Tanwar, L.S.
Thadani, **H.K.**
Tripurari Lal
Verma, Dr. **S.P.**
Vijay Kumar
Wasan, **V.P.**
Yadav. Dr. **R.S.**

MATERIALS CHARACTERIZATION

Aggarwal, Dr. A.K.
Amar, V.K.
Ananthamurthy, Dr. R. V.
Bhagavannarayana, G.
Bohra, Dr. J.N.
Dhawan, U (Mrs.)
Garg, R.K.
Gupta, Dr. P.K.
Gupta, Pr bhat Kumar
Gupta, Dr. S.K.
Halidar, Dr. S.K.
Jitendra Rai
Krishan Lal, Dr.
Kundra, Dr. K.D.
Malhotra, G.L.
MewaSingh.
Nagpal, Dr. K.C.
Narendra Kumar.
Parashar, Dr. D.C.
Parthasarathy, S.
Pradhan, Dr. **M.M.**
Ramachandran R. (Mrs.)
Raman, Dr. (Mrs.) Vasantha
Rao, S.U.M.
Sarkar, Dr. **A.K.**
Shanna, Dr. S.D.
Sharma, Dr. S.K.
Suri, D.K.
Trehan, J.C.
Vijay Kumar, Dr.

CRYOGENICS & SUPERCONDUCTIVITY

Babbar, N.K.
Ekbote, Dr. **S.N.**
Gera, S.C.
Gupta, Dr. **A.K.**
Hari Krishan, Dr.
Jain, Dr. A.P.
Jayaram, Dr. 8.
Kasturi Lal
Kataria, Dr. N.D.
Man Mohan Krishan
Narlikar, Dr. A.V.
Natarjan, Dr. N.S.
Rai, Dr. Ramji
Reddy, Y.S.

Samanta, S.B.
Saxena, R.B.
Sharma, Dr. R.G.
Sundaram, R.
Tomar, Dr. V.S.
Vashisht, S.C.

APPLIED PHYSICS PROJECTS

Aggarwal, A.K.
Agnihotri, Dr. (Mrs.) S.A.
Anandan, C.
Anandani, R.C.
Bachan Singh
Bahl, S.D.
Basu, Dr. A.
Bawa, Dr. S.S.
Bhateja, R.C.
Bhattacharya, Dr. P.
Bhawalkar, Dr. R.H.
Bindal, Dr. M.M.
Biradar, Dr. A.M.
Chakraborty, **T.K.**
Chopra, Rajeev
Devendra Singh
Dhar, Ajay
Dixit, Dr. P.N.
Ganga Parshad
Gupta, A.K.
Hegde, Dr. M.S.
Jain, Dr. S.C.
Kamalasanan, Dr. M.N.
Kar, Dr. (Mrs.) Mecnakshi
Kumaraswamy, B.V.
Loganathan, B.M.
Malik, I.A.
Misra, Dr. S.C.K.
Nayar, R.K.
Panwar, Dr. O.S.
Panwar, **V.S.**
Ramadhar Singh, Dr.
Ram Prasad
Saini, K.K.
Shah, Dr. **V.V.**
Sharma, Dr. C.P.
Sharma, D.C.
Sharma, S.L.
Singh, Dr. B.P.
Singhal, Dr. S.K.
Subhash Chandra, Dr.
Suresh Chand, Dr.
Tagra, O.P.

Vaishya, Dr. J.S.
Ved Singh
Verma, Dr. B.S.
Verma, N.S.
Verma, S.S.
Virendra Babu

MATERIALS

Aftab Ahmed Aggarwal,
R.K.
Arora, Dr. N.K.
Ashok Kumar, Dr.
Awasthy, B.R.
Bahl, Dr. O.P.
Balbir Singh
Bangari, N.S.
Bhatia, Dr. Gopal
Bindal, Dr. V.N.
<;hakravarty, Dr. B.C.
Chhotey Lal
Das, Dr. **B.K.**
Datta, **K.K.**
Dhami, Dr. T.L.
Ghosh, Dr. **P.K.**
Goel, R.C.
Govindaswamy, C
Hanspal, S.S.
Harish Chander,
Jain, (Mrs.) Kiran
Jain, Dr. S.K.
Janardan Singh, Dr.
Kalsi, H.S.
Kapur, S.K.
Khullar, S.M.
Khurana, B.S.
Kotnala, Dr. R.K.
Manmohan, S.B.
Manocha, Dr. **L.M.**
Mathur, Dr. **R.B.**
Mohan Lal, Dr.
Mukesh Chandra
Narang, **H.P.**
Narayanaswamy, **N.**
Ramanathan, P.V.N.
Ramanathan, S.
Ram Kishore, Dr.
Saksena, Dr. **T.K.**
Sastri, Dr. V.D.P.
Satbir Singh
Seth, Dr. R.L.
Shanker, Dr. V.

Sharda. S.K.
Singha!. S.K.
Singh, Dr. P.K.
Singh. Dr. S.N.
Singh. Dr. V.R.
SivaRam, P.
Som. Dr. J.N.
Subhash Chandra
Tandon. Dr. R.P.
Tripathi, Dr. R.B.
Verma.C.L.

RADIO SCIENCE DIVISION

Aggarwal Dr. (Mrs.) **S.**
Arya. B.C.
Banerjee. A.
Banerjee. Dr. **P.K.**
Bhattacharya. Dr. **K.**
Chopra. (Mrs.) P.
Dabas. Dr. R.S.
Dua. M.K.
Dutta. Dr. H.N.
Garg S.C.
Ghosh. Dr. A.B.
Goel. Dr. **M.K.**
Gupta. J.K.
Jain. Dr. A.R.
Jain. Dr. S.L.
Kundu. (Mrs.) N.
LakhaSingh
Lakshmi. Dr. (Mrs.) D.R.
Mahajan. Dr. **K.K.**
Mahendra Mohan. Dr.
Malhotra. P.L.
Nakra. D.R.
Pandey. Dr. V.K.
Pasricha, Dr. P.K.
Prasad. M.V.S.N.
Raina. Dr. M.K.
Rajput. S.S.
Ramna Murty Dr. Y.V.
Rao. Dr. B.C.N.
Rao. Dr. M.N.M.
Reddy. Dr. B.M.
Sachdeva. V.P.
Saha. Dr. A.K.
Saksena. Dr. R.C.
Sarkar. Dr. S.K.
Sarma. Dr. S.B.S.S.
Shakdhar. M.L.
Sharma. Dr. M.C.

Shastri. (Mrs.) S.S.
Somayajulu. Dr. Y.V.
Srivastava. Dr. B.N.
Subrahmanyam. P.
Tandel. C.B.
Tewari. D.K.
Thomas. John
Tyagi. Dr. T.R.
Uppal. Dr. G.S.
Upreti. U.C.
Vashisht. A.R.S.
Venkatachari. Dr. R.
Vijay Kumar. P.N.
Vohra. V.K.
Zalpuri. Dr. K.S.

WORKSHOP

Anand. J.R.
Chhibbr. **M.K.**
Dua. C.S.
Harish Chand
Khanna. R.
Nagpal. M.L.
Ojha. J.N.
Poddar. H.N.P.
Sarkar. M.L.
Sehgal. M.G.

GLASS TECHNOLOGY WORKSHOP

Biswas. M.K.
Chandan Singh
Hans. G.S.
Jusht. M.C.
Kani Ram
Kamai! Singh
Razdan. D.N.
Sen, S.S.
Sengupta. S.K.
Shashi Bhushan
Vashisht. J.P.
Verma, M.L.
Verma. V.P.

WORKS AND SERVICES

Kapur. S.S.
Krishnamurty. K.V.
Kumar. C.S.P.
Makhloga. K.S.

Raj Singh
Sharma. J.C.
Singh R.S.
Tomar. T.R.

Library

Ashok Kumar
Dhawan. S.M.
Phull. S.K.
Srivastava. G.S.
Sudarshan Kumar

COMPUTER FACILITY

Jain. V.C.
Saksena. **T.K.**
Sethi. **N.K.**

PLANNING & LIAISON

Arora. G.K.
Balchandani. **M.K.**
Bhakri. S.S.
Khanduja. R.S.
Khullar. F.C.
Kohli. P.K.
Malik. **M.K.**
Manda!. (Mrs.) S.
Rao. M.K.D.
Sharma. S.K.

EMERITUS SCIENTISTS

Ali. Dr. (Mrs.) S.Z.
Baveja. K.D.
Sen. Dr. D.
Verma. Dr. A.R.

RESEARCH ASSOCIATES/POOL OFFICERS

Agarwal. Dr. S.K.
Goswami. Dr. (Mrs.) S.N.N.
Kar. Dr. J.
Karmaker. Dr. D.D.
Malhotra. Dr. B.D.
Padam. Dr. (Miss.) G.K.
Parsad. H.K.
Ravcesh Kumar

Risa!Singh. Dr.
 Sharma. Dr. R.K.
 Subrahamanyam.Dr. C.V.

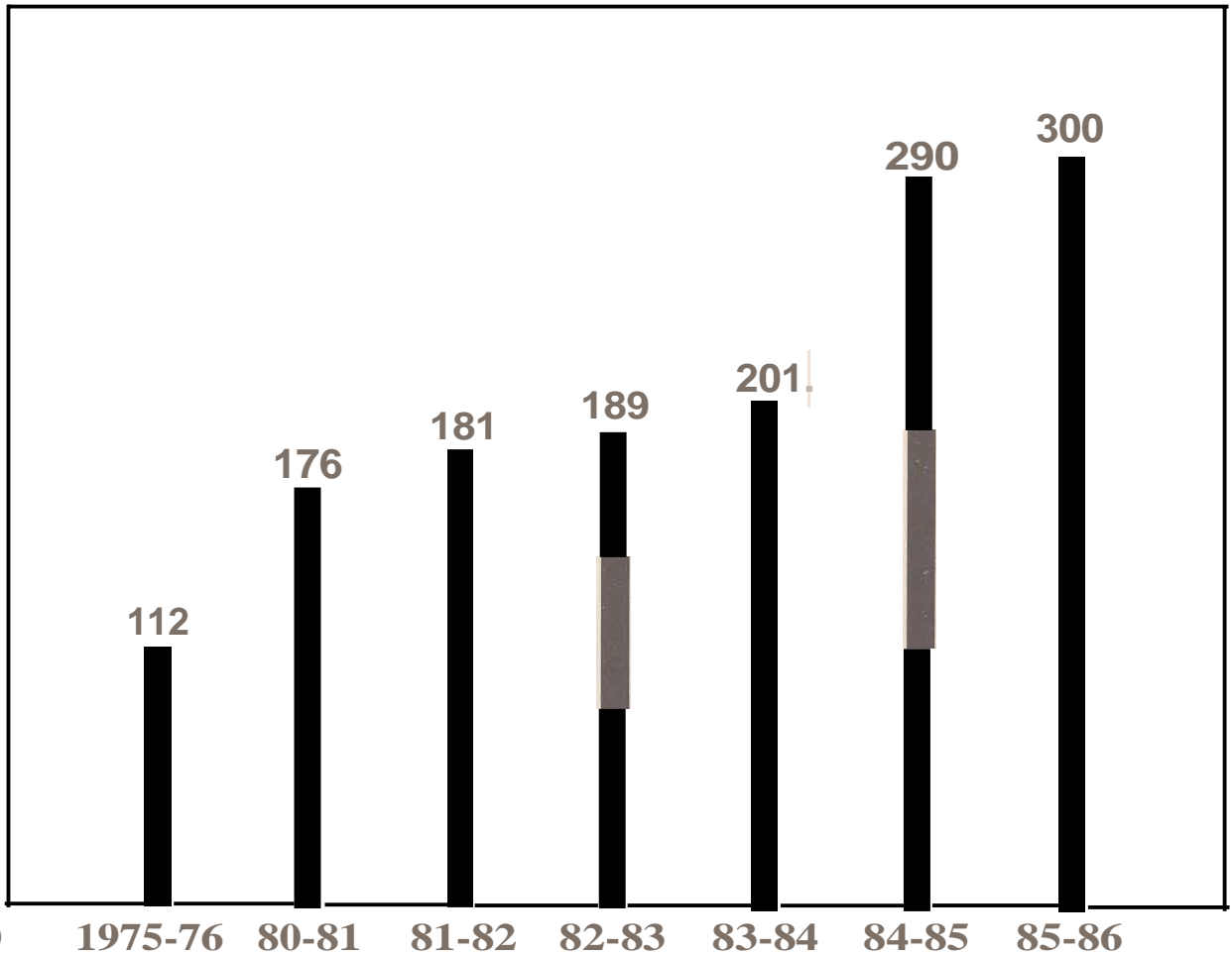
OTHERS

Dhawan. R.C.
 Dwivcdi.S.
 Juneja. S.L.
 Thakur. Dr.. Arvind

ADMINISTRATION/ACCOUNTS-

Bansal. P.O.
 Bhasin. R.K.
 BijaySingh
 Chopra. B.B.
 Dewan Singh
 Diwan.B.K.
 Gupta.S.L.
 Joseph. (Mrs.) S.A.
 Lal. D.B.

Lal. R.B.
 Lakhpat Singh
 Meni.O.P.
 Pandey. S.S.
 Pran Nath
 Sardana. J.M.
 Sharma.J.C.
 Sharma. R.K.
 Verma.O.P.
 Vidya Sarup.



GROWTH OF TOTAL SCIENTIFIC MANPOWER 1975-85.
 <Scientist B & above>

VISITS ABROAD

SI. No.	Name of Scientist	Month(s)	Country(s) visited	Purpose
2		3	4	5
1.	Shri M.L. Das	April. 1985	France	Visited BIPM for recalibration of prototype Kgs & to undergo in-house training in calibration.
2.	Shri P.K. Dutta	May-Oct.,85	U.K.	CSIR-British Council TCTP Award.
3.	Dr. A.P. Jain	May.1985	Japan	Attended the meeting-cum-Conference of the Commission Clg International Instt. of Refrigeration, Paris.
4.	Dr. A. Sengupta	For 16 months w.e.f. 3rd June, 85	F.R.G.	Fellowship offered by the German Academic Exchange Services.
5.	Dr. G.M. Saxena	May-June, 85	U.S.A.	Attended the 39th Annual Frequency Control Symposium at Philadelphia and visited Kansas State University.
6.	Dr. L.M. Manocha	June-Nov., 85	Japan	Under JSPS Fellowship.
7.	Dr. S.R. Gupta	June, 1985	Canada	For getting trained in the operation and maintenance of CTPT Comparator Assembly equipment at Soleman Instruments.
8.	Dr. N.D. Kataria	June-Aug., 85	F.R.G.	Attended the International Conference on Superconducting Quantum Device (SQUID).
9.	Dr. A.P. Mitra	July, 1985	Italy	Attended the Conf. on South-South & South North Cooperation in Science.
			France	To discuss URSI matters with UNESCO, ICSU etc.
		Oct., 85	F.R.G.	Attended the National Committee of URSI & ICSU.
			USA	Discussion on MAP matters

2	3	4	5
			with U.S. Academy of Science &NASA.
		France	Attended the meeting of CIPM.
	Dec.,85	USA	Attended the meeting of Glo- bal Ionosphere & Aeronomy Study.
10. Dr. Ved Ram Singh	July, 85	Australia	Attended the 4th meeting of world Federation on Ul- trasound in Medicine & Bio- logy.
	Nov.-Dec., 85	Japan&U.K.	INSA-Royal Society Ex- change Programme.
11. Dr. V.N. Bindal	July, 1985	Australia	Attended the Seminar 'Stan- dardization and Measurement in Diagnostic Ultrasound'.
12. Dr. P.C. Mehendru,	Sept., 1985	F.R.G.	Participated in the 5th In- ternational Symposium on Electretes (ISES) and visited Laboratories.
13. Dr. S.R. Das	Sept., 85	Spain	Attended the 8th European Conference on Visual Percep- tion.
14. Dr. P.C. Jain	Oct., 1985	South Korea	Participated in the workshop on 'National Standards Sym- posium'.
15. Dr. B.M. Reddy	Sept-Oct., 85	U.S.A.	Attended the International Workshop on Sundial and vi- sited U.S. Naval Res. Lab.
	Dec.,1985	Iraq	As a member of the Indian Delegation.
	March, 1986	USA	SUNDIAL Workshop.
16. Dr. S.P.Singal	Oct., 85	France	Presented a review paper on Radio Waves propagation Studies.
17. Dr. A.K. Hanjura	Oct.,85	USSR	S&T Exchange Programme.
18. Dr. Y.V. Ramanamurty	Oct.-Jan., 86	FRG , Belgium	Worked with Prof. Rawar at FRG and attended Intl. Con- ference on Ionosphere.

	2	3	4	5
19.	Dr. S.C.Jain	Oct.. 1985	U.K.	Presented a paper on Development of High Crystal positive typecoloured liquid.
20.	Sh.Mukesh Chandra	Nov.. 1985	Bulgaria	Participated in the World Exhibition of Achievements of young inventors.
21.	Dr. K. Lal	Jan .. 86	Italy	Participated in the Winter School on 'Technology Characterisation & Preparation of Epitaxial Electronic Ma- terials.

PATENTS FILED/ACCEPTED/SEALED

Patent No.	Title	Inventors
FILED:-		
612/DEL/85	Heat sensitive process for document copying purposes.	P.K. Gupta & Vasantha Raman (Mrs.).
1124/DEL/85	A new technique for deposition of amorphous silicon films by glow discharge decomposition of silane in cascade reactors.	P.N. Dixit, R. Bhat-tacharya, O.S. Panwar, V.V. Shah.
ACCEPTED:-		
156459	Process for the coating of solar cells with anti-reflection <i>film</i> .	A. Prasad, S. Balakrishnan (Mrs.), S.K. Jain, S.N. Singh, N.K. Arora & G.C. Jain.
15642	Diffusion boat for simultaneous diffusion of? and N depants into silicon wafers.	S.N. Singh, N.K. Arora, A. Prasad & V.K. Sharda.
SEALED:-		
158367	A process for the production of substrates electrically coated with indium-tin oxide to provide transparent electrically conducting & infrared reflecting surface thereon.	N. Kumar, C.P. Sharma, S. Chandra, A.C. Rastogi & V.G. Bhide.
153763	Process for the production of printed electrode pattern for use in electro-optical display devices.	N. Kumar, B. Bahadur, V.K. Kondawar, S. Chandra & V.G. Bhide.
154065	Method for manufacture of improved liquid crystal digital display panels.	S.S. Bawa, V.K. Kondawar, S. Chandra & V.G. Bhide.

PREMIA & ROYALTIES OF THE PROCESSES RELEASED EARLIER AND IN PRODUCTION. (upto 31.12.1985)

Process	Party	Royalty (Rs.)
He-NeGas Laser	M/s Thermometers & Thermometric Appliances. New Delhi.	1.001
Indelible Ink	M/s Mysore Lac & Paint Ltd.	60,000
Soft Ferrites	M/s Ferrites India Ltd.. Bangalore.	2.400
Mi rowave.Components. X-Band.	M/s Vidy-u1Yanira Udyog. Modinagar.	1.191
Normal Angle Beam Probe.	M/s Technotronics Industril's. New Delhi.	400

EXPEDITION TO ANTARCTICA

Mr. D.R. Nakra was a member of the Vth. Antarctic Expedition conducted between Dec. 85 to Mar. 86. The experiment sent were VLF field strength measurements, microbarograph and riometers. These consolidated our earlier observation on radio communi-

cation problem and on auroral particle precipitation events. : rie:,e experiments were successfully conducted for a period of 2 months and results brought back for analysis. **A** new feature has been added on a trial basis. Antarctic air samples have been collected in pre-evacuated vessels and brought back for analysis for some trace gases and pollutants with the help of gas chromatography facility developed at **NPL**.



Mr. D.R. Nakra conducting an experiment at Dakshin Gangotri base.

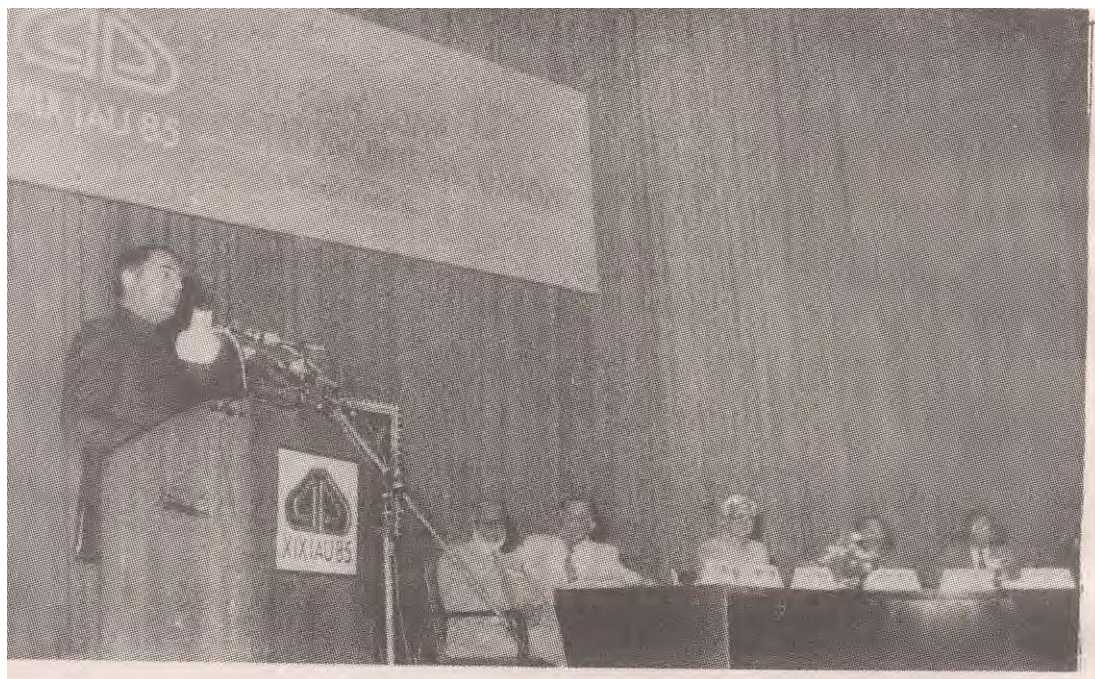
THE XIX GENERAL ASSEMBLY OF THE INTERNATIONAL ASTRONOMICAL UNION

The XIX General Assembly of the International Astronomical Union was held at Vigyan Bhawan, New Delhi in Nov., 1985 (19th to 28th) & was dedicated to the memory of the Late Prof. Vainu Bappu.

A total of 1400 persons, about 1100 from abroad, from more than 70 countries participated. The opening ceremony was held at the Srisfort Auditorium & the General Assembly was inaugurated by the Prime Minister Shri Rajiv Gandhi. A commemoration stamp representing HALLEY's COMET in 1910 was specially issued to mark the occasion of the IAU General Assembly. Two committees, National with Prof. M.G.K. Menon as its Chairman & local with Dr. A.P.

Mitra as its Chairman, were constituted to plan & look after the arrangements of the General Assembly. The secretariat of the Local Committee functioned at NPL with Dr. B.S. Mathur as its convener.

Most of the local arrangements which varied from booking of the premises for meetings & hotels to accommodate more than 1200 persons to various clearances including security & visa, to transportation, cultural events, parties, excursions, programmes for accompanying persons etc. were arranged by the staff of the NPL. As per the comments received from the various sources, it was the most successful & enjoyable General Assembly ever held.



The Prime Minister Shri Rajiv Gandhi, inaugurating the XIX General Assembly of I. A. U. Seated from left to right are Prof. M. G. K. Menon, Dr. R. Hanbury Brown, Shri Rajiv Gandhi, Shri Ram Niwas Mirdha, Dr. C. N. R. Rao & Dr. A. P. Mitra.

**RECEIPTS ON ACCOUNT OF TESTIN / CALIBRATION / GLASS FABRICATION AND OTHER
CHARGES REALISED DURING 1985-86**

Activity	Amount(Rs.)	No. of Reports
CALIBRATION		
1. Mass Standards	74,466	448
2. Length Standards	8,000	5
3. Length Metrology	1,79,950	1001
4. Temperature standards	86,110	248
5. Optical Standards	2,53,665	332
6. Force Standards	2,20,153	511
7. High Vacuum & Pressure Standards	16,000	27
8. Acoustical Standards	42,670	59
9. Time & Freq. Standards	500	1
10. D.C. Standards	37,650	94
11. Cap. & Ind. Standards	11,300	67
12. AC, LF & HF Standards	68,518	76
13. Microwave Standards	9,150	76
MATERIAL ANALYSIS & SPECIALIZED TESTING		
I. Material Analysis	51,695	35
2. Chemical Testing	1,800	36
Glass Fabrication	2,07,184	
Carbon Products	2,040	
PZT Materials	8,380	
Total	12,78,831	3052

PROCESSES RELEASED TO THE INDUSTRY

Process	Party	Premium	Royalty	Nature
Silver impregnated graphite contacts	M/s Simplicity International, 10, Basant Lok, Vasant Vihar, New Delhi.	15000/-	5%	Non-exclusive
Flat plate solar collector	M/s Chandra Industries, HIG 20, Subhash Nagar, Bhopal.	3000/-	2%	Non-exclusive

MEMBERSHIP OF RESEARCH ADVISORY COUNCIL

Prof. S. Chandrasekhar. Raman Resear:h 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. P. Krishna. Professor of Physics. Banaras Hindu University. Varanasi-221 003.	Member	Dr. R. Chidambaram. Director (Physics Group), Bhabha Atomic Research Centre, Trombay. Bombay-400 085.	Member
Prof. S.K. Joshi. Department of Physics. University of Roorkee. Roorkee-247 672.	Member	Dr. R.G. Kumble. Director. Department of Science & Tech._ Technology Bhawan. New Delhi-110016.	Member
Dr. G. Venkataraman. Jawaharlal Nehru Fellow, Reactor Research Centre. Kalapakkam. Madras-603 102.	Member	Shri B.K. Sinha. Director General, Indian Standards Institution, 9. Bahadur Shah Zafar Marg, New Delhi-110002.	Member
Prof. (Mrs) Sulochana Gadgil. Centre for Atmospheric Physics. Indian Institute of Science. Bangalore-560 012.	Member	Dr. R. Vijayaraghavan. Tata Institute of Fundamental Research. Colaba. Bombay-400 005.	Member
Prof. K.P. Sinha, Chairman. Centre for Theoretical Studies. Indian Institute of Science. Bangalore-560 012.	Member	Dr. S. Varadarajan (earlier), Dr. A.P. Mitra (later). Director General (SIR). CSIR. New Delhi-110001.	Member (Ex-Officio)
Dr. A.K. Sreedhar, Director, Solid State Physics Lab.. Delhi-I 10007.	Member	Dr. Kailash Chandra, Acting Director, NPL. New Delhi-110 012.	Member (Ex-Officio)
Prof. V.K. Gaur. Chairman. Coordination. Council for Physical and Earth Sciences Group. N.G.R.I.. Hyderabad-500007.	Member (Wx-Officio)	Dr. B.S. Mathur, Scientist. National Physical Laboratory, New Delhi-110012.	Member Secretary

MEMBERSHIP OF EXECUTIVE COMMITTEE

Dr. A.P. Mitra. Director (earlier), Dr. K. Chandra, Acting Director{later} National Physical Laboratory, NewDclhi-110012.	Chairman	Dr. B.S. Mathur. Scientist. NPL. New Delhi-110012.	\kmbcr
Prof. J.K. Choudhury, 23.Jadavpur North Road, Calcutta-700032.	Member	Dr. S.K. Sharma. Scientist. NPL. NewDelhi-110012.	\frmb.:r
Prof. S.K. Joshi, Department of Physics, University ofRoorkee, Roorccc-247 672.	Member	Sr. Finance &Accounts Officer. NPL. New Dclhi-110012.	Mc-mbcr
Dr. A.K. Srccddhar, Director, Solid State Physics Lab. Delhi-I 10007.	Member	Chairman. Coordination Council for Physical & Earth Sciences, Group ofCSIR.	Permanent Invitee
Dr. B.M. Reddy, Scientist. NPL. New Delhi-I IO012.	Member	Director General. SIR CSIR, cw Delhi-I IO001 OR His Nominee	Permanent
		Administrative Officer, NPL. NewDelhi-I IO012.	Member

HONOURS & AWARDS

Dr. Kailash Chandra was elected the first President of the Metrology Society of India.

The Indian Cryogenics Council (West Zone) has adjudged the development of Liquid Air Plant at NPL as the best work in the area of Cryogenics Technology for the year 1984-85 and awarded Prof. M.C. Joshi Memorial Prize.

Mr. Mukesh Chandra was awarded a Gold Medal at the World Exhibition of Achievements of Young Inventors at Plodiv. Bulgaria. for Piezoelectric Microphone & Displacement Transducer.

The name of Dr. V.D.P. Sastry has been included in the first edition of "Marguis International Who's Who in Optical Science and Engineering."

Dr. S.K. Sharma and Shri S.U.M. Rao were awarded Trophies and Certificates of Award for the best Micrographs of **TEM** and **SEM** in Materials Science

respectively by the Electron Microscope Society of India.

Dr. Ravi Mehrotra won the first prize for his talk on 'Low Dimensional Coulomb Systems at the colloquium organised by the Indian Physical Society at Calcutta.

Dr. **V.R.** Singh was presented with a certificate of appreciation for his lecture on 'Current Scientific Research and Clinical Application of Ultrasound in India' at a meeting by the Japan Society of Ultrasonics in Medicine, held at Kobe, Japan.

Dr. **K.K.** Mahajan, Miss **M.V.** Srilakshmi and Shri **J.** Kar won the best paper award in the area of "Atmospheres of Other planets. Cosmic Evolution. Astronomy and Astrophysics Related Studies" during the National Space Science Symposium held at Guwahati.

Dr. D.R. Pahwa and Dr. S.P. Singal won the second best poster prize for their paper during the National Space Science Symposium held at Guwahati.

Dr. Krishan Lal was invited to deliver a seminar on High Resolution **X-ray** Diffraction Characterization of Substrates, Interfaces and Epitaxial Layers at the Winter School held at ICTP, Trieste, Italy.

ADVICE/CONSULTANCY

The Acoustic Standards Section has provided consultancy services regarding acoustical treatment of auditoria, reformation in sound system etc. to the Safdarjung Hospital, New Delhi; Vidhan Sabha Mandap of U.P., Lucknow; Harijan Avas Nigam, Sultanpur.

The Length Standards section has provided consultancy service to M/s Optiregion/Spectra Vision, Delhi regarding the processing of He-Ne Laser plasma tubes.

The A.C., L.F. & H.F. Standards section assisted M/s Videotronics, New Delhi, regarding reconditioning of black & white TV picture tubes.

Consultancy services were provided by the Radio Science Division on HF and Microwave communication to the Defence Departments, BSF, ISRO, P&T, **IMD** and Railways. The services included frequency and power optimisation, antenna advice, radar operational problems, aperture medium coupling losses, duct propagation and total HF link planning.

COLLABORATION WITH OTHER INSTITUTIONS/AGENCIES

The Materials Characterization Division collaborated with (i) Department of Metallurgy, Centre for Nuclear Research (AEC), Grenoble (France) regarding studies of microstructure of carbon doped chromium films, (ii) Institute of Metrology, Gosstandart, Moscow (USSR) regarding properties of materials and physical constants (iii) Institute of Crystallography, Moscow, on crystal growth & lattice imperfections. The Division also collaborated with other institutes like CEERI, CRRI, NGRI, UP, SPL, NTPC, etc. and universities like BHU, AMU, IARI, AilMS, Pant Nagar and Bombay.

The Radio Science Division had collaborations with ISRO, ERTL, IMD, P&T, ISAC, VSSC, TIFR, **BARC**, **IISc** Universities of Calcutta, Udaipur etc. In the international field the Division collaborated with The Environment Research Laboratories of NOAA, Boulder (U.S.A.) & Meudon Observatory! (France).

The Standards Division had international links with the International Bureau of Weights & Measures

(France), IMGC (Italy), VNIIFTRI (USSR), **A.P.M.P.**, Commonwealth Science Council & UNESCO. The Division had active collaboration with Deptt. of Weights & Measures, LS.I., Deptt. of Electronics, Deptt. of Telecommunications, ISRO, Indian Railways & Industry.

SYMPOSIA/SEMINARS/WORKSHOPS/ TRAINING COURSES

1. Third ReVJew Committee meeting & the Training Workshop of the Asia Pacific Metrology Programme, organised jointly by UNESCO & Commonwealth Science Council & **CSIR** was held at NPL in Dec. 1985. It was attended by 35 delegates from 19 countries. The aim of the Workshop was to assist the participating countries in the development of infrastructure and trained manpower in selected fields of Metrology.
2. The IMAP Workshop on Scientific Problems of Middle Atmosphere was held in April, 1985. The course was organized by Dr. A.P. Mitra, the Chairman of the Scientific Advisory Committee of **IMAP**.
3. The Workshops on High Pressure Science and Technology and on High Pressure Techniques in Metal Forming and Material Synthesis were held during April-May 1985.
4. A training programme on Precision Measurement in Industry was organized jointly with the Metrology Society of India during Oct. 1985. About 60 participants from industry/organisations attended.
5. Four trainees from Bahrain & Bangladesh were trained in the Standards Division.
6. The training programmes in Computer Programming Languages (**FORTRAN** & **BASIC**) were organized at the laboratory in Oct. 1985 & Jan. 1986 for the staff.
7. The students of Delhi College of Engineering; Govt. Training workshop, Ahmedabad; MNR Engg. College, Allahabad & BITS, Pilani got training in various activities of the laboratory.
8. The Trade Training Course, in the trades of Fitter, Electrician and Carpenter, was continued & the classes were held in the evenings for the group D & daily wages staff.