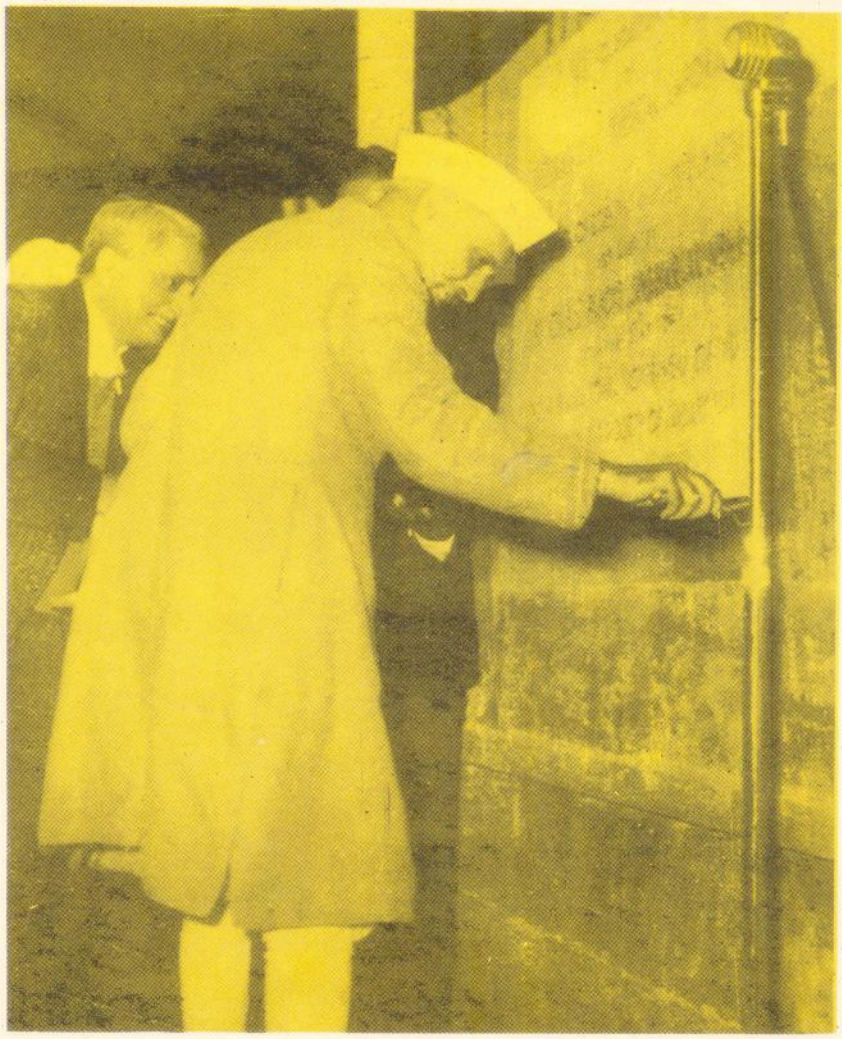
ANNUAL REPORT 1987-88



NATIONAL PHYSICAL LABORATORY
NEW DELHI

CONTENTS

Preface

As the nation celebrates four decades of its progress and achievements, we at NPL are also proud to be associated with the progress and achievements in the field of science and technology of the country. The National Physical Laboratory was established in 1947 with the purpose of conducting R & D in the areas of physics appropriate to the needs of the country. All of us at NPL feel committed to fulfil the expectations which the nation has from us. In the following pages we present the report of the activities of the laboratory for the year 1987-88.

The major efforts of the laboratory are in the thrust areas which are decided on the basis of the national needs and the expertize available at the laboratory. During the year the R & D effort was mainly in the areas of Standards, Materials including Materials Characterization, Superconductivity and Atmospheric Sciences.

In the area of Standards the efforts were continued for further improvements in the accuracies of standards maintained at NPL. International intercomparison of a number of standards was done to ensure the traceability of these standards to standards maintained by other countries. The International intercomparisons were carried out with China (in dimensional metrology); Italy (in pressure standards); U.S.A. (in vacuum standards) and USSR (in electrical standards).

An angle goniometer was fabricated and a mass comparator of 500 kg capacity was set up. The laser interferometer was set-up for the absolute calibration of accelerometer. The Standard Time and Frequency Signal dissemination from ATA, Delhi was started. The primary standards of microwave power measurement have been improved and a technique has been developed for absolute calibration of inductive voltage dividers within uncertainty of 1×10^{-8}.

The assistance, to the industry and Govt. Departments in the form of calibration and testing of measuring instruments, was continued and 2017 test reports issued.

Polycrystalline silicon ingots of 85 mm Dia. were grown for photovoltaic cells, Beta-alumina tubes of diameter 25 mm were fabricated for the sodium sulphur battery project. The work of development of transducers in underwater acoustics was continued. The weaving of 3D carbon fibre preforms for C-C composites was done successfully. Amorphous silicon solar cells of 1 Sq. cm. area and having about 7% efficiency were fabricated & integrated panels made. The projects on development of interference filters for ISRO, and highly conducting copper coating on ferrite rods for DRDL, were completed successfully. A prototype of Xeroradiographic machine was supplied to AIIMS for trials.

The characterization facilities were provided to users specially in respect of chemical composition, structural and crystalline perfection. The research work on defects in silicon single crystal wafers was continued.

In the field of Superconductivity basic and applied studies were carried out and the activities were strengthened. The new bismuth based superconductors were studied and Josephson tunnelling effects investigated. The experimental techniques of preparation of the material as wires was continued. Efforts to obtain the desired grain structure were made. The effects of compaction and sintering conditions of high temperature superconducting materials were studied.

In the area of Radio and Atmospheric Sciences the design of SROSS payload was finalized after severe checks. Its fabrication work has started. The rocket and balloon experiments were conducted successfully. The laboratory has participated in the finalization of design of the Indian MST Radar. Extensive measurements of HF field intensities from commercial transmitters and radio noise were collected.

In the area of technology transfer the know-how processes of Silver Impregrated Graphite Contacts and Flat Plate Collectors were released to the industry whereas the processes of Thin Film Optical Coatings and Liquid Nitrogen Containers were released for the first time.

The XVII Krishnan Memorial Lecture was delivered by Prof. D. Shoenberg, FRS, on Feb. 25, 1988. The topic of the lecture was "Sealing wax and String".

The laboratory organised an Open Day on Nov. 3, 1987 for school children. An exhibition was also arranged which highlighted various activities and achievements of the laboratory. A large number of distinguished persons and scientists visited the laboratory during the year. This included Dr. Heinz Reisenhuber, Minister of Research & Technology, F.R.G; Academician A.L. Yanshin; Prof. C.R. Rao; Sir Rudolf Peierls and Dr. K.V. Klitzing.

Dr. B. Jayaram was awarded the CSIR Young Scientist Award. About 130 papers were published in reputed national and international journals and about 60 research reports were produced during the year. Four scientists were awarded Ph.D. degrees.

S. K. Joshi

(S.K. JOSHI)

Director

STANDARDS

Under international intercomparison of the APMP a metre bar from NIM, China was compared with that of NPL. An angle goniometer incorporating moire radial gratings was fabricated. An electronic mass comparator of 500 kg. capacity was set up and various types of straingauge type load cells were developed.

The international intercomparisons were carried out with IMGC, Italy using solid state differential pressure transducer and with NBS, U.S.A. using air piston gauge as a transfer standard. Photometric calibration work was stepped up for the GLS lamps industry. The project of monitoring the temperature of armature conductor of traction motor for BHEL was completed. Calibration of various temperature measuring instruments was done. The laser interferometric set up for absolute calibration of accelerometer was established. Evaluation of precision hydrophone calibration was done and studies were made to evaluate the effective radiating area of transducers.

Standard Time and Frequency Signal dissemination from Delhi Earth Station of the Deptt. of Telecommunications was commissioned. Continuous time linkage to BIH, France has been established. Primary standards of microwave power measurement have been perfected for the range of frequencies 5.8 GHz to 18.0 GHz. The uncertainty achieved lies within $\pm$ 0.17% to $\pm$ 0.20%. An injection voltage technique for absolute calibration of inductive voltage dividers within an uncertainty of 1×10^{-8} has been developed. The International Intercomparisons were carried out with Australia and USSR. Calibration service was provided to various Govt. Deptts., Defence Establishments, Industry and R&D Institutions.

LENGTH STANDARDS

The section maintains an iodine stabilised He-Ne laser at 633 nm. In the 3.39μm He-Ne/CH_4 laser the laser frequency is servolocked to a narrow absorption line of the methane molecule. The laser has been made and the work on servo-locking its frequency is in progress.

Improvements in the slip-gauge interferometer, developed earlier, were made. These improvements would minimise the effect of the variation of the temperature of the system on the final measurements. A slip gauge, even upto length of 200 mm. can be calibrated with an accuracy of 0.1 μm. A facility to calibrate an electronic distance meter (EDM) for small changes in the length has been developed. The atmospheric parameters and the least count of the E.D.M. are tha factors limiting the accuracy of the calibration.

Under international intercomparison of the APMP, a metre bar from NIM, China, as a travelling standard, was compared with the Pt.Ir. bar of N.P.L.

DIMENSIONAL METROLOGY

A stuay on the corrections to be applied due to local elastic deformation in slip gauge comparisons has been carrid out. Research studies on non-contact electro-optical sensor for dimensional metrological applications, such as end gauge calibration and silicon wafer thickness measurement, have been carried out. An angle goniometer incorporating Moire radial gratings has been fabricated for angular measurements..

Calibration of dimensional measuring standards, gauges or instruments for Echelon II, Echelon III or industrial laboratories has been continued. A suitable method has been devised for calibration of INCLINOMETER, which is used in civil engineering works for detection of land slides, subsidence, etc.

MASS, VOLUME, DENSITY AND VISCOSITY STANDARDS

1.Mass

Four 1 kg transfer standards of mass (2 of Stainless Steel and 2 of Nickel Chromium alloy) were intercompared using programmable electronic single pan mass comparator. Standard deviation of each set varies from 4 to 8 μg. Mean of 5 such sets were taken as the mean mass difference of the two weights giving rise to six independent equations and three degrees of freedom for the purpose of calculation of residual errors. Three such intercomparisons have been carried out.

These transfer standards were later on intercompared with National Prototype also and mass values were assigned to individual mass standards.

The results are as follows:-

	I	II	III
Relative value of Ŝ with respect to S	365	351	353 μg
Relative value of N with respect to S	-1,580	-1,553	-1,556 μg
Relative value of Ṅ with respect to S	-1,496	-1,470	-1,471 μg
Standard deviation from residular errors	4.1 μg	9.4 μg	8.4 μg

An electronic mass comparator of 500 kg capacity with readability of 100 mg has been set up and checked for (a) linearity (b) off loading and (c) repeatability. The linearity was found to be within ± 10 g repeatability has a S.D. of better than 0.2 g and the maximum difference between the observations at four corners with reference to centre was 8 g (off loading test).

2. Volume

For the purpose of establishing primary standards of capacity for large volume measurements, one 25 dm^3 automatic pipette fabricated at NPL, has been calibrated by gravimetric method in terms of the density of water. The uncertainty of measurement was 5 parts in 10^5. For the purpose of estimating systematic uncertainty in density of water used, the density of same water before and after calibration was determined against the reference solid density standard. The value of density of water used was found to be in agreement with the stated values in ISO Tables.

3. Density

The existing alcoholometers at 15°C have been recalibrated at 20°C as adopted by 01 ML, through hydrostatic weighing technique. The density of the liquid has been measured using a highly sensitive short range hydrometer calibrated with reference to our solid density standard. Alcoholometers upto the range of 50° have been calibrated.

4. Viscosity

Viscosity scale starting from the primary standard viz. double distilled water has been established upto 27 mm^2/s. In the process six master viscometers and four oils of different viscosity ranges have been standardized. The results are as follows:

Master Viscometers

Type	Viscosity Range (mm^2/s)	Constant (mm^2/s^2)	Standard Deviation of Constant (mm^2/s^2)
Ubbelohde (0C-M60)	Upto 3	0.003051	0.000001
Ubbelohde (NPL)	"	0.001933	0.000001
"	"	0.001950	0.000001
CANNON (NPL)	"	0.001883	0.000001
Ubbelohde (1-M-S2)	3-9	0.010617	0.000002
Ubbelohde (1-C-M-39)	9-27	0.025796	—

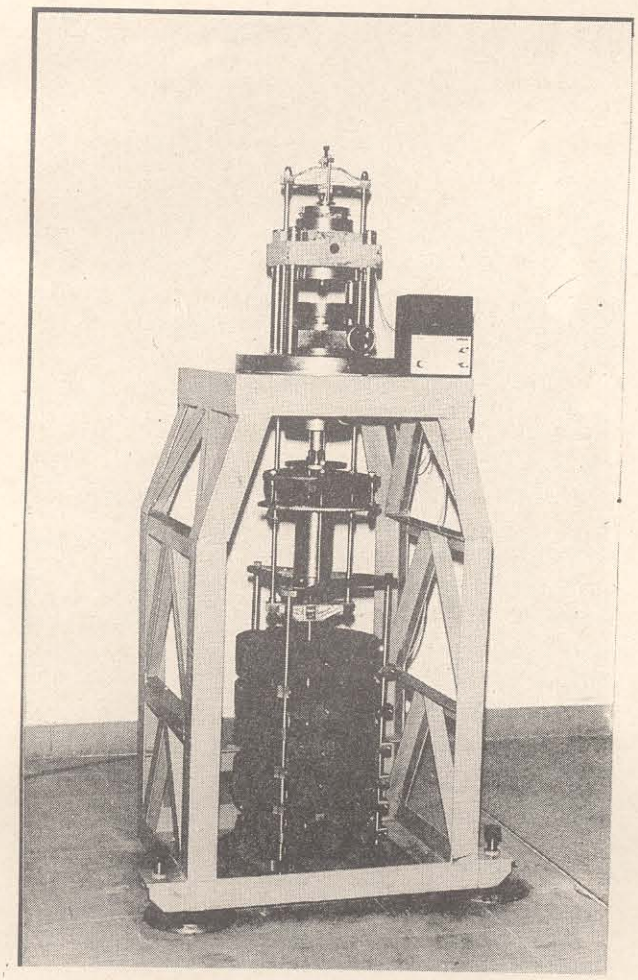
Viscosity of Standardized Oils

Designation of oil	Viscosity Value	Viscosity Range	Standard Deviation
S_3 (USA)	2.8334	1-6	0.0018
IOL	2.7346	1-6	0.001
S_6 (USA)	5.6888	3-9	0.001
S_{20} (USA)	18.5373	0.27	—

FORCE AND HARDNESS STANDARD

A Standard machine for Rockwell hardness has been designed and fabricated, and is now being tested and evaluated.

Various types of straingauge type load cells have been developed. Special mention is made for a 500 kN load cell. Output at the maximum force of 500 kN was designed to be 2 mV/V. This load cell was calibrated in 1 MN Force Standard machine which gave very stable reading.



Standard Rockwell Hardness Machine

PRESSURE AND VACUUM STANDARDS

1. Bilateral International Intercomparisons

To trace out the source of possible systematic errors in the measurement of pressure and to reaffirm the uncertainty within which the NPL and NBS (USA) can make the relative pressure measurements over the range 28-270 MPa, the comparison data obtained agreed within 6 ppm at higher pressures and 3 ppm at lower pressures into the zero pressure effective area.

The effective area of two pistons PGNPL-V2 and PGNPL-V1 was determined in the pressure range from 130 kPa to 8 kPa. The effective area was determined by measuring pressure 'P' with the Ultrasonic Interferometer Manometer. The effective area of PGNPL-V2 was determined in absolute as well in gauge mode for different gases such as Nitrogen, Helium, Argon and Carbondioxide at pressures 130 kPa, 100 kPa, 70 kPa and 40 kPa. The effective area was also determined for the different piston heights and rotational frequencies. The effective area of PGNPL-V2 for gauge mode at 128 kPa was found less by 8 ppm for nitrogen and 14 ppm for argon than the corresponding values of effective area obtained in absolute mode. From this bilateral intercomparison, it is concluded that the standards of the two countries are in agreement within 2-3 ppm in the barometric pressure region.

Four SRG rotors were calibrated both at IMGC, Italy and at NPL. While at IMGC, the calibrations were performed on their dynamic system only at two pressure values, the calibrations at NPL have been performed on our static expansion system. Also a whole range of pressures from $\sim$2 Pa to $\sim 3 \times 10^{-3}$ Pa has been generated. The $\sigma_{o,eff}$ values have been obtained by extrapolaing the σ_{eff} vs $P\sigma_{real}$ curve in the range of 0.2 to 2 Pa. The values of $\sigma_{0,eff}$ obtained for NPLI-1 and NPLI-3 have been found to be within 1% of the values obtained at IMGC while the two smooth balls NPLI-2 and NPLI-4 have $\sigma_{o,eff}$ values 2-4% higher than the corresponding values obtained at IMGC.

1.1 Critical Evaluation of the Piston Gauge Uncertainty

In continuation of the earlier work on the characterization of the primary pressure standard and the proper selection of the pressure transmitting fluid in the pneumatic pressure region upto 5 MPa, further results were obtained. These results were analysed with a view to obtain the effect of kinematic viscosity of the different working fluid on the operation and performance of the primary standard. The radial

clearance has been defined from the elastic theory taking into account the pressure distortion coefficient of the piston cylinder assembly and the initial clearance. On evaluation of the experimental data, it was found that as density and viscosity changed, the reproducibility in the fall rate and hence the value of P_z also changed and also a small change in the mean clearance from Ar and N_2 to He and H_2 was observed. Differential pressure standard using twin pressure balances was commissioned and established to measure the differential pressure in the range 30-150 kPa at high line pressures upto 8 MPa.

1.2 Establishment of Vacuum Standard to 10^{-6} P_a

Vacuum standard down to 10^{-6} Pa has been established by extending the lowest pressure limit of the dynamic flow system by installing a titanium sublimation pump to lower the base pressure and a permeation type flowmeter for measuring the low flow rates.

SEM pictures of the porous plugs used in the permeation type flowmeter were taken and the average pore area of a limited area of the plug material has been measured using an image analyser. The average pore area of the porous plug thus derived has been used to estimate the limits of the transition flow region of the plug conductance.

2. Surface Physics

The study of the deep level core electron loss energies of single crystal silicon in the (111) face was undertaken. The K-shell(1s) electron loss energy was measured to be 1842 eV. Earlier, the ELS in the transmission mode using 80 kV electron beam could give a value of 1s electron loss of silicon to be 1846 eV. The other core level loss energies like 2s and 2p electrons were also measured in the single crystal alongwith their volume and surface plasmon.

A new method called Internal X-ray Photoelectron Spectroscopy for utilising the same AES equipment was taken up where high energy electron beam (8-10 kV) is used to produce X-rays from the material to generate the photo-electrons and then measure the binding energies of the core-levels. The method was used to calculate the oxygen K-shell (1s) electron binding energy in SiO_2 by producing Si K- X-rays.

A detailed study on chemical shifts in core level binding energies of Ti and Si in formation of $TiSi_2$ was undertaken using SEELS, AES and IXPS. The core level shifts of Ti L_1, L_2 and L_3 and Si K, L_1 and L_2 level were measured using the above methods and the metallic nature of chemical bonding in $TiSi_2$ was established. A number of samples were studied for their elemental composition, nature of bonding alongwith depth profiling as a routine service work for other groups of the laboratory and some other institutes in the country.

TEMPERATURE STANDARDS

Temperature Unit Standard intercomparison was undertaken using thermocouples and fixed points between USSR & India. The fixed points of Indium, Tin, Zinc, Antimony & Silver agreed to within a microvolt ($\sim$0.1°C) using Russian thermocouples. Thermocouples made from Indian wire showed an agreement to within 4 μV at these fixed points.

A study was carried out on the working of Platinum vs Gold thermocouples fabricated from the wires available indigenously. An attachment was designed and fabricated on the heat-pipe principle for connecting to low-temperature Julabo circulator cum bath for calibration of full immersion thermometers in the low temperature range. Freon 11 was used in the interspace. The temperature difference between inside & outside the attachment was only 0.6°C at -80°C with half the attachment container exposed to atmosphere.

The calibration of various temperature measuring instruments received from industry and government departments was undertaken alongwith evaluation of thermal conductivity and linear expansion of some new materials. One SPRT was constructed, calibrated and evaluated for M/s BHEL, Madras.

For the maintenance of IPTS the following fixed points were maintained for calibration of SPRTs.

i) Triple point of water
ii) F.P. of Tin
iii) F.P. of Zinc.

A new design of high temperature platinum resistance thermometer was developed and fabricated for use upto about 1000°C. Incorporating modifications in the existing set-up for oxygen point, trial experimental runs have been made using available argon gas. Two capsule PRT's were made and

calibrated at Tr. Pt. of water, for the Superconductivity Project.

OPTICAL RADIATION STANDARDS

Photometric calibration activities were stepped up in view of great demand from the industry for calibrated reference standards due to the introduction of mandatory I.S.I. certification for G. L.S. lamps. Some basic studies in the area of radiometry were conducted. An attempt was also made to give quantum theoretical base to the classical definitions of radiometric quantities.

Water samples collected on route to the VI Antarctic Expedition were analysed for some of their optical and chemical properties.

INFRARED RADIATION STANDARDS

The optical set-up for radiance/irradiance measurement in 0.8 to 6 microns was completed and the measurements were performed on a few lamps. In order to get normalized values, the program of the APPLE IIe computer was modified successfully. In order to optimize the measurement, the optical alignment of the complete system including the auxilliary optics was checked and adjusted.

In order to establish transmittance and reflectance standards in 2 to 15 microns spectral region, the specular reflectance measurements at near normal incidence were performed for several freshly deposited films (aluminium and gold on optically flat surfaces) and polished silicon surface. The computed reflectance values may be treated as Primary Standard values which agree well with experimental values. Thus, the spectrophotometer was calibrated radiometrically for reflectance measurements.

The measurements of specular reflectance and transmittance were performed on various mirrors, dielectric coatings etc. The efforts were being made to improve upon the reproducibility of the measurements. The set-up for absolute measurement of absorption coefficient using photoacoustic spectrophotometer was completed with the provision of measurement of both amplitude and phase of the photoacoustic signal and the measurements were performed on a few samples. Infrared and photoacoustic spectroscopic facilities were provided to various sections of the laboratory and other institutions.

The project "Development of the system to monitor the temperature of armature conductor of 165-M DC traction motor" in collaboration with BHEL, Bhopal, was completed to their satisfaction.

ACOUSTIC STANDARDS

The laser interferometric set-up for absolute calibration of accelerometer was established and some tentative data was collected. The results agreed well with other existing techniques.

Studies of the characteristics of boundary layer thermal structures associated with frontal disturbances of dust storm and thunderstorm etc. in Delhi were undertaken. Studies concerning coastal boundary layer at Tarapur and chemical composition of aerosoles at Delhi were further extended. Attempt was made to obtain fascimile records of the vertical channel of Doppler Sodar and to operate second channel of the Doppler System.

Sound absorption characteristics of perforated conical absorbers and the effect of location of a damping layer on the absorption characteristics of typical false ceiling constructions were studied.

ULTRASONIC STANDARDS

Work was done on the evaluation of precisiveness of hydrophone calibration. Experimental measurement of axial pressure amplitude variation as a function of distance has been carried at 1,5, 7.5,10 & 15 MHz. For these measurements long tone bursts have been used to eliminate noise. The theoretical axial distribution was calculated for various frequencies by choosing different radiating areas. Preliminary studies indicated that the variation between geometrical and effective radiating area was only 6% at 15MHz.

It was observed that the sensitivity of the Medikoteknik PVDF needle shaped hydrophone has decreased with time. For the evaluation of the precision of the reciprocity technique, therefore, a Medisonics PVDF probe hydrophone, freshly calibrated at NPL, UK, was being used. Measurements have been carried out at 7.7 MHz and 10MHz, using the reciprocity

techniques, which would be extended to other frequencies.

Mounting arrangements for Schlieren System of CW Ultrasonic beam visualisation have been optimised. The cross section of the laser has been enlarged to 2.5 cm. Experiments are underway to check the familiar laws of ultrasonic reflection etc.

CHARACTERIZATION OF SOLAR THERMAL DEVICES

The work regarding the development and fabrication of proto-type copper disc pyrheliometer for the measurement of solar radiation (with an accuracy of ± 0.6%) using an Epply tracking system was completed. The facilities were used for recording transmittance, reflectance (both specular and hemispherical) and absorptance data on variety of samples received from outside parties and other groups of NPL.

TIME AND FREQUENCY STANDARDS

Standard Time and Frequency Signal (STFS) dissemination uplink from Delhi Earth Station (DES) of Department of Telecommunications at Sikandrabad was commissioned in March, 1988. An Atomic Cesium Clock, Synchronised to UTC (NPLI) was also installed at DES and STFS transmission are directly based on this atomic clock. The data over one year has been taken at NPL to check the long term assurance and reliability of the equipment, encoder and decoder and to conduct the failure analysis. Five decoders were developed for Department of Electronics and the decoder has now been modified for automatic propagation delay corrections, STFS via INSAT-1B is now a fully operational system ready to be exploited by the users.

The high frequency transmitters at 10 MHz and 15 MHz were replaced with more powerful (8 kW average power), auto-tuned transmitters thus increasing the efficiency and coverage of ATA services.

NPL has been continuously monitoring the data from GPS Satellites and after some initial cross checking with other International Laboratories has started sending UTC (NPLI) data to BIH since August, 1987 which is now being included in BIH circulars.

DC ELECTROMOTIVE FORCE, RESISTANCE AND CURRENT STANDARDS

Mutual intercomparison of the e.m.f. value of the national group of saturated cells in temperature controlled air enclosure was continued during the year. Model 732A Fluke 10-volt reference standards based on the Zener diodes were assigned values traceable to the national volt. The 100 kV high voltage divider was calibrated for its resistance against the national standards of resistance and calibration of 10 kV dc voltage sources of user agencies was carried out with accuracy of 1 in 10^4. Studies on the development of an electronic voltage standard was continued and stability of about 5 ppm for ten hours was achieved.

The dc standards of resistance were maintained in the form of one ohm standards resistors traceable to the calculable capacitor and a scale of resistance from 1 Ω to 10 MΩ in a constant temperature oil bath.

L.F. & H.F. IMPEDANCE STANDARDS

1. Absolute Calibration of Standard Inductive Voltage Divider

The Injection Voltage Technique for absolute calibration of a standard 3-decade inductive voltage divider, to be used as a reference standard, was established with an uncertainty of 1 part in 10^8, without reference to any other standards or fundamental electrical units. For this purpose precision doubly shielded toroidal injection and detection transformers have been fabricated. The experimental set up utilizes a boot-strapping method wherein one-tenth section of the standard IVD is compared in turn with the secondary voltage of a stable 10:1 step down transformer. The ratio errors are obtained by progressively summing the sectional errors.

1.1 Precision Automatic Capacitance Bridge

A 3-stage ratio transformer was fabricated for precision automatic capacitance bridge being developed in collaboration with Jadavpur university. The reference side of the transformer is effectively an independent pair of inductive dividers. The capacitance channel is a 22- bit binary divider while the conductance channel is a 14-bit binary divider.

1.2 H.F. Impedance Standards

Coaxial capacitance standards having nominal values 5 pF, 10 pF and 15 pF were designed & fabricated. The stability of these capacitors was found to be of the order of 0.01%/year. These capacitors serve as transfer standards at Echelon I level and as reference standards at Echelon II level.

The values of the H.F. standards of capacitance (Air lines) were extrapolated to 10 MHz using the capacitance standards at 1 kHz realized through the calculable capacitor. Using these standards the LCR bridges were calibrated, thus establishing facilities for calibration of L,C,R standards & bridges upto 10 MHz.

A Helmholtz coil system to give about 25 gauss uniform field at the centre was designed & fabricated. With its help and a variable mutual inductor, a method for calibrating search coils with an accuracy of 0.5% was set up.

A.C. AND L.F. STANDARDS

One more constant temperature oil bath of high temperature stability, with a modified and more efficient oil circulating system, was fabricated. A modified and improved multipoint Fire Alarm System was developed and a prototype was made.

Work has been started to establish compatibility amongst Zera electronic wattmeter/energy meter, Rotek calibrator and electrodynamic wattmeter.

HF AND MICROWAVE STANDARDS OF VOLTAGE, CURRENT, POWER, FREQUENCY AND NOISE

1. Developmental Studies

Microwave power standards based on pure calorimetric loads of novel design were perfected and evaluated for XN, X and Ku bands covering the frequency range 5.8 to 18 GHz. These calorimetric loads are well matched over the entire frequency bands with high effective efficiency of the order of 99.9% and can withstand microwave power upto few hundred millwatts directly. The total uncertainty in microwave power measurements using these loads is 0.17% to 0.2%.

1.1 International Intercomparison

The intercomparison of LF voltage standards upto a frequency range of 100 KHz was carried out with VNIIM, USSR. The agreement in the assigned values of voltage by the two participating countries is within 15 ppm upto 10 KHz and 30 ppm at 100 KHz at 3,5 and 10 volt level.

An intercomparison of AC voltage and current was carried out with National Measurements Laboratory, Australia. A travelling standard, precalibrated against Australian Standard was brought by Mr. Charles Franchimon of NML. It was assigned values against NPL Standards. The agreement in voltage at 5 volt nominal value is within 20 ppm in the frequency range of 57Hz to 100 KHz and in current at 1 Ampere nominal value is within 10 ppm in the frequency range of 57 Hz to 1 KHz.

H.F. AND MICROWAVE ATTENUATION AND IMPEDANCE STANDARDS

Six quarter wave short circuits were designed and developed as a standard of reflection coefficient at Ku-band (12.4 to 18 GHz) microwave frequencies. The precision waveguide of residual VSWR 1.004 and precision termination of low VSWR (Element VSWR = 1.005) and two multistub tuners were designed and developed at Ku-band microwave frequencies. These precision components were developed to establish tuned reflectometer technique at Ku-band microwave frequencies for calibrating waveguide standard mismatches. Coaxial and rotary vane attenuators were calibrated for different organisations.

MATERIALS

Under joint programme with CEL, polycrystalline silicon ingots upto 85 mm diameter were grown. Research on impurity segregation and defects in silicon and contact materials was carried out. Better techniques were used to fabricate larger diameter beta-alumina tubes of higher fracture strength. The developmental work regarding the ISRO sponsored project on fluorescent screen for X-ray imaging was initiated and samples were prepared and characterized. A newly developed direct pusle technique to study ferroelectric liquid crystals was developed. Development of transducers in underwater acoustics, supported by DOD and DOE, has reached advance stage and measurement facilities were being updated. Methodology for weaving 3-D carbon fibre preforms, with any given configuration for carbon-carbon composites, was developed. A simple process was evolved for developing special impregnating pitches. The work on high pressure hot extrusion and cold forging was carried out for developing some strategic components using warm forging technology for defence applications.

SILICON AND SILICON DEVICES

Under NPL/CEL joint programme on "Multicrystalline Silicon Ingot Technology" several multicrystalline silicon ingots for 76 mm dia and 50 mm × 50 mm cross section cells have been grown by directional solidification using crucible lowering method. These ingots were further processed at Central Electronics Limited for wafer slicing and solar cell fabrication using low cost screen printed silver contact process, as practised in CEL's own production line. Solar cells of efficiency > 8.5% (without anti-reflection coating) have been made using these ingots. This order of efficiency is considered to be good in view of the fact that the cells were without the antireflection coating and the grain size was limited to less than 3 mm owing to the smaller cross sectional area of the ingots.

A plasma oxidation set up for silicon has been fabricated and thin SiO_2 films on silicon wafers have been grown. Some studies to evaluate SiO_2/Si interface and surface passivation properties of SiO_2 layer have been made. The work on the fabrication of solar cell structures capable of yielding high open circuit voltage, V_{oc}, has been started. V_{oc} values in the range of 620-640 mV have been realised.

A number of studies have been carried out on silicides used as contact material in microdevices. Various samples of Ti and Si bilayer films and single layer films of Ti on Si wafers have been separately anealed in the temperature range 600-800°C for various durations and studied. Dynamic stress measurement in such films using a capacitance method and static stress measurement using interference method are being set up. Various other parameters of these films such as resistivity and sheet resistance, microstructure and compositional analysis and microdistribution of phases have been studied using conventional four point probe technique, TEM, SEM and X-ray diffraction, etc.

Efforts have been made to computerise DLTS measurement with the help of an IBM personal computer and a Keithley Data Acquisition System. DLTS peaks have been successfully obtained. Investigations were also carried out to determine the quantum efficiency of n^+-p-p^+ structure based, thin epitaxial silicon solar cells. Effect of annealing on segregation of impurities to grain boundaries and surfaces in silicon has been studied with particular emphasis on kinetics in order to identify the diffusing species in each case.

The spectral responsivity apparatus was further improved by the addition of ELH lamp simulating AM 1.5 solar spectrum for bias light and by the design of a suitable noise filter to ensure that signal to noise ratio remains high even at wavelengths for which solar cell responsivities are very low. The system can now handle cells as large as 80 mm × 80

mm for spectral responsivity measurement under one sun AM 1.5 solar irradiance.

The studies made using this system on the effect of bias irradiance on the spectral responsivity of silicon solar cells led to the results that single crystal and n-type polycrystalline wafer solar cells showed no bias light effect upto one sun while p-type polysilicon wafer solar cells showed large bias light effect in the form of large increase in the long wavelength responsivity. On the other hand epitaxial silicon solar cells showed variable bias light effect depending upon factors like epilayer thickness and substrate dopant.

Microstructural analysis and chemical phase identification/microdistribution and microfracture were studied using SEM, X-ray diffraction techniques. Experimental facilities to measure the transition temperature (T_c), temperature variation of sample resistivity and Meissner effect etc were set up. The critical current, J_c, measurements are being done using dc and pulse techniques. The highest value of J_c achieved so far in our sample is > 100 A/cm^2 (at 77K, O Tesla).

BETA ALUMINA TUBES FOR SODIUM SULPHUR BATTERY

A number of experiments have been conducted for making β''-Al_2O_3 granules under various conditions using anhydro laboratory spray drier. Some of the tubes fabricated during these trials have been supplied to CECRI, Karaikudi for actual use. Partially stabilized zirconia as an additive in β''-Al_2O_3 has been studied during the period. A few percent of this additive has been observed to increase the mechanical strength to 200 MPa.

A few β''-Al_2O_3 tubes of 25 mm diameter have been prepared by zone sintering. After testing, these tubes have been found to be good in quality. Attempts are presently being made to fabricate tubes of 50 mm diameter.

ULTRASONICS AND ELECTROCERAMICS

1. High Power Ultrasonic Systems (Sponsored-DOD)

The facility for comparison, calibration of hydrophones using the method of active impedance termination was extended to 400 psi. Sensitivities of various hydrophones with pressure were compared. Receiving hydrophones were developed using thin walled piezoelectric element of dimensions (length 22.6 mm, wall thickness 3 mm). The performance of the hydrophones was compared with that of a standard B&K hydrophone. It was observed that the response of the neoprene hydrophone was fairly flat below 30 kHz and the sensitivity was comparable to B&K 8103 hydrophone. In the mid frequency range, however, fluctuations were observed in sensitivity, which may be objectionable for some measurements. Efforts were being made to minimise the fluctuations. The design of the assembly for the reciprocity coupler technique, for calibration of small hydrophones upto 3000 psi, was completed and is under fabrication.

2. Development of Parametric System (Sponsored-DOE)

A few more primary sources of single and multielement type with S.P.L. of 210 dB re 1μ Pa m^{-1} were fabricated. These have been made rugged and leak proof for continued operation in water. Studies have been completed on a 3 element line in cone transducer. To have an idea of the nonlinear nature of the medium, the acoustic output of the primary source was recorded stepwise at various distances upto 26 metres by progressively taking the driving voltage to the maximum at each step.

A modulator and a driver stage has been assembled using Ic1496 and a operational amplifier 531. The parametric acoustic arrays were generated at frequencies below 50 kHz, using a broad band single element transducer. The carrier was 321 kHz and the modulating frequency varied from 12.5 kHz to 25 kHz. In this mode, singnals of different frequency and also its second multiple were observed.

The circuit developed was used to excite the multielement mosaic transducer in conjunction with the kilowatt amplifier. The pulse duration is kept from 0.4 ms to 1 ms. In the detector circuit, a low pass filter

was used to reduce the carrier amplitude. Parametric signals showed the following characteristics:

i) the low frequency signal appeared in the duration of the tone burst,
ii) the frequency of the received signal could be varied continuously from 2 kHz to 8 kHz by varying the frequency of audio signal to the multiplier,
iii) the signal was very directive, with a 3dB beam width of 3.5°,
iv) signals were recorded upto 15 metres and their propagation characteristics studied.

Studies were made of echo reduction and insertion loss in butyl rubber sheets and composite sample consisting of butyl rubber, cork and aluminium powder to which wedges were bonded with various spacings. It was observed that introduction of closely spaced wedges of length 12 cm improved the echo reduction by 5 dB at low frequencies.

In connection with the work on O.A.T.S a cruise was organised by NIO to take acoustic noise measurements at a depth of 750 m in the sea. The measuring instruments consisting of ITC-6080C hydrophone was supplied by NPL. The recording system was furnished by NIO. The measuring instruments were moored for six hours, using deep sea mooring (2600 m) off the Coast off Vishakhapatnam. Our scientists participated in this cruise programme (No. 40) on Sagar Kanya from 19.3.88 to 29.3.88.

To the existing test tank (5.7 m × 4.8 m × 2.1 m) a test channel of length 18.2 m, breadth 3.7 m and depth 2.1 m was provided to facilitate studies on parametric systems. Work was done on the design of a X-Y trolley having a provision of walk way for allowing fixtures of systems. The design of a projector trolley to handle the heavy projectors was made.

3. Piezoelectric Ceramic Materials

Low loss PZT-4 rings were produced and supplied to various agencies. Large diameter transducer elements with diameter 62 mm, wall thickness 5.08 mm and length 50.8 mm were produced for underwater acoustic applications. Transducer elements and discs for low and high frequency transducers for parametric work were fabricated. To meet the requirement of the consumer industries production of standardised composition based on Pb (Zr, Ti)O_3 and lead metaniobate were carried out.

4. Ultrasonic NDT & Exploratory Studies

The development of a method to evaluate resolution of various ultrasound NDT transducers was done and calibration blocks were developed. The work was carried to investigate the flaws and structural properties of Iron pillar, near Qutab Minar, Delhi.

Acoustical measurements of polyester vessel were taken by making stepwise increase in wall thickness from 1 mm to 10 mm. It was observed that insertion loss remained fairly small (-2dB) while reflection coefficient varied from 7dB to 11dB. The vessel was subjected to pressure to find out the response of a projector under pressure.

LUMINESCENT MATERIALS AND DEVICES

1. Development of fluorescent screen for high energy X-ray imaging (Sponsored-ISRO)

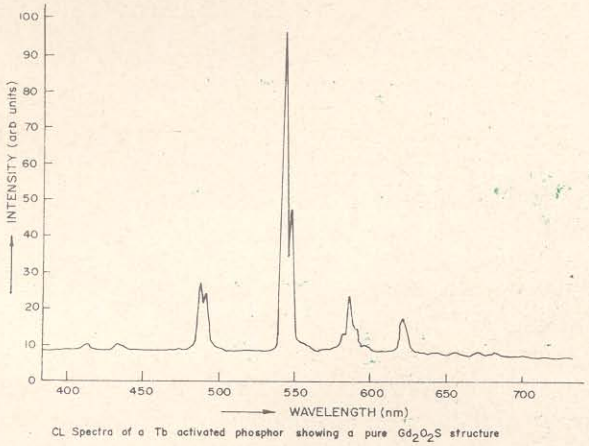
Steps were initiated for the procurement of indigenous starting chemicals particularly the RE oxides. The preparation of the GOS: Tb sample was started and about 20 samples were prepared and characterized. Samples of Gd_2O_2S: Tb phosphor were prepared by sulfurisation flux method varying Tb concentration. The phosphor powder was examined by SEM and visually under optical microscope for its particle size and crystallinity. X-ray powder diffraction patterns (XRD) of all these samples confirmed a pure GOS composition.

For optimisation of Tb conc. samples were prepared varying the Tb conc. from 0.15 to 3.0 mole %. Cathodoluminescence (CL) output measured for each of the six samples showed a gradual increase in CL output with increasing Tb conc., (Table I).

Table 1

Sample	Tb conc. in GOS: Tb	CL Output (Arbitrary Units)
1.	0.15 Mole %	2.26
2.	0.30 "	3.00
3.	0.60 "	3.20
4.	1.00 "	3.60
5.	2.00 "	4.00
6.	3.00 "	2.50

The efforts were directed towards development of a synthesis process for large grain GOS phosphor. The processing conditions in the sulfurisation flux method were varied. Higher firing temp. (1150°C), longer firing time (upto 3 hrs.) and use of sod./pot. phosphate along with the flux were tried. The phosphor samples obtained were crystalline with an av.PS of 8 microns. The C L output of these samples, however, decreased apparently with grain growth. A typical spectra of a GOS sample is shown in the figure, which matches quite well with the reported spectra.



CL Spectra of a Tb activated phosphor showing a pure Gd_2O_2S structure

The X-ray diffraction pattern of one of these crystalline GOS: Tb phosphor samples showed some extra diffraction lines apart from the lines corresponding to the GOS phase. This indicated presence of some other phases. The C L output of this sample was also less (about 55%) than that of the sample which showed complete conversion to GOS. X-ray Fluorescence analysis of this sample showed reduced Sulfur counts (60 to 70%). This study points to the necessity of control on synthesis parameters.

Experiments for film formation were initiated for a preliminary assessment of these samples under X-rays. Aluminium substrates of 150 × 100 × 6 mm size were used. The films were formed by "settling method" using nitrocellulose as binder. The layer thickness was measured to be about 70 microns.

The efforts were made to analyse material constituents and final phosphor for impurity content. Metallic impurities like Fe, Ca are known to act diversely in RE phosphors. Impurity analysis by Atomic Absorption was obtained for typical metallic impurities and are tabulated, (Table II). It appears from table that some of the above metallic impurities may be playing a crucial role in the C L output.

Table II

Sample	Impurities in ppm				
	Ca	Mg	Fe	Na	K
Gd_2 (India)	90	6	9	11	0.1
GOS: Tb (Indig.)	85	51	17	266	ND

1.1 Simulation of Simultaneous Reaction and Spray Drying

This activity is an extension of R&D on phosphor pilot plant activity, in collaboration with IIT, Delhi. A mathematical model which incorporates mass transfer with instantaneous chemical reaction and heat and mass transfer to cover simultaneous reaction and drying has been proposed. The differential equations derived for the model have been solved as an initial value problem using Runge-Kutta method. The model is applied to simulate the simultaneous reaction and drying of ZnS prepared by absorbing hydrogen sulfide gas in ammoniacal solution of Zinc Chloride. The variations of temperature, humidity, droplet diameter, moisture content and concentrations of reactants are predicted along the length of the column and are compared with the experimental data.

CARBON FIBRES, COMPOSITES AND PRODUCTS

1. Carbon Fibres

Studies were continued to modify the available PAN precursors and a new technique of PAN fibre modification by incorporating certain carboxylic groups in the fibres prior to oxidation step was evolved. The

treatment provided useful modifications in the reaction kinetics during oxidation of PAN fibres. The tensile strength & youngs modulus of the modified fibre showed an improvement of about 70%whereas the activation energy for cyclization reaction was reduced from 130 KJ/mol. to about 100 KJ mol. A simple and novel process was developed for making a special coal tar based pitch for the advanced carbon products like the carbon-carbon composites etc. The process is capable of giving a low QI special pitch.

2. Carbon—Carbon Composites

2.1 Development of C/C Composites for Biomedical Applications (Sponsored-DST/SCTIMST)

The project was completed in March 1988. The R&D was carried out and two batches of composites were made, each batch consisting of thirty plates. The reproducibility of the density, mechanical properties, porosity etc. of the composites was ascertained. These samples were sent to SCTIMST, Trivandrum.

2.2 Fracture behaviour of C/C Composites

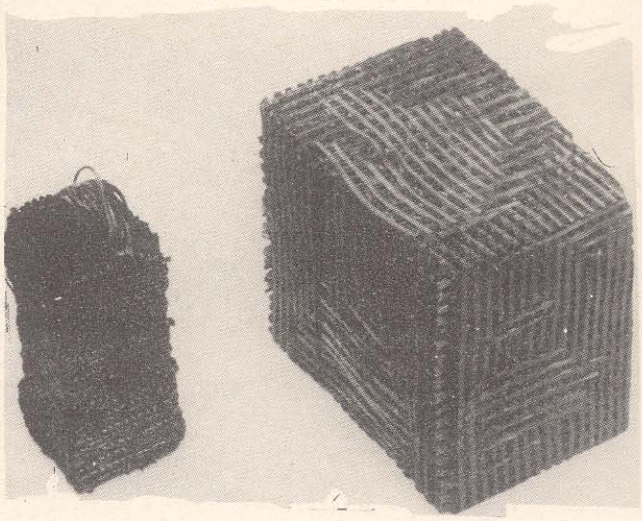
Carbon/Carbon composites made with surface treated carbon fibres and heat treated to 1000°C possessed very strong fibre/matrix bonding. On flexural loading, composites were found to exhibit tensile type failure with catastrophic fracture at low load. However on heat treatment to 2700°C, the fibre/matrix interactions were found to be not too strong. As a result, the composites which failed catastrophically, now exhibited mixed mode failure with high strength. For developing composites having high strength, one has to have proper fibre/matrix bonding.

2.3 Weaving of 3D Carbon Fibre Preform for Composites

For making C/C composites for aerospace and defence applications, multidirectional carbon fibre woven preforms are needed. R&D was carried out and a suitable technique was evolved for three directional weaving with carbon fibre. Different kinds of woven preforms were made, one of them was densified to make C/C composite. (Fig.).

2.4 Oxidation behaviour of Carbon Fibres and Composites

The oxidation behaviour of different carbon fibre derived from PAN Pitch was studied. These carbon fibres were heat-treated to 1200°C and 2500°C. Heat treatment of carbon fibres upto 2500°C reduced the weight loss only in the initial stages i.e. upto 700°C, after this there was no appreciable effect of heat treatment except in case of isotropic pitch fibres. C/C composites were coated with Boron and Phosphorous compounds to increase their resistance towards oxidation. Preliminary experiments were done to coat C/C composites with Silica and Zircon by Sol-Gel method.



Carbon Fibre 3d Preforms

2.5 Glassy Carbon

The periodical check-up of the glassy carbon dental implants fixed into the human-being at the Army Hospital, Delhi, was continued during the last one year and was found to be satisfactory.

3. Cinema Arc Carbons

Experiments on photometric characteristics of Cinema Arc Carbons made in collaboration with Bureau of Indian Standards have led to drafts on light output specifications and method of measurement of screen illumination. These specifications drafts were

approved by the BIS Cinematographic Equipment Sectional Committee and would help prevent improper screen lighting in cinema theatres, which could be health hazard to the public.

4. Aviation Grade Brushes

Scale-up work on all the varieties of the Aviation Grade Brushes was completed and the samples were sent to M/s. HAL, Nasik. The technology is ready for transfer.

Studies on pitch fractions made from three varieties of pitch including one imported Japanese pitch and bitumen based pitch were made using thermal treatment in nitrogen, air and carbondioxide at temperatures upto 723°K. Rheological studies were also made at two shear rates at various temperatures. The carbon materials were made from the pitches and they were investigated by X-ray diffraction and SEM. The 'd' values were found lower for cokes from solvent extracted pitch and the SEM photographs of the three pitches indicated the presence of anisotropic phase in the pitch fraction.

HIGH PRESSURE PHYSICS & TECHNOLOGY

Investigations were continued to develop diamond compacts using different binders and to increase the hardness of these compacts. Different catalyst solvents were used to develop single crystal cBN from hBN. The effect of hydrostatic pressure on superconducting compounds was also studied.

A sponsored project on the development of missiles components by Warm forging technology was taken up in collaboration with Defence Metallurgical Research Laboratory, Hyderabad for the prototype development of "Motor body component" for defence. Design of tooling and sequence of operation of two components was completed. Few trial runs on the development of Mn-Al-C alloy, a new magnetic material, by hot extrusion process were made. This is a collaborative work with NML, Jamshedpur.

Major efforts have been made on the development on tooling to be mounted on 500 tonne press for the development of High T_c superconducting material by hot extrusion technology. Initial trials were made, and sound extrusions were obtained with extrusion ration 5:1. Parameters were optimised using silver casing and finally extrusion ratio of approx. 20:1 was achieved.

A market survey for demand of composite tubes was conducted. Few composite tubes made by us were shown as exhibits at Okhla. The development of composite tubes upto 50 mm outer diameter was initiated. In this connection a flange forming device was designed. A fixture was also designed and fabricated to support large diameter tubes during shear spinning.

DISPLAY DEVICES

Direct method for the spontaneous polarization, dynamics of polarization reversal amongst uniform stable states of polarization and for the polarization-change from a zero field favoured state to either of a stable state and the molecular reorientation processes that successively takes place in the bulk or the boundary surface layers in ferroelectrics were extensively studied by analyzing the current response to triangular and square wave pulses. Molecular reorientation processes which take place successively within the bulk and the boundary surface layer were studied by the appearance of polarization current humps on the triangular wave response. Dynamics of polarization reversal for switching amongst uniform stable states and for the changes from zero field favoured state to either of the stable states were studied by applying symmetric and asymmetric square wave pulses. The technique was successfully applied to ferroelectric liquid crystals and to solid ferroelectrics. (Fig. 1).

The computer simulations of the director's distribution following Berreman's approach was done extensively in a super twisted nematic cell containing La-Roche-LC-mixture 3010. It was seen that the director's distribution depended critically on the total twist angle ϕ_t, the surface tilt angle Θ_o and the ratio d/p (cell-thickness/pitch). The ϕ_t and Θ_o were optimized to yield small bistability ($\Delta V = 0.06$) and relatively large change in the mid plane tilt angle ($\Delta \Theta_m = 51°$) for an unstrained system with $\phi_t = (d/p)\ 360°$. The optimum value of Θ_o and ϕ_t were found to be 15° and 240° respectively.

The effect of varying d/p was also studied in great details for a high surface tilt ($\Theta_o = 30°$) and a high twist ($\phi_t = 270°$) cell (with $d/p = 0.75$ for unstrained case). It was found that as d/p decreased, the

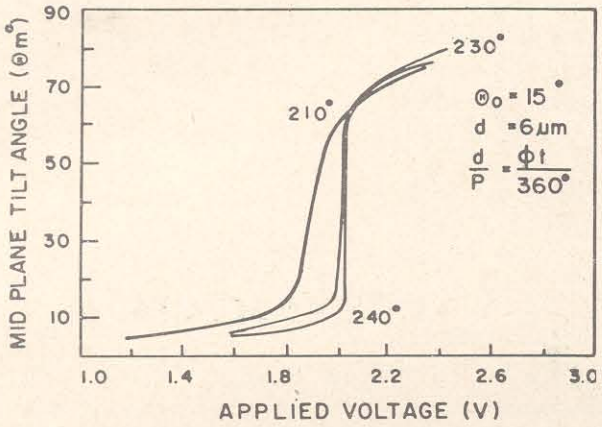


Fig. 1 Optimization of the surface tilt and twist angle for La-Roche Liquid Crystal mixture 3010 in Supertwisted birefringent configuration.

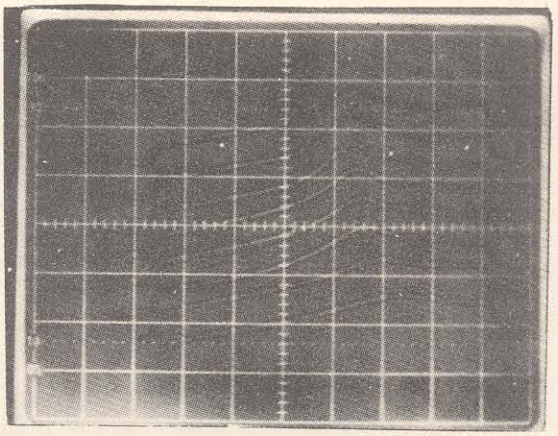


Fig. 2 Oscillograph of a polarization reversal (switching) current for a 3 μm thick sample of a ferroelectric liquid crystal DOBAMBC at 76°C and at 15 Hz for triangular pulses at different fields. (A) 60KV/cm, (B) 56KV/cm, (C) 47KV/cm, (D) 40KV/cm, (E) 33KV/cm, (F) 27KV/cm, (G) 20KV/cm and (H) 13KV/cm. Ordinate scales are arbitrarily chosen and only half of the pulse is shown.

bistability range increased and as such when $d/p \backsim 0.6$, the high tilted state continued to exist even without any applied voltage. On the other hand, as d/p increased, the bistability decreased. As a matter of fact the solutions for the director's configuration in the high tilted state were observed well beyond the limits of d/p = 1.0. The overstrained cells with $d/p \backsim 0.75$ could be of vital importance from the practical point of view. (Fig. 2).

A new conducting polymer poly-naphthalene oxide-pyrrole was electrochemically generated. Measurements of electrical conductivity carried out as a function of temperature have revealed that log δ varied as $T^{-1/4}$ indicating that the variable range hopping mechanism was perhaps operative at low temperatures. Besides, preliminary ESR measurements were conducted on both BF_4 doped and undoped polyanilenes with a view to unravel the role of conjugational defects such as polarons and bipolarons in the transport of charge in these typical conducting polymers. (Fig. 3).

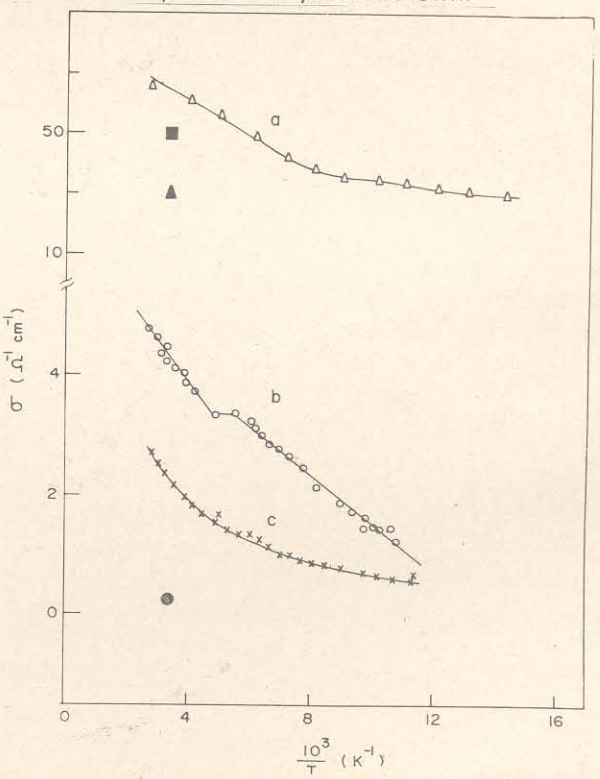


Fig. 3 Variation of electrical conductivity, δ as a function of $\frac{10^3}{T}$ for (a) ClO_4^- –doped polypyrrole (b) ClO_4^- -doped polyphenylene-oxide-pyrrole and (c) BF_4^- -doped poly-α -naphthol-pyrrole. Points ■, ▲ and ● correspond to values of electrical conductivity, δ determined at 294K for BF_4 -doped polyvinylchloride-polypyrrole, $InCl_4$ -doped polyacetylene-polypyrrole and BF_4 -doped polypyrrole-poly-N- (p-nitrophenyl)-pyrrole respectively.

CHARACTERIZATION OF MATERIALS

Support was provided by the group in all the major areas of materials characterization, namely, chemical composition, structural characterization and crystalline perfection. High T_c superconductors, carbon fibres and composites, polymer films, device quality silicon single crystals, diamonds and chalcogenide crystals were among the investigated materials. Research investigations were pursued in all disciplines of materials characterization. Stresses induced by thin oxide and nitride deposits in silicon single crystals were measured experimentally using high resolution X-ray diffractometric techniques. Stress levels varied from about 2×10^8 to about 4×10^9 dynes/cm^2. Part of this work was done in collaboration with CEERI and SCL. Crystal defects in silicon single crystal wafers induced by processes involved in microelectronic device fabrication, were studied by high resolution X-ray diffraction methods and EPR spectroscopy. The effects of compaction and sintering conditions on high T_c superconducting materials were studied by X-ray diffraction and electron microscopy techniques. Four phases, namely, CuO, $YBa_2Cu_3O_x$, Y_2BaCuO_5 and $Ba_2Cu_3O_5$ were identified. Low temperature oxidation was found to lead to inter and trans granular cracks which may lead to serious limitation in critical current density.

CHARACTERIZATION OF MATERIALS REGARDING PURITY & COMPOSITION

1. Chemical Methods

The development of new methods for determination of sulphate radicals, phosphorus, boron, oxygen and traces of silicon in metals by using techniques of atomic absorption spectrophotometry; u.v., visible spectrophotometry and gas chromatography was carried out. A high vacuum facility was set up for the evacuation of stainless steel and other samplers for collection of samples of air or any gas for compositional characterization. A quadrupole mass spectrometer (V.G. Micromass 200) was commissioned for the determination of composition of gases and air samples upto ppm concentrations.

About eighty samples received from different divisions of NPL and from various government and private organizations including Election Commission, DNES, DESU and IIT Delhi were characterized. Extensive work was done in collaboration with CEERI, to study the migration of impurities by chemical methods in high power devices to understand the causes of failure.

1.1 FTIR Absorption and UV-Visible Emission Spectroscopy

Various materials such as silicon, ultrapure silicon, IR window materials, high T_c superconductors, were characterized by FTIR spectrophotometry. In silicon and ultra pure silicon, a region of 4000-400 cm^{-1} was scanned to see the multiphonon absorptance and impurity absorptance. Quantitative estimation of impurities such as oxygen and carbon was carried out using Fourier application programme. Infrared transmission of KCl and KBr single crystals grown at NPL was measured in the region 4000 to 350 cm^{-1}.

Absorptance characteristics of high T_c superconductors were studied. It was observed that characteristic bands of $BaCo_3$ exist in the sample where the solid state reactions are not complete. Characteristic bands of tetragonal and orthorhombic phases of superconductors were also observed. Aluminium alloy plates were analysed by emission spectroscopy for the activity of xeroradiography. This method was also used for analysis of CVD and F-Z silicon samples.

1.2 X-Ray Fluoroscence Spectrometry

The newly acquired X-ray Fluorescence Spectrometer was tested thoroughly by running many standard qualitative analysis programmes. It was used to provide infrastructural support to different projects including qualitative XRF measurements on Cu Ga_x In_{1-x} Se_2, carbon composites and fibres, Y-Ba-Cu-oxide superconducting materials, silicon and air borne samples. Semiquantitative analysis of sulphur content for the LMD project was also done.

For quantitative analysis of impurities in silicon matrix, efforts were made for creating standard samples with known amount of impurities. The silicon powder, ground to size $\leq 37\mu m$ could not be pressed into a pellet without a binder. Different adhesives, such as n-butylmethacrylate, polyvinyl alcohol, starch, boric acid and polyethylene glycol powder were tried for making a reasonably strong pellet. Polyethylene glycol powder was found to give the best results.

1.3 Electric Paramagnetic Resonance Spectroscopy

EPR investigations were made to detect and characterize paramagnetic impurities present in synthetic diamonds. Presence of different transition metal impurities dispersed in the material was detected. Well defined three line EPR signal due to nitrogen impurity, similar to that observed in natural diamond crystals, was obtained in synthetic diamonds also. The Nickel used as catalyst was observed almost in all the samples.

In collaboration with CEERI, EPR spectroscopic investigation on process induced damages in silicon wafers was undertaken. Preliminary measurements have shown that EPR absorption signal observed in BF_2+ ion-implanted silicon wafer was identified with dangling bonds formed due to amorphization of the silicon during ion implantation process. EPR measurements were also made on single crystal silicon.

EPR investigations were carried out on vanadyal and copper ions doped in $ZnOB_2O_3$ and $PbOB_2O_3$ glasses in order to get the information on the glass structure. It was observed that in these mixed glasses the tetragonal distortion along v^{4+}(vanadyl)-oxygen bond decreased when V_2O_5 was replaced by CuO. This work was done in collaboration with Physics Department of M.D. University, Rohtak. EPR measurements were made for different NPL projects like Display Devices, LMD, Thin Film, Cryogenics & Superconductivity.

CHARACTERIZATION OF MATERIALS REGARDING CRYSTAL STRUCTURE

1. X-ray Diffraction Methods

X-ray diffraction measurements of large number of samples of superconducting materials, carbon fibres and composites, synthetic diamonds, CdTe, tungsten carbide, boron nitride, GdTb, x-ray fluorescent screens were carried out.

The effects of compaction, sintering conditions, Zr incorporation, silver incorporation (as cladding material) in superconducting compound $YBa_2Cu_3O_{7-x}$ have been studied. Preferred orientation and changes in lattice parameters have been correlated with the above effects. Silver does not seem to enter the lattice upto 50 wt% and preferred orientation was observed for (ool) reflection.

In collaboration with CEERI, high quality LPCVD grown polycrystalline silicon films, Titanium silicide, Nickel silicide and Cobalt silicide films and superconducting thick films were studied. The crystallite size and x-ray texture was also reported. In collaboration with IACS, Calcutta, the studies of stacking faults and defects parameters in the tellurium selenium alloys were carried out. The line profile of (110) reflection was studied in details.

Studies on the chalcogenide systems Ga_2Te_3, In_2Te_3 and CuGaInSe have been extended further. Atomic positions for the compositions $CuGa_{0.5}In_{0.5}Se_2$ have been finalised and crystallite size determined by recording the peak profiles of several reflections. Effects of aging, anealing and grinding of Ga_2Te_3 have been studied in details.

Assistance was provided to various research institutes including CEERI; CECRI; CRRI; GBFS, Bokaro; IIT-Delhi and University of Delhi regarding the analysis of their materials.

1.1 Electron Microscopy and Electron Diffraction Techniques

About 200 samples from different projects and outside institutions were examined by TEM and about 540 samples were characterized by SEM to study their surface structure, morphology and grain growth. The materials included high T_c superconductors, carbon-carbon composites & fibres, ß-alumina, polysilicon $TiSi_2$, CuInS & CuInSe etc. The institutions assisted were I.I.T, Delhi; Delhi University; S.P.L., Delhi; D.S.L., Delhi; Kurekshetra University; Thapar Corporate R&D Centre, Patiala; C.E.E.R.I; C.E.L., Sahibabad, R.R.L., Bhubaneshwar and R.R.L., Jorhat.

Some work on the study of structure of high T_c superconducting materials by using TEM was initiated. Different fluids were used to disperse the powder and it was found that dichloroethylene was quite suitable as suspension medium for $YBa_2Cu_3O_x$ powder. Success was achieved to resolve lattice plane parallel to C axis in some cases. Grain structure and grain growth was studied in $YBa_2Cu_3O_x$ as a function of sintering conditions. Equiaxed grain morphology changed to faceted grain at about 960°C and the presence of other phases was observed in the samples. Four phases viz CuO, $YBa_2Cu_3O_x$, Y_2BaCuO_5 and $Ba_2Cu_3O_5$ were clearly observed using SEM and EDS techniques. It appeared that multiple phases were formed due to the decomposition of 1, 2, 3 phase at temperature above 950°C and thereby destroying the superconducting properties of 1, 2, 3 phase. It was further observed that low temperature oxidation at 450°C resulted in inter and trans granular cracks which probably led to serious deterioration of critical current density.

Superconducting films of Y Ba Cu oxide deposited on to strontium titanate substrate prepared by RF sputtering were studied by SEM and EDS. The deposited films showed little structure while localised regions revealed multiple flower like patterns. Stoichiometry of the films was found to depend strongly on target to substrate distance. Composition variation from centre of the substrate to the periphery was also observed. The target composition was also found to change after several sputtering operations.

The data on the study of microstructure and elemental analysis of Cr-C films, prepared under different partial pressures of methane, by magnetron sputtering technique on to stainless steel substrates at different temperatures was analysed. The results have led to the interesting conclusions: (i) films grown at higher pressure of methane (2.7×10^{-1} Pa) showed amorphous and crystalline phases simultaneously present; (ii) Si was found in the films indicating that it got trapped after the cracking of Silicone oil (iii) Amorphous zones contained Cr and C consistantly throughout the specimen.

A study of the structure of $Zn_xCd_{1-x}S$, $CuInS_2$, CuInSe and ZnCdS films was carried out. Changes in the structure as a result of preparation conditions were studied. The optical properties of these films were explained on the structure of these films & correlation established.

CHARACTERIZATION OF MATERIALS REGARDING PERFECTION

1. High Resolution X-ray Diffractometric, Topographic and Diffuse X-ray Scattering Techniques

Stresses induced by deposition of thin films like oxides in the substrate silicon wafers were quantitatively measured. The curvature of the lattice planes of the substrate produced by triple stresses was measured by multi crystal X-ray diffractometers. The radius of curvature was found to vary from about 50 m to several hundred metres. From this, the stress is evaluated by using standard relations. Deposits like oxides, polysilicon and nitrides were investigated. A large number of samples of 100 mm diameter silicon wafers coated with silicon dioxide were also characterized for stress levels for M/s. S.C.L, SAS Nagar. The stresses were found to be in the range of 1.5×10^8 to 4×10^9 dynes/cm^2. Similar measurements were also made on specimen of Si with thin film in collaboration with CEERI. In these specimen stresses were found to be in the range of 3.9×10^8 to 1.9×10^9 dynes/cm^2.

High resolution X-ray diffractometery and topography method were used to study the interaction of charge carrier with lattice during two dimensional conduction in Si MOSFETs. In topographs small changes in contrast could be observed. Microdensitometer records of a series of Si MOSFETs taken before during and after the conduction were thoroughly analysed for quantitative evaluation of changes in the intensity observed in topographs. Small changes were detected. This work is being pursued jointly with P.T.B, FRG.

Crystalline perfection of 100 mm dia silicon single crystal wafer was evaluated by recording diffraction curves and high resolution topographs using (111) and ($\bar{2}20$) diffracting planes multicrystal X-ray diffractometers. The orientation of the straight edge was determined by a new direct and non-destructive method employing high resolution traverse topographs. Determination of surface orientation was carried out by using a new diffractometric method for M/s SCL, SAS Nagar.

The study of point defects and their aggregates in magneto-optic films deposited on gadolinium gallium garnet single crystals were carried out by high resolution X-ray diffractometry and diffuse X-ray scattering measurements. The quadruple crystal X-ray diffractometer was used to accurately determine the value of the lattice mismatch between the film and the substrate. The mismatch was found to change with composition. Analyser crystal was used in these measurements. Traverse topographs were recorded from the film, the interface and the free surface.

Last year a comparative study of diffracted X-ray intensities from diamond and silicon single crystals was carried out. Nearly perfect silicon carbide crystals have been chosen for a systematic study of diffracted intensities. Preliminary experiments were carried out with the following reflections: $11\bar{2}0$, $10\bar{1}0$, $10\bar{1}1$, $10\bar{1}2$, $10\bar{1}3$, $10\bar{1}4$, 0006, 0012, 0018.

1.1 Preparation of high T_c Superconducting Materials

High temperature superconducting material was prepared by ceramic techniques using different firing temperatures. These samples were analysed by X-ray diffraction and microprobe analysis. The onset temperature for superconducting was found to be around 81 K. The samples also showed strong Meissner effect. Oxygen content determined by gas chromatography was found to be in the range 6.83-6.88. Synthesis of high T_c material like $YBa_2Cu_3O_{7-x}$ was carried out using precipitation technique. Different routes like carbonates, oxalates, hydroxides of the metal ions have been tried. Precipitation as hydroxide was found advantageous as the material remained compact and there was no contamination of cations. This resulted to lower sintering temperatures, sharp transitions and good Meissner effect.

1.2 Surface Area and Porosity Measurements

R&D activities were continued on the activated carbon fibres using indigenous rayon yarn. A sample of activated rayon yarn was also prepared under severe conditions of activation. The BET surface of this sample was found to be 3542 m^2g^{-1}. Samples of activated carbon granules received from NTPC were tested for surface area and porosity. Carbon molecular sieve of the Cryogenics Division was tested for surface area. In collaboration with CEERI, samples of single crystal silicon, deposited with different thicknesses of oxides, were characterized using Krypton adsorption at liquid nitrogen temperature.

STANDARD REFERENCE MATERIALS

Crystallographic orientation of the surface of five silicon single crystyal wafers was determined accurately by using a new high resolution X-ray diffractometric method. The angle between the wafer surface and the nearest crystallographic plane was determined experimentally. The plot of the angular orientation of the diffraction vector as a function of the azimuthal orientation is a sine curve. This curve defines the crystallographic orientation.

S. No.	Specimen	Type of doping	Nominal orientation	Angle between the surface and nearest crystallographic plane arc, min.
1	SRM-1	n-type	(100)	6.02
2	SRM-2	n-type	(100)	30.96
3	SRM-3	n-type	(100)	31.61
4	SRM-4	n-type	(100)	4.13
5	SRM-5	P-type	(111)	21.85

High purity water (18megaohmcm) obtained from the dionization unit was further subjected to purification in all quartz sub boiling distillation apparatus. A few batches were prepared. The evaluation of trace constituents like Fe, Cu, Mg, Ca, Zn, Pb etc were attempted using flame mode of atomic absorption spectrophotometer. The samples were concentrated 100 times by evaporation and/or complexation with ammonium pyrollidine dithiocarbamate (APDC) and extraction with MIBK. The trace elements in these solutions were still not detectable in the flame atomic absorption spectrophotometer. Further concentration of these elements is being tried.

SUPERCONDUCTIVITY

Basic studies on high temperature superconductors have suggested the possible existance of phases which might be superconducting at room temperature. Both Mossbauer and Hall measurements carried out on Yttrium based superconductors have given some insight into the nature of superconducting state. The new bismuth based superconductors were studied and Josephson tunnelling effects have been investigated. From the applications point of view, efforts were being made to prepare Y-Ba-Cu-O in the form of films and multifilamentary wires in a silver matrix. The critical current of these wires is, however, low so far. The experiments were conducted for the optimum conditions for the desired grain structure and density of the samples.

HIGH TEMPERATURE SUPERCONDUCTIVITY

1. Basic Research

NPL's Superconductivity Group was the first ever to suggest in May, 1987, the possible existence of room temperature superconductivity in the temperature range of +15 to +26°C in Y-Ba-Sr-Cu-O samples. The resistance versus temperature curves showed resistance drops occurring at these temperatures. These drops were corroborated to the possible presence of superconductivity through careful investigation of inverse a.c. Josephson tunnelling effect which showed microwave induced d.c. voltages persisting upto these temperatures. Earlier, similar studies on Y-Ba-Cu-O system had indicated superconductivity at -70°C in conformity with the parallel studies reported from elsewhere. Collaborative efforts with CEERI have further shown the possible presence of superconductivity at room temperature in fluorine implanted Y-Ba-Cu-O-F samples after suitable heat treatment.

With the discovery of Bi and Tl based high T_c superconductors in early 1988 interest at NPL was partly reoriented to these new materials and several samples of Bi-Ca-Sr-Cu-O were successfully fabricated which showed superconductivity in the liquid nitrogen temperature range.

TIFR-NPL collaboration using Mossbauer spectroscopy of tin substituted Y-Ba-Sn-Cu-O samples have shown that Sn is substituted in two crystallographically dissimilar sites. Mossbauer absorption across the superconducting transition showed anomaly. The work has suggested the relevance of linear chains of the unit cell in high T_c and the likely importance of phonons.

Hall measurements made using 7T superconducting magnet system have shown that the current carriers in the oxide superconductors are holes. The carrier concentration, estimated from these studies, agreed well with the reported data from Japan and U.S.A. At T_c the Hall coefficient showed an abrupt anomaly. This has been explained in terms of the granular nature of the oxide superconductors. Granular nature of the high T_c ceramic superconductors was conformed by host of a.c. and d.c. Josephson effect studies carried out on the bulk materials. Intergrain Josephson tunnelling was demonstrated. SQUID like behaviour under small magnetic fields was also detected. Both point contact and break junctions were also fabricated and studied with the object to use them in high sensitivity SQUID devices.

Screen printed films of Y-Ba-Cu-O have yielded T_c values in the range of 90 to 70K. Attempts were underway to use thin film deposition techniques. R.F. sputtering techniques have resulted in thin films on substrates of polycrystalline strontium titanate which have T_c onset of 90K and R = 0 at about 50K.

2. Applied Work

R&D work on high temperature superconducting Y-Ba-Cu-O system was taken up. The emphasis was on optimising the various processing parameters

involved in the standard ceramic technique so that superconducting samples of the desired quality can be produced in large scale. With some refinements in the processing techniques it was possible to reduce the calcined particle size from an initial value of 3 μm to 1.7 μm and then to 0.9 μm. With this breakthrough, larger quantities of raw material ($\frac{1}{2}$—1 Kg batch size) were now being taken up for processing in each run. The chemical coprecipitation technique was used for further reduction in the particle size and better chemical homogeneity. A percursor to the 1:2:3 nominal composition with amorphous type structure was successfully obtained by the coprecipitation method through careful control of reaction temperature and basicity (pH). Some of the characteristic chemical reactions as well as oxidation/deoxidation kinetics of the raw/calcined/sintered material upto 1000°C, were studied, using thermogravimetric and differential thermal analysis. Sample densification equal to 94% of d_{th} was achieved after extensive studies. As many as two hundred sintering/calcination experiments were conducted to determine the optimum conditions for the growth of desired grain morphology and densification in the samples.

For magnet applications the material has to be fabricated in the form of multifilamentry embedded in a metal matrix for thermal stabilization. The efforts were made to produce fine wires in silver matrix using superconducting $Y_1 Ba_2 Cu_3 O_{7-x}$ compound. Our studies had earlier shown that silver as much as 60 wt. percent neither changed the transition temperature T_c nor the crystal structure of this compound. Wires, produced by powder compaction technique, are superconducting with T_c between 85 and 90K but have lowcritical current density, J_c = 45 $A.cm^{-2}$ at 77K as per 1μv/cm criterion. The wire, however, goes completely normal at J_c = 778$A.cm^{-2}$

The low value of J_c is attributed to (1) low density of the superconducting core (2) weak intergrain couplings (3) mismatch of thermal expansion coefficients of the silver matrix and compound and (4) low purity of the raw materials used.

RADIO SCIENCE

Several major contributions in the areas of SROSS payloads, radio communications and radio and atmospheric physics were made. Some of the substantial results obtained earlier under IMAP were consolidated. The Sross aeronomy satellite payloads have progressed through a series of check out and testing systems. The mechanical designs of both the sensors have been finalised and fabrication initiated. The rocket and balloon programme, including the second phase of the Indo-USSR ozone campaign and the NPL-UTK nitric oxide, was executed successfully. The gerdien condenserballoon data was analysed and interpreted. Considerable technical contribution was made through the realisation of the accumulation of positive potential and the gandola during balloon flights.

The microwave radio refractometer was flown on the aircraft of the Indian Navy and attempts were made in obtaining radio refractivity data by flying kytoon aboard the ship. Extensive measurements of HF field intensities from commercial transmitters and of atmospheric radio noise were collected to form valuable inputs to CCIR in these respective areas. Anamalous long distance reception of Pakistan TV over a number of regions in India was investigated and the data interpreted.

Analysis of data frompioneervenus orbiter has shown that the electron temperature variability in the venusian ionosphere is controlled by solar wind heating. Satellite Beacon studies of the ionosphere continued with special emphasis on spatial correlation of ionospheric electron content, travelling ionospheric disturbances and scintillations at a number of frequencies. The group also contributed liberally in finalization of the fabrication design of the Indian MST Radar.

INDIAN MIDDLE ATMOSPHERE PROGRAMME

1. Rocket and Balloon Experiments

The second phase of Indo-USSR Ozone Campaign was caried out between December 3-7, 1987 from TERLS, Trivandrum. During this campaign, 22 rockets were launched carrying various payloads of ozone of different institutions. The participating institutions and laboratories were NPL, Physical Research Laboratory, Ahmedabad, Indian Meteorological Department, New Delhi, Indian Institute of Tropical Meteorology, Pune, from Indian side, and Soviet Groups from SCHECNE. Indian side had 4 daytime and 3 nighttime flights. NPL payloads included UV sensors operating at 2550, 2900 and 3100°A for the measurement of ozone concentrations and a visible sensor on 4500°A for determining the attitude of the rocket. These payloads were fabricated, tested and calibrated and duly GATE tested for qualifying for the rocket flights. These payloads were then integrated and various preflight tests were conducted at the rocket range. The two NPL flights were held on December 5, 1987. All experiments performed well and good data was obtained throughout the flights.

NPL payloads of propagation experiment, Langmuir probe, Lyman-Alpha and Ozone experiments were tested, calibrated and qualified for flights. Afterwards, these payloads were handed over to the rocket range for integration alongwith the Nitric Oxide and the Electron Temperature Probe payloads contributed by UTK, Japan. The mechanical and the electrical integration of all the payloads was carried out successfully for the flight scheduled for May 1988.

The data obtained from the Langmuir probe payloads flown on 3 balloon flights conducted during the year 1985 and 1986, was analysed to show the effect of gondola charging during the ascent of balloon. It was established from the data that during its ascent, balloon gondola gets heavily charged to +ve voltage with reference to the atmosphere. The gondola then gradully discharges in more than 1.5 hours when the balloon floats at ceiling altitude. This heavy charging of gondola affects the true measurements of all the

ionisation experiments and hence cannot be neglected. It is expected that this problem is due to generation and accumulation of static-charge over gondola and this problem may be due to the development of heavy charge on the balloon itself. This problem is being investigated in depth for optimising the balloon experiments for Middle Atmosphere Studies.

Analysis of the Gerdien Condenser data obtained by the IMAPC-C Balloon experiment of 22 December 1986 was done and negative ion conductivity and concentration were obtained in the height range of 22.6km to 32.4km. Conductivity varied from 2.5×10^{-13} mho/m at 22.6km to 1.5×10^{-13} mho/m at 32.4 km; whereas the negative ion density varied from 3×10^{-2} cm^{-3} at 22.6 km to 2.5×10^{1} cm^{-3} at 32.4km.

1.1 Solar Radiation Measurements

In this programme solar UV-B radiation for global and direct were measured at ground by filter photometers. Under the IMAP net-work solar UV-B photometers installed at different locations in India started taking observation for global radiation for building erythemal dose data for different months and season.

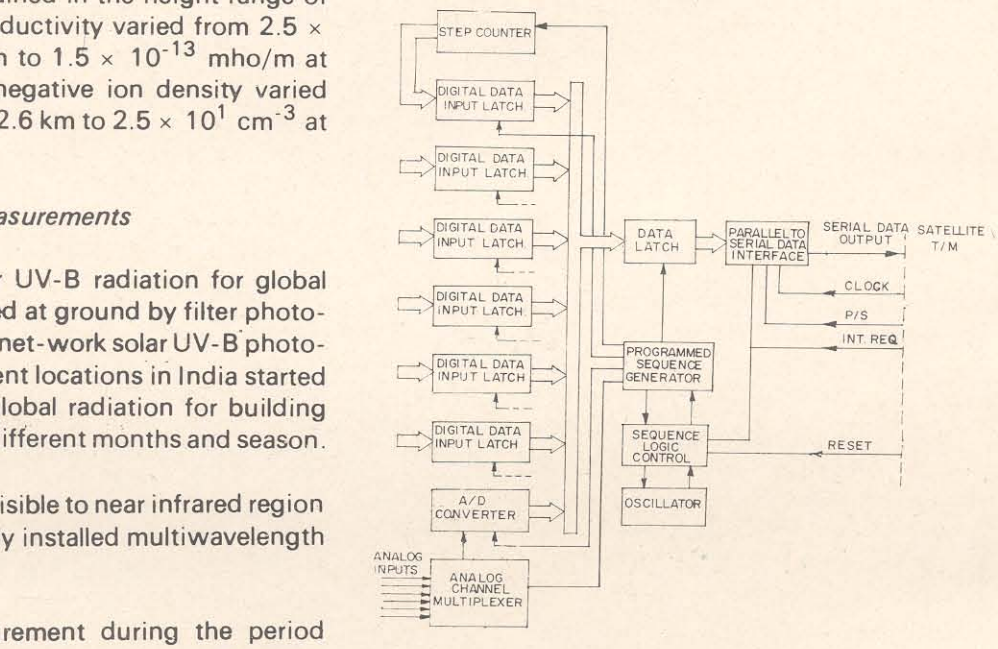
Direct solar radiation in visible to near infrared region were measured by newely installed multiwavelength radiometer.

Sun photometer measurement during the period April to November 87 were used to derive Angstrom turbidity coefficient and optical extinction coefficient at 368, 500, 675 and 778 nm wavelengths. Data analysis of last several years (1982-87) of UV-B radiation has shown maximum radiation during year 1986 incomparison to previous years. This is in anticorrelation with total ozone values for different years.

SROSS AERONOMY SATELLITE

1. RPA and EPS payload electronics

Based on the recommendations of the Standing Review Committee, additions and alterations were incorporated in the designs of RPA and EPS payloads. A redundant data acquisition and T/M interface was designed using conventional logic circuits instead of a microprocessor chip. The block diagram of the data acquisition unit is shown in Fig. These units are used to store the data from the payloads in the on-board memory; and then transfer the same to the satellite telemetry in a particular format for further transmission of the data to ground In case, the main unit stops working, the redundant unit can be switched on through a ground telecommand.



Block diagram of the redundant data acquisition system and satellite telemetery interface

In order to achieve better realiability and reduce the cross-interference among the two payloads, it was decided to have all the above units separately and independently for the two payloads. In order to achieve better flexibility in the on-board operation of the two payloads in different modes, it was decided to use two words of data-commands (32 bits total) instead of one word of data-command used earlier. The electron and ion electrometers in the RPA payload were modified to accommodate 10 gain ranges, instead of 8 gain ranges for accommodating larger variations in electron and ion currents expected during the life time of the satellite in high solar activity period.

The designs of electronic circuits for both the payloads were suitably modified and it was decided to fabricate *one more version* of pre-engineering model of both the payloads. Fresh layouts and artworks for PCBs were made for both the payloads as per re-arrangement and distribution of various circuits within different PCBs. The sample layouts and artworks for few PCBs were got approved by the Quality Assurance Division of ISAC, Bangalore. These models of both the payloads are being fabricated keeping in view the following allocated power, size, weight and other specifications from the spacecraft:

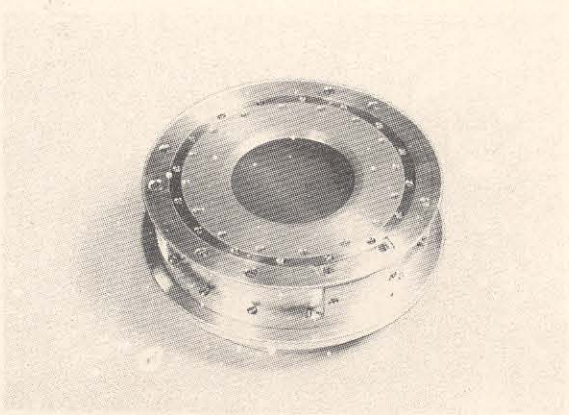
	RPA	EPS
Power	3.6 W	1.36 W
Size of Electronic Box	250× 200× 135mm	216× 120× 135mm
Total Weight of Sensors and electronic boxes	6 Kg	2 Kg
Total No. of PCBs	9	6

1.1 Sensors and other Hardware

The mechanical designs of the RPA and EPS sensors and the electronic boxes were finalised. The fabrication of RPA sensors was taken up in the workshop and two proto-types of the sensors were fabricated (Fig). A fixture for assembling the grids of RPA sensors was designed and fabricated. The grids of the sensor consist of tungsten mesh of 100 and 50 mesh per inch and of wire diameter of 0.025 mm. The fabrication of the engineering models and the flight models of RPA sensor was started.

Electron and ion sources for calibrating and testing of RPA electron and ion sensors are being developed with the help of CEERI. The work of fabrication of sources has been initiated there. For testing and quick checking of the payload performance during various phases of payload integration with the satellite sub-system, a ground checkout system is being developed. The design has been worked out and the interface between the PC and the payload was developed.

For testing and checking the RPA payload electronics, the electron and ion current sources were simulated. These sources are designed on the basis of simulated current profiles expected in real time flight of the satellite by the RPA sensors operating in various modes for measuring the electron and ion densities, their tempeatures and irregularities.



RPA SENSOR

RADIO AND ATMOSPHERIC PHYSICS

1. Planetary Ionospheres

The vari[illegible]e ionospheric electron temperatur[illegible] dynamic pressure (SWDP, [illegible] from the electr[illegible] ...eter experiments, aboard the Pioneer Venus Orbiter. A number of dayside periapsis orbits with SWDP varying from 2×10^{-8} to about 1.7×10^{-7} dynes cm^{-2} were selected to study changes in Te. It was seen that there is a statistically linear relationship between the SWDP and Te which is seen to vary from 3000°K to more than 10,000° K at an altitude of 250 km, during the above mentioned SWDP range. These results imply that electron temperature variability in the Venusian ionosphere is essentially controlled by solar wind heating.

2. Ionospheric and Neutral Atmospheric Modelling

Reference atmosphere for the Indian sub-continent

were generated by using the Mass Spectrometer and Incoherent Scatter, model MSIS-86. Three Indian stations, namely Trivandrum, Ahmedabad and Delhi, covering a latitude range from the equator to the mid-latitude, were selected and the reference atmospheres generated for those stations. Tables of neutral temperature, total mass density and number density of 0, N_2, H_2, Ar, H, N for only one station, Delhi, were given. The altitude range covered was 90 to 1000 km and profiles were generated every two hours of local time for 10.7 cm solar flux of 75, 100, 125, 175, 200 and 225 units.

A model was developed for the zonal and meridional wind over Thumba (9°N) covering the height range of 1-60 km. The data base for this has been the radiosonde and Rocketsonde data covering the sixteen year period from 1971-86. The model is helpful in planning rocket and balloon flights and also in other studies.

Using the ionospheric data collected over the Indian stations during the last three decades, NPL has developed a statistical model for predicting the values of F region peak parameters for different times of the day and different months and for any level of solar activity. Combining this NPL method for estimating peak parameters of foF_2 and hmF_2 (derived from M (3000) F_2) and the IRI program for profile shape, reference ionospheric models were generated for all the Indian ionospheric stations for midday and midnight, for three seasons and three levels of solar activity. For Indian rocket launching stations, however, since such a good data base is not yet available, these profiles will be useful for both radio communication purposes and aeronomical studies.

The URSI/COSPAR Task Group on the IRI is currently at work to formulate a new description of electron density distribution in the middle ionosphere. Making use of the available ionogram-derived electron density profiles over Delhi and Ahmedabad during the IGY/IGC period and attempt was made to model the electron density distribution using the LAY functions. It turned out that a 2 parameter (excluding the F_2 peak parameters, hmF_2 and NmF_2) LAY function represents the electron density distribution over Delhi and Ahmedabad well.

2.1 Tropospheric and lower Stratospheric winds over Pokar Flat (Alaska)

The sample data obtained from Pokar Flat MST radar covering four days period from January 31 to February 3, 1982 was analysed. The three radial velocities, measured by the two 'oblique' and one 'vertical' beam, as recorded on the tape, were converted to zonal (U), meridional (V) and vertical (W) & were then averaged over one hour interval and their temporal and spatial variations studied. It was found that the time series of vertical velocity with time resolution of about 2 minutes showed evidence of periodic, though less regular, oscillations with amplitude of 0.5 to 1 ms^{-1}. The diurnal plot of one hour averaged vertical velocity showed a value very close to zero. The zonal velocity averaged over 1-hour period generally showed an eastward trend, with magnitude of variation in the range of 5 to 20 ms^{-1} at heights of 12.5, 14.7 and 16.9 with more variability at 10.3 km. The meridional velocity generally remained southward at higher heights with magnitude of fluctuations varying between 1 to 10 ms^{-1} and again with more variability at 10.3 km altitude. The variability of zonal and meridional velocities suggested that the lower region is more unstable as compared to higher regions.

2.2 Turbopause Region and F-region Electron Densities

An analysis of three simultaneously measured ionospheric parameters namely the ion-neutral collosion frequency (V_{in}) in the lower thermosphere, ion drift (V_z) and electron concentration (N_e) in the F2 region was made. These parameters were taken from the incoherent scatter radar measurements at Arecibo for the period August 1974 to May 1977. As the major atmospheric neutral constituent near turbopause is molecular nitrogen, the variations in ion neutral collision frequency were taken as an indicator of variation in the neutral concentration. Results of the analysis showed that variability in peak elecron density (N_m) cannot be explained on the basis of changes in the F-region vertical ion drift alone.

3. Satellite Beacon Studies

The IEC obtained simultaneously at three locations. Lunping (22.7°N, 130.0°E), Guwahati (23.8°N, 83.6°E) and Udaipur (22.6°N, 69.6°E) situated along the crest of the Northern equatorial anomaly, indicated that the correlation of IEC between pairs of locations was a function of local time and was smaller compared to that obtained for similar longitudinal separations at midlatitudes. An empirical model for

calculating the ionospheric electron content (IEC) was developed. It requires only a per-calculated set of co-efficients as input and eliminates the necessity to integrate electron density profiles.

Equivalent slab thickness during the period 1978-80 showed significant diurnal and seasonal variations for both lunar and solar variations. There is no apparent correlation between these variations and sunspot activity. The occurrence of lunar semi-diurnal component, coincides with the diffusion caused by the additional fountain effect generated by the lunar semidiurnal variation of the equatorial electric field.

The Faraday rotation data from the satellite ETS-II was continuously recorded. Analysis of the amplitude and Faraday rotation data showed that during summer TIDs occured equally both during day and night. In winter, the occurrence was more at night than during day. The average period observed at night was greater than the average period observed during daytime. During summer months TID occurrence decreases with solar activity upto about 120 units of solar flux. The analysis of 3-station data around Hyderabad showed that TIDs move in all directions. However, there were two preferred directions of motion viz. 160° and 310° azimuth. The TIDs were absent during the post midnight hours. The TID velocity vector was found to rotate anticlockwise.

4. Scintillations

Systematic time differences observed in the onset of postsunset VHF scintillations, recorded simultaneously at a meridian chain of stations in the Indian sector, were analysed. As the Plasma bubble rose in the equatorial ionosphere, after its generation in the bottomside of the F-layer, the low latitude extremities of the bubble propagated away from the equator in such a way that the upper height limit of the irregularities defined the latitudinal limit of the scintillation occurrence associated with the given event. From the time delays observed in the onset of postsunset scintillations between an equatorial and a low latitude station and between two low latitude stations and the altitudinal differences over the magnetic equator between their respective field lines corresponding to the F-region heights, the average bubble rise velocities between two altitudinal slabs were determined. The velocities varied from about 50 to 390 m/s between the altitudes of 450 to 1140 km and from about 15 to 200 m/s between 1140 to 1270 km.

VHF nighttime scintillation observations from stations extending from equator to 21°N magnetic latitude along 84°E longitude in the Indian zone and at Lunping (23°N, 122°E, mag. lat. 14.9°N sub-ionospheric), were examined for large number of geomagnetic storms of varying strength. For cases in which recovery phase of the storm starts during midnight to dawn local time sector and whose DST value goes below–100 nT, strong postmidnight scintillations extending well beyond sunrise hours were observed at locations from 84°E to 122°E longitudes and in a wide latitudinal belt particularly in the Indian zone. Also, equatorial region of both the zones, showed considerable postmidnight increase in h'F as well as in spread F. In cases of those storms whose recovery phases start during local daytime hours, then on the following night scintillation and spread-F activities were found to be suppressed completely or partially depending upon the maximum negative excursion of DST. The results are useful for characterisation of storm associated scintillation activity for prediction purposes.

5. Microwave/Millimeter Wave Radiometry

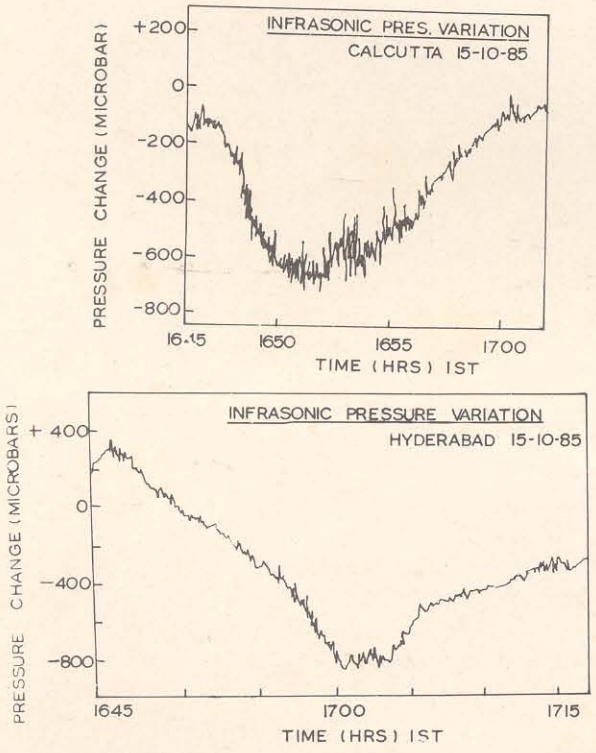
The values of attenuation for fog and mist during the winter were evaluated. The cumulative distribution of antenna temperature for fog and mist showed that for 0.2% of time the antenna temperature for intense condition of fog and mist was 92°K. Liquid water content in gm/m^3 for various measured values of attenuation and for different fog heights were found as also the predicted values of visibility. Studies were also made for determination of precipitable water vapour and cloud liquid in x and k bands. The presence of clouds change microwave radiometric measurements by increasing the total atmospheric emission through the liquid water emission and by attenuating emission from other atmospheric components. Observations over New Delhi during the monsoon period for cloud liquid showed that liquid content varied from 0.1×10^3 to 6.1×10^3 g/m^2 and water vapour from 3×10^4 to 8.5×10^4 g/m^2. The corresponding antenna temperature showed a change between 10 to 120°K above the sky level. The average value of the integrated water vapour content for winter, pre-monsoon and post monsoon were also determined. The work to establish 37 GHz millimeter wave radiometer was continued.

6. Indian Mesospheric, Stratospheric and Tropospheric Radar (MST-Radar)

A preliminary design review (PDR) was held which resulted in freezing the radar design up to subsystem level. The fabrication of laboratory prototypes has been taken up. NPL contributed significantly specially in design of radar controller, data acquisition and signal processing systems. A new approach was evolved towards ST mode operation.

7. Studies with Microbarograph

Infrasonic pressure variations recorded by microbarograph were studied for cyclones, using data from Hyderabad and Calcutta. It was found some characteristic infrasonic waves were recorded at both Calcutta and Hyderabad when the cyclone was still at sea. Relative time difference of the onset of these wave trains depended on the distance from the cyclone centre whether it is nearer to Hyderabad or Calcutta. There seems to be a cause and effect relationship between infrasonic pressure variation and microseisms generated during a cyclone, both reaching a peak amplitude when the cyclone crosses the coast.



Infrasonic pressure variations at Calcutta and Hyderabad. The cyclone was nearer to Calcutta on this day.

8. Antarctica measurements

In VII Antarctica expedition three experiments for the measurement of global UV-B radiation, direct solar radiation at 310 nm and a sunphotometer for optical extinction coefficient were sent. The measurements were made at station Maitri on nearly all clear days during the months of Jan. Feb. 1988. The preliminary results indicated large scale change in daily ozone values during this period.

The data of VI Antarctica expedition were analysed and it was observed that global radiation at 310nm wavelength was higher by a factor of 10 than the radiation received at 300 nm wavelength. Also atmosphere was clear during Jan. & Feb. 87 for the higher wavelengths and optical extinction with aerosol was observed only by 368 nm measurement.

RADIO COMMUNICATIONS

1. Longterm Solaractivity Predictions

The long-term prediction of current Solar cycle No. 22 was updated using the regression coefficients established by the sunspot-number data of past 21 Solar-cycles. The present cycle started with a minimum in Sept. 1986. Predictions made at that time using the available information on earlier cycles indicated present cycle No. 22 to be a low Solar activity cycle. However, the growing phase of the cycle during the period 1987-88 indicated a high activity Solar-cycle and accordingly the predictions for smoothed monthly means for the cycle were updated.

1.1 Long term ionospheric predictions

A special project to complete an Atlas of ionospheric F-region parameters over the Indian subcontinent was undertaken. This is based on foF2 and M (3000) F2 data collected for the last 2-3 solar cycles for 8 Indian and 2 Russian stations. A computer programme to calculate the errors of prediction has also been included. Frequency plans for the communication links with their reflection points over the Indian subcontinent can be obtained with the help of this document.

Based on the monthly variability of foF2 at a low latitude station, Ahmedabad, it was observed that seasonal patterns of monthly median foF2 may be

used for estimating the extent of prediction of foF2 on a month-to-month basis. First order auto regression scheme on deviations of foF2 from average seasonal patterns was used. It is shown that seasonal patterns over at least two years need to be averaged to give predictions of monthly median foF2 two to three months in advance. The statistical model estimates of the uncertainties in month-to-month predictions of foF2 are lower than those given by CCIR method and are of the order of day-to-day and hour-to-hour fluctuations in the observed foF2 values.

1.2 HF Field Strength Measurements at Delhi

The field strength meter was used to measure the signal strength of several HF broadcast transmissions routinely since September 1987. A data analyser was used with the meter to determine the upper median and lower decile values of signal strength. The collected data was analysed to estimate ionospheric absorption losses for circuits which control points in India and outside and the values were compared with those estimated using the various available empirical relationship including the CCIR recommended formulae. It was observed that the ionospheric absorption values derived from experimental data in general were higher at equatorial and low latitudes in comparison to those derived from CCIR formulae. The fading patterns of various high frequency transmissions were also analysed to determine the rapidity and severity of fading and other fading characteristics at Delhi to help in radio system planning.

1.3 Studies on Atmospheric Radio Noise

The atmospheric radio noise at Delhi on different frequencies in the HF range was measured. The data collected over the last seven months at Delhi was analysed and compared with the predicted values of CCIR and with the earlier measurements made in Delhi by All India Radio and also with those estimated from thunder storm activity data collected by the Japanese Ionospheric Sounding Satellite during 1978-80. It was observed that CCIR predicted atmospheric noise values did not agree with the measured values in India. It was also noticed that the existing measured data on radio noise in India was inadequate to meet the requirements of radio engineers for planning of efficient HF radio systems and it is planned to monitor radio noise at several HF frequencies in different parts of India.

1.4 Rain Rate Measurements

The rain and other forms of hydrometeors decrease the reliability and time availability of microwave systems. The maximum ra n fall intensity recorded in Delhi was around 200 m m/hr; it was around 280 mm/hr, at Shilong and at Tirupati the value was 160 mm/hr while at Warangal, it was 110 mm/hr. The probability distribution of the rain rate was also estimated. The simultaneous results obtained by the India Meteorological Department using conventional rain gauges having integration time of 15 minutes indicated that the value of rain intensity was of lower order by a factor of 1.2-1.9. The rain rate of high order follow the log-normal distribution while the lower values are found to be associated with Poisson distribution. The relevance of these studies is obvious from the plans India has to operate around 12 to 14GHz both for LOS and satellite links.

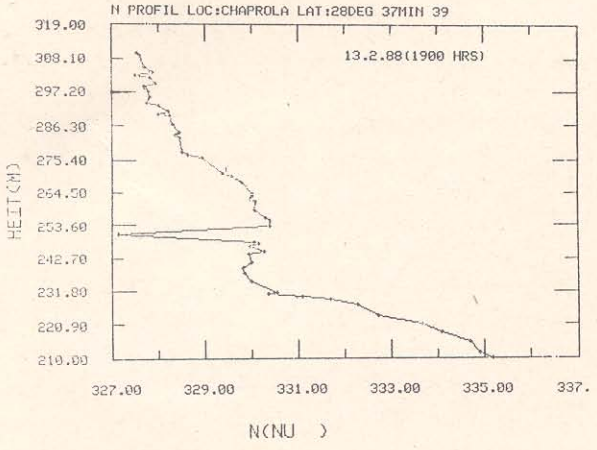
1.5 Kytoon Measurements of Atmospheric Boundary Layer

In order to explore the lower most part of Atmosphere Boundary Layer, Kytoon flights were conducted at a microwave repeater site, (Chapraula, long. 77°28', lat. 28°37.5') 30 kms north-east of Delhi at the request of the Department of Telecommunications. Eight flights were conducted in the representative regimes of the day. A typical N-profile is shown in fig.

A sensor package was flown aloft akite upto a maximum height of 200m above the groud. The respective sensor accuracies were:

Temperature (day bulb)	: ± 0.01°C
Temperature (wet bulb)	: ± 0.01°C
Pressure	: ± 0.01 m bar

The observations made from the soundings were: Temperature inversion was observed every evening right from ground to a maximum height attained in the flight. Ground based humidity inversion was also observed during evening and late night hours, the thickness of which varied between 40 m to about 100 m. Lowest gradient between surface and 100 m. was found to be -85 N/Km and highest -200 N/Km during night hours while during day time it varied between -45 N/Km to -75 N/Km.



1.6 Anomalous VHF Band Propagation.

The daily scanning of all the TV channels was made to monitor the anomalous reception of TV signals. The TV transmissions of Pakistan operating on Ch-5, Ch-10, Ch-11 were received alongwith other Indian stations from 0745 onwards during 15-16 March, 1988. Pakistan TV signals were indentified on the basis of their test cards and language and the signal levels were determined with the help of a spectrum analyser. The radio sonde data of Ayanagar observatory, New Delhi and Patiala for 15th and 16th March 1988 were collected from India Meteorological Department. With the help of various path loss prediction techniques, it was concluded that the reception of Lahore (Ch-5) and Mirpur (Ch-11) TV transmissions was due to reflection from elevated layers occuring in the lower boundary layer. The strong signal level observed at Delhi were due to the high transmitter powers coupled with the anomalous propagation conditions occuring over Northern plains.

1.7 Software Package for Evaporation Duct

The range at which a radar can detect a target is greatly influenced by atmospheric ducting phenomena. Studies on seasonal variation and latitudinal distribution of evaporation ducts over Indian Ocean were completed. A completely automatic computer programme that works on a small computer like IBM PC was developed. The programme computes the signal levels at different ranges in an evaporation duct. A sample Radar operating at 3 GHz with a transmitter height of 10 m radiating 75KW power was assumed. The signal levels were evaluated using ray theory for different duct heights ranging from 15 m to 40 m with gradient of -200 N/Km and -300 N/Km. The output includes horizontal coverage diagrams depicting target height Vs range for different elevation angles, field strength plots for free space and ducting conditions, and signal level as a function of duct thickness refractivity gradient at a fixed range.

1.8 Microwave Refractometer

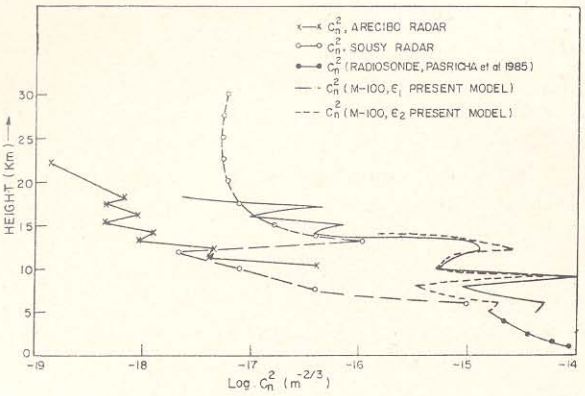
From the refractivity, pressure and temperature measurements using airborne microwave refractometer, the altitude distribution of water vapour density was derived. The water vapour of water data derived from microwave refractometer was compared with that obtained from radiosonde data. It was seen that the average nature of radiosonde derived profiles was similar to the refractometer profile but the fine structure of water vapour density was well represented in refractometer measurements.

1.9 Modelling of turbulance structure constant

An attempt was made to derive Cn^2 profile upto about 17 km using the available M100 and balloon data. Cn^2 is dependent upon eddy dissipation rate, horizontal gradient of wind velocity, outer scale of turbulance, atmospheric pressure, temperature, specific humidily. Measured and model values of above parameters were taken over Thumba and a computer program was built to derive Cn^2 profile. Cn^2 profile was then used to estimate signal to noise ratio profile for planned Indian MST, Radar.

2. Theoretical Studies of Scintillations

Single scattering theory was applied to the problem of ionospheric scintillations. The characteristics of scintillation indices computed with two power spectra; Gaussian and Kolmogorov; were studied in



Height distribution of C_n^2

detail. Theoretically computed scintillation index was compared with that observed at 327 MHz at Ooty. It was found that the scintillation index computed with the Kolmogorov spectrum was in closer agreement with that observed at Ooty. The problem of trans-ionospheric radio beam waves propagating through a turbulent layer was studied and analytical expressions for beam-wave wander and spread were derived with the power-law spectrum of ionospheric irregularities by using phase screen model. Some numerical computations were carried out to estimate the possible beam-wave spread for SROSS. Recent development in the optical scintillation theory was adapted to the ionospheric geometry in order to study the ionospheric scintillation phenomena in presence of multiple scattering. In the forward scattering limit, Markov approximation was employed to derive wave statistics for a plane wave. In the process, an integro-differential equation characterizing scintillation phenomena was obtained.

APPLIED PHYSICS PROJECTS

The projects of development of space qualified multicavity interference filters for ISRO and highly conducting copper coating with a protective coat of gold on ferrite rods for DRDL were completed. Amorphous silicon solar cells of 8 sq. cm. area with nearly 7% efficiency were fabricated. First prototype of Xeroradiographic Machine was delivered to AIIMS, New Delhi. The first phase of hospital trials has established the usefulness of xeroradiography in routine applications under Indian conditions. In the area of Cryogenic systems, water cooled heat exchanger was developed and tested and the know-how for the liquid nitrogen containers was released to the industry.

THIN FILM AND AMORPHOUS MATERIALS

1. Thin Film Optical Coatings and Devices

The sponsored project on development of space qualified interference filters was successfully completed. Four batches (16 filters) covering four bands in the visible and near IR regions were fabricated and supplied to Space Application Centre, Ahmedabad for final tests. The filters were subjected to environmental tests (viz. –35°C, + 70°C, 95% humidity at 45°C, duration 24 hrs. for each test) and the filters survived all the tests and a satisfactory performance report was obtained.

The sponsored project of DRDL, Hyderabad, on the development of highly conducting copper coatings on ferrite rods, was successfully completed. Under the sponsored project from HAL, Nasik, 25 pieces of Gunsight Reflector Glasses developed and fabricated at NPL were supplied for their use in MIG-21 fighter planes.

Forty pieces of interference filters having eight central wavelengths and covering the spectral region from 0.45 micron to 1.1 micron were fabricated and supplied to M/s Opto-Mech Engineers, Hyderabad against payment. The filters are used by the firm in the fabrication of multiband ground truth Radiometers.

1.1 Transfer of know-how of Thin Film Optical Coatings

The process on the fabrication of "Thin Film Optical Coatings" has been transferred to M/s Haryana State Electronics Development Corporation, Chandigarh through NRDC.

2. Development of Amorphous Silicon Solar Cells (DNES sponsored)

Narrow gap p-i-n solar cells of at least 1 sq. cm. area with approximately 7% efficiency were successfully developed in a separated multizone plasma CVD reactor wherein cross contamination of the constituent p, i & n layer was completely eliminated. Large area cells (approximately 8 sq. cm.) were developed and a scheme of integration of a number of these cells on a 100 mm × 100mm precoated transparent and conducting glass was successfully implemented. These panels are made for 3, 4, 5 and 6 volts applications by suitable combination of 100 mm × 100 mm modules which easily deliver about 100 mA current under normal solar intensity.

XERORADIOGRAPHY

An improved prototype of xeroradiographic machine was handed over to AIIMS, New Delhi for field trials. The machine developed at NPL is manually operated, incorporating all provisions to develop X-ray image in a single unit. Some problems like failure of power supplies and some other components which appeared in initial stages were solved and XR machine was made operational to give good quality picture.

Radiologists of AIIMS examined the XR prints thoroughly and found the quality of XR images (hand phantoms) good as it gave all details which are expected in a good X-ray image. Though the picture quality was satisfactory the X-ray dose for these

pictures was high compared with film radiology which employs film screen combination. The charging and developing parameters were further optimised and equally good quality XR image could be obtained at 20 mAs and 50 KV_p (FSD = 100 cms). Efforts were being made to further reduce the X-ray dosage in existing machine by suitably adjusting the charging and development parameters. Addition of relaxation chamber with XR machine is being made. To achieve complete reproducibility in contrast and density pattern for XR prints, an electronically operated aerosol generating and developing assembly is being fabricated.

Electrical and dielectric properties of polymeric materials such as vinyl chloride-vinyl acetate (VC:VAc) copolymers and vinyl chloride: vinyl accetate:vinyl alcohol (VC:VAc:VA) terpolymer were investigated over a wide range of frequency and temperature. Its glass transition, structural morphology and water absorption were also investigated to see its suitability for device applications.

CRYOGENIC SYSTEMS AND DEVICES

1. Cryo-Coolers for Guided Missiles

Infrared detectors (mercury, cadmium and telluride) cooled at 77K, in-situ, are used as the latest techniques for guidance of missiles. The efforts have been made to get reliable Joule Thomson orifices as expansion valves in the diameter of about 50 microns. Using these J.T. orifices new cryo coolers have been developed with the repeatable (micron finish) mandrels and correspondingly longer shelf life in the flight and comparatively repeatable results. A few coolers are being perfected to be given to IRDE Dehradun for their actual field trials

1.1 Liquid Nitrogen Containers

The know-how for the liquid nitrogen containers was released to M/s Asiatic Oxygen Ltd., Calcutta.

1.2 Liquid Nitrogen Plant

Some of the sub-components of this system like water cooler were developed and perfected during the year. In addition water cooled heat exchanger was developed and tested. Efforts have also been made to develop another sophisticated heat exchanger.

The PSA unit was installed. The gaseous nitrogen from the PSA was produced at about 1 Bar and condensed at the same pressure. About 14,500 litres of liquid nitrogen was supplied during the year including outside agencies such as AIIMS, Malaria Research Institute, NBPGRI & IARI, Pusa etc.

1.3 Cryo Probes for Neuro Surgery

R&D was carried out to develop Cryo probes based on J.T. expansion for neurosurgical operations at AIIMS. The total system was developed and tried on an animal at the Institute. Although our unit functioned very well, but it was observed that it produced considerable bleeding and hence may not be suitable for such purposes.

TECHNICAL SERVICES

1. WORKSHOP

The workshop provided assistance to various projects of the laboratory. About 2517 jobs were handled during the year. Some of the major jobs were fabrication of prism and making of diffractometer; housing arrangement; goniometer; units of solar UVB; X-ray movement plate & Sross payloads etc.

About 590 jobs regarding making of designs and drawings, writing of charts and making of graphs were completed during the year. Some of the major jobs were Mechanical comparator; universal rotating table; magnetic tape testing device; Sross; solar cell device etc.

2. GLASS WORKSHOP

The unit assisted various projects of the laboratory in the design and fabrication of glass and silica equipment. The main divisions and sections served were Materials; Materials Characterization; Superconductivity; Standards; Cryogenics and Thin Film.

During the year, the unit assisted various outside organisations in the fabrication of activated carbon column, liquid purification apparatus, double distillation apparatus, Dewars and Dewar flasks. The reconditioning and repairing work was also done. The institutions/organisations included BHEL, IARI, AIIMS, LNJP Hospital, CRRI, Delhi University, Punjab University, NGRI, I.I.Sc.-Bangalore & I.I.T., Kanpur. The receipts of the jobs completed amounted to Rs. 1.76 lakh approximately.

3. INSTRUMENTATION

Work on the development of $5\frac{1}{2}$ digit voltmeter (DVM) was started. Display circuits were hooked up and are being tested. Circuits for Analog-to-Digital converters, microprocessor controls and display drives were designed and being fabricated.

Ultrasonic parameters of invitro bone and kidney stone samples were measured. Electrical and mechanical properties of bone were determined. An acoustic lens for tumour therapy (hyperthermia) system was designed. A microprocessor-based ultrasonic dosimeter was also designed and developed.

About 49 instruments were repaired and about 300 instruments were checked and tested for their workability. The major equipment handled were TGA unit, Electronic Analyser, Superconducting Magnet Power Supply, Automatic Flash Guns, Automatic Mass Calibration Unit, Power Supplies, Digital counters, Electronic Typewriters and Generators etc.

4. LIBRARY

Under the modernization programme the library acquired stand alone PC/XT computer. Stock verification report, journal subscription, budget control, directory preparation were some of the key activities for which the computer was extensively utilized. The Canon PC reader-cum-printer, having the special facility for reading the matter stored on microfilm/microfische and also taking its print, was procured and made operational.

The library acquired complete sets of British standards, IEC standards, ISO standards in microformats. 646 titles were added which included "Encyclopedia of Physical Science and Technology". 18 new journals were added to current subscription list raising the total number to 319. Library started a new service by which a computerised list of current journals put up for display was provided for reference and consultation for scientists. A total of 5337 items were given on loan, 513 on inter-library loan to organisations from Delhi and outside, which included University of Delhi; IIT; Delhi; Defence Science Centre; Indian Oil Corporation etc. 2390 references were supplied to scientists working in 35 projects under the SDI service programme. 15 bibliographies were prepared on demand.

5. COMPUTER FACILITY

The Computer Facility with VAX-11/780 Computer

system and terminals was in regular operation. Computational facilities, data transfer from different types of tape formats, graphic display and plot facilities, consultancy on computer programming and numerical techniques were provided to the scientists.Computer terminals were installed in different divisions to enable the scientists to access the computer directly from their place of work. The administration was provided with a small computer system consisting of one PC-AT with 3 PC's. It was used to computerise the activities of administration, accounts, stores & purchase and monitoring & evaluation sections.

6. RAJ BHASHA

The unit has done the translation work of administrative/scientific/technical nature. Most of the proformas & registers were prepared in the bilingual form.

The issues of Samiksha–a quarterly bulletin in Hindi were published. The Hindi classes were also held regularly and seven officers have qualified the prescribed Prabodh/Praveen Examinations.

7. SYMPOSIA/WORKSHOP/TRAINING COURSES

1) Basic Programming language course was organised for the NPL staff from 1-14 April, 87.
2) Specialized training in Mass, Volume and Density Measurements was provided to 14 officers from Malavi, Zambia, Laos, Sudan, Indonesia, Tanzania, Seychelles, Burma, Afghanistan, Uganda,and Malaysia between 1st April to 8th May, 87.
3) A training programme on NDT was organised at NPL from 20-24 April, 87 in collaboration with NDT Society.
4) A training course for STQC (DOE) and Defence personnel on "Remote on-line calibration for T & F standards", was organised at NPL from 28th April to 2nd May, 87. Visits for the trainees were also arranged.
5) A lecture course on VAX/VMS operating system was held on 11th, 12th & 14th May, 87 for the NPL staff.
6) A workshop on Studies of Mask Making & Replication Techniques was held on 15th June, 87 in collaboration with CEERI.
7) Three batches of Scientist B's were provided training between May-July 87 under the CSIR Orientation Programme.
8) Shri H.V. Patel, Scientist of SAC, Ahmedabad was given training in the HF & Microwave measurements for one week in July, 87.
9) A workshop on the "Characterization of Materials for Electronics" was held at NPL from 15-18 September, 87, in collaboration with DOE.
10) A workshop on "Industrial Metrology" was held from 1-4 September 87, jointly with the Metrology Society of India.
11) Two weeks training on SEM was given to a technical assistant from Thapar Corporate R&D Centre, Patiala in the month of Feb., 87.
12) Training was given to Mr. Dorgiin Agchbayar of Mongolia on "Growth of Polycrystalline Silicon and Characterization" for 3 months, Sep-Nov. 87 under the ITEC programme of G.O.I.
13) Indo-Soviet workshop on Experimental Mineralogy was held from 14-16 Dec., 87. This was collaborated by Allahabad University and sponsored by INSA.
14) A workshop on "Standard Reference Materials" was held from 17-18 March, 88
15) A course on Carbon and Graphite was organised from 7-11 March, 88 in collaboration with Indian Carbon Society.
16) Five students of M.Sc. from I.I.T., Delhi; I.I.T., Kanpur; and A.M.U., Aligarh visited NPL for six weeks under the stipend scheme of CSIR.

APPENDICES

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3. Agarwal, S.K., Jayaram, B., Gupta, A. and Narlikar, A.V.—Studies of superconductivity of Y-Ba-Ca-Cu-O and Y-Ce-Ba-Cu-O systems.
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4. Gupta, A.K., Jayaram, B., Agarwal, S.K., Gupta, A. and Narlikar, A.V.—Observation of inverse A.C. Josephson Effect in bulk Y-Ba-Sr-Cu-O upto room temperature.
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7. Gupta, A.K., Agarwal, S.K., Jayaram, B., Gupta, A. and Narlikar, A.V.—Observation of inverse a.c. Josephson Effect in bulk Y-Ba-Cu-O possessing high Tc.
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11. Jayaram, B., Agarwal, S.K., Gupta, A. and Narlikar, A.V.—Possible superconductivity above 230 K in Y-Ba-Cu-O system containing Sr. and Ca.
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17. Sharma, R.P., Prasad, K.G., Jayaram, B., Agarwal, S.K., Gupta, A and Narlikar, A.V.—Mossbauer studies of Sn in the high T_c superconductor Y-Ba-Sn-Cu-O.
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11. Pandey, V.K. and Mahajan, K.K.—Seasonal and solar activity changes of F-region electron density, electron temperature and protonospheric heat flux during the declining part of sunspot cycle 20.
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APPLIED PHYSICS PROJECTS

1. Panwar, V.S., Ramadhar Singh, Mathur R.B., Mehendru, P.C. and Gupta, N.P.—Glass transition temperature of VC:VAC copolymer and VC:VAC:VA terpolymer.
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TECHNICAL SERVICES

1. Agarwal, R. and Singh, V.R.—Determination of design parameters for an ultrasonic kidney stone disintegrator.
JASA Vol. 83, S-89.
2. Singh, V.R., Rao, MKD, Yadav, S., Jain R.K., Singh, J.M., Atul Kumar and Mohan, M.—Computer analysis of ultrasonic biometry of the human eye.
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4. Yadav, Sanjay, Singh, R.P., Ahmed, A., Agarwal, R. Singh, V.R., Misurya, R.K., Raj, G.A., Sural, A. and Vishwakarma, G.K.—Design of a focused ultrasound system for tumour therapy.
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PATENTS FILED

Aggarwal, Dr. R.K., Bhatia, Dr. Gopal and Bahl, Dr. O.P.—Development of special pitch for carbon-carbon composites No. 1187/DEL/87.

BOOKS/PROCEEDINGS

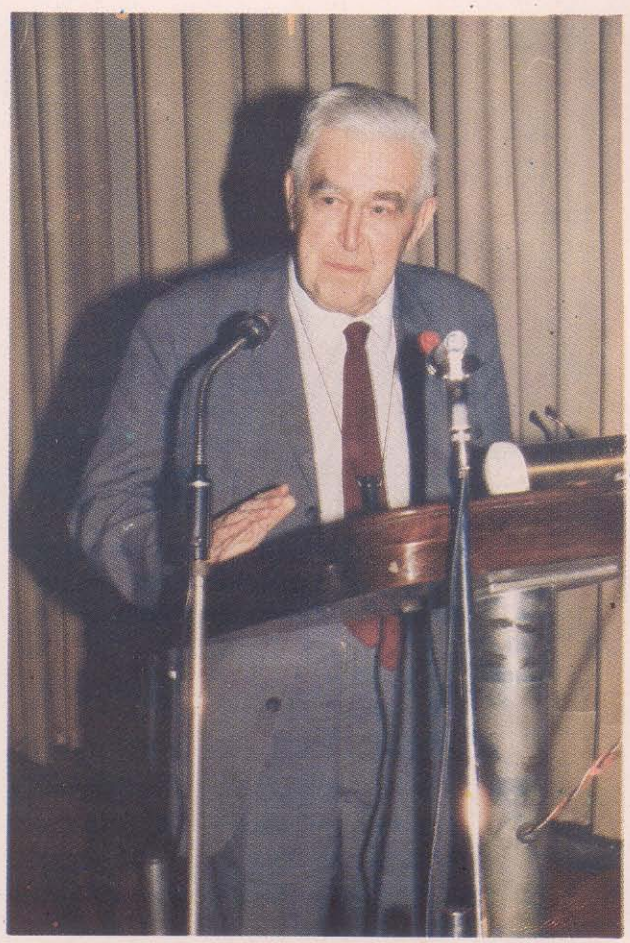
A proceedings of "National Workshop on Ozone" held at INSA, New Delhi in April, 1987 was published. The proceedings contains the recommendation on the future research in Ozone and related topics.

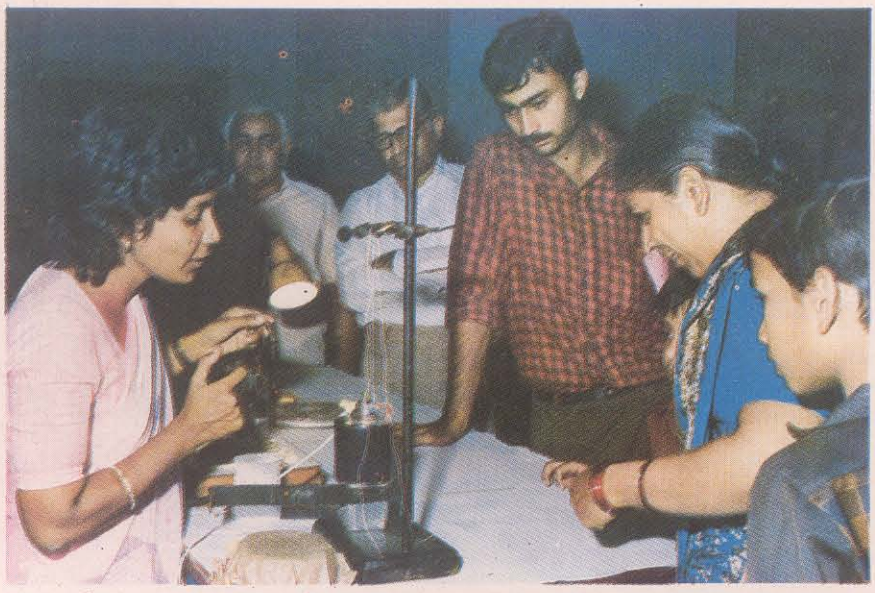
KRISHNAN MEMORIAL LECTURE

The XVII Krishnan Memorial Lecture was delivered by Prof. D. Shoenberg, FRS, former Director, Cavendish Laboratory, University of Cambridge, U.K. on Feb. 25, 1988. Prof. Shoenberg chose the title of his talk as "Sealing wax and String".

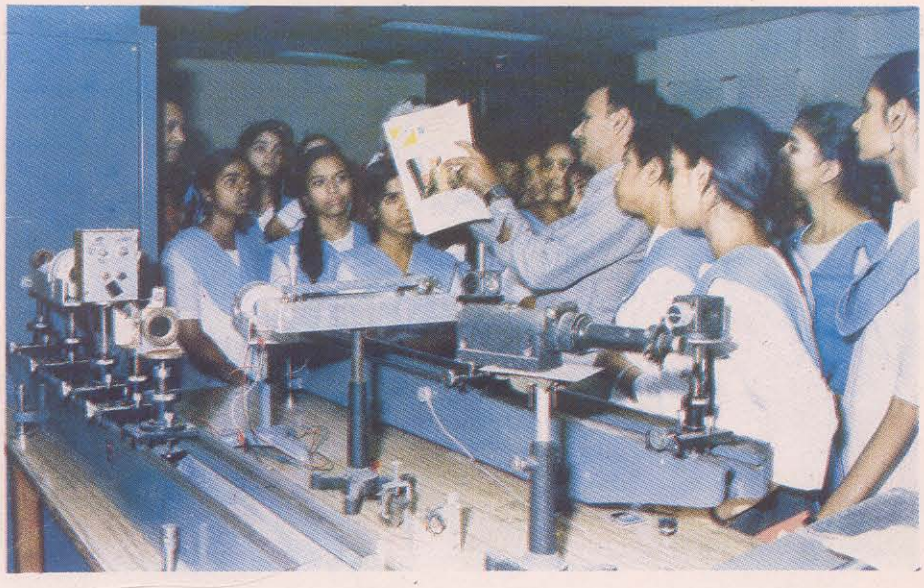
Prof. Shoenberg came in close contacts with Krishnan when he spent a year in 1953 as an UNESCO expert to establish the Low Temperature Physics Section at the NPL. He recalled that Krishnan was very much of a polymath, an exponent of Hindu philosophy, an excellent reconteur, would often bring up curious side lights on the history of science, was a keen player of tennis, and kept a record of latest scores of cricket and football matches.

Prof. Shoenberg simulated the historic experiment performed by Krishnan in his studies on magnetic anisotropy of crystals. The basic equipment used by Krishnan was literally sealing wax and string, for he used a fine quartz fibre to suspend his crystal and some shellac with which the quartz fibre could be attached to a torsion head at one end and the crystal at the other. He further described how Krishnan used his *'green fingers'* in performing precision experiments and used *'grey matter'* in explaining a variety of baffling problems in physics only to dominate the Indian science in the post 'Raman Effect' era.



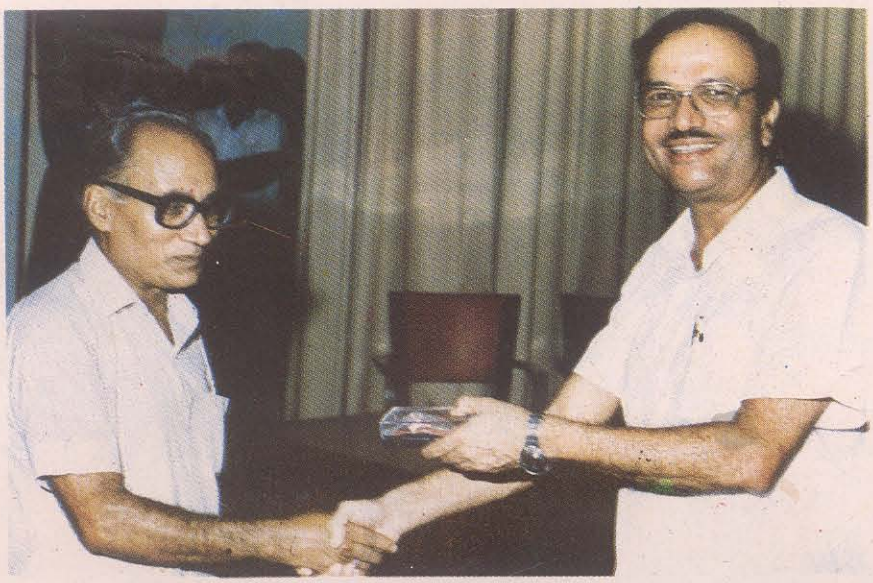


OPEN DAY AT NPL



Dr. S.K. Joshi, Director, NPL, handing over the know-how document of Thin Film Optical Coatings to Dr. Jagpal Singh of Haryana State Electronics Development Corpn., Chandigarh.

Dr. Mary. L. Cleave, astronaut (NASA) visited NPL and gave a talk about her space flight.



Dr. S.K. Joshi, Director presenting memento on 45th CSIR Foundation Day

RESEARCH REPORTS

STANDARDS

1. Indigenous development of Rubidium vapour frequency standard—G.M. Saxena, A. Chatterjee & B.S. Mathur, No. 87-29.

2. Photoacoustic spectra of light and heavy water—R.S. Ram & Om Prakash, No. 87-30.

3. A pyrhliometer based on transient principle—J.S. Vaishiya & M.S. Hedge, No. 87-35.

4. Development of techniques for electroplating high quality knife-edges required for 1 kg primary standard balance and finding the rate of deposition of hard chromium plating—M.L. Das & S.V. Gupta, No. 87-37.

5. Design and development of broad band standard mismatches of VSWR 1.10, 1.20 and 1.30 for XN-Band microwave frequencies—P.S. Negi, R.S. Yadav, Ram Swarup & K. Chandra, No. 87-51.

6. Statistics of electrons and holes in heavily doped n-silicon—S.R. Dhariwal, V.N. Ojha & G.P. Srivastava, No. 87-52.

7. International Intercomparison of pressure standards in the Pneumatic Pressure Region 0.4-4.0 Mpa between NPL (India) and PTB (F.R. Germany)—J.K.N. Sharma, K.K. Jain & A.K. Bandopadhyay, No. 87-54.

8. Realization of triple point of water—Ram Krishan & S.K. Nijhawan, No. 87-60.

9. Calibration of inclinometers—N.K. Aggarwal, R.P. Singhal & P.C. Jain, No. 87-61.

10. Establishment of density stdd. at NPL—Mohinder Nath, S.S. Bhamra & S.V. Gupta, 88-03.

11. Dimensional measurement and calibration facilities using laser interferometer at NPL—P.C. Jain, N.K. Aggarwal, Veena Roonwal & R.P. Singhal, No. 88-04.

12. Design and development of high frequency standard capacitors—Omkar Nath, M.R. Nagar, Sharwan Kumar, S.L. Dahake & K. Chandra, No. 88-05.

13. The realisation of boiling point (90.188K) and Triple point (54.361 K) of oxygen as low temperature fixed points on the international practical temp. scale—Ram Krishan, J.K. Gupta, V.P. Sharma & K.D. Baveja, No. 88-08.

14. International Intercomparison of capacitance standard using 10 pf and 1 *nf* capacitor, as travelling stdd. under Asia Pacific Metrology Programme—K. Chandra.

15. Acoustic sounding studies of the Atmosphere Boundary Layer—S.P. Singal, No. 30, N.Z. Meteorological Service, Wellington, New Zealand.

MATERIALS

1. Molecular reorientation processes and dynamics of polarization reversal in thin surface stabilized ferroelectric liquid crystal DOBAMBC—S.S. Bawa, A.M. Biradar & Subhas Chandra, No. 87-16.

2. A dual electron gun thin film deposition system for refractory metals and silicides—P.K. Ashwani Kumar, S.T. Lakshmi Kumar, Vijay Kumar & S.K. Sarkar, No. 87-18.

3. Pilot plant production of pure silicon—B.R. Awasthy, N.S. Bangari, H.P. Gupta, Prem Prakash & Vipin Kumar, No. 87-19.

4. Application of high power ultrasonics in benefication of coal fines—V.N. Bindal, S.K. Jain, R.L. Seth & Yudhisther Kumar, No. 87-22.

5. Development of PZT ceramic transducer materials for general purpose power transducer application—V.N. Bindal, Janardan Singh, Ved Singh, Narayana Swami & N.C. Soni, No. 87-24.

6. Ferroelectric liquid crystals dynamics and displays—S.S. Bawa, A.M. Biradar & Subhas Chandra, No. 87-25.

7. Solubility limits of SiO_2, GeO_2 and SnO_2 in Ni-zu ferrite system and cation distribution in the special lattice of the substetuteol ferrite—Satbir Singh, R.B. Tripathi & B.K. Das, No. 87-31

8. Vertical float method of ultrasonic power measurement—V.N. Bindal, Ashok Kumar, S.S. Hanspal & Subhash Chandra, No. 87-32.

9. Ultrasonic method to monitor the effect of environ-

mental pollution on marble stone structure—V.N. Bindal, Ashok Kumar, Yudhishther Kumar & Jagdish lal, No. 87-33.

10. An optical method of measuring tilt bias angle of liquid crystals—S.C. Jain, H.K. Singh, Mrs. K.S. Balakrishnan & S. Chandra, No. 87-36.

11. Initial stages of reaction and barxier heights in Nickel silicide interface growth—A.C. Ratogi, P.K. John & B.Y. Tong, No. 87-38.

12. Composition, structure and electrical behaviour of the interface between Ni, and Si under pulsed inocherent height irradiation—A.C. Rastogi, P.K. John & B.Y. Tong, No. 87-39.

13. Phase transformations at the metal silicon interface under pulsed transient annealing—P.K. John, A.C. Rastogi, B.Y. Tong, S.K. Wong & X. Wu, No. 87-40.

14. An electrochemical barxier process for inhibiting p-Cuxs grain boundary growth in thin film CdS solar cells—A.C. Rastogi, S. Salkalochen & K.S. Balakrishnan, No. 87-41.

15. Thermal diffusivity measurement using the pholvelecture effect—P.K. John, L.C.M. Miranda & A.C. Rastogi, No. 87-42.

16. Initial stages of light induced interface reaction of N films with silicon—A.C. Rastogi, P.K. John, M. Deminski, B.Y. Tong, X.W. Wu & S.K. Wong, No. 87-43.

17. Dynamics of Ni Si, interface reactions induced by pulsed inocherent light—A.C.Rastogi,M. Dembinski, P.K. John, B.Y. Tong, X.W. Wu S.K. Wong, No. 87-44.

18. Doped microcrystalline silicon produced by LDCVD—J. Yao, A.C. Rastogi, N. Du, X.W. Wu, P.K. John, B.Y. Tong & S.K. Wong, No. 87-45.

19. Improvements in stoichiometing and stability of p-Cu_xS in thin film CdS solar cells—A.C. Rastogi & S. Salkalochen, No. 87-46.

20. New amorphous silicon-boron alloy—K.P. Chik, N. Du, P.K. John, E. Du, A.C. Rastogi, K.M. Tom, B.Y. Tong, S.W. Wong, X.W. Wu & J. Yao, No. 87-47.

21. A mechanism for induced surface degredation of high resistive Ga As during device fabrication—A.C. Rastogi, C.K. Teh & F.L. Weichman, No. 87-48.

22. Photovoltaic performance of thin film CdS-Cu_2S solar cells with electroformed junctions—A.C. Rastogi, No. 87-49.

23. The influence of chromium oxide addition on thin dielectric and electro-mechnical properties of Pb (Zn Ti) O_3ceramics—V.N. Bindal, Janardhan Singh & Ved Singh, No. 87-50.

24. Computer modelling of the director configuration in a supertwisted nematic liquid crystal cell—Harish K. Singh, S.C. Jain & S. Chandra. No. 87-56.

25. Resistivity of standard reference silicon crystals—N.K. Arora, S.N. Singh, B.K. Das & R. Kishore, No. 87-58.

26. Temperature variation of pitch in some chiral doped Nematic liquid crystals—S.C. Jain, Harish Kumar Singh & Mrs. K.S. Balakrishnan. No. 87-59.

27. Investigation on the fabrication of PZT Ba_2 Si_2 Tio_8glass ceramics—V.N. Bindal, Janardhan Singh, R.P. Tandon & N.C. Soni, No. 88-01.

28. Recent developments in processing and charaterization of polycrystalline & alumina solid electrolytes—B.K. Das, Balbir Singh, H.S. Kalsi, S.M. Khullar, R.C. Goel, S.K. Sharda & Mrs. K. Jain, No. 88-09.

CHARACTERIZATION OF MATERIALS

1. Study of voids in silver films by transmission electron microscopy—S.K. Sharma & G.L. Malhotra, No. 87-15.

2. A New X-Band EPR spectrometer—S.K. Gupta, No 87-21.

3. High purity water its preparation and use in cleaning electronic materials—P.K. Gupta & A.K. Aggarwal, No.87-23.

4. Characterization of 100 mm diameter silicon single crystal wafers for Semiconductor Complex Ltd., S.A.S. Nagar, No 87-27.

RADIO SCIENCE

1. Relationship between field strength of ELF/VHE wave generation by modulated HF heating of Auroral electrojet and magnetic field variations—R.C. Saxena, No. 87-17.

2. Equivalent depths of vertically propagating equatorial Kelvin waves—K. Bhattacharya, No. 87-20.

3. On the response of Ionospheric Magnetization to solar wind dynamic pressure from Pioneer Venus Measurements—J. Kar & K.K. Mahajan, No. 87-26.

4. An experimental set up for L-Band scintillation stu-

dies with Marits at signals—P.N. Vijay Kumar & Y.V. Somayajulu, No. 87-28.

5. On the scaling and parameterization scheme for the spectra from proposed Indian MST Radar Facility—A.R. Jain, No. 87-34.

6. Laser Hetrodyne system for height profiles of atmospheric minor species—S. L. Jain & B.C. Arya, No. 87-53.

7. Reference electron density profiles for Indian Ionospehric station—S.S. Singh, S. Shastri, M.K. Goel & S. Aggarwal. No. 87-55.

8. International Reference Ionosphere Profile for Indian rocket launching station—S.S. Singh, M.K. Goel & B.C.N. Rao, No. 87-57.

9. Turbidity and ultra-violet radiation measurement at Antarctica during VI Indian expedition—A.K. Hanjura, S.D. Sharma, M.C. Sharma & B.N. Srivastava, No. 88-02.

10. Studies on ionospheric scintillation for radio system application—D.R. Lakshmi, R.S. Dabas & Lakha Singh, No. 88-06.

11. Comparison of ionospheric electron content variations at three widely spaced stations along the Northern anomoly crest—P.K. Bhuyan & T.R. Tyagi, No. 88-07.

12. Electron content measurement over Delhi using Faraday rotation records of VHF signal from geostationary satellite ETS-II—J.K. Gupta, Lakha Singh, P.N. Vijaykumar & T.R. Tayagi, No. 88-11.

13. Variation of Antenna Temperature due to attenuation by fog and mist at 9.6 GHz—M.K. Raina, No. 88-12.

Ph. D's AWARDED

R.K. Jain	Studies on mechanical and thermal behaviour of carbon fibre reinforced phenolic and furan composites—Delhi University
V.N. Ojha	Effects of heavy doping in semiconductor & semiconductor junctions—Delhi University
V.S. Panwar	Charge storage & transport mechanisum in high polymers—Meerut University
R. Ramchandran (Mrs.)	Synthesis of Si (IV) Al (III), Mn (II) Al (III) and Co (II) Al (III) μ oxo/iso-propoxide and their reactions with nitrogen and oxygen containing ligants—Delhi University

DISTINGUISHED VISITORS/SCIENTISTS

(Visited NPL between 1.4.87 to 31.3.88)

Sl.No.	Name	Institute/Country	Date
1.	Dr. Hollis Charles	Director, Caribbean Industrial Research Institute, Trinidad	April, 4
2.	Mr. D. Kendimenov, Mr. Georgi Georgier, Dr. S.Kolev	Bulgarian Delegates	April, 24
3.	Dr. Kasturi Rangan, Col. Pant	ISAC, Bangalore	April, 29
4.	Mr. Lu Guo Chen Mr. Wan Yuan Xi Mr. Tian Shon Yun Dr. Li Yinan	Chinese Academy of Sciences Beiging	May, 1
5.	Mr. H. Ramamurthy Mr. K. Natrajan Mrs. R. Ray Mr. R.S. Burmee	Department of Atomic energy	May, 19
6.	Dr. Wesley Tanaskovic	University of Tokyo	May, 22
7.	Dr. Sneh Bhargava	Director, AIIMS, New Delhi	May, 23
8.	Dr. C.C. Tukurdwa Mrs. R.M. Makombe Mr. D. Chingurei Mr. L.A. Munyawarara	Ministry of Znelstry & Tech. Zimbabwe	May, 25
9.	Dr. S.I. Smirnov Mr. A.P. Scvoslianov	State Scitipe Research Institute of Power Engg., Moscow,	July, 6
10.	Mr. Alejandro Lichanco	Journalist from Philippines	July, 17
11.	Mr. Allx Chaches Mr. Ronald E. Haususer Ms. K. Wagner Mr. David Duo Mr. Kevin Murdoor Mr. Stephen S. Strong Ms. J. Hudgings Mrs. Amy Sillman Mrs. Francis Wong	U.S. Students, Indo-U.S. Exchange Programme, Coordinated by CBSE	Aug,, 4
12.	Dr. Heinz Reisenhuber Dr. J. Cumbser Dr. L. Baugmarten Dr. E. Abel Mr. H. Schelz	Delegates of Federal Ministry for Research & Technology, FRG.	Aug., 17
13.	Mr. Dhruba Adhikany	Journalist from Nepal	Aug., 24
14.	Mr. M. Guzir Rahman	Journalist from Bangaladesh	Aug., 24
15.	Mr. Bal Krishan	P.T.I., New Delhi	Aug., 24
16.	Dr. Fesgio Trindadle	EX. Director, U.N. Centre for Science & Technology for Development	Aug., 4
17.	Dr. Hoffman	Director, DAAD, F.R.G.	Sept., 22
18.	Dr. Han Dyckim Mr. Thach Can	Vietnamese Delegates	Oct., 21
19.	Sir Rudolf Peierls, FRS	Oxford, U.K.	Nov., 10

20.	Mr. A.T. Alexandrav (Leader) Dr. (Mrs.) V.L. Taseva Dr. I. Enchev Mrs. C.V. Kutzarova Mr. D. Kendimenov Mr. M. Dimitrov Mrs. I. Petrouska	Bulgarian Delegates	Nov., 16
21.	Mr. Jean Claude Lehmann	Director, Centre National de la Rechchche Scientifiq (CNRS) Paris.	Nov., 26
22.	Mr. Joseph W.B. Bredie Mr. Jhang Zhi Wu	World Bank, Washington, U.S.A.	Dec., 3
23.	Dr. Yoshio Hagiwara & Mr. S.N. Wazir,	Exec. Vice President Mitsui SRC Dev. Co. Ltd. Japan Director, Metallurgical & Engg. Const. (P) Ltd., Ranchi	Dec., 7
24.	Prof. C.R. Rao	Visiting Professor, U.S.A, delivered 1st Ramanujan Memorial Lecture	Dec., 17
25.	31 trainees	From developing countries attending 20th International Training Programme in standardization	Jan., 19
26.	Mr. Jean-Pierre Lebrun (Dir. Gen.), Mr. Norbert Anselman Mr. Guibe	Commission of the European Constitution, Brussels, Belgium.	Jan., 21
27.	Dr. Leomd Sumarokov	Dy. Chairman, USSR State Comittee for Science and Technology.	Jan., 25
28.	Mr. John C. Wright	President, Alhama University, USA	Jan., 25
29.	Prof. Dr. Smith	Governor, Thailand Institute of Scientific and Technological Research, Thailand	Feb., 8
30.	Dr. D.J. Barnes	DSIR, Newzealand	Feb., 9
31.	Dr. John Henson, Mr. Robert Arbuth	Minister & Member Cul. Affairs, British Council	Feb., 10
32.	Dr. K. Toh	Ministry of Science & Technology Poland.	Feb., 11
33.	Acad. A.L. Yanshin	Vice President, USSR Academy of Sciences.	Feb., 11
34.	Dr. Peter Best	Australia	Feb., 12
35.	H.E. Yousef Ahmed Al Shirawi	Minister for Industry& Development, Bahrain.	Feb., 22
36.	Prof. N.A. Staab Dr. H.J. Husburg	President, Max Planck Society, FRG.	March, 15
37.	Dr. G. Landwebr	DAAD, FRG	March, 16
38.	Prof. Burcham (Pres.) Dr. Hassan	DAAD, FRG.	March, 18
39.	Mrs. Rohan Chabat & Mr. Michel Brunt,	Asstt. Director, Scientific Tech. Co-operation, French Ministry of Foreign Affairs, Paris. Scientific Attache, Embassy of France, New Delhi.	March, 23
40.	Mr. Gregob S. Mr. Ezio Andreta	E.E.C, Brussels	March, 23
41.	Dr. Saad Abbadi (Pres.), Dr. Eisa	Sudanese National Council for Research, Sudan.	March, 30

SPECIAL LECTURES

Sl. No.	Speaker	Topic & Date
1.	Dr. Dipankar Home, Saha Institute of Nuclear Physics, Calcutta.	The quantum measurement problem—April 6
2.	Dr. S. Asokan, I.I.Sciences, Bangalore.	Chalcogenide glasses, high pressure effects and short range order in these materials—April 15
3.	Prof. C.N.R. Rao, Director, I.I.Sc., Bangalore	High temperature Superconductors—May 28
4.	Prof. Rajendra Singh, University of Dklaholna Norman, USA.	Development trends in semi conductor processing—July 1
		Materials and processing perspective for solar photovoltaics—July 3
5.	Dr. S.I. Smirnov, Senior Scientific Fellow, State Scientific Research Institute of Power Engineering, USSR.	Achievements of science and engineering in utilization of renewable energy sources—July 6
6.	Dr. A.P.B. Sinha, N.C.L., Pune	Recent work on high temperature superconductors at NCL—July 16
7.	Dr. M.P. Das, Sambhalpur University	Theory of high superconductivity—July 22
8.	Dr. T. Venketasan, Bell Communications Research, New Jersey USA.	High temperature superconductivity in thin films—July 27
9.	Mr. Baldev Raj, Indira Gandhi Centre of Atomic Research, Kalpakkam.	NDE activities at Indira Gandhi Centre of Atomic Research, Kalpakkam—July 31
10.	Dr. G.V. Venkataraman, Reactor Research Centre, Kalpakkam.	Life and Science of C.V. Raman—Aug. 8
11.	Prof. Anupam Madhukar, University of Southern California.	Atomistic nature semiconductor interfaces—Aug 14
12.	Prof. J.A.D Mathew, University of York, England	Quasi-atomic excitations at rare earth surfaces—Aug. 14
13.	Prof. H.O. Berktay, University of BATH, UK.	Under water acoustics and some applications in oceanography—Sept. 14
		Non linear Acoustics and parametric sources and receivers—Sept. 21
14.	Dr. P. Hariharan, Deptt. of Physics, CSIRO Australia	Interferro-metric metrology, current trends & future prospects—Sept. 17
		Holography and its application—Sept. 18
15.	Dr. Ian Glover, University of Bradford, UK.	Antenna cross polar modelling—Oct. 1.
16.	Dr. Enric Vilar, Visiting Scientist, UK.	A detailed analysis of long-term statistics and dynamic properties of 50 years point rainfall rate in the context of microwave communications—Oct. 15
		Theoretical and experimental studies of amplitude and phase scintillations at Portsmouth Polytechnic in high and low elevation satellite path—Oct.20
		An experimental programme to investigate transhorizon microwave propagation and interference at 11 GHz over the English Channel—Oct. 28
17.	Dr. Debashish Chowdhary, I.I.T., Kanpur	Relaxation-limited versus diffusion limited growth—Oct. 26
18.	Dr. J.A.G. Knight, Deptt. of Production Engg. University of Nottingham.	Ultrasonic sensor research in Nottingham—Oct. 30
19.	Prof. P.K. Das, I.I.T., Delhi.	Droughts and climate changes—Nov. 17
20.	Prof. S.M. Bhagat, University of Maryland, USA.	High temperature superconductivity—Nov. 19
21.	Dr. S.R. Valluri, Former Director NAL, Bangalore.	Research and Development Management—Nov. 23
22.	Dr. R. Krishnan, Lab. DE Magnetisme, CNRS France.	Magneto optical recording physics & materials—Dec. 1
23.	Dr. J.E. Bouree, CNRS, France.	Photoassisted deposition and direct writing of AL on silicon for IC applications—Dec. 3
24.	Dr. B.K. Pal, Shimla University	Industrial revolution and industrialisation in India with special reference to growth of Physics—Dec. 3
25.	Dr. V.N. Singh, University of Maryland, USA.	Laser remote sensing of atmosphere—Dec. 4
26.	Dr. Praveen Choudhry, IBM, USA.	High temperature superconductors—Dec. 7
27.	Prof. Jeray Cuomo, IBM, N. York Town, Labs. USA.	High temperature superconductivity—Dec. 8.
28.	Prof. Bengt Multquist, Swedish Institute of Space Phys., Kiruna	Swedish space physics programme and Eiscat—Dec. 9
29.	Dr. W. Hayes, President St. John's College, Oxford.	High temperature superconductors—Dec. 9.
		Evolution of research at Clarendon—Dec. 9.

30. Dr. Klaus V. Klitzing, Nobel laureate, Max-Planck Institute, F.R.G.

31. Dr. King-Ning Tu, IBM Thomas J. Waloon Research Centre, New York
32. Prof. Shuzo Hattori, Nagoya University, Japan.

33. Mrs. L.H. Brace, NASA Godard Space Flight Centre, Greenbelt Maryland, USA.
34. Dr. Mary L. Cleave, NASA Astronaut, USA.
35. Dr. W.I. Milne, University of Cambridge, UK.
36. Dr. C.R. Rao, University Professor, University of Pittsburgh USA.

37. Prof. A.H. Marshak, Louisiana State University, USA.
38. Dr. Rajendra K. Bordia, E.I. Du Pont De Nemours & Co., USA.
39. Dr. S.C. Jain, Ex-Director, SSPL, New Delhi.

40. Prof. J. Mahanty, Dept. of Theoretical Physics, The Australian National University Canberra, Australia.
41. Dr. A. Jayaraman, Bell Laboratory, New Jersey, USA.
42. Dr. V. Dosaj, Dow Corning Co., USA.

43. Dr. J. Niemeyer, PTB-Braunschweig, FRG.

44. Dr. R.C. Bhudhani, California University, USA.

45. Dr. K.C. Symth, NBS, Maryland, USA.
46. Prof. I.C. Percival, School of Mathematical Science, Queen Mary College, London.
47. Dr. J.R. Patel, At & T Bell Laboratories, New Jersey, USA
48. Dr. B.K. Chakraverty, CNRS, Centre National DE La Resherche Scientifique, France

49. Prof. S.T. Wu, University of Alabama

50. Dr. Murray Dryer, NOAA Boulder.
51. Prof. R.E. Bogner, Dean, University of Adelaide, Australia
52. Dr. R.V. Gomatam, International Secretary of Bhaktivedanta, Bombay

53. Dr. A. Hauser, Martin Luther University, Halle

54. Dr. P. Ganguli, I.I.Sc. Bangalore

55. Dr. Sriramachari, Director, Institute of Pathology ICMR, New Delhi
56. Mr. Charles Frenchimon, National Measurement laboratory CSIRO, Australia

57. Prof. T.P. Das, State University of New York.

58. Swami Satya Prakash Saraswati, Arya Samaj, Mandir Marg, N. Delhi.
59. Prof. Heinz-otto-Peithen, FRG

60. Dr. S.K. Joshi, Director N.P.L.

Recent research activities in the field of low-dimensional electronic systems—Dec 10
Metal and poly-si reactions—Dec. 10

Laser metrology applied to microelectronics & Laser Microscopy—Dec 10
Langmuir probe measurements from dynamics explorer and pioneer Venus—Dec. 10
Lecture cum-discussion of her space flight—Dec 11
Photo CVD of amorphous Si:H alloy films—Dec. 17
Ramanujan Memorial Lecture on Uncertainty Randomness and creation of new knowledge—Dec 17
Transport equations in inhomogenious material—Dec. 18
Synthesis and processing of oxide superconductors—Dec 21
Anderson transitions vs Wigner condensation of electron gas in silicon inversion layers—Dec. 28
Theory of the scanning tunnelling microscope—Dec. 28

Raman scattering studies on high temperature superconductors—Dec 30
Technology trends in production of semiconductor grade silicon—Dec. 31
Ac Josephson effect in high Tc superconductors—Jan. 2
Josephson series array voltage standard—Jan. 15
Metal-Insulator transition in high Tc superconductors—Jan. 12
Optical studies of flame chemistry—Jan. 13
Chaos in Hamiltonian systems—Jan. 15
Surface atom location using X-ray standing waves in UHV—Jan. 18
Status of high temp. superconductors—Jan. 27
Possible Bose Condensation of space electron pairs in high Tc oxide—Feb. 4
MHD Modelling and Simulation facility at Alabama University—Jan. 29
On Inter-planetary Modelling—Jan. 29
Ultrasonic sensing and Instrumentation—Feb. 2

Man and machines prospectives on the philosophical foundations of artifical intelligence—Feb. 3
Structure and physical properties of liquid crystals—Feb. 4
High temperature superconductivity in oxide systems Feb. 8 & 9.
Illustrations in scientific presentation—Feb. 11

The development of Ac-Dc transfer standards at National Measurement Laboratory CSIRO, Australia—Feb. 29
Electronic structure and associated properties in adsorbed atoms at surfaces—Mar. 3
Ist Dr. Atma Ram Memorial Lecture—Atma Ram aur unka vyaktitva—Mar. 10
Complex dynamical systems and the Mandelbrot—Mar. 16

High temperature superconductors and materials and mechanism of superconductivity—Mar. 18

VISITS ABROAD

(1.4.87 to 31.3.88)

Sl. No.	Name of Scientist	Country	Month	Purpose
1.	Dr. J.N. Som	U.K.	April-Dec.	British Council Programme for Ultrasonic Standards.
2.	Sh. Pardeep Mohan	Italy	April-June	IMGC for intercomparison in Vacuum Standards
3.	Dr. B.M. Reddy	Argentina	March-April	To attend bi-regional Conference workshop on "Radio Propogation Res. & Application and to complete URSI hand book on "Radio propogation".
4.	Sh. Anil Govil	USSR	April	Under Indo-USSR Metrology Programme at VNIIM.
5.	Dr. D.C. Prashar	USA	May	To participate and present a paper in the Intl. Workshop on Analytical Techniques.
6.	Dr. V.N. Bindal	Poland, U.K., Hungary	May-June	To attend a conference and to coordinate the project & scientific cooperation.
7.	Dr. P.K. Pasricha	USSR	May-July	Under Indo-Soviet Bilateral Exchange project on "Radio Science" of INSA.
8.	Dr. R.K. Aggarwal	France	April-June	Under CSIR-CNRS Exchange Programme for development of C-C Composites and glassy carbon.
9.	Dr. V.R. Singh	Finland & Japan	June	To participate and present papers at the 6th Congress of EFSUMB at Helsinki and the 1st Congress of AFSUMB at Tokyo.
10.	Dr. J.K.N. Sharma	Italy, USA, FRG, France	June-July	Visited IMGC, NBS, PTB & LNE regarding latest developments in the area of Pressure & Vacuum Stdds.
11.	Dr. B. Jayaram & Dr. S.K. Agarwal	Italy	July	To attend special Adriatica Research Conference on High Temp. Superconductors.
12.	Sh. Malkiat Singh & Sh. Balbir Singh	USSR	July-Sept.	As members for organising Science & Technology Exhibition in Leningrad.
13.	Dr. S.C. Garg	USA	Aug-Sept.	Under CSIR-NSF Exchange programme to work with Prof. Hanson's group at University of Texo's at Dalas.
14.	Dr. K. Chandra	China	July	For attending training seminar on calibration and verification and meeting of APMP.
15.	Sh. Jitendra Rai	USA	July	For equipment training with M/s. Perkin Elmer, USA in the operation of gas chromatography.
16.	Dr. K.S. Zalpuri	Japan	July-Aug.	To visit Prof. Ogawa's Lab. in Tokyo in connection with Nitric Oxide experiment.
17.	Dr. K.K. Jain	USA	Sept.-Oct.	Under UNDP Project for Establishment of Primary and Transfer Pressure Stds.
18.	Sh. V.P. Wasan	USSR	August	Under Indo-USSR S&T Programme at VNIIM.

Sl. No.	Name of Scientist	Country	Month	Purpose
19.	Dr. J. Kar	Canada	August	To attend and present a paper in 19th Gen. Assembly of Intl. Union of Geodesy & Geophysics (IUGG) at Vancouver.
20.	Dr. Krishan Lal	Perth, Australia	August	To participate and deliver a talk on "High Resolution X-ray Diffractometric Topographic and Diffuse scattering of Si layers.
21.	Dr. R.B. Mathur	France	Sept.-Feb.	To work with Prof. Bothorel, Director Centi Pascal, France on Carbon Fibres and Composites.
22.	Dr. R.P. Tandon	U.K.	Aug.-Oct.	Under MOU Project on ultrasonic standards at Leeds.
23.	Dr. A.P. Jain	France& Sweden	Aug.-Sept.	To attend XVIII Intl. Main Congress of Refrigeration at Vienna & to visit M/s. United Stirling.
24.	Dr. S.N. Singh	France	Sept-Oct.	Under CSIR-CNRS exchange Programme to carry out studies of opto-electronic properties of polycrstalline silicon.
25.	Dr. Gopal Bhatia	S. Korea	Sept-Nov.	As a consultant under UNIDO Programme.
26.	Dr. S.K. Joshi	USA	Sept.-Oct.	To visit NBS and to attend XIX General Assembly of IUPAP.
27.	Dr. O.S. Panwar	Dublin	Oct-June, 88.	To take up research fellowship offered by University Council and Board of Trinity College, Dublin.
28.	Dr. S.K. Sharma	Japan	Oct.-Nov.	Under INSA-JSPS exchange Programme.
29.	Dr. K. Chandra	FRG	October	To attend symp. on Metrology at PTB.
30.	Dr. B.K. Das	Japan & USA	October	To attend annual meeting of American Ceramic Society and to have discussion with MITI.
31.	Dr. V.D.P. Sastri	USA	October	To attend conference on 'OPTICS, 87 and to visit solar energy Research Institute.
32.	Dr R.V. Ananthamurthy	GDR	March-April	To visit under S&T cooperation between CSIR & GDR
33.	Dr. S.L. Jain & Dr. D.R. Pahwa	Australia	February	To attend & present a paper at the Intl. Conference on Remote Sensing of the atmosphere & ocean.

CONSULTANCY

Sl. No.	Title	Party	Amount (Rs.)
1.	Setting up of zero-static pressure duct for desert cooler.	M/s Frac Power Motors, 334, Jonapur Mehrauli, New Delhi	6100
2.	Acoustical treatment of multipurpose hall of Sultanpur, U.P.	Ex. Engineer Unit III, CPWD Sultanpuri (U.P.)	12500
3.	Development of certain ferrites for Defence Applications.	M/s K.V. Microwave Materials, Plot 5-51, Site IV, Industrial Area, Sahibabad (U.P.)	6000
4.	Acoustic treatment of the auditorium of Indian Society of International Law, New Delhi.	Ex. Engineer Construction Div. 2, CPWD, New Delhi.	11500
5.	Acoustic treatment of the auditorium of Moti Ram-Babu Ram Govt. Degree College, Haldwani.	Ex. Engineer Construction Div., CPWD, Haldwani, (U.P.)	11500
6.	Acoustic design of International Conference Centre at Seychelles.	Ex. Engineer, CPWD Consultancy Services, Nirman Bhawan, New Delhi	12500
7.	Noise Abatement Measure for Calcutta Metro.	Metro Railways, 33/1, Chowringhee Road, Calcutta.	30000
8.	Acoustical treatment of auditorium of ICMRT.	Regional Manager, LKO Div., Harijan Evam Nirbalvarg Avas Nigam Ltd., ICMRT, Indira Nagar, Lucknow.	11500

PREMIA & ROYALTIES RECEIVED

Process	Party	Rs.
Ceramic Capacitors	M/s Satelite Engg., Ltd., Ahmedabad.	2000
	M/s B.N. Bhaskar & Sons, New Delhi.	2000
	M/s Matchwel Electricals Ltd., Pune.	2000
Vacuum Leak Detector	M/s Vacuum Instruments, New Delhi.	2000
Monocrystalline Silicon.	M/s Semiconductor Ltd., Bombay.	2000

SPONSORED/SUPPORTED PROJECTS

Sl. No.	Title	Agency	Fund received during the year. (Rs. lakhs)
	NEW PROJECTS		
1	Fluorescent screens for real time X-ray imaging.	ISRO	–
2.	A study of degassing characteristics of Materials in ultra-high vacuum.	DST	1.200
3.	Low dimesional coulomb systems	DST	13.116
4.	Multi-crystalline silicon for solar cells.	CEL	30.200
	CONTINUING PROJECTS		
1.	Augmentation of Primary Electronic Standards.	DOE	30.011
2.	Improving the quality & reliability of standard Time & Frequency signals to Echelon II Laboratories.	DOE	0.625
3.	Calibration Service Programme under NCTCF.	DST	2.600
4.	Development of parametric system for detection of objects in sea-bed	DOE	3.120
5.	Development and characterization of Acoustic Transducers & Materials for applications in Ocean Engineering	DOD	6.438
6.	Development of big size carbon-carbon composites	DRDL (Hyd.)	1.600
7.	Development of process know-how for Aviation Grade Brushes	HAL (Nasik)	–
8.	Preparation, Characterisation & Precision Measurements of Semi Conducting Materials	DST (Indo/U.S)	2.055
9.	Tropospheric & Ionospheric Communications in HF & Microwave Bands	Defence	6.000
10.	Monitoring of solar ultraviolet radiation at the ground in UV-B region.	ISRO	0.300
11.	Development of gas chromatographic facilities for measurement of minor constituents in the atmosphere	DST	
12.	Development of thin film Josephson Junction and Planar DC Squids.	DST	
13.	Study of defect structure in nearly perfect Silicon single crystals.	DST	5.79
	PROJECTS COMPLETED		
1.	Fabrication & testing of Interference Filters.	SAC (ISRO)	
2.	Investigation of hydrogenated amorphous Silicon films.	DNES	2.000
3.	Evaluation of carbon fibre reinforced carbon.	DST	0.810
4.	Development of optical components for MIG Plane.	HAL	

RECEIPTS ON ACCOUNT OF CALIBRATION/TESTING AND OTHER CHARGES REALISED DURING 1987-88

Activity	Amount (Rs)	Reports
CALIBRATION		
Length Standards	14,500	06
Dimensional Metrology	2,37,520	448
Mass Standards	2,85,884	430
Force & Hardness Standards	4,45,550	412
Pressure & Vacuum Standards	19,375	10
Temperature Standards	2,12,595	282
Optical Radiation Standards	3,48,446	149
Acoustic Standards	82,010	43
Time & Frequency Standards	2,347	04
D.C. Standards	76,710	71
LF & HF Impedence Standards	70,685	61
AC & LF Standards	23,750	17
HF & Microwave Attenuation and Impedance Standards	26,030	18
HF & Microwave Standards of Power, Voltage, Frequency & Noise	64,250	30
Materials Characterization	22,347	36
GLASS FABRICATION & MATERIALS		
Glass Fabrication	1,75,417	–
PZT Materials	21,643	–
Silver Paste	4,526	–
Carbon Products	2,725	–
Interference Filters	40,000	–
Total	21,76,310	2,017

ACTUAL EXPENDITURE

Budget Head	Rs. (Lakhs)
Pay & Allowances (P1, 2, 3)	445.000
Contigencies (P4)	82.363
Maintenance (P6)	9.833
Chemicals & Equip. (P7)	59.985
Works (P5-1)	3.480
Services (P5-2)	8.414
Equipment (P5-3)	104.189
Books & Journals (P5-4)	24.485
Total	737.749

HONOURS AND AWARDS

Dr. S.K. Joshi was awarded the K.S. Krishnan Lectureship of INSA of 1987 on the topic "Surface States in Semiconductors".

Dr. B. Jayaram was awarded the CSIR Young Scientist Award for his work on high temperature superconductivity.

Dr. A.V. Narlikar was elected Fellow of the Indian Academy of Sciences, Bangalore.

Dr. Krishan Lal was elected as a member of the Commission on Crystal Growth and Characterization of the International Union of Crystallography for the period 1987-90.

Dr. B.S. Mathur was nominated as a Member, Working Group, Time Transfer with Modern Techniques, IAU Commission 31.

Dr. V.R. Singh received Medal of Asian Federation for Societies of Ultrasound in Medicine and Biology.

Dr. V.N. Bindal was nominated as a member of the Advisory Board of the Journal "Ultrasonic" of U.K.

STANDARD REFERENCE MATERIALS

A workshop on standard reference materials was held on March 17 & 18, 1988 at NPL with a view to undertake the development of standard reference materials which are required for calibration of different equipments, standardization of different methods and techniques. 28 delegates from seven laboratories of CSIR and one from BIS participated in the workshop. The delegates described in details the requirements of standard reference materials in their respective areas.

A short term programme for one year duration was prepared under which SRM's on trace elements like lead and cadmium in high purity water and SRM of mild steel will be prepared by an inter-laboratory effort. A directory containing information on major equipments, scientists and their expertise in different laboratories of CSIR will be prepared. A three year programme on preparation of SRM's of high purity water with certified values of trace elements, high purity inorganic acids, steels and alloys, some pesticides and benzoic acid as calorometric standard was suggested.

CSIR FOUNDATION DAY

NPL participated in the Foundation Day Celebrations of CSIR and organised a function on September 26, 1987 at the laboratory when mementoes were awarded to 164 staff members of the laboratory who had completed 30 years of service in the CSIR on that date.

The children of the staff members also received the cash awards on the basis of an Essay Competition held on September 20, 1987, in connection with the celebration of the Foundation Day of CSIR.

OPEN DAY

The laboratory organised an Open Day on Nov. 3, 1987, on the occasion of the 99th Birthday of Late Prof. C.V. Raman, the Nobel Laureate.

About 2,100 students alongwith 125 teachers from about 50 local schools visited the laboratory on this day. A number of students of colleges & University of Delhi also visited.

An Exhibition highlighting the activities and achievements of the laboratory was organised. This included the National Standards of Mass, Length, Time, Temperature, Volt and Microwave; Electronic and Engineering Materials; Superconductivity; Thin Films; Display Devices; Characterization of Materials and Radio Science.

The selected rooms and sections were kept open including Laser Holography, Sross, Superconductivity etc. Special audio-visual programmes were also arranged and scientific films were shown. The young science students were exposed to the physics oriented activities and instruments.

PERSONNEL

(as on 1.4.1988)

DIRECTOR, JOSHI, DR. S.K.

SCIENTISTS & OFFICERS

STANDARDS

LENGTH

Chitnis, Dr. V.T.
Dahiya, Dr.H.S.
Dandavate, Dr V.D.
Kanji Lal, A.K.
Kathuria, Dr. Y.P.
Kulkarni, Dr. V.G.
Ram Narain
Roy, B.K.
Vardhan, (Mrs.) Kowsalya

DIMENSIONAL METROLOGY

Aggarwal, N.K.
Jain, Dr. P.C.
Karfa, M.
Khanna, R.K.
Roonwal, (Mrs.) V.
Sharma, V.D.
Singhal, R.P.
Tanwar, L.S.

MASS, VOLUME, DENSITY & VISCOSITY

Das, M.L.
Gupta, Dr. S.V.
Kohli, N.K.
Mathur, B.G.
Mohinder Nath
Nangia, S.N.
Tripurari Lal.

FORCE & HARDNESS

Anil Kumar
Chaudhury M.K.
Dasgupta, M.K.
Dhawan, J.K.
Sharma, R.S.

PRESSURE & VACUUM

Bandopadhyay, Dr. A.K.
Chakraborty, Dr. B.R.
Gupta, A.C.
Jain, Dr. K.K.
Pradeep Mohan
Sharma, Dr. D.R.
Sharma, Dr. J.K.N.
Siva Prasad, Dr. S.M.

TEMPERATURE

Bhatnagar, K.N.
Dutta, P.K.
Luthra, R.K.
Mansha Ram
Singh, Y.P.
Srivastava, N.K.
Wasan, V.P
Ojha, Dr. V.N.

OPTICAL RADIATION

Bhola, O.P.
Joshi, Dr. K.C.
Kailash Chand.
Kandpal, Dr. H.C.
Mahesh Chander Dr.
Manrai (Mrs.) S.

INFRARED RADIATION

Gupta, Dr. Devendra
Joginder Singh
Om Prakash
Ram, Dr. R.S.
Verma, Dr. S.P.

ACOUSTIC

Bhaskar, H.L.B
Gera, Dr. B.S.
Gautam, C.B.L.
John, P.C.
Khanna, R.M.
Mohanan, Dr. V.
Pahwa, D.R.
Sharma, Omkar
Singal, Dr. S.P.

SOLAR THERMAL DEVICES

Bhawalkar, Dr. R.H.
Devendra Singh
Hegde, Dr. M.S.
Thind, S.L.
Vaishya, Dr. J.S.
Ved Singh

TIME & FREQUENCY

Bahadur, Dr. Harish
Banerjee, Dr. P.
Chatterjee, (Mrs.) A.
Goel, G.K.
Gurdial Singh
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Kothari, Dr. P.C.
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Raj Singh
Sharma, J.C.
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Sen, Dr. D.

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Rajinder Prasad, Dr.
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Sharma, M.M.
Sharma, R.K.
Soni, S.S.
Thakur, Dr. Arvind

RETIRED

Singh, S,K.
Somayajulu, Dr. Y.V.
Sood, P.C.
Taneja, K.C.

STAFF STRENGTH

(As on 1.4.1988)

Category	Grade	Number
SCIENTIFIC		
Group IV	Scientist B to Director	299
TECHNICAL		
Group III	Scientist A & Technical Officers A to C	92
Group III & II	Technician (II) to S.T.A.	500
Group I	Helper to Workshop Asstt.	101
		992
ADMINISTRATIVE		
	Officers	17
	Establishment	149
	Group D	127
		293
	Total	1285

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Dr. S.K. Joshi, Director, NPL, New Delhi-110 012.	Member (Ex-Officio)
Dr. B.S. Mathur, Scientist, NPL, New Delhi-110 012.	Member Secretary

FELICITATIONS TO DR. A.P. MITRA

A function was held at the NPL on March, 21, 1988 to feliciate Dr. A.P. Mitra, Director-General, CSIR on his election as a Fellow of the Royal Society for his scientific leadership and his theoretical and experimental work on physico-chemical processes in the atmosphere, particularly the effects of solar flares in the ionosphere and the environmental consequences of irreversible processes affecting the middle and lower atmosphere, the work that he has done during his long association with the National Physical Laboratory, as the Head of the Radio Science Group and later as Director, NPL.

Prof D.S. Kothari presided over the function which was attended by Prof. M.G.K. Menon, Prof. Yash Pal and a large number of distinguished Indian Physicists.

Prof. M.G.K. Menon observed that it was the first time that a Director General of CSIR while holding this office had received this unique distinction and it was a matter of great pride to CSIR and to all its consituent laboratories.

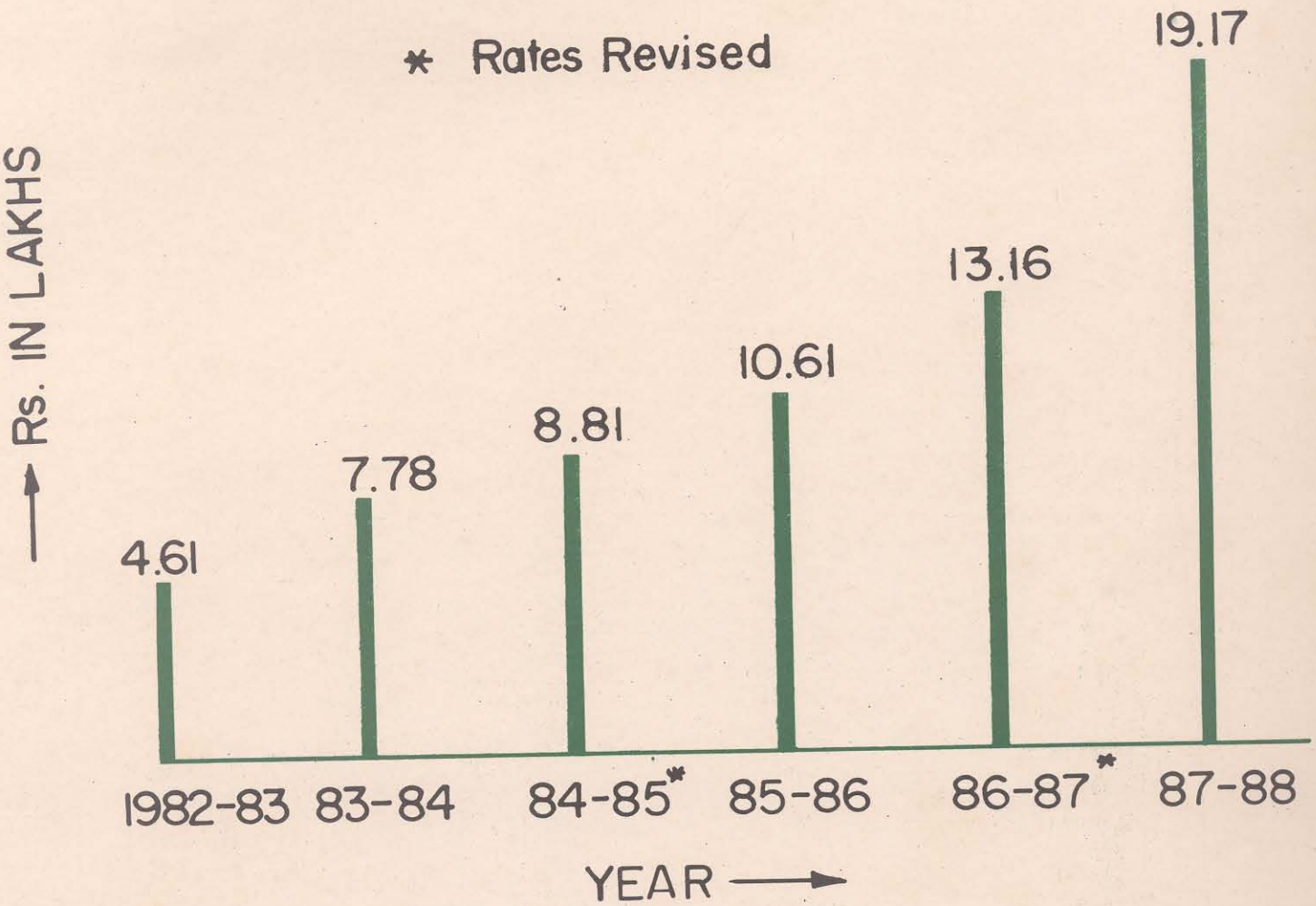
MEMBERS OF EXECUTIVE COMMITTEE

Dr. S.K. Joshi, Director National Physical Laboratory, New Delhi-110 012.	Chairman	Dr. S.K. Sharma, Scientist, NPL, New Delhi-110 012.	Member
Prof. J.K. Choudhury, 23, Jadavpur North Road, Calcutta-700 032.	Member	Sr. Finance & Accounts Officer, NPL, New Delhi-110 012.	Member
Dr. A.K. Sreedhar, Director, Solid State Physics Lab, Delhi-110 007.	Member	Chairman, Coordination Council for Physical & Earth Sciences Group of CSIR.	Permanent Invitee
Dr. B.M. Reddy, Scientist, NPL, New Delhi-110 012.	Member	Director General, CSIR, New Delhi-110 001. OR His nominee.	Permanent
Dr. B.S. Mathur, Scientist, NPL, New Delhi-110 012.	Member	Administrative Officer, NPL, New Delhi-110 012.	Member

PROCESSES RELEASED TO INDUSTRY

Sl. No.	Process	Party	Terms
1.	SIG Contacts	M/s. Modison Metals Pvt. Ltd., 33, Nariman Bhavan, Bombay.	Premium–15,000/- Royalty–5%
		M/s Precious Metal Corpn., 50, Bank of India Bldg., 185, Sheikh Memon Street, Bombay.	Premium–55,000/- Royalty-5%
2.	Flat Plate Collectors (Tubes & Sheets)	M/s C.E. Meghraj, H. Siddaiah Road, Shimoga-577202	Premium–3,000/- Royalty–2%
3.	Thin Film Optical Coatings	Haryana State Electronics Development Corporation Ltd., Chandigarh.	Premium–95,000/- Royalty–2½%
4.	Liquid Nitrogen Containers.	M/s Asiatic Oxygen Ltd., 8, BBD, Bag East, Calcutta.	Premium–15,000/- Royalty– Rs 60 per unit

GROWTH OF CALIBRATION / TESTING CHARGES



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