NPL REPORT 1975

NATIONAL PHYSICAL LABORATORY
Hillside Road, New Delhi

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CONTENTS

DIVISION OF STANDARDS

STANDARDS

One of the important objectives of the Laboratory is the establishment, maintenance and up-dating of the national standards of physical measurements at internationally accepted accuracies. This activity, which is a statutory obligation, demands continuous research on standards and on techniques of measurements, utilizing latest techniques, very close to the frontiers of knowledge.

The report presents the activities on the following standards :

(i) Length standards ;
(ii) Mass standards ;
(iii) Photometric and radiometric standards ;
(iv) Temperature standards ;
(v) Low pressure and high pressure standards ;
(vi) Force standard ;
(vii) Acoustical standards ;
(viii) Time and Frequency standards ; and
(ix) Electrical and electronic standards.

CALIBRATION & TESTING

Another objective of the Laboratory attended to by this Division is the periodic calibration of standards of measuring instruments and equipment used by various governmental and other testing authorities, industries, Defence, etc., against the national standards, and supply of standards to various agencies, to ensure uniform scientific, industrial and commercial measurements. As a corollary to this, the Division also undertakes the calibration of instruments and testing of industrial products and appliances for performance, life, and for effect of environmental conditions.

The report presents this activity under the following categories :

(i) Length metrology ;
(ii) Mass, volume & hydrometers ;
(iii) Photometry, colorimetry and radiometry ;
(iv) Heat ;

(v) Low pressure and high pressure ;

(vi) Engineering materials ;

(vii) Acoustics ;

(viii) DC calibration ;

(ix) AC and high frequency calibration ;

(x) Microwave calibration & testing ; and

(xi) Test and Evaluation Centre for electronic and electrical equipment & components.

1. STANDARDS

1.1 LENGTH STANDARDS

Scope and Objectives

(i) Maintenance and upgrading of the standard of length and its utilisation for standardization and for other precision linear measurements ; and

(ii) Research on improvement of the standard and development of instruments and techniques for precision measurement of length.

The existing standard of length at the NPL is the National Prototype Metre which is a copy of the International Prototype Metre.

The technical objectives are :

(1) Periodic calibration of the Laboratory Standard Metres against the National Prototype Metre ;

(2) Development of iodine absorption stabilised He-Ne lasers and installation of Kr^{86} lamp for use as primary standards ;

(3) Development of laser frequency inter-comparison system for maintenance of the standards by frequency stability determination ;

(4) Development and calibration of He-Ne lasers stabilized at the peak of the power output curve for use as transfer standard ;

(5) Development of an interference comparator and other measuring systems for standardization of gauges in terms of the wavelengths of laser and Kr^{86} radiations ; and

(6) Development of longitudinal comparator.

Progress

One Laboratory Standard Metre bar was recalibrated against the National Prototype Metre. The new calibration values agreed to within the measurement precision of 0.5 μm with the earlier calibration.

A holographic kit was developed as a project sponsored by a private firm. The commercial production of the kit was also started during the year.

Work was completed on holographic interferometry with wave-front shear, and a method of double-focus holographic interferometry was developed. This is expected to find applications in wind tunnels and other gas flow measurements. Attempts were made to use the three-beam holographic technique for strain analysis.

Research was continued on the effect of laser radiation field on life time of excited Ne atoms.

1.2 MASS STANDARDS

Scope and Objectives

(i) Design and fabrication of 1 kg balances (including interchangeable pan balance) for the comparison of 1 kg standards against the National Prototype Kilogram with precision commensurate with the internationally accepted accuracies ;

(ii) Design and fabrication of weights in multiples and sub-multiples of 1 kg, and to establish their values in terms of the National Prototype Kilogram ;

(iii) Intercomparison of the NPL 1 kg standards against the standards of other nations ; and

(iv) Design and fabrication of other high precision balances and to conduct research pertaining to weighing designs and development of standards of unit of mass.

Progress

1 kg Interchangeable Pan Balance : The machined and cast parts like beam, carriage and pans were given a fine finish. In addition, the base for interchange-mechanism and some small parts of the balance were made.

1 kg Modified Balance : A 2 kg capacity Oertling balance, with initial sensitivity of 1 mg per division was under modification. During the period under report, the weight changer, and release & arrest mechanism were motorised, and with this, the balance gave more consistent performance over the manual operation. A new weight changer was also designed to improve upon the performance of the existing one. Fabrication of the weight changer according to the new design was started in the NPL workshop.

Fabrication of Standard Weights : A number of observations of mass values of eight experimental weights made from nickel-free stainless steel obtained from NML Jamshedpur, were made to study the suitability of the material over long period of use. Six 20g experimental weights were made from Niomonic-75 nickel-chormium alloy supplied by DMRL, Hyderabad, and values of their masses were obtained.

Recalibration of Standard Weights : Five sets of NPL Standard Weights (consisting of 100 g to 1 mg) were recalibrated.

1.3 PHOTOMETRIC & RADIOMETRIC STANDARDS

Scope and Objectives

Establishment and maintenance of scales for luminous intensity, luminous flux, colour temperature and reflectance standards.

The main objective is to bring all photometric, colorimetric and radiometric measures under a consistent measurement system, traceable to the national standards maintained at the NPL.

Secondary standards of light in the form of incandescent lamps calibrated by the BIPM are maintained and intercompared among themselves as well as against standards from other national laboratories for luminous intensity (candela) and luminous flux (lumen) to an accuracy of about 2-3%. Another set of lamps maintains the colour temperature scale.

Progress

Preparation of working standards and laboratory standards of luminous intensity, luminous flux, and colour temperature was continued.

The double-sphere method for measurement of absolute reflectance was tried. Results obtained were within an accuracy of 2%.

An equipment was set up for transfer of spectral irradiance from international standards to reference working standards.

1.4 TEMPERATURE STANDARDS

Scope and Objectives

To realise the International Practical Temperature Scale 1968, or as it may stand amended under the authority of the General Conference on Weights and Measurures, Sèvres, France, for ensuring uniformity in temperature measurement in science and industry.

Progress

Platinum Resistance Thermometry (Temp. Range 630° C to −259° C)

Some new stem-type platinum resistance thermometers were fabricated. These, alongwith the previous set of platinum resistance thermometers, were calibrated or recalibrated at the fixed points of triple point of water, boiling point of water and freezing point/melting point of zinc.

Thermo-couple Thermometry (Temp. Range 630° C to 1064° C)

Maintenance and recalibration of the existing set of standard Pt—Pt 10%Rh thermo-couples was the main activity during the year. A furnace with a platinum wire heater was fabricated for calibrating these thermocouples above 1064° C upto 1400° C.

Maintenance of the optical pyrometer was one of the activities during the year. Fabrication work of the optical system of the photo-electric pyrometer was also carried out.

1.5 LOW PRESSURE AND HIGH PRESSURE STANDARDS

Scope and Objectives

The emphasis, for the present, has mainly been on the establishment, maintenance and updating of standards for low pressures from one atmosphere down to 10^{-8} torr. Development of vacuum instruments and systems with a view to helping the vacuum instruments industry in upgrading the quality of their instruments is another activity. Scientific research in surface science and in allied fields forms another major objective of this activity.

Progress

During the period under report, the maintenance and improvement of the standard Mcleod gauge to serve as a primary standard of pressure in the range 10^{-3} to 10^{-6} torr, formed a major activity. This gauge uses variable compression technique and corrects for capillary depression error. It also ensures that there are no sorption errors in the system. The Ishi & Nakayama effects, and errors due to thermal transpiration were also eliminated. The accuracy of this system is $\pm 2\%$, and it is capable of achieving an ultimate vacuum $\sim 10^{-7}$ torr after necessary baking for a few hours. Except for the measuring gauge, all the components used in this system are from indigenous sources.

As the bakeable Mcleod gauge has some inherent disadvantages, and a large number of precautions have to be taken while using the same, preliminary investigations were undertaken on the fabrication of a dynamic system using the orifice method.

Oil Manometer : A compact oil manometer providing a continuous reading range from 10 to 10^{-2} torr was designed and developed. The readings of this manometer are comparable with Mcleod gauge having sensitivity of 1.4×10^5mm/torr for 1 mm length of mercury. The method of deairation of oil under vacuum was used to eliminate errors as a result of the difference in the density of the oil in the two columns of the manometer.

Vacuum System for Scanning Electron Microscope : For development of a scanning electron microscope—an inter-institutional project identified by the Coordination Council for the Physical & Earth Sciences Group of CSIR Laboratories—work was initiated on the design of a high vacuum system capable of producing a vacuum of 10^{-6} torr.

Vacuum Components : Two-way metal vacuum valves, and manually operated quarter-swing valves were developed.

Silver-impregnated Graphite Contacts for Relays : Silver-impreguated graphite contacts for relays developed earlier for use in railways, underwent life tests under actual operating conditions, and the feedback on these tests was studied for making necessary improvements in them.

1.6 FORCE STANDARD

In order to verify material testing machines, force measuring instruments are required. These proving devices are to be calibrated at regular intervals.

The Laboratory maintains the unit of force 'Newton' to an accuracy of 4 in 10^5. A 3,000 kgf dead-weight machine designed and developed at the Laboratory is used to calibrate force measuring devices for the industry and various R & D and other organisations.

For proving devices of higher capacities, work on modification of a universal testing machine for calibration of devices at various steps of load upto 20,000 kgf, with an accuracy of 0.1%, using a hydraulic multiplication system of approximately 1 : 100, was pursued.

Work on the development of a calibrating machine for calibration of force measuring devices upto a capacity of 100,000 kgf (1 MN), by hydraulic multiplication was also started, and the main cylinder-piston assembly with facility for rotating the cylinder was fabricated. A test frame for testing the cylinder was also made.

1.7 ACOUSTICAL STANDARDS

Scope and Objectives

To maintain primary/derived standards relating to measurements in acoustics such as sound pressure, vibration acceleration and displacement, hearing thresholds for air and bone conduction, and audio frequency voltage.

Fig 1

Arrangement for measuring sound absorption coefficient of a sample material (on the floor), by the reverberation method. The sound diffusers, as also an omnidirectional loudspeaker, are seen suspended from the ceiling to give random diffusion of sound in the room as required by International Specifications governing such measurements. The reverberation room can also be used for measurement of sound power output of ma chines, calibration of microphones under diffuse field conditions, psychoacoustic measurements etc.

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Progress

Laboratory standard accelerometers were checked for sensitivity, by inter-comparison.

Standard replay chain for calibration of magnetic recording tapes and magnetic tape recorders working at 19 cm/s tape-speed was re-checked.

The reverberation room of the Acoustics Block was fully commissioned. *(Fig 1)*. The room is designed to meet the ISO recommendations in this regard. Measurements on the diffuseness of reverberation room were carried out in the empty room and with higher absorbing sample on one surface. It was found that with the suspended diffusing plates, the diffuseness was adequate in the frequency range 100—4500 Hz even with a highly absorbing sample in the room.

Work of lining anechoic room with absorbing wedges was continued. The ceiling and all side-walls down to the false floor level were completely lined.

1.8 TIME AND FREQUENCY STANDARDS

Scope and Objectives

Updating and maintaining the base units of time and frequency, and disseminating standard time and frequency signals to the nation and the neighbouring countries, constitute the objectives of this activity. The aim is to have standard time and frequency broadcast round the clock at different frequencies increase the accuracy of transmission, and develop atomic time standards.

Progress

Rubidium Vapour Atomic Standards : The NPL, in collaboration with the Advanced Centre of Electronics Systems, IIT, Kanpur, undertook the development of a laboratory model rubidium gas cell frequency standard, where light of wave-length 7947Å from Rb^{87} source filtered by Rb^{85} vapour filter cell causes pumping of the atoms out of F=1 *hf* level of the Rb^{87} in the absorption cell. The operation of a rubidium standard is based on a hyperfine transition in Rb^{87} gas.

The Rb-frequency standard *Optical Unit* consists of magnetically shielded region with a Rb^{87} lamp with oscillator, Rb^{85} vapour filter cell, and a microwave cavity with Rb^{87} vapour absorption cell placed inside it.

Magnetic Shield : The magnetic shield consisting of one outer netic and three inner co-netic cylinders, was developed. The co-netic cylinders are used as linear shield because of their high attenuation characteristics. Outer netic cylinder has only medium attenuation but does not saturate as easily as co-netic. Listing from the inner cylinder

to the outer, the diameters made were 12, 15, 17 and 20 cm and their respective lengths were 33, 35, 37 and 42 cm. The space between the shielding cylinders was filled with glass wool. This measure avoids conductive cooling and vibration. The ends of the shielding cylinders were covered with caps of the same shielding material. The only openings in the outer magnetic shield left were those for the wires of the necessary supply and control voltages, and a small hole to provide access to the tuning shaft of the microwave cavity.

Rb^{87} Lamp : The lamp consisting of a bulb blown from pyrex tubing to a diameter of 1 cm, with wall thickness of 0.1 mm, was made. The bulb was filled with Rb metal and noble gas at 5 torr. The use of this noble gas lowers the striking potential for the lamp. The lamp is excited by a 100 MHz oscillator.

Filter Cell : A cylindrical bulb was filled with Rb^{85} and argon buffer gas at 50 torr for use as a filter cell. Addition of the buffer gas to the filter cell broadens and shifts the Rb^{85} absorption lines, resulting in an improved filtering effect.

A test bench, for testing various components like rubidium lamp, absorption cell, photo-detector etc., was fabricated. It uses Zeeman pumping principle where magnetic field and radio frequency field applied to the absorption cell are tuned to the proper resonance line.

Time & Frequency Dissemination Service : Since May 1974, the transmission of standard time and frequency signals by the NPL, under the call sign ATA, from its 10 MHz transmitter at Greater Kailash, has been directly based on cesium atomic clock housed at the monitoring station at the NPL main building. From 1 January 1975, the transmission time for these signals was increased from 4 to 6 hours per day on all working days, and in August 1975, a more powerful transmitter (8 kW peak envelope power) was installed in place of the original one (2 kW peak envelope power) at the frequency of 10 MHz. During the period under report, the entire tube electronics of ATA was changed with integrated circuit electronics. This resulted not only in reliability and ease of operation & maintenance, but also the replacement of the cumbersome 240 V battery system with only two 12-volt batteries for continuous uninterrupted operation of ATA time units.

HF Monitoring : So far monitoring at the NPL was done only at high frequency, and the stations tracked were, besides ATA itself, JJY (Japan), RKW and RWM (USSR); WWV and WWVH (USA) etc. A considerable accuracy was achieved in monitoring these stations, and an epoch time to within a milli-second was easily realised. The improvement was possible due to the use of time interval counters and externally triggered dual-trace or dual-beam oscilloscopes.

1.9 ELECTRICAL AND ELECTRONIC STANDARDS

Scope

The programme on establishment, maintenance and updating of the primary & transfer standards of various parameters such as voltage, current, power, attenuation, impedance, frequency, noise etc. covering DC, AC, high frequency and microwave ranges, constituted an area of thrust during the year. A ten-year programme of work giving details of the accuracies to be achieved, list of equipment with specifications, staff, environmental conditions etc., to be completed in two phases of 5 years each, was drawn up.

1.9.1 Standards of DC Voltage and Resistance

Objective

Realization of the national standard of electric current [ampere] by maintaining the national standards of electromotive force [volt] and electrical resistance [ohm]. This is achieved through :

(i) Mutual inter-comparison of emfs of the national bank of stable Weston cadmium cells by measuring their differences with a vernier potentiometer, to a precision of 1 part in 10^6 ; and

(ii) Mutual inter-comparison of resistances of the national bank of standard resistors by substitution method, and measuring their differences using modified Wheatstone shunt bridge housed in the same oil bath as the one containing the 1 ohm standard resistors, to an accuracy of 5 parts in 10^7.

These standards are internationally cross-checked from time to time to ensure their accuracies.

Progress

Inter-comparison of the national bank of thirty-five standard cells by measuring the differences of their emfs was carried out. Inter-comparison of the national bank of twelve one-ohm standard resistors was also undertaken.

1.9.2 Realization of the Unit of DC Voltage through Josephson Effect

Objective

To undertake work on Josephson Effect for realization of the unit of DC voltage, following the international trend.

Progress

Solder-blob junctions were studied in detail for their DC characteristics and for radiation effects of microwaves at liquid helium temperatures. These junctions were also studied for the temperature-dependence of their critical currents.

Solder-blob junctions were irradiated with microwave frequencies (10 GHz) at various power levels from 0 to 80 mW. Microwave induced steps super-imposed on the I-V characteristics were seen clearly. Critical currents varied with power. These experiments showed promise for the realization of the Josephson voltage standard.

This work pertains to the group working on Josephson tunnelling. (*See* Section 2.8 on page 42).

1.9.3 AC & High Frequency Standards

Objective

Development, maintenance and up-dating of AC and high frequency standards for electrical parameters like voltage, current, power, attenuation, impedance, frequency and noise etc. in the frequency range 30 Hz to 1000 MHz.

Progress

The universal electro-dynamometer based on AC/DC substitution technique for measurement of voltage, current, and power at a frequency of 50 Hz was made operational. The voltage range of the experimental set-up for AC & high frequency voltage measurements was extended to cover 100mV-30V, depending upon the frequency of operation in the frequency range 100 Hz to 100 MHz. This set-up employing a set of thermal converters can be used to measure AC current (20A) upto 1 MHz, utilising the AC/DC substitution method. The accuracy of voltage measurement was also improved to lie between 0.1% to 1.5%, depending upon the voltage range and the frequency of operation. Work was also started on the indigenous development of a set of thermal voltage converters (100mV-100V) for being used as working standards in the frequency range 100 Hz to 10 MHz.

The AC/DC substitution technique to improve the measurement accuracy of RF power (10μW-10mW) in the frequency range 10 MHz-1 GHz was also set up. The power measurement can be made with an accuracy of the order of $\pm$ 1% in the entire frequency range.

Objective

Development, maintenance, and up-dating of the standards of measurement for microwave attenuation, power, impedance, frequency and noise.

Progress

Microwave Attenuation : Work was continued on microwave attenuation measurement using sub-carrier IF technique based on 30 MHz WBCO standard attenuator *(Fig 2)*. The over-all accuracy of the system was estimated to be 0.05 db per 10 db in the range 0 to 60 db. Work on audio substitution technique was also started.

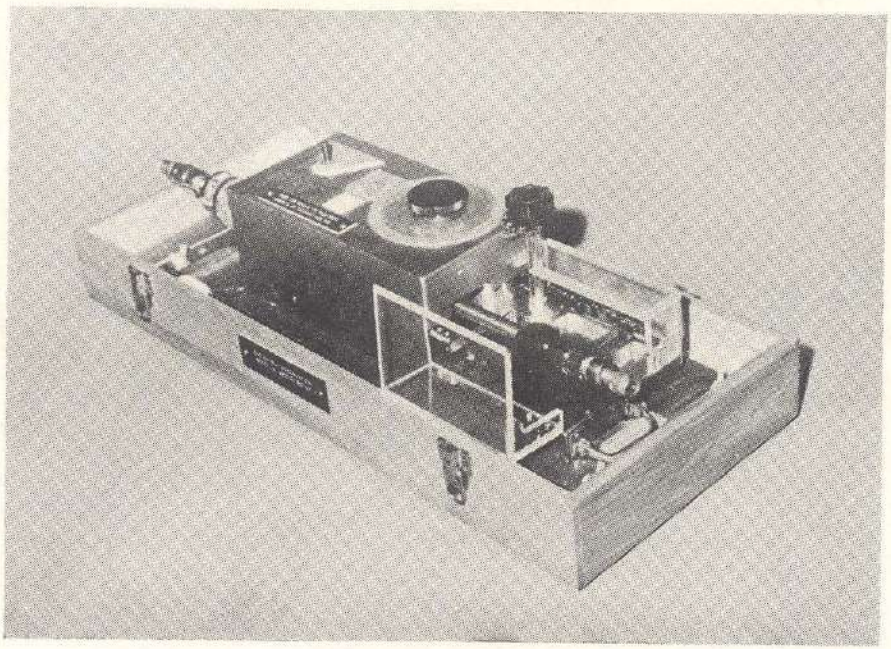


Fig 2 30 MHz Waveguide Below Cut-Off Standard attenuator.

Microwave Power : The work was continued to improve the accuracy of power measurement in X-band from 2% to 1%, using a DC self-balancing bridge procured from the NBS, USA.

Microwave Impedance : The standard reflectometer technique for measurement of return loss was investigated. An accuracy of return loss measurement of 0.1 db per 10 db for return loss range upto 40 db was established. Perfect $\lambda/4$ short circuits for several frequencies in the X-band were designed.

2. CALIBRATION & TESTING

2.1 LENGTH METROLOGY

Scope and Objectives

(i) Calibration of precision engineering gauges for linear, thread and angle measurement ;

(ii) Testing of measuring instruments, equipment, tools and materials for linear dimensions (length, angle, straightness, flatness, etc.) including prototype testing ;

(iii) Development of methods and instruments for calibration and testing ; and

(iv) Calibration and certification of standard length measures for the Directorate of Weights and Measures.

Facilities exist for making linear measurements to the accuracies detailed below :

(a) Line standards upto 1 metre length with precision of 0.5 μm ;

(b) End standards upto 4 metre length with precision of 1 μm per metre ;

(c) Length of smaller gauges upto 100 mm (silp gauges) in terms of wavelength of Hg^{198} radiations with accuracies ranging from ± 0.03 μm to ± 0.1 μm ;

(d) Testing of surface plates and straight edges for flatness in sizes of 100×100 mm^2 to 1000×1000 mm^2 as per standard specifications ;

(e) Various dimensional measurements including thread measurements involving precision finer than 0.01 mm ; and

(f) Angle measurement with precision of 1".

Progress

Test and calibration of secondary length standards, various types of engineering gauges and other products was undertaken. 575 test reports were issued during the year 1975-76 and about Rs. 31,000 were realized as test fee. Design of a comparator for measurement of sub-divisions of a metre bar was made.

2.2 MASS, VOLUME AND HYDROMETERS

Scope and Objectives

(i) Testing and calibration of (a) precision weights including standards for Weights & Measures Enforcement Departments of the country, (b) volumetric glassware, (c) hydrometers of various types, and (d) butyrometers ;

(ii) Testing of balances and weighing machines ;

(iii) Supply of authenticated copies of standards of mass to the industry, research institutions and to the Department of Legal Metrology; and

(iv) Supply of standard measures of capacity to the state departments for enforcement of weights and measures.

Progress

236 test reports were issued during the year 1975-76, and about Rs. 27,000 were realized as test fee.

2.3 PHOTOMETRY, COLORIMETRY AND RADIOMETRY

Scope and Objectives

(i) Testing and calibration of lamps, luminaires, materials for light and colour control, optical instruments, systems and components, photometric instruments etc. ;

(ii) Measurement of optical properties of materials, viz. colour, spectral reflectance and transmittance, optical density, opacity etc. ; and

(iii) Supply of NPL-made integrating spheres.

Progress

During the year 1975-76, 149 test reports were issued and an amount of Rs. 76,000 was realized as test fee.

2.4 HEAT

Scope and Objectives

(i) Testing and calibration of platinum resistance thermometers, thermocouples, optical pyrometers, and mercury-in-glass thermometers ;

(ii) Study of the thermal properties of materials ; and

(iii) Testing of domestic refrigerators and refrigeration appliances.

Progress

During the year 1975-76, about 150 test reports were issued and an amount of about Rs. 23,000 was realized as test fee. Also transfer

standard platinum resistance thermometers were constructed and supplied to the Instrumentation Ltd., Kota.

2.5 LOW PRESSURE AND HIGH PRESSURE

Scope and Objectives

(i) To set up calibration facilities for various types of pressure/vacuum gauges for the ranges (i) 760 torr to 1 torr, (ii) 1 torr to 10^{-2} torr, and (iii) 10^{-2} torr to 10^{-6} torr ; and

(ii) To test the performance characteristics of vapour diffusion pumps and oil rotary pumps according to ISO and ISI specifications.

Progress

A system for studying diffusion pump speed, ultimate vacuum, and other characteristics by the conductance method as per ISO and ISI specifications was designed and fabricated.

The system designed earlier for testing of characteristics of rotary pumps as per ISO and ISI specifications was standardized upto capacities ranging from 15 l/min to 1000 l/min.

2.6 ENGINEERING MATERIALS

The following testing facilities for engineering materials exist at the Laboratory :

(i) Tensile strength measurement, compression tests on metals and concrete cubes, plotting stress strain curves (Maximum load — 100,000 kgf) ;

(ii) Hardness tests — Rockwell, Brinell & Vickers Pyramid — on metals ;

(iii) Bend test ;

(iv) Izod and Charpy impact test ;

(v) Torsion test on wires upto about 4 mm diameter ;

(vi) Transverse tests ;

(vii) Load tests on materials handling machines, e.g. jacks, hoists, chain pulley blocks etc. ; and

(viii) Calibration of proving rings, universal testing machines, impact testing machines and hardness testing machines.

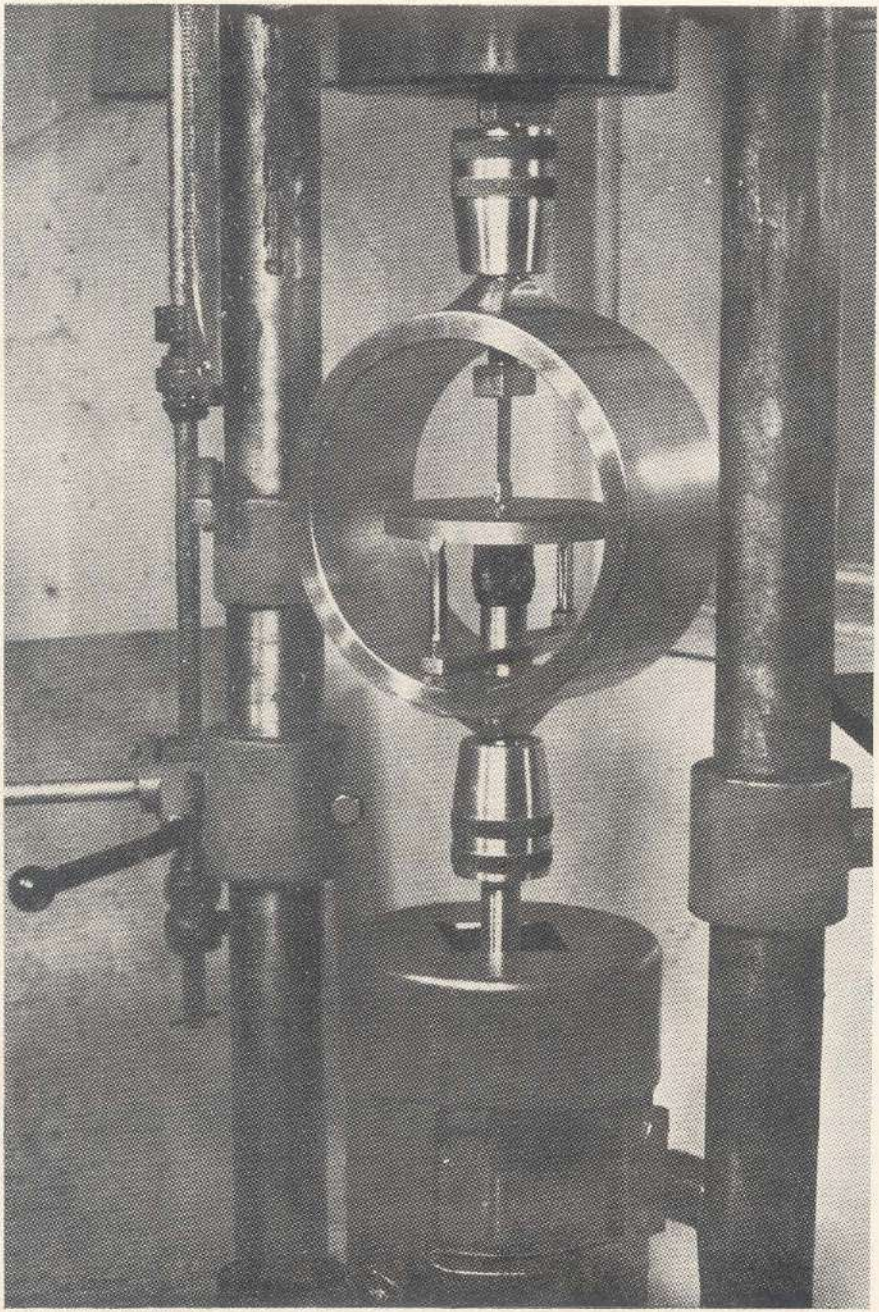


Fig 3 Verification of a universal testing machine using a calibrated proving ring.

Fig 3 shows verification of a universal testing machine using a calibrated proving ring.

Progress

About 380 test reports were issued to outside parties and an amount of about Rs 68,000/- was realized as test fee during the year 1975-76.

2.7 ACOUSTICS

Scope and Objectives

(i) To calibrate instruments used for acoustic and electro-acoustic measurements in terms of the acoustical standards ;

(ii) Testing of acoustic and electro-acoustic devices and materials for their performance characteristics and properties, to measure noise produced by machines, and to check complete electro-acoustic systems and acoustic performance characteristics of auditoria ;

(iii) Rendering advice on problems of noise reduction, acoustic design and treatment of auditoria, hearing protection etc. ; and

(iv) Investigating specific problems arising out of the work done in standardization, calibration, testing and consultancy.

Facilities exist for testing items like motion picture projectors, magnetic recording tapes, audiometers, hearing aids, ear defenders, automobile horns, electric sirens, sound absorbing materials, sound insulating materials, tuning forks, vibration generators, sound level indicators, tachometers, ultrasonic therapy units, loudspeakers, microphones, amplifiers, sound reproducing equipment etc.

Progress

Periodic calibration of laboratory measuring instruments was continued. Tests were carried out on over 40 items. Two measurements of noise and vibration in machines at site, one measurement of noise in aero-engine test-bed, and two measurements of noise and reverberation in studios were also carried out.

Consultancy

Nine cases of consultancy were handled. Of these, 6 cases were a spill-over from the previous years. The cases handled included acoustic treatment of recording studios and auditoria, suppression of noise in air-conditioning systems, and design of sound re-inforcement systems.

2.8 DC CALIBRATION

The group working on the establishment of DC standards, undertook calibration work also.

Calibration of standard cells, standard resistors, potentiometers, voltage dividers and current shunts etc. from several public and private sector undertakings, including Defence laboratories, was undertaken, and about 50 test reports were issued.

2.9 AC & HIGH FREQUENCY CALIBRATION

The group working on the establishment of standards for AC, and high frequency measurements, undertook calibration work also.

Use was made of the following existing facilities for rendering calibration service to outside parties including public sector undertakings, Defence laboratories and other organisations :

(i) Calibration of RF power meters from 10 μW to 100 mW with an accuracy of $\pm$ 1% ;

(ii) Calibration of audio and RF signal generators (frequency range extending upto 100 MHz) in the voltage range 10mV to 30 V ;

(iii) Calibration of VTVMs, power meter calibrators, voltage calibrators and low-power attenuators in frequency ranges extending from power frequencies to several hundred MHz ;

(iv) Measurement of characteristic impedance of coaxial cables upto 1000 MHz ; and

(v) Measurement of various parameters of transistors and diodes upto 1000 MHz.

2.10 MICROWAVE CALIBRATION & TESTING

The group working on the establishment of standards for microwave measurements undertook testing and calibration work also.

Calibration and testing of microwave components and instruments was continued for both private and public sector undertakings. About 200 test reports were issued during the year 1975-76.

2.11 TEST AND EVALUATION CENTRE FOR ELECTRONIC AND ELECTRICAL EQUIPMENT AND COMPONENTS

Scope

(i) To act as a national laboratory facility for environmental testing, calibration and evaluation of electronic and electrical products ; and

(ii) To operate field exposure stations and to carry out studies in tropicalization.

Objectives

(i) To provide quick and efficient test facilities to electronic and electrical industry and other user organisations such as Defence, Civil Aviation, DGS&D, ISI etc. ;

(ii) To carry out primarily developmental and type testing according to the Indian Standards Institution (ISI) specifications or any other national specifications required by the user ;

(iii) To analyse the performance of components and equipment to acquire failure-rate data and to carry out failure analysis studies to evaluate the reliability in order to advise the industry to improve its products and the users in the planning of systems ;

(iv) To carry out correlation studies between the accelerated laboratory tests and the performance of the products under actual environmental conditions, through setting up of several field stations representing different climatic and other environmental conditions, and to make this information available to all interested parties—both national and international ;

(v) To carry out systematic studies in tropicalization of components and equipment ;

(vi) Based on the test data, studies and experience, to suggest and advise revision and/or updating of the ISI specifications ;

(vii) To offer calibration facilities with established traceability to the national standards of physical measurement of the NPL ; and

(viii) To perform such other specialized services or render advice, as may be required from time to time.

Progress

NPL has set up facilities for evaluation of electronic components under various environmental conditions by subjecting them to accelerated tests such as dry heat, dry cold, damp heat etc. of different severities.

A field exposure station was set up to carry out these tests under actual climatic conditions available in Delhi. Simultaneously, reliability studies on indigenous electronic components were also initiated. During the year 1975-76 about 340 environmental, electrical and mechanical tests on electronic and electrical equipment & components, TVs and radios, were carried out, and an amount of about Rs. 54,000/- was realized as test fee.

TABLE—I

Statement of Receipts on account of Calibration and Testing Work done by the Division of Standards during 1975-76

Activity	*No. of Test Reports*	*Test Fee (in Rs.)*
Length Metrology	575	30,865.01
Mass, Volume and Hydrometers	236	26,634.00
†Photometry, Colorimetry and Radiometry	149	76,303.01
Heat	148	23,399.00
Low Pressure and High Pressure	7	660.00
Engineering Materials	381	68,346.50
Acoustics	44	11,670.00
*DC, AC & HF Calibration	60	14,341.67
Microwave Calibration & Testing	208	19,350.00
Test and Evaluation Centre for Electronic & Electrical Equipment and Components.	342	54,042.00
Total	2150	3,25,611.19

†Includes the receipts of the Spectro-Chemical Analysis Section of the Division of Specialized Techniques (*See Table II on Page 46*).

*Represents the receipts of the erstwhile Electronics Division.

DIVISION OF SPECIALIZED TECHNIQUES

The activities of the Division of Specialized Techniques are organized into three major groups *viz.*,

1. Specialized Techniques Group ;
2. Cryogenics Group ; and
3. Solar Energy Group.

The Specialized Techniques Group undertakes the testing of materials for purity, crystallinity and perfection, and also carries out investigations in the frontiers of science in the respective fields of work. The Group also undertakes investigations on the precision measurements of some of the physical properties of the vast variety of materials in bulk as well as in thin film state.

The Cryogenics Group directs its attention to the study of the peculiar phenomena that occur at low temperatures e.g. Josephson Effect, Kondo Effect etc., research and development of cryogenic plants, study of superconducting materials and systems, and preparation of fine powders by cryo-chemical techniques, etc. The Group also renders cryo-technical advisory services to the other groups of the Laboratory and to the outside institutions and organisations.

NPL had earlier done some pioneering work in the field of solar energy utilization for domestic applications. In the wake of the energy crisis, a comprehensive report entitled "Solar Energy : Promise and Challenge", was prepared jointly by the CSIR and the NCST, in which the NPL scientists played a very significant role. A sequel to this has been the renewal of interest in this area, and the constitution of a Group on Solar Energy for intensifying efforts in harnessing solar energy.

1. SPECIALIZED TECHNIQUES GROUP

Introduction

With the over all fast development of science and technology on the one hand and the industry on the other, the demand for materials with precise specifications & newer and newer materials is growing equally fast. In order to fulfil this requirement, increasing efforts are being made to study why materials behave as they do, and whether we can tailor

materials to the required specifications. It has been clearly established that to achieve reliability and reproduceability of any device, it is extremely essential to characterize materials very precisely for purity, perfection and their relevant physical properties. With further increase of sophistication in industry, the stringency of materials characterization is great and, in fact, as industry becomes more and more science-based, it requires extremely well characterized materials.

The Specialized Techniques Group not only undertakes the testing of materials for purity, crystallinity and perfection, but also undertakes precise measurements of the physical properties of materials.

Objectives

The main objectives of the Group are :

(i) To cater to the needs of the various scientists in the Laboratory for testing of materials for purity, perfection, crystallinity and physical properties ;

(ii) To extend its services to other research institutions/laboratories and to the industries in the country, for characterization of materials ;

(iii) To undertake jointly or individually, programmes for understanding the relationship between the composition, structure, imperfection and other relevant physical properties ; and

(iv) To undertake certain R & D programmes in the frontiers of science.

1.1 ANALYTICAL CHEMISTRY SECTION

Progress

The Section continued its activity of chemical analysis of a wide variety of materials for the other groups within the Laboratory as also for outside parties, and development of newer methods of analysis and synthesis of those chemicals which are not made in the country.

During the year 1975-76, the Section issued 196 test reports to outside parties, and an amount of about Rs. 29,000 was realized as test fee. These samples included cast iron, different kinds of steels, pig lead, aluminium, zinc metal, high purity copper, lime, cement, water, quartz, lubricants, chromium plated, galvanized or anodised metals, breath analysers etc. In the course of chemical analysis, a few problems of developmental nature were also undertaken. Some of these are indicated below :

Determination of Iron and Phosphorus in Boiler Feed Water in ppb range : Method for trace determination of iron using diphenyl phenanthroline with 2-butanol as the extractant was standardized. This reagent has the advantage over other known colorimetric reagents of iron for its being highly sensitive and selective. The method of extraction of the molybdate complex was also followed in the case of determination of phosphorus, as this method enables the concentration and separation of phosphorus from a large quantity of the sample. It was also possible to purify the chemicals which interfere with the determination of phosphorus.

Determination of Selenium and Tin in High Purity Copper : The amount of selenium and tin present in electrolytic grade copper is only in ppm range. The method prescribed in the Indian Standards for the estimation of these metals was not found suitable. Colorimetric estimation of these metals using diaminobenzidine and haematin reagents respectively was carried out. Conditions for the determination of these were standardized.

Spectrophotometric Determination of Palladium using 4 Methyl Benzene Azo Acetylacetone : A new reagent by substituting 4 methyl benzene azo group in acetylacetone was synthesized. Its potential as a colorimetric reagent for determination of metal ions was investigated. It was found that palladium forms a complex with 4 methyl benzene azo acetylacetone which has maximum absorption at 500 mμ. The molar extinction coefficient of the complex is 3000.

Preparation of Special Chemicals : Assistance was rendered to the groups working on Liquid Crystals and Cryogenics by way of preparing ferric oxalate, dimethyl dichlorosilane, cholesteryl chloride, cholesteryl nonanoate, cholesteryl oleyl carbonate etc.

Evaluation of Chemical Pollutants in Water : A programme for evaluation of chemical pollutants in water was undertaken in collaboration with the Central Board for Prevention and Control of Water Pollution. NPL was recognised as one of the reference laboratories for the analysis of pollutants in water.

TGA & DTA Studies : Thermogravimetric behaviour of various materials was studied under different conditions. Thermal behaviour of copper iminodiacetate dihydrate was studied for the Jadavpur University. Jute fibres, organo-metallic compounds and some other samples were studied for the other groups of the Laboratory.

1.2 SPECTRO-CHEMICAL ANALYSIS SECTION

Progress

The Spectro-Chemical Analysis Section tested samples of phosphors, super-conducting materials, carbon products, ferrites etc. for the other groups of the Laboratory as well as for outside parties. A total of about

270 determinations were made. Some of the highlights of the Section are indicated below :

A study of the elemental composition of different ferrous alloys was made and a list of elements, which are usually associated with these alloys, was prepared.

A procedure was devised to recover for re-use the graphite carrier electrodes which get contaminated after a burn. A programme was initiated for the setting up of a facility for the use of only a smaller length of the electrodes and for shaping of the metal electrodes using an electrode shaper.

A Hartmann type of slit with colinear edges was made, using the punching technique. A timer switch which controls the motor drive of this Hartmann slit was coupled suitably to the exposure control unit so that the total time during which the spectrum gets resolved would be the same as the time of exposure and complete burn of the sample.

A number of graphs on the luminance distribution of the sky at Delhi for solar altitudes 10° to 70° were prepared, and a report on the national activities on the subject of daylighting was compiled and submitted to the ISI.

1.3 INFRARED SECTION

One of the main objectives of this Section is to develop and provide a sensitive, selective and reliable characterization facility by infrared spectroscopy.

Progress

Fabry-Perot Type Far Infrared (200-400 μm) Spectrophotometer : The instrument was fitted with a repaired Golay cell and it was put back into working order. Experiments were also carried out to extend its range both towards the low and the high frequency sides.

Hilger H-800 Spectrophotometer (2 to 15 μm) : The commercial Hilger H-800 infrared spectrophotometer which had been inoperative for the last four years and for which no spares were available, was re-commissioned in early 1975 after readjusting its optical alignment, and complete overhauling of its electronics. The instrument was used for characterization of a sizeable number of materials for the other groups of the Laboratory.

In addition to the above two spectrophotometers, development of (i) a grating type far infrared (15 to 300 μm)spectrophotometer, and (ii) a high resolution spectrometer (1 to 3 μm), was also undertaken to augment the available facilities, so as to cover the entire spectral range from 1-300 μm.

Grating Type Far Infrared Spectrophotometer : The essential components for the instrument, viz. spherical mirrors, plane mirrors, grating holder, grating drive mechanism, chopper, and mirror-holders were designed and fabricated. The electronics and the control panels were mounted and wired. The two precise jobs i.e. the ruling of 4 lines/mm with blaze angle of 26° for a reflection grating, and conical light pipe to focus the beam at the detector window, were undertaken and completed. The optical aligment was checked and vacuum chambers to remove water vapour were designed and fabricated.

1 to 3 μm High Resolution Spectrometer : The grating drive mechanism, chopper, three-gear box, mirror mounts, slit and source holders for the instrument, were designed and fabricated. The blocking filters suitable for this spectral range were also procured.

Pyroelectric Infrared Detectors : Experiments were carried out to improve the sensitivity of pyroelectric infrared detectors developed earlier. Improvements were specially made in the electrode geometry, thickness of the crystal plate and in the preamplifier circuit. As a result of these modifications, the Noise Equivalent Power (NEP) of these detectors was improved from 7×10^{-7} W/Hz$^{1/2}$ to 7.5×10^{-8} W/Hz$^{1/2}$. *(Fig 4).*

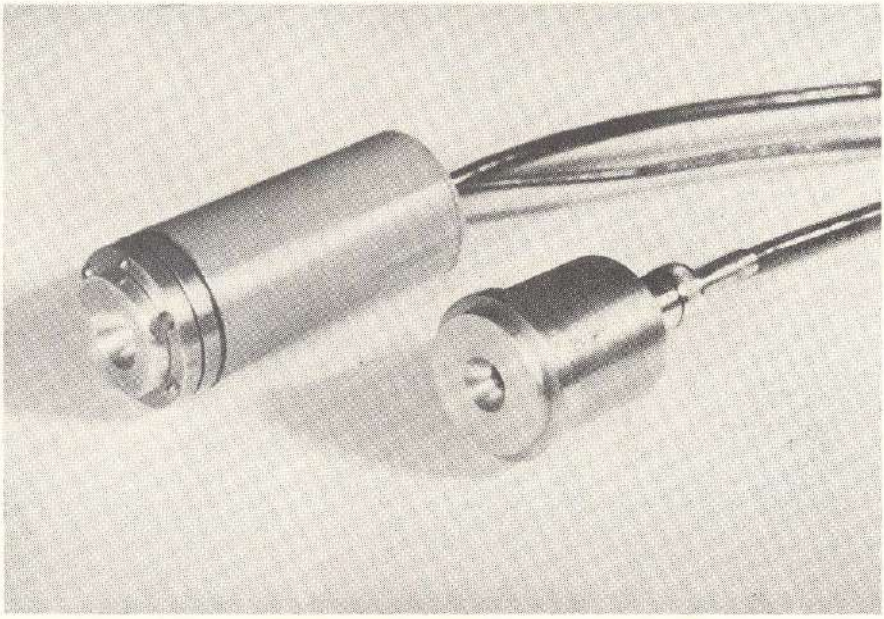


Fig 4 Two models of pyroelectric infrared detector assemblies developed and fabricated at the Laboratory. The preamplifiers are enclosed within the assemblies. These detectors, with a noise equivalent power (NEP) of 7.5×10^{-8} W/Hz$^{1/2}$, find a variety of applications in fast detection of radiant energy.

Infrared Sensing Torch : Use of the pyroelectric infrared detectors was made in the development of an infrared sensing torch. In this torch, the signal from the detector is given to a wide band amplifier and then to a voltage sensing circuit which consists of a silicon control rectifier (SCR) and a light emitting diode (LED). The power supply is made from dry cell batteries. Received infrared signal actuates the SCR which, in turn, operates the LED. The whole circuit is compact and is placed in a torch-like cylindrical envelope.

Theoretical Studies on Far Infrared Filters : Equations for five- and six-grid interference filters were used to calculate the transmission characteristics of different filters. The oscillating nature of the peak transmission was explained. Theoretical studies of reciprocal grid interference filters were also carried out. Expressions for phase angle, and condition of maximum transmission, were derived. It was found that these filters could be used as efficient low-pass transmission filters.

Exploratory R & D : Some infrared spectroscopic studies on carbon fibres, analgesic group of medical compounds, and edible oils were also made.

1.4 X-RAY DIFFRACTION AND FLUORESCENCE SECTION

Progress

This Section carried out X-ray analysis of a wide variety of materials received from government departments, industries, universities, ISI, and other groups of the Laboratory. X-ray analysis for crystalline phase-identification, orientation determination by X-ray Laue techniques, solid solution formation etc., were carried out for the following types of materials :

$LiNbO_3$ powder and single crystal ZnO film grown on Zn, orientation and cut of quartz oscillator plates, carbon fibre precursors as well as oxidised carbon fibres, CaS, electrographite samples, scum formed on silicon melts, Zn-Mn ferrites, Ba-Ca zirconate-titanate samples, battery-grade MnO_2 & MnO_2 ores, alumina powder made by freeze-drying and spray-drying method, activated alumina, Pb, Pb-Ti, transistor headers, cathode insulators for cathode-ray and television tubes, thread-guide materials, ceramic materials, thin films of Cu-MgF_2 on glass slides, accretions on Ajanta cave-paintings, Ga (As_x P_{1-x}) with X-ray determination of x, 'Insulin' from plants, clays, Zn and Bi rods, polymer films, copper oxalate, materials for very strong superconducting magnets, materials prepared under high pressure, manganese oxide, γ-Fe_2O_3, $LiFe_5O_8$, etc.

For some of the samples, fair amount of research had to be carried out in addition to routine testing.

Structure and Phase Transformations in Semiconductor Chalcogenide Materials : The work aims at synthesising chalcogenide materials (sulphides, selenides and tellurides), and obtaining complete knowledge about the crystal structure, thermal expansion, temperature range of stability, and transformation into the high-temperature phases for fabrication of devices based on these materials, as also a full understanding of the nature of extended defects in crystals, annealing behaviour, topotactic reactions, line-profile analysis for crystalline size determination, etc.

The work done during the year was as under :

Structure factors and powder line intensities were calculated for the high temperature gamma phase of In_2S_3, and compared with the experimental values visually estimated from the high temperature powder photographs. On the basis of this comparison, alternative arrangements of the types of S-In-S layers perpendicular to the basal plane can be differentiated.

The structure of InSe was finalised. X-ray thermal expansion data were obtained and the stability of the phase with rise of temperature was studied.

In continuation with the earlier work on Ga_2Se_3, the phase with nominal composition $Ga_2Se_{3.03}$ constituted a subject of close study. Single crystal Weissenberg films for various levels of the reciprocal lattice were taken, and a space group in the orthorhombic system was tentatively assigned. A large number of crystals have so far been examined for selection of a twin-free crystal. Diffractometer runs on powders and Gandolfi camera single crystal 'powder' films were under study for finalisation of results.

Crystal data on apophyllite were finalised. Thermal expansion data and high temperature transformations of this mineral from the Poona region of the Deccan traps, were also brought to conclusion.

X-ray Fluorescence Analysis : Work on the detection of small amounts of Hg in aluminium oxide prepared from amalgamated aluminium sheet was initiated. Research work on the estimation of rare-earth elements in the core material of cinema arc carbons was also carried out.

1.5 ELECTRON MICROSCOPY AND ELECTRON DIFFRACTION SECTION

Progress

Determination of the particle size, shape, size distribution, microstructure etc., of a variety of materials like ferrites, gamma ferric oxide,

greases, alumina, carbon fibres, superconducting materials like Nb-Ta, Nb-Ti, Nb_3Sn etc., of about 75 samples was undertaken during the year. Of special significance was the electron-microscopic examination of about 25 samples of iron oxide prepared within the Laboratory as a part of the programme on development of γ -Fe_2O_3 powder for magnetic tapes, and of about 20 samples of freeze-dried and spray-dried alumina powders together with the study of their particle size and shape. 9 samples of γ -Fe_2O_3 & CrO_2 supplied by the IIT Kanpur were also examined for their suitability as a magnetic tape material.

Other outside jobs of significance undertaken by the Section included examination of another three samples of reclaimed grease received from the Research, Design and Standards Organisation, Lucknow, and a few samples of carbon powder received from M/s India Carbons.

Specimen Preparation of Magnetic Powders : A method was developed for the preparation of specimens of ferromagnetic powders by dispersing them in plastic solution and then embedding the well-dispersed powder particles in plastic film to enable their proper examination under the electron microscope.

Development of Specimen Grids : An exploratory work on development of copper grids used in the electron microscope for specimen support was undertaken, using vacuum evaporation, electrolytic deposition, as well as photolithographic techniques. A few grids were produced and were also tested by optical and electron microscopes.

1.6 X-RAY DIFFRACTION TOPOGRAPHY SECTION

X-ray diffraction topography is an important tool for fundamental research as well as for routine testing of crystal perfection in some industries. X-ray diffraction topography can be used to detect and characterize (i) grain boundaries, (ii) low angle boundaries, and (iii) dislocations. For the grain boundaries and low angle boundaries, it is even possible to determine their angle. The dislocations can be resolved in good single crystals, and, their nature, i.e. whether they are edge or screw dislocations, and their Burgers vector, can also be determined. Besides, the method is non-destructive.

Progress

Microfocus X-ray Generator : Developmental work on microfocus X-ray generator was continued and all parts of the generator except the HT supplies were assembled and tested. A new anode assembly, with improvement in the insulation properties and with Mo target, was fabricated. The generator was used for taking topographs of α -Al_2O_3 single crystals.

Crystal Puller : A pulling attachment for growth of cadmium sulphide crystals from the vapour phase was completely designed, developed and installed. It pulls at a rate of about 10 mm/24 hrs.

Design work on a versatile crystal puller for growth of single caystals of opto-electric materials by Czochralski technique was also started.

Growth of α-Al_2O_3 Whiskers : CVD is one of the important methods of growth of good quality α-Al_2O_3 single crystals. A technique for growth of sapphire whiskers was developed using this technique. The reaction can take place by passing wet hydrogen over alumina powder, or allowing aluminium chloride vapour to react with carbon dioxide and hydrogen. Successful experiments were carried out upto 1500°C, and sapphire whiskers were obtained.

Growth of CdS Single Crystals : CdS single crystals were grown by the vapour deposition method. These crystals were characterized, using their electrical conductivity and optical absorption etc.

Precise Measurement of Lattice Constants of Single Crystals : Work on an experimental set-up for precise measurement of lattice parameters of single crystals was initiated. A scintillation counter for X-rays was fabricated and tested. A collimator, a pair of slits, and a new detector slit system were also designed and fabricated for this purpose.

Defect Structure in α-Al_2O_3 Single Crystals : Defect structure in α-Al_2O_3 single crystals was studied to understand deformation at the seed—crystal interface by using X-ray diffraction topography. The magnitude of strain was quantitatively analysed. Dislocation images were recorded in these crystals by using nearly pure dynamic diffraction, nearly pure kinematic diffraction, and partly dynamic and partly kinematic diffraction.

Electrical Conductivity and Thermo-emf Measurements on Garnets : Electrical conductivity and thermo-emf measurements were carried out on gadolinium gallium garnet (GGG), samarium gallium garnet (SGG), GGG with excess of Gd_2O_3, and GGG doped with MgO. The results of measurement of electrical conductivity and Seebeck coefficient showed a good correlation with each other.

High-Resolution Topography set-up for Diffuse X-ray Scattering : Conventionally, commercially available single crystal X-ray diffractometers are used for studying diffuse X-ray scattering. Some times photographic methods are also used. In these arrangements there are some serious experimental uncertainties due to the inherent limitations of the instrumentation. The minimum rotation that can be given to the crystal is 1/100th of a degree. With this arrangement, in general, the half-width of the diffraction curve is of the order of a degree or so. Due to this limitation in the angular movement it is not possible to take measurements

closer than that provided by rotation of 1/100th of a degree. Moreover the size of the X-ray source used in these investigations is not small and it can lead to the broadening of the X-ray diffraction curve which can be mistaken as due to the diffuse scattering produced by phonons. Keeping in view these limitations of the conventional methods, a new high resolution X-ray topography set-up was developed for the study of diffuse X-ray scattering.

This set-up has the advantage over the conventional experimental arrangement in as much as, (i) the X-ray source has a small focal size, (ii) the X-ray beam is collimated to a much better extent as compared to the single crystal diffractometer, and (iii) the crystal can be rotated by 1″. Due to these advantages the $K\alpha_1$ and $K\alpha_2$ components of the characteristic radiations are well resolved and their half-widths are about 40-50″. This permits diffuse X-ray scattering measurements to be made fairly close to the diffraction peaks.

Measurements were made around $K\alpha_1$ peak of the 400 reflection from a dislocation-free silicon crystal with angular interval of mis-setting of about 10″. The results obtained, as compared to the results reported in the literature, showed, that such a resolution had never been attained so for. Moreover the simple theory developed for explaining diffuse X-ray scattering in terms of scattering of X-rays from phonons was found to be inadequate as it did not explain the results for all values of phonon wave vectors.

The diffraction curves for silicon are known to have half-width of about 5-10″, whereas the experimental curves showed half-widths of about 40-60″. This was due to the fact that the mono-chromatisation of the radiation was not perfect. To overcome this difficulty, work on development of a multi-crystal X-ray diffractometer was undertaken.

In addition to the above, the Section carried out dielectric constant and dielectric loss measurements on a number of samples for the various groups of the Laboratory. A sample holder for dielectric and electrical conduction studies was also fabricated for the Jammu University.

1.7 ELECTRON PARAMAGNETIC RESONANCE SECTION

The activity of this Section essentially involves the detection and measurement of paramagnetic centres/impurities in various materials of technological importance, using electron paramagnetic resonance spectroscopy.

Progress

A variety of samples from industries and various groups in the Laboratory were investigated. Some of the interesting studies undertaken are reported below :

ESR Absorption in Jute Fibres : It was found that the raw jute fibre gives a broad ESR absorption line, characteristic of transition metal impurities like Cu or Co. The concentration of these impurities decreases on treating the jute fibre with NaOH or Na_2CO_3, and a new line due to some free radical appears.

ESR Absorption of Copper (II) Oxalate Complexes : Electron spin resonance of powdered copper (II) oxalate complexes with some aliphatic amines was studied. It was observed that these complexes show wide line ESR absorption of Lorentzian shape. The widths are, in general, smaller than those expected by dipolar coupling alone. These studies are useful in the interpretation of ESR results obtained with organic seeds and biological systems since the environment of transition metal impurities in these systems is also similar.

1.8 MÖSSBAUER SPECTROSCOPY

Considerable theoretical and experimental efforts were made to determine the sign and magnitude of the principle components of the electric field gradient (*efg*) tensor using Mössbauer Spectroscopy.

Because of the orientational order, liquid crystals provide a possible medium to align the molecules in and determine the sign of *efg*. Determination of (i) degree of orientational order, (ii) detection of phase transitions and study of transition phenomena, (iii) angle of inclination between the molecular orientation and normal to the plane of the smectic layers, (iv) anisotropy of *f*-factor (normal to the layers and in the layers), (v) anisotropy of molecular diffusion, and (vi) anisotropy of molecular vibration, are also of great significance for study of liquid crystals.

A systematic study of liquid crystals, using Mössbauer spectroscopic techniques, was initiated in smectic as well as nematic phase at low temperatures.

The smectic liquid crystal used for this study was monotropic smectic B liquid crystal, p-n-hexyloxybenzylidine-p-toluidine (HBT). $(C_7H_7)_2$ $SnCl_2$ and 1, 1′ diacetylferrocene were dissolved separately in HBT. The samples were oriented by the application of magnetic field of 10 kOe at the smectic B temperature, in two different directions i.e. parallel and perpendicular to the gamma ray beam. Intensity ratios as well as the

area under resonance as a function of temperature were calculated for two orientations at various temperatures. These gave some idea about the various transitions taking place. Experimental data were compared with the theoretical values, taking into consideration the molecular vibrational anisotropy, but it was found that it was rather impossible to get a fit until the anisotropy of the liquid crystalline lattice was taken into consideration.

An attempt was made to obtain Mössbauer effect in nematic phase. Experiments showed that it is possible to observe Mössbauer effect in nematic phase such as MBBA. The study by dissolving $(C_7H_7)_2$ $SnCl_2$ in MBBA at 8% by weight and then taking the Mössbauer spectra of the oriented and quenched-to-liquid-air-temperature sample of the solution, was initiated. Intensity ratios and the area under resonance were calculated as a function of temperature. Again it was found that to get a fit of experimental data with the theoretical values, it is necessary to take into account the lattice vibrational anisotropy of the liquid crystalline host.

Studies on the glass transitions of various liquid crystals—both smectic and nematic—were also started.

1.9 SULFAMPHTHALEIN INDICATORS

Scope and Objectives

The objective is the introduction of a new series of indicators for chemical analysis, and the related dyes for animal fibres and medicinal purposes. The work aims at the synthesis of sulfamphthalein indicators, purifying them to the chromatographic grade, and examining the physico-chemical characteristics, viz., melting point, formation constants, IR, Visible and UV absorption spectra, and pH of colour transformation which would comprise of the characterization of colour change in terms of (i) SCD for sensitivity of colour change, (ii) pH_{mec} correct to 0.01 pH units, and (iii) half band-width of change of SCD in pH units as a measure of the rapidity of colour change.

Derivatives of the sulfamphthalein indicators are proposed to be investigated for their utility in trace analysis and as metallochromic indicators.

Progress

Work was continued on the synthesis, purification & utility of sulfamphthalein indicators and their derivatives, made from the market-available starting materials. Some developmental activities taken up during the year, are described below :

Multipurpose Solvent Extractor : The multipurpose solvent extractor developed earlier, was fabricated in seven different capacities viz., 20, 50, 100, 200, 500, 1000 and 2000 ml.(*See also the Section on Glass Technology Development and Production Unit*). It is useful in preparation and purification of fine chemicals ; analytical determination ; industrial, agricultural and bio-chemical extractions ; clinical diagnostic aid ; environmental pollution ; research and academic pursuit ; and standardization.

Oxygen Flask Method for Determination of Sulphur in Steel : Starting from the use of the oxygen flask method for determination of sulphur in sulfamphthalein indicators, a new helical combustion boat was designed and got fabricated from siliminate, for determination of sulphur in steel. The dimensions of this boat, as would be suitable for combustion of 1g of steel, were standardized.

The method involves (i) mixing of 1g of steel with aluminium, some filter paper bits, and a little platinum, (ii) filling this mixture in a polythene bag containing a filter paper wick, (iii) placing the polythene bag in the NPL-designed ceramic helical combustion boat, (iv) suspending the boat from the stopper of a pyrex flask of 3 l capacity or more, and (v) flushing the flask with oxygen, and then providing flame to the filter paper wick and quickly inserting it in the flask.

A dazzling bright temperature of 1600°C or more could be obtained. At this temperature the steel fused and sulphur was converted to SO_3 which was titrated in 1:1 acetonic aqueous solution with 0.02 M barium perchlorate solution at a pH of about 5 using sulfoneazo III as indicator. End point was red to greenish blue.

The results obtained on two samples of steels obtained from the HSL, Durgapur, compared well with the reported results to within the limits allowed by the ASTM.

Micro-Determination of Lead : Xylenol Orange Analogue (XOA) was synthesised, starting from O-cresol sulfamphthalein. This metallochromic indicator was analysed for its content of sulphur and nitrogen by using the oxygen flask method, and the improved ammonia distillation apparatus developed earlier. The indicator was used for determining lead in microquantities. Lead formed a red complex with XOA having λ_{max} at 570 nm and 423 nm. The lead complex showed a significant behaviour in that while the absorption of the XOA indicator in forming the lead complex increased maximally at 570 nm, its absorption decreased maximally at 423 nm. The absorption of the complex was constant between pH 5-6. The complex obeys Beer's Law and shows a straight line relation between absorption and lead concentration upto 15×10^{-6}M Pb. The molar absorptivity index at 570 nm is 16,800 and at 423 nm it is 10,000.

Progress

Digital Master Clock : In continuation of an earlier project on digital clock sponsored by M/s KLB Electronics, New Delhi, a digital master clock to run five slaves was developed. The digital master clock controls the slaves, displaying both time and ambient temperature digitally on big filament lamp display panels with a digit size of about 35cm × 25cm. Display panels are fitted on the main panel of the master clock to monitor time and temperature. The master clock also incorporates programmable memory for the activation of any system. The salient features of this clock are : (i) running of ambient temperature and time displays in time sharing mode, (ii) using of large filament lamp displays for out-door installations and long distance viewing, (iii) provision for the programmed tape recorded announcements, and (iv) provision for the synchronisation of the master clock with the atomic clock, manitanied by the Time & Frequency Standards Section of the Laboratory. The accuracy of the master clock is therefore the same as that of the atomic clock.

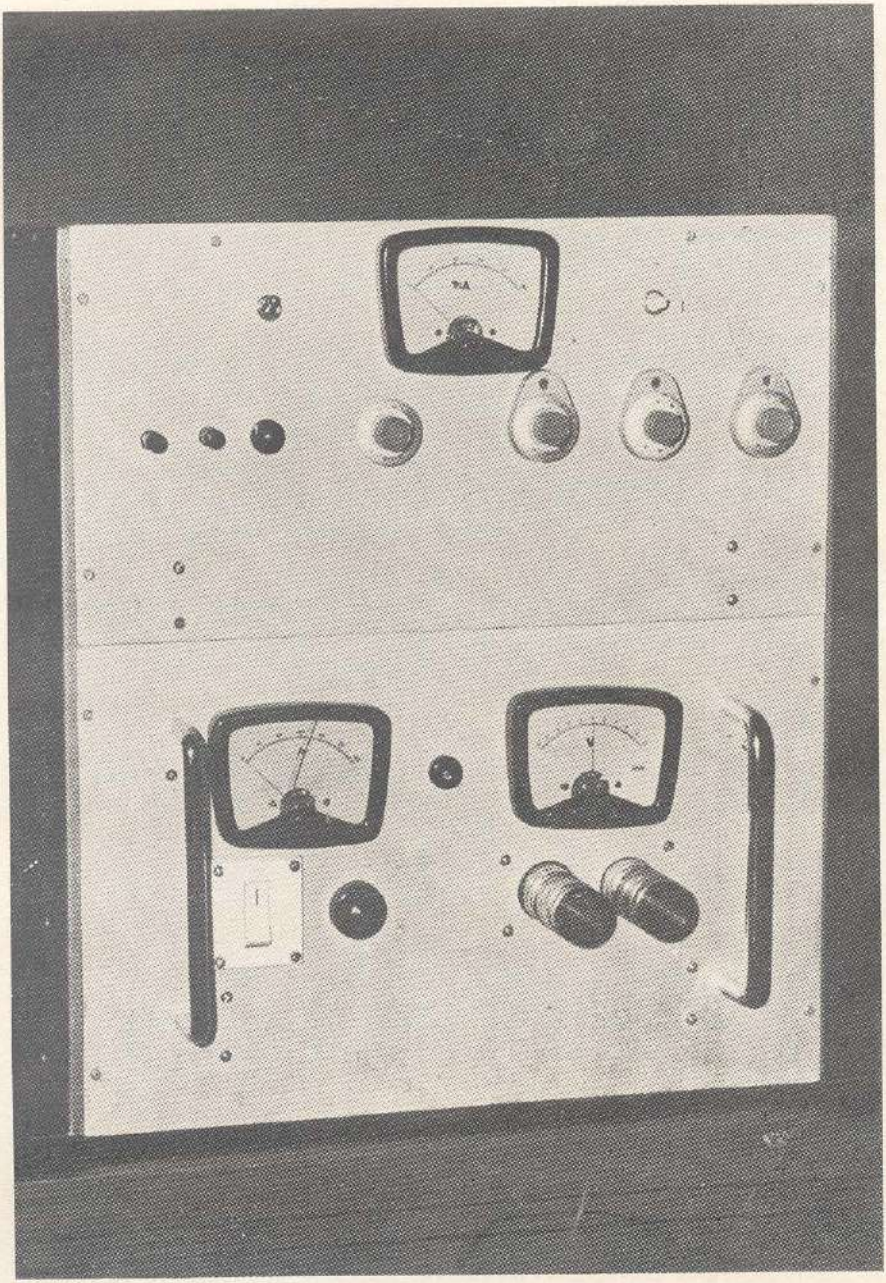
Work on development of an electronic master-clock which would run twelve clocks of electromechanical type, to be installed at various places in the Laboratory, was also completed.

Superconducting Magnet Energizer : A highly stabilized power supply with the ratings of 0 to 4 V and 0 to 50 A was designed and fabricated for energizing the superconducting magnet (12 kOe), made by the group working on development of superconducting materials and systems *(Fig 5)*. (*See also* Section 2.6 on Page 40).

Electronic Secretary : An electronic device to be used in conjunction with a tape recorder which replaces the engagement diary of a person thereby avoiding the need of either looking through it frequently or being reminded of one's daily appointments every time, was developed. The complete information about the daily engagements of a person for any desired number of days is pre-recorded sequentially. The device, which

Fig 5

Superconducting magnet energizer, designed, developed and fabricated at the Laboratory for energizing a 12 kOe superconducting magnet system, also developed at the Laboratory (*See* Fig 7). It can operate both in the constant current and the constant voltage modes with a stability of a few parts in 10^4 and a ripple of less than 0.2 mV rms. Equipped with trip circuits for switching off the output at any accidental onset of resistance in the superconducting magnet and for limiting the reverse voltage on an unexpected power failure, the supply also has provision to operate a persistent mode switch located in the superconducting magnet. ⇒



is programmable, then gives commands to the tape recorder for making announcements at different times of the day. Thus it would be possible to listen to all the deatils of one's engagements just before the actual appointment time.

Although the recorded info rmation might be pertaining to many days, yet the device can be programmed only to cover a single day's engagements at a time. It has, therefore, to be programmed every day and would give announcements of six engagements at different times of that day. However, the device can be custom-built to accommodate larger number of daily engagements also.

There is also a provision in the device to recall any particular information of any particular day, and to make necessary modifications to it at an instant's notice.

The device displays both time and date and continues to work uninterruptedly even in case of power supply failure.

2. CRYOGENICS GROUP

Introduction

Cryogenics finds tremendous applications in a variety of industries such as chemicals, steel, fertilizers, metal working, aerospace, food preservation etc. Apart from its industrial applications, cryogenics has another important and very useful phenomenon to offer, and that is, that many materials behave in a peculiar way at very low temperatures. Some materials lose their resistance at low temperatures and become superconducting. These superconducting materials are finding industrial applications for making very high field magnets, motors and generators. In certain developed countries, superconducting materials are being used for power generation, transmission, and high speed transportation. Similarly, cryogenics technology is being widely used to preserve food, fish and blood, and a still wider scope of its applications is envisaged.

2.1 CRYO-TECHNICAL SERVICES

This Section has an obligation to maintain and operate various liquefiers such as air, nitrogen & helium liquefiers. These croyogens were supplied to the various groups of the Laboratory and also to outside research institutions and industrial undertakings. Valuable assistance by way of technical advice to various scientists from within the Laboratory as also from outside was also given regarding design of cryostats and techniques of low temperature measurements etc. Liquid air vessels from outside the Laboratory were also taken up for repairs.

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Introduction

Cryogenics finds tremendous applications in a variety of industries such as chemicals, steel, fertilizers, metal working, aerospace, food preservation etc. Apart from its industrial applications, cryogenics has another important and very useful phenomenon to offer, and that is, that many materials behave in a peculiar way at very low temperatures. Some materials lose their resistance at low temperatures and become superconducting. These superconducting materials are finding industrial applications for making very high field magnets, motors and generators. In certain developed countries, superconducting materials are being used for power generation, transmission, and high speed transportation. Similarly, cryogenics technology is being widely used to preserve food, fish and blood, and a still wider scope of its applications is envisaged.

2.1 CRYO-TECHNICAL SERVICES

This Section has an obligation to maintain and operate various liquefiers such as air, nitrogen & helium liquefiers. These croyogens were supplied to the various groups of the Laboratory and also to outside research institutions and industrial undertakings. Valuable assistance by way of technical advice to various scientists from within the Laboratory as also from outside was also given regarding design of cryostats and techniques of low temperature measurements etc. Liquid air vessels from outside the Laboratory were also taken up for repairs.

2.2 CRYO—PROPERTIES OF MATERIALS

Cryogenic fluids require efficient thermal insulation against ambient heat, right from the stage of their liquefaction, to storage, transportation, and various types of other applications. Powders, such as perlite, were found to serve well for thermal insulation at low temperatures. Facilities exist to characterize such powders with regard to their thermal conductivity between liquid nitrogen temperature (7^.4 K) and room temperature (300 K).

2.3 CRYOGENIC PLANTS AND FACILITIES

Progress

Scroll Expander : Developmental work on a novel type of scroll expander for use in liquid air machines of medium size was initiated. It has many distinct advantages over the conventional expanders—*viz.* the expansion engines, turbo-expanders etc. It is useful for medium size plants, and is free from the problems of high wear and tear and such other difficulties that are faced in the fabrication of turbo-expander systems. This is because it runs at a low speed of a few thousand rpm only, while turbo-expanders operate at speeds of 40,000 to 50,000 rpm. The new expander system also offers potential applications in the development of solar-energy-run water pumps. The preliminary work in this direction was completed during the year.

Air Liquefier : A notable achievement during the year was the perfection of the laboratory type air-liquefier based on the Claude cycle, with detailed drawing and design of each individual part of the machine.

2.4 CRYOPROBES FOR EYE-SURGERY

Progress

During the period under report, work was continued on the improvement of the cryoprobes suitable for cataract removal and retinal re-attachment, and its extensive trials at the local medical institutions, to make the device trouble-free and fool-proof, before the release of the know-how to the industry. *(Fig 6).*

In the probe, N_2O/CO_2 is allowed to undergo Joule-Thomson expansion after passing through a narrow orifice which produces the requisite cooling. In order to reach the lowest temperature, the out-going gas is passed through a specially designed heat exchanger, to pre-cool the inflowing gas. The tip diameter of the pencil is 2 mm. The gas is allowed to pass into the system through an electromagnetic valve operated by a foot switch. The cryo-pencil is completely detachable from the control box for ease of storing, and reducing the possibility of any damage to the pencil.

Fig 6 Cryoprobe in operation for retinal detachment on a monkey, at the Rajendra Prasad Centre for Ophthalmic Sciences, All India Institute of Medical Sciences, New Delhi.

The cryo-pencil has two tips, one for cataract removal and the other for intra-vitreal purposes. A temperature of −50°C is reached for cataract, and −25°C for intra-vitreal applications. There is a separate pencil for retina, on which a temperature of −65°C is attained. The cooling times for both the pencils are 5-10 s.

2.5 CRYOCHEMICAL METHODS OF SMALL POWDER PREPARATION

Progress

Some of the sophisticated ceramic products such as high voltage ceramic capacitors (20 kV and above), and substrates for integrated circuits etc., cannot be made by using conventional ceramic technology consisting of grinding, ball-milling, forming, sintering etc. In these sophisticated ceramic compositions, it is necessary to start with materials composed of well characterized sub-micron particles, with perfect homogeneity even in respect of trace dopants. Cryochemical techniques are well suited for preparation of such fine powders.

A freeze drier developed at the Laboratory was successfully used to produce ultrafine powders of alumina.

In this process, an aqueous solution of $Al_2(SO_4)_3$ is sprayed through a fine nozzle into a tray containing hexane which is cooled by liquid nitrogen. Because of the very low temperature of liquid nitrogen (77.4 K), fine droplets are instantly frozen. These trays are then kept in the freeze drier. The pressure and temperature in the system is kept low enough so that ice directly sublimates into vapour without melting, and what is left are the very fine particles of $Al_2(SO_4)_3$. High speed rotary pumps (500 l/min) are continuously pumping on the sublimated water vapours. The water vapours are condensed in a liquid-nitrogen-cooled, specially designed condenser, before it is fed to the pump in order not to contaminate the oil of the pump. The entire process is rather long, taking about 6-8 hours for one tray.

The spray drier available with the Central Electronics Ltd., was also used to produce fine particles of alumina, with a view to comparing the quality of the powders produced by this technique with those prepared by the freeze drying process. In the spray-drying technique, $Al_2(SO_4)_3$ solution is sprayed through a fine nozzle into a chamber in which high pressure air at about 130°C-180°C is passed. The water of each fine particle coming out of the nozzle is again instantly evaporated to leave behind particles of $Al_2(SO_4)_3$.

Besides producing fine particles, these techniques have the advantage of giving very high homogeneity of small dopants like Mg in $Al_2(SO_4)_3$ which tends to increase its density. The powders produced were calcined

at 1000°C to 1200°C and characterized by X-ray and electron microscopy techniques. Preliminary investigations revealed particle size of about 200-300Å, and complete α-phase at 1200°C for Al_2O_3.

2.6 SUPERCONDUCTING MATERIALS AND SYSTEMS

Superconductors with their remarkable properties — disappearance of electrical resistance, and expulsion of magnetic field from the bulk of the material — are now being exploited for a variety of applications such as for high field magnets, motors and generators etc. About two years back a programme was initiated to develop superconducting materials and magnets.

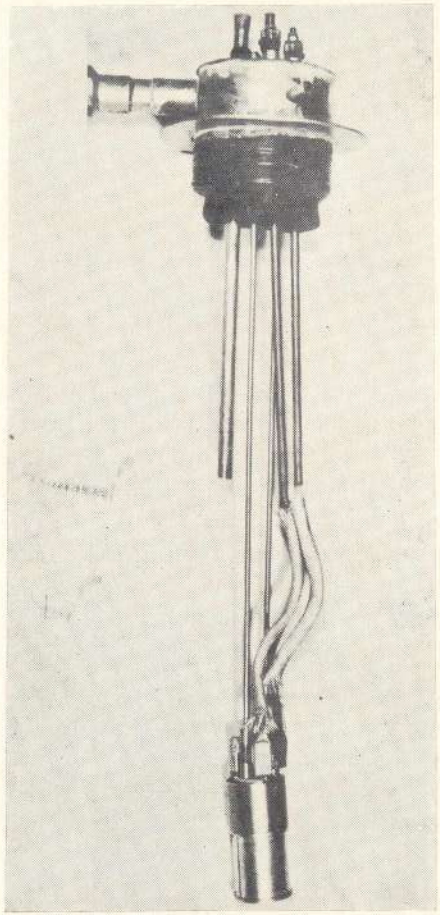

Fig 7 12 kOe superconducting magnet developed and fabricated at the Laboratory.

Progress

Superconducting Materials : Small lengths of single filamentary Pb-Bi and Nb-Ti wires with the matrix of copper were produced and their superconducting transition temperatures were found to agree with the standard values. Metallurgical structure of Nb-Ti was studied by transmission electron microscopy.

Nb_3Sn which belongs to A-15 structural group was successfully made by four different methods—(1) bronze route, (2) tin-coated copper route, (3) alloy process, and (4) liquid diffusion process. The first three methods are useful for making multi-filamentary conductors.

The growth, and the resulting microstructure of Nb_3Sn layer processed through the bronze route, were studied using scanning electron microscope. It was found that the higher the concentration of tin in the bronze matrix, the faster is the growth rate of Nb_3Sn, and smaller is the grain size.

A splat quenching set-up was fabricated and it was successfully used to produce Pb-Bi alloys. These alloys were found to be superconducting at higher temperatures than the normally prepared alloys.

Superconducting Magnet Systems : Under this programme, design and fabrication of a superconducting magnet system was taken up. A small superconducting magnet (12 kOe, 1 cm bore) was designed, fabricated and tested *(Fig 7)*. A highly stabilized power supply for energizing the superconducting magnet was also designed and fabricated jointly with the Electronics Section. (*See* Section 1.10 on page 34).

Superconducting Cavity Stabilized Oscillator : Very high Q is a property generally needed for precision oscillators. Since the highest Q that has been reported for Superconducting Cavity Stabilized Oscillators (SCSO) is 5×10^{11}, this device is now the latest addition to the list of frequency standards. Such an oscillator would, in effect, serve as an exotic clock of unprecedented stability which would neither lose nor gain more than a second in a thousand million years.

Work relating to the development of an SCSO was initiated during the year. A few Pb-cavities were fabricated.

2.7 THEORETICAL INVESTIGATIONS AT LOW TEMPERATURES

Progress

The problem of superconductivity in a one-dimensional system was investigated by the renormalization group technique. BGD (Bychkov, Gorkov and Dzyaloshinsky) model hamiltonian describing a one-dimen-

sional system of electrons was considered wherein the interaction matrix element was split into two parts. The main physics of this model is that the BCS pairing resulting from a net attractive interaction between electrons and the Peierls instability from lattice deformation, combine to give a single transition in which both effects contribute to the energy gap. This is done by considering vertex diagrams of the Cooper type and the zero-sound type. Analytical solutions in terms of Weierstrassian elliptic functions for the invariant coupling and the vertex function in the second-order renormalization were obtained. These solutions explicitly reveal the possible singular behaviour of the vertex function at a finite temperature.

2.8 JOSEPHSON TUNNELLING

This is a relatively new activity which was started a couple of years back to study the Josephson Effect so as to get an insight into the phenomenon, with a view to establishing an absolute standard of voltage based on the Josephson Effect, and for development of devices based on this Effect.

Progress

Preliminary work was started on Clarke solder blob junctions (SLUG). Solder blob junctions were selected due to their ease of fabrication, and ruggedness. These junctions were prepared by freezing a tiny drop of Pb-Sn solder on an oxidized niobium wire with two scratches on its surface. This formed a double-junction, which is also called the superconducting interferometer. The response of a double-junction to a magnetic field is a diffraction modulated interference pattern.

Magnetic field modulation was studied in the solder blob junctions, with period of oscillation of the order of a few mOe to μOe. This study has an application of SLUG as a sensitive magnetometer.

Self-field effects and temperature modulation were also studied. These gave an estimate of the junction asymmetry parameters and the inductance of the superconducting loop forming the junction.

Work on realization of the DC voltage through Josephson Effect is reported under section 1.9.2 on page 10.

3. SOLAR ENERGY GROUP

Progress

Solar Collectors : Realizing the fact that the heart of all solar thermal devices is the solar collector, emphasis was laid on the development, fabrication and testing of flat plate and concentrating solar collectors. A flat plate collector, using aluminium bonduct panels coated with commercially available black paint, was designed and fabricated.

To reduce the energy loss from the collector by way of radiation and to increase the absorption of the incoming solar radiation, it is necessary to coat the collector surface with a selective coating with absorptivity in the solar spectrum tending to 1 and emissivity in the infrared region beyond 3μm tending to 0.

The whole concept of selectivity in relation to glass and metal substrate was analysed. Various selective coatings amenable to mass production techniques were developed. In the electroplated selective coatings such as copper black, nickel black, and chrome black, the relationship between the process parameters and the microstructure of the coated surface on the one hand, and between the microstructure of the surface and the optical properties on the other, was investigated. These coatings were observed to be a distribution of tiny metal particles embedded in a matrix of its corresponding metal oxide. The process parameters affect the microstructure to a great extent which, in turn, affects the selectivity of the surface. It was found that the selectivity is optimum when the intergranular spacing is 3—4 μm.

Having investigated a relationship between the microstructure and the selectivity, it appeared possible to improve the selectivity by structuring the selective coating. A structured coating on a metal plate was made, using photolithographic techniques, and a master grating was prepared, using holographic techniques. No deterioration of structured selective coatings was observed even if the temperature exceeded 500°C.

The behaviour of the electroplated selective surface was studied in relation to thermal cycling. It was found that if the temperature during thermal cycling does not exceed 200-250°C, thermal cycling has no effect on both the micro-structure and the selectivity. However, when the temperature of the plate exceeds 250°C, there is deterioration in selectivity. This is due to the change in the microstructure.

Solar Water Heaters : A variety of solar water heaters were developed, fabricated and installed at a number of residential buildings. The one which became the most popular, uses a small circulating pump to circulate water from the collector on the top of the building to the storage tank installed in the bath room. Two thermocouples—one on the absorber plate and the other in the storage tank—are provided. The circulating pump is controlled by a switch which is actuated when the temperature of the absorber plate exceeds the temperature of the water in the tank by 5°C.

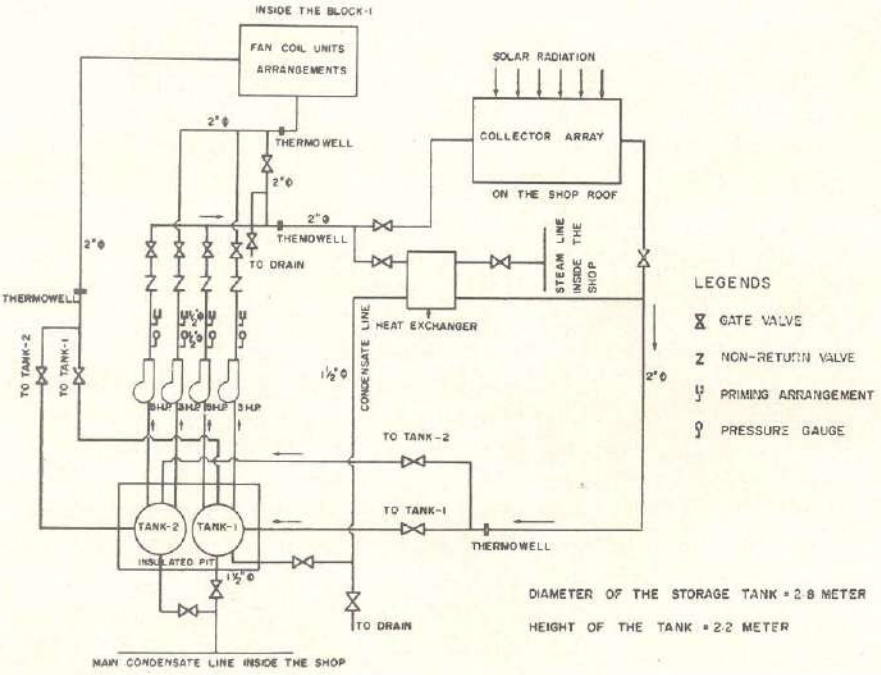

Fig 8 Design of the solar space heating system for the Hardwar factory of the Bharat Heavy Electricals Ltd.

Solar Space Heating System : One of the first major solar energy applications in which NPL succeeded was in the design of a solar space heating system for the Hardwar factory of the Bharat Heavy Electricals Ltd. *(Fig 8)*.

The low productivity in this factory in the second shift during the winter months was causing concern to the management, and this problem was posed to the NPL in April 1975. Some 200 of the NPL-designed flat-plate solar energy collectors were mounted on the roof of one section of the factory *(Fig 9)*, and these were used to heat the water stored in the underground tanks. In the evening, the hot water which attained temperatures as high as 60°C by 3 p.m., was circulated through fan coils over which air was blown. This generated a blast of hot air, which provided comfortable heating to the workers. The system started functioning successfully in December 1975. The system worked satisfactorily even when the days were cloudy.

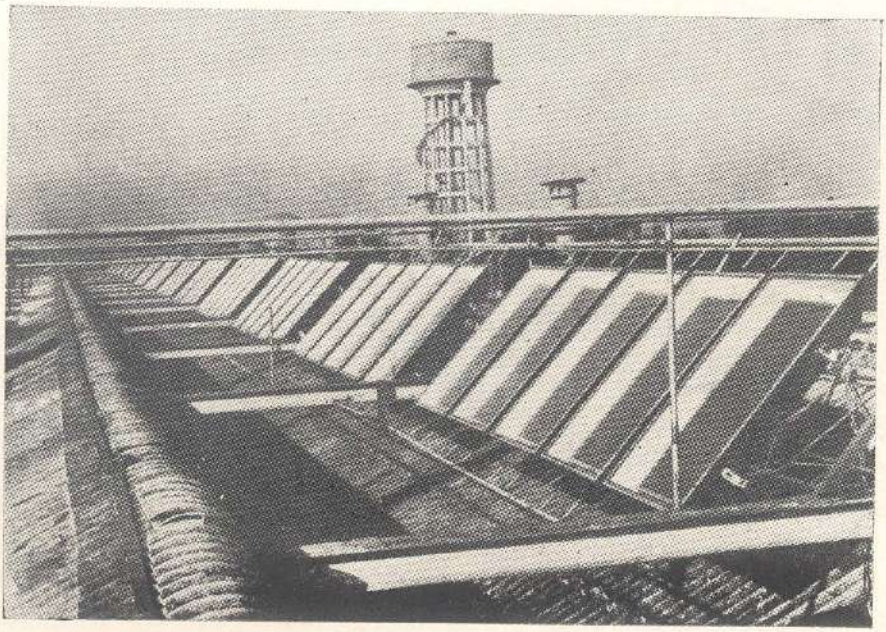

Fig 9 An array of NPL-designed flat-plate solar collectors installed on a section of the Hardwar factory of Bharat Heavy Electricals Ltd.

TABLE—II

Receipts from the Testing work done by the Division of Specialized Techniques

The various specialized techniques were also utilized by the other groups of the Laboratory. With the spare capacity available, this service was also made available to outside parties on payment of nominal charges. The receipts from this work during 1975-76 are given below :

Activity	*For other groups of the Laboratory*		*For outside parties*	
	Number of Test Reports	*Test Fee (in Rs.)*	*Number of Test Reports*	*Test Fee (in Rs.)*
(1)	(2)	(3)	(4)	(5)
1. Analytical Chemistry	27	3,390	196	29,460
2. Spectro-Chemical Analysis	26	10,580	□	□
3. Infrared Spectroscopy	48	4,775	—	—
4. Electron Microscopy	5	1,800	6	2,365
5. X-ray Spectroscopy	50	22,165	3	1,765
6. EPR Spectroscopy	13	2,850	—	—
7. Low Temperature Group	—	—	4	680
Total	169	45,560	209	34,270

Note 1 — The figures indicated in column (3) represent the test fee that could have been charged, had the work been done for some outside parties.

Note 2 — A number of jobs done for outside parties are not reflected in the above table as the service was rendered free of charge, and no test reports were issued.

Note 3 — □ The receipts of the Spectro-Chemical Analysis Section are included in the receipts for Photometry, Colorimetry & Radiometry activities of the Division of Standards *(See Table-I on Page 20)*.

TABLE – II

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DIVISION OF MATERIALS

The Division of Materials pursued R & D work in the areas of semiconductor materials and devices, magnetic materials, piezoelectric and dielectric materials and devices, low loss ceramic insulators, and carbon products. This R & D activity is complementary to the activities of the two experimental pilot plants *viz.* (i) Development-cum-Production of Electronic Components Unit and (ii) Carbon Pilot Plant.

The Division formulated and pursued time-targetted programmes of work on development of silicon controlled rectifiers, high frequency ferrites, high permeability ferrites, magnetic tapes, steatite and high alumina ceramics, high voltage ceramic capacitors, and carbon fibres, and also for establishment of a pilot production facility for monochrome TV phosphors. These formed a part of a coordinated programme of work on electronic materials drawn out by the various CSIR laboratories working in this area, with NPL as the coordinator.

1. SEMICONDUCTOR MATERIALS AND DEVICES

The Laboratory has been engaged in the area of semiconductor technology for the past few years. Research and development in this area incorporates activities in (i) silicon technology, and (ii) luminescent materials and devices.

1.1 SILICON TECHNOLOGY

The activities in silicon technology include preparation of polycrystalline silicon, growth of single crystal silicon, and development of high power silicon devices.

Progress

Polycrystalline Silicon : During the year, the quality of polycrystalline silicon produced in the Laboratory by the trichlorosilane method was improved appreciably. By confining to single batch cracking, repeated purity of 100-200 ohm cm N-type was achieved. Some of the significant achievements were :

A reactor with continuous feeding system of the ferro-silicon charge for the generation of trichlorosilane was designed ;

A combination of various factors affecting fractional distillation was optimized ; and

Cracking chamber was changed from the horizontal to the vertical position to reduce the possibility of breakage of silicon rods due to thermal expansion.

Single Crystal Silicon : The work envisaged development of indigenous know-how for growth of single crystals of silicon both by the Czochralski method as well as by the float zone method. Techniques of growing silicon single crystals with controlled doping were perfected.

Silicon Controlled Rectifiers : This work envisaged development of SCRs of ratings 400 A and above. A technique was evolved for fabricating a four-layer, three-junction device, by a single-shot diffusion.

1.2 LUMINESCENT MATERIALS AND DEVICES

Progress

Pilot Plant for Monochrome TV Phosphors : Phosphors for use in electron tubes such as cathode ray tubes, TV tubes, and radar tubes, had already been developed at the NPL. Based on the encouraging results, the NRDC sponsored the setting up of a pilot plant to produce 600 kg/year to 800 kg/year of monochrome TV phosphors at the NPL, at an estimated investment of Rs. 4.90 lakhs as risk capital.

The pilot plant was designed by the NPL scientists, and renovation of the premises for setting up of the pilot plant was completed during the year. Furnace bodies were also fabricated.

Cadmium Sulphide Phosphors : Studies were carried out on CaS phosphors in pure and stoichiometric form, for their optical and luminescence properties. Defect studies were also made.

2. MAGNETIC MATERIALS

In the area of magnetic materials, the Laboratory has been working for the past about two decades, and has developed a range of oxide magnetic materials *viz.* ferrites—both for the entertainment industry, as well as for professional use in the communication industry.

Upto the year 1974, various grades of ferrites for use in the frequency range 1 kHz to 300 MHz were developed for use as components in the radio and TV industry. Grades equivalent to Philips 3B7 and 3H1 for use in communication industry were also developed and passed on to the industry for large scale production. Based on these achievements the Government of India floated a public sector undertaking to take up the production of professional ferrites.

2.1 SOFT FERRITES

Progress

High Permeability Ferrites : A ferrite with initial permeability (μ_i) of $8000 \pm 20\%$ with Curie temperature $\Theta \geqslant 125°C$ and tan $\delta/\mu_i < 10^{-6}$ at 4 kHz, was developed. The effect of various additives such as SiO_2, Nb, V, Ti, Ni and Mo on the sintering kinetics and properties of these Mn-Zn ferrites was studied. Mn-Zn ferrite powders were also prepared by spray-drying and hydro-thermal oxidation. The latter process yielded good quality powders with particle size varying from 100-2000Å.

High Frequency Ferrites : A Ni-free grade of ferrite (NPL-10-1), for use upto 20 MHz in the short wave frequency, which has properties better than or equivalent to Philips 4D1, was developed. Cores and antenna rods made out of this grade were subjected to consumer acceptance tests and pilot production.

A Ni-Zn-Co ferrite with good TF and DF was also developed for use in the high frequency (1-15 MHz) pot cores used in the telephone lines. All the properties were better than or equivalent to Siemens K1 except the TF which was greater than 10^{-5} per °C for this grade.

2.2 SPECIAL FERRITES

Memory Cores : Work on Mg-Mn ferrite memory cores (50 mil and 80 mil) yielded batches which were approved by the consumers. Work on temperature insensitive Li base square loop ferrite was also started and initial experiments were carried out.

Magnetic Tape Technology : The objective has been to develop a small-scale magnetic tape coating unit with indigenous raw materials and equipment.

The prototype magnetic tape coating unit fabricated in the Laboratory with indigenous components became operational during the year. The raw materials used were tensiled polyester and γ-Fe_2O_3. Samples of γ-Fe_2O_3 received from the National Metallurgical Laboratory, Jamshedpur, and the National Chemical Laboratory, Poona, were tried on the magnetic tape coating plant.

γ-Ferric Oxide : The objective is to develop a cheap import-substitute for γ-Fe_2O_3. The laboratory scale experiments were encouraging and the powders conformed to the required B_s, H_c, and particle shape.

Magnetostrictive Ferrites : A material with Ni-Zn-Cu-Co composition was standardized. A die to make 20 kHz transducers was fabricated, and transducers were processed. The electromechanical coupling coefficient of these transducers was comparable to that of the imported transducers.

3. PIEZOELECTRIC & DIELECTRIC MATERIALS AND DEVICES

Development work on piezoelectric transducer materials for making different types of transducer elements used in piezoelectric and ultrasonic devices was continued alongwith regular pilot production of the material already developed.

The activities can be grouped in the following major areas :

1. Piezoelectric materials ;
2. High voltage ceramic capacitors ;
3. Technical ceramics ; and
4. Ultrasonic instrumentation and piezoelectric devices.

3.1 PIEZOELECTRIC MATERIALS

Progress

Technical improvements at various steps of the production process of NPLZT-5—a low power transducer element—resulted in less rejection rate, giving higher yield of the product.

Preliminary investigations were carried out on the development of NPLZT-6—a frequency-and temperature-stabilized material for electro-mechnical filters. A modified composition of lead zirconate titanate showed encouraging results.

Work on NPLZT-4—a material for high power applications in various ultrasonic applications such as ultrasonic cleaning, drilling, welding etc. and other high power transducer applications—was also initiated.

3.2 HIGH VOLTAGE CERAMIC CAPACITORS

Progress

Standardization work of pilot production of ceramic capacitors in 1 kV-4 kV working voltage range, using two standard compositions—MKD and TCD—was successfully done to get higher yield of the finished capacitors.

General purpose MKD-I type materials based on the composition $BaTiO_3$, $CaZrO_3$ and $PbZrO_3$ were developed. The standard composition having dielectric constant of 1800, was used to fabricate capacitances of the values 270 pF to 2500 pF. Some samples of the capacitors were supplied to consumers for acceptability tests. The technical specifications of the MKD-I type capacitors are listed in Table III.

TABLE III

Technical Specifications of MKD-I type High Voltage Ceramic Capacitors (K~1800)

Characteristics	*MKD-I*
Capacity Tolerance	$\pm$ 10%, $\pm$ 20%
Tan δ (at 30°C)	0.02
Test Frequency	1 kHz
Maximum Capacitance Change	$\pm$ 20%
Leakage Resistance	10,000 MΩ.
Flash Test Voltage	2×DC Working Voltage.
Oporating Temperature	0°C to 85°C
Values of Capacitance	270 pF to 2500 pF

The fabrication process of the power capacitors with high current ratings was developed for the use of the Bharat Heavy Electricals Ltd., Hardwar, for replacement of the imported capacitors used in the resonant tank circuits of induction heaters at high frequencies, by the indigenous capacitors.

3.3 TECHNICAL CERAMICS

The programme related to the development of high alumina and steatite bodies which find extensive applications as low-loss insulating ceramics at high frequencies.

Progress

Alumina Ceramics : Alumina bodies (99% Al_2O_3) with 8-10% porosity, were developed and supplied to the Bharat Electronics Ltd., Bangalore. These bodies had the following characteristics :

Dielectric Constant	~8.5
Dielectric Loss Factor	$\sim 5 \times 10^{-4}$
Resistivity at	
20°C	$>10^{14}$ Ω cm
200°C	$>10^{12}$ Ω cm
500°C	$>10^{8}$ Ω cm
Water Absorption	5 to 30%
Apparent Density	~3.2 g/cm^3

The items developed were used as alumina insulators & spacers, and as alumina housings, for microwave diodes.

Steatite Compositions : Two compositions (Steatite I & SPS-V) were prepared. One of these (Steatite I) was standardized for its electronic and physical characteristics which are listed below :

Firing Temperature	1260 ± 5°C
Dielectric Constant	5—7.5
Dielectric Loss	1×10^{-4}
Dielectric Strength	>22 kV/mm
Water Absorption	0
Density	2.9 g/cm^3

Compositions were developed for making cores for carbon resistors and high frequency insulators.

Steatite compositions in different sizes were sent to consumers for their acceptability tests.

Material composition for transistor headers and cathode insulators was identified during the year.

3.4 ULTRASONIC INSTRUMENTATION & PIEZOELECTRIC DEVICES

The objective is to develop various types of ultrasonic and piezoelectric devices using the NPL material, and to develop ultrasonic instrumentation.

Progress

Piezoelectric Micrometer : A prototype model of piezoelectric micrometer for fine movement was made *(Fig 10)*.

Ultrasonic Cleaner and Drill : A transducer and a concentrator horn for use in ultrasonic drill were developed. A series of magnetostrictive ferrite transducers were also developed for use in ultrasonic cleaners, and an attempt was made to develop a cheap commercial unit for use in cleaning of watches and such other items. The range of the magnetostrictive ferrite transducers developed at the Laboratory matched with the internationally used transducers for ultrasonic cleaning applications. Kp for magnetostrictive ferrite type resonator was studied under loaded conditions.

Piezoelectric Sandwich Transducers : A study relating to the sandwich transducers for applications in ultrasonic cleaning, drilling, cutting etc., under varied conditions of torque, was completed during the year.

New Developmental Activity : The following developmental work was initiated during the year :

(1) Twin normal probes (dead zone 6 mm) for ultrasonic non-destructive testing, and twin angular 2 MHz probes—35° and 70° ;

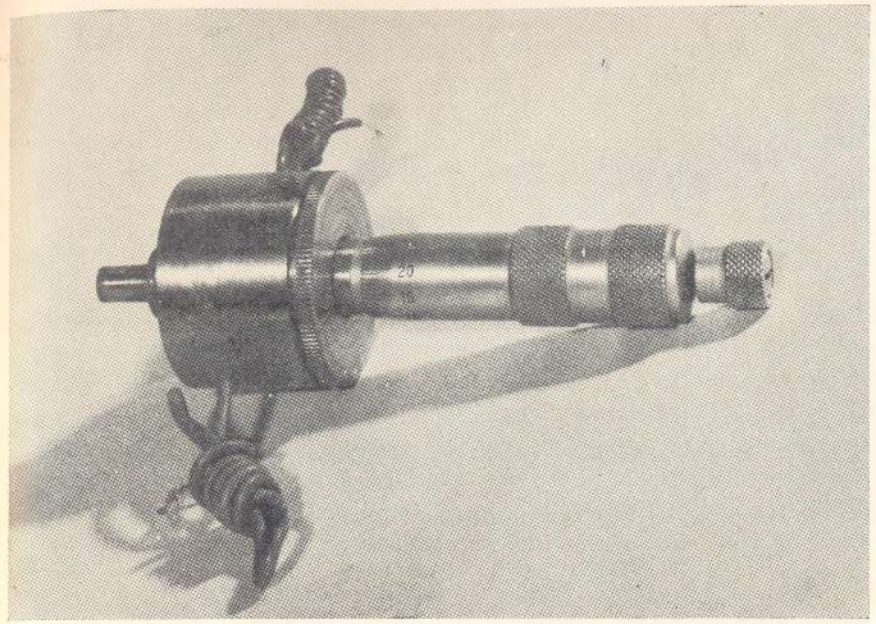

Fig 10 Piezoelectric micrometer developed at the Laboratory. The body to be displaced is mounted at the tip of the micrometer. The coarse movement upto a distance of 10 mm can be provided through the micrometer screw head, while the fine displacement in the range 0.025/μm to 15μm may be made by applying suitable DC voltage across the two terminals.

(2) Under-water acoustics transducers, and setting up of their testing facility ;

(3) Medical therapy probe head—16 W, 870 kHz ; and

(4) Closed type ultrasonic air transducers for remote control applications.

4. CARBON PRODUCTS

Activities in the area of carbon technology covered research and development work on (i) carbon fibres, (ii) arc carbons, (iii) midget electrodes, (iv) electrographitised grades of brushes, (v) carbon mixes, and (vi) carbon thrust bearings.

4.1 CARBON FIBRES

This developmental activity forms a part of a UNDP Country Programme on Composite Materials, with the Indian counterpart funding from the Department of Science and Technology, and it aims at the development of carbon fibres for use as hybrid reinforcement material for a variety of

applications, e.g. in making agricultural silos for storage of foodgrains, and for making large size fishing boats, corrosion free pipes for transportation of water etc. The material is ideally suited for use in making light-weight structures of high strength, to stand conditions of high fatigue.

Progress

Carbon fibres were developed using the following precursors :

PAN : During the year, the technology for processing carbon fibres using imported PAN(Poly Acrylo Nitrile) precursors, was perfected, and carbon fibres with a strength of 300×10^3 psi and a modulus of 33×10^6 psi were developed. Detailed work on characterization of precursor, oxidised fibres, and carbonised fibres was carried out. The techniques utilized to characterize materials at various stages of development included : X-ray diffraction, ESR, electron microscopy, stress-strain curves, infrared spectroscopy, adsorption studies, elemental analysis, and TGA and DTA studies.

Viscose Rayon : Viscose rayons obtained from M/s. Shriram Kota and M/s Century Rayon were carbonised, yielding the following results on a 48 hour batch basis :

M/s. Shriram, Kota	Strength : 80×10^3 psi Modulus : 8×10^6 psi
M/s. Century Rayon	Strength : 150×10^3 psi Modulus : 12×10^6 psi

Jute Fibre : The technology for processing carbon fibres using jute was perfected, and the following results were obtained :

Strength	40,000 to 150,000 psi
Modulus	2 to 8×10^6 psi

Pitch : Both petroleum pitch and coal tar pitch offer certain advantages over other precursors for making carbon fibres. Initial experiments on drawing pitch fibres were quite satisfactory.

Natural Precursors : Trials on carbonisation of natural precursors, such as Algin and Chitoson made by the Central Leather Research Institute, Madras, were initiated. Detailed characterization work revealed useful information for development of fibres.

Progress

Research and development work was carried out to improve the quality of cinema arc carbons, in order to obtain better performance in the electrical and light characteristics.

Rotating projector carbons to carry high currents required for projection of 70 mm films were developed and produced in the experimental pilot plant.

4.3 MIDGET ELECTRODES

Progress

Batches of midget electrodes were processed in the experimental pilot plant by scaling up the operations of centreless grinding and cutting. Training was also provided to the engineers of M/s. Britelite Carbons Ltd., Halol, for production of midget electrodes. The firm also put these into production.

The specifications of the NPL midget electrodes vis-a-vis electrodes of M/s. Britelite Carbons Ltd., for 8 mm rods, are as under :

Party	Apparent density (g/cc)	Electrical resistivity (Micro-ohm-) metre	Flexural strength (Newton/mm²)	Wetting time (minutes)
ISI	1.45 (min.)	60 (max.)	40 (min.)	15 (min.)
NPL	1.70	32	48	>15
Britelite Carbons Ltd.	1.70	30	42	>15

The electrodes processed at the experimental pilot plant of the Laboratory were also supplied to the battery manufacturers, and satisfactory performance reports were received from M/s. Estrela Batteries Ltd., Bombay, and M/s. Jesons Electronics Ltd., New Delhi. The electrodes were also tested at the Chief Inspectorate of Electronics, Bangalore and M/s. Geep Flashlight Industries, Allahabad. A few lakh pieces were supplied to M/s. Havero Industries Ltd., Bombay, and M/s. Koman Industries, Kaninad, for use in their dry cells.

4.4 ELECTROGRAPHITISED GRADES OF BRUSHES

Progress

EG Grades of brushes developed earlier, were improved in material composition and graphitisation techniques. Exploratory type of work in

respect of electrographite grades was done. It included laboratory trials for automobile grades, dense electrographite grades and open-texture electrographite grades.

4.5 CARBON MIXES

Progress

R&D work on carbon mixes was continued, as it forms an adjunct to pilot plant production and large scale production of carbon products.

In pilot plant production of carbon products, process operations *viz.* (i) dry mixing, (ii) wet mixing and (iii) extrusion, from a major part.

In dry mixing, the bulk density of the mix is an important quality-control parameter. Bulk density of different size fractions was determined.

In wet mixing, the binder content is an important quality control parameter. For different size fractions of the dry mix, the optimum binder content using different binders was determined.

In extrusion, the speed of extrusion is important for large scale production. Parameters like strength and electrical resistivity of baked products, using different speeds of extrusion were determined.

4.6 CARBON THRUST BEARINGS

Progress

Development of carbon thrust bearings for automobiles, is an import-substitution activity. Samples of carbon thrust bearings were developed and successfully tried on the NPL's staff cars.

DIVISION OF RADIO SCIENCE

The principal objectives of this Division are :

(i) To study, analyse and disseminate information on propagation of radio waves at all frequencies ;

(ii) To conduct research on the nature of the media through which radio waves are transmitted ;

(iii) To monitor solar-terrestrial environment ;

(iv) To provide space environment disturbance monitoring and predictions (solar-geophysical services, radio warning services) ;

(v) To explore new radio techniques for the use of communication, meteorology, geodesy, environment monitoring and time standards ;

(vi) To utilise the newly emerging techniques of space research in the study of the near space environment, and to explore new areas of applications ; and

(vii) To study and identify the extent of man-made and natural environmental hazards.

1. GROUND-BASED FACILITIES FOR ENVIRONMENT MONITORING

Scope and Objectives

(i) Development of facilities and competence in environment monitoring by radio methods, comparable to those in advanced countries ; and

(ii) To provide basic environment data required for practical radio communication and aeronomical studies, and research on techniques.

The project provides basic material for planning and optimum use of radio and TV broadcasts and other communication systems on a national basis, including rural areas.

Techniques used : The ionospheric environment was continuously monitored with a variety of radio techniques. The equipments used were:

(a) C-4 ionosonde ;

(b) Cosmic ray noise measurements with riometers at 28.5 and 30 MHz ;

(c) HF/LF/VLF propagation ; and

(d) A dopplometer at 10 MHz.

The measurements provide the basic raw material for prediction of radio propagation conditions via the ionosphere, as well as monitoring of disturbances to propagation conditions caused by events like solar flares and magnetic storms.

Progress

C-4 Ionospheric Recorder : C-4 ionospheric recorder was in operation for routine sounding of ionosphere throughout the year. The data obtained by the recorder was fed to the project on Radio and Space Services for appropriate use and dissemination. A computer programme developed earlier in this project was used for reduction of ionograms to electron density—true height (N-h) profiles.

Detailed studies were made on various existing methods of true height reduction, following a programme of URSI working group on the subject. It appears that techniques of reducing ionograms to N-h profiles have been generally perfected to such an extent that the inaccuracies in the reduction are found to be less than that of recording and scaling of the ionograms.

Neutral Nitric Oxide Densities in the Lower Ionosphere : Electron density profiles at medium latitudes derived from the radio wave propagation data for various solar zenith angles for different seasons, and for high and low solar activity, were used to interpret the variations of neutral nitric oxide, by comparison with models of ionization rates and effective recombination coefficients.

Type of Solar Flare Effect on 164 kHz in relation to the Stratospheric and the Mesospheric Circulation : It was found that the appearance and disappearance of those types of solar flare effects on 164 kHz radio waves (propagated over a distance of about 1600 km from Tashkent to Delhi) which show an initial increase in the field strength, is closely associated with the reversal in the latitude gradient of the stratospheric radiance from 20—52 km as indicated by the Nimbus 4 satellite observations. The reversal in the zonal wind component at 60—75 km is also closely related to the change-over from one type of solar flare effect to another. These results suggested that seasonally dependent structural changes in the stratosphere and the mesosphere may be responsible for the observed

preferential occurrence of a particular type of solar flare effect on 164 kHz in specific months. There appears to be a possibility of using this type of ionospheric effects as a diagnostic tool to study the mesospheric dynamics, besides getting information on the flare time X-ray activity and the chemistry of the D-region.

Electron Density Profiles from the Riometer Technique : Continuous operation of riometers was carried out with a view to study the normal and the disturbed ionosphere over Delhi (geographic lat 28.6°N). The main effort during this period was to derive a reliable electron density profile in the D-region using the multi-frequency riometer absorption data available for this station.

In an effort to understand the seasonal anomaly in absorption over Delhi, the riometer and the pulse absorption data over a period of solar cycle were examined. The analysis suggests that during the high sunspot period the winter absorption is always more than the summer value. A similar behaviour was also observed with the f_0F2 data over this latitude, suggesting that the seasonal anomaly is mainly due to the F-region alone.

Estimation of the Collision Frequencies and the Temperatures in the F-Layer from the Absorption Measurements : Estimation of the collision frequencies and the temperatures in the F-layer have been attempted from the pulse absorption measurements as well as with riometers. Diverging conclusions have been drawn by various workers. The pulse absorption measurements generally, as well as the riometer-cum-ionosonde analysis made earlier by this group, had shown that significantly lower values of temperatures in the F-region are obtained with the absorption measurements than with the other techniques. Some others, however, have sought to match the absorption results with the incoherent-scatter or the probe measurements with rockets and satellites.

During the period under report, the procedures of analysis for calculation of the temperature from the absorption measurements were examined in some detail. It was concluded that the only way to match the absorption results with the temperature obtained by the other techniques is to modify the relation connecting collision frequency and temperature.

Special Propagation Studies : From the f_0Es data available over the Indian stations, a study was made to enable the prediction of the percentage occurrence of Es at any time in the Indian sub-continent above any specific frequency. The studies are significant for obtaining Es interference potentiality of TV signals, and also for the use of equatorial Es for communication purposes during the day time.

Atmospheric Radio Noise : Using the measured data for atmospheric radio noise for the Indian stations, latitudinal and longitudinal variations for

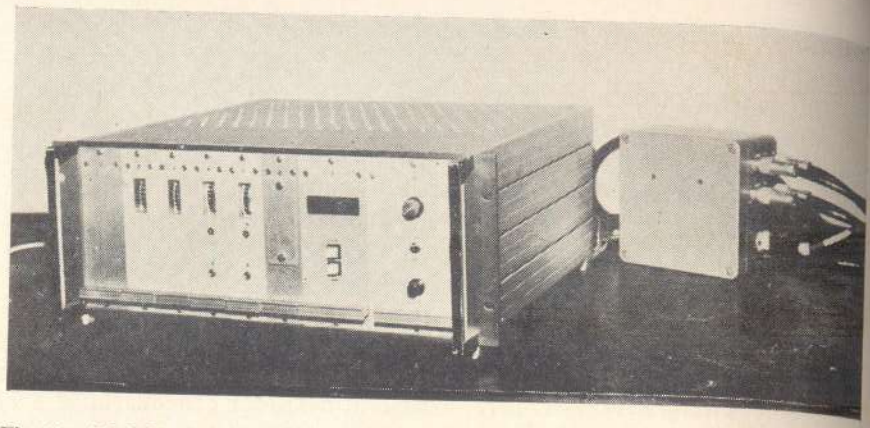

Fig 11 140 MHz ATS-6 radio receiving system designed jointly by the NPL and the Max Planck Institute, West Germany, under a collaborative programme with that Institute, and fabricated at that Institute. The system started recording both the amplitude and the phase of the radio beacon transmissions for the ATS-6 satellite from 1 August 1975 at the NPL, New Delhi, and later operated at the Gauhati University also.

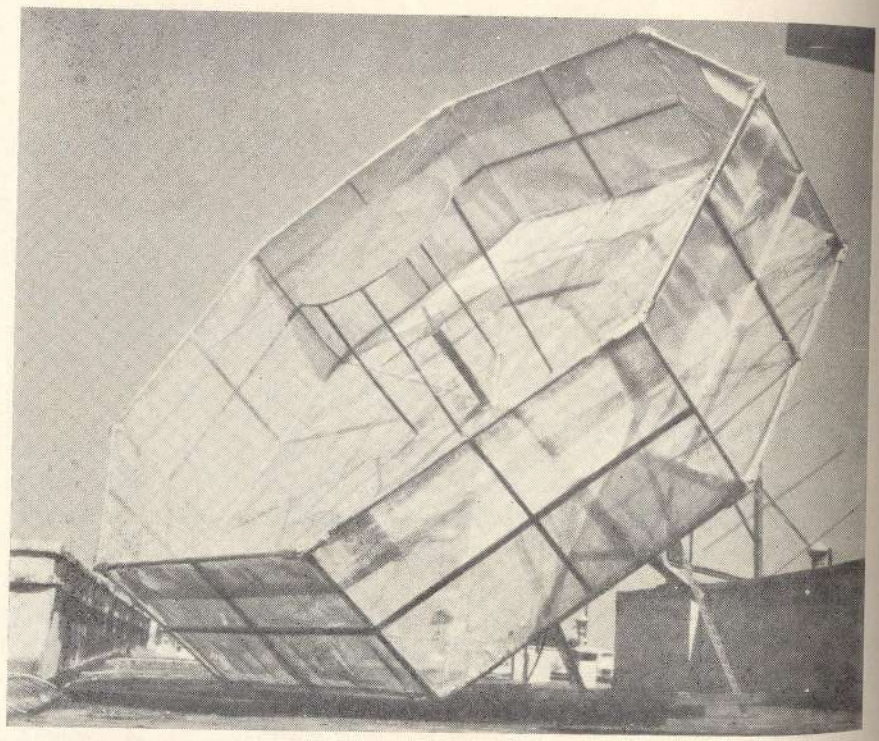

Fig 12 Short back-fire antenna for 140 MHz, designed and installed at the Laboratory for observation of the ionospheric effects on the signals transmitted by the ATS-6 satellite.

Scope and Objectives

(i) To predict HF radio propagation parameters in advance for various communication organisations in India ;

(ii) To develop new techniques of propagation most suitable for the Indian conditions ;

(iii) To collect, compile and disseminate ionospheric, solar and geophysical data ; and

(iv) To broadcast in advance, geo-alerts and other disturbances that cause disruption in communications.

Progress

Data Services : Radio and Space Services Group continued to be responsible for collecting and compiling of ionospheric and solar geophysical data from various ionospheric stations and organizations throughout the country. The compiled data were brought out regularly as monthly publications of ionospheric and solar geophysical data (RRC-A Part I and Part II).

The Group engaged in these services also acts as the Associate Regional Warning Centre for East and South East Asia. This is one of the international centres under IUWDS. The main responsibility of this Centre lies in quick distribution of daily solar geophysical data within the country, and to establish efficient channels of interchange of daily important data between stations within India and various Regional Warning Centres in the other parts of the world.

Installation of a Telex machine in 1975 improved the efficiency of the working of this Centre considerably. A plain-language message including all information was broadcast daily on the NPL standard time and frequency service (ATA) on 10 MHz at 1500 hrs., and by the AIR at 2240 hrs. IST.

Ionospheric Predictions : Predictions of high frequency propagation conditions via the ionosphere as well as the sunspot numbers six months in advance has been a major service provided for the various communication services in the country. This prediction service is the only comprehensive service existing in this country, and includes all the basic ionospheric parameters for the East zone, *viz.* 50°E to 170°E longitude.

A computer programme was tried out to obtain a second degree relationship between the sunspot number and 2-hourly f_0F2 values for all the 25 stations that are used in long term forecasting, to improve ionospheric forecasting.

Analytical Studies to Aid HF Communication : A study was made to find out the effect of magnetic and solar activity on HF communication at low and equatorial latitudes. The study indicated that while giving short term predictions for low latitudes, only major magnetic storms and solar flares can be accounted for. A detailed study undertaken on the effects of major magnetic and solar events established that HF radio communication using predicted parameters suffers only marginally if the reflection point is within $\pm 10°$ geomagnetic latitude. Besides these studies, some very specific problems at low latitudes were identified *viz.* (i) sharp sunrise increase in f_0F2, making it difficult to communicate at a fixed frequency (day or night), (ii) the anomolous shift in the geomagnetic anomaly peak, and (iii) large day to day variability in the propagation parameters, reducing the reliability of a link.

4. AERONOMY

Scope and Objectives

(i) To study the physics and chemistry of the upper atmosphere and the ionosphere ;

(ii) To measure cross-sections of processes of aeronomical interest in the laboratory ; and

(iii) To obtain basic reference information of the radio atmosphere for use in (a) communication, (b) atmospheric pollution and climatic changes, (c) satellite tracking, (d) navigation systems, and (e) systems design.

Progress

Semi-Annual Effect in the Neutral Composition : All the available measurements of O, O_2 and N_2 concentration measured in the lower thermosphere by the rocket experiments were analysed to study the seasonal changes in the neutral composition in the lower thermosphere. The maximum number of observations exist for the ratio O/O_2, and these show rather a clear semi-annual effect at 120 km. At 150 and 200 km, O/O_2 & O/N_2 values are, on the average, higher in the equinoxes than in summer and winter. These results are consistent with the seasonal changes observed in the ionospheric F2-region at the low latitudes.

Airglow Excitation Mechanisms : Results of electron impact excitation O_2^+ second negative bands and OI, OII permitted lines by 100 eV to 1 KeV electrons on oxygen gas were analysed. The ratio of the intensities are in good agreement with the values determined from the Franck-Condon factors. The prominent OI and OII permitted lines in the visible region of 3700 Å to 5000 Å were analysed. The relative integrated intensities of

OI and OII multiplets by electron impact on O_2 are different than the measured ratios in the aurora. This difference is quite marked in the case of the relative intensity of 4416 Å ($3P^2D° \rightarrow 3S^2P$) OII and 4368 Å OI lines. In the aurora the intensity is nearly equal, while in the electron impact excitation, the intensity of the 4368 Å line is 1/2 of the 4416 Å line. This analysis showed that in the aurora, the dissociative excitation mechanism might be the most important process for the excitation of the OII lines, whereas the OI atomic lines are also excited by the impact of electron on oxygen atoms present at the auroral height.

Chemistry of the D-region : A unified picture of the chemistry of the normal and the disturbed D-region has been evolved, using the six-ion chemical scheme originally proposed for solar flares. This work attempted to cover, in a single approach, conditions of quiet day and night, solar eclipses, flares, and polar cap events. The drastic decrease in the effective recombination coefficient comes out as a natural consequence of a sudden influx of O_2^+ production aided by increased dissociative recombination of the cluster ions with enhanced electron density. The most important point is that the chemistry of the lower ionosphere during polar cap absorption (PCA) is almost entirely identical with that of sudden ionospheric disturbance (SID), excepting a difference in the time scale, and the increased importance of negative ions during PCA conditions. The eclipse characteristics were also reproduced, if one accepts that the detachment from the heavy negative ions is more important than ion-ion recombination, and that it vanishes during totality.

Electron Density Distribution around the F-Layer Peak : Studies were conducted using high resolution electron density profiles obtained from the incoherent scatter measurements at Arecibo. These studies have shown that while the distribution is nearly α-Chapman type around the F2 peak, the scale height of the distribution is controlled by the height of the F-layer peak (h_mF) and is more or less equal to the scale height of the neutral atmosphere at the F-layer peak as obtained from the COSPAR International Reference Atmosphere (CIRA) model for the appropriate solar activity conditions.

Electron Temperature Models : Based upon an analysis of the large amount of data for Arecibo during low solar activity and for St. Santin during medium solar activity, electron temperature models were developed for the height range 120 to 500 km. These models have been compared with later measurements at other stations. The model values show a reasonable agreement with the measured values.

Estimates of Electron Heating Rates in the Top-side Ionosphere during Medium Solar Activity : From the OGO-4 data of ion composition, it was found that in the daytime the contribution of energy transfer to

lighter ions is negligible. From the temperature and density profiles over Arecibo, measured with incoherent scatter radar (10 February 1972, period of medium solar actitvity), the collisional loss (L_c) and conduction loss (L_{cond}) terms were calculated. Using the T_e and N_i measurements made with RPA on OGO-4 during the daytime in September-October 1967, estimates were made of L_c by adopting an atmospheric model with exospheric temperature of 1100 K. Available theoretical calculations of Q_e for both bottom-side and top-side through photo-electron flux calculations were found smaller by a factor of about 3 when compared to the present estimates.

Ion Composition Changes during the Geomagnetic Storm of 13 September 1967 : Information on the ion composition for the storm of 13 September 1967, was obtained from the analysis of the retarding potential analyser data of OGO-4. An important effect observed was that O^+ ion which is a minor ion at these altitudes at night, increased by an order of magnitude, while the lighter ions H^+ and He^+ did not change significantly. The total ion density, however, increased only by a factor of 2. The ion and the electron temperature (T_i, T_e) measurements during this storm period were examined. Both the quiet and the storm time observations at 01—02hrs. were in the range of 1100—1300 K for T_i and 1300—1500 K for T_e, and there were no indications of any definite changes during the storm. The observed increase in the O^+ density may possibly arise due to the upward flux of O^+ ions from the F-region altitudes since there is no other source available at night. To test this hypothesis the height variation of the F-region was studied for stations in the Indian zone. The Ahmedabad data clearly showed that the whole layer has moved upwards during the night. This increase in h_mF2 gives a flux of about $5 \times 10^8 - 10^9$ $cm^{-2}s^{-1}$ which was found sufficient to enhance the O^+ density to the required extent.

Ionospheric Effects of Solar Flares : A comprehensive study was made of the physics and chemistry of the ionospheric changes during solar flares from 50 to 1000 km, thus including not only the bottom-side ionosphere, but a good part of the top-side ionosphere also. A number of giant ionospheric events for which the ionospheric effects are large and well documented, as well as the "norm" of an average or a moderate flare, were identified. For these two categories, reference distributions were developed for percentage changes in the electron density, the effective recombination coefficient, and the water-cluster ion composition. For the F-region, changes in the ionization profiles were traced upto 1000 km, using the incoherent scatter observations during a number of flares. The chemistry of the flare-time changes in the lower ionosphere was examined, using the six-ion scheme.

5. ENVIRONMENTAL HAZARDS

Scope and Objectives

(i) Monitoring of the atmosphere upto a height of 1 km for use in hazardous situations in communication, aviation and air pollution ;

(ii) To layout the techniques alongwith complete instrumentation, and to calibrate it for monitoring parameters like temperature inhomogeneities, inversions, wind velocity and turbulence intensity in the lower atmosphere ;

(iii) To study the global and the regional aspects of atmospheric ozone depletion by natural and artificial means and also its consequences on the environment, with special reference to the Indian sub continent ; and

(iv) Climatic changes due to solar activity—possibility of long term forecasting.

Progress

A monostatic sodar system to study the thermal structure of the lower atmosphere to a height range of 600 m has been set up at the National Physical Laboratory. The acoustic antenna was surrounded by an acoustic shield designed in the shape of a nanogon, with a diagonal of 3.6 m. The height of the shield from the ground is 3.4 m.

Thermal Structure of the Lower Atmosphere : The continuous monitoring of the lower atmosphere with the help of the sodar, provided echograms which gave information about the structures associated with the thermal instabilities in the planetary boundary layer.

The plumes exist generally upto a height of about 200 m which is practically the limit of observation of the sounder during the daytime due to the high ambient noise of the surroundings.

The night time echogram shows multilayers.

Sodar Indexing : The structure on the sodar echogram is a characteristic of the time, season and the ambient micro-meteorological conditions of the lower atmosphere. The micro-meterological conditions determine the tropospheric propagation characteristics of the electro-magnetic waves and the hazardous situations in aviation and air pollution, making it thus possible to use the information available from the characteristic structure on the sodar echogram as an index for such situations. With this aim in view, the various types of observed structures on the sodar echograms were indexed from zero to nine. The indexing number is in the increasing order of turbulence under stable conditions.

Comparison of the Sodar Echogram Intensities with the Radiosonde Data : The extent to which the sodar echo intensity represents the radio refractivity conditions prevailing in the atmosphere can be studied by selecting a particular level on the sodar echograms and measuring the intensity level of its blackness and comparing it with the refractivity gradient data as available from the radiosonde observations made simultaneously. This exercise was done for the available sodar echograms at a height level of 150 m.

Earth's Ozone Environment : A new effort concerned the question of stratospheric ozone depletion, on which much work had been done in recent years in the USA. However, questions arose about the magnitude of the effect and the relative importance of the various sources, i.e. (a) Supersonic transport aircrafts (SSTs), (b) industrial chlorofluromethanes (CFMs), (c) volcanic er uptions, and (d) nuclear explosions. The principle effort during the year was to make acomparative estimate of the depletions from these different sources. Major reactions and their rates were also identified.

Work on the chemistry of ozone in relation to the changes in nitric oxide and chlorine in the stratosphere was taken up. To have a new look at the stratospheric chemistry, stratospheric ions were measured over the heights 23—40 km with a Gerdien condenser flown in a Menaka II rocket on 8 July 1975, at 1130 hrs.

DEVELOPMENTAL PROJECTS

In addition to the R & D projects undertaken by the Division of Standards, Division of Specialized Techniques, Division of Materials, and Division of Radio Science, the Laboratory pursued work on the following four projects termed as Developmental Projects :

1. Microwaves and Display Tubes Technology ;
2. Electrophotographic Machines ;
3. Thin Film Devices ; and
4. Liquid Crystal Devices.

1. MICROWAVES AND DISPLAY TUBES TECHNOLOGY

Scope and Objectives

The activities of this project have been in the following main areas :

(i) Design, development and batch-production of microwave components, circuits and instruments ;

(ii) Fabrication techniques for cathode ray tubes and TV picture tubes ; and

(iii) Development of composite displays (3-D photography and radiography).

The objective is to develop the technology, and then to transfer the know-how to the industry for commercial exploitation.

Progress

1.1 DESIGN, DEVELOPMENT AND BATCH-PRODUCTION OF MICROWAVE COMPONENTS, CIRCUITS AND INSTRUMENTS

General Purpose Waveguide Components : The designs of some waveguide components were perfected for S, KU and K-bands. These modifications in the designs were carried out to get better specifications for slotted lines, coaxial-to-waveguide adapters, cross-couplers and frequency meters etc. Gunn oscillator for KU-band was also fabricated.

In addition to M/s. KLB Electronics, New Delhi, and M/s. Scientific Instruments Co., Allahabad,—the two licencees of the NPL know-how for general purpose waveguide components who continued their pro-

puction—M/s. Vidyut Yantra Udyog, Modinagar—a new NPL licencee—, also started manufacturing the X-band components.

Coaxial Line Components : Work on coaxial components, e.g. 50 ohm matched terminations, fixed attenuators, frequency meters and short circuits was continued to achieve broad band characteristics over a frequency band 1.0 to 12.4 GHz. Coaxial line 50 ohm terminations in long length, with a maximum VSWR of 1.20 from 2 to 12.4 GHz, were fabricated. Work on 50 ohm matched terminations in short length (mini-terminal) DC to 4 GHz was also completed with a maximum VSWR of 1.10.

The broad-banding for coaxial fixed attenuators, with the ceramic central conductor coated with aquadag, was also achieved in the frequency range 1 to 12.4 GHz. The maximum attenuation spread with frequency is ± 2 db for 20 db attenuator. Studies were also conducted on minimising of the spread of attenuation with frequency. Two coaxial frequency meters (transmission type) from 2.5 to 10.2 GHz were fabricated, covering the ranges from 2.5 to 6.5 and 6.5 to 10.2 GHz. Coaxial fixed short circuits in type-N connector was designed and successfully fabricated. *Fig 13* shows some of the coaxial line components developed at the Laboratory.

Precision Waveguide Components : Precision moveable matched termination for X-band was fabricated with a maximum VSWR of 1.01 over the entire band. Prototype of the broad-band matched detector mount (X-band) gave a maximum VSWR of 1.40, and crystal output was constant within ± 1.5 db over the entire band. Work was initiated to reduce the VSWR and to achieve better crystal output characteristics with frequency. Most of the parts of a precision rotary vane attenuator (X-band) and precision moveable short circuit (X-band) were designed and completed.

1.2 FABRICATION OF CRT & TV PICTURE TUBES

Reconditioning of CRT & TV Tubes was continued as a service to the public. A special header with chilled water system was developed in order to cut down the processing time as well as the expenditure involved in re-conditioning or making of new tubes.

Rotating head machine for lacquering & sealing of TV picture tubes was designed.

Full facilities for testing and evaluation of TV picture tubes established so far were utilised, and 18 TV picture tubes of various makes were tested for the Electronics Trade and Technology Development Corporation Ltd., New Delhi.

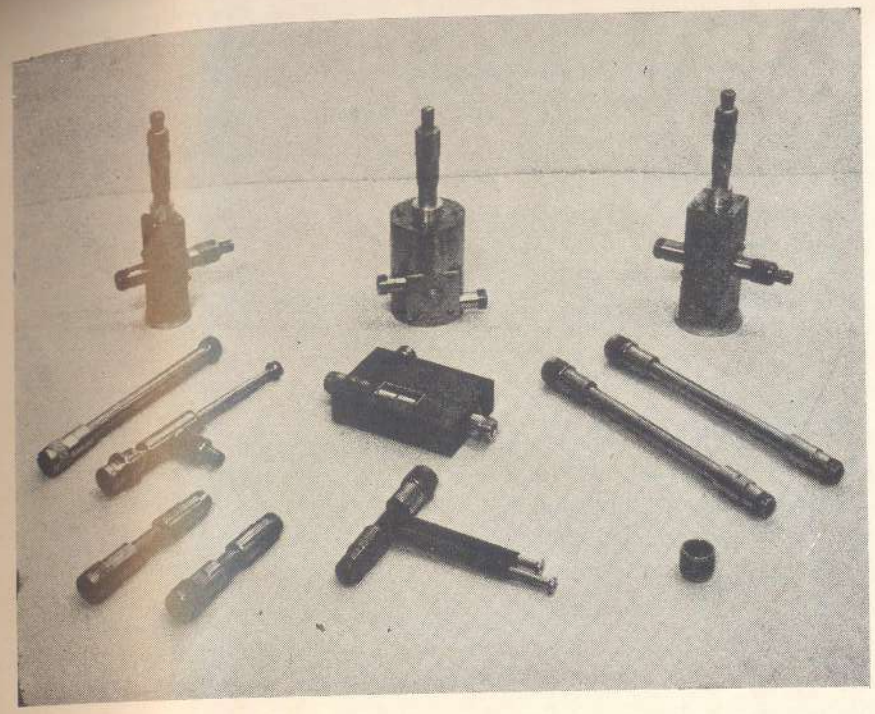

Fig 13 Coaxial line components developed at the Laboratory. *Left to Right, Top row :* **Coaxial frequency meters (6.5 GHz to 10.2 GHz, and 2.5 GHz to 6.5 GHz).** *Middle row :* **Coaxial terminator (2.0 GHz to 12.4 GHz), Tunable probe (3.95 GHz to 12.4 GHz), 10 db Directional coupler, Coaxial attenuators (3.0 GHz to 12.4 GHz).** *Bottom row :* **Fixed attenuators (6.0 GHz to 12.4 GHz), Double-stub tuner, Fixed short circuit.**

1.3 3-D PHOTOGRAPHIC DISPLAYS

Some more colour photographs were taken, based on the techniques of 3-D photography already developed at the Laboratory. Electro-forming techniques were successfully tried for making plate die to emboss lenticular grid on transparent PVC.

2. ELECTROPHOTOGRAPHIC MACHINES

Scope and Objectives

Electrophotographic machines are essential for document copying and for fast and accurate dissemination of information. Manually operated machines based on the principle of electrophotography and using selenium photoreceptors, have already been developed at the NPL with

completely indigenous resources, and the process know-how has been released to the industry through the NRDC, New Delhi.

With the development of the basic technology, work on the development of the following types of faster copying machines has also been taken up :

(i) automatic electrostatic photocopying machine using selenium plate photoreceptors ;

(ii) automatic electrostatic photocopying machine using selenium drums ; and

(iii) automatic electrofax machine, together with suitably coated paper, developer etc.

Progress

Selenium Plates : Eletrical and photoconductive studies of the selenium plates, with different interfacial coatings and over-coatings, were made to improve the quality of the plates.

Automatic Plate and Drum Machines : The first prototype of the automatic plate machine was fabricated and tested for its performance. The prototype was demonstrated to the National Research Development Corporation of India, New Delhi, and also to the representatives of M/s. Advani Oerlikon Ltd., Bombay.

A few parts of the automatic drum machine were also designed and fabricated.

Developer for the Automatic Electrostatic Photocopying Machine : Work relating to the modifications in the toner composition as well as in the carriers was continued during the year, with a view to improving the earlier composition of the developer for use in the automatic machine.

Paper Masters : Preliminary experiments were made on the development of paper masters to work with the machines using Se photoreceptors.

Electrofax Machine : Almost all the components of the first prototype had been designed and fabricated. A number of these components and parts were put to test, and modifications of some of them were undertaken.

Developers for the Electrofax Machine : Attempts were made to study various dielectric materials and their mixtures, for their suitability as liquid developers for the electrofax machine.

ZnO-Coated Paper : The process know-how for the sensitized ZnO-coated paper was released to M/s. Tokushu Menon, Madras, towards the end of 1974. As the process know-how had been developed on the laboratory scale only, it was necessary to conduct the experiments to determine

various parameters to coat the paper with the commercial plant at Madras. A number of experiments were carried out with various types of base papers, thickness of coatings, and their composition etc.

From the parameters determined with the help of the commercial plant at Madras, it was observed that some modifications in the composition of the product have to be made in order to make it economical. As such, certain changes in the composition and the raw materials were suggested to the firm.

During the year, the process know-how for sensitised paper was also released to M/s, Gadget & Appliances, Jaipur, and details of the process which they carried out at their factory were scrutinized and discussed from time to time.

Electrostatic Dust Collectors/Air Filters : Prototypes of air filters utilising electrets were designed on the basis of the studies carried out on the electrical & dielectric properties of various polymers. Parameters under which these polymers behave as long life electrets were evaluated. It is possible to remove tiny dust particles from the air with the electret assembly, which can be fitted to an air conditioner or to an air blower.

3. THIN FILM DEVICES

Scope and Objectives

(i) Development of thin film optical devices, and also, to a limited extent, putting the same into production, to cater to the needs of various agencies, specially the industries in the fields such as electronics, optics, infrared remote sensing, solar energy, eletro-optics and display systems etc. ; and

(ii) Investigation of the optical characteristics of thin film multi-layer systems which are useful in the development of the desired optical devices.

Progress

Colour Absorption Filters : Colour absorption filters are required for the suppression of side bands which appear in the transmission characteristics of thin film interference filters. Normally colour glass filters are used for this purpose, but the same are not available indigenously. As such, work was undertaken on the development of colour absorption filters using polymer films containing suitable chemical dyes. The films were grown by solution-growth technique, using PVC doped with different dyes.

During the period under report, the following optical devices were developed :

Two- and three-layer antireflection coatings ;

Cold mirrors and laser mirrors ; and

Neutral density filters, interference filters and beam splitters.

The following activities were also taken up :

Measurement of the optical properties of cermet films ;

Measurement of the refractive index of CaF_2 & MgF_2 composite films ; and

Modification of ellipsometer, and use of laser source for its alignment and calibration.

The following parties were rendered consultancy services during the year :

M/s. Vacuum Metallising Industries, New Delhi.

M/s. Polypack Industries, Agra.

M/s. Vacuum Coating Laboratories, New Delhi.

M/s. Sharp Edge Ltd., New Delhi.

4. LIQUID CRYSTAL DEVICES

Scope and Objectives

(i) Development of liquid crystal thermal & electro-optical display devices ;

(ii) Development of various chemicals suitable for thermal (using cholesteric liquid crystals) and electro-optical (using either nematic or mixtures of nematic and cholesteric liquid crystals) display systems ;

(iii) Decoding, driving & multiplexing of numeric, alphanumeric and other information displays ; and

(iv) Development of image convertor and intensifier devices.

Progress

4.1 LIQUID CRYSTAL THERMAL DEVICES

Liquid crystal thermal devices indicate temperature through colour display. During the period under report, various cholesteric materials were synthesised and characterized in the Laboratory. These are cholesteryl chloride, cholesteryl nonanoate, cholesteryl oleyl carbonate, and cholesteryl oleate. Production of these materials of more than 100 g per batch was achieved. A variety of thermal devices were made, using indigenously prepared cholesteric materials, and these were successfully tried for medical thermography, for recording room and body temperatures, for mapping microwave intensity patterns, and for display of de-icing patterns on wind shields etc. The process for making liquid crystal thermal devices was released to M/s. Darbari Industries, Allahabad.

4.2 ELECTRO-OPTICAL DISPLAY DEVICES

Liquid crystal electro-optical display devices are basically of two types, *viz.* (i) dynamic scattering type, and (ii) field effect or twisted nematic type. In the former, the ambient light is modified by forward scattering on creation of turbulence and electro-hydrodynamic instability in the liquid crystalline material on the application of an electric field, while in the latter, the light is modulated by rotation of the plane of polarisation. These are single plane displays for wide-angle viewing, and consume extremely low power ($\sim\mu$W).

Testing of Liquid Crystal Electro-optical Displays : Market approach, acceptance, and growth of any new device, depends on its reliability and performance. Liquid crystal displays were, therefore, subjected to various important operational, humidity, environmental and climatic tests. At the end of each test made on the cell, the physical and the electrical parameters such as physical appearance, contrast ratio, threshold voltage, current drain, response times, capacitance etc., were measured. Various experimental arrangements were set up to measure these parameters. For measuring the "turn-on" and "turn-off" times of the display, a programmable pulse generator which gives out rectangular pulses of variable amplitude at the frequency of 50 Hz and remains "on" for 1-2 seconds (controllable) and then "off" for 1-2 seconds, was designed. The experimental arrangement consisted of a photomultiplier set up with a high voltage power supply.

Sealing Techniques : In order to increase the operational life of the display devices, hermatic sealing of the cell is essential. A process was, therefore, developed by which a true hermatic enclosure of the cell became possible. Metal—glass soldering techniques were evolved for obtaining true hermatic sealing after vacuum-filling the cell with appropriate liquid crystalline material compositions.

Surface Alignment Technique : A better surface alignment technique was developed with a view to employing it in the fabrication of twisted nematic/field effect electro-optical displays. This technique involves "oblique" vacuum evaporation coating of certain dielectric materials such as silicon monoxide and magnesium fluoride of well-determined thickness and uniformity. Various important parameters were established for

getting the best homogeneous alignment of the liquid crystalline materials having positive dielectric anisotropy.

4.3 NEW CHOLESTERIC—NEMATIC COMPOSITIONS

Studies, both on nematic as well as nematic doped with cholesteric liquid crystalline materials, lead to the development of a new cholesteric—nematic composition which showed improved scattering characteristics comparable to a pure nematic material in a dynamic scattering mode (DSM) cell. Textural, laser diffraction, and light scattering studies on homeotropically aligned nematic material (MBBA) doped with cholesteryl nonanoate (CN) were carried out with or without the applied AC (50 Hz) electric field. In the narrow range of the pitch to the thickness of the cell, densely packed bubble domains grow in size on the application of the electric field. These bubble domains constitute a cholesteric phase with the spiral axis perpendicular to the substrate in a matrix of the homeotropically aligned nematic material. The increase in the bubble domain size on application of the electric field, constitutes a nematic—cholesteric transformation. Light scattering experiments indicated an optimum doping in relation to the threshold potential, contrast ratio etc.

Further studies were carried out on various combinations of nematics doped with cholesterics in respect of their respective dielectric anisotropies.

EXPERIMENTAL PILOT PLANTS

The laboratory has four Experimental Pilot Plants as under :

1. Piltot & Demonstration Plant in Hydrostatic Extrusion & Material Synthesis ;
2. Glass Technology Development and Production Unit ;
3. Development-cum-Production of Electronic Components ; and
4. Carbon Pilot Plant.

1. PILOT & DEMONSTRATION PLANT IN HYDROSTATIC EXTRUSION & MATERIAL SYNTHESIS

Scope and Objectives

Scientific and Technical

(a) *Short term :*

(i) Development of composite materials like copper-clad aluminium and alloy aluminium clad aluminium ;

(ii) Extrusion of hard-to-extrude materials like alloy aluminium and alloy steels ; and

(iii) Extrusion of complex shapes like gear profiles and twist drills.

(b) *Long term :*

(i) To undertake development of indigenous production equipment in hydrostatic extrusion ; and

(ii) To investigate the possibility of putting up similar units in hydro-forming and hydropressing.

Socio-Economic

(i) To reduce dependence on imported materials like copper, by development of composite materials ;

(ii) To make more efficient use of indigenous materials like hard aluminium alloys ; and

(iii) To cut manufacturing costs in the production of complex shapes such as gear profiles and twist drills.

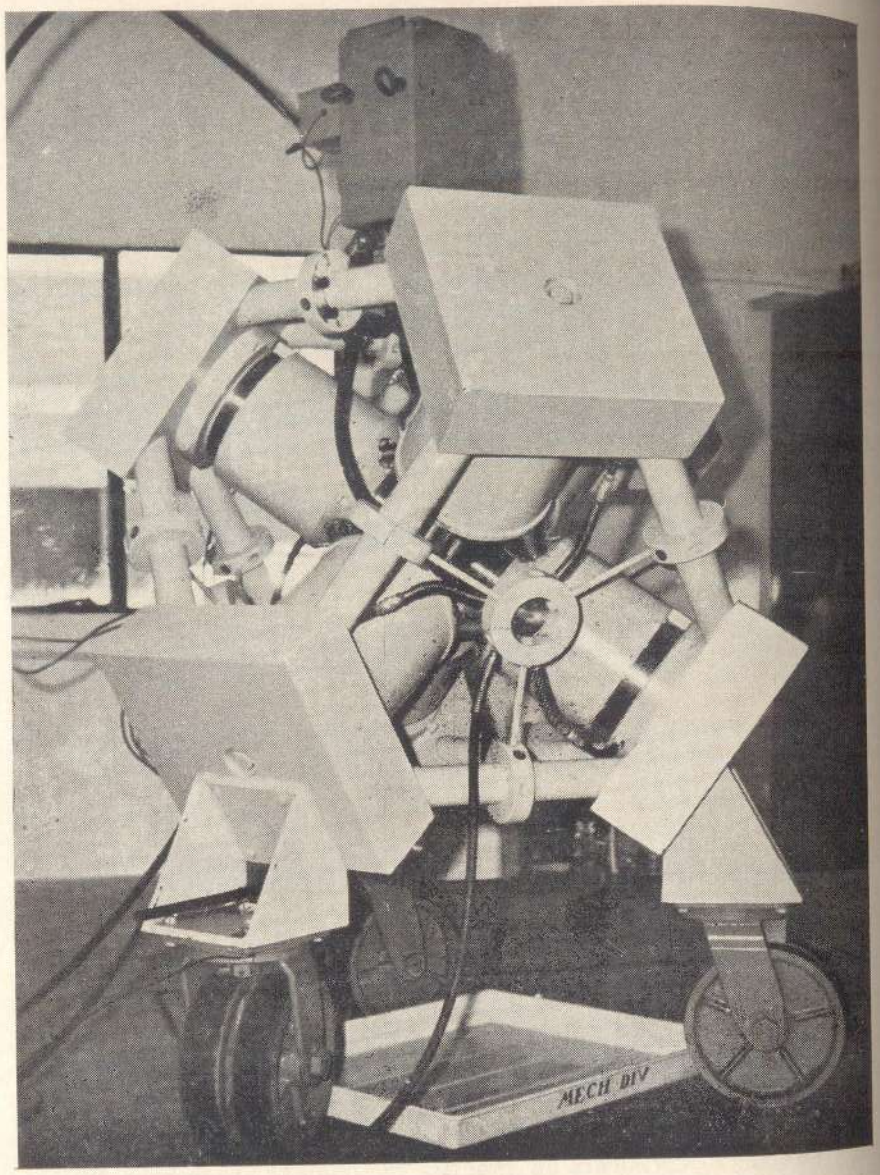

Fig 14 The 200-ton cubic press used for laboratory-scale production of industrial grade diamonds in various shapes and sizes. The material producing the diamonds is taken in a cubic form, and is subjected to uniformly high pressure under controlled high temperature to make diamonds.

Considerable work is being done in high pressure technology which holds promise of cutting down manufacturing costs, giving products with im-

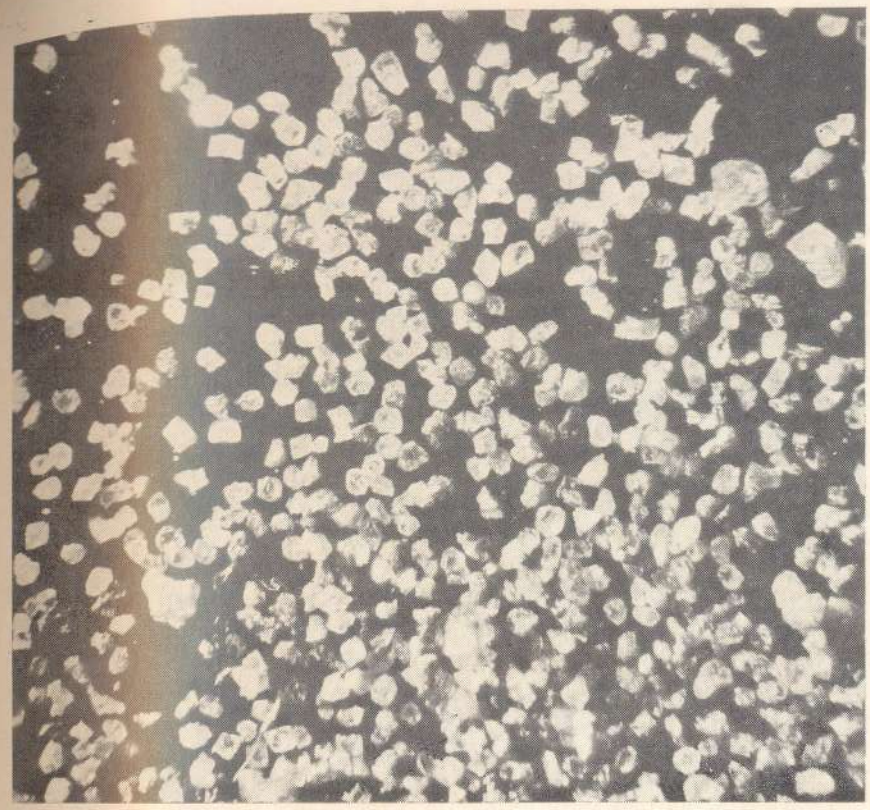

Fig 15 Photomicrograph of the industrial grade diamonds synthesised for the first time in the country, at the NPL, using the 200-ton cubic press.

proved mechani cal properties, lowering scrap, and introducing new materials which substitute expensive and scarce raw materials by cheaper ones.

Of immediate interest to the country, where this development will be of great help, is the development of (i) industrial diamonds which are presently being wholly imported at an estimated cost of Rs. 60 lakhs per year, (ii) composite materials like copper-clad-aluminium wires to effect a substantial saving in the use of copper, (iii) extruded tubes, shapes and sections in alloy steels and other hard-to-extrude materials e.g. titanium, zirconium etc.

NPL is establishing a pilot and demonstration plant in hydrostatic extrusion and material synthesis to meet these objectives. This phase of the work is receiving UNDP assistance.

Progress

The front block of the building for the pilot plant was completed by the CSIR Engineering Unit. The first equipment to be made available by the UNDP, *viz.*, the 200 ton cubic press, was installed and commissioned *(Fig 14)*. This is a laboratory press of compact design and can be put to a variety of uses in studies involving high pressure and high temperature. On this press, using high pressure and high temperature, synthetic diamonds were produced for the first time in the country, using a catalyst-solvent process *(Fig 15)*.

During the year, the list of the equipment to be made available by the UNDP, together-with their required specifications, was finalised. The plan for the counterpart facilities like tool room equipment, buildings and services, manpower requirements, and materials and supplies, was also drawn out.

2. GLASS TECHNOLOGY DEVELOPMENT AND PRODUCTION UNIT

This Unit undertakes fabrication and reconditioning of sophisticated scientific glass and silica equipment for use in the Laboratory as well as for outside organisations. It was started primarily to meet the Laboratory's own requirements of glass apparatus, but now it is working on semi-commercial basis.

The activities of the Unit can broadly be divided into 3 catagories :

1. Fabrication and reconditioning of standard glass items ;
2. Fabrication and reconditioning of specialised glass items ; and
3. Reconditioning of mercury arc rectifiers bulbs.

Under categories 1 and 2, some of the representative items fabricated, were :

(i) High vacuum stop cocks ;
(ii) High vacuum standard ground-glass joints ;
(iii) High vacuum standard ball & socket joints ;
(iv) Mercury & oil diffusion pumps ;
(v) McLeod gauges & manometers ;
(vi) Discharge tubes including laser tubes ;
(vii) Solid, liquid & gas extractors ;
(viii) Glass-to-metal seals ;
(ix) Teflon stop cocks ; and
(x) Gas & blood analysers etc.

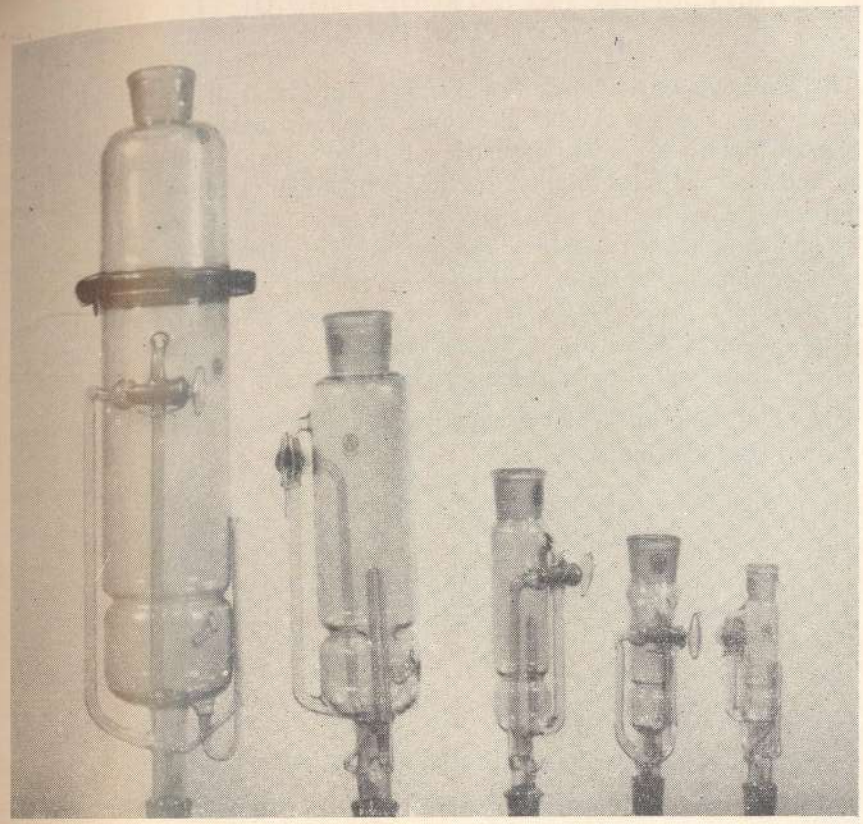

Fig 16 Multipurpose solvent extractor developed and fabricated at the Laboratory in different capacity ranges varying from 20 ml to 2l. It is useful in preparation and purification of fine chemicals ; analytical determination ; industrial, agricultural and bio-chemical diagnostic aid ; environmental pollution ; research and academic pursuit ; and standardization.

Fig 16 shows a set of multipurpose solvent extractors in different capacities developed at the NPL, and fabricated by this Unit. (*See also* Section 1·9 on Page 32).

Regarding the reconditioning of mercury arc rectifiers, NPL is the only institution in India which undertakes such jobs. This activity has been going on in this Unit for the past about 15 years, and it is not o ly a direct help to the users but it also contributes to the national economy by way of saving foreign exchange.

Earnings of the Unit, including jobs undertaken for the Laboratory during 1975-76, amounted to about Rs. 4.11 lakhs.

3. DEVELOPMENT-CUM-PRODUCTION OF ELECTRONIC COMPONENTS UNIT

This Unit acts as a laboratory for trying out the fruits of research and development in the area of electronic materials undertaken by the Division of Materials, on an experimental pilot plant production level, for establishing the repeatability and the commercial viability of the various processes developed by the Division. The main objective of this Unit is to pilot-produce (i) various types of piezo-electric transducers & high voltage ceramic capacitors, (ii) high frequency insulator components, (iii) professional grade Ni-Zn ferrite components, pulse transformers and mini inductors & oriented ceramic magnets using celestite ore, and (iv) silver paints, resistor paints and capacitor paints.

The plant undertook pilot production of the following items developed within the Laboratory :

(i) High frequency oscillator cores ;

(ii) TV deflection yoke cores ;

(iii) Cup and drum cores ;

(iv) E and C cores ;

(v) Magnetic tapes ;

(vi) Professional ferrites ;

(vii) High voltage ceramic capacitors ;

(viii) Piezo-electric materials and devices ;

(ix) Conducting silver cement ; and

(x) Low-loss ceramic insulators etc.

The sales recorded during the year 1975-76 were as under :

Item	*Quantity*	*Amount (in Rs.)*
Piezoelectric and dielectric materials and devices	17,219 pieces	39,348.65
Soft ferrites	1,60,143 pieces (2507.9 kg)	74,654.79
Hard ferrites	2,225 pieces (28 kg)	2,158.63
Silver cement	14.415 kg	21,198.25
	Total	1,37,360.32

4. CARBON PILOT PLANT

The work of the Carbon Pilot Plant is intimately associated with the research and development work on carbon products undertaken by the Division of Materials.

During 1975-76, this experimental pilot plant undertook small scale production of the items detailed below for supply to the user industry for trials, and for getting feed-back information for further R&D work on them, and recorded the sales as mentioned against each :

Item	*Quantity*	*Amount (in Rs.)*
Process Carbons	725 pieces	1,966
carbon rods	10,000 pieces	4,000
Rotating carbons	320 pieces	1,380
Carbon graphite rings	1,990 pieces	1,194
	Total	8,540

OTHER R&D ACTIVITIES

In addition to the research and development work undertaken by the four Divisions, the four Developmental Projects, and the activities of the four Experimental Pilot Plants, the Laboratory has some other R&D activities also, which are more in the nature of consultancy/advisory services. These include :

1. Design and development of Optical systems ;
2. Instrumentation services ; and
3. Sensory aids for the blind.

1. DESIGN AND DEVELOPMENT OF OPTICAL SYSTEMS

Scope and Objectives :

To help the Indian optical industry to assimilate the results of scientific research on optical systems through consultation. The workshops of the firms are themselves used as pilot plants to develop optical components and devices for which, as far as possible, the optical designs based on the existing tools and glass types are supplied. Feed-back from the industry is used to improve the standard of the products.

This activity has three functions, *viz.*, (i) research, (ii) design, and (iii) consultancy service to the industry, for development and production.

Progress

Research : During 1975, the main focus of activities was on the triplet section of the Mendeleef-type classification for lens systems, evolved earlier.

Design : During the period under report, attention was paid on optics for fresnel lenses.

Consultancy : A society working for the development of hills of Uttar Pradesh was helped to plan an optical industry in the hills on cooperative basis with a built-in R&D cell. Consultancy work relating to optics was also undertaken.

2. INSTRUMENTATION SERVICES

Scope and Objectives

(i) Maintenance and calibration of scientific, laboratory-type, electrical, electronic and electro-optical instruments and apparatus. Besides rendering this service to the laboratory, work from other institutional users in respect of imported instruments only, is also undertaken ;

(ii) Advice on instrumentation problems and also on the availability of Indian-made instruments and components of certain specifications ;

(iii) On-the-spot consultancy service for (a) assessment of damage to equipment, (b) technical advice on maintenance of equipment, and (c) inspection reports for initiating write-off, calibration or repairs ; and

(iv) Inspection service (for the NPL scientists only) for new equipment on arrival, or for instruments being returned to the Central Stores.

Progress

Instruments Servicing : 31 instruments were serviced for the NPL scientists. Another 26 instruments were serviced for outside parties.

Consultancy and Advisory Services : More than 135 requests were attended to.

3. SENSORY AIDS FOR THE BLIND

A suggestion was put forward by the Department of Social Welfare to explore the possibility of developing an aid for the blind, using tactile stimulation. Work was undertaken to examine the feasibility of a vibrotactile aid, and a blind aid unit was operated which could detect by tactile sensation upto a distance of about 1.25 m It was, however, observed that the skin cannot make out gradual variation in sensation as is in the case of the ear. Further work in this direction was, therefore, stopped. Efforts were, instead, concentrated on the development of an aid for giving the blind a sense of direction, using auditory perception. A device was developed in which a deviation in the direction results in a change in the frequency in the earphone. The user can revert to the original direction by turning, till the frequency is restored to the previous value.

SILVER JUBILEE CELEBRATIONS

The National Physical Laboratory, New Delhi, celebrated its Silver Jubilee on 23 December 1975. The celebrations were inaugurated by Shrimati Indira Gandhi, Prime Minister of India, and President, CSIR. A large and distinguished gathering including Shri K. D. Malaviya, Minister for Petroleum ; Shri I. K. Gujral, State Minister for Planning ; Shri P. N. Haksar, Vice Chairman, Planning Commission, and Vice-President, CSIR ; and Prof. Y. Nayudamma, Director General, Scientific & Industrial Research, attended the function.

Fig 17 Silver Jubilee of the Laboratory was celebrated on 23 December 1975. Seen in the picture is Shri P.N. Haksar, Deputy Chairman, Planning Commission, and Vice-President, CSIR, addressing at the inaugural function. Seated from left to right are Dr. A.P. Mitra of NPL ; Dr. A.R. Verma, Director NPL ; Shrimati Indira Gandhi, Prime Minister of India, and President, CSIR ; Prof. Y. Nayudamma, Director General, Scientific and Industrial Research, and Secretary to the Government of India ; and Dr. V. G. Bhide of NPL.

Extending a cordial welcome to the gathering on behalf of the nineteen-thousand-strong CSIR-family, Prof. Nayudamma said, 'The basic sciences of yesterday are the break-through technologies of today'. He added, 'The NPL, at the moment, has a programme on its plate which is an optimal blend of both basic and applied research to meet the relevant needs and demands of the country. The bright band of research workers and the devoted team of people in the NPL are poised, buoyant and confident to face the future to serve the cause of the country through science and technology.'

In his welcome address and his report on the achievements of the NPL during the past twenty-five years, Dr. A.R. Verma, Director, NPL, gave a glimpse of the salient achievements and highlights of the Laboratory whose foundation stone had been laid on 4 January 1947. He said, 'The objectives for which the Laboratory was founded, assigned to it a unique role. It is charged with the responsibility of establishing and maintaining the national standards of physical measurements and utilizing them for calibration and developmental testing'. The Laboratory, following the international trend, had started work on replacement of the old standards with standards based on quantum phenomena, and in this context, Dr. Verma highlighted the work on development of special helium-neon lasers for the establishment of the standard for length measurement, and on the study of the Josephson Effect for establishment of the standard of voltage. He also made a pointed reference to the Laboratory's work in the area of time and frequency, and said that in the whole of the South-East Asian region, NPL was the only place which was transmitting standard time and frequency signals at high frequencies. He said that the Laboratory had been undertaking work on calibration and developmental testing, and that the Laboratory had issued 40,000 test reports. During the last few years the Laboratory had set up a full-fledged unit for environmental and life tests so that electronic components, instruments and devices could be tested for their performance under different climatic conditions. It would act as a national facility for the northern region. A proposal for a National Calibration and Testing Service for coordinating and optimising the existing test facilities, and to ensure the traceability of their accuracy to the national standards maintained by the NPL, had also been drawn out, he added.

Dr. Verma said that the Laboratory had also a proud record in the field of research and developmental work in applied physics. He mentioned about the growth of the ferrites and the technical ceramics industry in the country, and the establishment of the Central Electronics Ltd. — a Government of India Undertaking — as a unique achievement to the credit of the Laboratory. He also said that the Laboratory had the distinction of being the only institution in the country, which was engaged

in the development of carbon products. He mentioned about the electrostatic photocopying machine, and liquid crystal thermal devices for monitoring and display of body-temperature in colour for locating hot or cold spots in the body, among the host of the other R & D achievements that the Laboratory had to its credit.

Dr. Verma also made a pointed mention about the strong group that the Laboratory had built up for the exploration of the properties of the troposphere and the ionosphere, and in the use of radio waves in communication, in space science and technology, in meteorology, in monitoring the solar-terrestrial environment etc., and the good use that was being made of the services rendered by this group, by the various user agencies. A special mention was made about 'Sodar' — a powerful technique developed by the Laboratory for studies on atmospheric pollution, radio communication and aviation hazards.

Dr. Verma observed, 'We have found that our best contribution — whether it be the development of photocopying machine or sophisticated X-ray topography camera, or Sodar, or air liquefier, or special ferrites, or carbon fibres — has come from a group which had high competence in basic physics and had the ability to solve the specific problems. The interaction between good physics and good applied work has been our strong point'.

'As we look back to our record of achievements with some satisfaction, we look to the future with a measure of confidence', averred Dr. Verma.

In her inaugural address, the Prime Minister called upon the scientists for a creative partnership between the state and science. She said that each laboratory should become a focal point for technological advancement in its area, and a centre of activity directed towards immediate needs while keeping track of the futuristic trends in that field, with an industrial complex emanating out of its efforts. She commended the Laboratory for its contribution in the growth of several industries including also the Central Electronics Ltd. in the public sector.

The Prime Minister further said. 'The National Physical Laboratory is fulfilling a large number of nationally useful functions. You have been told about it in some detail but I would like to specially commend its work as the custodian of the national standards of physical measurements. Its scientists have taken an important part in the standards movement and in improvement of the quality of its industrial products which is important for consumer protection and for export promotion. The NPL has done pioneering work in introducing the metric system. You have also been told about the national calibration service. The Laboratory has also made significant contribution to the development of our electronics technology'.

She said, 'Tremendous demands are made on scientists to prepare materials to required specifications. Unless we have clear understanding of why materials behave as they do, it is obvious that we shall not be able to tailor them to the required specifications. This comprehension can be obtained only through basic research'. Elaborating the point, she said, 'Take the diamond. a precious stone sought after not only for its glitter by the status-conscious, but also by the technologists, for its unique properties of hardness, electrical conductivity and so on. Nature produces diamonds from carbon at high pressures and temperatures. By understanding nature's processes, man has been able to make synthetic diamonds in his laboratory. Only a few countries have the technological know-how of making synthetic diamonds, and they zealously guard this know-how. Earlier I was told that the National Physical Laboratory has made a break-through and has produced synthetic diamonds in this Laboratory, and just now I was shown some of them as I was sitting at the table. The Laboratory should now concentrate on putting the process to commercial production so that the country can be self-sufficient in this important industrial material'.

Putting a word of caution, the Prime Minister said, 'The thousand and one problems of every day living cry out for the help of the insights of science. Yet, a disproportionate share of grants is earmarked for projects which have limited relevance either to our country or to science itself. Practieal results do show up unexpectedly from highly specialized basic science, but in our circumstances we need a better mix of projects taken up for investigation'.

Recalling back from her memory, Shrimati Gandhi remarked, 'Years ago my heart was gladdened to hear that the Laboratory had undertaken research into the use of solar energy. Probably the work was presented before it was fully tested, and there was much public criticism as a result of which it was given up. It is against the spirit of science to admit defeat or to be diverted from one's objective. The energy crisis makes it all the more incumbent to revive this experiment. Solar energy is one of the greatest resources our country has. We must find ways of harnessing it for our daily use'.

The Prime Minister also envisioned, 'It was not enough to deal with the problems of the day. Our vision and endeavour should reach out to the horizons of emerging scientific concepts and technologies. The science of today leads to the technology of tomorrow. Indeed, over the years, the time-lag between a scientific discovery and its industrial applications has decreased, correspondingly reducing the time of obsolescence. A developing and dynamic country like India must be prepared for the future'. She, however, also added, 'We have to find our own solutions to our

problems and to evolve a pattern of development which is relevant to our situations. Science will widen social divisions in the country if we do not make a deliberate effort to reach the fruits of science to the weaker sections of the society'.

Towards the end of her address, Shrimati Gandhi also spoke a few words in Hindi, for the benefit of that section of the officers of the Laboratory who could not understand English.

The Prime Minister also distributed medallions for distinguished service to Dr. K. N. Mathur, Shri T. V. Ramamurti, Dr. S. S. Chari, Shri Nau Nihal Singh, and Shri K. L. Mago. The members of the staff who had completed 25 years of service in the NPL also received medallions in commemoration of the Silver Jubilee Celebrations.

A two-day exhibition depicting the achievements of the Laboratory was also organized on the occasion. Licencees of the Laboratory also participated in this exhibition which exhibited among others, electrostatic photocopying machines, cinema arc carbons, midget-electrodes, lasers, photocells, ceramic products, vacuum instruments, all-glass distillation apparatus, and ultrasonic interferometer—products manufactured using the NPL know-how.

NATIONAL SYMPOSIUM ON EARTH'S NEAR SPACE ENVIRONMENT

A National Symposium on Earth's Near Space Environment was held during 18—21 February 1975 at the National Physical Laboratory, New Delhi. This was the first national symposium to be held under the joint auspices of the various national committees and organisations concerned with radio and space research in the country, *viz.* the Indian Space Research Organisation (ISRO), the Indian National Committee on Space Research (INCOSPAR), the Indian National Committee on Terrestrial Physics (INCSTP), and the Indian National Committee on International Union of Radio Science (INCURSI), and it constituted the fifth in the series of symposia in the field of radio and space research organised by the NPL since the IGY symposium held in 1961.

The Symposium was inaugurated by Prof. S. Dhawan, Chairman ISRO/ INCOSPAR, and was organised into the following sessions :

(i) Magnetosphere ;

(ii) Description of the F-region and the topside ionosphere ;

(iii) Description of the lower thermosphere/ionosphere ;

(iv) Monitoring of the environment ;

(v) Ionospheric small scale irregularities ;

(vi) Ionospheric waves and drifts ;

(vii) Solar interactions with the environment ;

(viii) Prediction and propagation ;

(ix) Meteorology and troposphere ;

(x) Solar wind and cosmic rays ; and

(xi) Potpourri.

Each session was started with a review talk in the concerned area. Popular lectures were also given on three of the evenings by Prof. J.N. Bhar, Prof. M.K. Vainu Bappu, and Prof. P. Koteswaran.

The symposium was attended by well over 200 delegates, and more than 300 scientific papers were presented.

NATIONAL SEMINAR ON CRYOGENICS AND ITS APPLICATIONS

Under the joint sponsorship of the National Physical Laboratory, New Delhi, (NPL), the University of Delhi, Delhi, (DU), and the Indian Cryogenics Council, Calcutta, (ICC), a National Seminar on Cryogenics and its Applications was held at the NPL from 20 to 22 November 1975. About 150 delegates from industries, R & D laboratories, universities, IITs, and representatives from relevant government departments, participated in the Seminar.

The Seminar was inaugurated by Prof. Y. Nayudamma, Director General, Scientific and Industrial Research. He started by making a bold offer, saying, 'If the industries come forth to sponsor research and development by 50%, the CSIR would be the first to put its share of 50%. A healthy rapport between industries and R&D laboratories, is the only way to make any meaningful progress in the economic development of the country'. Indeed Prof. Nayudamma's address was not just a formal inauguration, but it also gave the necessary impetus and a sense of direction to the Seminar. Before him, Prof A. Bose, the President of the Indian Cryogenics Society, briefly reviewed the progress made by the Society.

'Croygenics in India and abroad' was the topic of Dr. V. G. Bhide's talk which followed the inaugural function. It was a review which took stock of the present status of cryogenics in the country in the international background. Looking at the progress already achieved, he assessed the future requirements of cryogenics in various spheres, *viz*. agriculture, fertilisers, steel, and petro-chemicals etc.

Dr. Bhide's talk gave the appropriate setting and created the right mood for the session that followed, which concerned itself with the industrial cryogenics in India. Various industrial firms gave expositions of their present and projected activities in cryogenics. Expositions were given by the representatives of : Indian Oxygen Ltd, Bharat Heavy Plates and Vessels Ltd., Industrial Cryogenics and Chemical Plants Ltd., Asiatic Oxygen Ltd., Lloyd Insulations Ltd., Indo-Bell Insulations Ltd., Larsen and Toubro Ltd., Titan Engineering Company Ltd., and Industrial Gas Engineers and Consultants Private Ltd. These deliberations proved most

profitable in revealing the industrial status of cryogenics in the country, and the gaps that exist on the industrial scene.

At this stage the Seminar took a turn from down-to-earth realities of industries, to a frontier area of research *viz*. superconductivity. Prof. K.P. Sinha's talk on superconductivity was a vivid demonstration of how a highly complex subject could be made intelligible to a general audience.

The stage, which so far had been occupied by the industrialists, was now taken over by the experts from various R&D laboratories. Overviews of their activities were presented by scientists from the Bhabha Atomic Research Centre, Bombay ; the Tata Institute of Fundamental Research Bombay ; the Indian Institutes of Technology of Kanpar, Madras and Kharagpur ; the Indian Institute of Science, Bangalore ; the Indian Association for Cultivation of Science, Jadavpur ; the University of Delhi, Delhi ; and the NPL. These expositions revealed the strengths and the weaknesses of the individual research laboratories—an information so essential for possible collaboration.

In the subsequent sessions, there were invited talks and presentation of research papers from industries as well as research laboratories. The talks were on the frontier areas in cryogenics such as 'Superfluidity and superconductivity' by Prof. F. C. Auluck, 'Production of ultra pure gases' by Mr. D.K. Garg, 'Transport properties at low temperatures' by Dr. A.K. Sreedhar, 'One-dimensional superconductivity' by Mr. R. Sundaram, and 'Josephson Effect and its applications' by Dr. P. Chaudhari. Prof. Girish Chandra reviewed some of the major contributions made at the 14th International Conference on Low Temperature Physics, held at Helsinki. Over thirty research papers were presented.

The final session of the Seminar was a panel discussion which was chaired by Dr. A.R. Verma, Director, NPL. Some of the possible areas where industries vitally need the collaboration of R&D laboratories were tentatively identified.

NATIONAL CONFERENCE ON CRYSTALLOGRAPHY

A National Conference on Crystallography was held at the National Physical Laboratory, New Delhi, from 4 to 6 December 1975. This Conference was held as a part of the Silver Jubilee Celebrations of the Laboratory.

About 150 delegates from various parts of the country attended the Conference. Nine invited speakers, including three from abroad, gave talks on topics of current interest. More than 120 research papers were accepted for presentation in the following areas :

(i) Theoretical crystallography ;
(ii) Methods of structure determination ;
(iii) Organic structures ;
(iv) Inorganic structures ;
(v) Structure of biological and medical molecules ;
(vi) Synthesis of solid state materials ;
(vii) Growth of single crystals ;
(viii) Characterization of crystalline materials regarding purity and perfection ;
(ix) Twinning, polytypes and polymetric transformation ;
(x) Crystallographic computing ;
(xi) Experimental techniques and instrumentation ; and
(xii) Crystals in devices.

In all 19 sessions took place. Some of these sessions were parallel sessions.

The Conference opened with the welcome address by Dr. V.G. Bhide, Deputy Director NPL, on behalf of Dr. A.R. Verma, the Director of the Laboratory, who was indisposed.

The opening address of the Conference was delivered by Dr G. H. Schwuttke, IBM East Fishkill Laboratories, N. Y., USA, on 'Low cost silicon for solar energy applications'. Dr. Schwuttke emphasised the need to develop alternate sources of energy like the solar energy. He enumerated the difficulties in the way of converting solar energy into electrical energy by using solar cells in economically viable ways.

He observed that the raw material cost at present was very high as Czochralski-grown silicon single crystal wafers were used as the starting material for fabrication of solar cells. After the crystal is grown, and before it can be made available for further processing like diffusion etc, the process involves the stages of (i) cutting the crystal into thin wafers, (ii) grinding it, and (iii) lapping it. These steps not only involved a lot of time and manpower, but a lot of material was also wasted, as a result of which this technology was not economical.

He discussed a recent method, *viz.* the edge-fed capillary growth for continuous growth of thin ribbon of silicon, and emphasised that such a method has tremendous potential for solar cell applications. In this method the ribbon as such can be used, without the cutting, grinding and lapping operations. Morever, its rate of growth is also very large. One can visualise that rolls of ribbon material can be prepared in this fashion.

A film was also shown on the growth of ribbon crystals. A silicon ribbon grown by this method was also shown to the participants. The US plan to develop a big power station running completely on solar energy in the coming few years, was also discussed in some detail by Dr. Schwuttke.

Dr. P. Chaudhari of the Thomas J Watson Research Centre of the IBM, USA, who was on a visiting assignment at the NPL and the IIT Delhi, discussed another important technology *viz.* the magnetic bubble garnets technology. In the last few years a lot of work had been done on magnetic bubble materials like the magnetic garnet thin films. Dr. Chaudhari discussed that magnetic bubbles were particularly attractive as high density memory cores. If used with computers, these could help in reducing the size of the computer. Moreover, these magnetic cores were pretty fast in their working.

One of the important drawbacks in this technology, Dr. Chaudhari observed, was the lattice defects in the substrate material, which did not allow preparation of perfect magnetic bubble films. These defects had been investigated by using light microscopy, X-ray topography, and electron optical techniques. These investigations had eventually made it possible to prepare substrate material which was free from these defects, and which had made it possible to make working memories out of this material. He showed a short movie in which magnetic bubble devices were shown in operation.

One of the other important areas of crystallography which was discussed at some length in this Conference was structural crystallography. Prof. R. Srinivasan of the Department of Crystallography and Biophysics,

University of Madras, Madras, gave an invited talk on 'Some interpretive aspects of protein structural crystallography'. He described that at present the structure of large organic molecules is being generally tackled or worked out by using the principles of small molecule crystallography. However, the amount of data to be tackled in the final atomic coordinates is so large that some new methods and techniques are to be used. Dr. Srinivasan described some of the new methods for this purpose that had been developed and applied in his Laboratory.

Dr. W. Bardsley of the Royal Radar Establishment, Malvern, Worcs, UK, described the recent developments in the techniques of growth of crystals from the melt. Dr. Bardsley's Group had developed very versatile crystal pullers which had been commercialized and were being used at a large number of places. He described a recent advancement in which the rate of increase of the weight of the growing crystal is used to control the diameter of the crystal. An electrical signal, proportional to the increase in the weight of the crystal, was used as a feed-back for controlling the diameter of the crystal through the power fed to the heating system. This technique makes it possible to foresee small changes in the diameter of the crystal, which a manual operator finds almost impossible to detect. Technologically important crystals like those of III-V compounds, elemental single crystals, and also single crystals of oxides like garnets, had been successfully grown by the Group.

Dr. S. Ramaseshan of the Material Science Division, National Aeronautical Laboratory, Bangalore, discussed a model of the ionic crystals developed in his Group to describe the compressibility data by considering the ions to be compressible. In this model he proposed that when the ionic solids are compressed, their ions are compressed, and this increases their internal energy which is responsible for repulsion. Using this model, the repulsion parameters for alkali and halogen ions were calculated. These parameters had been used to explain the behaviour of 20 alkali halides over the pressure range 0—45 kbar. It was emphasised that, in this approach, the parameters are evaluated for the individual ions. The behaviour of the ionic solids then depends upon the nature of the ions that constitute them.

Dr. G.C Trigunayat of the Department of Physics and Astrophysics, University of Delhi, Delhi, described some of the recent developments in the study of polytypic crystals. The main emphasis was on the experimental investigation of X-ray diffraction from polytypes, carried out at high temperatures and at liquid nitrogen temperatures. Some recent theoretical work on the origin of polytypes and the calculation of internal energies, was also reviewed.

Dr. Krishan Lal of the National Physical Laboratory New Delhi, described two new high resolution techniques developed at the NPL, for measurement of diffuse X-ray scattering from single crystals. He showed that the conventional experimental methods used to measure diffuse X-ray scattering suffer from many experimental uncertainties. These uncertainties are mainly related to the lack of monochromatisation and collimation of the exploring X-ray beam and the limitations of minimum rotation (1/100th of a degree) that can be provided to the crystal or the detector. These limits had been overcome by using two techniques which made use of (i) a modified X-ray topography set up, and (ii) a multi-crystal X-ray diffractometer. He described datails of the equipment which had been developed at the NPL. The data recorded by these methods showed that the simple theory developed for explaining diffuse X-ray scattering in terms of scattering from phonons, is not adequate. With the multicrystal diffractometer, diffraction curves are obtained almost with the same half-width as the theory predicts for a particular diffraction maxima for perfect single crystals. In his comments Dr. Schwuttke mentioned that such a technique was very much required in the study of point defects in single crystals.

Dr. A. Sequeira of the Neutron Physics Section, Bhabha Atomic Research Centre, Bombay, spoke on neutron diffraction studies of biological molecules. He emphasised that the finer details of the molecular structure were not available at atomic resolution, by using conventional techniques. He discussed that neutron diffraction of crystals of small biological molecules could furnish this additional information. The high flux reactors could be used to study the structure of even large biomolecules, using neutron diffraction. The method had a particular advantage over the X-ray method, as hydrogen could be located. Some of the results obtained by neutron diffraction were also discussed.

Prof. D. S. Kothari delivered a popular talk on 'Matter and Mind' during this Conference.

CENTRAL WORKSHOP

The workshop executed about 2,900 work orders. A few major jobs done for R & D projects were:

(i) Differential micrometer.

(ii) Vacuum unit.

(iii) Laser mounts.

(iv) Beam for 1 kg balance.

(v) Tilting table for level testing.

(vi) Microwave components.

(vii) Moony type viscometer.

(viii) Anular mounts for Lang camera.

(ix) Goniometer head.

The Drawing & Design Section executed about 480 drawing & design jobs. A few important ones were:

(i) Oscillating system for hydraulic multiplication.

(ii) Vertical and sideway adjustment for linear comparator.

(iii) Gear box with 1:1800 (1 rev/hr).

(iv) Ultrasonic probes.

(v) Crystal rotation unit for pulling of single crystals by Czochralski technique.

(vi) Angular movement unit for recording X-ray diffractograms.

(vii) Multi heating zone refining apparatus.

(viii) TV picture tube regenerating machine.

(ix) Resonance cavity for atomic standard.

LIBRARY

The Library continued to provide library, documentation, and reprographic services to the scientists of the Laboratory—the Library service through its additions in the Library of books, journals and other literature of interest to the staff; Documentation service through its Selective Dissemination of Information (SDI); and Reprographic service through Majox-121 photocopier.

Library data on books, journals, photocopies and translations etc. during 1975 are given below:

Publications holdings as on 31 Dec 1975 (including books, journals and standards)	81689
Publications accessioned during the year (including standards)	4329
Standard Specifications added	2438
Journals subscribed	315
Photocopies and translations accessioned	88
Publications issued (including inter-library-loan)	13690
References provided in SDI (Manual service)	2000 (approx)
Bibliographies prepared on demand	6
Xerox copies supplied	7640 (approx)

The Library is recognised as a patent inspection centre, and it continued to receive Indian patents.

HONOURS AND AWARDS

Dr. A.R. Verma was elected as a member of the Commission on Symbols, Units and Nomenclature of the International Union of Pure and Applied Physics. He was also re-elected as a member of the International Committee of Weights and Measures (CIPM) Paris, on behalf of India.

Dr. A.P. Mitra was elected Vice Chairman of Commission-III on "Ionospheric Radio", of the International Scientific Radio Union (URSI), at its 18th General Assembly held at Lima, Peru, in August 1975. He was also appointed Chairman of the Standing Committee on General Assemblies and continued to be URSI representative on the International URSIGRAM and World Day Service.

Dr. V.G. Bhide was awarded the scale equivalent to that of the Director of the Laboratory. This award has been instituted to prevent diversion of the outstanding research talent to non-research assignments, and applies only to outstanding scientists and technologists who have acquitted themselves most spectacularly by creating new vistas of scientific research or technological break through.

Dr. S.C. Majumdar was awarded the J.C. Bose Premium for his paper "Some observations on distance dependence in tropospheric propagation beyond radio horizon" published in the Journal of the Institution of Electronics and Radio Engineers. This award was given to him for making the most outstanding contribution during 1974.

Dr. A.V. Narlikar was elected fellow of (i) Institute of Physics and (ii) Institution of Metallurgists (London). He was also elected as the secretary of the Regional Cryogenics Committee, North Zone.

Dr. R.G. Sharma was elected as an executive member of the Central Committee of the IPA, for 1975-77. He was also elected as a founder member of the Indian Cryogenics Council.

NRDC Invention Award (1975) was received by Dr. V.N. Bindal for development of an ultrasonic device to study Bragg diffraction. The award presented on the Republic Day (26 January 1975), carried a cash prize of Rs. 1000 for Dr. V.N. Bindal, and a bronze shield for NPL.

KRISHNAN MEMORIAL LECTURE—1975

Academician A. P. Vinogradov, Vice-Chairman, USSR Academy of Sciences, delivered the Krishnan Memorial Lecture-1975, on 17th February 1975. The topic of his lecture was '*The Metallic Phase of Planets & Meteorites*'.

Prof. Vinogradov started his talk by saying that iron is widely disseminated throughout the solar system and it takes the third place in it after silicon and magnesium—excluding gases. Iron can be found in metallic alloys with nickel and other elements in all meteorites.

The topic covered the specific properties of the metallic iron of meteorites, the origin of iron in the metallic nuclei of our planets, and finally the experimental foundations of the possible ways of formation of the iron metallic phase of planets and meteorites during the process of accretion of matter in the protoplanetic cloud.

Developing the subject of his talk, Prof. Vinogradov observed that an analysis of iron-bearing alloys from various types of meteorites shows that out of a total of about 70 chemical elements which can make alloys with iron, only about 15-20 chemical elements, notably typical syderopiles (Ni, Co, Au, platinoids Sn, Sb, As, Ge, Ga, Mo, P) are regularly concentrated in metallic iron. At the same time, some elements which are much more widely spread in the protoplanetic cloud and which also crystalized in the regular cubic form, *viz.* Mn, Ti, Cr, V—like many other entering into continuous solid solutions with Fe—are not found as components in meteoric iron. This observation, Prof. Vinogradov explained in terms of the partial pressure of oxygen in reversible equilibrium of metals with their oxides.

Concluding his talk Prof. Vinogradov said, 'In all likelihood, during the global separation of the matter in the protoplanetic cloud, the magnetic field played its role in separating ferromagnetic particles from dielectrics. Later, the iron particles easily stuck together and fused—thanks to their heat conductivity. All this makes us to look for a way of formation of metallic planetary nuclei in the formation of considerable masses of iron

pieces in the protoplanetic cloud, their hitting each other, and subsequent growth through accretion of the future planets nucleus'.

After the lecture, Prof. Vinogradov gave away the NPL Merit Awards—1975.

NPL MERIT AWARDS-1975

Development of Liquid Crystal Thermal and Electro-optical Devices

A team of young scientists consisting of Dr. Subhas Chandra and Shri Sukhmal Chand Jain and assisted by Dr. A.K. Sarkar and Sarvashri S.P. Suri, S.K. Kaicker and R.K. Medhekar, under the guidance of Dr. V.G. Bhide, was presented the NPL Merit Award-1975, and a cash prize of Rs. 1000, for developing the know-how for making a large variety of both liquid crystal thermal and electro-optical display devices.

Using indigenously prepared cholesteric materials, this team fabricated a variety of thermal devices which were successfully used for thermography, for recording room and body temperatures (*Fig 18*), for mapping microwave intensity pattern, for display of de-icing pattern on windshield, etc.

Fig 18 **A typical application of thermal liquid crystal films developed at the Laboratory, for medical diagnostics and a variety of other applications. The violet portion indicates the hot spot due to leprosy, and the adjoining blue portion indicates the spread of the disease. The unaffected portion does not create any change in the liquid crystal film which is brownish. The cholesteric material for making these films has also been developed at the Laboratory.**

The team also developed the various processes for making liquid crystal electro-optical devices both of the dynamic scattering and the field effect type. These displays compared favourably with those made elsewhere in the world and could be used in digital clocks, desk calculators and a variety of other digital instruments.

Development of Techniques for X-ray Topography

A camera for X-ray topography of single crystals was developed by a team headed by Dr. Krishan Lal and consisting of Sarvashri D.R. Pahwa, Vijay Kumar and Keshav Aggarwal.

Techniques and equipment were developed for the study of both the Lang and the Borrman topography. These techniques clearly delineate a variety of imperfections such as grain boundaries, dislocations, and stacking faults in a crystal. These techniques were successfully used for the study of imperfections in a large number of crystals, thereby contributing substantially to the understanding of imperfections in crystals.

This work had thus made available, for the first time in the country, a new and powerful tool for study of imperfections in crystals, and for this achievement, the team was presented the NPL Merit Award-1975, and a cash prize of Rs. 1000.

Design and Development of Sodar—an Instrument for the Location and Measurement of Thermal and Velocity Inhomogeneities in the Atmosphere

A team led by Dr. S.P. Singal, and consisting of Smti Mithilesh Saxena and Sarvashri J.R. Anand, B.S. Gera and S.K. Aggarwal was presented the Merit Award-1975, and a cash prize of Rs. 1000, for their success in designing, fabricating and establishing *Sodar*—a unique facility, the only one of its kind in India and one of the few in the world—for the location and measurement of the intensity of thermal and velocity inhomogeneities in the atmosphere. This is an information which can be used to infer and determine atmospheric processes and history.

This instrument was used successfully for monitoring inversion layers, meteorological disturbances, large-scale waves, and other phenomena of direct interest to tropo-scatter communication. Besides tropospheric monitoring for tropo-scatter communication, the instrument has tremendous potentialities for study of micro-meteorology, wind shear hazards and atmospheric pollution.

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1.	125/Cal/75	22.1.1975	A multi-exposure high-pressure X-ray powder diffraction camera.	Joginder Singh
2.	678/Cal/75	3.4.1975	A process for micro-encapsulating cholesteric material for use as a liquid crystal thermal device.	V.G. Bhide, Subhas Chandra & Sukhmal Chand Jain
3.	696/Cal/75	7.4.1975 28.6.1976*	Process for the preparation of a new type of liquid crystal material for use in electro-optical display devices.	V.G. Bhide, Subhas Chandra & Sukhmal Chand Jain
4.	699/Cal/75	7.4.1975	Surface wave probe for ultrasonic non-destructive testing.	V.N. Bindal & Vinod Gogia
5.	700/Cal/75	7.4.1975	A low cost electronic thermometer for bio-medical and other applications.	Surinder Singh & Ram Parshad
6.	702/Cal/75	8.4.1975	A liquid crystal electro-optical device.	V.G. Bhide, Subhas Chandra & Sukhmal Chand Jain

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10.	1842/Cal/75	25.9.1975	A pyroelectric infrared detector.	V.G. Bhide & M.M. Pradhan
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2.	136858	126/Cal/73	17.1.1973	15.3.1975	A precision pipette.	V.N. Bindal & A.K. Kansal
3.	136940	603/72	20.6.1972	5.4.1975	An ultrasonic interferometer.	S.P. Suri & Madhu Khuller (Miss)
4.	136955	397/72	2.6.1972	5.4.1975	Light intensity analogue to digital converter.	V.N. Sharma, V.K. Nayyar & V. Venugopalan
5.	137074	1714/72	23.10.1972	26.4.1975	Electronic high voltage detector.	T.N. Ghosh, P.N. Taneja, G.K. Sharma & R.P. Pande
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(during 1975)

Sr. No.	Complete Specification Number	Application Number	Date of Filing	Date of Acceptance	Date of Sealing	Title of the patent at Acceptance	Inventor(s)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.	134169	134169	3.1.1972	10.8.1974	19.4.1975	A strain gauge transducer.	Ved Ram Singh & Ram Parshad
2.	136301	245/72	18.5.1972	9.11.1974	26.7.1975	Improvements in or relating to a process for making photoconductive plates for electro-photographic machines.	P.C. Mehendru, D.C. Parashar, G.D. Sootha, Devendra Singh & Narendra Kumar
3.	136797	483/72	9.6.1972	1.3.1975	6.12.1975	An infrared detector.	S.P. Suri & Madhu Khuller(Miss)

PROCESSES RELEASED FOR COMMERCIALIZATION
(during 1975)

Sr. No.	Process Title	Party	Terms of Release		
			Premium	Royalty	Nature of Licence
(1)	(2)	(3)	(4)	(5)	(6)
1.	Midget electrodes.	M/s. Shreyas Engineering and Chemical Industries Pvt. Ltd., Bangalore.	Rs 10,000	3%	Non-Exclusive
2.	Ultrasonic interferometer for velocity measurement in liquids.	M/s. Bharat Electromech Engineers, New Delhi.	Rs 3,000	5%	Non-Exclusive
3.	Gas lighter.	(i) Mr. Badri Prasad Poddar, Calcutta.	Rs 1,000	5%	Non-Exclusive
		(ii) M/s. Jaisons Gas Industries, Bombay.	Rs 1,000	5%	Non-Exclusive
		(iii) M/s. Protex Engineers, Calcutta.	Rs 1,000	5%	Non-Exclusive
		(iv) M/s. Sarda Electronics, Ahmednagar.	Rs 1,000	5%	Non-Exclusive
4.	Liquid crystal thermal devices.	M/s. Darbari Industries, Allahabad.	Rs 3,000	5%	Non-Exclusive
5.	Sensitized zinc oxide paper for electrophotocopying machine.	M/s. Gadget and Appliances, Jaipur.	Rs 5,000	5%	Non-Exclusive

(Contd.)

Sr. No.	Process Title	Party	Terms of Release		
			Premium	Royalty	Nature of Licence
(1)	(2)	(3)	(4)	(5)	(6)
6.	Carbon tracks for volume control. (*Sponsored*).	M/s. Springs and Stampings Ltd., Faridabad.	Rs 20,000		
7.	Suitability of indigenous raw materials for preparation of Soderberg anode paste. (*Sponsored*).	National Industrial Development Corporation, New Delhi.	Rs. 10,000		
8.	Processing of scrap graphite into anode. (*Sponsored*).	M/s. DCM Chemical Works, New Delhi.	Rs 5,000		
9.	Soft ferrites. (Indian Patent No. 87993).	M/s. Sanfrite Industries, New Delhi.	Nil	2.5% (Rs.5,000 as advance)	Non-Exclusive
10.	Hard ferrites. (Indian Patent No. 93725).	M/s. Sanfrite Industries, New Delhi.	Nil	2.5%	Non-Exclusive
11.	Synthetic optical crystals from alkaline earth fluorides.	M/s. Materials & Allied Technology, New Delhi.	Rs 3,000	4%	Non-Exclusive
12.	Ultrasonic probes for non-destructive testing—angle beam probes and surface wave probes.	M/s. Vibronics Pvt. Ltd., Bombay.	Rs 5,000	5%	Non-Exclusive

PROCESSES WHICH HAVE GONE INTO PRODUCTION
(during 1975)

Sr. No.	Process Title	Party	Year of Release	Terms of Release		
				Premium	Royalty	Nature of Licence
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	Projector carbons. (Indian Patent Nos. 76683, 85737).	(i) M/s. Isocarbon Co. Pvt. Ltd., Visakhapatnam.	1971	Rs 10,000	3%	Non-Exclusive
		(ii) M/s. Rashtriya Vikas Ltd., Varanasi Cantt.	1972	Rs 10,000	3%	Non-Exclusive
2.	Cadmium sulphide photo cells.	M/s. Bharat Photonics Ltd. Meerut. (Mr. Desh Deep Agarwal, Meerut).	1973	Rs 2,000	5%	Non-Exclusive
3.	Ultrasonic interferometer for velocity measurement in liquids.	M/s. Bharat Electromech Engineers, New Delhi.	1975	Rs 3,000	5%	Non-Exulusive
4.	Waveguide components for microwave applications.	M/s. Vidyut Yantra Udyog, Modinagar.	1974	Rs 2,500	5%	Non-Exclusive

(Contd.)

Sr. No.	Process Title	Party	Year of Release	Terms of Release		
				Premium	Royalty	Nature of Licence
(1)	(2)	(3)	(4)	(5)	(6)	(7)
5.	Metal graphite brushes. (Carbon blocks).	M/s. Moba Carbons, Bombay.	1973	Rs 10,000	5%	Non-Exclusive
6.	Soft ferrites. (Indian Patent No. 87993).	M/s. Indian Ferrite Industries, Bangalore.	1968	Nil	2.5%	Non-Exclusive
7.	Microwave components. (S, K & Ku bands).	M/s. KLB Electronics, New Delhi.	1974	Rs 2,500	5%	Non-Exclusive
8.	He-Ne laser.	M/s. Thermometers and Thermometric Appliances, New Delhi.	1973	Rs 2,500	4%	Non-Exclusive
9.	Midget Electrodes.	M/s. Shreyas Engineering & Chemical Industries Pvt. Ltd., Bangalore.	1975	Rs 10,000	3%	Non-Exclusive
10.	Distillation Apparatus.	M/s. Scientronics Instruments, New Delhi.		Rs 10,000	2.5%	Non-Exclusive

REPRESENTATION ON ISI COMMITTEES

No. & Name of the Committee			Members
AFDC		*AGRICULTURAL & FOOD PRODUCTS DIVISION COUNCIL*	
AFDC	34	*Dairy Products and laboratory apparatus*	Dr. S.V. Gupta (P) Mr. Mohinder Nath (A)
AFDC	34:1	Milk products	Dr. P.K. Gupta (P) Mr. J.C. Trehan (A)
AFDC	34:2	Methods of test and laboratory apparatus	Dr. S.V. Gupta (P) Mr. Mohinder Nath (A)
BDC		*CIVIL ENGINEERING DIVISION COUNCIL*	
BDC	5:P 1	Panel for application of acoustical plastic finish	Dr. M. Pancholy (P)
BDC	12:3	Day light standards	Dr. S.R. Das (P) Dr. V.D.P. Sastri (A)
BDC	12:5	Architectural acoustics and sound insulation	Dr. M. Pancholy (P)
BDC	12:8	Forced ventilation (Industrial)	Mr. Nau Nihal Singh (P) Mr. Shiv Nath (A)*
BDC	19	*Sieves, sieving and other sizing methods*	Dr. M. Pancholy (P) Dr. P.T. John (A)
BDC	19:1	Sieves	Dr. M. Pancholy (P) Dr. P.T. John (A)

* From 10.12.1975 Mr. Shiv Nath nominated as Principal Member.

(Contd.)

No. & Name of the Committee			Members
BDC	19:2	Sizing by methods other than sieving	Dr. M. Pancholy (P) Dr. P.T. John (A)
BDC	22:5/A-1	Helmets	Mr. M.K. Das Gupta (P)
BDC	31	*Building materials and components sampling*	Dr. M. Pancholy (P) Dr. P.T. John (A)
BDC	60	*Hydraulic structures instrumentation*	Dr. B.K. Agarwala (P)
BDC	64:P 12	Panel on lighting & ventilation	Mr. K.S. Sarma (P)
BDC	64:P 15	Panel on acoustics & sound insulation	Dr. M. Pancholy (P)
CDC		*CHEMICAL DIVISION COUNCIL*	
CDC	1	*Chemical standards*	Mr. V.M. Bhuchar (P)
CDC	1:P 2	Panel for sampling procedures for general chemical products	Mr. V.M. Bhuchar (P) (Con)
CDC	17:14	Polyester fibre reinforced plastics	Dr. S.S. Chari (P)
CDC	26	*Water*	Mr. V.M. Bhuchar (P) Mr. Jitendra Rai (A)
CDC	26:P 1	Panel for methods of test for water and effluents	Mr. V.M. Bhuchar (P)
CDC	27:2	Ceramic whiteware	Dr. V.N. Bindal (P) Mr. S. Rangarajan (A) (upto 20.8.1975) Mr. A.K. Mehrotra (A) (from 20.8.1975)
CDC	27:3	Whiteware & technical ceramics	Mr. A.K. Mehrotra (P)
CDC	33	*Laboratory glassware and related apparatus*	Mr. Mohinder Nath (P) Mr. B.G. Mathur (A)

Contd.)

No. & Name of the Committee			Members
CDC	33:1	Volumetric glassware	Mr. Mohinder Nath (P)
CDC	33:2	Thermometers	Mr. T.D. Bansal (Con)
CDC	33:3	Hygrometers	Mr. V.P. Wasan (A)
CDC	37	*Thermal insutation materials*	Mr. Mohinder Nath (Con)
CDC	37/P 1	Panel for terminology & methods of test for thermal insulation	Mr. T.D. Bansal (C)
CDC	37/P 6	Panel for thermal insulation materials for cryogenic temperatures	Mr. T.D. Bansal (Con)
			Dr. M.S.R. Chari (P) (upto 14.5.1975)
			Dr. J.S. Dhillon (A) (upto 14.5.1975)
			Dr. J.S. Dhillon (P) (after 14.5. 1975)
			Dr. R.G. Sharma (A) (from 14.5.1975)
ISAC/S-2		Safety equipment	Dr. M. Pancholy
CPDC		*CONSUMER PRODUCTS & MEDICAL INSTRUMENTS DIVISION COUNCIL*	
CPDC	12	*Medical glass instruments & appliances*	Dr. K.C. Joshi (P)
			Dr. S.V. Gupta (A)
EDC		**MECHANICAL ENGINEERING DIVISION COUNCIL*	Dr. B.K. Agarwala (P)
EDC	1	*Engineering standards*	Dr. B.K. Agarwala (P)
EDC	1:1	Atmospheric conditions for testing	Dr. B.K. Agarwala (P)
EDC	36	*Optical and mathematical instruments*	Mr. P.C. Jain (P)
			Mr. Ram Prasad (A)

* Statutory representation to NPL.

(Contd.)

No. & Name of the Committee			Members
EDC	36:1	Drawing instruments	Mr. P.C. Jain (P)
EDC	36:2	Optical instruments	Dr. S.R. Das (P)
			Mr. Ram Prasad (A)
EDC	36:3	Surveying instruments	Mr. P.C. Jain (P)
EDC	36:5	Materials & components for instruments	Mr. Ram Prasad (P)
EDC	41	*Commercial weights & measures*	Dr. A.R. Verma (C)
EDC	41:1	Commercial weights, lengths and capacity measures	Mr. P.C. Jain (P)
EDC	41:3	Taximeters	Mr. P.C. Jain (P)
EDC	43	*Engineering metrology*	Mr. P.C. Jain (P)
EDC	43:2	Precision measuring equipment	Mr. P.C. Jain (P)
EDC	43:3	Gauges	Mr. Mohinder Nath (P)
EDC	43:4	Surface roughness	Mr. P.C. Jain (P)
EDC	57	*Chemical engineering*	Dr. J.K.N. Sharma (P)
EDC	57/P 2	Panel for standardization of vacuum equipment	Dr. J.K.N. Sharma (P)
EDC	62	*Compressors*	Mr. Naunihal Singh (P)
EDC	66	*Refrigeration and airconditioning*	Mr. Naunihal Singh (P)
EDC	66:1	Air-conditioning and refrigeration appliances and commercial refrigerators	Mr. Naunihal Singh (P)
			Mr. R.S. Khandekar (A)
EDC	70	*Screw threads*	Dr. B.K. Agarwala (P)
CWCE		*Standing Working Committee, Mechanical Engineering*	Dr. B.K. Agarwala (P)

(Contd.)

EXECUTIVE COMMITTEE
(As on 31st December, 1975)

Chairman

Dr. A.R. Verma
Director
National Physical Laboratory
New Delhi

Members

Dr. A.S. Bhaduri,
Director,
National Test House,
Calcutta.

Dr. A.K. Kamal,
Head,
Department of Electronics
& Communication Engineering,
University of Roorkee,
Roorkee,
(U.P.)

Mr. U. Venkateswarlu,
Managing Director,
Central Electronics Ltd.,
NPL Campus,
New Delhi.

Dr. V.G. Bhide,
Scientist (Director's Grade),
National Physical Laboratory,
New Delhi.
(*Member-Secretary*)

Dr. S.R. Das,
Scientist 'EI',
National Physical Laboratory,
New Delhi.

Dr. K.K. Mahajan,
Scientist 'C',
National Physical Laboratory,
New Delhi.

Mr. H.L. Khurana,
Accounts Officer,
National Physical Laboratory,
New Delhi.

Mr. Nau Nihal Singh,
Administrative Officer,
National Physical Laboratory,
New Delhi.

Permanent Invitees

Director-General, SIR
(or his nominee)

Chairman, Coordination
Council for Physical and
Earth Sciences Group of
CSIR Laboratories.

Receipts on Account of Fabrication, Supply and Servicing of Instruments etc. during 1975-76

Sr. No.	*Item*	*Rs.*
1.	Instruments servicing	4,820.00
2.	Supply of thin film coatings etc.	15,988.00
3.	Supply of photometric integrator	4,000.00
4.	Supply of GLS lamps	1,000.00
5.	Supply of Moire gratings	4,880.00
6.	Supply of ice-point equipment	275.00
7.	Supply of platinum resistance thermometers	12,500.00
8.	Supply of crystals etc.	3,010.00
9.	Supply of microwave components	4,550.00
10.	Repair/supply of He-Ne lasers and optical flats	6,270.00
11.	Repair and supply of probes and ultrasonic instruments	4,407.15
12.	Repair and supply of metal detectors	1,179.50
13.	Repair of TV picture tubes	2,500.00
14.	Workshop jobs	4,797.45
15.	Miscellaneous jobs	80.00
16.	Packing and forwarding charges	413.00
	Total	70,670 10

STAFF STRENGTH
(as on 1st June, 1975)

Category of Staff	NPL	DPEC	CPP	GTU	HEMS	TEC	Total
(A) *Gazetted/Officers Ranks*							
A.1 Scientific Officers	112	8	—	—	2	4	126
A.2 Technical Officers	36	5	—	4	—	—	45
A.3 Non-Technical Officers	5	—	—	—	—	—	5
A.4 Part-Time Officers	1	—	—	—	—	—	1
Sub-Total (A)	**154**	**13**	—	**4**	**2**	**4**	**177**
(B) *Non-Gazetted/Establishment*							
B.1 Scientific Establishment (SSA & JSA)	49	6	1	—	—	—	56
B.2 Technical Establishment	337	93	2	48	4	19	503
B.3 Non Technical Establishment	112	10	—	2	—	3	127
Sub-Total (B)	**498**	**109**	**3**	**50**	**4**	**22**	**686**
(C) *Class IV Staff*	**205**	**2**	—	**5**	—	**6**	**218**
TOTAL (A) + (B) + (C)	**857**	**124**	**3**	**59**	**6**	**32**	**1081**

Note 1: 'Technical' covers the 'Auxiliary Technical' Staff also.
Note 2: The information has been drawn from the Conventional Budget Document of the Laboratory. Scheme posts are excluded.

Abbreviations Used:

NPL : National Physical Laboratory (Main Laboratory).
DPEC : Development-Cum-Production of Electronic Components Unit.
CPP : Carbon Pilot Plant.
GTU : Glass Technology Development-Cum-Production Unit.
HEMS : Pilot & Demonstration Plant in Hydrostatic Extrusion & Material Synthesis.
TEC : Test, Evaluation & Calibration Centre for Electronic & Electrical Equipment & Components.

EXPENDITURE (1975-76)

(Rs. in lakhs)

Activity	Recurring	Capital	Total
(A) Main Laboratory	116.162	23.609	139.771
(B) Test, Evaluation & Calibraton Centre for Electronic & Electrical Equipment & Components (TEC)	5.462	—	5.462
*(C) Pilot Plants			
(i) Development-cum-Production of Electronic Components Unit (DPEC)	15.275	7.173	22.448
(ii) Glass Technology Development-cum-Production Unit (GTU)	6.188	0.129	6.317
(iii) Carbon Pilot Plant (CPP)	1.432	1.110	2.542
(iv) Pilot & Demonstration Plant in Hydrostatic Extrusion & Material Synthesis (HEMS)	1.517	25.120	26.637
Sub-Total (C)	24.412	33.532	57.944
TOTAL (A) + (B) + (C)	146.036	57.141	203.177

*The break-up of the expenditure into 'Recurring' & 'Capital' in respect of the Pilot Plants is on the analogy of the expenditure incurred under these categories in respect of the Main Laboratory.