NML

# ANNUAL REPORT 1970-71



NATIONAL METALLURGICAL LABORATORY
JAMSHEDPUR, INDIA

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## NATIONAL METALLURGICAL LABORATORY

COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH

JAMSHEDPUR, INDIA

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# 1. INTRODUCTION

The National Metallurgical Laboratory has passed through another year of all-round progress in its research and development work. Besides consolidation of research activities in the diverse fields, research and development projects have been further streamlined to suit the minimum requirement of the country's needs. The outstanding achievement of the Laboratory, during the period under review, has been the successful and pioneering trials for the production of tonnage quantities of prereduced iron ore pellets and sponge iron. The production of prereduced blast furnace burden as well as sponge iron forms an important advance in the interest of India's developing steel economy, since the development of a process to produce raw materials for direct steel manufacture is of vital significance to the country. The Planning Commission and the Ministry of Steel have evinced great interest in establishing a well-planned facility at the National Metallurgical Laboratory for larger scale trial production of sponge iron.

During the period, metallurgical industries both in the public and private sectors continued increasingly to call upon the assistance of the NML in diversified fields pertaining to raw material problems, quality of production, process control, etc. The 500 tonnes per day Fluorspar Flotation Plant of the Gujarat Mineral Development Corporation, for which the National Metallurgical Laboratory acted as consultants right from pilot plant investigations to the commissioning stage, has been finally commissioned and our scientists participated in the commissioning trials at Ambadongar. Coming in its wake, the Hindustan Copper Ltd commissioned the NML for consultancy services for their 1000 tonnes per day Copper Concentrate Project at Rakha. Similarly, the NML was assigned the project for evaluating and providing data required for the design and setting up of a plant for the extraction of nickel and cobalt from Sukhinda deposits in Orissa. The test data, based on laboratory bench scale investigations, have already been supplied to the sponsors.

An event of equal significance and far-reaching importance is the establishment of the 'Central Creep Testing Facility', having 150 test points at the National Metallurgical Laboratory with assistance from the United Nations Development Programme. The national importance of this project can be visualized from the fact that it was approved not only by the highest executive bodies of the CSIR but also at a Seminar convened by the Laboratory at which besides representatives of the Steel Ministry and research institutes, top representatives of the concerned industries, such as Hindustan Steel Ltd, Tata Iron & Steel Co. Ltd, Bharat Heavy Electricals Ltd and other public and private sector industries actively participated. A significant feature of this project is financial participation by the user Ministries by way of contribution towards capital and recurring expenditure.

Detailed plans have also been worked out for the establishment of Multipurpose large-scale hydro-cum-electrometallurgical facility for the extraction of nickel and other non-ferrous metals. This project has also been approved by the governing body of the CSIR and is proposed to be set up with the financial participation by the Ministry of Steel & Mines.

The long range research projects on substitute alloys have yielded encouraging results. The scope of work in the field of non-ferrous metals has been further enlarged and close contacts have been made with the Non-ferrous Metal Manufacturers' Association and the Ministry of Steel & Mines particularly with their programmes on aluminium, lead, zinc and copper projects. The Director, NML, has been appointed a member of the Board of Directors of Hindustan Copper Ltd. The Non-ferrous Metal Manufacturers' Association are going to hold their Council meeting shortly at the NML. The opportunity will be utilized to identify problems of the industry so that the Laboratory's research activities in the field of non-ferrous metals may be suitably reoriented to meet the industry's immediate requirements.

Corrossion is another important field in which NML has done outstanding work and made major strides. The Laboratory is being increasingly called upon by industry to urgently tackle the various corrosion problems faced by them. As a national recognition of the outstanding work done in this field, one of the scientists of the Laboratory engaged on corrosion research has been awarded the National Metallurgists' Day award for 1970.

The Laboratory has also done significant work on the development of ferrite magnets. The importance of this work has been recognized by the Inventions Promotion Board by conferring a Republic Day award on the scientist of the Laboratory who developed this product.

The Four foundry stations set up by the National Metallurgical Laboratory at Batala, Madras, Ahmedabad and Howrah have been rendering very useful service to the regional industries. Their assistance has been duly acknowledged by the local industries. Similarly, the Marine Corrosior Research Station at Digha has been conducting very useful studies on metallic corrosion in marine atmospheres and in sea-water.

A programme has been initiated by the Laboratory to maintain close contacts with industry by organizing 'get-togethers' with metallurgical industries and to establish 'Customer-Contractor' relationship with them. Effective use has also been made of several seminars and symposia held in the country by deputing scientists of the Laboratory in large numbers not only to participate in them but also to make use of these opportunities to contact local industrialists and entrepreneurs and for visits to factories for identification of industrial problems. As a result of these increasing contacts and the interaction between scientists of the Laboratory and the industries, several new projects of immediate importance to the country's requirements have been started in the Laboratory.

The total number of projects handled during 1970-71 was 126 of which 98 were of applied nature and 28 on basic research. Twenty-six projects were sponsored by industry, 96 were undertaken on the initiative of scientists in the Laboratory and 4 in collaboration with national and international organizations, including the United Nations Industrial Development Organization, National Bureau of Standards, USA, Hindustan Steel Ltd, etc. Nearly 40 projects were completed during the period. These projects along with other activities of the Laboratory during the period under review are presented in subsequent pages.

During the period under review the Laboratory earned a sum of Rs 3.835 lakhs for services rendered by it to industry and to other research institutions.

# 2. RESEARCH INVESTIGATIONS

## 2.1 Sponsored Projects

### 2.1.1 *Asswan Iron Ore from Egypt* (Sponsor: UNIDO)

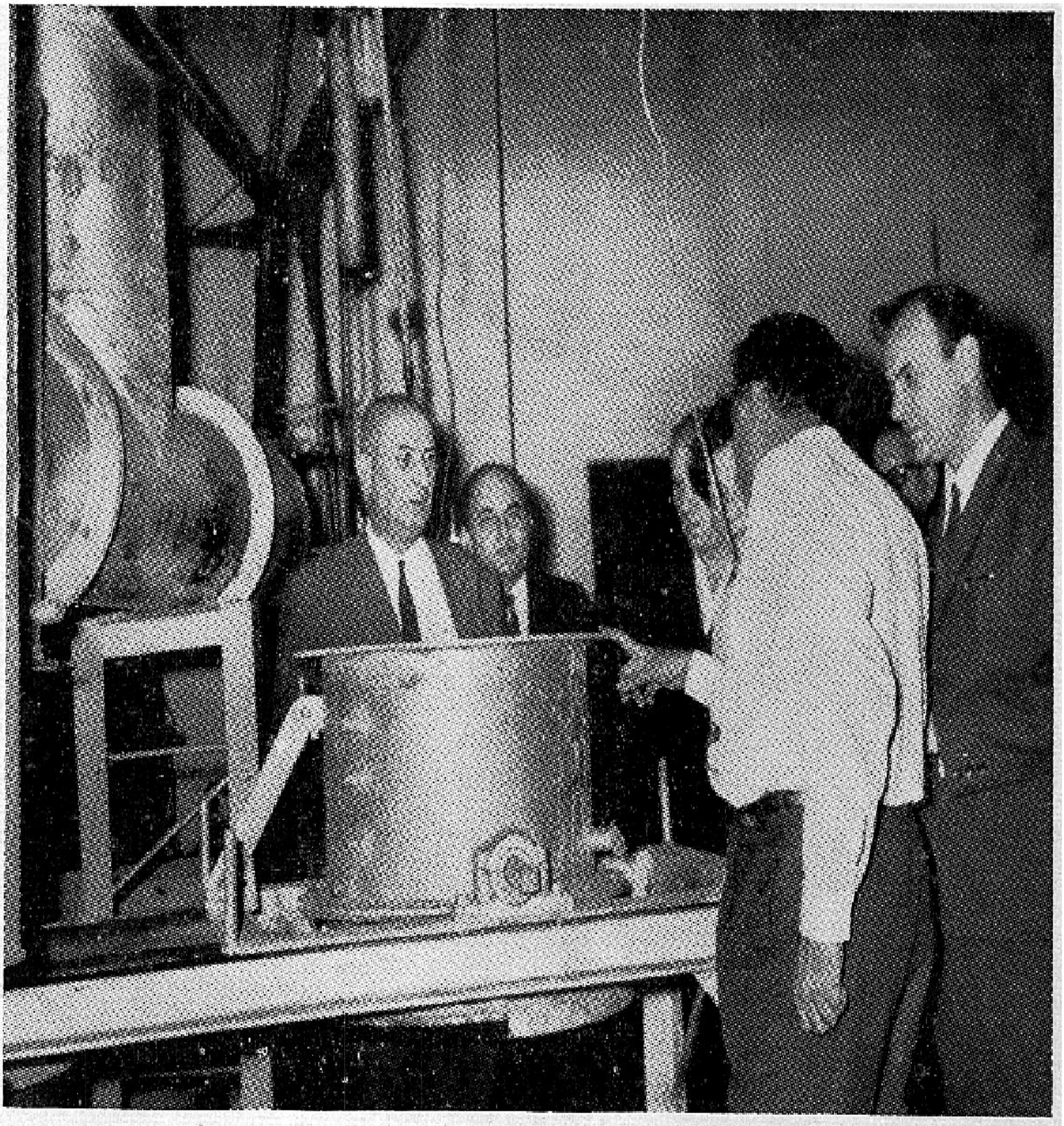
**2.1.1.1** *Beneficiation* — Three samples representing (i) run of mine ore, (ii) 15 to 80 mm size lumps, and (iii) fines (up to 15 mm) were received for bench scale beneficiation. The investigations showed that

(i) straight high intensity dry magnetic separation of the run of mine ores, ground to 65 mesh and deslimed 65 to 200 mesh, did not give satisfactory results. Reduction roast followed by wet magnetic separation yielded a concentrate of 51·2% Fe content with 90·2% Fe recovery. Washing followed by reduction roast and magnetic separation did not yield a better concentrate. Further tests are in progress to improve iron recovery.

(ii) lumps of 15 to 80 mm size yielded a concentrate assaying 44·2% Fe with Fe recovery of 76·67% by dry magnetic separation. Fine grinding to 150 and 200 mesh did not improve the product. Low temperature reduction followed by low intensity wet magnetic separation of 200 mesh material yielded a concentrate with 49·4% Fe content with Fe recovery of 91·9%. Wet magnetic separation at still higher sizes did not yield an improved product. Further work is in progress.

(iii) the fines up to 15 mm size treated by low temperature reduction followed by wet magnetic separation of 200 mesh material yielded a concentrate containing 54·68% Fe with Fe recovery of 89·3%.

**2.1.1.2** *Physical and chemical characteristics* — Various properties, viz reducibility, decrepitation, apparent porosity, bulk density, apparent specific gravity and physical strength, as also the chemical composition, were determined for the run of mine ores.



Shri G. P. Mathur, Head, Ore-Dressing Division, explaining the 'Pot grate furnace' used for determining the heat hardening characteristics of iron ore pellets, to the visiting Russian experts connected with the Bokaro Steel Plant

**2.1.2** *Beneficiation and Pelletization of Bailadila Iron Ore*
(Sponsor: National Mineral Dev. Corpn)

Detailed studies on grinding, beneficiation and pelletization were carried out with 12 samples of iron ore from Bailadila deposit No. 14. It was concluded that the samples had to be ground to 85% through 325 mesh, wet or dry, and 1% bentonite and 0·36% limestone are required to be added for making good quality pellets.

**2.1.3** *Beneficiation Studies of Laterite Iron Ore in Clayey Matrix*
(Sponsor: M/s. Sesa Goa Ltd, Panjim, Goa)

The investigation has been continued from the previous year. During the current year, heavy media separation of the lumps and jigging of the fines improved the concentrate but alumina was still found to be high, though iron and silica contents could be brought within acceptable limits.

Overall concentrate produced by washing at —30 mm size is followed by heavy media separation of the lumps and jigging of the fines assayed from 55·5 to 62·35% Fe and 11·7 to 6·8% alumina with a total iron recovery of 74·6%.

**2.1.4** *Appraisal of Raw Materials for Iron Making*
(Sponsor: National Mineral Dev. Corpn)

Tests carried out with NMDC samples indicated that the decrepitation temperature was between 400° and 420°C for hematite, laterite, laminated hematite and fluky ore.

An apparatus for standard reducibility tests was set up which provided a suitable $CO/CO_2$ ratio, even as it still contained 1-4% free oxygen.

**2.1.5** *Beneficiation of Manganese Ore*
[Sponsor: M/s. Manganese Ore (I) Ltd]

Beneficiation studies by jigging of the samples yielded from 43·13 to 47·67% Mn in the $-\frac{1}{4}''$, $+1/10''$ size range and 43·73 to 48·03% Mn in the coarse size of $-1''$, $+\frac{1}{4}''$. The recovery of Mn was 89·8 and 89·4% respectively. Both the concentrates are of export quality.

### 2.1.6 *Beneficiation of Phosphate Rock*
(Sponsor: G.S.I., Rajasthan Circle)

**2.1.6.1** *Jhamarkatra (B), Udaipur, Rajasthan* — Straight flotation, followed by one cleaning, yielded a cleaner concentrate of 34·6% $P_2O_5$ from the original 23·0% $P_2O_5$ (recovery 59%). Calcination followed by slaking and desliming yielded a sand fraction with 34·8% $P_2O_5$ (recovery 87·0%). The grades obtained satisfy the specification for the fertilizer industry.

**2.1.6.2** *Karbaria Block, Udaipur* — Flotation, carried out after grinding the sample to 75% through 200 mesh using sodium oleate as collector, followed by 3 cleanings of rougher float, yielded a concentrate with $P_2O_5$ content of 31·9% compared to the $P_2O_5$ content of 22·7% of the original samples, giving a recovery of 78·47% $P_2O_5$. Further tests are in progress.

### 2.1.7 *Beneficiation of Low Grade Molybdenite from Karadikuttam, Madurai Dist., Tamil Nadu*
(Sponsor: G.S.I., Tamil Nadu Circle)

**2.1.7.1** Industrial grade molybdenite concentrate (L-2) was prepared by flotation with fuel oil and cresylic acid after three cleanings, using sodium cyanide, when 54·5% Mo (90·8% $MoS_2$) was obtained with 71% Mo recovery. Regrinding the cleaner tailings followed by reflotation yielded a second concentrate. The overall recovery of 81·6% with 53% Mo in the concentrate was obtained; the original ore contained 0·108% Mo.

**2.1.7.2** The low grade (L-3) molybdenite samples containing 0·038% Mo were selectively floated using fuel oil and cresylic acid, followed by reflotation of reground rougher float three times and yielded a concentrate with 43% Mo (71% $MoS_2$) (Mo recovery of 70·7%). Bulk sulphide flotation followed by differential flotation did not improve the grade and recovery.

### 2.1.8 *Beneficiation Studies on Wolframite Samples*

**2.1.8.1** *Degana, Rajasthan* (Sponsor: Director of Mines & Geology, Rajasthan) — Finer grinding was indicated by tabling coarser materials. A concentrate of 25·65% $WO_3$ from original 0·123% $WO_3$ was obtained by tabling followed by high intensity magnetic separation, using —48 mesh particles. High tension separation of different sized fractions did not yield encouraging results. Further work is in progress.

**2.1.8.2** *Bankura, West Bengal* (Sponsor: M/s. Gouripur Industries Ltd, Calcutta) — Gravity separation followed by magnetic separation yielded a concentrate containing 5·4% $WO_3$ from samples originally assaying 0·1% $WO_3$ with recovery of 3·95%. Further tests are in progress.

**2.1.9** *Beneficiation of Low Grade Kyanite, Dahagaon, Maharashtra* (Sponsor: Maharashtra Minerals Corpn, Bombay)

Various gravity methods, viz. heavy media separation, jigging, tabling and spiralling, have been attempted for preconcentrating the samples. Tabling and spiralling gave encouraging results. Further tests are in progress.

**2.1.10** *Manganese Metal*

**2.1.10.1** *Ferro-manganese slag* (Sponsor: M/s. Khandalwal Ferro Alloy Ltd, Bombay) — Investigations for utilization of ferro-manganese slag containing 36 and 24% Mn for production of electrolytic manganese metal have been carried out and found technically feasible. But comparative economics of electrolytic manganese metal production between ferro-manganese slag and the ore as raw material indicated that the ore was more viable than even high manganese slag.

**2.1.10.2** *Ores* (Sponsor: M/s. Sandur Iron & Manganese Ore Ltd, Nagpur) — The suitability of the ore samples for production of electrolytic manganese metal under standard conditions has been tested and report submitted.

**2.1.11** *Extraction of Nickeliferrous Ores, Surabil-Sukerangi, Kumardah Sector* (Sponsor: G.S.I., Calcutta)

Investigation has been successfully completed, resulting in nickel recoveries of 88% in bench scale work.

**2.1.12** *Utilization of Ni-Cu-Mo Concentrates* (Sponsor: Uranium Corpn of India, Jadugoda)

The extraction characteristics of Ni, Cu and Mo containing ores from Jadugoda were completed on bench scale. Sulphate roasting and leaching with water/sulphuric acid followed by solvent extraction yielded recoveries of 95% Ni and 88% Cu.

**2.1.13** *Grinding Characteristics of Diamondiferrous Tuff Samples*
(Sponsor: M/s. Diamond Mining Project, Panna, M.P.)

The investigation has been continued from the last year. During the current year, grinding tests carried out in closed circuit with 60 and 100 mesh sieves at 250% circulating load indicated the work index value of 19·3 kWh/tonne for dry grinding conditions.

**2.1.14** *Recovery of Metallics from Furnace Dross Samples*
(Sponsor: M/s. Leader Engg. Works, Jullunder)

Tumbling followed by screening and tabling the fines yielded 93·1 and 88·1% by weight of the metallic values.

**2.1.15** *Recovery of Zinc Values from Zinc Ash and Dust*
(Sponsor: M/s. Khandalwal Tubes Ltd, Bombay)

Zn values were recovered successfully by agglomeration and leaching techniques.

**2.1.16** *Utilization of Zinc Waste*

**2.1.16.1** (Sponsor: Hindusthan Zinc Ltd, Udaipur) — A successful method has been developed which enables 98% removal of chlorine with negligible Zn loss from zinc ash resulting from cathode sheet melting furnace in electro-winning zinc.

**2.1.16.2** (Sponsor: M/s. Khandalwal Tubes Ltd, Bombay) — A method has been developed to separate metallic Zn values from Zn ash obtained as a byproduct in galvanizing plants. The zinc oxide thus produced met the rigid specifications of the rubber industry.

**2.1.16.3** (Sponsor: M/s. Travancore Cochin Chemicals Ltd, Kerala) — A method has also been developed to produce rubber grade zinc oxide from zinc hydroxide obtained as waste byproduct during the production of sodium hydrosulphite.

**2.1.17** *Recovery of Copper from Leaded Brass*
(Sponsor: Ordnance Laboratory, Katni)

The recovery of copper from leaded brass (60% Cu-30% Zn-2% Pb) was successfully concluded and a report submitted to the sponsors.

**2.1.18** *Production of Fe-Mo from Concentrates*
(Sponsor: Uranium Corpn of India, Jaduguda)

The feasibility of producing Fe-Mo from concentrates supplied by the Jaduguda Plant of Uranium Corporation of India was studied.

It was established that improvement in the Mo content of the concentrates was essential, before it could be used to produce Fe-Mo alloy of the required specifications.

**2.1.19** *Wear and Abrasion Resistant Cast Iron*
(Sponsor: Tata Engg. & Locomotive Co. Ltd, Jamshedpur)

In continuation of the work reported last year, a fresh set of blades with heavier compositions was prepared and sent to M/s. Telco Ltd, Jamshedpur, for evaluation under actual service conditions.

**2.1.20** *Production of Al-Ti Hardener Alloys*
(Sponsor: Ministry of Defence, New Delhi)

The process for making Al-Ti hardener alloys was successfully developed using an exothermic briquette composition containing rutile. The project has been completed and a report sent to the sponsor.

**2.1.21** *Study of Creep-rupture and Other Related Properties of Cr-Mo-V Steel*

**2.1.21.1** (Sponsor: M/s. Bharat Heavy Electricals Ltd, Hyderabad) — Five heat-treated cast blocks of $\frac{1}{2}$ Cr-$\frac{1}{2}$ Mo-$\frac{1}{4}$ V steels were sent by M/s. Bharat Heavy Electricals Ltd, Hyderabad, for creep-rupture tests. Stress rupture at 525°C at 18, 20 and 22 kg/mm$^2$, along with ageing embrittlement study, metallographic examination for grain size inclusion contents and microstructure of as received, as aged, chemical analysis and high temperature tensile tests were completed. The results corroborated very closely to the values obtained in Czechoslovakian Laboratories. Final report has been submitted to the sponsors.

**2.1.21.2** (Sponsor: M/s. Bharat Heavy Electricals Ltd, Tiruchirapalli) — Machined specimens for stress rupture tests of $\frac{1}{2}$ Cr-$\frac{1}{2}$ Mo-$\frac{1}{2}$ V steel supplied by M/s. Bharat Heavy Electricals Ltd, Tiruchirapalli, were tested. Stress rupture at 525°C for repeated timings of 3000, 5000 and 10,000 hours were initiated at 18·5, 20 and 22 kg/mm$^2$. Some of the specimens fractured much before the expected time because of machining and other internal defects. These tests are being repeated along with other tests which are in progress.

**2.1.22** *Discolouration of Copper Tapes During Transport and Storage*
(Sponsor: M/s. Hindusthan Cables Ltd, Roop Narainpur)

The nature of discolouration and its inhibiting property on steel tape wrapped over the copper tapes used for coaxial cable for telephones was studied. The presence of the discolouration film which consisted of a mixture of $Cu_2O$ and CuO reduces further attack but not to a considerable extent. The progress of tarnishing and the electrical properties of the tarnished tapes were examined in different environments. Increase of moisture materially affected the life of the cable.

**2.1.23** *Reclamation of Rusted Dynamo Stampings*
(Sponsor: M/s. Bharat Heavy Electricals Ltd, Hyderabad)

Rusting of high-silicon dynamo stampings, under the varnish, within a very short period, has been investigated. On the basis of accelerated corrosion and various physical tests a suitable method for prevention of corrosion was evolved and the necessary flow sheet for the purpose has been suggested.

**2.1.24** *Corrosion of Boiler Super-heater Tubes*
(Sponsor: M/s. Indian Oil Corpn, Barauni)

Recommendations made, based on critical study of the tube surfaces, include (1) cleaning of existing tubes, (2) control of feed water, and (3) precautionary measures during shut down.

**2.1.25** *Studies on Refractory Plastics and Castables*
(Sponsor: Indian Standards Institution, New Delhi)

Full-fledged testing facilities were developed for evaluating refractory plastics and castables, on the recommendation of the Indian Standards Institution. Testing of six Indian refractory plastics and 10 refractory castables was completed. Facilities are now available for exhaustive testing of plastic and castable refractories for the industry.

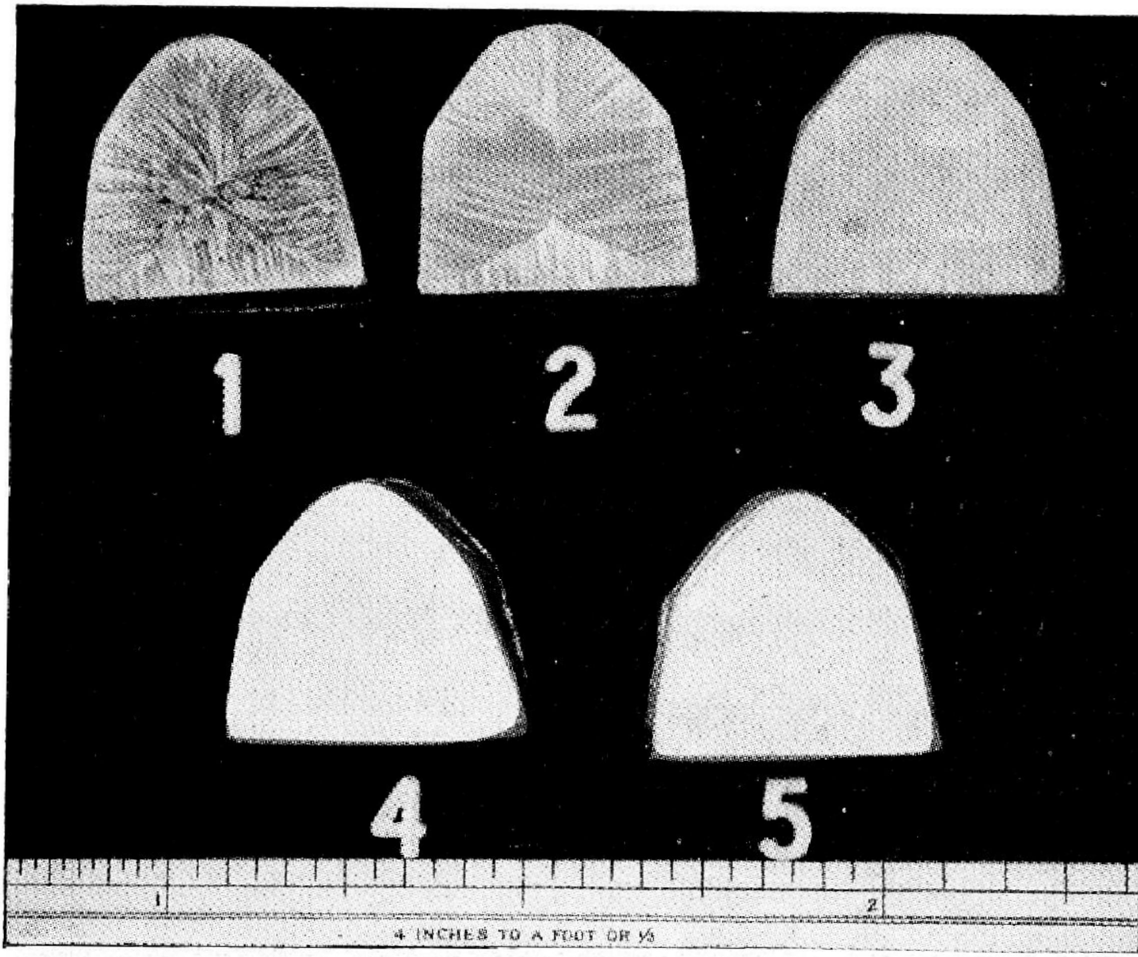
**2.1.26** *Aluminizing of Fasteners*
(Sponsor: Central Institute of Fisheries Technology, Cochin)

A large number of bolts, nuts and other fasteners, received from the party, were successfully aluminized, using centrifuging technique, and supplied to the party.

## 2.2 Industrially Oriented Projects

**2.2.1** *Development of Al Alloy Conductors*

**2.2.1.1** *PM-2 conductor alloy cables* — The technically superior Al conductor alloy (PM-2), developed at the NML, had previously been




Microstructures of conventional EC grade aluminium (1, 2, 3) as compared to the microstructures (4, 5) of the PM-2 conductor developed by NML — Properzi cast successfully drawn into wires after casting by both Properzi and direct-chill semi-continuous casting techniques. In further industrial trials, the Properzi cast alloy was drawn to wires of still smaller diameters after intermediate annealing. These wires showed high electrical conductivities. Corroborative results were obtained both at NML and at the laboratories of the industries. The possibilities of manufacturing communication cable from this super ductile conductor alloy are being explored.

**2.2.1.2** *Alloy aluminium conductors* — With a view to develop suitable aluminium alloys from commercial grade aluminium, for use in place of ACSR conductors in power transmission, studies were initiated on some Al-Si alloys containing one or more alloying additions, viz. copper, zinc, magnesium, etc. 10 kg heats of four aluminium alloys were prepared and the ingots obtained were hot worked to 1·5 $cm^2$ section rods. Work is in progress on preparing wires from these rods and their subsequent heat treatment, and mechanical and electrical testing.

### 2.2.2 *Modification in Al-Si Alloys*

It was reported earlier that sodium sulphide had been found to be an effective modifier for Al-Si alloys. However, the water of crystallization present in the salt was found to cause blowholes in the castings which offset the advantages gained by modification. The best results were obtained when the salt was dehydrated completely under vacuum at 300°C. Statistically, no spectacular improvements in microstructure or mechanical properties could be obtained on inoculation even with the dehydrated salts.

### 2.2.3 *Aluminium Cast Iron*

Heats of aluminium cast iron, containing 22-23% Al, 1·5-1·8% C, 1·0-1·5% Si, 0·4-0·7% Mn and low S and P, were made in a high frequency furnace. Composition of cast iron was controlled to give the desired final composition of Al cast iron. Bottom pouring ladle was used for the metal in the sand moulds. Heavy shrinkage and blowholes were observed in the castings when usual gates were provided in the moulds. The test bars were found to be unsuitable for testing. Improvement in the design of gates and risers produced sound castings without any shrinkage or blowholes. It was observed that the graphite had a tendency to segregate in the upper half of the castings. Even though the castings and test specimens were sound, the tensile strength was found to be rather low. Chromium addition also did not show any improvement in the tensile strength of the test bar.

**2.2.4** *The Technology of Production of Copper-clad Aluminium Sheets*

Copper-clad aluminium sheets possesses excellent electrical and thermal conductivities and has special application as terminal connectors. The production technology has been established in stages: (i) optimum condition for bonding by rolling, (ii) condition of annealing and rolling the clad product, and finally, (iii) the appropriate mechanical and thermal treatment required to impart the desirable properties in the finished product. Work is under progress to improve annealing treatment due to low drawability.

**2.2.5** *Development of Nickel-Silver Alloy for Electrical Contact Springs*

The work has been initiated to develop the process know-how for melting, casting and working techniques of nickel-silver alloy No. 107, used for making contact springs in telecommunication, refrigeration and computer industries. The heats prepared in gas-fired furnace with proper fluxes maintaining an oxidizing atmosphere were quite satisfactory at pouring temperature of 1250°C. Intermittent annealing was found necessary for cold rolling. Hot rolling with heavy reductions developed sidecracks. Study of hardness values with other mechanical properties of the cold-rolled materials has almost been completed. Other properties as required for spring application are under progress

**2.2.6** *High Conductivity Resistance Electrode*

Copper-based alloys suitable for use as non-consumable resistance welding electrodes, particularly copper-silver and copper-chromium alloys, have been developed. The technology with respect to melting and casting has been worked out. Cold-rolled rods of copper-silver and copper-chromium alloys had respectively a hardness between 120-122 Brinnel and 75-80 Rockwell B, and electrical properties of 94-95% and 80% IACS.

**2.2.7** *Brazing Alloy-clad Aluminium*

Production technique of aluminium-silicon brazing alloy-clad aluminium sheet with different component ratio has been developed. Furnace brazing and dip flux brazing, using brazing alloy-clad aluminium sheet have been continued with different types of fluxes.

**2.2.8** *Aluminium Base Bearing Alloys*

A suitable composition was developed which resulted in sound castings with all the desirable bearing properties. The material when subjected to 20% cold reduction followed by heat treatment at 200°C for 6 hours gives maximum hardness. During extrusion to $1\frac{1}{8}''$ dia rod at 350°C the billet developed a pressure of 1200 psi; the hardness of the extruded rod was found to be about 60-65 BHN. The material was fabricated for use as floating bush and supplied to Indian railways for service trials with a view to economize on imported non-ferrous metals in the Indian railways.

**2.2.9** *Magnetic Materials*

**2.2.9.1** *Ferrite magnets* — Work on the preparation and properties of ferrite magnets has been continued. The effects of variables, viz. grinding period, iron oxide content, etc , were investigated on the magnetic properties of mixed ferrites. The properties of the ferrites prepared after compaction under the magnetic field were also studied.

**2.2.9.2** *Alnico V alloys* — The columnar crystal growth in Alnico magnets have been studied using (i) solid state phase transformation, and (ii) controlled solidification in the mould. In the first method though the grains coarsened considerably, no growth along the columnar direction was detected. In the second method it was possible to grow columnar crystals 5-10 mm in length using chill plate at the bottom of the mould. With such moulds and hot tops the length of the columnar crystals could be increased to about 20 mm. Experiments are under way to study the effect of small additional elements on the growth of columnar crystals. Magnetic properties of the columnar Alnico magnets are also under investigation.

**2.2.10** *Preparation of Anhydrous Metal Halides*

**2.2.10.1** *Direct chlorination* — The operating parameters have been evaluated using impure magnesites from Almora, Salem, Ajmer and Mysore in the pelletized form for preparing anhydrous magnesium chloride. Methods and conditions controlling the physical properties of the pellets, suitable as feed for chlorination furnace, have been standardized. The magnesium chloride produced is found to be suitable for preparation of electrolytes in metal production and for fluxes.

**2.2.10.2** The dehydration characteristics of dihydrate magnesium chloride have been studied in a fluidized bed in HCl atmosphere using commercial grade magnesium chloride hydrate. The composition of the fluidized media, HCl, moisture and air greatly influences the quality of the final product. The study is in progress to determine optimum conditions for preparing anhydrous magnesium chloride.

**2.2.11** *Preparation of Aluminium Fluoride*

**2.2.11.1** The time and temperature of decomposition of ammonium aluminium fluoride prepared by fluoboric acid with admixture of alumina have been investigated and standardized. The product is of a high grade containing 88-91% $AlF_3$ and meets the specifications for use in aluminium industry.

**2.2.11.2** *Iron-free Cryolite* — Tests carried out for removing iron from process liquor by Amberlite IR-120, ion exchange resins, before precipitation of cryolite, showed appreciable removal of sodium along with iron, which have to be replenished, thus affecting the economy of the process.

**2.2.12** *Tin-free Steel for Canning Industry*

**2.2.12.1** *Double stage process* — The investigation was carried out for a suitable substitute for tin plate specially for handling dry and less corrosive products. The metal/metal oxide coating on steel having firmly adherent and sufficiently ductile properties have been successfully developed on bench scale. Corrosion tests under boiling sodium chloride solution, citric acid solution and indoor atmospheric exposure show good compatibility in comparison to other tin-free steel produced abroad.

**2.2.12.2** *Single stage process* — Electrodeposition technique with respect to different variables for a very thin layer of chromium and chromium oxide on steel substrate by a single stage process has been investigated. Large-scale trials are in progress to obtain bright lustrous plate.

**2.2.13** *Manganese Metal*

Studies on the reduction of manganese ore with solid fuel, viz. charcoal, have been completed. Use of fuel oils as a reductant did not show promising results in bench scale kiln.

Bench scale experiments on the reduction of manganese ore with coke oven gas and coke in a vertical kiln have also been completed and tested in a larger pilot vertical kiln. Reduction and leaching recovery of 90% have been obtained. Fuel oil as a reductant in a pilot vertical kiln is under investigation.

**2.2.14** *Nickel Extraction*

A simple method for the extraction of nickel by eliminating pressure leaching and other cumbersome process steps has been developed. Results are promising with 55% Ni recovery. Work is under progress.

### 2.2.15 *Recovery of Germanium and Gallium from Coal Ash*

Tetrachlorides of germanium and gallium have been obtained successfully in bench scale experiments. It is planned to smelt the ash and flue dust samples obtained from various collieries and thermal power stations with limestone, coke and copper oxide in an electric furnace to obtain germanium-rich regulus for scale up chlorination studies.

### 2.2.16 *Refining of Selenium and Tellurium*

After successfully completing large-scale experiments for the recovery of selenium and tellurium from electrolytic copper slimes, minipilot plant work has been initiated for compling a feasibility report.

### 2.2.17 *Production of Ferro-silicon* (75% *and above*)

High quality ferro-silicon of 75% and higher grade was successfully prepared. Report is under preparation.

### 2.2.18 *Atmospheric Zinc Distillation and Fine Powder*

Campaigns have been conducted in a Pontzen furnace to obtain comparative techno-economic data on the vacuum distillation of zinc drosses. The report is being compiled.

Further, production of zinc dust by shock cooling, utilizing the same basic distillation process, followed by powder formation, has also been continued.

### 2.2.19 *Fluo-solid roasting of complex sulphide concentrates*

Preliminary studies on bench scale using stainless steel fluidized bed reactor, under controlled conditions, yielded a roast leading to leaching recoveries of 91% Cu and 86% Zn. It is planned to use the Dorroco fluidized bed roaster for development work on bulk concentrates from Sikkim and other sources.

### 2.2.20 *Production of Metal Powders*

**2.2.20.1** Course Al and Zn powders up to +200 mesh were successfully prepared by air atomization technique. Al powders are found suitable for use in Alumino-thermic reduction process. Lead, tin and zinc powders, up to 200 mesh, were produced and found suitable for use in pigments. The work has been completed and the process has been released for commercial exploitation.

**2.2.20.2** *Bimetallic powders* (Prealloyed) — Prealloyed bimetallic powders of Cu-Pb, of required specification for the production of automobile bearings, have been successfully prepared. The process is now ready for commercial exploitation.

**2.2.20.3** *Iron powder* — The increased efficiency of the compressed air as atomizing agent has been tested at a metal temperature of 1280°C. The degree of atomization of molten cast iron was 61·1 and 40·2% (below 100 mesh size) at the final pressure of 5·5 kg/cm² and 3·5 kg/cm² respectively. The degree of atomized powder (below 100 mesh size) with superheated steam as atomizing agent was increased from 15 to 42% by increasing the steam pressure from 3 to 4 kg/cm² respectively. When oxygen was used as atomizing agent, the degree of atomized powder was found to be poor, and only a maximum of 25% —100 mesh powder could be obtained at 3·5 kg/cm² pressure. The degree of atomization could not be improved even by modifying the shape and size of the nozzles and pouring funnel. It was observed that atomization was hampered due to the pressence of moisture in the compressed air, resulting in the deposition of a considerable quantity of metal on the atomization ring.

**2.2.21** *Preparation of Catalysts*

**2.2.21.1** *Silver catalyst for use in the manufacture of formaldehyde* — A process to prepare silver catalyst has been developed as an import substitute. Salient steps of the process are : (i) preparation of pure silver powder, and (ii) its agglomeration into coarse granules having high porosity, large surface area and resistance to sintering at the reaction temperature. The conversion efficiency of methanol to formaldehyde by using the prepared catalyst was found to be 65-80%.

**2.2.21.2** *Regeneration of used silver catalyst* — A process for the regeneration of spent industrial silver catalyst, in powdery form, by chemical and electrochemical methods has also been worked out. The granules prepared from the powder showed a good conversion efficiency and sintering resistance.

Feasibility of the process and testing of the product for industrial use are under progress.

**2.2.22** *Aluminium-Magnesium* (7-10%)-*Misch Metal Wrought Alloys*

**2.2.22.1** Al (8-8·5%)-Mg (2·5-3%)-Misch metal alloy were cast in 4 in.² ingots for industrial scale rolling trials for ascertaining the rollability of the alloy.

**2.2.22.2** *Al-Mg-Misch metal-chromium wrought alloys* — The effect of addition of small quantities (0·10-0·42%) Cr to Al (6·5-8%)-Mg (0·5%)-misch metal alloys for developing stress corrosion resistant wrought alloys was studied. Proof stress for each composition was found to be comparable with other similar high strength alloys. Hot rolling of some of the compositions was satisfactory. Metallographic studies of the cast and hot rolled specimens have also been carried out. Further developmental work is in progress.

**2.2.23** *Treatment of Iron Ore Pellets*

**2.2.23.1** *Incorporating flue dust* — Flue dust collected from low shaft furnace dust collector has been investigated in preparing the iron ore pellets. Dust analyses 43·019% LOI, 12% Fe and 25·84% $SiO_2$. Flue dust in as received condition was added to —3 mm size iron ore, using 1% bentonite and 15% moisture. Pellets were heat treated at 900°C. The shatter index of green and heat treated pellets was found to be poor. Hence, —200 mesh flue dust fines were used for preparing the pellets. Heat treatment was carried out between 800° and 1000°C for one hour in $N_2$ atmosphere. Increasing the dust content in the pellets up to a maximum of 10% and heat treatment at 1000°C produced better results. The metallic content increased with 20% flue dust in the pellet mix and when heat treated at 1000°C, but the shatter index dropped appreciably. It was concluded that the reduced materials would not be suitable for any particular purpose with only shatter index as criteria.

**2.2.23.2** *Testing of prereduced iron ore and prereduced pellets* — Prereduction of iron ore and pellets was carried out in an oil-fired rotary kiln. Physical strength, i.e. shatter and abrasion strength, decrepitation, porosity and bulk density of the product were measured and chemical analysis was carried out to assess its suitability for either steel making in electric furnace or as feed for the blast furnace.

**2.2.23.3** *Pelletization and prereduction of iron ore pellets* — Pellets were prepared with 1% bentonite, 15% moisture and varying amount of coke fines (5-20%) and subsequently dried at room temperature. Reduction was carried out in a rotary kiln heated by coke oven gas. Hot reduced pellets after discharge from the kiln were covered by solid fuels to minimize reoxidation during cooling. Chemical and physical properties of the pellets were not satisfactory. The shatter index on +6 mm size was between 80 and 90%.

When these pellets were reduced in a stationery oil-fired kiln, manually operated and mixed with different solid fuels, the reduction rate was not encouraging mainly due to oxidizing nature of the atmosphere. The shatter index was almost identical.

**2.2.23.4** *Prereduction characteristics of iron ore pellets with non-metallurgical coals* — Pellets were prepared using different coals, charcoals and coke with Donamalai iron ore and the static bed reduction characteristics were studied by varying ore/coal ratio, time and temperature. It was possible to obtain 95-96% reduction of iron ore pellets in one hour using coals from Singarani or Ghughus, which were found to be better than charcoal, coke breeze and Saltore coal. Increased reduction potential of the reductants was observed by decreasing the ore/coal ratio on account of increased particle contact. The maximum iron content compares favourably with theoretical limit, which is nearly 91%.

**2.2.23.5** *Influence of prereduction on the electrical resistivity of iron ore pellets charged at various temperatures* — The voltage current characteristics were determined with iron ore pellets and the resistivity of prereduced charge was made with 25 V. A temperature of 800°C was attained in 70 minutes. Further experiments were carried out by placing 3" thick heat-hardened unreduced pellets between two carbon discs. The resistivity rose from 1·5 megohm to 8 ohm at room temperature and 850°C respectively. The experiments are being continued with 10-100% reduction of pellets.

**2.2.24** *Experimental Small Cupola*

**2.2.24.1** Commercial $CaC_2$ and foundry grade carbide were used to improve cupola iron melts. One to three wt% of carbide was added to the metal charged and the fuel to metal ratio was maintained at 1 : 5. This resulted in a higher melting rate as also a higher temperature of the tapped metal. The carbon pick up due to increase in the metal temperature was also studied using 50% steel scrap in the charge, maintaining a constant 20% flux addition. Further work is in progress.

**2.2.24.2** *Improvement in cupola operation* — In modifying a hot blast cupola, it was observed that increasing the height of the heat exchanger of air blast did not give any appreciable improvement in performance. The top gas outlet temperature was 600°C whereas hot blast temperature was 230°C, and the metal temperature was 1300°C. By incorporating a number of fins of mild steel plates inside the heat exchanger unit the hot blast temperature could be increased by 10-15°C. The radiation losses were minimized by proper lagging of the heat exchanger unit and hot blast pipes. Metal temperature was increased between 1230-1345°C by using hot air blast through heat exchanger in an acid lined cupola.

Different parameters, viz. effect of hot air blast at temperature between 100° to 600°C along with oxygen enrichment in acid and basic lined cupola with fuel rate, melting rate and composition of cast iron, are under study.

**2.2.25** *Pneumatic Steel Making*

**2.2.25.1** *Basic-lined side-blown converter* — Experiments carried out with high silicon medium phosphorus pig iron to produce usable steel in basic-lined side-blown converter showed that the converter lining had shorter life. Basic pig iron with less than 2% silicon yielded satisfactory product. Desiliconization of the pig iron by ore addition and oxygen lancing in the ladle was not found to be encouraging. By melting high silicon pig with steel scrap in the cupola and slow oxygen lancing was partially successful in achieving silicon reduction.

**2.2.25.2** *LD converter* — Liquid hot metal (high silicon pig) from cupola was blown for 27 minutes in the LD converter with addition of preheated lime powder and ferro-manganese. Blown metal contains with respect to silicon and phosphorus as 0·14% and 0·20% from the original hot metal of 5·2 and 0·54% respectively.

By adding ferro-chrome to the high silicon hot metal (4·5-5·9% Si) and varying the blowing time between 16-23 minutes, a maximum of 25% chromium pick up was obtained in the blown metal. The desiliconized pig iron (1·2% Si) was also used to study the effect of slag basicity on chromium pick-up. Low slag basicity and high phosphorus in the metal did not encourage the chromium pick-up.

**2.2.26** *Low Alloy Steels*

**2.2.26.1** *Thermomechanical treatment of low-alloy steels* — Six low alloy steels were thermomechanically treated at temperatures between 800° and 850°C, i.e. above their $Ac_3$ points, by quick forging followed by quenching. High hardness for most of the alloys were noticed in forged samples given approximately 50% reduction, with little further change in hardness even on tempering at 300° or 400°C. Martensitic structure of very fine grain size was formed except in two heats where coarser structure with longer needles was noticed. It was also found that Mn addition produces comparatively higher strength than addition of Ni. The strength values were maintained between 120 and 130 tons/in.$^2$ with slight drop during tempering. Satisfactory combinations of tensile strength, ductility and impact properties were attained by tempering.

**2.2.26.2** *Low alloy high strength structural steels* — After completing tests from small heats, further work was continued to study the improvement in weldability and other properties of low alloy low carbon steels having Mn/C ratio between 10 and 15 with low vanadium addition. The lower temperature impact tests of the materials rolled under controlled temperature were carried out along with higher deformation (55%) in a single pass. It was observed that 40 ft.lb tough/brittle transition temperature was gradually lowered with the increase of the percentage deformation up to 40%. With further increase in the deformation %, the threshold temperature was slightly raised but remained below that obtained with 30% deformation. 40% deformation at 950°C appeared to be optimum to obtain best impact resistance at subzero temperature.

Work has been initiated on controlled rolling of niobium bearing low carbon manganese-silicon steel along with optimum range of alloying elements essential to obtain lower-temperature transformed products.

### 2.2.27 *High Strength Alloys*

The Fe-Al-Si system is being investigated. The Fe-4% Al-1% Si and Fe-4% Al-2% Si alloys were forged and samples from these were aged between 300° and 500°C for periods up to 100 hours and in some cases up to 1000 hours. These samples are being studied for their microstructure and hardness.

### 2.2.28 *High Temperature Alloys*

To cover high temperature range the Fe-Cr-Al system alloy was modified by varying the composition and the addition of trace elements for grain refinement and scale resistance. Though the surface of cast alloy ingot was satisfactory even with comparatively coarser grains, some grain refinement was obtained with the addition of trace elements, but all ingots were brittle. Higher hardness was observed in ingots having some refined grains.

Work is in progress on the effect of addition of grain refiners on working behaviour of the alloys.

### 2.2.29 *High Strength High Temperature Materials*

The work was divided into two parts : (a) development of unidirectionally recrystallized lamellar pearlitic steel, and (b) development of dispersion strengthened alloys. Necessary set up was fabricated to obtain pearlitic lamellae oriented along longitudinal direction. Preliminary tests conducted with a procutectoid steel (0·5-0·6% C) wire indicated an increase of strength by 30%. Metallographic examination also indicated some orientation of lamellae. With improvements in the apparatus the yield strength rose by about 70% and UTS by 30%. Further improvement in the apparatus is under way to cover the temperature range, composition of alloy and improvement in strength by cold drawing the UDR treated steels.

For development of dispersion strengthened alloys by powder metallurgy or internal oxidation method, it is proposed to investigate Al-$Al_2O_3$ and iron or stainless steel base alloys using $Al_2O_3$, $ThO_2$ or MgO powders. Necessary processing equipments are under collection.

### 2.2.30 *Ausforming of Spring Steel*

Specimens of Si-Mn spring steel were ausformed between 400° and 450°C and 10 to 50% reduction was given. Hardness increased with increased reduction to the specimen and varied between 415 and 460 VPN.

### 2.2.31 *Studies on Mn-substitution Maraging Alloys*

Six maraging alloys containing 0·05 to 0·11% N, 5, 6 or 12% Ni, 5 or 12·5% Mn, 0 or 5% Mo, 0 or 9·6% Co, and 0 or 3·45% Ti were examined for their high temperature age hardening behaviour and mechanical properties. 12% Ni and 5% Mn with or without Mo were martensitic at room temperature and showed encouraging age hardening properties. 5% Ni and 12% Mn alloys were 40% austenitic and did not respond to any age hardening treatment but cold rolling resulted in an increase in martensitic content (90%), and improvement in physical properties. X-ray diffraction studies showed that maraging phases were $Ni_3Mo$ and $Fe_2Mo$ with Mo, and $Ni_3Ti$ and $Fe_2Ti$ with Ti.

### 2.2.32 *Stainless Steels*

**2.2.32.1** *Nickel-free steel* — In continuation of the work reported last year, investigations were carried out to improve the hot workability of Ni-free Cr-Mn-N stainless steel. A number of heats were cast into slabs, homogenized at 1050°C for different duration before rolling into flat bars and successfully rolled at 1000°C to 0·1″ thick sheets.

Another set of heats of Cr-Mn-N stainless steel with small additions of copper and nickel were cast at 1600°C into ingot moulds provided with hot tops, where critical and calculated amounts of nitrogen were necessary. Ageing studies at temperature range between 600° and 700°C showed non-magnetic properties without any increase in the hardness.

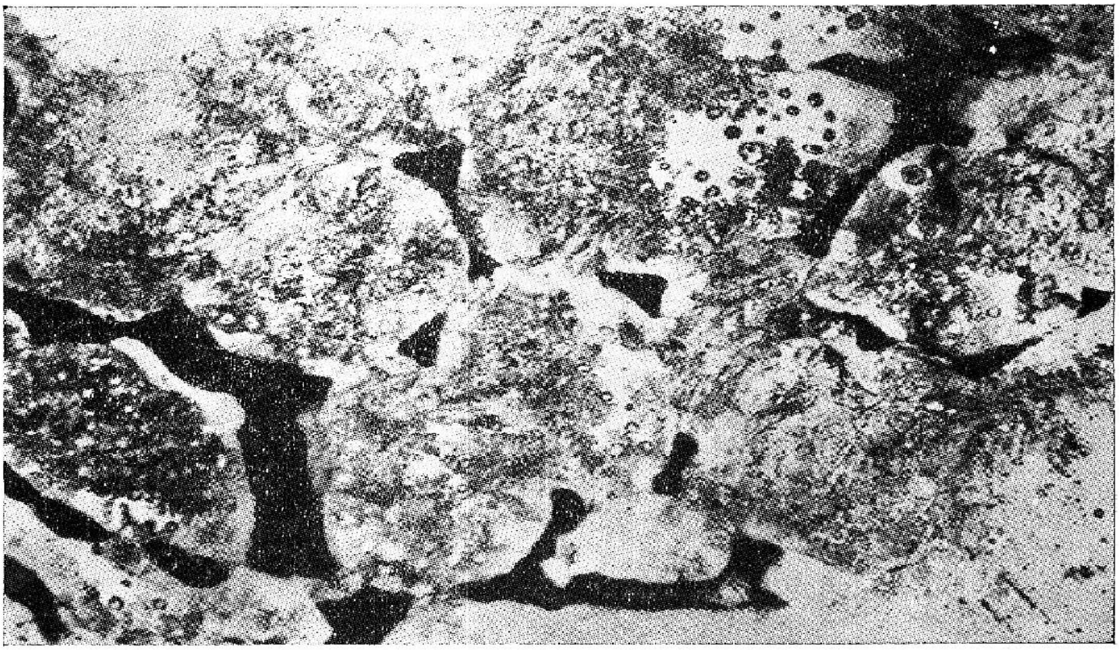
Castings of impeller blade made from Cr-Mn-N stainless steel (0·39% N) showed gas cavities at the centre of the sections.

**2.2.32.2** *Austenitic creep resisting steels* — Earlier work on Cr-Mn-N-C austenitic steels had shown that creep fracture originated from matrix/precipitate interface. Further work has been undertaken with a view to modify precipitate structure by suitable prior ageing treatment. Since creep properties are highly structure sensitive, it was considered that suitable alloying additions, viz. strong carbide or nitride forming elements such as Al, Ti and W together with proper heat treatment of the alloy would improve the properties considerably. Experiments on the effect of such additions to the basic Cr-Ni-N-C steel has shown significant improvement in resistance to grain coarsening, and solution treatment for four hours or longer is required to be done at high temperature. Further, these alloys show considerable age hardening and no signs of overageing even after 1000 hours at 750°C and that ageing at 750°C improved creep properties. Creep tests on alloys with Mo addition are under progress.

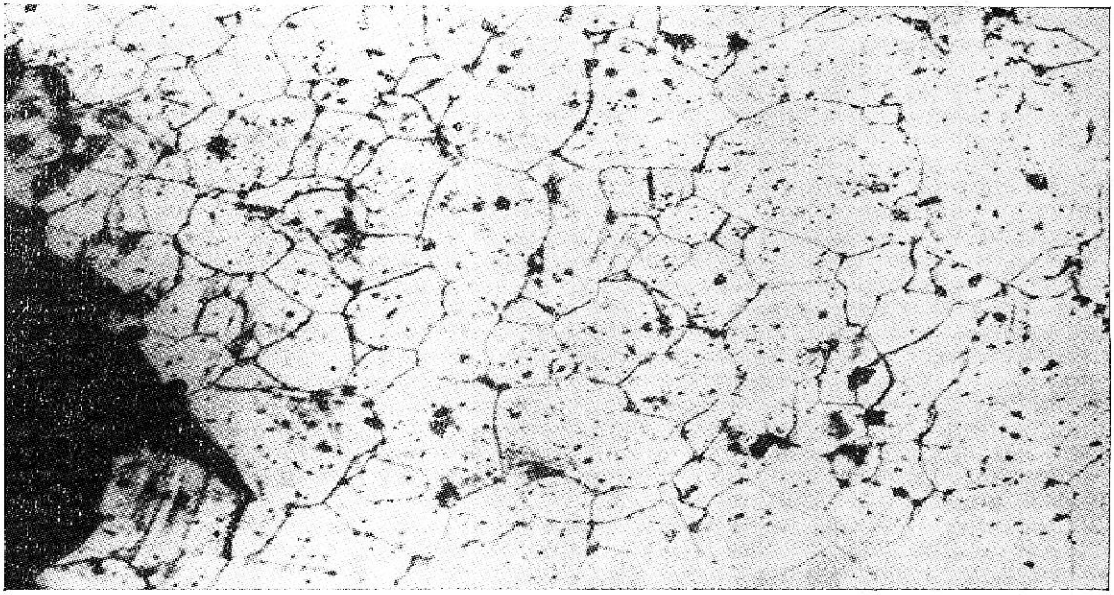
**2.2.32.3** *High chromium high manganese iron* — Preliminary studies of the properties of high chromium austenitic iron replacing nickel (15-17%) with manganese were carried out by making a number of heats containing 2-2·5% C, 2-2·5% Si, 12% Mn and 17·5-35% Cr. Test specimen were prepared from sand mould casting of 3/4″ bars. It was observed that about 12% Mn is sufficient to yield austenitic structure in the as cast iron with C, Si and Cr approximately as 2·3, 2·0 and 17·5 to 35% respectively. On normalizing, the massive carbide broke down to smaller sizes with precipitations of very fine pearlitic phase at a few isolated places in the metallic matrix. The hardness of as cast samples was between 300-375 BHN, but dropped by 30-70 points on normalizing. Expansion values were in the range 12 to $14 \times 10^{-6}$ inch per inch measured at 400, 600, 800 and 1000°C. These were comparable to those containing 15% Ni in place of Mn. Oxidation was neglibily low in Cr-Mn steel at 1000°C and in the order of 0·0005 to 0·001% but comparatively high, about 600 times greater than Cr-Ni steel. Further work is in progress to confirm the results.

**2.2.32.4** *Ferritic stainless steel* — Investigation has been carried out to determine the alloying effects of Al and Si as addition elements on the properties of non-transformable 17% chromium stainless steel containing molybdenum. Mechanical properties and corrosion resistant properties of six steel samples are being determined.

**2.2.32.5** *Stainless steels for safety razor blades* — The work was taken up to study the chemical composition and metallurgical characteristics of



Longitudinal section of the creep-ruptured specimen taken near the ruptured zone of alloy composition: C, 0·58; Cr, 18·23; Mn, 17·82; N, 0·30; Ti, 0·19; Al, 0·51; and Mo, 1·09 wt%, solution treated at 1250°C for 4 hr and air-cooled; tested at 700°C, 20 kg/mm², 42 hr



Longitudinal section of the creep-ruptured specimen taken away from the ruptured zone of alloy composition: C, 0·58; Cr, 19·26; Mn, 14·13; N, 0·52; and Mo, 2·02 wt%, solution treated at 1250°C for 4 hr and air cooled, tested at 700°C, 20 kg/mm², 42 hr steel used for available brands of razor blades and factors determining the quality. Simultaneously, work is being carried out to standardize the melting and working processes for a steel composition used for razor blade manufacturing.

**2.2.33** *Carburizing of Grain Refined Steels at Higher Temperature*

In order to obtain a hard surface backed by a tough core in engineering steel, which is dependant upon the composition, grain-size, carburizing temperature and heat treatment schedule employed. Six samples of steel with different compositions were carburized at temperatures 930°, 1000°, and 1050°C for 8 hr, $3\frac{1}{2}$ hr and $2\frac{1}{2}$ hr respectively and case-depth (apparent) and case hardness were determined.

**2.2.34** *Cryogenic Steel*

To develop an indigenous composition of cryogenic steel in place of 9% Ni steel universally used, low carbon steel compositions having 7 to 9% Mn, with Ti and Nb as grain refiners were investigated. As cast and forged hardness of 380 and 373 VPN respectively were obtained. Microstructure shows acciluar ferritic structure. Further work is in progress.

**2.2.35** *Application of Investment Casting for Making Milling Cutters*

To obtain good surface finish in milling cutter in investment casting, a series of experiments were conducted with proper blending of different waxes and its injection, precoating and investing, dewaxing and then casting. A wax injection unit was designed and fabricated for the purpose.

**2.2.36** *Development of Die and Tool Steels*

**2.2.36.1** *Die steels* — Dies of 0·04″ and 0·062″ dia. bore were made from PM 501 steel developed at NML and properly heat treated. Samples were sent to industrial die makers for commercial tests. Field trials have shown good performance.

Isothermal transformation characteristics of the steels were studied at different temperatures between 500° and 950°C. X-ray powder photographs of electrolytically extracted residues from the isothermally treated specimens were taken for phase identification. A set-up for studying the effect of liquid metal corrosion on this steel has been made. Further work is in progress.

**2.2.36.2** *High speed tool steels* — The development of cast cutting tools of 18-4-1 high speed steels has been carried out in two phases: (i) casting of tools in final shape, and (ii) heat treatment to achieve required properties.

18/4/1 high speed tool steel was cast into bars in moulds. The optimum austenitizing temperature was obtained at between 1150-1300°C and time between 2-10 minutes. The hardness obtained was higher than 800 VPN. A higher austenitizing temperature eutectic structure appeared.

**2.2.37** *Extrusion and Slip Casting of Non-plastic Refractory Materials*

Calcined alumina with a number of organic binders has been assessed for utility for extrusion purposes in a laboratory scale extruder operated through hydraulic compression testing machine. Arrangements were completed to produce artefacts of acceptable shapes and sizes for evaluation under actual service conditions.

**2.2.38** *Studies on Dense Carbon and Carbonaceous Materials*

Study of calcination characteristics of Indian petroleum cokes and physical properties of coaltar pitches has been completed. A pilot plant has been installed for production of dense carbon aggregate on the basis of the know-how developed. Soderberg paste and carbon refractories can also be produced in this pilot plant. An apparatus for testing the resistance to corrosion in aluminium-bath of carbon artefacts was developed and tested.

Packing densities of single, two and three component mixes of carbon particles were measured for collecting data for production of soderberg paste.

**2.2.39** *Development of High Alumina Cement from Indigenous Raw Materials*

**2.2.39.1** *Cement* — On the basis of extensive studies on the effect of certain oxides in the raw materials on the properties of calcium aluminate cements of the cement fondu type, semi pilot plant scale experiments were undertaken for production of these cements both by fusion as well as by sintering methods utilizing bauxite from Saurashtra and limestone from Tamilnadu. The initial melts obtained from fusion furnace had poor cementing properties. Further, the furnace lining of sillimanite was attacked severely and alumina lining was found most suitable.

Sintering studies indicated that the atmosphere and temperature in the sintering kiln have important effects on the behaviour of bauxite/limestone mixes. Further detailed study is in progress.

**2.2.39.2** *Ramming mixes* — Production of high alumina ramming mixes using natural raw material was achieved on a pilot-scale. The mix was supplied for the induction furnace of Indian Copper Corporation, Ghatsila, where the lining, drying, heating and commissioning of the furnace were undertaken by the NML scientists. The lining has given creditable account of trouble-free service. Formulation of ramming mix to serve under various sets of operating conditions against various enquiries is under investigation.

**2.2.40** *Studies on Clays and Bauxite from Jammu and Kashmir*

A large number of compositions using bauxite clays were formulated and standard size bricks were pressed, baked and tested for their physical and thermal characteristics. 85% grog (1500°C) and 15% clay showed appreciably good physical properties. Further work is in progress.

**2.2.41** *Hot-top Compositions and Exothermic Chemicals*

**2.2.41.1** A number of compositions were developed from agricultural wastes with suitable heat insulation properties and adequate stability when submerged in molten steel for hot-top purpose. Preliminary trials in an alloy steel works were successful. Data obtained are being used to scale up the production of hot top of the insulating type.

**2.2.41.2** The industrial exothermic mixture components were analysed and with the suggested ingredient in the compounds such exothermic compounds were developed. These were found suitable for steel plants.

**2.2.42** *Tar Bonded Dolomite*

Preliminary work was taken up to study the possibility of improving the performance of basic oxygen furnace converters after an on the spot study at a steel plant of their dolomite practice and wear pattern of dolomite linings in LD converters. Rourkela plant of Hindusthan Steel and Bokaro Steel Ltd have shown interest in the work.

**2.2.43** *Development of Submerged Arc Welding Fluxes*

A submerged arc welding unit was installed to facilitate the testing of the fluxes developed at the Laboratory and those made by licensees, in actual operating conditions. A number of high manganese fused-flux compositions have been tested. Development work is under way for basic fluxes also.

### 2.2.44 *Metallurgical Slags*

Liquidus and crystallization characteristics along with essential properties of Indian Blast Furnace slags were determined using hot stage microscope and classical quench method. 32 compositions of 24-26% alumina with $CaO/SiO_2$ ratio between 0·10 and 1·30 were prepared and tested.

### 2.2.45 *Study of Indigenous Foundry Moulding Materials*

The moulding characteristics of Indian Foundry sands, bentonites, bonding clays and other binding materials, viz. dextrine, resins, etc., and their suitability for various types of castings have been under study. The effect of heat on the bonding properties of some indigenous bentonites was also studied by the DTA method.

### 2.2.46 *Recovery of Metallic Values from Wastes*

**2.2.46.1** *From drosses, wastes and fines* — The agglomerating technique was successfully developed and patented particularly with zinc drosses. Process is now available for commercial exploitation.

**2.2.46.2** *From scrap by filtration* — The laboratory scale experiments were continued on the recovery of metals from (i) Zn dross containing about 95% Zn, (ii) dross containing about 92% Al, and (iii) from Al-1% Fe alloys. The feasibility of scaling up the work to semi-industrial scale is being examined.

### 2.2.47 *Utilization of Electrical Furnace Gases*

For utilization of hot gases generated during smelting in electrical furnace either for pre-reduction or pre-heating of burden material, a small unit is under fabrication along with gas utilization ancillaries.

### 2.2.48 *Effect of Alternating Current on Corrossion of Metals*

Studies carried out to determine the effects of ac on corrosion of mild steel at various frequencies and current densities in view of increasing use of ground return circuits for distribution of electrical power. It was observed that at higher current density dissolution rate increased and with higher frequency corrosion rate decreased. The effect on other metals particularly aluminium is being continued.

**2.2.49** *Testing of Various Inorganic Coatings on Steel Exposed to Industrial Atmosphere at Jamshedpur and Digha*

To conduct atmospheric corrosion at different exposure sites in India, panel of steel samples, painted and unpainted, have been exposed initially at Jamshedpur and Digha, since December 1969 with periodical observations.

**2.2.50** *Plastic Coatings on Metals for Corrosion Protection and Metal Finishing*

Organosol coatings on metals have been assessed for blister resistance and thermal stability. For evaluation of marine and atmospheric corrosion properties of the prepared organosol composition, panels were exposed at NML and at Digha since Nov. 1970. For thermal stabilization various non-ionic stabilizers have been tested. Primer compositions based upon phenolformaldehyde with nitrile rubber and epoxy, acryloid and epoxy were developed and their performance is under investigation.

**2.2.51** *Integral Colour Anodizing of Al and Al Base Alloys*

Integral colour anodizing was studied for obtaining integrally coloured anodic coatings on the surfaces of Al and some Al base alloys during anodizing process in different organic baths, so that separate colouring of anodized products could be eliminated. It was possible to obtain faint bluish, pinkish, greenish and yellowish colours from a single bath on commercial Al. Further work is in progress.

**2.2.52** *Standard Samples*

Preparation of standard samples and analytical work with respect to plain carbon steels 0·2 and 0·4% C and alloy steels have been nearly completed. Certificates from outside testing centres are under progress.

Preliminary work to prepare ferro-manganese and fluorspar standard samples has been continued.

**2.2.53** *Analysis of Metals, Alloys, Minerals, etc.*

**2.2.53.1** *Chemical analysis* — During the year 2866 samples with 9066 radicals were chemically analysed for different divisions and in connection with the investigations sponsored by outside parties.

**2.2.53.2** *Spectrographic analysis* — Thirty two samples were analysed for ninety-two radicals quantitatively and two hundred two samples were qualitatively analysed during the period. Non-availability of suitable photographic plates has remained a big bottle-neck.

**2.2.53.3** *Petrological and microscopic studies* — Petrological study and microscopic examinations of 28 ores and minerals were conducted. X-ray fluorescence analysis of 550 samples with 600 radicals were also performed.

**2.2.53.4** *Differential thermal analysis* — After replacing the defective component 3 samples were analysed for confirmation of mineral phases in ores and others.

**2.2.53.5** *Gases in metals* — Two hundred samples of metals and alloys were analysed for gases. Besides 60 samples of gas were analysed for their composition.

## 2.3 Applied Basic Research Projects

### 2.3.1 *Structure of Liquid Metals*

**2.3.1.1** *Cadmium-antimony system* — In continuation of the earlier work on the structure of Cd-Sb alloys it has been observed that even though $Cd_{40}Sb_{30}$ clusters were present in the liquid state, the metastable $Cd_4Sb_3$ intermetallic compound was not detected in the solid state. Crystallization of the melt into metastable $Cd_3Sb_2$ occurred at relatively slower rates of cooling, subsequenly changing to stable CdSb even at room temperature.

**2.3.1.2** *Aluminium-silicon system* — Investigations on the structure of five liquid Al-Si alloys containing 1-14% silicon were continued using the technique of centrifuging liquid metals, The results of chemical analyses at different points were statistically evaluated for concentration gradient, correlation co-efficient and for confidence ranges of the results. These results are now being examined to plan further work on the Al-Si system.

**2.3.1.3** *Cadmium-zinc system* — Six binary alloys containing 10-90% zinc were prepared and centrifuged in liquid state for four different periods of time (15 min. to 4 hours) at three temperatures (300-530°C). The centrifuged samples were quenched *in situ* and metallographic examination of the ingots showed a concentration gradient. For confirmation and corroboration of these results, by methods other than chemical analysis, techniques such as back-scattering with radio-isotopes and X-ray fluorescence are under development.

### 2.3.2 *Thermodynamic Properties of Liquid Metals and Alloys*

**2.3.2.1** *Lead-antimony system* — Structural investigation of liquid metal, using high temperature centrifuging technique, conclusively established the existence of clusters and incipient instability immediately above the inflexion region in the liquids. It was established that incipient immiscibility does not exist above the liquidus temperature for the entire composition range of liquid Pb-Sb system. The present work was undertaken to seek thermodynamic confirmation of the existence of incipient immiscibility between 400° and 500°C by employing e.m.f. cell method. The activities calculated from e.m.f. values indicated positive deviation of Raoult's law in liquid solution. Further work is in progress to confirm the observations in the critical composition ranges.

**2.3.2.2** *Second order transformation in liquid metals and alloys; DTA study* — The variation of specific heat with increasing temperature of liquid metals and alloys, which exhibit one or more lambda transistions, was studied using the DTA technique; ferritic stainless steel was used as the reference material. From the DTA curves of heating and cooling cycles of liquid tin, liquid lead and four liquid lead-antimony alloys containing 6-35% Sb, it was observed that (a) lead does not exhibit any transformation in liquid state; (b) liquid tin shows the existence of transformations spread over a range of temperatures; (c) all the lead-antimony alloys, except one with 20% antimony, showed clear discontinuities. The lead —20% Sb alloy did not show any structural change. These results confirmed the earlier findings that second order transformations may occur in certain metals and alloys with associated structural changes in the liquid state.

**2.3.2.3** *Liquid metals and solidification* — The annealing characteristics of rapidly cast aluminium-4 to 33% copper thinfilms in vacuum between 110° and 450°C for 30 min. to 4 hours were studied. Investigation of the changes in microstructure, microhardness and lattice parameters showed that at rapid solidification rates the lattice of Al can accommodate Cu atoms in excess of normal equilibrium concentration. On annealing, the excess Cu atoms diffused out of Al lattice, thereby increasing the lattice parameter, till equilibrium alpha solid solution values were attained. This was confirmed in alloys containing 12, 19 and 33 wt% Cu. The deviation of lattice parameter from that of pure Al may be due to spinodal mechanism of decomposition of supersaturated solid solution in Al with 3·9 and 7·5 wt% Cu. Metallographic studies of the thin films showed dendritic and predendritic regions, the latter being formed due to rapid solidification. The solidification rate, calculated from dendritic arm spacing measurements, was of the order of $10^4$ deg. C/min.

**2.3.2.4** *Metallographic study of the solidification of Al-Cu alloys* — The details of the cast morphology and phase distribution in Al-Cu alloys were studied by a modified anodic oxidation technique. The following observations were made:

(i) The dendritic cells are clearly revealed which increase with copper content up to solid solubility and decrease thereafter. Further, the cell size is independent of grain size, and the cell boundaries are eliminated on prolonged annealing at 500°C.

(ii) The individual particles of phase are nucleated along the dendritic cell boundaries and later, depending upon its amount, impinge with one another, giving rise to a continuous phase film.

(iii) The coring phenomenon was observed in primary solid solution and the phase.

(iv) Cold work and recrystallization are necessary to destroy the cast structure completely.

Further work is in progress with alloys made of super-pure metals.

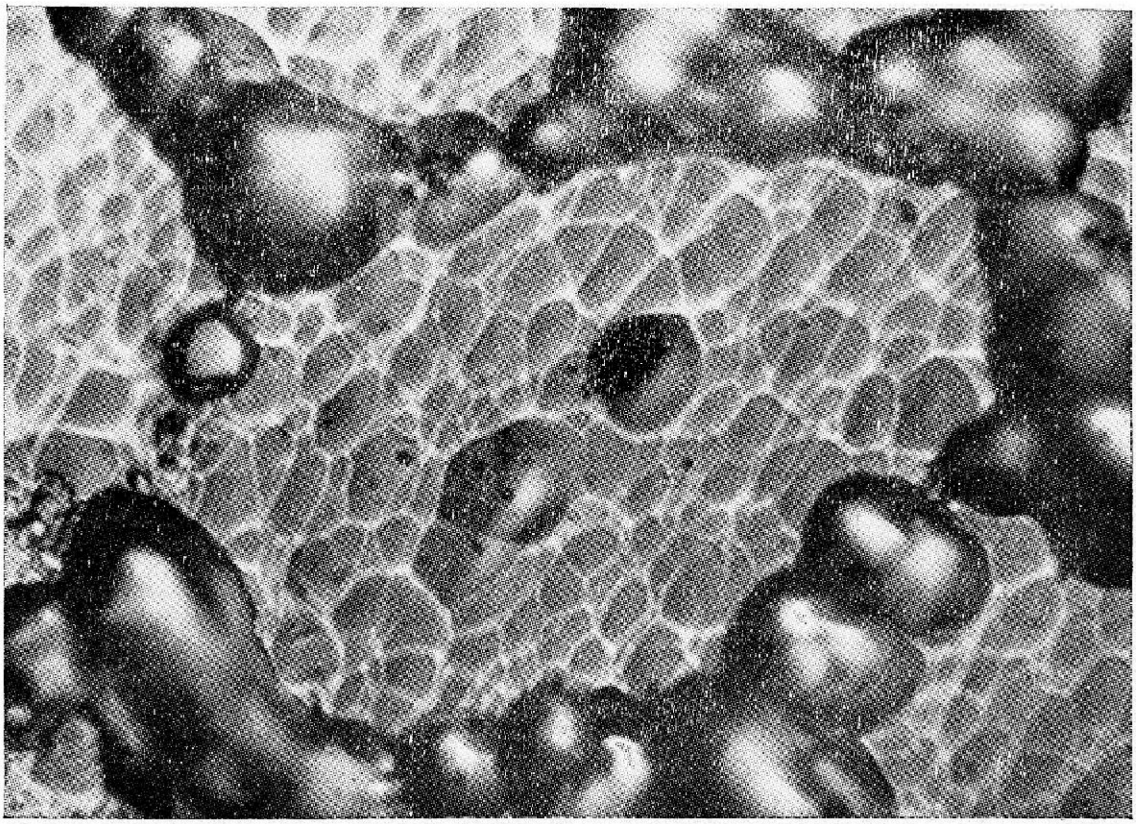
**2.3.3** *Co-efficient of Thermal Expansion of Metals and Alloys*

The relationship between magnetic coupling and coefficient of expansion of Al-Mn alloys, 2-8% Mn, was studied by measuring these properties between room temperature and 400°C.

The work has also been extended to low melting alloys of lead-tin and lead-cadmium systems at temperatures between room temperature and 125°C. It was observed that the coefficient of expansion of those alloys was proportional to the volume per cent of the phase present. Further work is in progress.

**2.3.4** *Preferred Orientation in Extruded Rods*

The variation of texture was studied by X-ray diffraction, from the surface to the centre of the middle and rear portions of the duralmin and commercially pure aluminium rods extruded at 360°C with exit speed of 60 ft/min.



Photomicrograph of Al-7% Cu, using anodic oxidation technique

### 2.3.5 *Grain Size Control of Non-ferrous Metals and Alloys*

In continuation of the work carried out last year on the development of PM-120 inoculant for grain refinement of Al alloys, a large-scale (30 kg) batch of the inoculant was prepared in the form of pellets and tried on industrial scale heats. The inoculant showed high efficiency in industrial scale operations.

### 2.3.6 *Curie Temperature of Cobalt Alloys*

The experimental set-up for measuring curie temperature of cobalt alloys in inert atmosphere has been modified. Parts of the new set-up are being fabricated, including cleaner cobalt melts for use as support rods.

### 2.3.7 *Universal Bath for Electropolishing of Al and Al Alloys*

The polishing conditions for Al and different compositions of Al-base alloys, in the universal electrolyte consisting of absolute alcohol, butylcellosolve and perchloric acid, were studied with respect to bath temperature, current density and voltage.

### 2.3.8 *Electrodeposition of Composite Materials*

Electrodeposition of nickel-alumina composites with 3·8% alumina from a modified Watts bath containing alumina have been investigated. The physical and mechanical properties are found superior to those of pure nickel deposits.

### 2.3.9 *Kinetics of Malleablization*

In continuation of the work reported last year the study of malleablization characteristics of pig iron have been continued by the additions of different percentages of elements such as Mn, Cu, Al and B either singly or in combination.

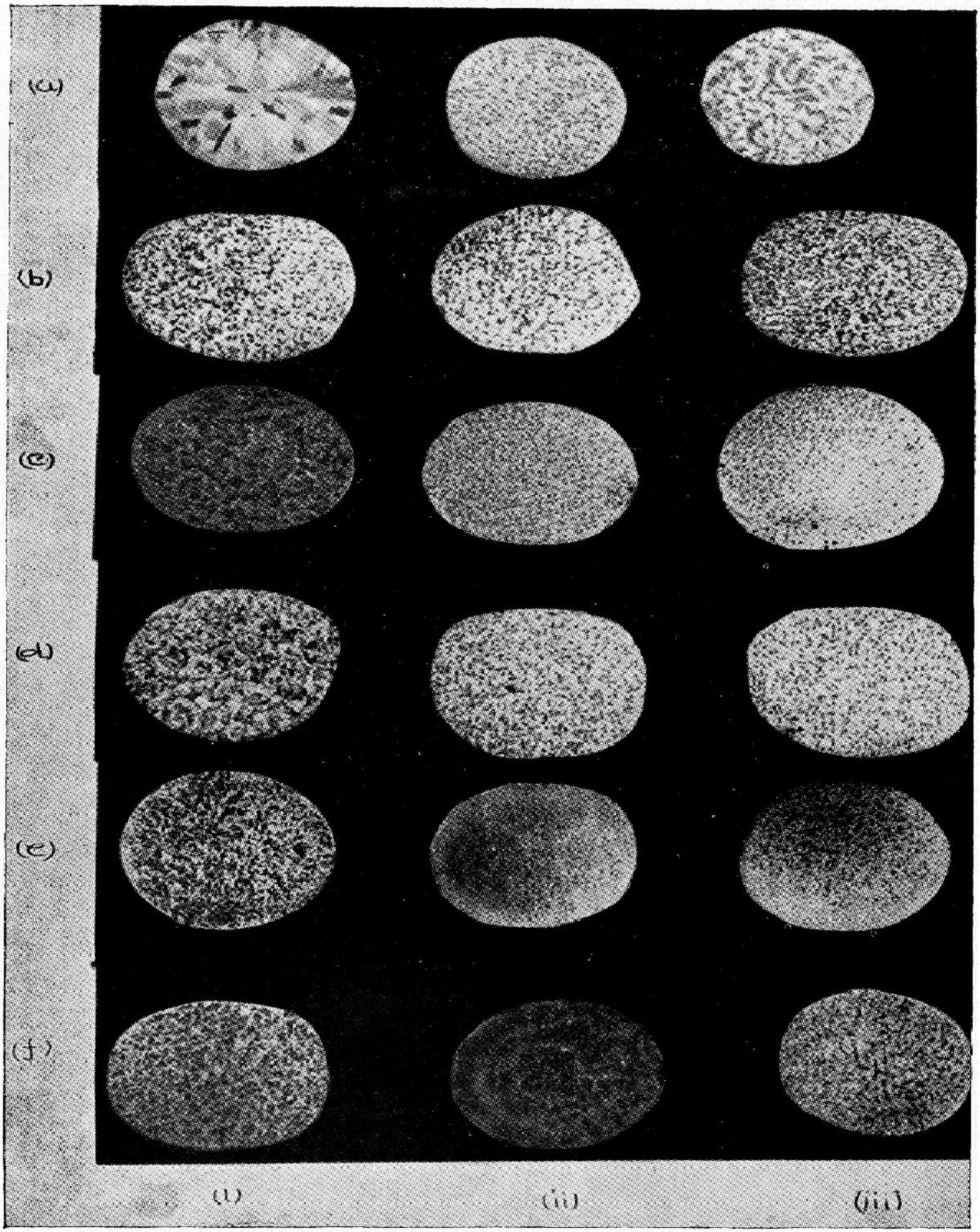
### 2.3.10 *Thermal Conductivity of Iron Ores*

Thermal conductivity of Bailadila iron ores was determined at temperatures between 50° and 350°C. The values varied between 0·11 and 0·12 Cal cm/cm$^2$/sec/°C.

### 2.3.11 *Study of the Reduction Mechanism of Iron Oxides by Solid Carbon and Carbon Monoxide*

The following inferences have been deduced from the study:

(i) Reduction of iron oxide progresses simultaneously with the increase in $CO/CO_2$ ratio.




Macrophotographs of (a) Al, (b) LM-3, (c) LM-5, (d) LM-7, (e) LM-11, and (f) LM-14 alloys under the following conditions: (i) without inoculant, (ii) inoculated with PM-120, and (iii) inoculated with commercially available inoculant

(ii) Rate of indirect reduction decreases with increase in the reduction percentage of iron oxide while the rate of direct reduction remains almost constant.

(iii) Removal of oxygen from iron oxide by direct reduction depends solely on the percentage reduction at any stage and not on the ore/carbon ratio.

(iv) The total reduction increased due to direct reduction of iron oxide by CO and reaction of carbon with unreduced iron oxide.

**2.3.12** *Influence of Associated Ingredients on the Mechanism of Gaseous Reduction of Hematite*

A comprehensive investigation has been carried out to elucidate the effect of associated ingredients on the reduction kinetics of hematite. Briquettes prepared from chemically pure hematite with variable amounts of calcium carbonate at a pressure of 100 $kg/cm^2$, sintered and reduced between temperatures 600° and 900°C in purified hydrogen atmosphere. Progressive loss in weight was recorded in a thermogravimetric balance and it was found that higher porosity in the briquettes due to calcium carbonate accelerated the reduction rate.

The fractional reduction as a function of time was obtained for different samples from the extrapolated reduction data. The reaction rate constant and intraparticle diffusivity were deduced by means of a graphical analysis. From an average value it was concluded that the overall reaction rate was controlled by chemical step.

**2.3.13** *Macro and Microporosity of Some Indian Iron Ores*

The experiments were repeated using hydrogen absorption method to assess the macro and microporosity of some iron ores and it was found that the values were representative for determining available surface area.

**2.3.14** *Effect of SiC Formation in Submerged Arc Furnace*

Effect of formation of silicon carbide on electrical conductivity of submerged arc electric furnace charge has been initiated.

**2.3.15** *Electrical Conductivity of Submerged Arc Furnace Burden Materials*

Systematic study is being started to determine the electrical conductivity of wide range of submerged arc furnace burden mixes, using an apparatus developed for the purpose.

### 2.3.16 *Investigation into the Mould Wall Movement of Nodular Cast Iron*

Mould wall movement of nodular cast iron in green sand moulds has been investigated using various indigenous sodium base, calcium base and chemically treated clays for making moulds using constant method of mould compaction. Less mould wall movement occurred in moulds made with sodium base bentonite than in those with calcium base bentonite. Most stable moulds could be mades using chemically treated clays.

### 2.3.17 *Microstructure of Basic Bricks and Related Physical and Mechanical Properties*

Determination of the specific gravity, porosity and bulk density of 25 specimens was carried out. Spalling resistance was also determined on prepared specimens. 30 micrographs were taken of different specimens to study the microstructure and mineral constituents. Investigations on the other physical properties of basic bricks used in steel plants are in progress.

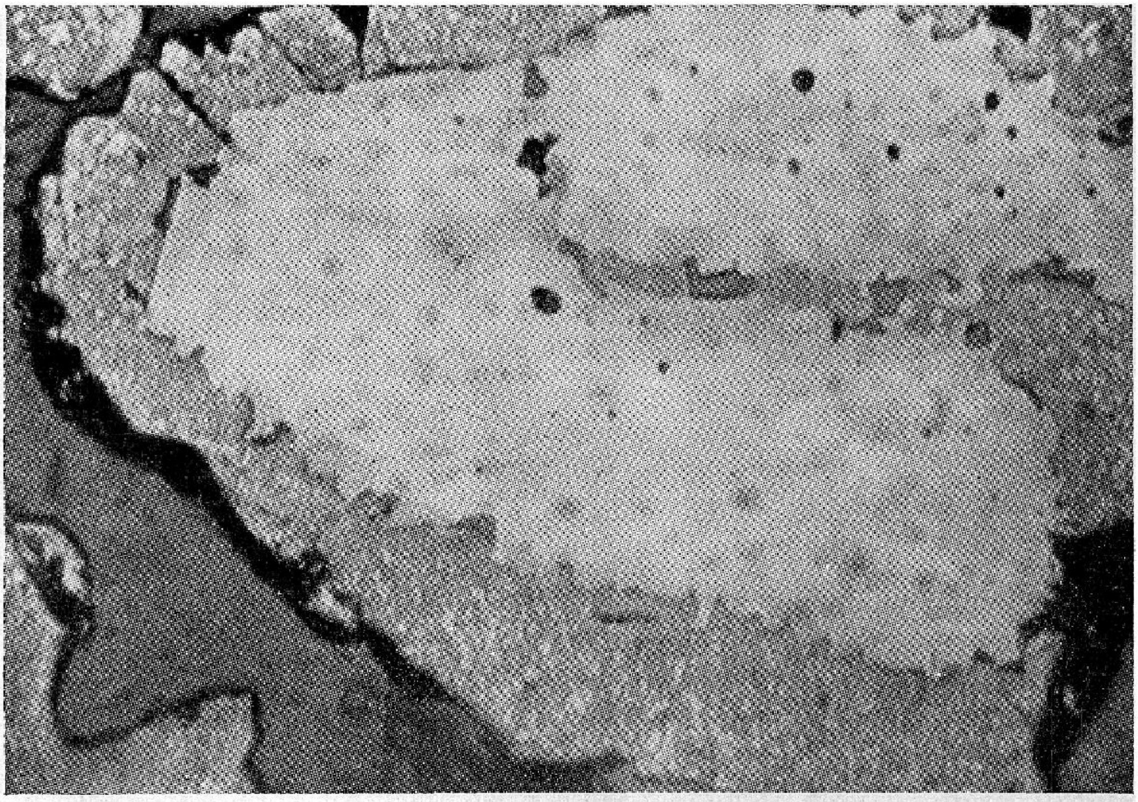
### 2.3.18 *High Alumina Slag*

**2.3.18.1** *Sulphur capacity* — Various slag characteristics including the sulphurization power of high alumina slag obtained in the Indian Blast Furnaces have been studied. A synthetic slag was melted in graphite crucible in a medium frequency furnace and equilibrated with previously prepared pig iron containing 1% S and radioactive $FeS^{35}$. The sulphur content was estimated after different time periods. Equilibrium was found to be attained after 1 hour. Further work with slags of different compositions in an atmosphere of carbon monoxide, carbon dioxide and nitrogen has been initiated.

**2.3.18.2** *Surface tension and fusion temperature* — Sessile drop does not form on platinum surface thereby surface tension from the shape of the drop could not be directly evaluated. Though the fusion temperature of slag could be recorded in hot stage microscope by observing the changes in the state of solid compacts, the technique could not give reliable data as the slag wetted the platinum surface. Relative methods are being developed for an approximate idea of surface tension and its variation with composition or temperature.

### 2.3.19 *Evaluation of Inhibitor Efficiency and Hydrogen Pick up by Steel during Pickling*

Isobutyl, S-butyl, T-octylmercaptans and 2-marcaptobenzothiazole preferentially inhibited cathodic reaction more than the anodic reaction



Photomicrograph of chrome-magnesite bricks showing direct bond when used in normal $H_2SO_4$ for pickling. With quinoline and acriflavine as inhibitors increase in temperature resulted in increased corrosion rate whereas with acridine the corrosion rate decreased. No change of $H_2$ content was observed with quinoline. These compounds inhibited both anodic and cathodic reactions.

**2.3.20** *Studies on Stress-corrosion Characteristics of Al-Mg Alloys*

Sheet specimens were tested in a spring loaded stress corrosion testing machine fabricated at NML. Specimens of Al-Mg-Misch metal alloy developed at NML were found to be highly stress-corrosion resistant.

**2.3.21** *Stress Corrosion Cracking of Copper Alloys*

A number of binary and ternary Cu alloys as wires and sheets have been used to standardize the technique of measuring the cracking susceptibility and change in electrical resistance during cracking at different temperatures.

**2.3.22** *Modified Analytical Procedures*

**2.3.22.1** A rapid spectrophotometric routine method for determination of vanadium in alloy steel has been developed and established in which chromium, iron and molybdenum do not interfere at 460 $\mu$u. In presence of tungsten, correction for chromium becomes necessary.

**2.3.22.2** A spectrophotometric method has been developed for the estimation of molybdenum, tungsten and silicon in molybdenite, wolframite and aluminium alloys.

**2.3,22.3** Spectrographic analytical methods for (i) aluminium and aluminium alloys using synthetic standards, (ii) low alloy steel, and (iii) magnesium in nodular cast iron by solution technique have been developed and established.

# 3. PILOT PLANTS ACTIVITIES

## 3.1 Low Shaft Furnace Operation

In order to study the conditions for continuous smooth working of the thiessen disintegrator and to attain maximum production at each tuyere with consistency in metal composition, the furnace was blown in with nut coke as fuel, Orissa mineral iron ore, Satna limestone and Assam dolomite. The thiessen disintegrator was found to work smoothly under the conditions of experiments. However, maximum production at each tuyere could not be attained due to shorter period of furnace operation. The consistency in metal composition was disturbed when nut coke was either partly or fully replaced by Kolsit.

## 3.2 Experimental Blast Furnace

Experiments, using Orissa mineral iron ore, Madras limestone and pearl coke, indicated that reduction was not satisfactory due to hanging and hence the smelting operation could not be continued for more than 6 hours. Arrangements for recording the temperatures at different heights, top gas pressure and quantity of air have been made and further trials are contemplated with the modifications.

## 3.3 Production of Prereduced Iron Ore Pellets

After standardizing the different parameters of reduction of heat hardened or green iron ore pellets with non-metallurgical coal, pilot plant trials were conducted in a rotary kiln.

Mixtures of sized iron ore and non-metallurgical coal in the form of pellets were charged in the rotary kiln at a rate of 200-300 kg per hour. Over 85% reduction of the iron ore pellets was obtained. Special arrangements were made near the kiln discharge to avoid reoxidation of reduced material and to cool it.

## 3.4 Beneficiation Studies with Pyrite-Pyrrhotite Samples from Saladipura, Rajasthan

On the bais of bench scale studies to produce a fertilizer grade concentrate, straight flotation as well as gravity separation followed by flotation yielded a concentrate of 41·5% S, in continuous pilot plant tests. Total S recovery in the concentrate is 95%.

## 3.5 Studies with Graphite Samples from Palamau, Bihar

Based on batch scale, pilot scale beneficiation studies of the graphite samples were carried in pneumatic cell which compared favourably with Denver cells. The sample was graphite schist and 20-60 cm blocks were mixed with 7 cm lumps and fines in suitable proportion. Rougher concentrate, regrinded to 200 mesh followed by cleaning, produced a graphite concentrate of 77·72% of F.C. and 11·17% ash from original mixed samples containing 16·58% F.C. and 75·1% ash with F.C. recovery of 70·6%.

## 3.6 Preparation of Fluorine Chemicals

### 3.6.1 *Synthetic Cryolite Preparation*

The material balance and standardization of the process was carried out up to 14th cycle with steady yield.

### 3.6.2 *Large Scale Trials on Cryolite Process*

The agitators, reactor vessel, centrifuge, rotary vacuum filter, storage vessel along with pumps have been installed with electrical fittings. Pipeline work is under progress.

## 3.7 Manganese Pilot Plant

The pilot plant campaigns were successfully organized to collect operational data on reduction, leaching, purification and electrolysis with various types of ores and about 1·9 tonne of the metal were collected, out of which more than one tonne of the metal was despatched to various organizations.

## 3.8 Calcium Metal, Semi-pilot Scale

After successful working on bench scale extraction of calcium, semi-pilot scale production compaign has been initiated.

### 3.9 Studies on Nickel Extraction (Sukinda)

Pilot scale proposal for extraction of nickel at the instance of the sponsor was drawn up, after successfully completing the Ni extraction from lateritic nickel bearing ores.

## 3.10 Use of LTC Katkona Coke in High Carbon Fe-Mn Production

The large scale trials in a 500 kVA submerged arc furnace were successfully conducted replacing metallurgical coke, in the production of ferro-manganese.

### 3.11 High Alumina Cement

Production of high alumina cement and calcined kyanite in tonnage lots is being carried out for use in construction of carbon pilot plant.

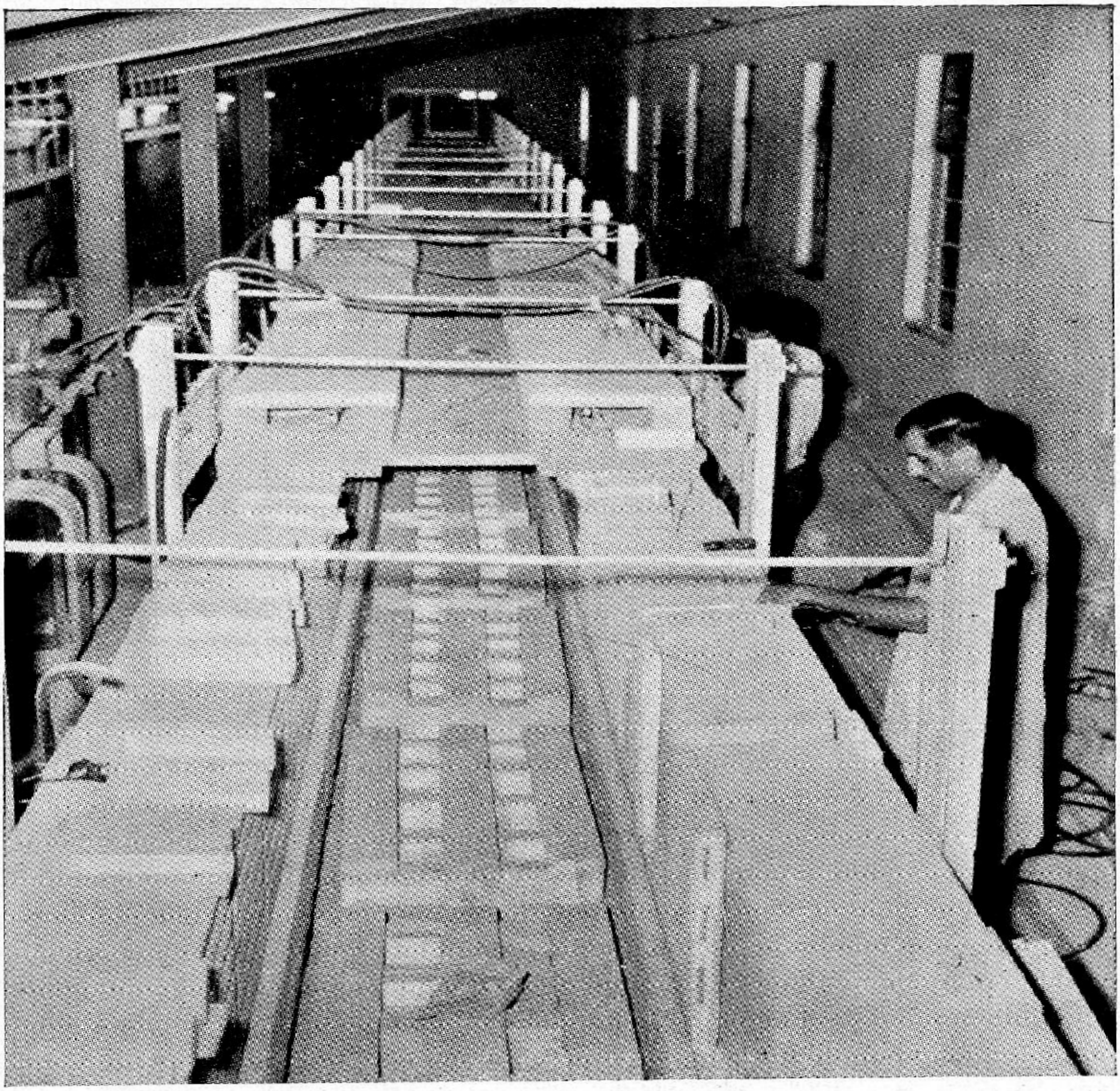
Castables developed for roof of reheating furnace in a public sector steel plant were found quite suitable. The cement produced has been used for substituting the same obtained from Russia in another public sector steel plant. Cement and other refractory materials consumed for fabrication of electrical resistance furnace were also supplied in various schemes in the laboratory.

### 3.12 Hot-dip Aluminizing

Modifications were made in the aluminizing plant for improving continuous aluminizing of 101 mm wide 0·46 mm thick mild steel strip by incorporating (i) asbestos pad and graphite block as wiper, (ii) blowing of gas on the surface of the bath near the exit end of the strip and (iii) use of molten salt at the exit end. Aluminized strips were cold rolled to give better finish. Tensile and cupping tests of the aluminized strips were carried out. The thickness of coating, total coating weight and alloy layer coating weight were also determined.

### 3.13 Dense Carbon Pilot Plant

The dense carbon aggregate pilot plant has been almost ready for commissioning. The plant was fully designed by NML Scientists and a very large part of fabrication including tunnel kiln (temperature 1350°C) has been undertaken by NML Staff. The carbon aggregate will substitute the imported low ash metallurgical coke and be used for soderberg paste and carbon refractories, using Indian petroleum coke as raw material.



A tunnel for Dense Carbon Aggregates Pilot Plant (nearing completion)

# 4. SPECIAL PROJECTS

## 4.1 Setting up of Central Creep Testing Facilities at NML

The proposal to set up creep testing facilities was approved by CSIR and Govt. of India with special funds from UNIDO Council. The detailed plan of operation was also finalized with UNDP and UNIDO. Suitable action with respect to building and staff was taken up.

## 4.2 Standard Samples (PL-480 Project)

The project was sponsored with National Bureau of Standards, Washington, for preparing ferro-alloy standard samples with PL-480 funds.

### 4.2.1 *High Carbon Ferro-manganese*

The samples −60, +100 mesh, obtained after crushing in batches, are under analytical tests.

### 4.2.2 *Low Carbon Ferro-manganese*

The materials are much harder than high carbon grade and the fines resulting during grinding are pyroferric in nature. As such small quantities could only be processed at a time. Chemical analyses of different sieve fractions have been continued.

### 4.2.3 *Ferro-titanium*

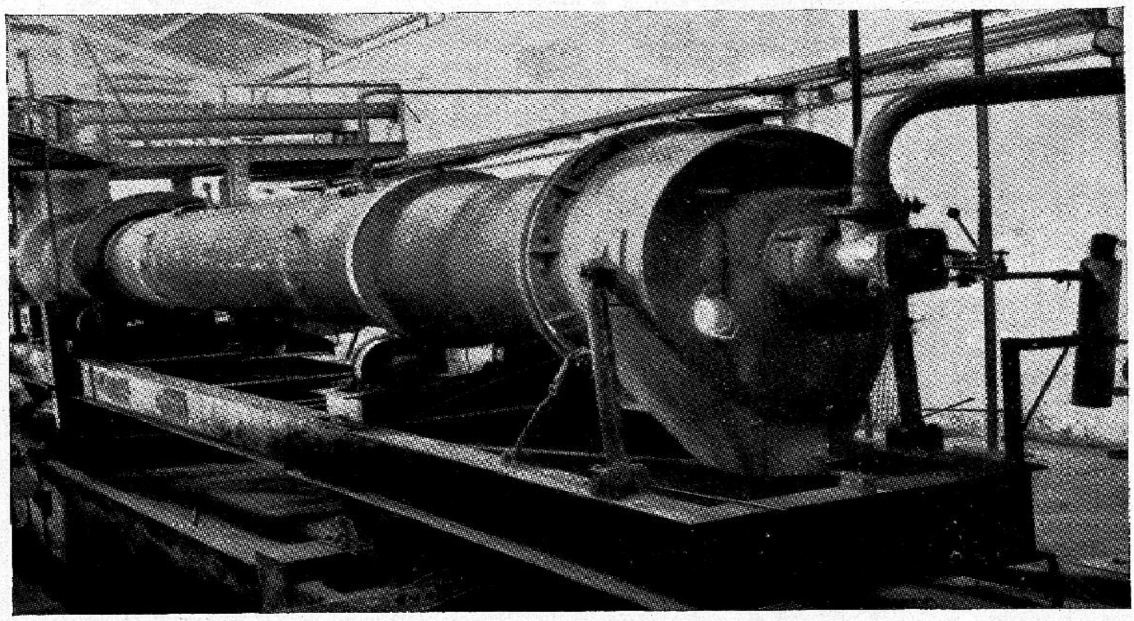
The samples collected at the first instance were not within specification. Samples with exact composition range are under collection.

## 4.3 Sponge Iron

Campaigns were conducted for production of sponge iron by rotary kiln and vertical shaft furnace utilizing non-metallurgical fuels:

**4.3.1** Sized Dalli-Rajhara iron ores, assaying 65% Fe, mixed with Singarani coal were charged in a rotary kiln, with special water seal arrangement near the discharge end of the kiln, at a rate of 200-300 kg per hour maintaining a temperature around 1100°C. Sponge iron produced indicated a reduction of the iron ore to the extent of 85-90%.

**4.3.2** Initial campaigns were conducted with iron ore (Orissa minerals) and solid fuels, viz. non-coking coals from Wardha valley or from Singarani colliery and charcoal in a specially designed 22 cm dia and 115·5 cm long, vertical externally heated reactor with screw conveyor at the bottom to withdraw the products for assessing the functional characteristics of the shaft furnace. The reaction zone was 30 cm. Ring formation was observed above the reaction zone at different levels. The constitution of the ring was under study by petrographic, metallographic and X-ray diffraction methods. The use of non-coking coal and charcoal for degree of metallization, reducibility, temperature and time are under investigation.



Rotary kiln used for tonnage production of sponge iron

# 5. ENGINEERING ACTIVITIES AND FACILITIES

## 5.1 Design and Mechanical Engineering

### 5.1.1 *Research and Development*

**5.1.1.1** The feasibility report prepared for

(a) Electrolytic manganese metal production sponsored by Manganese Ore (I) Ltd.

(b) Electrolytic iron powder

(c) Electrolytic copper powder

(d) Ferro-vanadium prototype production unit

**5.1.2** The pilot plant detailed proposal for

(a) Sukinda Nickel

(b) Surabil-Sukerangi Nickel

**5.1.3** The process design evolved for

(a) Packaged type flotation mill for graphite beneficiation

(b) Sponge iron rotary kiln and related ancillary plant

### 5.1.4 *Development*

(a) Development and fabrication of prototype units and instruments required for metal powders

(b) Commissioning of equipments for strip aluminizing plant

### 5.1.5 *Miscellaneous Facilities*

Adequate service rendered through machine shop, fabrication shop and pattern shops. Numerous tracing and printing were made for various research/development projects.

## 5.2 Electrical

### 5.2.1 *Development*

**5.2.1.1** To study the temperature profile, i.e. isothermal zone at various temperatures up to 1000°C and other characteristics of control, one console of resistance is under development for creep testing of steel and alloys at high temperature.

**5.2.1.2** Various items for electroslag refining equipment have been finalized for procurement.

### 5.2.2 *Installations*

Electrical installations and commissioning of several equipments, power distribution systems were executed at (i) Dense carbon aggregate pilot plant, (ii) Cryolite pilot plant, and (iii) Strip aluminizing pilot plant.

### 5.2.3 *Design and Fabrication*

300 kW electric tunnel kiln and its heating element support, Tie line (for transfer of power from pilot plant sub-station to technical block sub-station), several high temperature resistance furnaces along with internally wound open element furnaces and extra high voltage transformer for electronic equipments have been designed, fabricated and installed for operation.

### 5.2.4 *Repairs and Preventive Maintenance Facilities*

A number of major break down of specialized electrical equipments were attended and rectified. Repairs of several general electrical installations were also carried out.

## 5.3 Electronics

### 5.3.1 *Development*

**5.3.1.1** A saturable core reactor was designed and fabricated for use in high current electronic potentiostat.

**5.3.1.2** Some of the imported components of precision temperature controller were substituted and satisfactory performance obtained.

**5.3.1.3** Suitable dc amplifier (solid state) for amplifying the photo-electric current from photo resistors has been designed and is under fabrication.

### 5.3.2 *Maintenance*

Following are the major maintenance, testing and calibration work, carried out:

(i) Repair and modification of electron microscope

(ii) Repair of Derivatograph

(iii) Repair and modification of DTA apparatus

(iv) Repair of Magna potentiostat

(v) Servicing and modification of Philips X-ray diffractometer

(vi) Repair of Zeiss spectrophotometer

(vii) Calibration of RFT frequency meter

(viii) Instrumentation of Dense carbon pilot plant

(ix) Maintenance of MBPP and FPTD instruments

## 5.4 Civil Engineering Service

Various civil engineering jobs relating to maintenance of water, gas and air to the Laboratory and pilot plants, erection of plants, equipments and building of Dense carbon plant and Cryolite plant, etc., and extension of buildings, etc., were conducted during the period under review.

## 5.5 Glass Blowing Facilities

Twenty-five special and complicated glass and silica equipments and parts required for research activities were fabricated along with 700 other glass blowing jobs completed during the year.

# 6. PUBLICATIONS

## 6.1 NML Technical Journal

NML Technical Journal has maintained its tradition of publication of the latest technological developments at NML and outside in various metallurgical disciplines and is highly appreciated by scientists, technologists and industrialists at home and abroad. Exchange agreements with 60 Indian and 66 foreign publications were established and the journal is subscribed to by nearly 160 organizations and individuals.

## 6.2 Proceedings of Symposia

The proceedings of the Symposium on "Recent Developments in Non-ferrous Metals Technology", Vol. II — Copper and Its Alloys and Vol. III — Other Non-ferrous Metals and Alloys, were published during the year.

## 6.3 Monograph

The Monograph entitled "Atlas on Transformation Diagrams of Low Alloy Steels" by R. K. Dubey, P. K. Gupte and B. R. Nijhawan was published.

## 6.4 Special Reports

A number of Special Reports were prepared in conformity with the demand of industries and government organizations covering the problems of iron and steel, mineral processing and extraction techniques and industrial investigations in these fields of interest and expertise and facilities available at the Laboratory. Reports were also prepared for the C.S.I.R. handbook, achievements of NML in research and development, and for Public Accounts Committee of Parliament.

## 6.5 Papers Published, Presented and Communicated

Seventy-two papers were published, presented and communicated for publication during the period. The details are furnished in Appendix I.

## 6.6 Research and Investigation Reports

Fifty-six research and investigation reports were prepared during the period. Details are furnished in Appendix II.

# 7. INDUSTRIAL LIAISON, PUBLIC RELATION AND EXTENSION SERVICE

In order to bridge the credibility gap between research and industry, as far as possible, closer and purposeful contacts were established with various industries for (i) making technological forecasting, (ii) identification of industrial problems through joint technical meetings and providing latest technical data towards better utilization of expertise and facilities available at NML, and (iii) creating awareness and confidence amongst the growing metallurgical units for the developed processes at NML. Discussions were also held to screen out as many as one hundred applications by Indian firms for foreign collaborations, vis-à-vis products/processes.

Training facilities in the field of mineral beneficiation and agglomeration, metallography, foundry, heat treatment, metal working, extraction metallurgy, corrosion, chemical analysis, X-ray diffraction and electron microscopy were extended to twenty students of metallurgy from different technical institutes. Besides, a large number of technical personnel from engineering colleges, industry and research institutes were also imparted training in their specialized field.

## 7.1 Visitors

During the period under review the following important visitors, as well as a large number of visitors from industries, universities, technical institutions, etc., also visited the Laboratory and its pilot plants:

1. Dr R. S. Barnas, Director, Research and Development, British Steel Corpn, London
2. Mr Charles B. Baker, Secretary General, International Iron & Steel Institute, Brussels, Belgium
3. Mr Pancier, Unesco Expert, National Institute of Foundry & Forge Technology, Ranchi
4. Dr Johari, Manager, Metal Physics, Illinois Institute of Technology Research Institute, Chicago, USA
5. Dr Martin E. Abel, Adviser, Ford Foundation
6. Dr Byer, Consultant, Ford Foundation
7. Dr V. G. Pande, Consultant, Ford Foundation

8. Mr Endre Lendvai, Research Fellow, Hungarian Research Institute of Iron Industry
9. Dr Iran Jeney, Scientist, Hungarian Institute of Cultural Relation, Budapest
10. Dr S. Sugamata, General Manager, Mineral Division, Nippon Steel Corporation, along with a team of 11 Japanese experts on iron and steel
11. Shri S. Kumarasundaram, Head, Survey Team, Industrial Development Bank of India, along with other members
12. Shri R. Venkataraman, Member, Planning Commission, New Delhi
13. Shri K. V. Seshadri, Secretary to the Cabinet, Government of India, New Delhi
14. Members, Expert Committee of the Central Research & Development Board for the Iron & Steel Industry, New Delhi, Ministry of Steel & Mines, New Delhi
15. Team of four Soviet experts from IIT, Kharagpur
16. Shri A. D. Sarkar, Senior Lecturer, Flintshire College of Technology, UK
17. Dr M. L. Joshi, Manager, Exploratory Materials Group, IBM Burlington Lab., Vermont, USA
18. Shri S. K. Dam, Head, APO Study Mission on Iron & Steel Foundry Practice
19. Dr P. Dayal, Senior Industrial Adviser, Head, Technical Committee on Lead, along with two members
20. Team of Soviet experts on iron and steel from Bokaro Steel Plant, Bokaro

## 7.2 Technical Aid and Services

The technical enquiries from 60 government and semi-government organizations, 195 from private sector industrial organizations and 65 enquiries pertaining to details of processes/patents of the Laboratory were attended to.

In addition to 10 sponsored projects carried over from the previous year, 26 new sponsored projects involving ad hoc experiments were undertaken during the year and 28 of the total sponsored projects were completed. Technical service and assistance were rendered to 52 industrial units, Government institutions and large scale industries.

# 8. NML FIELD STATIONS

## 8.1 Foundry Stations

The Foundry Field Stations at Batala, Madras, Howrah and Ahmedabad have been rendering tecnnical guidance to industries both in the small scale and medium scale sectors on diverse aspects of foundry technology, wnich included proper selection of foundry raw materials, analysis of ferrous and non-ferrous metals and alloys, testing of sands and bentonites, etc. The technical enquiries from industries located in the respective regions pertaining to tne application of modern tecnniques of production, use of scientific metnods of melting and casting, quality control and elimination of various casting and moulding defects, production technique to produce castings conforming to export requirements were also attended to. Extensive work has been performed in exploiting regional resources in collaboration with the Geological Survey of India and the State Geology and Mining Departments.

Proposals for the diversification and expansion of the activities of these field stations to meet regional demands, especially in regard to evaluation of the minerals available in the neighbouring areas, are under active consideration.

## 8.2 Marine Corrosion Research Station, Digha

This station has continued the work in the following research projects for the study of corrosion and protection of metals and alloys.

**8.2.1** The atmospheric corrosion of the samples with different coatings exposed under marine environmental conditions:

(a) Aluminium panels, which showed black patches

(b) Plastic coated steel panels having varying coating thickness and composition

(c) High conductivity aluminium wires developed by NML along with INDAL and HINDAL wires

**8.2.2** Evaluation of the corrosivity of Digha atmosphere. It was found that with increased distance from Digha the corrosivity decreased. Beyond a distance of 1 km mild steel and zinc showed low decrease in corrosion.

**8.2.3** Sea water corrosion. Detailed studies on the effect of chromate inhibitor on sea water corrosion of mild steel coupled to zinc, aluminium and copper are under progress. Sodium benzoate, as inhibitor, did not give encouraging results of corrosion on mild steel.

# 9. LIBRARY, DOCUMENTATION, TRANSLATION AND REPROGRAPHIC SERVICE

## 9.1 Library

The Library added 2500 new books and 500 journals were subscribed along with 125 received on exchange programme during the year. Extensive service of the Library supported by central documental service, viz. abstract cards for metallurgical information, was availed of by many individuals and outside institutions in addition to the various research divisions of the laboratory. To facilitate the scanning and selection of materials by scientific staff, a weekly publication entitled "Index of Current Titles" covering periodicals received during the week, has also been introduced.

## 9.2 Documentation Cell

A monthly publication "Documented Survey on Metallurgical Developments", an abstracting service from current periodicals, is being circulated to scientific staff of the laboratory and to various research and educational institutions and to industries.

## 9.3 Translation Cell

To disseminate advancements in the field of metallurgy published in different foreign languages, a monthly publication "Survey on Metallurgical Developments" containing English translations of abstracts of metallurgical interest from various French, German and Russian technical periodicals was brought out and widely circulated to scientists of the laboratory and metallurgists in research, educational institutes and in industry.

In addition, fifty-two technical articles were translated into English from Russian, German and French publications for reference to the research staff of the laboratory. Oral translations were also rendered for the benefit of the research workers.

## 9.4 Reprographic Service

Photostat, reflex prints and microfilms were made from scientific papers of interest for the research staff of the laboratory. Microphotographs, X-ray photographs and photographs of apparatus and equipments, etc., of various projects were also made.

# 10. GENERAL

## 10.1 Colloquia

Thirty Colloquia and lectures were arranged covering the various metallurgical aspects of which 16 were given by NML staff members. The following 14 lectures were delivered by eminent scientists on different subjects of metallurgical interest:

| | |
|---|---|
| 1. Polytypism in Crystals | Prof. R. Srinivasan, Centre of Advanced Study for Physics University of Madras<br>8.10.70 |
| 2. Diffusion of Gr II and V Elements in Silicon | Shri M. L. Joshi, Manager, Exploratory Materials Group IBM, Burlington, Vermont USA<br>27.11.70 |
| 3. Structure of Molten Metals | Shri M. L. Joshi<br>28.11.70 |
| 4. Fundamental Studies on the Role of Carbon Dioxide in a Calcite Flotation System | Dr A. K. Biswas, Associate Professor, Dept. of Metallurgy, IIT, Kanpur<br>15.12.70 |
| 5. Kinetics of Dissolution of S in Aqueous Sulphuric Acid Solution | Dr A. K. Biswas<br>29.12.70 |
| 6. Self Diffusion in Cs-Cl Type Ordered Alloys | Dr Devendra Gupta, IBM Watson Research Centre USA<br>5.1.71 |
| 7. Strengthening Mechanism in Some Alloy Steels | Prof. P. R. Dhar, Head of the Materials Science Centre IIT, Kharagpur<br>29.1.71 |

| | |
|---|---|
| 8. Tarnishing Reactions, Part I | Dr S. C. Sarkar, Asst. Professor, IIT, Kharagpur<br>11.2.71 |
| 9. Tarnishing Reactions, Part II | Dr S. C. Sarkar<br>12.2.71 |
| 10. Fatigue Mechanism in Iron | Dr H. M. Dalal, IBM, Fishkill Lab., USA<br>6.3.71 |
| 11. ESR Process in Hungary | Mr Andrew Lendvai, Visiting Scientist from Hungary<br>27.3.71 |
| 12. Behaviour of Metals under Creep and Mechanism of Creep | Dr Rajendra Prasad, Prof. & Head of the Dept. of Metallurgy, BIT, Sindri<br>29.3.71 |
| 13. Refractory Metal or Ceramic Fibre Reinforced Metal Composition | Dr Rajendra Prasad<br>30.3.71 |
| 14. Role of Orthokinetic Coagulation in the Production of Cleaner Steels | Dr S. Jha Ajit, Asst. Professor, RIT, Jamshedpur<br>31.3.71 |

## 10.2 Specialized Equipments

Purchase and Stores Sections were active during the year in procuring specialized equipments, raw materials, etc. Some of the important additions to equipments are as below:

1. Electrically heated high temperature furnace
2. Polarograph controller, potential type OH-102
3. Hounsfield tensometer
4. Submerged arc welding unit
5. Flame photometer
6. X-Y recorder
7. Universal pulse generator
8. Industrial X-ray unit

9. Magna and Time Potentiostat

10. Automatic Double Beam Recording Microdensitometer

## 10.3 Safety First and First Aid Section

Periodic inspection to safety measures at various hazardous points were carried out; as a result no major casualty occurred during the year. The workers were amply provided with safety materials and necessary garments wherever required.

## 10.4 Societies

NML Staff Co-operative Credit Society helped the staff members in meeting their urgent financial requirements creditably and transacted nearly 2·36 lakhs.

Co-operative Consumers' Stores has continued to supply rationed and non-rationed foodstuffs and other general merchandise to the staff at reasonable prices.

The NML Canteen continued to cater for lunch and snacks which it supplied to members of the staff at subsidized prices.

NML Club maintained its sporting and social activities and organized a number of special functions.

## 10.5 Staff News

### 10.5.1 *Honours and Awards*

1. Dr V. A. Altekar, Director (NML)

   Independence Day (1970) Award from the Inventions Promotion Board on his invention " Process of Electro-thermal Zinc Dust Smelter "

2. Dr Ved Prakash, Scientist (NML)

   Independence Day (1970) Award from the Inventions Promotion Board on his invention on " Ferrite Magnets "

3. Dr A. K. Lahiri, Scientist (NML)

   National Metallurgist's Day Award (1970) for his outstanding contributions in the field of corrosion prevention

## 10.5.2 *Foreign Deputation/Training in India and Abroad*

| | |
|---|---|
| 1. Prof. V. A. Altekar<br>Director | (i) Under Indo-Soviet Scientific & Cultural Exchange Programme, USSR, to study the research organizations in the field of science and technology<br>(ii) To attend the 9th International Mineral Processing Congress, Prague, Czechoslovakia and to visit different research centres<br>(iii) To discuss with UNIDO and UNDP, Vienna, Austria, regarding the project on Beneficiation of the Asswan Iron Ores for proper study and evaluation at NML<br>23.4.70 to 23.6.70 |
| 2. Shri B. N. Das<br>Scientist | To attend the International Conference on Copper under the auspices of Institute of Metals, London, at Amsterdam, Netherlands<br>18.9.70 to 3.10.70 |
| 3. Shri G. D. Sani<br>Scientist | Colombo Plan training at UK in the field of development of low and medium alloy high strength structural steel and related mechanical techniques<br>25.9.70 to 4.4.71 |
| 4. Dr Manjit Singh<br>Scientist | Exchange programme to UK to study specialized experimental techniques as applied to liquid metals and solidification and also to study metallurgical problems arising out of the engineering uses of aluminium and its alloys specially with regard to solidification<br>8.1.71 to 12.4.71 |

| | |
|---|---|
| 5. Shri B. L. Sengupta<br>Scientist<br>and<br>6. Shri P. K. Sinha<br>Scientist | Short term course at IIT, Bombay, in the field of Agglomeration of Ores<br>7.12.70 to 24.12.70 |
| 7. Shri K. N Gupta<br>Scientist | Short term course at University of Bombay in the field of Chemical Process Economics<br>19.10.70 to 28.10.70 |
| 8. Shri A. Dutta<br>Field Officer | (a) Short term course at IIT, Kharagpur, in the field of Foundry Technology<br>13.7.70 to 3.10.70<br>(b) Short course at IIT, Kharagpur, in the field on Advanced Foundry Practice<br>16.11.70 to 12.12.70 |
| 9. Shri M. N. P. Verma<br>Field Officer | Short course at IIT, Kharagpur, in the field on Foundry Technology<br>1.2.71 to 24.4.71 |

**10.5.3** *Postgraduate degrees received by NML Staff and Research Fellows*:

| | |
|---|---|
| 1. Dr Inder Singh, Ph.D. | Ranchi University for his thesis on " The role of inhibitors in acid dissolution of iron and its alloys " |
| 2. Dr B. P. Verma, Ph.D. | Ranchi University for his thesis on " Physico-chemical properties of electrolytic manganese dioxide containing co-deposited trace elements " |
| 3. Dr P. K. Panda, Ph.D. | Ranchi University for his thesis on " Oxidation of copper and its alloys " |
| 4. Dr S. S. Sachdeva, Ph.D. | Patna University for his thesis on " Transformation in binary alloys using X-ray diffraction and other techniques " |

**10.5.4** *The following Universities have recognized NML as a Research Centre for postgraduate degrees*:

(i) Agra

(ii) Banaras Hindu University

(iii) Bihar

(iv) Bombay

(v) Madras

(vi) Panjab

(vii) Jadavpur

(viii) Andhra

(ix) Sri Venkateswara

(x) Patna

(xi) Calcutta

(xii) Utkal

(xiii) Ranchi

(xiv) IIT, Kharagpur

(xv) London

# APPENDIX I

## Papers Published, Communicated and Presented

1. *Thermal reduction of manganese ores with solid fuels: Part I — Charcoal,* A. M. Pande, P. L. Sengupta, N. Dhananjayan & H. K. Chakravarti, *NML Technical Journal,* Vol. XII, No. 3, 1970.

2. *Studies on leaching of bulk Ni-Cu-Mo sulphides,* A. K. Saha, R. N. Misra & P. P. Bhatnagar, *NML Technical Journal,* Vol. XII, No. 3, 1970.

3. *Spectrographic analysis of low alloy steels by solution technique,* M. K. Ghosh, *NML Technical Journal,* Vol. XII, No. 3, 1970.

4. *Some observations on manganese steel bimetallic couples from the point of view of cathodic protection,* K. P. Mukherjee & D. K. Khan, *NML Technical Journal,* Vol. XII, No. 3, 1970.

5. *Silver as catalyst,* B. N. Singh, *NML Technical Journal,* Vol. XII, No. 3, 1970.

6. *Development of hydrochloric acid pickling of steel in India,* D. D. Akerkar & M. J. Shahani, *NML Technical Journal,* Vol. XII, No. 4, 1970.

7. *Spectrographic analysis of nodular cast iron for magnesium,* M. K. Ghosh & H. K. Chakravarti, *NML Technical Journal,* Vol. XII, No. 4, 1970.

8. *Recent trends in extraction of selenium & tellurium from electrolytic copper slimes,* Narinder Singh & S. B. Mathur, *NML Technical Journal,* Vol. XII, No. 4, 1970.

9. *Some observations on the production of ferro-coke,* B. K. Paul, S. R. Joti & A. N. Kapoor, *Trans. Indian Inst. Metals,* June 1970.

10. *Smelting of high titania ore with non-metallurgical fuels,* A. B. Chatterjea, J. Goswami, S. K. Biswas, R. Santokh Singh & J. S. Padan, *Trans. Indian Inst. Metals,* June 1970.

11. *Preliminary studies on carburizing characteristics of Nb treated steels*, R. K. Sinha, M. R. Kulkarni & R. Chattopadhyay, *Trans. Indian Inst. Metals*, June 1970.

12. *Technology of production of phosphor-bronze spring*, B. N. Das & S. K. Banerjee, *Trans. Indian Inst. Metals*, June 1970.

13. *Deformation sub-structure of copper-manganese alloys*, U. K. Chatterjee, A. K. Lahiri & T. Banerjee, *Indian Jr. of Technology*, Vol. 8, No. 4, 1970.

14. *Calcination characteristics of petroleum coke*, Bimal Chatterjee, H. P. S. Murthy & Nikhil Sarkar, *Indian Jr. of Technology*, Vol. 8, No. 10, 1970.

15. *Effect of forming pressure on the physical properties and high temperature load bearing characteristics of basic refractories*, T. V. Prasad, *Trans. Indian Cerm. Society*, Vol. XXIX, No. 1, 1970.

16. *Constitution and mineralogy of Indian blast furnace slag*, R. V. Hargave & M. R. K. Rao, *Trans. Indian Cerm. Society*, Vol. XXIX, No. 1, 1970.

17. *Mechanism of electro-deposition of manganese in alpha & gamma modification*, N. Dhananjayan, *Jr. of the Electro-Chemical Society*, Vol. 117, No. 8, 1970.

18. *Effect of holding time in the liquid state on the solidification of aluminium-copper eutectic alloy*, Rajendra Kumar & Manjit Singh, *Journal of the Australian Inst. of Metals*, Vol. 15, No. 3, 1970.

19. *Production of electrolytic iron powder*, S. N. Sinha, S. K. Ray & V. A. Altekar, *Chemical Age of India*, Vol. 22, No. 3, 1971.

20. *Changes in electrical resistance of brass during stress corrosion cracking*, A. K. Lahiri & S. P. Nayak, *Br. Corrosion Journal*, Vol. 6, March 1971.

21. *Influence of liquidus on stability of liquid eutectic system*, Rajendra Kumar & C. S. Sivaramakrishnan, *Trans. Indian Inst. Metals*, December 1970.

22. *Aluminium conductor*, Rajendra Kumar, *Science Today*, December 1970.

23. *Structure of liquid cadmium-antimony alloys*, Rajendra Kumar & C. S. Sivaramakrishnan, *Jr. of Met. Science*, January 1971.

24. *Corrosion control in modern town planning*, A. K. Lahiri, *Jr. of Assn of Engineers*, **46** (1), 71.

25. *Protection of waterline against external and internal corrosion*, A. K. Lahiri & V. A. Altekar, *Jr. of Assn of Engineers* (Spl issue), Nov. 1970.

26. *Some observations on the structure of ancient steels from South India and its mode of production*, K. N. P. Rao, J. K. Mukherjee & A. K. Lahiri, *Bull. of Historical Metallurgy*, London, **4** (1), 1970.

27. *Effect of rolling scale on corrosion of mild steel*, H. R. Thilakan, A. K. Lahiri & T. Banerjee, *Indian Jr. of Technology*, Vol. 8, April 1970.

28. *Some observations on the protective properties of the sprayed Al coatings*, A. K. Lahiri & S. R. Kaviraj, Tisco, 17 July 1970.

29. *Studies on sintering and pelletization of raw materials for iron and steel industry*, N. Chakravarty & G. P. Mathur, Tisco, 17 Dec. 1970.

30. *Structure stability of rapid solidified Al-Cu super-saturated solid solutions*, Rajendra Kumar & S. K. Bose, *Scripta Metal*, June 1971.

31. *Explosive bonding of thermostat bi-metals*, S. K. Banerjee, J. D. Williams & B. Crossland, *Metallurgia*, March 1970.

32. *Some metallurgical observations on explosively cladded stainless steel on mild steel*, S. K. Banerjee, *Trans. Indian Inst. Metals*, September 1970.

33. *Techno-economic aspects of mineral beneficiation*, S. K. Banerjee & G. P. Mathur, Souvenir Publication, Mineral Convention at Ahmedabad, September 1970.

34. *Phase transformation in electrolytic alloys with special reference to Cu-Sn system*, S. Misra & T. Banerjee, communicated for publication in *Indian Jr. of Technology*, New Delhi.

35. *Refractory practice in copper foundries*, H. P. S. Murthy, communicated for publication in *Indian Journal of Engineers*, Calcutta.

36. *Grain size control in aluminium and aluminium alloy ingots and castings*, Rajendra Kumar, communicated for publication in *Jr. of Inst. of British Foundrymen*, UK.

Nayak & A. K. Lahiri, communicated for publication in *Indian Jr. of Technology*, New Delhi.

38. *Distribution of antimony at the grain boundaries of copper-antimony alloy using radioactive traces*, K. D. Maji & H. R. Tipler, communicated for publication in the *Trans. of Indian Inst. of Metals*.

39. *Structure of some* 17% *Cr-Mn-N-C stainless steel*, P. L. Ahuja, B. N. Halder & S. S. Bhatnagar, communicated for publication in *Jour. of Material Science*.

40. *Determination of work index by Holme's method — A case study*, G. S. Ramakrishna Rao, K. Vijayraghavan & G. P. Mathur, presented at the seminar on Particle size determination at IIT, Madras, November 70.

The following papers were presented at the 24th Annual Technical Meeting of Indian Institute of Metals, at Roorkee, December 1970:

41. *Influence of associated ingredients on the mechanism of gaseous reduction of hematite: Part I — Calcium carbonate*, T. C. De & A. B. Chatterjea.

42. *Vinyl coating in progress*, P. Prabhakaram & V. A. Altekar.

43. *Rapid method for determination of beryllium in presence of iron & aluminium*, H. P. Bhattacharya.

44. *Rapid routine method for determination of vanadium in alloy steels*, A. Ghosh & H. P. Bhattacharya.

45. *Study of the reduction mechanism of iron ore by solid carbon and carbon monoxide*, B. K. Paul, S. R. Joti & A. N. Kapoor.

46. *Inhibitive properties of aniline and its derivatives*, Inder Singh, S. Kisku, A. K. Lahiri & V. A. Altekar.

47. *Structure of iron between* 770° *and* 910°*C*, L. J. Balasundaram.

48. *Activity of carbon in austenite iron at* 1000° *and* 1200°*C*, A. K. Nayak, P. P. Bhatnagar & B. R. Nijhawan.

49. *Activity of carbon in* 4·3 *and* 6·4% *chromium containing iron-chromium carbon alloy at* 1000°*C*, A. K. Nayak & P. P. Bhatnagar.

50. *Effects of W, Ti & Al on the precipitation of creep behaviour of Cr-Mn-N-C austenitic steel*, R. Choubey & K. Prasad.

The following papers were communicated for presentation at the Annual Convention of Inst. of Indian Foundrymen held at New Delhi, April 1971:

51. *Inoculation of cast iron*, G. N. Rao & P. K. Gupte.

52. *Impact of melting procedures on foundry technology*, C. S. Krishnan, K. M. Chowdhury & Rajendra Kumar.

53. *Studies on mould wall movement of nodular iron castings*, R. R. Dash, R. K. Dubey & P. K. Gupte.

54. *Development of shellac as binding material in foundry*, T. A. Beck, R. K. Dubey & P. K. Gupte.

55. *Spectrographic analysis of nodular cast iron for magnesium*, M. K. Ghosh & H. K. Chakravarti.

The following papers were presented at the Seminar on Welding at NML, February 1971:

56. *Some metallurgical problems in welding*, B. N. Das.

57. *Technical development in explosive welding of metals*, S. K. Banerjee.

The following papers were presented at the Symposium on Vacuum Science & Technique at B.A.R.C., Bombay, February 1971:

58. *Some experience in melting with electron beam melting furnace*, N. K. Das & L. J. Balasundaram.

59. *Thermal reduction of lime for production of calcium metal by aluminium powder under vacuum*, A. K. Nayak.

The following papers were presented at the 35th Annual General Session of the Indian Cerm. Society at Ahmedabad, March 1971:

60. *A study on the raw materials and refractory properties of Dewaldhar magnesite in the Almora region*, P. C. Sen & M. R. K. Rao.

61. *Studies on the high temperature mechanical properties of some french castable refractories*, M. C. Kundra.

The following papers were presented at various seminars and/or technical meetings:

62. *Crystallographic instability in the cadmium antimony system,* Vijay Kumar, J. K. Mukherjee & Rajendra Kumar, presented at the Sixth Annual Seminar on Crystallography, Madras, February 1971.

63. *Corrosion control practice of underground water pipes,* A. K. Lahiri & V.A. Altekar, presented at the All India Conference on Engg. Materials & Equipment, Calcutta, November 1970.

64. *Beneficiation of low grade ores and minerals of Rajasthan,* P. V. Raman & G. P. Mathur, presented at Seminar on Properties of Mineral Based Industries of Rajasthan, Jaipur, Rajasthan, Oct. 1970.

65. *Metallographic studies of rapidly solidified aluminium-copper alloys,* Rajendra Kumar & S. K. Bose, presented at the IV Annual Tech. Meeting of International Metallographic Soc., U.S.A., Nov. 1970.

The following papers were communicated for presentation at the Symposium on Corrosion in Chemical Industries at Neyveli, Tamilnadu, June 1971.

66. *Corrosion problem in chemical industries — Some case studies,* S. Rao Addanki, K. P. Mukherjee & A. K. Lahiri.

67. *Methods for inspection of process equipment against corrosion damage,* A. K. Lahiri.

68. *Use of stainless and other alloy steels in chemical processing industries,* K. P. Mukherjee, A. K. Lahiri & V. A. Altekar.

69. *Plastics and protective coatings in chemical industry — A review,* P. Prabhakaram & V. A. Altekar.

The following papers were communicated for presentation at the Symposium on Thermal Analysis, B.A.R.C., Bombay:

70. *Second order transformation in liquid metals and alloys — DTA study,* Rajendra Kumar & Gangotri Misra.

71. *Thermal expansion coefficient of some low melting point alloys,* L. J. Balasundaram & A. N. Sinha.

72. *Thermal quantitative and thermodynamic analysis of binary Mg-Sn and ternary Al-Zn-Sn alloys by calorimetry and deriving the phase diagram and their thermodynamic values,* A. K. Nayak.

# APPENDIX II

## Scientific Investigations Completed and Reports Prepared

1. Flotation studies on a low grade copper ore sample from Nallakonda block, Agnigundala area, Guntur Dt., AP — Sachchidanand Prasad, S. K. Banerjee & G. P. Mathur (I.R. 575/70).

2. Determination of grindability and Bond's work index of a rock phosphate sample from Rajasthan — K. Vijayaraghavan, G. S. Ramakrishna Rao & G. P. Mathur (I.R. 576/70).

3. Determination of work index and rates of setting and filtration of three iron ore concentrates from NMDC Ltd — K. Vijayaraghavan, G. S. Ramakrishna Rao & G. P. Mathur (I.R. 577/70).

4. Moulding characteristics of the sand sample No. LSS-2 — R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 578/70).

5. Moulding characteristics of the sand sample No. LSS-3 — R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 579/70).

6. Moulding characteristics of the sand sample No. CSS-10 — R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 580/70)

7. Beneficiation studies with a sample of lateritic iron ore in clayey matrix from M/s. Sesa Goa Ltd — R. K. Kunwar, P. D. Prasada Rao, G. S. Ramakrishna Rao & G. P. Mathur (I.R. 581/70).

8. Investigation on Rampur sand — Amitava Das, Ashimesh Dutt & G. N. Rao (I.R. 582/70).

9. Investigation on Girphala sand — A. Das, A. Dutt & G. N. Rao (I.R. 583/70).

10. Investigation on Baltora sand — A. Das, A. Dutt & G. N. Rao (I.R. 584/70).

11. Moulding characteristics of sand sample GSI III — K. S. Vijayanarayanan, N. V. Naidu & G. N. Rao (I.R. 585/70).

12. Moulding characteristics of sand sample GSI IV — K. S. Vijayanarayanan, N. V. Naidu & G. N. Rao (I.R. 586/70).

13. Moulding characteristics of sand sample GSI V — K. S. Vijayanarayanan, N V. Naidu & G. N. Rao (I.R. 587/70).

14. Moulding characteristics of sand sample GSI VI — K. S. Vijayanarayanan, N. V. Naidu & G. N. Rao (I.R. 588/70).

15. Beneficiation studies on a low grade copper ore from Dhukonda block, Agnigundala area, AP — S. K. Sengupta, P. V. Raman & G. P. Mathur (I.R. 589/70).

16. Recovery of magnetite from ICC tailing — G. S. R. K. Rao & G. P. Mathur (I.R. 590/70).

17. Studies on the recovery of metallics from the dross samples from M/s. Leader Engg. Works, Jullundur (I.R. 591/70).

18. Beneficiation of a low grade graphite schist sample from Khepchishi Hill, Bhutan — R. Ganesh & G. P. Mathur (I.R. 592/70).

19. Determination of Bond's work index of a phosphate rock sample received from M/s. Fertilizer Corpn of India Ltd, Sindri — K. Vijayaraghavan, G. S. Ramakrishna Rao & G. P Mathur (I.R. 593/70).

20. Beneficiation of a low grade rock phosphate sample from Dakan Kotra area, Udaipur Dist., Rajasthan — M. V. Ranganathan & G. P. Mathur (I.R. 594/70).

21. Investigation on failure of Roll shaft — B. N. Das & B. N. Ghosh (I.R. 595/70).

22. Testing of 'Acetofloats' received from M/s. Acetochemicals Ltd, Calcutta — R. K. Kunwar, M. V. Ranganathan & G. P. Mathur (I.R. 596/70).

23. Studies on leaching of bulk Ni-Cu-Mo sulphide — A. K. Saha, R. N. Misra & P. P. Bhatnagar (I.R. 597/70).

24. Studies on the extraction of nickel from low grade nickeliferrous limonite ores from Surabil-Sukerangi, Kumardah Sector, Orissa — M. S.

Mahanty, A. K. Saha, D. S. Tandon & P. P. Bhatnagar (I.R. 598/70).

25. Corrosion of boiler superheater tubes — A. K. Lahiri (I.R. 599/70).

26. Moulding characteristics of sand sample UPSS-1 — R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 600/70).

27. Moulding characteristics of sand sample UPSS-2 — R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 601/70).

28. Moulding characteristics of sand sample UPSS-3 — R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 602/70).

29. Moulding characteristics of sand sample JSS-1 — R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 603/70).

30. Investigation on sand sample BBI-48 — P. R. Sastry, R. Prasad & G. N. Rao (I.R. 604/70).

31. Moulding characteristics of sand sample GSI VII — K. S. Vijayanarayanan, N. V. Naidu & G. N. Rao (I.R. 605/70).

32. Moulding characteristics of sand sample GSI VIII — K. S. Vijayanarayanan, N. V. Naidu & G. N. Rao (I.R. 606/70).

33. Moulding characteristics of sand sample GSI XI — K. S. Vijayanarayanan, N. V. Naidu & G N Rao (I.R. 607/70).

34. Decrepitation test of Bailadila iron ores (I.R. 608/70).

35. Pelletization of metallurgical grade fluorspar concentrate from GMDC using cheaper binders — P. C. Bose, G. P. Mathur & V. A. Altekar (I.R. 609/70).

36. Beneficiation studies on a low grade graphite sample from Chunga-Bansdih Mines, Palamau, Bihar — S. K. Sengupta, P. V. Raman & G. P. Mathur (I.R. 610/70).

37. Beneficiation of manganese ore fines received from M/s. Manganese. Ore (I) Ltd, Nagpur — G. Radhakrishnan, P. V. Raman & G. P. Mathur (I.R. 611/70).

38. Batch and pilot plant beneficiation studies with a pyrite-pyrrhotite sample from Saladipura, Rajasthan — P. D. Prasad Rao, C. Satya-

narayana, K. Vijayaraghavan, G. S. Ramakrishna Rao & G. P. Mathur (I.R. 612/70).

39. Reduction of silica content of a magnesite sample from Ajmer Dt., Rajasthan — C. Satyanarayana, S. K. Banerjee & G. P. Mathur (I.R. 613/70).

40. A preliminary test report of the manganese ore from Sandur Iron & Manganese Ore Ltd on its suitability for production of electrolytic manganese metal under standard conditions — A. M. Pande, P. L. Sengupta, N. Dhananjayan & H. K. Chakravarti (I.R. 614/70).

41. Determination of Bond's work index of an iron ore concentrate sample from Kudremukh — K. Vijayaraghavan & G. P. Mathur (I.R. 615/70).

42. Corrosion of metals in the marine atmosphere at Digha — S Rao Addanki, A. K. Dey, D. K. Khan & T. Banerjee (R.R. 274/70).

43. Some observations on protective properties of sprayed aluminium coating — A. K. Lahiri & S. Kaviraj (R.R. 275/70).

44. Calcination characteristics of petroleum coke — Bimal Chatterjee, H. P. S. Murthy & Nikhil Sarkar (R.R. 276/70).

45. Electrical resistivity — A tool to measure stress corrosion cracking — A. K. Lahiri & S. P. Nayak (R.R. 277/70).

46. Studies on the high temperature mechanical properties of some French castable refractories — M. C. Kundra (R.R. 278/70).

47. Structure of liquid cadmium-antimony alloys — R. Kumar & C. S. Sivaramakrishnan (R.R. 279/70).

48. Mould and core coatings for copper base alloys — G. N. Rao, R. N. P. Gupta & R. M. Krishnan (R.R. 280/70).

49. First research report on vinyl coatings — P. Prabhakaram & V. A. Altekar (R.R. 281/70).

50. Structural stability of rapidly solidified Al-Cu super-saturated solid solutions — Rajendra Kumar & S. K. Bose (R.R. 282/70).

51. Effects of W, Ti and Al on the precipitation and creep behaviour of Cr-Mn-N-C austenitic steels — R. Choubey & K. Prasad (R.R. 283/70).

52. Influence of associated ingredients on the mechanism of gaseous reduction of hematites, Part I — Calcium carbonate — T. C. De & Dr A. B. Chatterjea (R.R. 284/70).

53. Recovery of copper and zinc from scrap leaded brass — B. V. S. Yedavalli, A. K. Saha & D. S. Tandon (R.R. 285/70).

54. Fluo-solid roasting of complex copper lead and zinc sulphides from Sikkim — B. V. S. Yedavalli, P. V. Viswanathan, S. R. Srinivasan & P. P. Bhatnagar (R.R. 286/70).

55. Metallographic studies of rapidly solidified Al-Cu alloys — Rajendra Kumar & S. K. Bose (R.R. 287/71).

56. Development of shellac as binding material in foundry — T. A. Beck, R. K. Dubey & P. K. Gupte (R.R. 288/71).

# APPENDIX III

## Patents & Processes

### (a) Patents filed

1. Indian Patent No. 126062 — An improved method for the removal of vanadium from vanadium-pig iron — Prof. V. A. Altekar & Shri P. P. Bhatnagar

2. Indian Patent No. 129079 — Improvements in ore relating to preparation of powdered iron — Shri S. K. Ray & Shri Sachidananda Sinha

### (b) Patents accepted

1. Indian Patent No. 118902 — A process for production of electrolytically deposited manganese dioxide containing iron — Shri B. P. Verma, Dr J. K. Mukherjee & Dr T. Banerjee

2. Indian Patent No. 119958 — Development in or relating to the production of aluminium alloy anodes for cathodic protection — Shri K. P. Mukherjee, Dr A. K. Lahiri & Dr T. Banerjee

### (c) Patents sealed

1. Indian Patent No. 118902 — A process for production of electrolytically deposited manganese dioxide containing iron — Shri B. P. Verma, Dr J. K. Mukherjee & Dr T. Banerjee

2. Indian Patent No. 118916 — A process for stabilization of ferrosilicon — Shri R. N. Misra & Shri P. P. Bhatnagar

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|---|---|
| 3. Indian Patent No. 119958 | Development in or relating to the production of aluminium alloy anodes for cathodic protection -- Shri K. P. Mukherjee, Dr A. K. Lahiri & Dr T. Banerjee |

**(d) Processes released through NRDC of India**

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|---|---|
| 1. Production of metal powders by atomization of molten metals (Non-patented) | 1. M/s. Sinterfine Metals Powders, New Delhi (1.8.70) |
| | 2. Shri A. K. Misra, B.37/111, Parvati Bhavan, Baijnath (Kamachaa), Varanasi 1 (7.9.70) |
| 2. Brightener composition for bright nickel plating (Non-patented) | 1. M/s. Dunlop India Ltd, Calcutta 16 (1.9.70) |

# APPENDIX IV

## Sponsored Investigations Completed

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| 1. Beneficiation studies on a low grade kyanite sillimanite sample ($D_3S_2$) from Dahagaon area, Nagpur | Director of Geology & Mining, Govt of Maharashtra, Nagpur |
| 2. Determination of grindability and Bond's work index of rock phosphate sample from Rajasthan | Director of Mines & Geology, Govt of Rajasthan, Udaipur |
| 3. Flotation studies on a low grade copper ore from Nallakonda block, Agnigundala Area, Dt Guntur, AP | Director General, Geological Survey of India, Calcutta |
| 4. Beneficiation studies with a sample of lateritic iron ore in clayey matrix | M/s. Sesa Goa Pvt Ltd, Panjim, Goa |
| 5. Petrological studies of fourteen core samples of bore holes D 9A, D 10 & D 14 of Kanjamalai magnetite deposits, Salem | Tamil Nadu Ind. Dev. Corpn Ltd, Madras |
| 6. Determination of work index and rate of settling and filtration of three iron ore concentrates | NMDC Kudremukh Iron Ore Project |
| 7. Beneficiation of a pyrite pyrrhotite sample from Saladipura area, Dt Sikar, Rajasthan | Geological Survey of India Rajasthan (N) Circle, Jaipur |
| 8. Beneficiation studies on a low grade copper ore from Dhukonda block, Agnigundala area, AP | Geological Survey of India, Southern Region, Hyderabad (AP) |
| 9. Recovery of magnetite from ICC tailings | Indian Copper Corpn Ltd Ghatsila |

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|---|---|
| 10. Studies on the recovery of metallics from the dross samples | M/s. Leader Engg Works, Jullundur |
| 11. Beneficiation of low grade graphite schist sample from Khepchisi Hill, Bhutan | Director General, Geological Survey of India, Calcutta |
| 12. Determination of Bond's work index of a phosphate rock sample | The Fertilizer Corpn of India Ltd, Sindri |
| 13. Beneficiation of a low grade rock phosphate sample from Dakan Kotra area, Udaipur Dt, Rajasthan | GSI, Rajasthan (N) Circle Jaipur |
| 14. Investigation on failure of roll shaft | M/s. Tata Chemicals Ltd Mithapur |
| 15. Testing of Acceto-floats | M/s. Acceto Chemicals P. Ltd Calcutta |
| 16. Beneficiation studies on a low grade graphite sample from Chunga Bansdih mine, Palamau, Bihar | M/s. Madan Gopal Tribeni Prasad, Calcutta |
| 17. Decrepitation test of Bailadila iron ores | NMDC Bailadila Iron Ore Project |
| 18. Beneficiation of manganese ore fines | M/s. Manganese Ore (I) Ltd Nagpur |
| 19. Batch and pilot plant studies with a pyrite pyrrhotite sample from Saladipura, Rajasthan | M/s. Pyrites, Phosphates & Chem. Ltd, Dehri on Sone |
| 20. Pelletization of metallurgical grade fluorspar concentrate using cheaper binders | M/s. GMDC, Ahmedabad |
| 21. Studies on the reduction of silica content of a magnesite sample from Ajmer Dt, Rajasthan | Director of Geology & Mining Govt of Rajasthan, Udaipur |
| 22. Recovery of metallics from zinc ashes and dust | M/s. Khandalwal Tubes Ltd Bombay |

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|---|---|---|
| 23. | Report on the utilization of high manganese slag from the ferro-manganese plant for the production of electrolytic manganese metal from ferro-manganese slag | M/s. Khandalwal Ferro Alloys Ltd, Bombay |
| 24. | Studies on the extraction of nickel from low grade nickeliferrous limonite ores from Sarabil-Sukerangi-Kumardah Sector, Orissa | Geological Survey of India Calcutta |
| 25. | Determination of Bond's work index of an iron ore concentrate sample from Kudremukh | NMDC Kudremukh Iron Ore Project |
| 26. | Investigation on metallurgical quality of cylinder block | Gujarat State Fertilizers Co. Ltd., Baroda |
| 27. | Cause of rejection during manufacture of stainless steel surgical instruments | Indian Drugs & Pharmaceuticals Ltd, Madras |
| 28. | Causes of failure of indexing can | M/s. Metal Box Co. of India Ltd |

# APPENDIX V

## The Executive Council Members

1. Sir A. Ramaswami Mudaliar
   (*Chairman*)
   India Steamship House
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2. Dr. D. P. Antia
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3. Dr. R. V. Tamhankar
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4. Dr Brahm Prakash
   Director, Metallurgy Group
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5. Dr. P. Dayal
   Industrial Adviser (Metals)
   Director General of Technical Development
   Internal Trade & Co. Affairs
   Ministry of Industry
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6. Prof. T. R. Anantharaman
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   Varanasi 5

7. Shri F. A. A. Jasdanwalla
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   Bombay 27

8. Shri R. L. Khanna
   Indian Copper Corporation Ltd
   P.O. Ghatsila, Dist. Singhbhum

9. Shri K. C. Khanna
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   Durgapur Steel Plant
   Durgapur 3, Dt. Burdwan

10. Prof. V. A. Altekar
    Director
    National Metallurgical Laboratory
    Jamshedpur 7

11. Director-General
    Scientific & Industrial Research
    New Delhi

12. Financial Adviser, C.S.I.R.
    New Delhi

# APPENDIX VI

## The Scientific Advisory Committee

1. Prof. V. A. Altekar
   (*Chairman*)
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2. Dr. R. V. Tamhankar
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   Defence Metallurgical Research Laboratory
   Phisalbanda
   Hyderabad 23

3. Dr. Brahm Prakash
   Director, Metallurgy Group
   Bhabha Atomic Research Centre
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4. Dr. P. Dayal
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