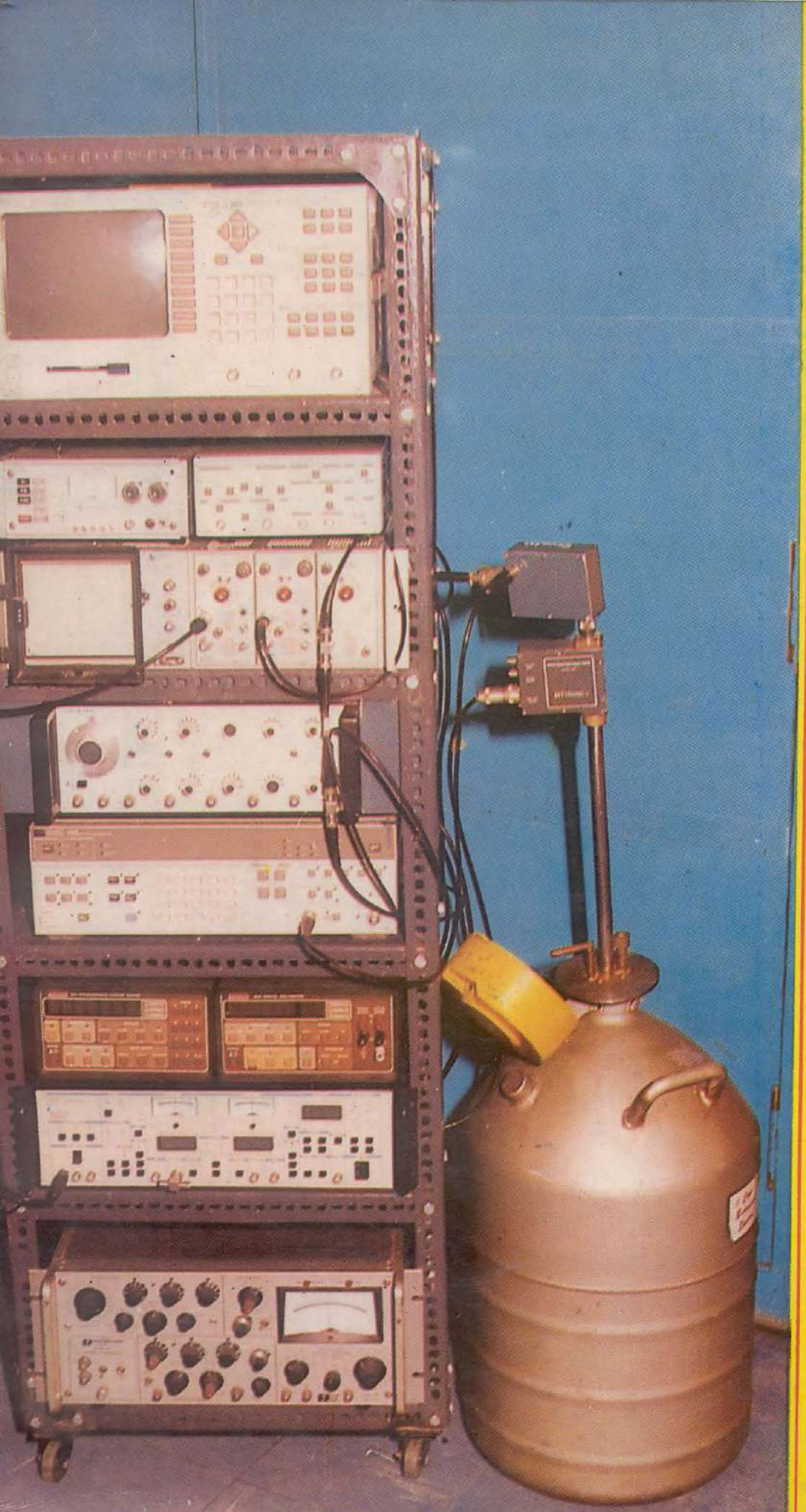

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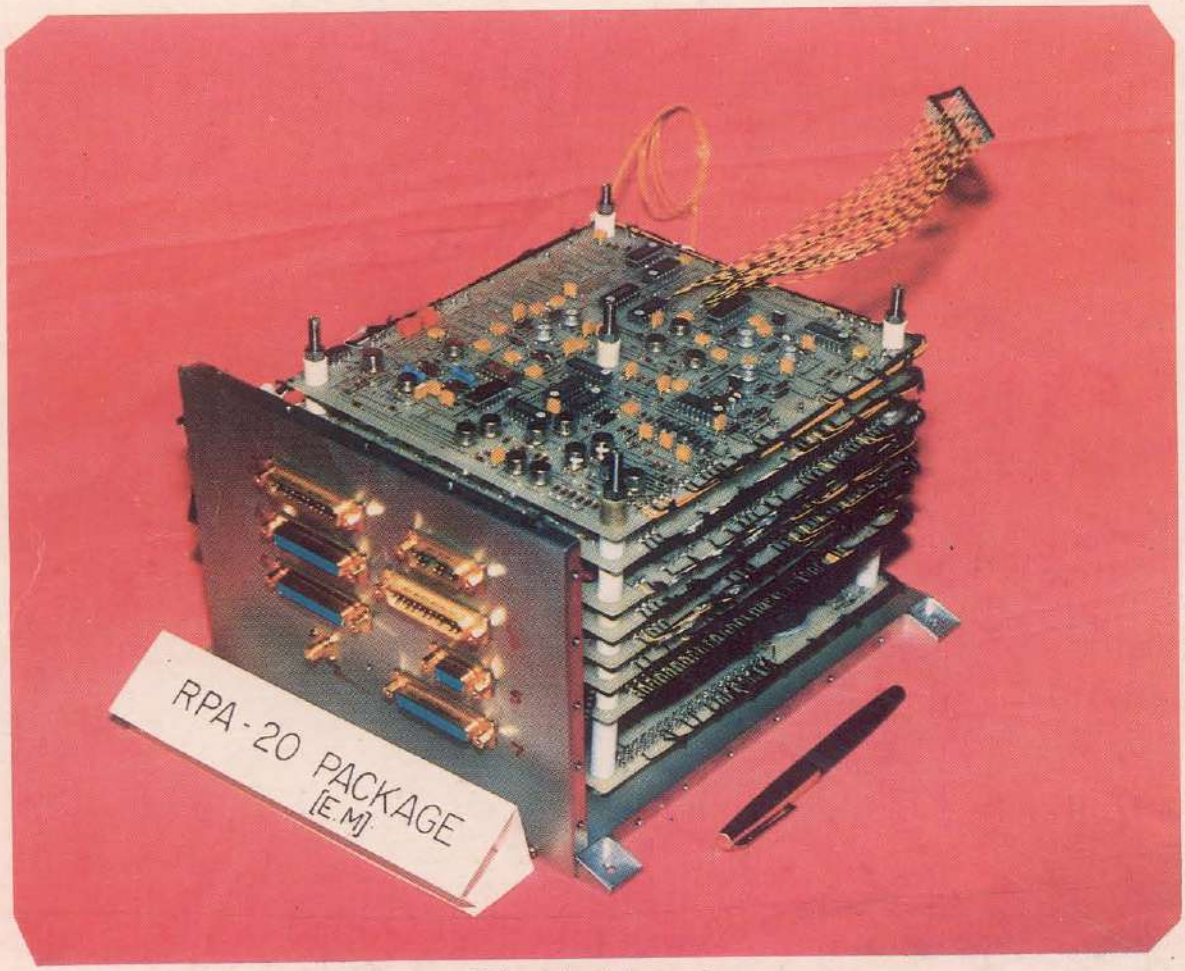
NATIONAL PHYSICAL LABORATORY

NEW DELHI



RPA payload electronics.

Cover—Experimental set up for characterization of High Tc RF SQUIDs at NPL.

Back cover—He^3 —He^4 dilution refrigerator operating at NPL.

NATIONAL PHYSICAL LABORATORY NEW DELHI 1989-90

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CONTENTS

Director's Report

This report presents a brief account of research activities carried out in the National Physical Laboratory during the year 1989-90. The laboratory concentrated its activities on the national programmes of High Temperature Superconductivity, Standards and Metrology including Calibration Service Programme and SROSS Aeronomy Satellite. In addition the laboratory thrust programmes also made steady progress.

In the area of Standards, the laboratory continued its progress in the maintenance and updating of a number of primary standards. Quantum Hall resistance measurements were made on gallium arsenide heterostructures for providing the value to a standard resistor which will soon be used as a primary resistance standard at NPL. International intercomparison of a number of standards was carried out. The CIMET-NPL training workshop, covering some areas of standards and legal metrology, was held in which fourteen trainees from various commonwealth countries participated. Two 1 kg standards of mass, fabricated and calibrated at NPL, were gifted to the Govt. of Vietnam. The laboratory provided the calibration and testing service to the industry and public/private sector undertakings. The receipts of charges realised during the year increased by about 33% and amounted to about Rs. 33 lakhs.

The research and development activities on modern materials were continued. The amorphous silicon solar cells, having high efficiency of about 10%, were developed which exhibited high short circuit current and good fill factor. The project of development of full size fluorescent screens for ISRO was completed. The work of oxidation resistant carbon-carbon composites appears promising. A programme on photonics, related to optical computing, was started. Hard laser mirrors, having over 99.5% reflectivity, were developed. The high resolution diffractometric characterization of silicon single crystal wafers, implanted with boron, was completed.

The progress of the project on development of high temperature SQUID was satisfactory and the DC SQUID behaviour was observed in break junctions of high Tc material at 77K. A demonstration of rf SQUID, using grain boundary weak links in a micro-bridge of bulk Y Ba Cu O, with two superconducting loops, was fabricated and is working very well. Efforts were continued in synthesizing flexible tapes of superconducting oxides. Studies were continued to develop superconducting thin films by metallo-organic decomposition method. The critical current density of silver clad superconductor was marginally improved. A theory of heavy fermion superconductivity was proposed on the basis of an effective interaction between heavy quasi-particles and the electron-phonon interaction. The He^3-He^4 dilution refrigerator system became operational and temperature of about 5 milli Kelvin was achieved.

A new project, International Geosphere Biosphere Programme, was started for monitoring the short and long term trends of ozone, greenhouse gases and aerosols. The measurements of methane efflux, from paddy fields in some locations in northern India, were made. The fabrication of the engineering model of RPA satellite payload for SROSS was completed. A monostatic sodar system was set up at the site of Indian Petrochemicals Ltd., Nagothane, for studying the

behaviour of the atmospheric boundary layer. An instrumented tower was installed by our scientists at Maitri, during the ninth expedition to Antarctica. High altitude balloon experiments were conducted successfully for the measurement of ion conductivities, densities and mobilities.

There was active collaboration with scientific institutions, universities and scientific departments. These included BHEL, BIS, ISRO, DST, DOD and DNES. Memorandums of understanding were signed between IIT, Delhi-NPL and BITS, Pilani-NPL, for the promotion of academic, research cooperation and undertaking joint projects. The quantum of support from the sponsored projects, from other agencies, has more than doubled since last year and has increased from about Rs. 124 lakhs to about Rs. 292 lakhs. The processes of electronic energy saver and flexible graphite were released to the industry for first time.

Prof. S. Chandrasekhar, of University of Chicago, delivered the twentieth Krishnan Memorial Lecture on the topic "The Intellectual achievement that the Principia is". Shri K.R. Naryanan, former Minister of State for Science & Technology, delivered the Jawaharlal Nehru Centenary Lecture, titled "Jawaharlal Nehru and the promotion of Scientific Temper in Indian Society" on the Foundation Day of CSIR. A number of distinguished scientists visited NPL and delivered lectures. They included Dr. B. Batllogg, Prof. Huu Dang, Prof. G.B. Donaldson, Prof. A. Guinier, Prof. C de Jeger, Prof. D.S. Kothari, Dr. H. Maeda, Prof. N.F. Ramsey, Prof. M.M. Sharma, Dr. Y. Tanaka and Dr. A. Urbanek.

A number of our scientists won awards and honours. Dr. J. Kar received the CSIR Young Scientist Award. Dr. V.V. Shah and his team were awarded Rs. 50,000 by NRDC for their invention regarding the development of space qualified multicavity Interference Filters. Dr. P.K. Pasricha and Dr. Risal Singh were the members of the ninth Antarctic Expedition.

The age-wise analysis of our scientists indicated that 33% are below the age of 40 years and 26% will be retiring in the next ten years. In order to maintain the strength of human resources, the task ahead will be to recruit about ten brilliant young scientists each year during the eighth plan.

About 150 papers were published by the scientists in national and international journals and 20 research reports were produced during the year. Four issues of NPL Technical Bulletin were brought out. Four scientists were awarded doctorate degrees by different universities. A number of scientists were sent abroad for specialized training, presenting papers and attending international conferences/meetings under exchange programmes.

A few thousand students of various schools and colleges of Delhi visited NPL on the open day and were acquainted with the activities of the laboratory. An exhibition and special audio-visual programmes were arranged on that day. More than a dozen bright post graduate students spent two months during summer working on research projects under the guidance of NPL scientists.

Dr. Raja Ramanna, the Chairman of our Research Council was appointed the Minister of State for Defence. We now have Prof. B.V. Sreekantan, a distinguished scientist, as our new Chairman.

S. K. Joshi

(S.K. JOSHI)

STANDARDS

LENGTH & DIMENSIONS

1. LENGTH

A portable unit of frequency stabilised He-Ne laser based on two mode thermal stabilisation technique, was developed. The performance of this unit was checked against an iodine stabilised 633 He-Ne laser maintained as a primary standard of length/wavelength and found satisfactory. A few units of such portable laser will be supplied to the users for field trial. A laser interferometric system using a linear dividing machine and an optical microscope, was being made. A laser based interferometric system for calibration of slip gauges was ready for use.

A project on development of a frequency stabilised He-Ne laser at 3.39 μm was started in collaboration with FIAM, Moscow, under Indo-USSR collaborative programme. Some essential items like stable laser cavity, servocontrol electronics etc., for building a small prototype unit, were procured from USSR. The He-Ne laser tubes and methane absorption cells were made and the unit was being assembled.

Under Indo-US collaborative programme, a project on development of laser standards for length and frequency measurements was initiated.

A project entitled 'Photolithographic mask aligner, using modified Moire technique, sponsored by Department of Electronics was initiated. Under this project positioning accuracies of different Moire signal maximum slope detection techniques were compared to select the best technique for the proposed mask aligner. The possibility of using Moire technique for maskwafer gap control was also investigated.

A new method for the calibration of accelerometers was attempted by using the optical fibre vibration sensor developed earlier. The sensitivity of the microdisplacement sensor was improved using a switching technique. A new optoelectronic transducer for vibration amplitude measurement was also developed.

Calibration of length measuring machine was carried out for BHEL divisions at Haridwar and Hyderabad. Technical assistance was provided to the Govt. Mint, Bombay, regarding machines used there for engraving and calibrating metre bars of secondary & working grades. Similarly, technical advice was rendered to the Survey of India, Dehradun, for modernising their measuring tape/wire calibration facility using laser interferometer.

2. DIMENSIONAL METROLOGY

Using an electro-optical sensor the studies of induced vibrations for the installation of the measuring machine were carried out. A photoelectric line scale positioner and a 3-dimensional inductive probe used for dimensional measurements were designed for the fabrication. A portable test bench for testing of taximeters and autorickshaw meters was designed and is being fabricated. The modernisation and automation of facility for interferometric calibration of slip gauges was initiated.

Calibration of heavy items belonging to Bharat Pumps and Compressors Ltd., Allahabad, and Bharat Heavy Electricals Ltd., Bangalore, were carried out at site.

MASS, DENSITY & VISCOSITY

The maintenance of NPL standards of mass and their periodic recalibration was continued. Several sets of weights were recalibrated. Mass values of all the standards agreed well within the stipulated accuracy with those assigned earlier. Quite a few standard weights were recon-

ditioned by deplating and electroplating afresh and adjusting their mass values. Four weights in stainless steel-2 of 1 kg and 2 of 10 g were received under Asia Pacific Metrology Programme for round robin test and these were calibrated. Two 1 kg standards of mass, fabricated and calibrated at NPL, were gifted to the Government of Vietnam.

Two additional silicon cylinders were prepared for use as transfer standards of density in conjunction with the solid sphere. An electronic circuit was fabricated to convert an existing 1 kg balance in a servo-controlled, electomagnetic force compensating balance for small forces. One 50 dm^3 automatic pipette in stainless steel was fabricated, calibrated with an accuracy of 1×10^{-4} and supplied to Research & Development Establishment, Dighi, Pune.

The work relating to establishment of viscosity scale upto range of 700 mm^2/s was continued. Nine master viscometers were standardized.

FORCE

A collaboration was entered with M/s. F.I.E. Research Institute, Ganganagar, Maharashtra, for the fabrication of 1MN hydraulic Multiplication System, based on the design data provided by NPL. The system will be used for calibration of force proving devices. In this collaboration, two machines of 1MN capacity would be fabricated by the Inst. and one of the machines would be supplied to NPL free of cost. Both the machines were fabricated and one was installed at the premises of F.I.E.R. Institute. This machine was tested for its quality and accuracy by our scientists. The other machine was under fabrication and would be transported to NPL. The calibration of force measuring devices such as proving rings and dynamometers was done for the industry.

PRESSURE VACUUM

1. PRESSURE

A systematic theoretical investigation was carried out to study the effect of viscosity of thepressure transmitting fluids on the measurement of pressure using piston gauges. The fluid flow equation was modified to determine the fall rate with pressure, taking the pressure dependent viscosity and the radial clearance between the piston and cylinder terms, into account. The near constancy of the fall rate with pressure could be avoided with the less viscous fluid or by increasing the clearance. The initial clearance obtained from the experimental data of fall rate, showed a weak dependence of pressure, which was attributed to the effect of viscosity of the pressure transmitting fluids.

Primary pressure standard based on the principle of controlled clearance between piston-cylinder was well characterized using UNIVIS J-13 as pressure transmitting fluid at 23°C and an uncertainty value of 190 ppm was associated with the pressure measured by this standard. A few fluids either in pure form or as mixtures with some organic solvents were used to determine their viscosity as a function of pressure upto 700 MPa. On the basis of these studies 2 or 3 fluids/fluid mixtures were selected and it was found that the fluid Reolube DOS manufactured by M/S CIBA Geigy was most suitable for transmitting pressure. Primary pressure standard was again characterized using this fluid in the normal way upto 700 MPa. In this case, the operating jacket pressure value was increased upto 85-90% of the stall jacket pressure value as compared to 45-55% in the case of UNIVIS-13. Further, by using the experimentally observed cylinder distortion coefficient value, upto 500 MPa and extrapolated to 700 MPa, an overall uncertainty in the pressures measured upto 700 MPa by this gauge could be improved to a new value of 120 ppm.

2. VACUUM

A comparative study of the two primary pressure standards, static and dynamic gas expander systems, was carried out. The two systems were compared by using spinning rotor gauges

as the transfer standard in the pressure region 6 $\times 10^{-3}$ to 2 $\times 10^{-1}$ Pa. When the variation of the orifice conductance with pressure was taken into account, the σ_{eff} values for calibration on the dynamic system indicated an agreement of $\pm$ 0.3% between the two systems in the above pressure range. The factor 'A' relating the orifice conductance with the Knudsen number was estimated to be 0.1 $\pm$ 0.006 which lied in the range of values obtained by earlier workers. The mutual compatibility of the two primary pressure standards was established.

A study of line pressure effect on zero shift in the capacitance and quartz spiral gauges was carried out in detail by using different gas media. For this purpose MKS gauges, of types 310 and ranges of 1000 torr, 100 torr and 1 torr full scale and type 398 of range 10 torr full scale were studied. A careful analysis of the above experimental results showed that the zero shift for a particular line pressure was dependent on the dielectric constant of the gases. An attempt was made to find out an equation which could be used to find out the zero shift at any line pressure by simply knowing the dielectric constant of the gas under consideration. The study was carried out by using CO_2, Ar, N_2, O_2, H_2 and He gases upto a line pressure of 1000 torr. The effect of line pressure on the zero shift of quartz bourdon spiral gauge, was studied for different gases. The results obtained for different gases showed different types of trends in zero shift, though in all the cases the zero shift was negative with respect to the increase in line pressure.

A modified mathematical equation for calculating the effective conductance of the orifice assembly, connected in dynamic vacuum system, was derived. An attempt was made to modify the equation reported by Bureau *et al.* (Rev. Sci. Instrum. 23, 1952) by taking the end effect into account on the basis of the new short tube transmission probability developed by Santeler (J. Vac. Sci. Technol. A4, 1986). The molecular conductance value thus obtained was found to be in close agreement with the corresponding experimental value extrapolated from the conductance versus pressure curve. This modified formula could be used to determine the effective conductance of the orifice assembly irrespective of the position of the orifice inside the tube connecting the two chambers.

3. SURFACE PHYSICS

Barium fluoride films were deposited on Si and InP substrates at 10^{-6} Torr pressure by thermal evaporation. The characterization of these films was done using Auger Electron Spectroscopy. The desorption of fluorine from the barium fluoride films induced by the electron beam incidence was observed. The desorption seemed to follow the Fiebleman-Knotek model in which the desorption depended on the beam dose and not on the beam energy. Slow electron energy loss spectroscopy (SEELS) was employed to observe changes in core levels and valence band. The desorption cross section for fluorine and the critical electron beam dose necessary to initiate electron stimulated desorption (ESD), were estimated. Since the desorption of fluorine resulted in metallic-like barium on the surface, this could be used as a technique for depositing clean monolayers of Ba on cathode materials.

Auger electron spectroscopy (AES) studies for depth composition profile and film substrate interface were performed on thin films of Y Ba Cu O grown by co-evaporation on alumina, barium titanate, magnesium oxide and silicon substrates. Though the stoichiometries did not show the 1-2-3 configuration, the Tc for these films was measured to be 90K. The composition depth profiles of various elements constituting the HTSC monitored the interface characteristics of films. It was clearly seen that for a sharp interface (atleast clearly on Si substrates) it is necessary to keep the substrate temperatures less than 850 K. Above this temperature the interface deteriorated due to the interdiffusion of the materials, while films deposited below 850 K showed a reasonably sharp interface. This

work was done in collaboration with the Electrotechnical Inst. CEPR, Slovak Academy of Sciences, Bratislava.

TEMPERATURE

Repeated observations were carried out at freezing point of copper using black body which is now a primary fixed point on ITS-90. The results were used to recalibrate the tungsten strip lamp and intercomparison with VNIIM, USSR was completed. With a view to find more precise alternatives to 10% Rh Pt vs Pt thermocouple, studies were conducted on different thermocouples namely Pd vs Pt, Pd vs Pu and Pd vs Ag at the freezing points of Indium, Tin, Zinc, Antimony & Silver using ingots and available wires.

Studies on an extension bath, working on heat pipe principle were being extended to temperatures below 0°C to –75°C. A cryostat was designed and used to calibrate long stem platinum resistance thermometers at 90.1 K. Triple Point of mercury was realized with a reproducibility of ± 1 mK. Calibration of temperature measuring instruments and testing of thermal properties of materials as per ITS-90, was undertaken for industry and Govt. Deptts.

OPTICAL RADIATION

For calibrating tubular lamps and GLS lamps of high lumen values and of large size, a 2.5m diameter integrating sphere was set up. In this sphere, provision was made to calibrate four tubular lamps in succession without disturbing the system. It has reduced the time taken for calibration and increased the accuracy of measurements.

An automatic data recording goniophotometer for measuring the luminous flux for tubular lamps and fittings was set up. Also a manual goniophotometer for testing and calibrating high pressure discharge lamps with fittings was got ready.

A facility for measurement of the absolute spectral responsivity (ampere/watt) of photodetectors was completed. This was utilised for intercomparison of silicon photo-diodes of USSR to those of NPL. The work on spectral shift due to source correlation was done. The shift theoretically predicted by Prof. Emil Wolf, of the University of Rochester, was demonstrated using very simple experimental set-up used in optical measurements. It was suggested that the procedure hitherto followed in optical measurements may have to be given a new thought in the light of this newly discovered phenomenon. Elaborate studies of the phenomenon of spectral shift in relation to setting accurate and reproduceable scales of spectroradiometry, defining systems used for optical measurements, the study of emission spectroscopy of ions doped in different matrices etc. were made.

INFRARED RADIATION

The facility for irradiance measurement in the spectral region of 0.8 to 14 μm was setup by using a variable temperature black body as the standard source. Inorder to extend the facility for a variety of sources and also to minimize the uncertainty, necessary modifications in the setup were being carried out.

A design for the absolute measurement of reflectance at normal incidence by using bare minimum optical components was proposed and a bread-board model was set-up to work out feasibility of the design. Measurement of absolute values of reflectance was carried out on various surfaces of low as well as high reflectances at He-Ne Laser wavelength. The work of establishment of transmittance standard in 2 to 14 μm spectral region was pursued. The photoacoustic spectrophotometer was maintained and samples from various projects of the laboratory and other institutions were studied. The spectroscopic study of ink for its colour estimation was also carried out.

NPL had also contributed in planning of the Technological Nursery for Optics Research and Development (TNORD). This will be managed by an independent society.

The studies on luminance and illuminance characteristics of tropical sky were continued. A study was also made on different aspects of solar radiation in connection with the assessment as fuel for PV energy conversion systems. Some samples of solar cells from BHEL, Hyderabad were tested for their spectral response performance.

ACOUSTICS

Specific noise control measures were worked out in order to reduce the impact of railway noise on future inhabitants of the dwelling units in a proposed residential complex by the side of existing railway tracks. An optoelectronic transducer consisting of a rectangular aperture and a twin photodetector was developed for measurement of very small vibration amplitude. The transducer combination can be used for the calibration of standard accelerometers. A vibration survey was carried out in various rooms of NPL in order to ascertain existing vibration levels in standard laboratories wherein precision measurements are carried out.

Sodar was operated regularly during the year. Improvements were made in the electronic circuitry and portable antennas using different formats were designed and evaluated. Developments were also made to redesign and fabricate a dependable Sodar facsimile recorder. Modifications in receiver and transmitter parts of co-variance Doppler Sodar system were made to enhance signal to noise ratio in order to get a measure of Doppler frequency shift.

A monostatic sodar system was set up at the site of Indian Petrochemicals Ltd., Nagothane (Maharashtra) where a gas cracker complex is being set up. The behaviour of the atmospheric boundary layer will be studied over a period of one year since air quality needs to be monitored due to changes in the character of wind, stability and turbulence regimes over different seasons of the year as also diurnally.

The testing, calibration and evaluation of acoustical products and devices were done for the industry.

ULTRASONICS

A miniature needle type-probe hydrophone was constructed. The frequency response of the hydrophone in the frequency range 0.3 MHz to 2 MHz was studied. Studies were made on a number of NDT transducers in the frequency range from 2.25 MHz to 7.5 MHz.

The facility for vibration amplitude measurement was installed under a collaborative project with the British Council. A vibration isolation table for the interferometer was procured and positioning system for transducer was fabricated. The displacement amplitude of a 1 MHz transducer faced with an optically polished 4 mm. steel plates vibrating in air, was measured. Maximum amplitude of vibration was found to vary from 2 nm to 10 nm as a function of excitation. The profile of displacement amplitude over the surface was also studied.

Continuous efforts were made to induce hospitals to get their ultrasonic scanners calibrated. Calibration of a linear array scanner, in the imaging mode, was carried at the All India Institute of Medical Sciences.

FLUID FLOW MEASUREMENT

Designs of volumetric vessels of capacity 100 l, 200 l, 500 l, 1 m^3, 2m^3 & 10 m^3, to handle flow range between 0.04 l per second to 175 l per second, from the test rig were prepared. The laboratory lay-out plan indicating location of various facilities for setting up the National Primary Standards in the area of flow were finalized. The requirements of technical specifi-

cations of the area where to locate the primary flow standards based on over-flow pipette of 50 l capacity and its certification using gravimetric methods, were studied. Adequate inputs and requirements of calibration in the country were also taken from the Fluid Flow Research Institute, Palghat. Some preliminary work was initiated to set up ultrasonic Doppler shift technique for measurement of water flow rate.

TIME & FREQUENCY

The design and development of automatic recording system, for time comparison via passive TV technique, was completed. Two units were fabricated, tested and preliminary measurements were taken using these units. A newly developed microprocessor based ATA format generator was commissioned. It is very compact, reliable and has remote control facility. It has unique features for voice announcement and auto tripping.

The time transfer uncertainty using STFS broadcast via INSAT-IB was narrowed down to $\pm$ 10 microseconds from an earlier value $\pm$ 25 microseconds. This uncertainty is due to perturbation in the satellite orbit due to attraction by sun, moon and solar radiation pressure which were not taken into account. A new programme was developed for prediction of the satellite orbit taking into account all the perturbing parameters mentioned above to get the new accuracy limits in time transfer.

For filling up of the rubidium isotopic cells, the vacuum of the order of 6×10^{-7} mbar was achieved using silicon oil diffusion and Edwards rotary pumps. A precision low noise signal processor for monitoring rubidium hyperfine signal was developed and tested. It consisted of UAF 41 band pass active filter and a low noise amplifier. This circuit is very compact and is capable of processing very weak signal of the order of few microvolts.

DC STANDARDS

The maintenance of the emf values of the group of saturated standard cells in temperature controlled air enclosure was continued. The dc standards of resistance in the form of one ohm standard resistors were maintained during the year. Preliminary experiments on quantum Hall resistance standard were carried out. Calibration of sophisticated dc measuring instruments, including resistors, cells, electronic voltage standards, and shunts was carried out.

Quantum Hall resistance measurements were made on GaAs heterostructures at 4.2K and distinct plateaus were recorded for i = 2 and i = 4. Quantum Hall resistance corresponding to these steps is used to provide the value to the standard resistor.

HF IMPEDANCE AND AC, LF

1. *HF Impedance*

Regarding the collaborative work with Jadavpur University for the automatic precision capacitance bridge, a power amplifier, power supplies and other circuits were developed to couple the transformer unit to the processor unit.

William's dual admittance bridge for precision measurement of L,C, R and Q was set up and it works satisfactorily. Facilities for calibration of search coils, fluxmeters and standard magnets were established.

A precision 3 decade low frequency inductive voltage divider was designed and fabricated for use in the frequency range 50Hz to 1 KHz. The inductive voltage divider has high input impedance, voltage rating of five times the frequency at 50Hz, and ratio accuracy of 2 parts in 10^7. The precision temperature control circuit of the transfer standard 10pF silica capacitor was repaired and put back in operation. Similarly the

special electronic control unit of the calculable capacitor, which was damaged due to heavy surge was repaired.

2. *AC and LF Standards*

The electronic test equipment SDE 106 for power and energy calibration, with balanced and unbalanced loads, was commissioned. The accuracy obtained in power and energy calibration with this system is 0.05%, the phase angle accuracy is 0.1% and voltage & current accuracy is 0.01%. The frequency stability of the system is of the order of 0.05%.

Phase standard model 5000 clarke-hess was set up for measurement and calibration of phase from 0° to 360° with an accuracy of 0.005° from 1V to 100V upto 1kHz. The knowhow document of constant temperature oil bath was prepared for the technology transfer. The calibration of power, energy, current & potential transformer standards for various laboratories/institutions & industries was provided.

HF AND MICROWAVE POWER

Some parts of coaxial matched termination for setting up primary standard of HF and microwave power in coaxial configuration were got fabricated and tested for broadband matching characteristics and encouraging results were obtained.

The final version of primary standard X-band waveguide noise source was being evaluated. Periodic in-house calibration of primary standards of power in different bands was carried out. A number of standards and precision instruments received from user agencies were calibrated.

HF AND MW ATTENUATION AND IMPEDANCE

The precision waveguides were developed for establishing tuned reflectometer technique at K-band (18.0-26.5 GHz) microwave frequencies for calibrating standard mismatches using quarter wave short circuits at K-band spot frequencies as reflection coefficient standards. The reduced height waveguides were also designed for standard mismatches of VSWR (voltage standing wave ratio) 1.10, 1.20 & 1.30. The low VSWR terminations for tuned reflectometer technique and standard mismatches were under fabrication.

Precision step attenuator, programmable attenuator, coaxial tester and rotary vane attenuator were calibrated for Defence and other organisations.

CALIBRATION SERVICE PROGRAMME

More than 700 organisations, user departments, industries and others were contacted under the Calibration Service Programme for dissemination of the relevant information. As a result, 30 organisations have so far applied for accreditation of their calibration facilities/laboratories. After launching of the programme, 6 expert panels and Steering Committee for Calibration (SCC) had their meetings to finalise the procedural details to start and operate the accreditation process. The assessors for assessment of applicant laboratories were identified and the action for accreditation of these laboratories is in progress. NPL has also been accepted as the member of the National Conference of Standards Laboratory, USA for the year 1990.

The requirements and benefits of accreditation were presented to the industrial trainees attending the training courses organised by Ministry of

industry, Asian Congress for Quality and Reliability and in the workshop of IECQ system organised by STQC. Various technical bulletins, & news bulletins of industrial associations have published information in regard to the programme in their regular publications.

CALIBRATION TESTING

The laboratory provided the calibration and testing service to the industry and public sector organisations. The calibration work for reference and secondary standards of national measurement standards was carried out. The calibration of instruments for testing, evaluation and quality assurance was done. The characterization of products for chemical, thermal and porous properties and crystalline and structural perfection was also done. The calibration of length measuring machine and heavy items was done by the scientists at the premises of the industry/organisation such as M/s Bharat Heavy Electricals Ltd. and M/s Bharat Pumps and Compressors Ltd. The calibration work for reference and secondary standards of mass and analytical weights, was carried out for state departments and industry. Some of the parties which availed the calibration/testing facilities of NPL are listed in this report.

Various items calibrated/tested included slip gauges, proving rings and dynamometers; linear array scanner; pipettes, burettes, hydrometers and viscometers; temperature measuring instruments; GLS lamps and tubular lamps; acoustical products and devices; electronic and electrical instruments and components such as resistors, cells, shunts, electronic voltage standards, current and potential transformers and attenuators.

CIMET—NPL TRAINING WORKSHOP

The CIMET—NPL Group Training Workshop in Metrology was held from Nov. 20 to Dec. 8, 1989. The workshop was sponsored and funded by Fellowship & Training Programme of Commonwealth Secretariat, London, coordinated by Commonwealth Science Council, London and organized by Commonwealth—India Metrology Centre (CIMET), NPL New Delhi.

Dr. A.P. Mitra, DG, CSIR inaugurated the workshop. The areas of Mass, Length, Volume and Temperature Standards, Calibration and Testing and Legal Metrology were covered in this workshop. Fourteen participants from commonwealth countries viz. Zimbabwe, Kenya, Malaysia, Seychelles, Malta, Uganda, Papua New Guinea, Guyana, Cyprus, Ghana, Bangladesh and Saudi Arabia attended.

The Indian members of the Faculty were drawn from NPL, BIS, Deptt. Of Weights & Measures and Controllorates of W/M of Delhi Administration and Assam. Mr. J.J. Connolly of National Measurement Laboratory, Australia and Dr. K. Chandra, UNDP Expert from Saudi Arabia were the faculty members from abroad. Besides lectures, the participants were shown the experimental demonstrations and facilities of the Standards Division.

Field visits were arranged to the laboratories of BIS, Controllorate of W/M Delhi Administration, Bharat Petroleum Corporation and prepackaging unit of Hindustan Vegetable Oil Corporation, to acquaint them with the dissemination of national standards in the industrial laboratories and institutions. Two participants from Ghana and Uganda were given training for three months in the Electrical and Acoustic Standards for their specific problems.

MATERIALS

SILICON AND DEVICES

1. *Crystalline*

A process for directional solidification of multicrystalline silicon ingots was developed where by the ingot could be released and the crucible saved for use in the next runs. Similar experiments on polycrystalline Ge ingots yielded material suitable for fabrication of infrared lenses. High open circuit voltage larger than 630 mV at room temperature was achieved in single layer polycrystalline silicon solar cells without antireflection coatings.

An ultra high vacuum system (Riber, Model-UNI-107P) capable of giving vacuum better than 10^{-9} torr was commissioned. Computer simulation of diffusion of B, P, As and Sb impurities into Si was carried out. Advanced models of diffusion under oxidizing and non-oxidizing conditions were incorporated into SUPREM II software package.

1.1 *Amorphous*

The development work of fabrication of thin film amorphous silicon solar cells was continued. The measurements carried out by constant photocurrent method, on samples grown at 18 A°/S deposition rate showed disorder energy in the range of 50–90 meV which compared well with the reported results for films grown at low deposition rates. The density of gap states turned out to be $10^{17}/cm^3/eV$. IR absorption data confirmed only a-Si : H stretching bond at 2000 cm^{-1} and wagging bond at 630 cm^{-1}. No shift of the band at 2000 cm^{-1} towards higher wave number with the increase of the deposition rate was observed.

The high efficiency (10–11%) cells developed at NPL, exhibited the best short circuit current and good fill factor but the Voc values were lower when compared with reported results. In order to understand and optimize the deposition parameters it was essential to know the values of thickness and doping profile of the various constituent regions of the p-i-n structure. The efforts were being made to use the facility of SIM measurement available at IIT, Delhi & IACS, Calcutta.

Investigative work on the development of diamond like carbon coatings (DLC) was initiated. DLC films deposited by plasma CVD technique (using methane gas) on both the surfaces of a polished silicon wafer showed an increase in transmission from 45% (for uncoated silicon) to 93% at 5.0 μ wavelength.

INTERFACES AND MICROSTRUCTURE

Electronic behaviour of extrinsic dielectric, yttrium oxide—silicon, crystal interfaces was investigated and found that electron beam deposited yttrium oxide-Si structures displayed MOS capacitor action. The studies of dependence of dielectric constant and trapped positive charges on oxygen annealing were conducted indicating the application of such structures as high density storage capacitors in dynamic memories.

Preliminary studies on diamond films deposited on silicon were undertaken. Semiconductor heterojunctions were also studied. In situ electrodeposition of p-typed doped low resistivity CdTe thin films was carried out. The problem of compensating nature of defects in CdTe, was overcome by evolving parameters for the growth of single crystal films. Experiments were also conducted for in situ selenization by electrochemical means to form photoactive $CuInSe_2$ material in thin film form. This constitutes an essential first step to develop a low cost technology for thin film polycrystalline solar cells.

A set up for low pressure chemical vapour deposition of yttrium iron garnet thin films was made using volatile metallo-organic complex as basic source. Initial experiments on formation of component oxide were carried out and its growth kinetics and deposition mechanisms were studied.

LUMINESCENT MATERIALS

The work on the ISRO sponsored project, of development of fluorescent screens for real time X-ray imaging, was continued towards the development of terbium activated gadolinium oxysulfide phosphor, preparation and testing of fluorescent screens using both imported and NPL developed phosphor. In the phosphor development work, the preparation parameters were optimised by preparing samples at high firing temperature (1150 and 1200°C), using purer starting materials and measuring the cathodoluminescence (CL) output of each of the sample. The samples matching the imported phosphor in their CL output were successfully prepared and the capacity was enhanced from 5 to 25 g per batch.

The experimental fluorescent screens of full size (300 mm × 225 mm) using both NPL and imported phosphorus were prepared by settling technique which resulted in highly uniform layers. A series of fluorescent screens were prepared on tungsten substrates with varying thicknesses for optimising sensitivity and contrast levels at 9 MeV and 15 MeV x-ray energies. The NPL's screen on 1.25 μ thick tungsten, when finally tested at SHAR under 9 MeV and 15 MeV Linac machines, was found to be comparable with imported screen used at SHAR as regards visibility, dose rate and resolution requirements. SHAR has now accepted NPL fluorescent screens on tungsten subtrates for 15 MeV NDT applications in their ER 110 Varian imaging system. The goal of developing the fluorescent screens for ISRO with two (numbers) full size screens, was achieved.

Electroluminescence in powdered terbium activated gadolinium oxysulfide phosphors was observed. The variations in the preparative methods and design of EL cell resulted in the appreciable increase in EL brightness. The work for further reducing the threshold voltage was in progress. The dc luminescence under ac field was thought unlikely to be due to mere photo-excitation by UV generated from plasma discharge, but more likely to be due to field excitation of Tb in gadolinium oxysulfide lattice.

DISPLAY DEVICES

1. *Photonics Materials*

Photonics means that whatever one had been doing with electrons one should be able to do with photons and perhaps better. A new R & D programme on Photonics, related to optical computing, was started. An optical switch was fabricated by which one can direct a laser beam from one channel to another direction through electro-effects in suitable liquid crystals in a specially designed Dove prism configuration.

Initial experiments were carried out to prepare the electro-optical switches using nematic (NLC) and ferroelectric (FLC) liquid crystals. A liquid crystal switch capable of switching polarized light from one part to another was prepared using NLC. This voltage controlled device switches polarized light with few m. sec. response. The switch has a low insertion, low cross-talk and low operating voltage.

A total internal reflection electro-optic switch using ferroelectric liquid crystal was also fabricated. The switching response time of the switch was about 150 μ sec. and gave a contrast ratio of better than 5×10^6 at 30 volts. The switch using FLC should find a wide arrays of applications in fibre optic communication systems and intra-site video relay networks.

Very interesting polymer-based liquid crystal

display films (PDLC) were developed. The electro-optical display films scatter the incident light in the off state and become transparent on application of electric field. These films were characterized for their performance characteristics using a variety of polymers. The electro-optical performance characteristics of PDLC films using two different polymers, namely, poly (methyl methacrylate) PMMA and poly (vinyl chloride: vinyl acetate 17%) PVC: VAC-17 and liquid crystal mixture E-8 were studied in detail. It was found that PMMA-based PDLC films prepared by solvent induced phase separation technique have superior mechanical and electro-optical properties than the PVC: VAC-17 based PDLC films. The performance characteristics of PDLC films improved significantly with increasing temperature (Fig). The finite solubility of liquid crystal mixture in the polymer affects the properties of the polymer matrix and hence the electro-optical performance characteristics significantly.

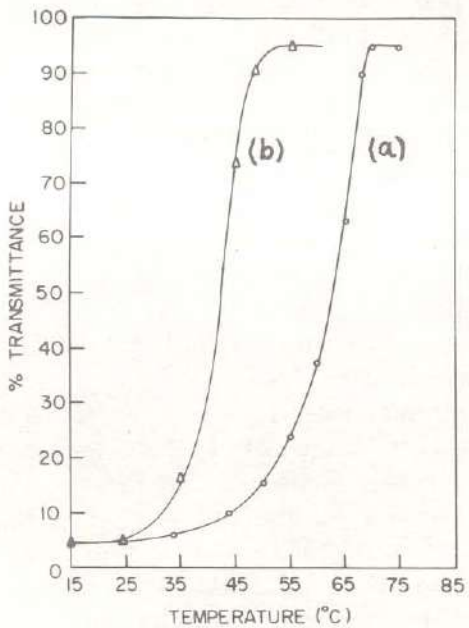

Fig. Transmittance as a function of temperature of PMMA (a) and (b) PVC:VAC based PDLCs with 1:1.5 liquid crystal composition

2. *Conducting Polymers*

European Economic Community has sponsored a project—"Synthesis, characterization and application of some conducting polymers", in collaboration with University of Oxford, U.K.

A large number of conducting polymers such as poly-p-phenylene, poly-n-phenylene, poly (n-phenyl-anilene), poly (o-toluidine), poly (p-toluidine), poly (p-anisidine) and poly (O-anisidine) were synthesized using chemical technique. The results indicated that poly (o-anisidine) was soluble in trifluoroacetic acid, chlorobenzene, tetrahydrofuran and DMF whereas poly-p-anisidine dissolved in pyridine, DMF, trifluoroacetic acid. Poly-permigraniline was synthesized which predicted to exhibit non-linear optical properties. Electrical conductivity, infrared and elemental analysis techniques were utilized to characterize some of these conducting polymers.

To facilitate investigations valence-effective-Hamiltomain (VEH) calculations of conducting polymers were undertaken and lattice fluctuations were considered to effect on the mobility of charge carriers in conducting polymers. The work of deriving graphical analog using Monte-Carlo calculations for delineating the details of structural transitions was done.

Development of metal/organic semiconductor Schottky junction as an alternative to metal/inorganic semiconductor junction was carried out. Metal/poly-pyrrole (PP) junctions were prepared using electro-chemically deposited doped PP films of different thicknesses and In, Sn, Ti and Al as electrodes. It was established that it was possible to prepare Schottky barrier on PP films with metals having work functions lower than that of PP. The conductivity studies and capacitance measurements indicated a two carrier charge transport in PP. The characterization of PP with respect to work function, Fermilevel and carrier concentrations were carried out. The optimum device characteristics can be achieved by controlling doping level of polymer and the metal work function.

UNDER WATER ACOUSTICS

The development and characterization of acoustic transducers and materials for oceanographic applications was continued.

1. *Ultrasonic Systems*

The receiving sensitivity of the omnidirectional radial mode transducers was studied in the frequency range 10 KHz-30KHz. A command transducer of frequency 16–18 KHz based on sandwich structure was designed using lumped equivalent circuit approach.

A coupler reciprocity technique for the calibration of small hydrophones at low frequencies and high hydrostatic pressures was developed. The sensitivity of B & K hydrophone was measured upto a pressure of 500 psi. at frequency of 4 KHz. The high pressure tube assembly with sliding carriage was fabricated and installed. An x-y hoist for lifting the end plugs for the tube assembly and top plug of Benthos system was installed. Characterization of transducers at high electric drivesextensive measurements was made on electromechanical parameters such as capacitance and tan δ of piezoelectric ceramic elements upto electric field of 3 KV/cm. It was observed that the variation for various material samples varied from 0.002 per KV/cm to 0.01 per KV/cm.

1.1 *Parametric Acoustic System*

Studies were made on the detection of an airbacked metallic reflector placed behind a 0.5 metre thick layer of sand and mud using parametric acoustic arrays. The sponsored project on development of parametric system for detection of objects embedded in sea bed was completed. The studies were made on the performance of a 1.8 KHz transducer using various types of mountings and as a function of the length of backing cavity. Relative measurements in the NPL tank showed that the source level could be boosted by 7dB by tuning the cavity. Inter-comparison calibration of ball hydrophones from the University of Birmingham, was carried out using three transducer reciprocity technique. Agreement was observed within 1 dB in the hydrophone sensitivity over the frequency range 10 KHz-60 KHz.

1.2 *Piezoelectric Ceramics*

Tubular transducer elements were provided for further studies on pinger transducer. More studies were made on microwave dielectrics, resulting in the improvement of mechanical quality factor.

CARBON PRODUCTS

1. *Carbon Fibres*

The present carbonization line of the experimental pilot plant was augmented to heat-treat the carbon fibres upto 1300°C. PAN fibres (precursor A) impregnated with carboxylic acid were prestretched before oxidation, to provide modified PAN fibres (precursor B) of superior mechanical properties. The impregnation also helped in supressing the exotherm and enhancing the rate of cyclization during oxidation. The preliminary experiments on the development of carbon fibres from these precursors showed that a high degree of post spinning stretch to the PAN precursor before oxidation was not a viable process from the high performance fibre point of view. Studies on the low temperature thermal stabilization of PAN fibres showed that by controlling the temperature and time of stabilization a definite structure consisting of intramolecular and intermolecular cross links between the adjacent molecular chains could be formed.

A novel technique of thermal oxidation of PAN was evolved and established, without evolution of a number of condensable tarry products. This has increased the production rate of carbon

fibres and decreased the frequent stoppages for cleaning the reaction vessels. Characterization by X-ray diffraction of natural graphite flakes intercalated with ICl & Br_2, revealed that the even stages were stable for graphite-Br intercalation compound whereas odd stages were stable for graphite-ICl intercalation compound.

1.1 *Carbon–Carbon Composites*

The 3D carbon fibre woven preform was characterized for density, fibre volume content and irregularity if any. The preform was also inspected by NDT techniques. Work under the project "oxidation resistant carbon/carbon composites" sponsored by DRDL, Hyderabad, was completed. The crack-filled silicon carbide coatings, developed under this project, were found to provide excellent resistance to oxidation of C/C composites upto about 1700°C.

The carbon/carbon composites were made using carbon fibres having different mechanical properties i.e. high strength, high modulus and intermediate modulus fibres. Preliminary results showed that these fibres possessed characteristic surface groups which make strong bonding with the matrix. Work was initiated to coat carbon/carbon composites with suitable silicon based ceramics such as silicon oxinitride. Silicon oxinitride films were prepared by hydrolysis of tetraethy orthosilicate followed by heating in the presence of ammonia. The characterization of these films was being done.

Extensive work was done on the formulation of an improved process for the production of special pitch containing QI in the range of 0.02–3.5% for the carbon-carbon composites.

2. *Impregnating Pitch*

The impregnating pitch by solvent fractionisation method was prepared on a 5 kg. batch level. The quantity of solvents and number of stages were reduced. Helicopter burshes needed by the Air Force Deptt. Chandigarh were evaluated and two varieties matching the physical properties were made. The testing of carbon brushes and activated carbon was done.

HIGH PRESSURE TECHNOLOGY

In the project of superhard materials, new catalysts were being evaluated for the synthesis of cBN by subjecting hBN to high pressure temperature conditions. The role of oxygen present as impurity in the starting material was critically studied.

The equilibirium of aluminium garnet (pyrope) and chromium garnet (knorringite) solid solution, under high PT conditions, was studied as a joint work with the University of Allahabad. Some other geological systems were also studied under high PT conditions. Regarding sponsored project on the study of electrical behaviour of earth's mantle forming rocks/minerals the instrumentation was obtained and commissioned.

CHARACTERIZATION

PURITY AND COMPOSITION

1. *Chemical Methods*

R & D work was done to develop more sensitive and specific methods for the determination of traces of impurities in different materials. Spectrophotometric method was developed for the determination of mercury in biological samples. A method was developed for the separation of tungsten and molybdenum from steel for their gravimetric determination.

The analysis of reagents including acids and solvents, regarding the collaborative project with CEERI, Pilani, was carried out. About one

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hundred samples of different materials were analysed for their composition and impurity content for various organizations in the country.

Testing of samples of silica activated carbon and bone charcoal received from the industry and institutions were carried out for BET surface area and porosity. The surface area measurements were also done on samples of silicon wafers of different thickness regarding collaborative work with CEERI, Pilani.

1.1 *FTIR Spectroscopy*

Research investigations were carried out on silicon single crystals and high Tc superconducting materials. For infrared absorption studies of Y Ba Cu O ceramic specimens by FTIR spectrophotometer at different temperatures around Tc have shown that the eigen vector values calculated by using the unscreened rigid ion model were very close to experimental values of infrared active phonons. Infrared absorption studies on p-doped silicon crystals at liquid helium temperature have shown that stress induces splitting of bands due to transitions: 1s(A1) to $2p_{\pm}$, $3p_{\pm}$ and $4p_{\pm}$. No such splitting was observed for bands with ground states 1s(E) and 1s(F).

FTIR measurement facilities were provided to scientists of NPL as well as outside institutes (IIT Bombay and CEERI, Pilani). Changes produced by thin deposits on silicon single crystals on their IR absorption spectra in the range 4000–400 cm^{-1} were studied.

1.2 X-ray Fluorescence Spectrometry

The epoxy resin (araldite) was found to be very good binder material and the pellets so formed were of high strength, allowing convenient and repeated handling. In quantitative analysis of major elements it was observed experimentally that consistent and reproducible fluorescent intensities were obtained only when standard elemental components were converted to solution form before mixing. Based on this experience a number of standard samples with known concentration of phosphorus in silicon matrix were synthesized and studied. The calibration curve obtained was linear with minimum detectable limit of approximately 50 ppm of phosphorus in silicon matrix.

The mineral ore samples from Directorate of Mines, Govt. of Orissa, were studied for platinum content. The maximum amount of platinum in these samples, determined by spiking method, was of the order of 100 ppm. The compositional analysis of original and the damaged boiler tubes of M/s Gujarat Heavy Chemicals Ltd. was carried out for the failure studies.

1.3 *Electron• Paramagnetic Resonance Spectroscopy*

EPR studies of as grown and air annealed $CuInSe_2$ samples prepared by chemical method, were made to understand different types of defects obtained during oxidation process. On annealing the samples in air two types of EPR signals were obtained which were assigned to the intrinsic defects. The relative strength of these signals were found to depend strongly on annealing temperature, its duration and Cu : In ratio.

EPR study of natural diamonds was continued. Analysis showed that observed spectra were due to two different nitrogen centres. One centre was identified with isolated substitutional nitrogen having unpaired electron on one of the four C-N bonds (P_1 -centre) whereas the other centre was associated with the presence of three nitrogens in the nearest neighbour sites of a carbon vacancy (P_2 -centre).

In collaboration with CEERI, Pilani, samples of silicon wafers implaned with BF_2^+ ions were studied for understanding the defects formed during ion implantation. Samples were implanted with ion beam having energy in the range 25–180 keV and with ion dose 1×10^{13} to 1×10^{16} ions/cm^2. The spin density of dangling

bands calcualted for each sample was found to be proportional to the energy and dose of the implanted ions suggesting an increase in the amorphization of the crystal during the process.

STRUCTURAL CHARACTERIZATION

2. *X-ray Diffraction*

A few hundred samples from different projects of the laboratory were characterized by X-ray diffraction techniques. These included superconducting materials, carbon fibre, kidney stones, SiC, Gd_2O_2S, amorphous Si films, $LiNbO_3$, Al_2O_3, $CuInSe_2$, $PbTiO_3$, and CdTe. Assistance was provided to various reasearch institutes including CEERI, Pilani; CRRI, New Delhi; IARI, New Delhi; IIT, Delhi; University of Delhi and NTPC, New Delhi for characterization of their samples. High temperature X-ray diffraction work, from room temperature to 310°C, was carried out on some thermotropic liquid crystalline polymer samples received from NCL, Pune. No crystalline phase change was observed.

X-ray diffraction analysis of high Tc material, Y Ba Cu O and thick films of this material deposited on magnesia stabilised zirconia substrate, were carried out. Similar studies were also carried out by adding small quantities of Sb_2O_5 upto 1.0 mole percent. Studies of different dopants were also done.

In Bi Sr Ca Cu O superconducting system, the effect of Pb doping was studied. In the Pb free samples, two phases low Tc (85K) 2-2-1-2 phase and high Tc (110K) 2-2-2-3 phase were found, whereas no 2-2-1-2 phase was observed in the Pb doped samples. The effect of Sb doping in this compound was also studied and the results showed that with increase in Sb content the fraction of 2-2-1-2 phase decreased while 2-2-2-3 phase increased. The effect of long annealing on Pb and Sb doped high Tc material was studied and observed that the gradual formation of high Tc phase with long annealing of nearly 200 to 250 hrs. was evident from the carrying intensity of low angle line at $2\theta \sim 4.7°$.

In 2-2-1-2 films of this system, prepared by spraying technique on MgO substrate and annealing in air, yielded the highly oriented films with c–axis prependicular to the substrate. Studies on Tl Ba Ca Cu O superconducting system, synthesized at high sintering temperatures, were carried out for phase analysis. The studies were carried out on high Tc, Gd Ba Cu O materials synthesized by varying the cooling rates. The diffraction pattern of these samples conformed to normal distorted pervoskite type structure except the quenched ones which indicated a phase transformation with time. High Tc material, where Gd was replaced by Sm, quenched in a similar way, gave diffraction pattern of tetragonal lattice.

Vaporization study of Ga_2Te_3, backed by TGA and X-ray diffraction measurements, was carried out extensively. Both temperature of vaporization and time of heating influenced the final results. To stabilize the zinc-blende lattice of Ga_2Te_3, various dopants were tried in making the structure stable by replacing 5% of Ga atoms by zinc or by addition of 20 mol% of In_2Se_3.

Orientation work using Laue technique, was carried out on two large grown single crystals of $LiNbO_3$. Stereographic projections were constructed for each Laue photograph and indexing of selected reflections at the zone intersections was done to reveal the crystal growth direction and the indices of faces formed. Theoretical studies on vapour adsorption on porous materials were continued further.

2.1 *Electron Microscopy and Diffraction Techniques*

Transmission and scanning electron microscopes (TEM, SEM) were used for the characterization of materials regarding their structure, surface morphology, topography and compositional analysis. The facilities were provided to various R & D institutions, industries and un-

iversities including CEERI, Pilani; CEL, Sahibabad; Uptron: IACS, Calcutta; Universities of Banaras, Rajasthan and Sri Venkateswara.

About 200 samples from various projects of the laboratory, CSIR laboratories, R & D Organisations and universities were characterised for their structure with TEM. These included superconductors, a-Si :H, polymer films, metal oxides, carbon composites, amorphous C films, compound semiconductor films, metal couples, metal and alloy films. About 1500 samples were investigated for surface structure/morphology and micro-analysis. Samples of the failed boiler tubes from M/s Gujarat Heavy Chemical Ltd. New Delhi were investigated for surface microstructure and composition.

The samples of high Tc superconductor belonging to Bi Sr Ca Cu O system were prepated under varying conditions of calcination and sintering. The surface morphology and elemental analysis of the material was investigated by SEM and EDS respectively. The resistivity of the material at low temperature revealed that there were at least three distinct phases which showed superconductivity. High Tc superconductor of Y Ba Cu O doped with tungsten and antimony and Bi Sr Ca Cu O doped with lead in bulk form were characterized with SEM and EDS (Energy Dispersive Spectrometer). The effect of doping on the superconducting properties in correlation with micro-structure, density was investigated. The superconducting phases were detected and analysed for their elemental composition. Thin films of Y Ba Cu O and Bi Sr Ca Cu O prepared by r.f. sputtering and electron beam evaporation techniques were analysed for their elemental analysis. It was established that the composition of the thin films obtained after evaporation was different from the starting material used in target and the evaporation boat.

The studies of the structure and optical properties of thin metal couples of Au-Sn were initiated. The films of Au-Sn having different thickness were deposited by thermal evaporation and their structure was investigated by TEM and electron diffraction techniques.

CRYSTAL GROWTH AND PERFECTION

1. *Five crystal X-ray Diffractometer*

A five crystal system was designed and developed in the laboratory and is under rigorous testing. This is an improved facility over the four crystal X-ray Diffractometer developed earlier. The present system allows high resolution X-ray diffraction experiments to be performed without introducing dispersion due to mismatch in the lattice parameters of the specimen crystals and the monochromators.

1.1 *High resolution X-ray Diffraction Studies*

Accurate measurements of peaks and integrated intensities were made on natural diamond crystals of Type I and Type II and were intercompared. Similar experiments were also performed on silicon single crystals and compared with the results of diamond crystals. A four crystal X-ray diffractometer was used in three crystal mode and (+,–,+) configuration. Diamond crystals were (111) platelets obtained from the collection of Late Prof. C.V. Raman. Infrared absorption measurements were used to classify these specimen into Type I and Type II categories. Silicon single crystals were (111) discs with diameter of 23 mm and thickness of ~1 mm. Diffraction curves and traverse topographs were used to evaluate crystalline perfection. Diamond crystals were also examined under polarising microscope. Following four reflections were used: 111, 333 (Bragg geometry) and $\bar{2}20$, $\bar{4}40$ (Laue geometry).

The silicon crystals gave very sharp diffraction curves as expected. Diffraction curves obtained from Type I specimens were sharper (typical half-width : 20 arc sec for $\bar{2}20$ reflection) in comparison to Type II crystals (typical half-

widths : 50 arc sec for $\bar{2}20$ reflection). However, peak intensities of Type II crystals were highest and those of silicon were the lowest. It was seen that the nitrogen free Type II crystals give anomalously higher peak intensities inspite of their lower degree of perfection in comparison to nearly perfect Type I crystals. In the same type of crystals, the peak intensity was observed to decrease with increase in half-width as expected.

1.2 *Defect structure and Topographic Characterization*

Silicon single crystal wafers (100) were implanted at CEERI, Pilani with boron and investigated before and after implantation. The dose was varied in the range, 10^{13} to 10^{16} cm^{-2} and the energies of implanted ions in the range 25 keV to 180 keV. High resolution diffractometric characterization was carried out on some of these wafers. This work is being done in collaboration with CEERI, Pilani. The multicrystal X-ray diffractometer used for diffuse X-ray scattering measurements was improved by replacing the existing 3rd monochromator stage by a newly developed sophisticated turntable. A linear movement track was incorporated in the specimen stage.

The existing double crystal X-ray diffractometer was updated by incorporating a plane 125 mm diameter silicon single crystal monochromator with its surface along (111) lattice planes. Traverse topographs of 100 mm diameter (100) silicon single crystal wafers were recorded in Bragg geometry. The monochromator was oriented for diffraction from (511) lattice planes in asymetric Bragg geometry. The triple crystal X-ray diffractometer was also updated by incorporating a precise and smooth linear traversing stage. This stage enables total traverse of 150 mm with smallest steps of 0.001 mm. The movement is controlled by a microprocessor system.

As a part of extensive study of stress induced by thin deposits of Si_3N_4 and SiO_2 on silicon single crystal wafers used for microelectronic device fabrication, a number of blank wafers of 50 mm diameter were characterized regarding their crystalline perfection and radii of curvature of lattice planes. Diffractometry and curvature measurements were used. Topographs of selected wafers were also recorded. Thin films were deposited on these wafers at CEERI, Pilani.

High resolution X-ray diffractometric and topographic methods were used for evaluation of crystalline perfection of $LiNbO_3$ crystals for the Institute of Inorganic Chemistry, USSR. Individual grains were reasonably perfect. A typical half width of diffraction curve for 006 reflection was 18 arc sec. Traverse topographs revealed very low angle boundaries.

1.3 *Growth of single crystals and data base development*

Experiments on growth of $LiNbO_3$ single crystals from melt on an indigenously developed crystal growth system, were carried out. It was found that non-stoichiometry of the compound was mainly responsible for the blackening of the charge. Experiments on growth of single crystals of high Tc superconducting materials by flux method were carried out. Single crystals of KCl, KBr and NaCl were grown and supplied to scientists of NPL and to Universities of Amritsar; Delhi and Agra.

A data base is being generated and a software for storage, processing and retreival was developed in collaboration with the NPL Computer Centre. The data on crystal growth, having nearly 700 entries, was also stored.

STANDARD REFERENCE MATERIALS

The standard solutions of lead and cadmium were prepared in high purity water and provided to seven laboratories. The measurements were

being carried out at different intervals of time to assess the shelf life of the solutions. The data on measurements of these solutions by atomic absorption spectrometry was compiled.

Different batches of nitric acid were subjected to sub-boiling distillation process and estimation of trace constituents was carried out. The determination of phosphorus in high purity silicon was carried out by atomic absorption spectrometric method using bismuth phosphomolybdate complex. The determination of bismuth was carried out in the complex and correlated with phosphorus content. Silicon matrix did not cause interference in the method as it was volatilized as silicon tetrafluoride.

CONDENSED MATTER PHYSICS

HIGH TEMPERATURE SUPERCONDUCTORS

1. *Basic Studies*

Substantial studies were continued with respect to various catonic sites in 2-1-4, 1-2-3, Bi 2-1-2-2 and Tl 2-2-2-3,, in collaboration with Shriram Institute for Industrial Research, Delhi. For the first time Zn substitution was investigated in all the four systems. The results showed that the rate of Tc depression was nearly identical in them, indicating that the mechanism of superconductivity in the four systems must be essentially the same although their Tc values vary from 12K for 2-1-4 system (with Sr content of 0.25) to 125K for Tl 2-2-2-3. In 2-1-4 system doped with Sr more than 0.3 there was no superconductivity. This is due to the creation of O-vacancies. Interestingly, it was revealed that partial substitution of Ce and Pr for La revived Tc in higher Sr doped samples. For the first time T* phase was reported as a mixed phase in La-Ce system. Ni substitution in Bi 2-1-2-2 was also studied and compared with the results obtained in Y- and Er 1-2-3. The Tc (R =O) above 200K was observed in Er 1-2-3 system and for the first time we have been able to report a diamagnetic susceptibility drop also occurring at this temperature. This gives credence to extra high Tc superconductivity. The volume fraction of the extra high Tc phase was estimated to be 1% of the majority 90K phase. Increase in the volume fraction would possibly pave the way for the eventual stabilization of the extra high Tc phase. Some success was achieved in respect of synthesizing flexible tapes of these oxides, but their Tc is still low (72-75K).
Ni and Zn substituted samples were studied for Xanes, with University of Rajasthan and XPS studies with University of Pune. Hf and Dy doped samples were investigated with IIT, Kanpur for EPR, microwave absorption and Raman studies. Detailed studies on the thermoelecteric power (TEP) of R Bo Cu O and Bi Sr Ca Cu O systems, a new type of percolation, was proposed for TEP of the granular superconductors. It was argued and shown that percolation threshold for TEP was much smaller that for electrical resistivity.

An interesting observation of enhanced Tc in calcium free Ti compounds of the series $Tl_m Ba_2 Ca_{n-1} Cu_n O_x$ was made. Three different starting compositions (2-2-0-1, 1-2-0-1 and 2-2-0-2) were studied extensively with varying conditions of preparation. Under the optimized conditions, the highest Tc (onset) $\approx$ 115K and Tc (zero) $\approx$ 95K was found. The XRD studies showed the transformation of all the three nominal compositions into 2-2-0-1 phase with different Tc's. The effect of high temperature sintering was studied on the $Tl_1 Ba_2 Ca_{n-1} Cu_n O_x$ systems where *n* varied from 1 to 5. It was found that under optimized conditions of preparations the final phase composition obtained could vary considerably from the starting or nominal composition.

The attempts to make single phase high Tc material by partially replacing Bi by Pb and Pb + Sb were made. Almost single phase material with Tc = 112K could be reproducibly prepared

with the nominal composition $Bi_3 Po_1 Sr_3 Ca_3 Cu_4 O_y$ through optimization of process parameters. A major emphasis was to enhance Tc in e-beam deposited thin films on MgO and $SrTiO_3$ substrates by Pb doping. Films with Tc = 100K could successfully be deposited by using a pellet of nominal composition Bi_3 Pb_2 Sr_3 Ca_3 Cu_4 O_y as the evaporation source with excess of Pb than in the bulk and with controlled time of annealing giving better superconducting characteristics.

1.1 *Processing Studies*

Pb doped superconducting compounds of Bi Pb Sr Ca Cu O prepared by the standard ceramic method, were studied to obtain better critical current density (Jc) in bulk samples. By the use of double calcination and slight change in the sintering temperatures and soaking times, high Tc (110 K) single phase samples of critical current density 1000 $A.cm^{-2}$ (77K, OT) were prepared. The c-axis orientation of the grains together with sample densification was found to improve. Again, the sintering time required was only one half of the time required otherwise. The use of Sb as an additive in these compounds, was observed to promote grain growth and nucleation of 2-2-2-3 phase.

The Y-based 1-2-3 compounds were produced in large batches by the solid state route. Several types of studies were carried out on tablets sintered from these powders to improve the Jc. The use of double calcination with intermediate mixing improved the phase purity and chemical homogeneity. Jc of 500 $A.cm^{-2}$ (77K, OT) was achieved in sintered bulk samples.

It was also studied that $Ag_2 O$ addition in 1-2-3 superconductor, reduced normal state resistivity in films as well as bulk samples. It also promoted densification and grain growth. $Sb_2 O_5$ did not dissolve in the 1-2-3 lattice and promoted grain growth upto 0.4 mole % of $Sb_2 O_5$ concentration. No significant improvement in the critical current density was observed in these cases. The use of W, as an additive was found to improve the critical current density upto 0.4 mole %. Studies were carried out to develop superconducting thin films of the 1-2-3 compound by metallo-organic decomposition method.

Magnetic shields in close and open ended tube shape, required for SQUID application, were developed from the 1-2-3 compounds. Several numbers of close ended tubes of 25 mm ID and 150 mm length were prepared which withstood thermal cycling reasonably well. The best results available indicated a shielding capability upto 10G of applied field (dc) at 77 K.

Under Indo-USSR scientific cooperation, joint experimental studies were undertaken by NPL scientist in USSR laboratories on the Bi based 2-2-1-2 and 2-2-2-3 compounds. The specific properties studied were influence of additives and oxygen annealing on the Tc, chemical stability and transport properties, Hall effect and thermoelectric effect in Ag and Pb doped samples.

1.2 *Superconducting Wire*

The critical current density Jc of silver clad Y Ba Cu O HTSC was marginally raised from 66 to 169 $A.cm^{-2}$ at 77K. The Jc in silver clad Bi (Pb) Sr Ca Cu O wires was found to be 440 $A.cm^{-2}$ at 77K. Several substitutions were attempted to increase the proportion of 110 K phase and Jc. A wide bore superconducting magnet (clear bore 84 mm) capable of producing 7T magnetic field was fabricated. The magnet uses two winding sections, fibre glass as interlayer material and wax as impregnant. To operate the magnet in persistant mode a switch was developed alongwith a jointing technique.

A project on superconducting magnetic separator, sponsored by Planning Management Board (DST), was taken up in collaboration with Bharat Heavy Electricals Ltd., Hyderabad and National Mineral Development Corpn.,

Hyderabad. The separator will be of high gradient magnetic type where a field of about 6T will be provided by a six section superconducting magnet of Nb-Ti and high field gradient by stainless steel matrix in a room temperature bore of more than 100 mm. The design of the magnets and cryostat was finalised.

1.3 *High Temperature SQUID*

This work is major input to a multi-laboratory project of CSIR. The primary objective of the project was to study the Josephson effects in various types of Josephson junctions and to fabricate and characterize SQUIDs made of high Tc superconductors. During the first phase it was planned to develop a demonstration SQUID based on either bulk or thick film of high Tc superconducting material while the development of SQUIDs based on thin films will be undertaken during the second phase.

A cryostat to fabricate break junctions of desired normal state resistance and critical current was developed locally and used to study break junctions of Y Ba Cu O. Both DC and AC Josephson effects in the junctions were observed at 77K. Microwave-induced Shapiro step in the I-V characteristic of the junction were clearly observed as shown in (Fig. 1). DC SQUID behaviour in break junctions at 77K was observed for the first time (Fig. 2).

A simple and low cost technique of spray pyrolysis was developed for fabricating Bi Sr Ca Cu O (2212) thick films of thickness as low as 5 μm on MgO (100) substrates. After annealing in air near the melting temperature, highly oriented films with C-axis perpendicular to the substrate were obtained. The films showed sharp superconducting transition with zero resistance at 85K. The transport critical current density of the film at 77K and at zero field was of the order of 4000 A cm^{-2}. Thick films of Y Ba Cu O with Tc (O) around 85K were also fabricated.

Microbridges and DC SQUID structures were

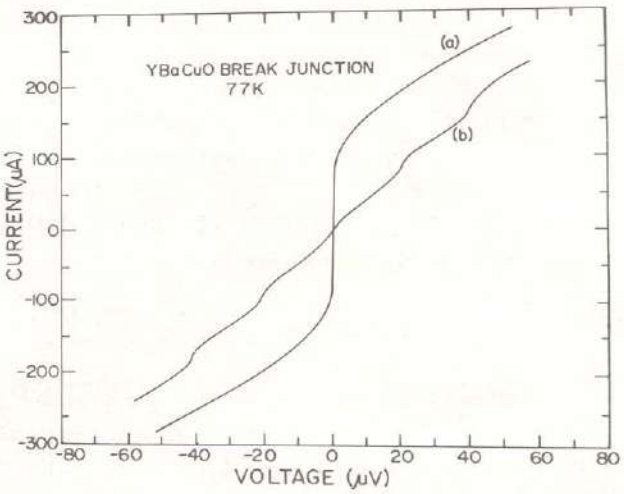

Fig. 1

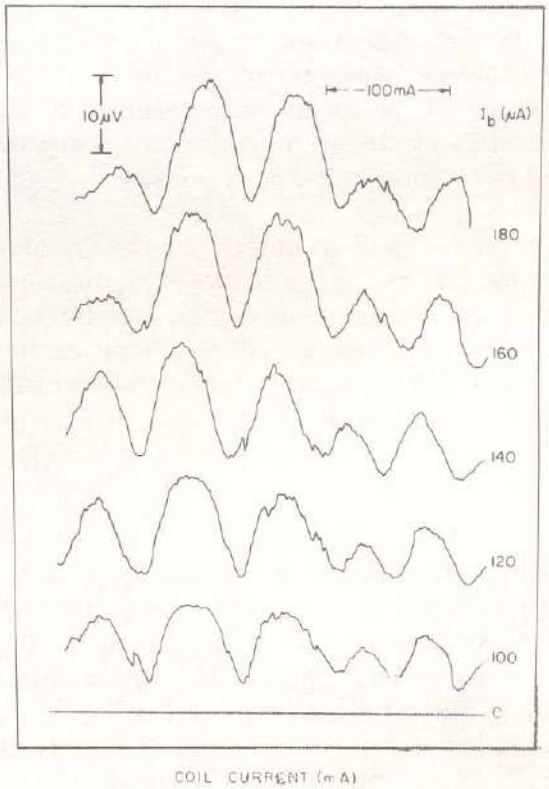

Fig. 2

patterned on Y Ba Cu O and Bi Sr Ca Cu O films prepared by spray pyrolysis technique. These patterns were generated both by photolithography followed by chemical etching as well as by laser ablation techniques. AC and DC Josephson effects due to grain boundary weaklinks were observed in these microbridges at 4.2K. Microwave-induced Shapiro steps were clearly observed in the I-V characteristic of the microbridge. Variation of step amplitude as a function of microwave power and frequency was investigated. The temperature dependence of the critical current of the microbridges was studied which suggested that the weaklinks were superconductor-normal-superconductor type. Superconducting quantum interference effects were observed at 4.2K in DC SQUID structures fabricated on 5 μm thick Y Ba Cu O and Bi Sr Ca Cu O films prepared by spray pyrolysis techniques. Quasiperiodic oscillations were clearly observed in V-B curves.

Effect of thermal cycling at temperatures between 4.2 and 300K on the R-T curves of the film was investigated with a view to use these films for device applications. The superconducting transition remained unaffected upto seven thermal cyclings as long as the moisture did not condense on the films. However, if the moisture was allowed to condense on the films, the Tc of the films deteriorated. Preliminary work was initiated to coat the films with suitable polymers in order to protect them from moisture.

Thin films ($\sim$1 μm) of Y Ba Cu O were prepared by rf diode sputtering on $SrTiO_3$ substrates, using a single composite target. The influence of change in sputtering parameters such as traget-substrate distance, rf power, gas pressure and substrate temperature in attaining a particular stoichiometery of the film was studied in detail. Microbridges were patterned on these films by conventional techniques. DC and AC Josephson effects were observed in these microbridges due to grain boundary weaklinks.

A two-hole rf SQUID using grain boundary weaklinks present in a microbridge of bulk Y Ba Cu O was fabricated. Periodic oscillations in V-B characteristic of the SQUID were clearly observed at 77K. The spectral density of the flux noise in the white noise region is $5 \times 10^{-4}\ \Phi_0 / \sqrt{Hz}$. The flux noise is found to be frequency dependent below 200Hz. The results showed a reasonable beginning in designing and development of liquid nitrogen temperature SQUID using grain boundary Josephson junctions.

The varian thin film deposition unit was incorporated with a Knudson Cell (K-cell) for depositing components, Y, Cu and BaF_2. Y and Cu was deposited by e-beam evaporation whereas BaF_2 was deposited by K-cell, on a number of substrates like Sr TiO_3, Al buffered Si substrates, YSZ buffered Si substrates. The total film thickness was maintained $\approx$1 μm. Post deposition oxidation was carried out in a microprocessor controlled furnace, both in dry and wet conditions. At 900°C the oxidation was carried out in wet condition, there after in dry condition. R vs T measurements indicated metallic behaviour of the thin films on $SrTiO_3$ substrates whereas those on other substrates indicated some anomaly i.e. semiconductivity. On these substrates significant amount of 2-1-1 phase was found to be formed. Efforts were also made to deposit thin films of Y Ba Cu O by using the bulk superconducting material in the K-cell, but the operation had to be abandoned because of severe outgasing.

LOW TEMPERATURE PHYSICS

A He^3-He^4 dilution refrigerator system became operational. In the test runs the lowest temperature achieved was between four and five milli-Kelvin. The refrigerator will be used to conduct experiments on a quasi one—dimensional system of bare electrons floating on a liquid helium surface. A dilution refrigerator control unit was designed and tested. This electronic instrument has programmable current sources to control

various stages of the refrigerator. An electronic instrument was fabricated and tested to measure the level of liquid helium in a cryogenic bath. The instrument was built with components available locally and costed much less than using imported counterparts.

An efficient algorithm was developed to compute the complexity of a string of characters. This algorithm is much faster than the ones available in literature when dealing with quasi-periodic or random strings. Computer simulations were continued further and many more parameters related to the dynamics of vortices and 2D Josephson arrays were studied.

A software implementation of phase sensitive detection was developed to measure low level voltage signals. The polarity of the excitation current was switched at a low frequency and the voltage signal from the samples was digitised. The digitised voltage time series data was processed by a computer. A voltage resolution of about 3 nanovolt was achieved. V-I characterisitics of high Tc superconducting pellets were measured with this high resolution. A direct measurement of first and second derivatives of the V-I curves is possible with this technique.

THEORETICAL STUDIES

A method was developed to obtain effective interaction between heavy quasi particles that exist in heavy–fermion systems by combining the Coulomb interaction and the electron–phonon interaction. The role of the new interaction in determining superconducting order in heavy–fermion systems has been clarified. It is found that an appropriate strength of the interaction leads to p wave superconductivity. The calculated values of the superconducting transition temperature are found to be in good agreement with experimental values for $CeCu_2Si_2$, URu_2Si_2, UBe_{13}, UPt_3 and other heavy fermion systems.

A mechanism for interlayer coupling in $YBa_2Cu_3O_{7-x}$ was suggested. The mechanism involved the out of phase displacement of bridge O_4 atoms induced by an oxygen-hole mediated charge transfer from an in-plane $d_{x^2-y^2}$ orbital to a mainly out of plane $d_{3z^2-r^2}$ orbital. The existence of a new symmetry in the extended Hubard model near half filling relevent to high Tc superconductivity was established.

Electronic structures of substitutionally disordered alloys were studied. Computations on gold based alloys revealed the details of relativistic effects and their importance in analyzing alloying effects on the electron states.

DEVELOPMENTAL PROJECTS

THIN FILM

The fabrication of interference filters of various types was continued. The multicavity wide-band interference filters were supplied to SAC, Ahmedabad for use in the INSAT II VHHR payload. Narrow-band interference filters having bandwidth 3.0 nm were designed and fabricated.

Hard laser mirrors comprising 21 alternate layers of TiO_2 and SiO_2 were developed. The mirrors exhibited a reflectivity of over 99.5%. Theoretical computations, for the design of a non-polarizing and achromatic beam splitter comprising periodic non-quarter wave symmetrical layer stacks, were carried out.

BETA ALUMINA TUBES

The alumina and sodium aluminate materials from NALCO were evaluated for the production of beta-alumina tubes. The sintered density of 3.00 g/cm^3 and ionic resistivity of 10 ohm. cm. at 300°C, were achieved. The batch size was

increased and a number of batches were processed.

About 450 tubes of 10 mm dia. and 50 mm dia were synthesised. About 120 tubes were supplied to CECRI, Karaikudi and 22 tubes to IGCAR, Kalpakkam, for making and testing of sodium sulphur battery and sodium cell respectively. The test reports have indicated satisfactory performance. A new set of die and punches were fabricated and about twenty alpha-alumina headers for 50 mm tubes were processed and machined. A ball mill, strength testing machine and a box type furnace were procured and made operational for use.

XERORADIOGRAPHY

For reducing the X-ray dosage on xerographic photoreceptor, thermally stimulated discharge current studies in a-Se and polymer based a-Se films were made. The mechanisms of relaxations near Tg and photo-induced defect levels in a-Se films were also studied. The investigations defined the position of defect levels/traps in a-Se films which played a vital role in governing the photo/X-ray conducting properties of these films and also explained a correlation between the photoinduced defect states and intrinsic defect states.

CRYOGENIC SYSTEMS

The liquid nitrogen plant, based on Stirling Cycle, was tested for liquid nitrogen production and different production rates were achieved. About 24,000 litres of liquid nitrogen was produced and distributed to the various R & D groups in the laboratory. There was no major breakdown or failure in the operation of the plant. A pneumatically operated high pressure booster was developed which can fill N_2 gas at 6000 psi in 1.5 litre bottle in half an hour duration.

A miniature cryo cooler with a length of 25 mm was developed and demonstrated to a team from SSPL., New Delhi. A glass system was developed which used ammonical solution and copper spiral for the analysis of O_2 as an impurity in the mixture of gas.

A project for the fabrication of suitable glass receptacle for the long term preservation of the Constitution of India, on a request from Parliament Library, was taken up. The helium purity monitor was shown in working order to the Parliament Library staff. The other part i.e. fabrication of glass receptacle using soldering technique was under development. Another refrigerator for immunisation programme, was being developed with certain modifications to satisfy the desired requirements.

RADIO SCIENCE

INTERNATIONAL GEOSPHERE BIOSPHERE PROGRAMME

This is a new programme, started during the year, for monitoring the short and long term trends of ozone, greenhouse gases and aerosols.

1. *Solar radiation measurement*

The measurement of solar UV-B radiation by photometers built by NPL, was continued and direct solar radiations from 290 nm to 340 nm at intervals of 2 nm were recorded by a spectroradiometer. The multiwavelength radiometer was also usedto determine the optical depth due to aerosols during different seasons of the year. The data of last six years were utilised to determine the actual variation of erythemal doses during the period and this was compared with theoretically estimated values. The variation of doses are in anticorrelation with atmospheric ozone measured over Delhi during this period. The work of writing a computer programme to derive aerosol size distribution and concentration in the atmosphere was in progress.

A model calculation to predict solar UV-B radiation intensity and lower cutoff wavelength during the antarctic ozone hole was carried out. Due to large solar zenith angle during antarctic hole period (September to October) the lower cut off wavelength did not shift much below 290 nm. However, the intensity in lower wavelength did not shift much below 290 nm. However, the intensity in lower wavelength region increased four fold at 290 nm and nearly twice at 300 nm. The increase beyond 315 nm was not appreciable in comparison to normal period. It was found that the intensity at 290 nm during antarctic hole (total ozone 110 DU) was nearly same which Indian station at Kodaikanal received during summer months at local noon.

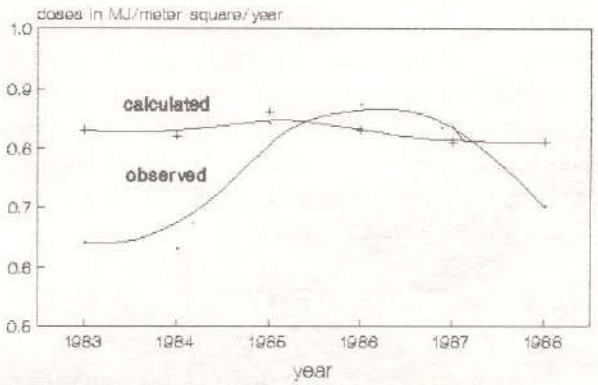

Fig. Solar UV -B doses at Delhi, observed and theoretical values.

1.1 *Laser heterodyne system*

The monitoring of the vertical profiles of ozone, water vapour and nitrogen dioxide was continued. A large number of profiles obtained during this year and average reference profiles of ozone, water vapour and nitrogen dioxide over New Delhi were obtained using laser heterodyne system. The system was interfaced with a computer for storing the data. Simultaneous observations to get ozone profiles by laser heterodyne system at NPL and balloon ozonesonde at IMD, New Delhi, were in progress.

1.2 *Global ozone trends*

A detailed survey of stratospheric, tropospheric and polar ozone was carried out. Intercomparison between Dobson series was

done and difference in trends over Indian ozone monitoring stations was estimated. Height profile of ozone was obtained from Umkehr, balloonsonde, rocketsonde and satellite data. Longterm study of seasonal ozone over Delhi revealed a secondary maximum in autumn, which appeared to be of photochemical origin. Due to global interest in surface ozone, collection of existing data over Indian subcontinent was initiated for trend analysis.

1.3 *Infrared studies*

A new project namely solar infrared spectroradiometer was initiated. INSAT 1-B satellite data was interpreted to understand the effects of aerosols on visible and infrared ranges in the presence of ozone and water vapour. An experimental facility for monitoring of solar infrared radiations in the 2.5 to 14.5 μ m spectral range was started. The system has the capability of scanning the whole spectral range in 20 minutes and can be changed for one minute and 10 minutes scan also. The data would be utilized for the study of atmospheric aerosols, minor constituents, extinction coefficients and turbulence etc.

1.4 *Green house gases*

The measurement of methane efflux from rice paddy fields in Northern India was done. Two campaigns were conducted in this regard for the evaluation of methane budget from rice paddy field into the atmosphere. Gas chromatographic study was made to understand the carbon dioxide exchange between atmosphere and the sea at different temperatures in relation to green house effect.

SROSS AERONOMY SATELLITE

The fabrication of the engineering model of RPA satellite payload for SROSS 'C' was completed. An additional supplementary payload was added to the above payload. After the environmental testing for space qualification, the fabrication of flight model will be done. The work of engineering model was started after completion of the design review of the RPA payload. The payload electronics was divided into 12 PCB's and their layouts were prepared and got qualified as per space qualification guidelines. The PCB's were fabricated at ISAC, Bangalore, wired and tested individually for the integrated assembly of the payload electronics. This is being tested and calibrated.

Simultaneously the fabrication of parts for RPA sensor was taken up and one sensor was assembled. Some guidelines were then made in respect of the sensor parts fabrication and assembly procedures in consulation with ISAC. The design of mechanical assemblies for the RPA sensor mounts over the satellite top deck was frozen and these assemblies were fabricated for the engineering model. The work of gold plating over the sensor parts was initiated at NAL, Bangalore. Pure gold was converted into gold potassium cyanide at Nuclear Fuel Complex, Hyderabad. The final electron source, fabricated by CEERI, Pilani, was also received for calibrating the RPA electron sensors. The structure and formats for orbit and altitude information and RPA and PP data were finalised for recording on computer compatible tapes in a form suitable for processing by NPL-computer and also for quick look analysis by PC–AT.

RADIO COMMUNICATIONS

1. *Consultancy services*

Consultancy was rendered to BEL, Ghaziabad on the radio climatology over certain selected regions in India, for the design of 8 GHz digital link for defence services. In collaboration with ITRC, Lucknow a kytoon campaign was conducted at Yamunanagar to study the inversion heights for fixing the chimney height of the proposed super thermal power station by NTPC. The design of the low level wind shear alert

systems was finalised and the systems were being developed at S.V. University, Tirupati.

1.1 *ARWC services*

The period 1989-1990 has witnessed an unusual increase of solar activity with some of the severest solar events of the current solar cycle No. 22, occurring during the period. As a sequel to this severe activity a variety of terrestrial effects were observed and Associate Regional Warning Centre (ARWC) issued serveral special warnings and forecasts on magnetic and ionospheric conditions to aid radio communicators and geophysical experimentors. Special studies were conducted using the observational data collected over Indian latitudes for the events of March, August and Sept. 1989. ARWC continued to predict daily and weekly averages of solar radiation in 10.7 cm wave length to aid ISRO, Bangalore in estimating orbital decay of IRS satellites.

1.2 *Rain rate studies*

The rain rate studies using fast response rain gauges were continued. Based on the data collected at New Delhi, Shillong, Tirupati, Bombay and Warangal, probability distributions of the rain rate have emerged. The rain rate duration of high rain intensities was estimated. Such durations are important to estimate the period of deep fades and fadeouts in tropospheric communication links.

1.3 *Long distance VHF propagation*

To study the propagation characteristics over mixed landsea paths, Rupavahini transmissions originating from Sri Lanka were recorded at Tirunelveli and Pondicherry in collaboration with All India Radio. The data were analysed with the help of different prediction techniques and it was inferred that the signal propagated through a combination of scattering, reflection and ducting for different percentages of time.

1.4 *Propagation characteristics in the 50-70 GHz band*

The crowding of microwave spectrum by the various users and subsequent interference effects have forced frequency allocators and system designers to look for higher and higher frequency bands for both terrestrial and earth space applications. Various propagation phenomena like oxygen absorption, water vapour absorption, rain attenuation and scintillation scattering performance of communication system in the 50-70 GHz band were examined. The absorption due to oxygen and water vapour was deduced on the basis of meteorological data whereas rain attenuation was estimated on the basis of fast response rain rate data. It was found that in this band the absorption, phase dispersion caused by oxygen, and attenuation due to rain were major impairments compared with water vapour absorption and scintillation effects in limiting the system performance.

1.5 *GHz scintillation studies*

Post sunset ionospheric scintillation measurements at 4 GHz from INSAT-IB (74°E) satellite taken during the increasing half of the current solar cycle 22 at Sikandrabad (22.5°N magnetic latitude subionospheric) along 149°E geomagnetic meridian in the Indian zone were analysed.

Surprisingly, during September/October 1989, very severe scintillations with peak to peak fluctuations exceeding 20 dB were observed at this latitude, which is normally beyond the day time crest of the equatorial anomaly.

Simultaneous measurements were also taken from an equatorial station Chenglepet (5.2°N geomagnetic meridian plane) during September-October 1989. Observations showed that scintillations at Sikandrabad were conditional to their prior occurrence at Chenglepet. As compared to the equatorial location, the onset of scintillations at 22.5°N

magnetic latitude was later and also they died out first at the higher latitude. Another unexpected feature observed during the period of simultaneous observation was that the intensity of scintillations at the equatorial location was much less and never exceeded 5 dB peak to peak with onsets, while at 22.5°N magnetic latitude it normally exceeded 10 dB peak to peak.

1.6 *Propagation mechanisms of TV signals*

The anomalous long distance TV signals received at Delhi were studied during the declining and rising periods of solar cycle for Band I and Band III, along with field strength measurements on spectrum analyser. In both the declining and rising periods of solar activity a very high percentage of these TV reception in Band I were observed during high solar activity as compared to low solar activity in nonsummer months.

1.7. *Longterm Ionospheric and Solar predictions*

The routine bulletins of sunspot numbers, predicted six months in advance, were published regularly. Besides, a revised estimate of the peak of the present sunspot number cycle (No. 22 since 1749) gave a peak value of the order of 190 sunspot numbers, likely to occur in March 1990. Regular predictions of two ionospheric parameter viz. foF2 and MUF (4000) F2 over the East zone were made six months in advance for use in planning of HF communications by different organisations. The studies to improve the predictions of communication parameters over the Indian subcontinent were continued.

1.8 *Field Strength measurements and Radio Noise*

Field strength measurements of several broadcast stations operating on different frequencies were carried out at New Delhi as envisaged in CCIR (International Radio Consultative Committee) resolution and recommendation to facilitate improvements in HF propagation prediction method. Field strength data were being provided to CCIR on regular basis. The measurements of field strength were also conducted at Pune, of standard time and frequency transmissions at 5, 10 and 15 MHz during 1989.

Analysis of atmospheric radio noise (ARN) measurements made during 1987-1988 was completed. The results revealed large discrepancies in measured ARN values when compared to CCIR predictions especially in their diurnal behaviour. The NPL measured values of ARN showed good agreement with earlier measured values of All India Radio at Delhi. The ARN measurements were also carried out at Pune in Oct. 1989.

ANTARCTIC STUDIES

The antarctic programme was given a new thrust by installation of a 9m instrumented tower at Maitri by NPL team, during the 9th expedition, with fast response temperature, humidity, wind and pressure sensors for computing the fluxes of heat and momentum in the lowest planetary boundary layer. Besides the measurement of solar UV-B radiation, the turbidity was measured by sunphotometer and using polarizers, the polarization of radiation were also determined enroute to Antarctica. The data on UV-B radiation intensities collected during 8th expedition and by winter team was being compared for anticorrelation with total ozone values measured by satellite during this period. It was found that the planetary boundary layer over Antarctica was in the convective state for most of the period during summer.

A most sophisticated laser heterodyne system with wide band (1 GHz) acoustic-optic spectrometer was under development, in collaboration with Meudonde Observatoire, PARIS, to monitor various minor constituents at Antarctica. The system has many advantages of light weight, more efficient, high spectral resolution, a large number of channels (500) and

computer interfaced. A computer software programme was developed and tested to get vertical profiles using inversion technique with the laser heterodyne system for environmental conditions in Antarctica from data available from other organizations.

The air samples collected during the last expedition were evaluated and analysed for methane, carbon dioxide and nitrous oxide whose concentrations were 1.6 $\pm$ 0.02 ppm, 404 $\pm$ 10 ppm and 363 $\pm$ 10 ppb respectively. Aerosol, SO_2 and NO_2 sampling collected enroute and at Maitri were being evaluated. Some work was done on the carbon dioxide absorption-desorption in sea water collected from equator and the results indicated strong relation between Co_2 intake and sea water temperature.

RADIO AND ATMOSPHERIC PHYSICS

1. *Atmospheric studies of other Planets*

At present it is not clear whether the planet Mars has a significant intrinsic magnetic field or not. Using results from stellar mass loss observations, it was shown that, the intrinsic magnetic field of the early Mars was strong enough to deflect the solar wind and form a well defined magnetosphere. The implications of such a paleo-magnetosphere were considered from the point of view of atmospheric evolution. It was found that escape of atmospheric constituents through the polar regions could contribute significantly to the atmospheric loss which has been inferred from spacecraft observations.

Considering the Venus ionopause as an interface of finite thickness bounded by magnetosheath region and backed by ionospheric region, the MHD Kelvin-Helmholtz instability of the boundary layer was studied. Effects of some of the field and flow parameters of the boundary layer on the growth rates of surface waves were studied. It was concluded that the K-H instability may provide adequate explanations for the generation of wave-like structures on the ionopause. Under suitable conditions, the low frequency surface waves can grow appreciably before they are convected to lower altitudes in the dayside ionosphere of Venus. The growth and convection of surface wave could give rise to large scale magnetic fields observed at lower altitudes below the ionopause in the dayside Venus ionosphere.

1.1 *Electron Precipitation*

Adopting a model for electrostatic wave energy, its interaction with suprathermal electrons was studied. Change in pitch angle of interacting electrons in the vicinity of atmospheric loss cone was computed and its variation with suprathermal energy and amplitude of electrostatic wave at $w = 1.5\ w_{ce}$ was studied. Electrons once diffused into the loss cone are lost to collision dominated lower ionosphere. The variation of precipitating electron flux with electrostatic wave amplitude was studied.

1.2 *Incoherent scatter studies*

The electron density height profiles from the incoherent scatter measurements at Arecibo were analysed for the derivation of various parameters like the depth and width of E-F layer valley and semithickness parameter for the bottomside F-region. These parameters were derived from the Gulyaeva's formula using the height of peak electron density and the solar zenith angle. The parameters are being now compared with actual values of depth and width as seen in the height profiles.

1.3 *Equatorial F-region electric fields*

It has been established from a detailed analysis of the evening height rise of F layer in the equatorial region that this phenomena strongly depended on solar activity. The solar activity control of the above phenomena is explained due to large variation with solar activity of the longitudinal gradient of E region conductivity

during the postsunset period. Based on the E region model calculations it was shown that the longitudinal gradient varied by a factor of 2 from low to high solar activity.

The equatorial F region electric fields were studied during the storms from analysis of h'F variations (base of the F layer) over Thumba/Kodaikanal in the evening period. About 40 storms were studied during the high activity periods of 1969 and 1978. Three types of effects were observed (i) a marginal variation from quiet time values (ii) lower than quiet time and (iii) higher than quiet time. While the first two types were commonly observed, the third types are rare. In some cases it was observed that there was an increase in h'F on the first day and decrease on the second day of the storm and also vice-versa.

1.4 *Satellite Beacon studies*

The VHF signals of the geostationary satellite ETS-II for Faraday rotation and amplitude scintillations and L-Band signals of the geostationary satellite INMARSAT for amplitude scintillations were monitored. A three-station network at Hyderabad, Vikarabad and Shadnagar was operated from Dec., 26, 1989 to Jan. 22, 1990 for acquiring data for Travelling Ionospheric Disturbances (TIDs) studies during high solar activity period. An analysis of the Faraday rotation data for the ascending period of solar activity i.e. 1975-80 showed that occurrence of post sunset secondary maximum increased with solar activity. Further, the occurrence was more in winter than in equinoctial periods, there being no occurrence in summer months. Faraday polarisation fluctuations occurred only on those days when both amplitude scintillations and secondary maximum were present. The solar flare-induced increases in ionospheric electron content of the ionosphere, inferred from the data for the period Jan-Dec. 1980, were found to vary between 3 to 7%. A theoretical analysis of the effect of gravity wave-ionisation interaction on Faraday rotation showed that the perturbation was maximum when the angle of propagation of the gravity waves lies between 60 to 80 degrees and depended upon period and velocity of the wave. Further the perturbation calculated by taking into account the spatial extent of the wave is shown to be measureable even in those directions where according to earlier workers there should be none. This explains the observation of TIDs moving in all directions.

1.5 *Middle atmosphere*

A high altitude balloon experiment (IMAP C-5) was successfully conducted over Hyderabad (17.5°N, 78.6°E) on April 22, 1989, for the measurement of positive and negative ion conductivities, densities and mobilities using a Gerdian condenser experiment. Elaborate precautions were taken to eliminate the problem of "gondola charging" which was vitiating ionisation measurements for the last several years. Uninterrupted good data was obtained from 4 km to 16.5 km and with disturbances occurring above this height. Analysis of the data was completed upto 16.5 km. There was agreement between the observed and theoretically estimated profiles of both positive and negative ion mobilities.

Another payload on the above balloon experiment was the Langmuir probe as part of the ionization intercomparison campaign of IMAP-C. An additional objective of this campaign was to investigate the problem of gondola charging that was observed in the three previous flights conducted during 1985-86. The same combination of payloads as was used in the previous campaigns was kept. The gondola was redesigned and its configuration modified. The data showed that there was no charging of gondola in this flight. The preliminary analysis of the data showed that the conductivities (+ve and –ve ions) increased exponentially with altitude and the positive and negative ion conductivities were more or less equal upto about 25 km, above which the positive ion conductivity was

found to be larger and at 36 km it was about 1.2 times the negative ion conductivity.

Measurement of mesospheric nitric oxide concentration was made over Thumba by a rocket borne payload, launched aboard RH 300 MKII rocket on Sept. 26, 1989 as part of the Ledge campaign of IMAP-C. The same rocket carried two propagation receiver payloads operating on frequencies 1865 kHz and 2610 kHz respectively for the measurement of D-region and lower E-region electron density. All the payloads gave good data throughout the flight. Under the DYANA campaign two rocket flights were conducted from TERLS on March 12 & 13, 1990. Both flights carried payloads for the measurement of stratospheric ozone and included optical sensors operating on wave lengths 255, 290 and 310 nm in the UV region and 450 nm in the visible region. All the sensors worked satisfactorily and good quality data were obtained throughout the flights.

1.6 *Microwave/millimeter wave radiometry*

An ultra sensitive, portable, direct reading millimeter wave radiometer operating at 37 GHz was put into operation. Preliminary experiments were successfully carried out for determination of atmospheric attenuation coefficients for short haul communication links, remotesensing of sub-soil moisture and general terrain mapping and solar radioastronomy. Also, inversion techniques were developed for obtaining integrated water vapour content and water vapour height profiles over New Delhi (28.6°N latitude), using ground based microwave radiometric observations at 18.95 GHz, 22.235 GHz and 22.4 GHz.

Based on the liquid water content for various measured values of attenuations for different fog heights and making use of visibility versus liquid water content, predicted values of visibility in terms of observed attenuation in dB were determined at 9.6 GHz. Microwave radiometric measurements of slant path attenuation at 11 GHz with antenna looking at the oblique incidence were taken. Alongwith the microwave radiometric measurements, instantaneous rainfall rate was determined with a fast response of 10 seconds upto electronic raingauge.

1.7 *MST Radar*

NPL was associated with the test and evaluation of engineering prototypes of various subsystems developed at SAMEER (Society for Applied Microwave Electronics Engineering Research, Bombay) for ST radar and with the computations regarding array alignment and beam pointing accuracy of the radar. The installation of ST system was started.

Long period oscillations in winds at middle atmospheric heights over Thumba showed large inter-annual variations. The amplitude of annual oscillation at tropospheric height was found to show a good correlation with solar activity whereas semi-annual oscillation amplitude at stratospheric heights, showed strong anti-correlation with solar activity. This type of study is important for understanding the effect of solar activity on terrestrial atmosphere.

INFRASTRUCTURAL FACILITIES

LIBRARY

The library provided library, documentation, and reprographic services to the scientists of the laboratory. Under the computerisation programme, circulation control software was designed and developed. Computerisation of main jobs at the circulation counter was made operational. At present the work of issue and return of documents is regulated offline.

The library strengthened its collections by making new additions in physics and related sciences. 601 new books were procured and 114 books in Hindi were added. 350 journals were subscribed and 2,349 volumes of periodicals were added. 40 specifications of standards were added raising the total collection to 29, 587.

The library continued to receive Indian patent specifications from the Indian Patent Office, Calcutta, as an inspection centre for patents in Delhi. The library provided document-loan service, inter library loan service, bibliography service, literature search service, and reprographic service to the scientists. About two lakhs copies were turned out on the photocopying machine. About 1,200 outside users from various institutions and universities visited the library during the year.

The Photography section processed about 8,000 prints and slides during the year. A process was developed for making colour slides from B&W graphs and charts.

COMPUTER FACILITY

The VAX-11/780 and Zenith SC computer systems were utilized for about 1,400 hours in the year. The 100 KVA voltage stabilizer was installed which kept the systems running during the periods of low voltage supply.

The facility was used for the following problems:

Ionogram reduction, study & modelling of E region valley, F region wind, thermospheric winds, F2 layer parameters, upper atmosphere and trans-ionospheric scintillations; design of thin film optical devices; design and development of the sterling engine and simulation of 2D-Lattices; study of structural stability of solids, high temperature super conductors and molecular orbital cluster calculation; modelling of diffusion of boron, phosphorus, arsenic and antimony in silicon and high efficiency silicon solar cells; database on electronic materials and crystal growth; analysis of EPR spectra and simulation of light intensity patterns on diffraction from a system of gratings.

The facility was utilized for the preparation of pay bills and allied jobs. The facility was also used by outside organizations to a limited extent on payment basis.

WORKSHOP

The workshop assisted in fabrication and repair work connected with various projects of the laboratory. About 2,100 jobs were handled during the year. Some of the major jobs were: fabrication of parts of Sodar facsimile recorder, antenna and antenna mount; optical mount jigs; probes; mounting brackets; and SROSS payload. A lathe with a swing of 600 mm and 3 m bed was added and a centre lathe was fitted with numerical control under the modernisation programme. The Drawing and Design section served the scientists in their design work and preparation of graphs and charts.

The section of *Mechanical Processing Activity* also provided assistance in the fabrication of jobs. Rivet wires in the diameter range of 4-10 mm of aluminium alloys were successfully produced using hot extrusion followed by drawing. The wires met IS specifications and were approved by HAL for aerospace applications. The work in the sponsored project for the development of motor body component of 2014 high strength aluminium alloy for missile for DMRL, Hyderabad was undertaken and the component was successfully forged.

GLASS WORKSHOP

The glass unit assisted various R & D projects of the

laboratory in the fabrication of glass and silica apparatus, stop-cocks, seals and chromatography columns. About 700 jobs were handled during the year. The jobs worth Rs. 2.731 lakhs approximately were completed during the year.

Various universities and R & D institutions were served in the fabrication and supply of glassware such as Dewar flasks, double distillation apparatus, stop-cocks, adapters and quick-fit assemblies. The parties included BITS, Pilani; IOL, Faridabad; IARI, New Delhi; IISc Bangalore and universities of Punjab, Aligarh, JNU and Jamia Millia Islamia. Special technique was developed for the fabrication of solar collector tube for the Deptt. of Non-Conventional Energy Sources New Delhi.

INSTRUMENTATION

Regarding the development of $5\frac{1}{2}$ digit electronic digital voltmeter the imported modules were received and display circuits were fabricated and tested. Analog input circuits were hooked up and after testing the complete circuit was coupled together. For the development of microprocessor-based $5\frac{1}{2}$ digit DVM the design of AC & DC input circuits was improved and the circuits were developed and tested. The work of development of temperature controlled crystal oscillator was continued and a constant voltage float charger was developed for providing 33V/3Amp.

The development in biomedical instrumentation was carried out. Ultrasonic and piezoelectric parameters of bone and bone tumours were measured. An ultrasonic lithotripter (kidney stone disintegrator) was developed by using focal system. A non-invasive technique was developed for temperature measurement in the tumour during hyperthermic study. An array of transducers was designed for the study of complex biological and other fibrous materials.

Instruments received from other groups of NPL and outside agencies were analysed, repaired and made functional. Electronic circuits, a sequential timer, precision stable d.c. supply for expandometric ph meter and 10 MHz crystal oscillator with dividing frequencies were designed and fabricated for other R & D projects. Effects of ultrasonic stress, temperature and electromagnetic interference noise etc. were investigated on the electrical characteristics of different types of integrated circuits, solid state devices and digital systems.

Ph.D's AWARDED

Name	Title	University	Guides
Ajay Dhar	Electrical and optical properties of unreduced and reduced lithium niobate single crystals.	Delhi	Prof. A. Mansingh, Delhi University. Dr. B.K. Agarwala, NPL.
Lakha Singh	Investigation of behaviour of ionosphere using beacon satellite.	Panjab	Dr. Y.V. Somayajulu, NPL. Dr. T.R. Tyagi, NPL
L.S. Tanwar	Metrological studies with an electro-optical sensor.	I.I.T, Delhi	Prof. B.N. Gupta, IIT-D.
J.C. Trehan	Synthesis and structural investigations on Bis (p-Biphenyl) tin (IV) and Tris (p-Biphenyl) tin (IV) compounds.	Delhi	Prof. B.S. Garg, Delhi University. Dr. P.K. Gupta, NPL.

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5. Ram Swarup, Negi PS, Yadava RS, & K. Chandra—Design and development of standards for measurement of microwave impedance.
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7. Sharma JKN, Jain KK, Bandyopadhyay AK, & Molinar GF—International intercomparison of the differential pressure measurements from 300-1500 mbar at high line pressure up to 75 bar using solid state differential pressure transducer between NPL (I) and IMGC (Italy).
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RADIO SCIENCE

PAPERS

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14. Nagpal OP, Jain AR & Dhaka SK,—Zonal and meridional wind characteristics over Indian tropical atmosphere, Pt. II: study of long period atmospheric oscillation.
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RESEARCH REPORTS

1. Jain AR,—Antenna system of Indian MST/ST radar beam pointing accuracy requirement and possibility of calibration using a galactic radio source.
   No. 89-12.
2. Jain SL,—Vertical distribution of minor constituents in the atmosphere using Laser heterodyne system.
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3. Lakshmi DR, Iqbal Ahmad & Mangal Sain—Measurements of HF signal fading at NPL, New Delhi.
   No. 89-20.
4. Ramanamurty YV,—A simple radio method of inferring global stratospheric ozone.
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5. Ramanamurty YV,—Factors affecting model representation of the ambient electron density distribution in the middle atmosphere.
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6. Somayajulu YV, Garg SC, John T, Zalpuri KS,—Effect of volcanic debris on stratosphericion conductivity-Nevado Del Ruiz eruption event.
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7. Vijaya Kumar PN, Tyagi TR, & Setty CSGK, —A phaselock receiving system to monitor ATA 5 MHz carrier.
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INFRASTRUCTURAL FACILITIES

1. Singh VR & Agarwal R —Study of intensity in focal lobe for a focused ultrasonic stone removal device.
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2. Singh VR, Yadav S, Ahmed A, Misurya RK, Raj GA, Sural A & Vishwakarma GK —Measurement of ultrasonic velocity and attenuation in bone tumours, in vitro.
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3. Singh VR, Adya VP, Aftab Ahmed & Yadav S —A stress wave propagation technique for bone repair study.
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4. Singh VR & Chauhan S —An ultrasonic non-invasive temperature monitor.
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5. Singh VR & Awadhesh Prasad —Effect of ultrasonic stress on amplification of an operational amplifier device.
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6. Singh VR—Acoustical imaging techniques for bone studies.
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7. Singh VR, Chauhan S, Yadav S & Chakarvarti SK —Ultrasonic velocity as a measure of temperature non-invasively in biological media.
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8. Singh VR —Instrumentation and measurement techniques for acousto-optics studies in complex materials.
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9. Singh VR, Awadhesh Prasad —Acousto-electric effect in semiconductor materials and devices.
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10. Singh VR & Yadav S —Role of natural frequency of bone as a guide for detection of bone fracture healing.
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11. Yadav S & Singh VR —Electromagnetic phenomenon in bone.
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12. Awadesh Prasad & Singh VR —Theoretical approach for optimization of characteristics of digital measurement systems.
    J. Instn. Engrs. (I), 69, 1989, 59-61.
13. Yadav S & Singh VR —Advances in ultrasonic instrumentation in forensic medicine.
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15. Singh VR, Dubey RB —Stability of a precision temperature controlled crystal oscillator for an electronic counter.
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17. Yadav S & Singh VR —Development of a bone piezoelectric microphone pick-up for vibration measurements.
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18. Singh VR, Prasad A —Study of the characteristics of antiglaze screens against radiations from cathode ray tubes.
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20. Singh VR, Dubey RB —Design of a microprocessor controlled precision frequency counter.
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PATENTS

1. Aggarwal AK —An improved concentrating type solar cooker-filed, Nov. 89.
2. Kumar CSP, Anil Kumar & Bangari K —Electronic capacitive voltage regulator-filed, Sept. 89.
3. Kumar CSP & Ravi Krishnan B —An electronic capacitive ballast for fluorescent and other discharge lamps-filed, No. 797/DEL/89.

DOCUMENTS

1. Calibration Tables for Secondary Standards Capacity Measures (Admiralty Bronze) and other Metallic Measures (Galvanised Iron).

APPENDICES

SPONSORED/SUPPORTED PROJECTS

Title	Agency	Amount received during the year Rs. (lakhs)
COMPLETED		
Development of thin film Josephson junction and planar DC SQUIDS.	DST	–
Development of fluorescent screens for real time x-ray imaging	ISRO	–
Development of oxidation resistance and big size carbon-carbon composites	DRDL	1.425
Weaving of 3-D carbon-carbon composites	-do-	–
Development of gas chromatographic facilities for measurement of minor constituents in the atmosphere	DST	1.000
Monitoring of solar ultraviolet radiation at the ground in UV-B region.	ISRO	0.500
CONTINUING		
Augmentation of primary electronic standards.	DOE	34.932 (Eqpt.)
Improving the quality and reliability of standard Time & Frequency signals to Echelon II laboratories	-do-	–
Calibration Service Programme under NCTCF	DST	8.000
A study of degassing characteristics of materials in ultrahigh vacuum.	-do-	–
Low dimensional Coulomb systems.	-do-	2.900
Multi-crystalline silicon for solar cells.	CEL	1.350
Development of sodium sulphur batteries for electric vehicles.	DNES	–
Hydrogenated amorphous silicon films (Phase II)	-do-	–
Volatile metal organic compounds.	DST (Indo/USSR)	3.010
Study of electrical conductivity of mantle forming rocks/minerals under high temperature.	DST	–
Development of motor body component on prototype scale.	DMRL	–
Hot extrusion and cold forging.	British Council	0.500 (Spares)
Characterization of electronic materials.	DOE	–
Growth of nearly perfect crystals of oxides like lithium niobates.	DST (Indo/USSR)	6.160
Data base on electronic materials.	DST (Indo/USSR)	3.000
Development & characterization of acoustic transducer materials for application in ocean engineering.	DOD	–
Studies on high temperature superconductivity (ILTP-IISC)	DST (Indo-USSR)	0.300
Tropospheric and ionospheric communications in HF and microwave bands.	Defence	1.120
Ionospheric modelling for radio communication including effects of the artificial modification of ionosphere.	DST (Indo/USSR)	5.160
Preparation, characterization and precision measurements of semiconducting materials.	DST (Indo/US)	–
NEW		
Photolithographic mask aligner using modified Moire technique.	DOE	20.000

Study of the tropical boundary layer meteorology at Jodhpur using monostatic acoustic sounder and instrumented tower.	DST	5.000
Interaction of small gas molecules with semiconductor metal interfaces as studied by surface analytical techniques.	DST (Indo/US)	49.270
Establishment of transfer leak standards in vacuum metrology.	DST (Indo/US)	10.750
Metrological studies on standards of measurements.	-do-	39.000
R & D in Laser frequency standards.	DST (Indo/USSR)	5.000
Development of technology of indigenous manufacture of retroreflective sheeting/tape.	Surf. Transport	7.000
Compendium of R & D activities in the area of fibre reinforced composites in the country.	ARDB	0.870
Development of Laser resistant carbon fibre composites	-do-	7.080
Thin film polycrystalline interface cells.	CEL	1.000
Development of process simulator diffusion modelling.	DOE	2.730
Synthesis, characterization and application of some conducting polymers.	DST/EEC	8.448
Superconducting magnetic separator.	DST	14.100
Studies of polycrystalline bulk, thin films and single crystals of high temperature superconductor.	DST/EEC	13.244
Development of Stirling engines for power production.	DNES	5.500
Laser heterodyne system for the study of ozone and other minor constituents in Antarctica.	DOD	17.500
To monitor solar infrared radiation for studying minor constituents in atmosphere using infrared spectrophotometer.	DST	13.700
Development and decay of scintillation producing irregularities and gravity wave propagation in low latitudes.	DST	4.542
A ground based millimeter wave technique for ozone observations at Antarctica.	DOD	20.000
Development of expert optical system.	DOE	3.280
Technical feasilibity and concept proving in the area of biomolecular devices: technical development of biomass.	DST	21.315

PROCESSES RELEASED

S. No.	Process	Party	Terms
1.	Silver Impregnated Graphite contact	M/s. Industrial Carbon, 109 A, F Block, New Alipore, Calcutta.	Premium —Rs. 55,000 Royalty —5%
2.	Electronic Energy Saver	Govt. Tool Room & Training Centre, Rajaji Nagar, Industrial Estate, Bangalore.	Premium —Rs. 50,000 Royalty —3%
3.	Flexible Graphite Tape & Sheets	M/s. Rupindra Industries, D.S. 11/117, Tilak Nagar, New Delhi.	Premium —Rs. 25,000 Royalty —2%
		M/s. Jagjiwan Enchem Udyog Ltd., Ellisbridge, Ahmedabad.	Premium —Rs. 55,000 Royalty —2%

PREMIA & ROYALTIES

(period ending 31.12. 88)

PROCESS	PARTY	TOTAL AMOUNT (Rs.)	LAB. SHARE (40%) (Rs.)
Cinema Arc Carbon	M/s Advani Oerlikon Ltd., Bombay	4,00,000	1,60,000
	M/s Britelite Carbons Ltd., Baroda.	3,06,000	1,22,400
	M/s Isocarbon Co. (P) Ltd., Visakhapatnam.	1,768	707
Indelible Ink	M/s Mysore Lac & Paint Works Ltd., Mysore.	50,000	20,000
Midget Electrodes	M/s Britelite Carbons Ltd., Baroda.	18,906	7,562
K & S—Band Wave Guides	M/s Vidyut Yantra Udyog, Modi Nagar.	7,255	2,909
Distillation Apparatus	M/s Sciencetronia Instruments Co., New Delhi.	7,000	2,800
Silver Impregnated Graphite Contacts.	M/s Jyoti Refinery, Bombay.	635	254
Sequential Switching Device	M/s Beacon Electronics, New Delhi.	108	43

CONSULTANCY

Sl. No.	Title	Party	Amount (Rs.)
	ACOUSTIC STANDARDS		
1.	Fabrication & installation of a monostatic sodar at Nagothane, Distt. Raigad.	Indian Petro Chemicals Corpn. Ltd; Nagothane.	2,10,000
2.	Measurement of noise levels by sides of railway track in Moti Bagh, New Delhi.	Northern Railways, New Delhi.	25,000
3.	Acoustic treatment of the auditorium of Jamia Millia Islamia University, New Delhi.	C.P.W.D Pushpa Bhawan, New Delhi.	20,000
4.	Acoustic treatment of the auditorium of NDRI, Karnal.	C.P.W.D., NH II, Faridabad	15,000
	MATERIALS CHARACTERIZATION		
1.	Elemental and structural analysis of boiler tubes failure	M/S Gujarat Heavy Chemicals Ltd; New Delhi.	40,000
	INSTRUMENTATION		
1.	Improvement in sensitivity of foil resistance strain-gauges.	M/s SAAB Associates, New Delhi.	12,000
2.	Circuit analysis of osmometer.	Haryana Agricultural University, Hissar.	3,700
3.	Trouble shooting & restoration of Spectrometer.	I.V.R.I., Izatnagar	2,300
4.	Physical & ultrasonic properties of rubber sole sheets.	M/s Hindustan Rubber Mills, New Delhi.	300

RECEIPTS OF CALIBRATION/TESTING AND OTHER CHARGES REALISED DURING 1989-90.

ACTIVITY	AMOUNT (Rs.)	REPORTS
CALIBRATION STANDARDS		
Force & Hardness	9,37,675	513
Dimensional Metrology	4,77,700	396
Optical Radiation	4,45,467	89
Temperature	3,55,640	247
Mass	2,79,550	367
AC & LF	1,35,250	46
HF & Microwave	1,13,875	18
DC	1,09,000	88
Pressure & Vacuum	1,04,000	26
LF & HF Impedance	66,250	83
Length	43,500	5
Acoustic	42,350	19
Microwave Attenuation & Impedance	18,750	6
Time & Frequency	11,000	6
MATERIALS CHARACTERIZATION		
Chem. Methods	37,600	54
Others	73,450	25
TOTAL	**32,51,057**	**1988**
OTHER RECEIPTS		
Glass Fabrication	2,73,255	
PZT Material	22,593	
Inductive Voltage Dividers (STQC, New Delhi)	1,00,000	
TOTAL	**3,95,848**	

SOME PARTIES WHICH AVAILED CALIBRATION/TESTING FACILITIES

GOVERNMENT DEPARTMENTS

Bureau of Indian Standards, Faridabad, Bangalore, Sahibabad, Calcutta and Chandigarh.
C.P.W.D., New Delhi.
Central Excise Laboratory, Visakhapatnam.
Controller of Quality Assurance Electronics, Bangalore.
Controller of Weights & Measures, Delhi, Bihar, Nagaland and Jammu & Kashmir.
Deptt. of Non-conventional Energy Sources, New Delhi.
Director of Industries, Jaipur.
Election Commission of India, New Delhi.
Electricity Boards of Haryana and Punjab.
Electronic Regional Test Laboratories, New Delhi, Calcutta and Bombay.
Indira Gandhi Centre for Atomic Research, Kalpakkam, Tamil Nadu.
N.E. Rly, Gorakhpur; E. Rly. Mugalsarai and S. Rly. Tiruchurapalli.
National Test House, Ghaziabad and Calcutta.
P.W.D's of Bhilwara, Chitorgarh, Jodhpur, Jaipur, Ajmer and Bikaner.

PUBLIC—SECTOR UNDERTAKINGS

Air India, Bombay.
Bharat Electronics Ltd., Bangalore and Ghaziabad.
Bharat Heavy Electricals Ltd., New Delhi, Bhopal, Haridwar, Ghaziabad, Bangalore, Madras and Hyderabad.
Cement Corporation of India Ltd., Gulbarga and Yerragunta (A.P.).
Heavy Engineering Corporation Ltd., Ranchi.
HMT, New Delhi.
Hindustan Aeronautics Ltd., Koraput, Nasik, Lucknow, Kanpur, Bangalore and Hyderabad.
Hindustan Petroleum Corpn. Ltd., New Delhi.
Hindustan Vegetable Oil Corpn. Ltd., Kanpur.
Indian Oil Corpn. Ltd., New Delhi, Gauhati, and Barauni.
Instrument Design, Development & Facilities Development Centre, Ambala Cantt.
Maruti Udyog Ltd., Gurgaon.
Mishra Dhatu Nigam, Hyderabad.
N.T.P.C. Ltd., New Delhi, Durgapur and Jyoti Nagar (A.P).
Ordnance Factory, Nagpur and Pune.

PRIVATE UNDERTAKINGS

Associated Cement Co. Ltd., Ranchi.
Associated Instruments Mftg. Ltd., New Delhi.
Avery India Ltd., New Delhi.
Blue Star Ltd., New Delhi.
Borosil Glass Works, New Delhi.
Cosmos Ferrites Ltd., New Delhi.
Delton Cables, New Delhi.
Dunlop India Ltd., New Delhi.
ECE Industries Ltd., Sonepat.
Escorts Ltd., Faridabad.
Feeder Lloyds Corpn., (P) Ltd., New Delhi.
Freemans Measures (P) Ltd., Ludhiana.
Gammon India Ltd., New Delhi.
H. Guru Instruments (P) Ltd., Calcutta.
K.G. Khosla Compressors Ltd., New Delhi.
Kirloskar Cummins Ltd., Pune.
Larsen & Toubro Ltd., Bombay.
Lumino Lamps Ltd., Hyderabad.
Mahindra Ugine Steels Ltd., New Delhi.
Mysore Lamp Works, Bangalore.
Parkash Tubes Ltd., Bahadurgarh.
Rajasthan Alloys & Steels (P) Ltd., New Delhi.
Secure Meters (P) Ltd., Udaipur.
Shriram Fertilizers & Chemicals, Kota.
Simpson & Co., Madras.
Swastik Thermometer Co., Delhi.
Sylvania & Laxman Ltd., New Delhi.
Tata Engineering Locomotive Co. Ltd., Jamshedpur.
Tata Iron Steel Co. Ltd., Jamshedpur.
Usha Martin Indts. Ltd., New Delhi.

R & D LINKS WITH OTHER INSTITUTIONS

NPL had active collaboration with scientific institutions, universities, CSIR laboratories, Govt. Deptts. and international laboratories regarding scientific projects and studies in the areas of Standards, Superconductivity, Materials including Characterization and Radio Sciences. The names of the institutes, universities and departments with areas of collaboration of NPL are listed below:-

INDIA

Bharat Heavy Electricals Ltd., Hyderabad (Superconductivity)
Bureau of Indian Standards (Standards).
Central Electronics Engineering Research Institute, Pilani (Superconductivity, Characterization).
Central Electronics Ltd., Sahibabad (Silicon)
Central Glass & Ceramic Research Institute, Calcutta (Superconductivity)
Central Mechanical Engineering Research Institute, Durgapur (Atmospheric Sciences)
Central Pollution Control Board, Delhi (Acoustic Standard)
Department of Non-Conventional Energy Sources, New Delhi (Thin Film, Cryogenics)
Defence Research Development Laboratory, Hyderabad (Carbon Composite)
F.I.E. Research Institute, Ganga Nagar, (Maharashtra) (Force Standard)
Indira Gandhi Centre of Atomic Research, Kalpakkam (Beta Alumina Tubes)
Industrial Toxicology Research Centre, Lucknow (Atmospheric Sciences)
Indian Institute of Petroleum, Dehradun (Atmospheric Sciences)
Indian Institute of Technology, Kanpur (Superconductivity)
Indian Petrochemicals Corporation Ltd., Vadodra (Acoustic Standard)
Indian Space Research Organisation, Bangalore (SROSS Satellite, Luminescent Materials, Radio Science)
Jadavpur University (Impedance Standard)
National Environmental Engineering Research Institute, Nagpur (Atmospheric Sciences)
National Remote Sensing Agency, Hyderabad (Radio Science)
Osmania University, Hyderabad (Radio Science)
Poona University (Superconductivity)
Rajasthan University (Superconductivity)
Regional Research Laboratory, Trivandrum (Superconductivity)
Shriram Institute for Industrial Research, Delhi (Superconductivity)
S.V. University, Tirupati (Radio Science)
Vikram Sarabhai Space Centre, Trivandrum (Carbon Composite)

OVERSEAS

Asia Pacific Metrology Programme (Standards)
Commonwealth India Metrology Centre (Standards)

AUSTRALIA

Ionospheric Prediction Service, Sydney (Radio Science)

CZECHOSLOVAKIA

Electrotechnical Institute (CEPR), Bratislavia (Vacuum Pressure Standards)

FRANCE

Meudon-de Observatoire, Paris (Radio Science)

FRG

Institut fur Hochfrequenztechnik, Fachbereich, (Characterization)
Physikalisch Technische Bundesanstalt, Braunschweig, (Standards).

ITALY

Istituto di Metrologia "G. Colonnetti" (Vacuum Pressure Standards)

UK

Atomic Energy Research Establishment, Harwell (Ultrasonics).
Oxford University (Conducting Polymers).
Universities of Bath, Birmingham, Leeds, Strathclyde & Surrey (Ultrasonics).

USA

National Institute of Standards & Technology, Gaithersburg, Maryland (Standards, Characterization)
World Warning Agency, Boulder, Colorado (Radio Science)

USSR

Institute of Inorganic Chemistry, Novosibirsk (Electronic Materials, Crystal Growth)
Institute of Metal Physics, Sverdlovsk (Materials)
Moscow State University, (Materials)

VNIIFTRI (Standards)

VNIIM, Moscow (Temperature Standard)

JAWAHARLAL NEHRU CENTENARY LECTURE

Shri K.R. Narayanan, Minister of State for Science & Technology & Vice-President, CSIR, delivered the Jawaharlal Nehru Centenary Lecture, titled, "Nehru's role in the promotion of Scientific Temper in Indian Society", on Sept 27, 1989 at the National Physical Laboratory,New Delhi.

Nehru was intimately associated with NPL. *It is an institution he loved and admired and held up as a model of a scientific laboratory in the country.* Its contributions have been very notable and are known to you all. Jawaharlal Nehru's role in the development of science in India was too well-known for me to expatiate upon. His contribution was not limited to scientific education, the building up of a chain of great laboratories and the application of science and technology to development. Jawaharlal Nehru had thought of a wider role for science. He has conceived of science as something that is applicable to production, education, health etc., indeed to every aspect of life for the development and improvement of the human being and of society as a whole. All this is crystallised in the phrase "scientific temper". I quote Nehru from his "Discovery of India" on the subject.

"The applications of science are inevitable and unavoidable for all countries and peoples today. But something more than its application is necessary. It is the scientific approach, the adventurous and yet critical temper of science, the search for truth and new knowledge, the refusal to accept anything without testing and trial, the capacity to change previous conclusions in the face of new evidence, the reliance on observed fact and not on preconceived theory, the hard discipline of the mind — all this is necessary, not merely for the application of science but for life itself and the solution of its many problems. We live in a scientific age, so we are told, but there is little evidence of this temper in the people anywhere or even in their leaders. Science deals with the domain of positive knowledge but the temper which it should produce goes beyond that domain. It is, therefore, with the temper and approach of science, allied to philosophy, and with reverence for all that lies beyond, that we must face life". This sums up Nehru's entire approach to science and technology both in its practical applications and in its philosophical and cultural dimensions.

Today we know that the discoveries of science have more or less extinguished the distinction between mind and matter. One of my professors used to emphasize this distinction by the following question and answer "What is mind, No matter'. What is matter, Never mind."

Search is going on in science for the ultimate mystery of life. In Physics, the search is for the final particle and for the underlying "super-force". No less a scientist than Einstein has said how it was possible to grasp some of the truths about life in the way the ancients have dreamt, through abstract thinking and through the application of mathematics. What I am trying to say is that the scientific spirit, the scientific approach, was inherent in the Indian tradition, though it got marred through the social distortions and deterioration that took place in our country during its long and chequered history. It is this scientific temper that is at the root of Jawaharlal Nehru's approach to life. Nehru wrote:- "Politics led me to economics and this led me inevitably to science and the scientific approach to all our problems and to life itself". It was as a result of all this that in 1937 he became the Chairman of the National Planning Committee of the Indian National Congress. The interesting thing for us is that within this Committee he formed a group of scientists to work out the methods of applying science for India's development. It is during the same period that he addressed the Indian Science Congress. *"It is science alone that could solve the problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste, of a rich country inhabited by a starving people".*

The culmination of all this was in the Scientific Policy Resolution of 1958. The most important application of scientific approach by Nehru was in the realm of planning. The entire planning process itself under Nehru was in the best sense of the world a vast application of the method and the spirit of science to the development of India as a whole. Talking about people working in our laboratories, he said: "I think that with a large number of bright young men and young women working in these laboratories, will help gradually to spread the temper of science, the temper of dispassionate study, the temper of the

search for truth, regardless of consequences, that is so much needed today." Without scientific education there could be no meaningful dissemination of scientific temper among the people.

As the founder of Indian democracy in the modern sense, Nehru believed that democracy and science were interlinked. Another way he expressed his attachment to scientific temper and scientific values was through his efforts at social transformation whether it was in respect of the status of women in the Indian society, or the development of backward and depressed classes. It is important to remember that Jawaharlal Nehru combined in himself in a very unique manner the approach of humanism with the spirit of science.

Nehru looked at science without fear, in a very audacious manner. He did not want scientists to shy away from anything in the pursuit of truth. He advocated full freedom for scientific research with a boldness that was startling. The true scientist is a sage unattached to life and the fruits of action, everseeking truth wheresoever his quest may lead him. Today for a man to be considered educated he has to know something about science. It was as a result of the realisation of this modern predicament of the common man, as well as for paving the way for the modernisation of Indian society that Nehru advocated so incessantly the need for the creation of scientific temper and the popularisation of science in our society. So if we are to bridge this gap and disseminate scientific knowledge and promote scientific temper, it has become necessary for, at least, some of the important scientists to turn to popularisation. It is time that some scientists entered the field of scientific journalism.

One of the areas in which Nehru's scientific spirit manifested itself most gloriously and eloquently was in his campaign against the abuse of science and technology for war-like purposes. Nehru spoke at the J.C. Bose centenary celebrations. "We have arrived really at the brink of hell and the scientist has to think. Am I right in doing a work which drives the world in this terrible direction? .... The scientists are tied up hand and foot to the chariot of the State to make more bombs, to do this and that and then they do not know how to escape." And it is in this context that scientists have the social and world responsibility of not co-operating with or positively taking part in this armament race by providing good advice to the Presidents and Prime Ministers who are scientifically and technologically ignorant.

KRISHNAN MEMORIAL LECTURE

The 20th Krishnan Memorial Lecture was delivered by Prof. S. Chandrasekhar, NL, University of Chicago, Illinois, USA, on Nov. 29, 1989. The topic of the lecture was **"The Intellectual achievement that the Principia is".**

Dr. Chandrasekhar described Charles Newton's Principia as a work of great mathematical genius which was a subject of derision instead of praise by his contemporaries. It was unfortunate, that Principia, an immortal treatise on pure mathematics, was dubbed by the mathematicians of Newton's age as "occult in physics" and "absurd theories beyond human comprehension."

Some of the prepositions included in the Principia, like the Theory of Infinite Series, Binomial Theorem, etc. are of perennial relevance to mathematicians, the laureate said.

Earlier, Prof. Chandrasekhar recalled his association with Sir K.S. Krishnan, when he was working at the Indian Association for the Cultivation of Science, Calcutta with Prof. C.V. Raman. He donated copies of Dr. Krishnan's letters written to him over a period of 30 years to the archives of NPL, which were received by Dr. S.K. Joshi.

Dr. A.P. Mitra, Director General, CSIR presided over the function. The audience included physicists, scientists, research students and others. Dr. S.K. Joshi, Director, NPL presented a memento to Prof. Chandrasekhar on the occasion.

SPECIAL LECTURES

Speaker	Topic	Date
Dr. Jaroslave Sestak, Inst. of Physics, Czechoslovakia.	Phase relations Y-Ba-Cu-O superconductors.	April 4.
Mr. B.C. Moss, National NDT Centre, Harwell, UK.	Laser interferometer and its application to non-destructive testing.	April 5.
Ms. F.K. Brock Lehurst, National NDT Centre, Harwell, UK.	Laser ultrasound and its applications.	April 5.
Dr. E.L. Ivchenko, Physico-technical Inst. of the Academy of Sciences, USSR.	Optical spectroscopy of semiconductor superlattices.	April 6.
Dr. B.V. Smith, Deptt. of Electronic and Electrical Engg. Birmingham University, UK.	Sonar systems for mapping the sea floor.	April 26.
Dr. B.P. Singh, I.I.T, Kanpur	Optical bistability and optical computing.	May 4.
Dr. M.S. Ram Kumar, Robotics & Remote Handling Div., BARC, Bombay	Robotics & Remote Handling.	May 24
Dr. S.R. Rao, National Inst. of Oceanography, Goa.	Target search technique for marine archaeology and usefulness of geophysical survey systems.	May 26.
Prof. T.P. Das, State University of New York.	Theory of ionic crystals including high Tc superconductors.	June 19.
Dr. D.S. Parmar, Physics Deptt., Kashmir University, Srinagar.	Design and applications of monomeric and polymeric ferroelectric liquid crystals.	July 13.
Dr. P.K. Das, Deptt. of Ocean Development, New Delhi.	Is atmosphere warming up.	July 25.
Prof. Punit Boolchand Deptt. of Electrical & Computer Engg. Cincinnati University, USA.	Metallic dopants in cuprate superconductors.	July 25.
Prof. M. Kimata, Waseda University, Tokyo, Japan.	MBE growth of superlattices and their device applications.	August 1.
Prof. J.C. Launay, Universite de Bordeaux, France.	Crystal growth of Germanium by C.V.T. in microgravity.	August 21.
Prof. N.F. Ramsey Higgins, Harvard University, USA.	Cold fusion and time reversal symmetry.	September 1.
Prof. B.K. Rao, Commonwealth University, Virginia.	Hydrogen interaction in metal clusters.	September 6.

Speaker	Topic	Date
Mr. Dudlev Wallis, Chief Scientist, Cirrus Research Ltd., UK.	Lecture-cum-demonstration of noise/acoustical measurement instruments.	September 28.
Dr. R.P. Rao, Central Electrochemical Res. Instt., Karaikudi.	Phosphor materials and applications.	September 29.
Prof. Nagakura, Graduate University of Advanced Studies, Yokahama, Japan.	Magnetic field effects on photophysical and photochemical processes.	October 4.
Dr. F. Waeldele, PTB, FRG.	Development tendencies in the improvement of coordinate measuring machine performance.	October 27.
Dr. F.L. Pratt, Clarendon Lab. Oxford University, UK.	Optical properties of organic conductors.	November 6.
Prof. J. Pasupati, I.I.Sc., Bangalore	Quantum Hall Effect.	November 7.
Dr. T. Zdanowicz, Polish Academy of Sciences, Poland.	Characterization of silicon solar cells and solar cell batteries.	November 16.
Prof. C. De Jager, Foreign Secty., Royal Netherlands Academy.	Solar Flares.	November 17.
Prof. A. Guinier, Foreign Secty. Academy of France.	Experiments VS Theory.	November 17.
Prof. K.C. Wali, Deptt. of Physics, Syracuse University, USA.	Glimpses from the life of Prof. S. Chandrashekhar.	November 17.
Prof. A.P. Balachandran, Syracuse University, USA.	Fractional statistics, anyons and high Tc.	November 20.
Dr. S,C. Jain, Clarendon Lab., Oxford	Physics of $Ge_x Si_{1-x}$ strained epitaxial layers and devices.	November 27.
Prof. M. Inagaki, Toyohashi University of Technology, Japan.	Recent trends in R & D on carbon and other materials in Japan.	November 30
Dr. R.C. Chivers, Surrey University, UK.	Ultrasonic propagation in suspensions	November 30.
	Acoustic sea-bed characterisation.	December 5.
Dr. J.J. Connolly, National Measurement Lab. Sydney, Australia.	International Temperature scale, 1990.	December 5.

Speaker	Topic	Date
Dr. L. Bendersky, N.I.S.T., Washington.	Quasi-Crystals.	December 6.
Prof. R.K. Panday, Texas A & M University, USA.	Research in high Tc materials at Texas A & M University-single crystal films and ceramics.	December 21.
Dr. V.P. Aneja, North Carolina State University, USA.	Characterizing the ozone climatology at high elevations in the Southern Appalachians, USA.	December 22.
Prof. J.M. Schultz, Visiting Professor, University of Delaware.	Rapid phase changes in polymer fibres.	December 26.
Dr. Thomas R. Lettieri, NIST, Gaithersburg, Maryland.	Surface and particle metrology at the U.S. National Institute of Standards and Technology.	January 10.
Dr. H. Maeda, National Research Institute of Metals, Tsukuba, Japan.	High critical current densities in high Tc Bismuth Compound wires.	January 16.
Dr. B. Batllogg of AT & T Bell Labs. USA.	Survey of experiments on high Tc Cuperates.	January 18.
Dr. Virender Mahajan, M/s Aerospace Corporation, California, USA.	Optical imaging interference.	January 24.
Dr. Y.V. Vasiliev, Institute of Inorganic Chemistry, Fovosibirsk, USSR.	Low-thermal-gradient Cz technique. Modelling of some low pressure CVD processes	January 30. January 30.
Prof. G.B. Donaldson, University of Strathclyde, Glasgow, UK	Recent developments in SQUIDS and their applications.	January 31
	Harmonic generation and gramularity in YBCO-a new role for the critical flux state model.	February 1.
Dr. M.P. Das, Australian National University, Australia.	Understanding high Tc superconductivity-3 years since Bednorz and Muller.	February 1.
Dr. Stefan Benacka, Slovak Academy of Sciences, Czechoslovakia.	Weak Superconductivity research at Slovak Academy of Sciences.	February 2.
Dr. Y. Sudhakar, Max Planck Inst. Stuttgart, FRG.	Transport properties of a two dimensional electron gas.	February 15.
Dr. N. Anantaraman, National Superconducting Cyclotron Lab., Michigan State University, USA.	An outsider's impressions on status of physics and astronomy in India.	February 16.

VISITS ABROAD

(1.4.89 to 31.3.90)

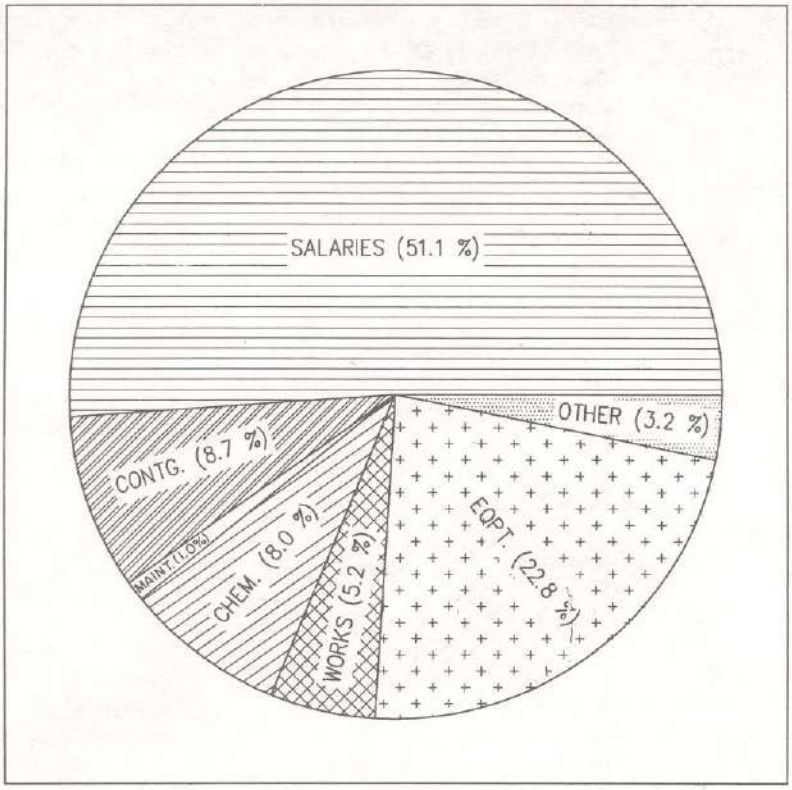
Scientist & Country	Purpose & Month
Dr. H.N. Dutta, UK	Presented a paper in the Intl. Conf. on Antennas and Propagation, University of Warwick, Caventry, April.
Dr. R.B. Tripathi, USA	Raman Research Fellow, worked in AT & T Bell Laboratory, New Jersey, April-Jan.
Dr. S.P. Singal, USSR	Indo-USSR Programme in the S & T area of theoretical and applied mechanism, May-June.
Dr. D.R. Lakshmi, USA	Presented a paper at the 'SUNDIAL' workshop at Virginia and visited world warning agency of SESC, Boulder, May.
Dr. P.K. Gupta, China	Presented a paper at the Intl. Symp. on Certified Reference Materials (ISCRM89') at Beijing and visited NIHSRM Centre, May.
Dr. V.S. Tomer, Czechoslovakia	Under CSIR-Czechoslovakia Academy of Science Exchange Programme, May-June.
Italy	For equipment training on UHV load-lock system, Feb.
Sh. M.K. Dasgupta, FRG	NPL-PTB Technical Development Programme, May-July.
Dr. R.G. Sharma, Japan	Participated in the Intl. Electrochemical Commission group meeting on super-conductivity held at Tokyo, May.
Sh. Vijay Kumar, FRG	Fellowship of GAES for study/training under DAAD Programme, June-Sept.
Dr. S.K. Joshi, FRG	Attended the steering committee meeting of the NPL-II Project-augmenting the National Standards of measurements, June.
USSR	Attended the joint council meeting of ILTP at Leningrad, July.
UK	Attended 2nd. meeting of the Intl. Advisory Committee of Commonwealth India Metrology Centre, July.
France	Attended the 4th Scientific Council meeting of Indo-French Centre for the promotion of advanced research (IFUAR), Sept.
FRG	For discussion regarding the areas of collaboration under INSA-DFG, Exchange Programme, Dec.
Dr. K. Chandra, FRG	Attended the steering committee meeting of the NPL-II Project-augmenting the National Standards of measurements, June.
UK	Attended 2nd meeting of the Intl. Advisory Committee of Commonwealth India Metrology Centre, July.
Dr. B.N. Srivastava, Japan	Attended the Intl. Seminar on ozone layer protection held at Tokyo, May-June.
Dr. T.R. Tyagi, USSR	Under Indo-USSR programme in the area of Radio Physics and Astro-physics, May-June.
Argentina	Presented papers at Intl. Symps. on Equatorial Aeronomy, and Beacon Satellite
FRG	and visited MPAE Lindau, March-April.
Dr. V.N. Bindal, UK, Spain & Indonesia	Regarding British Council Project, participated in Intl. Confs. June-July.
Pakistan	Delivered a talk at Ist. congress of ultrasonigraphy held at Karachi, Jan.
Dr. V.D. Dandavate, USSR	Under Indo-Soviet programme for cooperation in S & T, July.
Dr. A.P. Jain, USA	Attended the Inter Society Energy Conversion Engg. Conf. at Washington D.C., Aug.
Dr. S.K. Sarkar & Dr. G.S. Uppal	Canada — Attended the Intl. Symp. on Geoscience and Remote-sensing at Vancouver, July.

Dr. Krishan Lal, FRG	Under CSIR-KFA Programme and also visited few Institutions, July-Aug.
Peru	Visited under CSIR-CONCYTEC, Exchange Programme and CNRS, France on the way, Dec.
Japan	Visited M/s Rigaku Intl. Corpn. and National Lab. for high energy physics at Tsukuba; participated in CODATA task group meeting in Kyoto, February-March.
Dr. K.S. Zalpuri, Japan	For discussions on the nitric oxide rocket data at the Geophysics Research Laboratory, University of Tokyo, July-Aug.
Dr. S.C. Jain, USSR	Visited Instt. of Crystallography at Moscow under INSA-USSR Exchange Programme. Aug.-Oct.
Dr. A.B. Ghosh, Japan	Presented a paper at Intl. Symp. on antenna and propagation at Tokyo. Aug.-Sept.
Sh. H.P. Gupta, USSR	Under Indo-USSR programme of cooperation, Sept.-Jan.
Dr. N.D. Kataria, FRG	On scientist assignment at PTB, Braunschweig for a period of 2 years, Aug.
Dr. A. Sengupta, USA & UK	Visited NIST under Indo-US Project and British Antarctic Survey, Cambridge for discussions, Sept.-Oct.
Dr. B.S. Mathur, China	Under INSA-Chinese Academy of Sciences Exchange Programme, Sept.
Dr. P.C. Jain, FRG	Under PTB-AID Programme (NPL-II), Sept.
Dr. J.R. Anand, FRG	Under PTB-AID Programme (NPL-II), Sept. Oct.
Dr. Vasantha Raman, FRG	Presented a paper in the 3rd Intl. Symp. on highway pollution held at Munich, Sept.
Dr. Janardhan Singh, UK	For training in underwater acoustics under Indo-UK Project on ultrasonic standards, Sept.-Nov.
Dr. J.K.N. Sharma, Egypt & FRG	Attended the executive committee meeting of IUVSTA and the Intl. Conf. of vacuum and solid surface physics, Sept.
Dr. S.V. Gupta, FRG	Visited PTB and attended Flow Meko-89 conference, Oct.
Sh. Ram Prasad, Greece	Attended the Intl. Symp. on scientific cooperation at Athens, Oct.
Dr. B.M. Reddy, Australia	Presented a paper at the Solar Terrestrial Prediction workshop at Leura, Oct.
Sh. N.K. Babbar, Japan	Presented a paper at the Intl. Symp. of cryosurgery at Tokyo, Oct.
Dr. V.R. Singh, Malaysia	Presented a paper at the Intl. Chem. Conf. on silicon and tin at Kuala Lumpur, Oct.
Dr. B.K. Das, UK	Under CSIR-British Council Exchange Programme, Nov.
Dr. A.K. Hanjura, USA	Visited NIST, Boulder Colorado under Indo-US collaboration, Nov.-Dec.
Sh. Rajeev Chopra, USSR	Under Indo-Soviet S & T programme of cooperation, Nov.-Feb.
Dr. A.K. Gupta & Italy & UK	For training on UHV load-lock system in Italy and visited Deptts. of Phys.,
Dr. Neeraj Khare	Universities of Strathclyde, Glasgow, and Birmingham, Feb.-Mar.
Sh. Raj Signh, FRG	For training in the field of fluid flow measurement under NPL-PTB Technical Coopn., Mar.-Sept. 90.
Dr. K.C. Nagpal, FRG	For equipment training on D-500, X-ray diffractometer at M/s Siemens Corpn., March.
Sh. S.M. Khullar & USSR	Under S & T cooperation in the area of electronic materials, Mar.-Oct. 90.
Dr. Satbir Singh,	
Dr. D.C. Prashar, USA	Presented a paper at the Chapman Conf. on global biomass burning atmospheric climatic and biosphere implications, at Virginia, March.

ACTUAL EXPENDITURE

(1989–90)

Budget Head	Rs. (Lakhs)
Salaries	538.998
Contigencies	92.000
Maintenance	10.148
Chemicals	84.276
Works etc.	54.857
Equipment	240.494
Other	34.221
Total	**1054.994**
Sponsored Projects	258.289



HUMAN RESOURCES

SCIENTISTS OFFICERS

(as on 1.4.90)

DIRECTOR
JOSHI S K, Ph.D

STANDARDS

LENGTH & DIMENSIONS

Aggarwal N K, B.Sc., TO B
Chitnis V T, Ph.D., EI
Dahiya H S, Ph.D., Sc C
Dandavate V D, Ph.D., EI
Jain P C, Ph.D., EII
Kanjilal A K, B.Sc., TO B
Karfa M, M.Sc., Sc B
Khanna R K, B.Sc., TOC
Kulkarni V G, Ph.D., Sc C
Ram Narain, ITI, TO A
Ram Prasad, M.Sc., Sc EI
Roonwal V (Mrs.), M.Sc. TO C
Roy BK, B.Sc. , TO B
Sharma V D, M.A., TO A
Singhal R P,B.E., Sc EI
Tanwar L S, Ph.D, Sc C
Vardhan Kowsalya (Mrs.), M.E., Sc C

MASS

Das M L, M.Sc., Sc C
Gupta S V, Ph.D., Sc EII
Kohli N K, B.A., TO C
Mathur B G, B.Sc., TO C
Mohinder Nath, B.Sc., Sc EI
Tripurari Lal, M.Sc., Sc C
Verma S, (Mrs.), BSc., TO A

FORCE

Anil Kumar, B.Sc., Engg., Sc C
Chaudhury M K, AMIE, Sc C
Dasgupta M K, B.Sc. Engg, Sc F
Dhawan J K, B.E., Sc C
Sharma R S, M.Sc., Sc C

PRESSURE & VACUUM

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

TEMPERATURE

Bhatnagar K N, AMIE, Sc C
Luthra R K, M.Sc., Sc C
Mansha Ram, M.Sc., Sc B
Nijhawan S K, PDip. Engg., TO A
Saksena T K, Ph.D., Sc C
Singh Y P, M.Sc., Sc C
Srivastava N K, M.Sc., Sc C
Wasan V P, AMIE, Sc EI

OPTICAL RADIATION

Bhola O P, B.Sc., TO C
Chakraborty T K, AMIE, Sc C
Jai Bhagwan, B.Sc., TO A
Joshi K C, Ph.D., Sc EII
Kailash Chand, M.Sc., Sc C
Kandpal H C, Ph.D., Sc C
Mahesh Chander, Ph.D., Sc EI
Manrai S (Mrs.), M.A., Sc C
Vaishya J S, Ph.D.,-Sc EI

INFRARED RADIATION

Gupta D, Ph.D., Sc C
Joginder Singh, M.Sc., Sc EI
Om Prakash, M.Sc., Sc C
Ram R S, Ph.D., Sc C
Varma S P, Ph,D., Sc EI

ACOUSTIC

Bhaskar H L B, BSc. Engg., Sc B
Gera B S, Ph. D., Sc C
Gautam C B L, B.Sc., TO B
John P C, Gd. IETE, TO C
Khanna R M, DMIT, Sc C
Mohanan V, Ph.D., Sc EI
Pahwa D R, M.Sc., Sc C
Sharma Omkar, M.Sc., Sc C
Singal S P, Ph.D., Sc EII

FLOW MEASUREMENT & C.S. PROGRAMME

Bahl S D, ITI., TO B
Dwivedi S, M.Sc., Sc C
Govindarajan S, M.Tech., Sc B
Raj Singh, AMIE., Sc C
Sharwan Kumar Ph.D., Sc EI
Virendra babu, B.Sc., TO C

TIME & FREQUENCY

Bahadur Harish, Ph.D., Sc C
Banerjee P, Ph.D., Sc EI
Chatterjee A (Mrs.), M. Tech., Sc C
Goel G K, B.Sc., TO C
Gurdial Singh, Matric, TO A
Hanjura A K, Ph.D., Sc C
Mathur B S, Ph.D., Sc F
Saxena G M, Ph.D., Sc C
Saxena M (Mrs.), Gd. IETE Sc C
Sengupta A, Ph. D., Sc C
Shakdhar M L, B.Sc., TO C

DC STANDARDS

Batra V K M.Sc., Sc EI
Mahajan S K, Ph.D., Sc C
Mittal P K, B.Sc., TO B
Sircar B, B.Sc., TO B

HF IMPEDANCE & AC LF

Arora T R, ITI., TO B
Dahake S L, Ph.D., Sc EII
Gupta S R, M.Sc., Sc C
Gurmej Ram, B.Sc. Engg., Sc C
Kailash Chandra*, Ph.D., Dir. Gd.
Kaushik A R (Mrs.), Dip. Engg., TO A
Kewal Krishan, Gd. IETE., Sc C
Mittal M K, M. Tech., Sc C
Nagar M R, Gd. IETE., Sc C
Naib Singh, AMIE., Sc B
Omkar Nath, Ph.D., Sc C
Saxena A K, B.E., Sc C
Surinder Singh, ITI., TO B

HF, MICROWAVE, ATTENUATION

Aggarwal Ritander, AMIE., ScC
Agrawal V K, Ph.D., Sc EI
Bhatnagar H M, M.Sc., Sc C
Govil A K, M.Sc., Sc C
Kothari P C, Ph.D., Sc EI
Mendiratta R L, AIC., TO A

Negi P S, M. Tech., Sc C
Ram Swarup, M. Tech., Sc EI
Ranjit Singh, M.Tech., Sc B
Rustagi V K, B. Tech., Sc C
Yadav R S, Ph.D., Sc EI

TESTING & CALIBRATION

Ghosh A K, Dip. Engg., TO A
Mathur S P (Mrs.), B.A., TO B
Singh C P, H. School., TO C
Thadani H K, Gd. Brit. IRE., Sc EI
Thind S L, Dip. Engg., TO A

MATERIALS

SILICON, BETA ALUMINA & SUPERCONDUCTORS

Arora N K, Ph.D., Sc C
Awasthy B R, M.Sc., Sc C
Balbir Singh, AMIE., Sc C
Banerjee M K, ITI., TO A
Bangari N S, B.Sc., TO C
Chakravarty B C Ph.D., Sc C
Das B K, Ph.D., Sc EII
Goel R C, B.Sc., TO B
Gupta H P, B.Sc., TO A
Jain Kiran (Mrs.), M.Tech., Sc C
Kalsi H S, B.Sc., TO C
Khullar S M, AIC., TO C
Khurana B S, B.Sc., TO B
Kotnala R K, Ph.D., Sc C
Manmohanan S B, M.Sc., Sc C
Mohan Lal, Ph.D., Sc C
Prem Prakash, AIC., TO A
Ramanathan P V N, DII SC., Sc EI
Ram Kishore, Ph.D., Sc C
Ravi Kumar, Gd. IETE., Sc A
Reddi BV, Ph.D., Sc C
Sastri VDP, Ph.D., Sc EII
Satbir Singh, Ph.D., Sc C
Sharda S K, B.Sc., TO B
Singh P K, Ph.D., Sc. C
Singh S N, Ph.D., Sc EI
Tripathi R B, Ph.D., Sc. EI

INTERFACE, MICROSTRUCTURE DEVICES

Balakrishnan K S (Mrs.), M.Sc., TO A
Lakshmi Kumar S T, Ph.D., Sc C
Rastogi A C Ph.D., Sc EI

LUMINESCENT MATERIALS

Ghosh P K, Ph.D., Sc EI
Harish Chander, B.Sc., Engg., Sc C
Narang H P, M.Tech., Sc EI
Shankar V, Ph.D., Sc C

DISPLAY DEVICES & XERORADIOGRAPHY

Agnihotri SA (Mrs.), Ph.D., Sc C
Bawa S S, Ph.D., Sc EI
Bhateja R C, ITI., TO A
Biradar A M, Ph.D., Sc C
Ekbote S N, Ph.D., Sc C
Jain S C, Ph.D., Sc EI
Kamalasanan M N, Ph.D., Sc C
Malhotra B D, Ph.D., Sc C
Misra S C K, Ph.D., Sc C
Panwar V S, Ph.D., Sc C
Ramadhar Singh, Ph. D., Sc C
Saini K K, M.Sc., Sc C
Sharma C P, Ph.D., Sc C
Sharma D C, M.Sc., Sc EI
Sharma R K, Ph.D., Sc B
Subhas Chandra, Ph.D., Sc EI
Suresh Chand, Ph.D., Sc C
Verma N S, M.Sc., Sc B

UNDERWATER ACOUSTICS

Ashok Kumar, Ph.D., Sc C
Bindal V N, Ph.D., Sc F
Gupta S C, Gd. IETE, Sc EI
Jain S K, Ph.D., Sc C
Janardan Singh, Ph.D., Sc C
Mukesh Chandra, M.Sc., Sc C
Narayanaswamy N, B.Sc., TO B
Saksena T K, Ph.D., Sc EI
Som J N, Ph. D., Sc C
Subhash Chandra, B.Sc., TO B
Tandon R P, Ph.D., Sc C

CARBON PRODUCTS

Aggarwal R K, Ph.D., Sc C
Bahl O P, Ph.D., Sc EI
Bhatia Gopal, Ph.D., Sc C
Chhote Lal, Ph.D., Sc C
Dhami T L, Ph.D., Sc C
Hanspal S S, Gd. IETE., TO C
Kulshreshtha R K, B.E., Sc C
Manocha L M, Ph.D., Sc C
Mathur R B, Ph.D., Sc C
Raman Vasantha, (Mrs.) Ph.D., Sc C
Ramanathan S, ITI,. TO A
Seth R L Ph.D., Sc EII
Siva Ram P, M. Tech., Sc C
Verma C L, B.Sc., TO C

HIGH PRESSURE TECHNOLOGY

Aggarwal AK, B.E., Sc EI
Bindal M M Ph.D., Sc EI
Chopra Rajeev, B.E., Sc C
Dhar Ajay, Ph.D., Sc C
Nayar R K, Dip. Engg., TO C
Singh B P, Ph.D., Sc C
Singhal S K, Ph.D., Sc C
Verma S S, B.E., Sc C

CHARACTERIZATION

CHEMICAL METHODS

Aggarwal A K, Ph.D., Sc C
Amar V K, M.Sc., Sc EI
Bohra J N, Ph.D., Sc EI
Gupta PK, Ph.D., Sc EI
Gupta Prabhat Kumar M.Sc., Sc C
Jitendra Rai, M.A., TO C
Mewa Singh, M.Sc., Sc C
Parashar D C, Ph.D., Sc EII
Ramachandran R (Mrs.), Ph.D., Sc C
Sarkar A K, Ph.D., Sc C
Trehan J C, Ph.D., Sc EI

IR & EPR SPECTROSCOPY

Garg, R K, M.Sc., Sc C
Gupta S K, Ph.D., Sc C
Pradhan M M, Ph.D., Sc EI
Parthasarathy S, B.Sc., TO C
Rashmi (Ms.), Ph.D., Sc B

X-RAY MEASUREMENTS

Bhawalkar R H, Ph.D., Sc C
Dhawan U (Mrs.), M.Sc., Sc C,
Kundra K D, Ph.D., Sc EI
Nagpal K C, Ph.D., Sc EI
Suri D K, M.Sc., Sc C

ELECTRON MICROSCOPY

Malhotra G L, AMIE., Sc EI
Narendra Kumar, M.Sc., Sc EI
Rao S U M, M.Sc., Sc C
Sharma S K Ph.D., Sc EI

CRYSTAL GROWTH & PERFECTION

Ananthamurthy R V, Ph.D., Sc C

Bhagavannarayana G, M.Sc., Sc C
Haldar S K, Ph.D., Sc C
Krishan Lal, Ph.D., Sc G
Sharma S D, Ph.D., Sc C
Vijay Kumar, Ph.D., Sc C

CONDENSED MATTER PHYSICS

HIGH TEMPERATURE SUPERCONDUCTORS

Aggarwal S K, Ph.D., Sc B
Ashwini Kumar P K, Ph.D., Sc C
Dutta P K, B.E., Sc C
Gumber V K, M.Sc., Sc C
Gupta A K Ph.D., Sc El
Hegde M S, Ph.D., Sc El
Jayaram B*, Ph.D., Sc B
Kataria N D, Ph.D., Sc C
Khare Neeraj, Ph.D., Sc B
Kumaraswami B V, M. Tech., Sc C
Manmohan Krishan, M.Sc., Sc C
Narlikar A V, Ph.D., Sc F
Natarjan N S, Ph.D., Sc C
Ojha V N, Ph.D., Sc C
Reddy Y S, M.Sc., Sc C
Samanta S B, BSc., (Hons.)., TO B
Sarkar S K, Ph.D., Sc. El
Sharma M L, M.Sc., Sc C
Sharma R G, Ph.D., Sc El
Tomar V S, Ph.D., Sc C
Upadhyay P L (Ms.), Ph.D., Sc B
Yadav V S, Dip. Engg., TO A

THEORY & LT PHYSICS

Joshi S K, Ph.D., Dir.
Mehrotra Ravi, Ph.D., Sc C
Rai Ramji, Ph.D., Sc C
Ratan Lal, Ph.D., Sc C

DEVELOPMENTAL PROJECTS

THIN FILMS & AMORPHOUS MATERIALS

Anandan C*, M. Tech., Sc B
Basu A, Ph.D., Sc C
Bhattacharya R, Ph.D., Sc El
Devindra Singh M.Sc., Sc El
Dixit P N, Ph.D., Sc C
Kar M (Mrs.), Ph.D., Sc C
Panwar O S, Ph.D., Sc C
Shah V V, Ph.D., Sc EII
Verma B S, Ph.D., Sc C

CRYOGENICS

Babbar N K, AIC., Sc C
Ganga Parshad, B.E., Sc C
Gera S C, B.E., Sc El
Hari Kishan, Ph.D., Sc C
Jain A P Ph.D., Sc F
Kasturi Lal, M.Sc., Sc C
Khandekar R S, Dip. Engg., TO C
Saxena R B, M.Sc., Sc C

RADIO SCIENCE

Abdul Hamid, B.Sc., TO A
Aggarwal S (Mrs.), M.Sc., Sc El
Arora R S, Ph.D., Sc El
Arya B.C, M.Sc., Sc C
Bahl Madhu (Mrs.), Gd. IETE., Sc C
Banerjee** A, M.Tech., Sc El
Banerjee P K, Ph.D., Sc El
Chopra P (Mrs.), Gd. IETE., Sc C
Dabas R S, Ph.D., Sc C
Dutta H N, Ph.D., Sc El
Garg S C, M.Sc., Sc El
Ghosh AB, Ph.D., Sc El
Goel M K, Ph.D., Sc C
Gupta J K, M.Sc., Sc C
Jain A R, Ph.D., Sc El
Jain S L, Ph.D., Sc El
Kar J, Ph.D., Sc B
Kundu N (Mrs.), Ph.D., Sc C
Lakha Singh, M.Sc., Sc C
Lakshmi D R (Mrs.), Ph.D., Sc El
Mahajan K K*, Ph.D., Sc F
Mahendra Mohan, Ph.D., Sc C
Maini H K, Gd. IETE., SC C
Malhotra P L, M.Sc., Sc C
Marwah Raksha (Mrs.), B.Sc., TO A
Nakra D R, B.E., Sc C
Pandey V K, Ph. D., Sc C
Pasricha P K, Ph.D., Sc C
Prasad M V S N, M.Sc., Sc C
Raina M K, Ph.D., Sc C
Rajput S S, M.E., Sc C
Ramanamurty, Y V, D. Sc., Sc El
Rao B C N, Ph.D., Sc F
Rao M N M, Ph.D., Sc F
Reddy B M, D. Sc., Sc F
Risal Singh, Ph.D., Sc B
Sachdeva V P, M.Sc., Sc C
Saksena R C, Ph.D., Sc El
Sarkar S K. Ph.D., Sc C
Sarma SBSS. Ph.D., Sc El
Sharma M C, Ph.D., Sc C
Shastri S K (Mrs.), B.Sc., TO B
Singhal S K. M.Sc., Sc C
Srivastava B N, Ph.D., Sc El
Subrahmanyam P, M.Sc., Tech., Sc C
Tandel C B, M.Sc., Sc C
Tanwar R S, M.Sc., Sc A
Tewari D K, M.Sc., Sc C
Thomas John, M.Sc., Sc B
Tyagi T R, Ph.D., Sc El
Uppal G S, Ph.D., Sc El
Upreti U C, M.Sc., Sc C
Vashisht, A R S, Matric, TO A
Venkatachari R, Ph.D., Sc C
Vijaya Kumar P N, M.Sc., Sc C
Vohra V K, AMIE, Sc C
Zalpuri K S, Ph.D., Sc C

INFRASTRUCTURAL FACILITIES

LIBRARY

Dhawan S M, M. Lib. Sc., Sc El
Phull S K, M. Lib. Sc., Sc El
Sudarshan Kumar, M.Sc., Sc C

COMPUTER

Jain V C, M.A., Sc El
Raizada Sanjay M.C.A., Sc B
Sethi N K, M.Phil., Sc C

WORK SHOP

Anand J R, Ph.D., Sc El
Chhibber M K, B.A,. TO B
Dharam Chand, ITI., TO A
Ganpat Singh, ITI., TO A
Harish Chand, ITI., TO B
Kewal Krishan, ITI., TO A
Khanna R, Dip. Engg., TO B
Marwah T R, ITI., TO A
Nagpal M L, ITI., TO B
Poddar H N P, B.E., Sc C
Sarkar M L, B.E., Sc C
Sehgal M G. ITI., TO B

MECH. PROCESSING ACTIVITY

Anandani R C, B.E., Sc C
Gupta A K, Ph.D., Sc El

Malik I A, Dip. Engg., TO C
Sikand Rajiv, Dip. Engg., TOA
Singh H B, ITI., TO A

GLASS WORKSHOP

Biswas M K, Middle., TO C
Chandan Singh, W/man Ist Cl., TO B
Hans G S, Matric., TO A
Jusht M C, Matric., TO B
Kani Ram, Matric., TO A
Karnail Singh, Matric., TO A
Razdan D N, Prajna., TO A
Sen S S, Middle., TO C
Shashi Bhushan, F. Sc., TO B
Vashisht J P, Matric., TO B
Verma M L, Matric., TO B
Verma V P Matric., TO C

INSTRUMENTATION

Aftab Ahmed, M.A., TO C
Banaudha Inderjeet, B.Sc., TO C
Prabhakar A C, Dip. Engg., TO C
Sachdeva D S, Gd. IETE., TO A
Singh V R, Ph.D., Sc EI
Ved Singh, M.Sc., Sc C

PLANNING, LIAISON MONITORING

Arora G K, M.Sc., Sc EII
Bhakri S S, M.A., TO B
Govindaswamy G, M.B.A., Sc EI
Kapur S K, B.Ch.E., Sc EI
Khanduja R S, M.Sc. Engg., Sc EI
Khullar F C, M.A., Sc B
Kohli P K, M.A., TO C
Mandal S (Mrs.), M.Sc., Sc C
Sharma S K, M.Sc., Sc C
Tewari Indra (Mrs.), M.Sc., Sc B
Tomer T R, M.A., TO B

SERVICES

Dhama J S, M.A., TO A
Dhawan R C, B.Sc., TO C
Garg P K, Dip. Engg., TO B
Kapur S S, Dip. Engg., TO A
Krishnamurty K V, Dip. Engg., TO B
Kumar C S P, M.E., Sc EI
Sharma J C, AMIE., Sc B
Sharma S L, ITI., TO A
Singh R S, B.Sc., TO B

EMERITUS SCIENTISTS

Das S R, Ph.D.
Verma A R, Ph.D.

RESEARCH ASSOCIATES
POOL OFFICERS

Choubey D R, Ph.D.
Goswami S N N (Mrs.), Ph.D.
Gupta S K, Ph.D.
Keshav Kumar Ph. D.
Murugasan T, Ph.D.
Padam G K (Ms.), Ph.D.
Pandya Arun, Ph.D.
Rajinder Prasad, Ph.D.
Ramachandran R (Mrs.), Ph.D.
Reddy G S Ph.D.
Rout D K, Ph.D.
Sharma S K, Ph. D.

ADMINISTRATION
ACCOUNTS

Anil Kumar B. Sc., SO
Bhasin R K, B.A., SPA
Chopra B B. Matric., SPA
Gaira B S B.A., AOI
Jagdish Kumar, M.A., SPA
Joseph S A (Mrs.), H. Sec., SPA
Joshi B C, B.A., SFAO
Meni OP, H. Sec., SO
Nirmal Singh, B.A., SO (F & A)
Parasar Jitender M.A., SO
Pran Nath, Inter., SPA
Prem Singh, B. Com., Dy. SPO
Sardana J M, Inter, SPA
Santosh Kumar, M. Com., FAO
Sharma DV, Matric., SPA
Sharma M M, B.A., Sr. COA
Sharma R K, M.A., SO
Soni S S, Prabhakar., SO (F & A)
Tagra O P, ITI., TO C
Thakur U N, B.A., Dy. SPO
Vijay Kumar, P.G. Dip., Sec. Off.

PHYSICIAN (PART TIME)

Thakur Dr. Arvind, MBBS;

*Abroad
**Expired, Mar. 30.

RETIRED

Chander Mani, Tech. VI
Chopra OP, STA
Choudhary SP, Tech. VI
Das SC, Tech. VI
Daulat Ram, Tech. VI
Dhar RN, Sc EI
Diwan Singh, TOB
Ganapathy TV, TOC
Gupta SL, SPA
Hari Chand, Tech. VIII
Hari Singh, Tech. VI
Inder Bhan, TOC
Janak Ram, W/S Asstt.
Jaswant Singh, Tech. VIII
Joginder Singh, Sc EI
Kishan Chand, Asst.
Kishan Chand, STA
Mohd. Shafique, Tech. VI
Murari Lal, Tech. VI
Narain Singh, Tech. VI
Om Parkash, Tech. VI
Satya Parkash, Tech. VIII
Sengupta SK, TOC
Sri Kishan, Tech. II
Srinivasan TR, Tech. VIII
Taneja PN, TOC
Thakur Singeshwar, Tech. VI
Trilok Singh, Tech. VI
Verma BD, Asstt.

OBITURIES

1. Dr. Ram Parshad, former Assistant Director of NPL, passed away on June 11, 1989. Dr. Parshad joined NPL as a Scientific Officer in 1950 and retired in Jan. 1975 as Head of Electronics Division. He continued working in NPL and guiding research scholars till his death. Dr. Parshad had published about 200 research papers and had a number of patents. He contributed extensively in the areas of Ultrasonics, Semiconductors, Electronic Standards and Instrumentation.

2. EXPIRED during the year

Banerjee A, Sc EI
Jagdish Rai, W/S Asstt.
Matta VK, SRF
Rishalo, Helper B
Swamy PN, Tech. VI
Upadhya DC, Tech. VIII

AGE–WISE ANALYSIS OF NPL SCIENTISTS

(as on 1.4.90)

Age (Ys.)→ Category	25 30	30 35	35 40	40 45	45 50	50 55	55 60
B	2	7	6	3	4	–	–
C	–	19	61	52	24	16	4
E-I	–	–	3	19	17	23	15
E-II	–	–	–	–	1	2	8
F, G & Dir	–	–	–	–	2	4	7
Total (299)	2	26	70	74	48	45	34

- In the category of scientist B's, 68% are below the age of 40 years.
- In the case of scientist C's, 64% are in the age range of 35 to 45 years.
- In the case of E-I, scientists, 52% are in the range of 45-55 years and 28% below 45 years.
- Regarding senior scientists, E-II, 91% are above the age of 50 years.
- Considering the total scientists, grade B and above; 26% are above the age of 50 years, 41% are between the range of 40-50 years and 33% are below the age of 40 years.

STAFF STRENGTH
(as on 1.4.90)

Category	Grade	Number
SCIENTIFIC		
Group IV	Scientist B to Director	299
TECHNICAL		
Group III	Scientist A & Technical Officers A to C	97
Group III & II	Technician (II) to S.T.A.	493
Group I	Helper A to Workshop Asstt.	129
		1018
ADMINISTRATIVE		
	Officers	20
	Establishment	149
	Group D	107
		276
	TOTAL	**1294**

RAJBHASHA

Rajbhasha unit brought out quarterly magazine — Sameeksha Rashtriya Bhotik Prayogshala, which is based on scientific & technical articles. NPL At a Glimpse, NPL At a Glance and two other pamphlets regarding NPL's activities were also brought out in Hindi and distributed on the Open Day. Parliamentary official language committee visited NPL and appreciated the publications brought out and suggested that these publications be made more informative and popular. On Sept. 14, NPL celebrated the Hindi Diwas and all its employees were asked to do their official work in Hindi to the maximum possible extent.

During the year one officer was sent to attend the special Hindi workshop which was organised by the Rajbhasha Sansthan. Six other employees of the laboratory were also sent for training in noting and drafting in Hindi organised by the Ministry of Home Affairs, New Delhi. Arrangements have also been made to impart training to employees in Hindi typing and Hindi stenography.

NPL CLUB

The club has about 375 members on rolls. During the year the club arranged three excursions to Nainital, Vaishnodevi & Shimla in which many members participated with their families and enjoyed the trips. The club carrom team performed well during the year and won both Singles & Doubles in Inter—CSIR (Delhi) Tournament. The table tennis Doubles was also won by the club team in this tournament.

Smt. Santosh Arora won the women's T.T. Singles in 22nd Shanti Swarup Bhatnagar Memorial Tourament held at Dehradun in Dec. 1989. The club cricket team was the champion in Inter—CSIR (Delhi) Cricket. Tournament and maximum number of players were included in the CSIR Delhi cricket team.

ACADEMIC RESEARCH COOPERATION

A memorandum of understanding was signed between Birla Institute of Technology & Science, Pilani (BITS) and National Physical Laboratory, for promotion of academic and research interaction and cooperation between two institutes. Under the memorandum of understanding:-

1. BITS will operate an off-campus centre at NPL and operate a programme for research fellows and other employees of NPL for obtaining their M.S. and Ph.D. degrees from BITS.

2. NPL will extend facility, upto ten students of BITS each semester, for doing research work needed for their M.Sc/B.E. theses at NPL.

3. NPL will continue to extend facilities for two months Summer Practice School-I programme at NPL for six B.E./M.Sc./M.Sc. (Tech.) students of BITS every year.

A Coordination Committee has been formed to coordinate and monitor the programme. Director—NPL and Director — BITS are the Co-Chairmen.

IITD—NPL

A memorandum of understanding was also signed between IIT, Delhi and NPL for undertaking user oriented joint sponsored research and consultancy projects.

Both IITD and NPL, have agreed to exchange of staff through deputation on full-time/part-time basis for a limited period and upto one year at a time for purpose of implementation of joint tasks. The two Institutes agreed to share their important R & D facilities and to hold joint conferences/workshops/training courses in areas of mutual interest.

NPL agreed to provide training upto 10, IITD students per year and staff members or research fellows/research associates of NPL, upto No. 5, working on approved joint projects, may be registered for the Ph.D. degree at IIT, Delhi.

HONOURS AWARDS

Dr. Jayanta Kar was awarded the CSIR Young Scientist Award in Physical Sciences for the year 1989. Dr. Kar has made significant contributions in the area of planetary atmospheres, particularly on the ionosphere of Venus.

Dr. V.V. Shah, Dr. R. Bhattacharya, Dr. B.S. Verma, Dr. (Mrs) M. Kar and Sh. T.K. Bhattacharya were awarded Rs. 50,000 jointly by NRDC on their invention for the development of Space Qualified Multicavity Interference Filters.

Dr. Krishan Lal was elected Fellow of the National Academy of Sciences India, Allahabad.

Dr. R.B. Tripathi was awarded Raman Research Fellowship by CSIR to work at the AT & T Bell Laboratories, NJ, USA, for nine months.

Dr. Ravi Mehrotra was awarded Raman Research Fellowship by CSIR to work at the University of California, Santa Barbara, USA, for six months.

Dr. Risal Singh and Dr. P.K. Pasricha were chosen as the members of the IX Indian Antarctic Expedition

RESEARCH COUNCIL

Dr. R. Ramanna (upto Feb. 90) 402, 9th Cross, R.N. Nagar, Bangalore-560032.	Chairman
Prof. B.V. Sreekantan (Mar. 90 onwards) INSA Srinivasa Ramanujan Professor, Tata Instt. of Fundamental Research, Bombay-400 005.	
Prof. R. Vijayaraghavan, Physics Faculty, Tata Instt. of Fundamental Research, Bombay-400 005.	Member
Prof. A.B. Bhattacharya, Centre for Applied Research in Electronics, Indian Instt. of Technology, New Delhi-110016.	Member
Prof. M.K. Dasgupta Instt. of Radio Physics & Electronics, Acharya P.C. Road, Calcutta-700 027.	Member
Prof. D. Chakravorty, Indian Association for the Cultivation of Science, Jadavpur, Calcutta-700 032.	Member
Prof. R. Narasimha, Director, National Aeronautical Laboratory, Bangalore-560017.	Member
Dr. S.G. Patil, Director, Deptt. of Electronics, New Delhi-110 003.	Member
Sh. K.R. Parameswar, CII-128, Moti Bagh, New Delhi-110071.	Member
Director General, CSIR or his nominee	Member
Dr. S.K. Joshi, Director National Physical Laboratory, New Delhi-110 012.	Member
Sh. G.K. Arora, Scientist, NPL.	Non-Member Secty.

MANAGEMENT COUNCIL

Dr. S.K. Joshi, Director, National Physical Laboratory, New Delhi-110 012.	Chairman
Dr. K. Chandra, Scientist (Dir. Gd.), National Physical Laboratory, New Delhi.	Member
Dr. B.M. Reddy, Scientist, National Physical Laboratory, New Delhi.	Member
Dr. B.K. Das, Scientist, National Physical Laboratory, New Delhi.	Member
Dr. (Mrs.) D.R. Lakshmi, Scientist, National Physical Laboratory, New Delhi.	Member
Dr. A. Sengupta, Scientist, National Physical Laboratory, New Delhi	Member
Dr. S.S.S. Agarwala, Scientist, Central Electronics Engineering Research Institute, Pilani-333 031.	Member
Sr. Finance & Accounts Officer, National Physical Laboratory, New Delhi.	Member
Director General, Council of Scientific & Industrial Research, New Delhi-110 001. Or, his nominee.	Permanent Invitee
Sh. M.M. Sharma, Sr. Controller of Administration, National Physical Laboratory, New Delhi.	Member Secretary

SYMPOSIA WORKSHOP

An international Indo-Soviet symposium on Crystal Growth was organised from Oct. 17 to 20. It was also sponsored by INSA and Deptt. of Science & Technology.

An Indo-Japanese workshop on pitch & pitch based products was held from Nov. 22 to 23. It was sponsored by the Indian Carbon Society.

An Indo-French school on Electron Microscopy in Materials Science was organised from Jan. 15 to 25. It was sponsored by INSA, DRDO, DST, DOE, DNES, French Academy of Sciences and CNRS.

An Indo-Soviet workshop on Electronic Materials was held from Jan. 17 to 19.

The fifth international symposium on Acoustic Remote Sensing of Atmosphere & Oceans was organised from Feb. 6 to 9. This was sponsored by ICTP (Italy), CSIR, DST, DOEN, DOE, AEC, ISRO, DOD, INSA, NAL, NIO, IITM, BIS, CPCB and DRDO.

A workshop on Awareness of Rapid Advances in Science & Technology (ARAST-2) was held from Feb. 19 to 24. It was organised by Commonwealth Science Council, London.

A workshop on Under-water Acoustic Measurement Requirements and Facility was organised on Aug. 18.

A national symposium on Ultrasonics was organised from Sept. 21 to 22.

TRAINING

A five-week training programme was organised in the area of legal metrology, for four foreign students from Indonesia and Tanzania in April-May. Similar training programme of one month was also organised for seven trainees from Kenya, Trinidad, Tobago, Zambia and Uganda in Sept.-Oct. The trainees were sponsored by the Deptt. of Weights and Measures, Ministry of Food & Civil Supplies.

Two scientists of CGCRI, Calcutta and NML, Jamshedpur were trained for one month in May-June, under CSIR-BITS Orientation Training Programme.

The officers of Weights & Measures Deptt., Govt. of Gujarat, received one week training in July.

A number of delegates from Bureau of Indian Standards were trained in calibration techniques from Sept. 11-27.

Training on establishment of triple point of water, was provided to representatives of M/s IDEMI, Bombay.

A representative of licensee, M/s Haryana State Electronics Development Corpn., Chandigarh, was trained in the fabrication of Thin Film Optical Coatings for which the know-how was transfered earlier.

Training was provided to two students of Motilal Nehru Engineering College, in the area of ultrasonic field characterization and to two students of H.B.T.I. Kanpur, in the area of transducer evaluation at high electric drives.

Three students of Sri Sidartha Institute of Technology, Marlur, Tumkur completed their practical training.

In addition a number of students and persons from other institutions received training at NPL in different areas of work.

NPL—TWENTY YEARS BACK

(from the Annual Report 1969–70)

DIRECTOR	Dr. A.R. Verma
MANPOWER	
No. of Scientists and technical officers	123
Total staff	951
EXPENDITURE	Rs. 91.04 Lakhs

SCIENTIFIC HIGHLIGHTS

Standards of 15 physical quantities were being maintained to internationally comparable accuracies. Major applied research projects in progress were—Professional Ferrites, Carbon Products, Electrostatic Photocopying Machine, Polycrysatlline Silicon, Microwave Components, He–Ne laser, Satellite Radio Beacon studies, Riometers, Rocket studies of lower ionosphere. Satellite transmissions of Explorer—22 were recorded.

The sponsored projects initiated were regarding the development of Silver Graphite Contacts and Colour Coating of sun glasses. The process for making thin film monitor and controller was passed on to NRDC for commercial exploitation. A set of equipment for testing 5,000 clinical thermometers in one shift was developed and supplied to ISI.

The year was very significant and quite a few applied research projects were completed, tried on the pilot plant scale or batch production scale and released to industry.

Prof. G.N. Ramachandran delivered the Krishnan Memorial Lecture on "Molecular Biophysics & Crystallography".

ANTARCTIC EXPEDITION

Mr. R. Ravindra of Geological Survey of India led the IX Indian scientific Antarctic Expedition which sailed from Goa on Nov. 30, 1989. Dr. Risal Singh and Dr. P.K. Pasricha represented NPL. The NPL scientists conducted following experiments enroute to Antarctica, at Maitri and Dakshin Gangotri:-

Atmospheric aerosol studies and ozone hole studies through solar UV-B radiation measurements. Studies of earth surface aerosols, sea surface water and minor constituents of air geographical locations.

OPEN DAY

NPL observed Open Day on Sept. 27, 1989 on the occasion of CSIR Foundation Day. The laboratory was kept open for the students and public. The students numbering about 4,000, of various schools and colleges of Delhi visited the laboratory. They were shown the activities of Standards, Superconductivity, Materials and Characterization. Special audio-visual programmes and scientific films were shown on this day. An exhibition and display of various activities was arranged. Mementos were also presented to the staff members who had completed 30 years of service. CSIR Foundation Day and essay competition awards were presented to the students by Dr. S.K. Joshi, Director NPL.

The exhibition of rare photographs of Pt. Jawaharlal Nehru was also arranged specially to celebrate the centenary year. Shri K.R. Narayanan, Minister of State for Science & Technology and Vice-President, CSIR, delivered the Jawaharlal Nehru Centenary Lecture "Jawaharlal Nehru and the promotion of scientific temper in Indian Society". Dr. A.P. Mitra, Director General, CSIR, presided over the function.

VISITORS

1. Batllogg B Dr; AT & T Bell Laboratories, N.J. USA; Jan 18.
2. Bialy Juliusz; Polish Ambassador to India; July 31.
3. Carpenter B Stephen Dr; Director, International Relations, NIST, USA; Feb 27.
4. Chandrasekhar BS Dr; Walther Meissner Inst., FRG; Jan 25.
5. Chandrasekhar S Prof; LASR, University of Chicago, USA; Nov 29.
6. Chivers RC Dr; University of Surrey, UK; Nov 27-Dec 8.
7. Das TP Prof; Deptt. of Physics, State University of New York, USA; June 20.
8. Guinier A Prof; French Academy of Sciences, Paris; Nov 17.
9. Heydemann Peter Dr; Science Counsellor, USA Embassy, New Delhi; Nov 24.
10. Huu Dang Prof; Chairman, State Committee for S & T, Socialist Rep. of Vietnam; April 18.
11. ISAKOV Victor; USSR Ambassador to India; Jan 30.
12. Jager C de Prof; Royal Netherlands Academy of Sciences, Amsterdam; Nov. 17.
13. Kang Hong Yol Dr; Chairman, Programme Development & Review Committee, International Department, Korea; April 17.
14. Lee Moo Nam Dr; Head International Department, Korea; April 17.
15. Li Baogue Dr; With delegation from China State Bureau of Technical Supervision; Nov. 3.
16. Maeda H Dr; National Research Inst. of Metals, Tsukuba, Japan; Jan 16.
17. Miyakawa H; Director, Agency of Industrial Science and Technology. Tokyo, with delegation; Mar 19.
18. Nagakura S Prof; Graduate University of Advanced Studies, Yokahama, Japan; Oct 4.
19. Ramsey Norman Prof; Harvard University, USA; Sept 1.
20. Rath BB Dr; Associate Director, Office of the Naval Research, USA; Nov 24.
21. Saalfeld Fred E Dr; Director, Office of the Naval Research, USA; Nov 24.
22. Smith BV Dr; University of Birmingham, UK; April 10-29.
23. Taillendier JFS Dr; CNRS, France with delegation, Jan 1.
24. Tanaka Y Dr; National Research Inst. of Metals, Tsukuba, Japan; Jan 16.
25. Thung Ho Si Prof; Vice-President, NCSR, Vietnam; Aug 4.
26. Urbanek Adam Dr; Inst. of Palaeobiology, Polish Academy of Sciences; Nov 17.
27. Wali KC Prof; Syracuse University, USA; Nov 17.
28. Zahuranec Bernard J Dr; Scientific Officer, Office of Naval Research, USA; Nov 24.

ABBREVIATIONS USED

AEC	– Atomic Energy Commission
ARDB	– Aeronautical Research Development Board
BHEL	– Bharat Heavy Electricals Ltd.
BIS	– Bureau of Indian Standards
CECRI	– Central Electrochemical Research Institute
CEERI	– Central Electronics Engineering Research Institute
CEL	– Central Electronics Ltd.
CGCRI	– Central Glass & Ceramic Research Institute
CMERI	– Central Mechanical Engineering Research Institute
CPCB	– Central Pollution Control Board
CRRI	– Central Road Research Institute
CSIR	– Council of Scientific & Industrial Research
DNES	– Department of Non-Conventional Energy Sources
DOD	– Department of Ocean Development
DOE	– Department of Electronics
DOEN	– Department of Environment
DRDL	– Defence Research Development Laboratory
DRDO	– Defence Research Development Organisation
DST	– Department of Science & Technology
HBTI	– Harcourt Butler Technological Institute
IACS	– Indian Association for Cultivation of Science
IARI	– Indian Agricultural Research Institute
ICTP	– International Centre for Theoretical Physics
IGCAR	– Indira Gandhi Centre of Atomic Research
IMAP	– Indian Middle Atmosphere Programme
IIP	– Indian Institute Of Petroleum
IIT	– Indian Institute of Technology
INSA	– Indian National Science Academy
ISRO	– Indian Space Research Organisation
ITRC	– Industrial Toxicology Research Centre
MST	– Mesospheric, Stratospheric & Tropospheric
NALCO	– National Aluminium Company Ltd.
NAL	– National Aeronautical Laboratory
NCL	– National Chemical Laboratory
NEERI	– National Environmental Engineering Research Institute
NIO	– National Institute of Oceanography
NMDC	– National Mineral Development Corporation
NML	– National Metallurgical Laboratory
NTPC	– National Thermal Power Corporation
RRL	– Regional Research Laboratory
RPA	– Retarding Potential Analyser
SAC	– Space Application Centre
SSPL	– Solid State Physics Laboratory
TERLS	– Thumba Equatorial Rocket Launching Station

Prof. S. Chandrasekhar who delivered the Krishnan Memorial Lecture with Dr. S.K. Joshi and Dr. A.P. Mitra.

NPL scientists performing an experiment at Maitri, Antarctica.

A view of Open Day in the lawns of NPL.