

NMML

ANNUAL REPORT

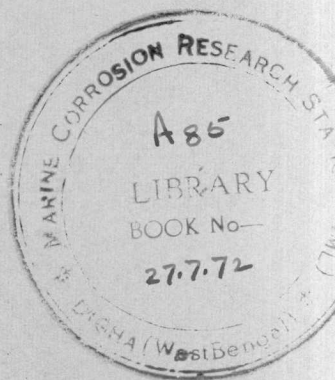
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NATIONAL METALLURGICAL LABORATORY
JAMSHEDPUR, INDIA

ANNUAL REPORT

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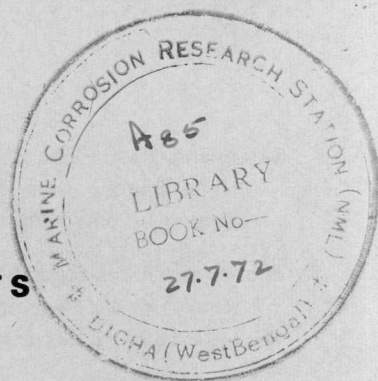


NATIONAL METALLURGICAL LABORATORY

COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH

JAMSHEDPUR, INDIA

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INTRODUCTION

The National Metallurgical Laboratory, during the period under review, has continued to make steady progress in its multiple research and development efforts in the various disciplines of metallurgy and has continued to forge close link with the industries so as to win their confidence. The full report on the pilot plant investigation on washing and pelletization of Donimalai iron ore was made available to National Mineral Development Corporation who are interested in setting up a pelletization plant at Donimalai in Mysore State. On behalf of M/s. Pyrites, Phosphate & Chemical Ltd., who are interested in setting up a plant for beneficiation of Amjhore pyrite, pilot plant investigation was successfully conducted and proposal for setting up a 1600 tons/day plant was submitted.

Laboratory and semi-commercial scale working of the PM-2 aluminium conductor developed in the Laboratory had demonstrated its superiority over electrical grade aluminium. Its commercial production was attempted in commercial firms and encouraging result was obtained.

Smelting trials were conducted in the pilot electric sub-merged arc furnace on the ferro-manganese using low temperature carbonized coke of Katkora colliery of Madhya Pradesh. The findings were made available to the sponsoring organization.

The National Metallurgical Laboratory has now entered into international arena and has been approached by United Nations Industrial Development Organization for undertaking pilot plant scale investigation for the production of pig iron from low grade iron ores from Asswan (U.A.R.) after beneficiation, agglomeration and pre-reduction. Negotiation in this connection has been finalised. Another international agreement has been signed for a collaborative research scheme for the preparation of standard reference materials of ferro-alloys with National Bureau of Standard, USA, under PI-480 Programme.

A successful Conference was held with top executives and shop managers of iron and steel plants of the country to identify problems of interest of iron and steel plants and to exchange information on problems of mutual interest in which areas NML can divert its efforts. A report on this occasion covering the work done at NML on problems of iron and steel industry which can be fruitfully supplemented with the assistance of iron and steel plants was prepared and circulated. Follow up action of this dialogue is actively pursued.



Top executives and chief metallurgists of Public & Private sector Steel Plants participated in a dialogue on the problems of iron and steel plants at NML. Mr. S. K. Nanavati, Mg. Director, Tata Iron & Steel Co. is seen at the centre, Prof. V. A. Altekar, Director, NML is on his left.

Another Conference on 'Development and Testing of High Temperature Materials' was held in collaboration with Research & Development Organization for Electrical Industries, Bhopal. The Conference was attended by scientists and technologists from Research & Development Organization for Electrical Industries, Bhopal; Bharat Heavy Electricals, Bhopal, Hardwar & Hyderabad; Hindustan Aeronautics; TISCO; HSL; Mahindra Ugine Steel; National Aeronautical Laboratory; Central Mechanical Engineering Research Institute and National Metallurgical Laboratory. The Conference which was convened by Research & Development Organization for Electrical Industries; discussed the scope of development of creep and heat resisting steels for power plant equipment and testing and evaluation of properties for the newly developed steels. It was recommended that facility must be established at the National Metallurgical Laboratory for setting up at least 150 test point Creep Testing Laboratory. Action has been initiated to establish this Laboratory with assistance of UNDP Special Fund and Govt. of India.

The National Metallurgical Laboratory has undergone a new orientation of its activities in the field of problem identification, project programming, process and product assessment, process development at industrial shop floors, transfer of technology through consulting engineering firms, establishing contact with entrepreneurs, chamber of industries and governmental agencies of various states.

The Laboratory published during the period the following publications in addition to its periodic quarterly NML Technical Journal which is running eleventh year of publication.

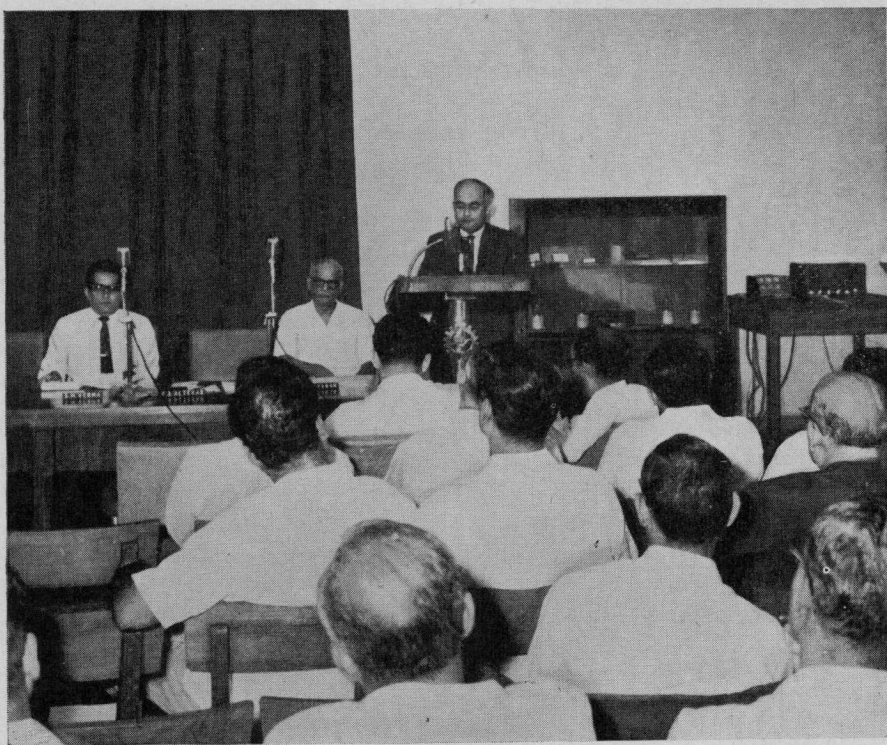
1. Proceedings of the Symposium on Recent Developments in Non-ferrous Metals Technology. Vol. I—Aluminium & its alloys. The Vols. II & III covering copper and other non-ferrous metals are under publication.
2. Monograph on "Structure of Electro-deposited Manganese Metal".

In the field of translation service, action has been initiated in bringing out monthly bulletins containing comprehensive and fully informative abstracts in English translated from French, German & Russian technical journals. Besides a fully documented survey on metallurgical developments reported in various technical journals is being published.

The following patents were taken during the period:

Applied for.

I.P. No.	Title
126062	An improved method for the removal of vanadium from vanadium pig iron.



Prof. V. A. Altekar, Director, NML addressing the Conference on "Development and Testing of High Temperature Materials."

Accepted.

- 119958 Development in or relating to the production of aluminium alloy anodes for cathodic protection.
- 118916 A process for stabilisation of ferro-silicon.
- 116520 An improved and modified process for the manufacture of ferrite magnets.
- 114500 Improvements in or relating to welding flux compositions and methods of making the same.

Sealed.

- 112574 A simple process for pre-heating the air blast in a cupola.
- 110814 Improvements in or relating to the production of fluoboric acid.

The following process which was earlier released was licensed to additional firms for commercial production.

1. Hot-dip aluminising of ferrous materials.

A brief resume of the progress of various projects and other activities is furnished in the Chapters to follow.

RESEARCH AND INVESTIGATION PROJECTS

1.0 Pilot Plant Studies on Washing and Pelletization of Donimalai Iron Ores. *Sponsored by National Mineral Development Corporation.*

At the instance of the National Mineral Development Corporation Ltd., detailed studies on crushing, screening (wet or dry), grinding and pelletization with a composite iron ore sample from Donimalai mines, Mysore State, were carried out with a view to supply data to M/s. M. N. Dastur & Co., a Consulting Engineering firm, for enabling them to prepare a feasibility report on pelletization of Donimalai iron ore fines.

Five types of ore samples received, were mixed in proper proportion to prepare a composite sample. The composite sample crushed to - 100 mm size, was wet screened at 3 mesh. —3 mesh sand mixed with cyclone under-flow from slime constituted the feed to pelletizer. Detailed pelletization studies with the mixed fines after wet grinding, were carried out and optimum conditions were determined for producing heat hardened pellets of good quality.

Pelletization tests were also performed with the composite fines obtained after dry screening and dry grinding as well as with fines obtained by wet screening and wet grinding of each of the five individual samples. These studies indicated the variations in pelletization characteristics of each of the different types of samples. A detailed report incorporating investigational data, as desired, was prepared and furnished.

1.1 Studies on Crushing and Washing of a Mixed Iron Ore Sample from Kiriburu Mines. *Sponsored by National Mineral Development Corporation.*

The National Metallurgical Laboratory earlier completed systematic and exhaustive pilot plant studies on the beneficiation and sintering characteristics of iron ore samples from Kiriburu Mines of the National Mineral Development Corporation Ltd. In the present investigation, the results obtained by washing a mixed sample according to the flow-sheet to be adopted in the washing plant after expansion of the Kiriburu iron ore mines, were discussed. Capacities of dewatering screens, classifiers and thickeners, required after modification of the plant were also suggested.

1.2 Beneficiation and Pelletization Studies on Iron Ore from Bailadila. *Sponsored by National Mineral Development Corporation.*

(a) Beneficiation and pelletization studies on a synthetic sample of iron ore fines from Bailadila deposit No. 14 of National Mineral Development

Corporation, was taken up, results of which are needed for the project report to be prepared by M/s. M. N. Dastur & Co. for the pelletization plant at Bailadila to be set up by N.M.D.C. The sample of synthetic fines together with another 8 samples weighing over 100 tonnes were sent by N.M.D.C. from Bailadila deposit No. 14 for the same purpose.

The sample as received assayed 64.5% Fe, 2.1% SiO_2 and 3.3% Al_2O_3 . The object of beneficiation was to bring down the Al_2O_3 content to 2-2.5%. Jigging yielded a concentrate 85.6% by weight assaying 66.7% Fe, 0.8% SiO_2 and 2.2% Al_2O_3 with a recovery of 89.2% Fe. One cleaning of the jig concentrate yielded a cleaner concentrate, 71.0% by weight, assaying 67.5% Fe, 0.6% SiO_2 and 1.5% Al_2O_3 with a recovery of 74.9% Fe. Batch pelletizing tests with each of the above grinds under varying conditions and heat hardening of the pellets are in progress.

(b) Work on a second sample from Bailadila deposit No. 14 of N.M.D.C. was taken up which was the representative plant feed sample (synthetic) for comparison of results. The sample as received assayed 65.0% Fe, 1.70% SiO_2 and 2.56% Al_2O_3 . Wet screening of the sample yielded a combined -30+6 mm product assaying 67.6% Fe, 0.7% SiO_2 and 1.4% Al_2O_3 with a recovery of 61.9% Fe. The classifier sand combined with the -6 mm fraction obtained from crushing the +30 mm washed fraction, assayed 66.4% Fe, 1.7% SiO_2 and 1.4% Al_2O_3 with a iron distribution of 35.4%. The slime assayed 53.2% Fe, 7.0% SiO_2 and 10.0% Al_2O_3 with a loss of 2.7% Fe.

Hydrocycloning of the slime yielded a cyclone underflow assaying 63.8% Fe, 2.6% SiO_2 and 3.1% Al_2O_3 with an additional recovery of 1.4% Fe. Bulk densities of different products obtained after wet screening, angles of repose of the classifier sand at different percentages of moisture, sieve and chemical analysis of sand and settling rates of cyclone overflow were also determined. Further work is in progress.

1.3 Beneficiation of Iron Ore. Sponsored by M/s. Sesa Goa Ltd., Goa.

A sample of iron ore with clayey matrix was received from M/s. Sesa Goa Ltd., for beneficiation studies with a view to produce lumps assaying over 61% Fe, and less than 1.5% SiO_2 and 4.0% Al_2O_3 . The test results indicated that it was not possible to reduce the alumina contents within the desired specification. The overall concentrate, produced by washing at 33 mm, followed by heavy media separation of the lumps at 2.9 specific gravity and jigging of the fines assayed 62.35% Fe, 1.27% SiO_2 , and 6.87% Al_2O_3 and recovered 74.6% of the total iron present in the sample.

2.0 Briquetting Tests on Metallurgical Grade Fluorspar.

Agglomeration tests were carried out on the metallurgical grade fluorspar concentrate produced at Mineral Beneficiation Pilot Plant for the Gujarat Mineral Development Corporation at Kadipani, by pelletizing technique and an investigation report was prepared earlier. Briquetting tests were carried out for the metallurgical grade concentrate from G.M.D.C. using the continuous briquetting press. With 3% lime and 6% molasses the briquettes at 20 tonnes pressure were good but the residual strength in dried briquettes kept over water deteriorated to 2.55 tonnes.

3.0 Recovery of Cu, Mo, Ni from Uranium Ore from Jaduguda Uranium Ore. Sponsored by Uranium Corporation of India.

The sample as received assayed 0.14% Cu, 0.17% Ni, 0.21% Mo, 68.3% SiO_2 , 7.32% Al_2O_3 , trace CaO, trace MgO, 7.41% Fe, 1.08% P_2O_5 and 1.1% sulphur. The pilot plant studies were aimed at floating selectivity molybdenite using fuel oil and cresylic acid in combination with or without sodium cyanide, for depressing the copper and nickel sulphide minerals followed by recovery of Cu, Ni minerals by conventional xanthate flotation. The pilot plant operation comprised of the following different runs:

Run No. 1. Selective flotation of Mo without using sodium cyanide followed by subsequent flotation of Cu, Ni minerals from the rougher Mo trials yielded (i) a rougher Mo concentrate assaying 1.49% Mo, 5.99% Cu and 3.3% Ni, with recoveries of 15.8% Mo, 31.2% Cu and 14.2% Ni in it, and (ii) a rougher Cu-Ni concentrate assaying 1.16% Cu, 1.5% Ni and 0.12% Mo with recovery 28.3% Cu, 31.6% Ni and 19.5% Mo in it.

Run No. 2. Selective flotation of Mo using sodium cyanide followed by subsequent flotation of Cu-Ni minerals from the rougher Mo tails yielded a rougher Mo concentrate assaying 35% Mo, 6.6% Cu, and 2.5% Ni with recoveries of 73.3% Mo, 53.7% Cu and 16.8% Ni respectively.

Run No. 3. Five cleanings of the rougher molybdenum concentrate using 0.25 Kg/tonne of NaCN added in stages yielded a cleaner Mo concentrate assaying 31.54% Mo, 1.1% Cu and 0.35% Ni with recoveries of 45.1% Mo, 0.2% Cu and 0.1% Ni. One cleaning of rougher Cu-Ni concentrate produced a cleaner Cu-Ni concentrate which when mixed with 1st cleaner Mo tails assayed 3.28% Cu, 2.67% Ni and 0.22% Mo with recoveries of 45.9% Cu, 30.5% Ni and 20.4% Mo in it.

3.1 Beneficiation of Low Grade Copper Ore from Nallakonda Block, Agnigundala area, Guntur Dist., Andhra Pradesh.

The sample as received assayed 0.92% Cu, 0.65% S, 2.78% Fe, 72.4% SiO_2 , 3.36% Al_2O_3 , 3.54% MgO, 0.07% CO_2 and 16.0 gm Ag/tonne of ore.

It was a lean copper ore. A grade of 26.6% Cu with a copper recovery of 88.9% was obtained.

3.2 Beneficiation of Low Grade Copper Ore from Dhukunda Block, Agnigundala Area, Andhra Pradesh.

The sample as received assayed 1.2% Cu. Flotation tests after grinding the sample to 43% - 200 mesh yielded a copper concentrate assaying 13.3% Cu with 88.2% recovery. Variation of *pH* showed that the loss of Cu in the tailings increased with increased addition of lime. Further tests are in progress.

4.0 Beneficiation Studies on a Low-grade Nickeliferous Laterite from Sukhinda, Orissa. *Sponsored by Geological Survey of India.*

A low grade nickeliferous laterite sample from Sukhinda, Orissa, assaying 1.0% Ni, 1.9% Cr₂O₃, 72.8% Fe₂O₃, 0.62% Mn, 0.43% S, 4.98% SiO₂ and 4.66% Al₂O₃ with traces of Co and Cu was received from Geological Survey of India, Eastern Circle, for beneficiation studies. The sample consisted essentially of goethite with minor amounts of clay, hematite, chromite, quartz, etc. The presence of any nickel mineral could not be conclusively established by petrological studies. High intensity magnetic separation studies undertaken on a -10 mesh deslimed sample, did not yield satisfactory results. Reduction roast followed by wet magnetic separation of the reduced material at 65 and 200 mesh sizes also did not give encouraging results. The results of tabling of the reduced material at 48 and 100 mesh sizes were also not satisfactory. Xanthate and anionic flotation tests were also performed to float off the nickel minerals from the sample but without success. The nickel was found to be uniformly distributed in all the products indicating that the ore was not amenable to concentration by any of the normal ore-dressing methods.

5.0 Beneficiation of Low-grade Galena from Bandalamottu Block, Agnigundala Area, Andhra Pradesh. *Sponsored by Geological Survey of India.*

A sample of low grade galena from Bandalamottu Block, Agnigundala area, Andhra Pradesh, was received from the Geological Survey of India, for beneficiation studies. The sample as received assayed 6.2% Pb, 1.87% S, 4.77% Fe, 11.55% SiO₂, 22.86% CaO, 13.82% MgO and 11.5 gm/tonne of Ag. Galena was the chief sulphide mineral in the sample and dolomitic limestone and quartz constituted the principal gangue. Most of the galena was liberated at -100 mesh size.

Flotation employing a feed of 62.4% - 200 mesh using potassium ethyl xanthate and cresylic acid yielded a rougher concentrate assaying 60.4% Pb

with a recovery of 98.1%. One cleaning of the rougher float improved the grade to 73.9% Pb with a recovery of 95.2% Pb in it. The concentrate was suitable for the extraction of metallic lead and also contained silver as a valuable by-product.

6.0 Beneficiation of a Complex Copper-Lead-Zinc Ore from Dariba—Rajpura Area, Rajasthan. *Sponsored by Geological Survey of India.*

A sample of low grade Cu-Pb-Zn ore from Dariba-Rajpura area, assaying 0.99% Cu, 4.8% Zn, 3.7% Pb, 4.2% Fe, 6.2% S, 47.5% SiO_2 and 1.3% Al_2O_3 was received from Geological Survey of India for beneficiation tests. Chalcopyrite, Galena, sphalerite, pyrite and pyrrhotite were the chief sulphide minerals whereas quartz and calcite with minor amounts of mica, chlorite etc. constituted the gangue. The Cu, Pb and Zn minerals were fairly free from the gangue at about 100 mesh for production of satisfactory grades of Cu, Pb and Zn concentrates.

Bulk flotation of Cu-Pb minerals followed by repeated cleanings of the Cu-Pb float yielded Cu and Pb concentrates analysing 24.6% Cu and 63.49% Pb with recoveries of the order of 70.5% Cu and 92.2% Pb respectively. Activation of sphalerite from the Cu-Pb tailings followed by repeated cleanings yielded a Zn concentrate analysing 53.52% Zn with a recovery of 82.5% Zn. A pyrite-pyrrhotite concentrate analysing 37.95% S and having a wt.% of 3.2 was also recovered from the tailings after Zn flotation. Increased recoveries of Cu, P and Zn in the final concentrates are expected in practice by recirculating the respective refloat tailings in the circuit.

7.0 Beneficiation of Phosphate Rock Sample from Kanpur Block of Udaipur Dist., Rajasthan. *Sponsored by Geological Survey of India.*

A sample of phosphate collected from 'Kanpur Block' in Udaipur District, Rajasthan and received from Geological Survey of India, assayed 12.66% P_2O_5 , 8.2% SiO_2 , 0.26% Al_2O_3 , 39.6% CaO, 9.65% MgO, 24.77% CO_2 and 27.32% L.O.I. with traces of FeO, Cl and Cu. Apatite and collophane were the chief phosphate minerals with calcite and quartz as principal gangue. Good liberation of phosphate from gangue was observed at —150 mesh. Flotation with a feed containing 97.3% —200 mesh and employing tall oil as collector and sodium silicate in combination with quebracho as gangue depressant yielded a rougher float assaying 15.55% P_2O_5 with a recovery of 92.3% P_2O_5 in it. Four cleanings of the rougher float employing 0.85 Kg/tonne of sodium silicate produced a refloat concentrate assaying 30.4% P_2O_5 , 0.53% SiO_2 , 48.2% CaO, and 16.25% CO_2 with a recovery of 66.5% P_2O_5 in it. Flotation with the calcined sample after removal of lime followed by two cleanings yielded a refloat concentrate assaying 34.06% P_2O_5 with a recovery of 58.1% P_2O_5 .

Although the refloat concentrate produced was of a fairly good grade, the recovery of P_2O_5 in it was low. Several tests were performed to improve the recovery as well as the grade but without success. This was due to high calcite content of the sample.

7.1 Beneficiation of a Phosphate Rock from Kataria Hill, Udaipur Dist., Rajasthan. *Sponsored by Directorate of Mines & Geology, Govt. of Rajasthan.*

A sample of low grade phosphate rock from Kataria Hill mine in Udaipur Dist., received through the Director of Mines and Geology, Govt. of Rajasthan, assayed 9.8% P_2O_5 , 23.6% SiO_2 , 0.59% Al_2O_3 , 1.1% Fe, 0.6% FeO, 17.3% CO_2 , 28.8% CaO, 11.8% MgO, 1.1% F and 0.5% SO_3 . The sample was subjected to exhaustive beneficiation studies with a view to produce a phosphate concentrate suitable for fertilizer use. Collophane and apatite were the chief phosphate minerals with dolomite, calcite and quartz as gangue. Even though a fair liberation of phosphate minerals occurred at about 150 mesh, the presence of fine inclusions of gangue in collophane and apatite indicated that production of a high grade P_2O_5 concentrate was unlikely by ore dressing methods. Heavy media separation tests performed on a $-1/2"$ (12.7 mm) sample did not give encouraging results. A number of fatty acid flotation tests employing several reagents as depressants for calcite and siliceous gangue were also performed but with no success. Calcination of the sample at about $1000^\circ C$ followed by slaking and desliming rejected most of the lime in the slime. Subsequent flotation of sand fraction after grinding to 78% -200 mesh yielded a phosphate concentrate assaying 34.27% P_2O_5 with a recovery of about 70% P_2O_5 in it. The concentrate is almost of a grade suitable for fertilizer use.

8.0 Batch and Pilot Plant Beneficiation Studies on a Low-grade Limestone Sample from Tal, Garhwal Dist., U.P. and Proposals for Setting up of a 1200 Tonnes Per Day Beneficiation Plant. *Sponsored by Directorate of Geology & Mining, Govt. of U.P.*

145 tonnes of low grade limestone sample from Tal, Garhwal District, U.P. were received from the Directorate of Geology and Mining, U.P. for beneficiation studies with a view to produce concentrate suitable for the manufacture of cement. The sample, as received, assayed 38.07% CaO, 24.28% SiO_2 , 2.76% Al_2O_3 and 2.10% Fe_2O_3 . Petrological examination of the sample showed that it was to be crushed to about 100 mesh size for liberation of calcite from the gangue.

Batch tests with the sample ground to 81% -200 mesh using oleic acid emulsion as collector and sodium silicate as depressant for gangue minerals yielded a calcite concentrate assaying 46.4% CaO, 8.4% SiO_2 with a recovery

of 97.2% CaO. Use of soap and rosin as collector also yielded a concentrate assaying 46.5% CaO, 12.2% insolubles, with a recovery of 97.3% CaO. Based on the results of batch tests, a flowsheet was developed for pilot plant operation, where large scale trials produced a concentrate assaying 46.4% CaO, 10.5% SiO₂ with a recovery of about 92% CaO. Design data for installation of a beneficiation plant suitable for treating 1200 tonnes of the sample per day were also worked out.

9.0 Pilot Plant Studies on Beneficiation of Amjhore Pyrite Employing Heavy Media Separation and Jigging and Proposals for Setting up a 1600 Tonnes/Day Treatment Plant. *Sponsored by M/s. Pyrites, Phosphates & Chemical Ltd.*

M/s. Pyrites, Phosphates & Chemicals Ltd., propose to instal a beneficiation plant to separate shale getting admixed with pyrite during mining operations at Amjhore, Bihar. The upgraded pyrite will be used by the Fertiliser Corporation of India, Sindri, for manufacture of sulphuric acid. Several samples of low grade pyrite from the deposit were tested earlier employing HMS treatment on batch scale and results were furnished. This work involved treatment of about 280 tonnes of low grade pyrite from Amjhore, in the heavy media separation pilot plant of the Laboratory. On the basis of the work done, a flow sheet was recommended and details of equipment for setting up a plant to treat 1600 tonnes of R.O.M. ore per day for producing 450 tonnes of concentrate including the cost of beneficiation were worked out.

10.0 Beneficiation of Pyrite-Pyrrhotite Sample from Saladipura, Rajasthan. *Sponsored by Geological Survey of India.*

A low grade pyrite-pyrrhotite sample from Saladipura area, Dt. Sikar, Rajasthan, assaying 16.2% S, 20.07% Fe, 1.6% Zn, 0.3% Cu, and 38.3% SiO₂ was received from Geological Survey of India, Rajasthan Circle, for beneficiation studies for the recovery of sulphur and also for the recovery of zinc as a by-product. Pyrite and pyrrhotite were the main metallic minerals in the ore followed by sphalerite and chalcopyrite. Non-metallic gangue consisted mostly of quartz.

Flotation employing 91% —200 mesh grind at 6.8 pH and using potassium ethyl xanthate and pine oil produced a bulk concentrate assaying 33.0% S with a recovery of 91% S in the concentrate. Three cleanings of the bulk concentrate produced a concentrate assaying 41.3% S with a recovery of 66.0% S. Attempts to recover zinc from the bulk concentrate were not successful.

11.0 Beneficiation of Graphite Sample from Sitampalli Mines, Andhra Pradesh. *Sponsored by M/s. S. Lal & Co., Calcutta.*

A low grade graphite sample from Sitampalli area, Andhra Pradesh, was received from M/s. S. Lal & Co., Calcutta, for beneficiation studies with a view

to produce a concentrate assaying at least 80% C and 3% volatile matter. The sample as received assayed 17.0% C, 79.9% ash, 2.5% volatile matter, 0.56% moisture, 0.19% S and 20.42% Fe in ash. Garnet was the principal gangue in the sample. Graphite was fairly liberated from the gangue at -150 mesh size.

Flotation employing a feed of 55% -200 mesh using kerosene oil as collector, after two cleanings yielded a graphite concentrate assaying 82% C and 2.16% volatile matter with a recovery of 91.5% C. The concentrate satisfied the grade requirements laid down by M/s. S. Lal & Co., Calcutta. Four cleanings of the rougher float improved the grade to 85.24% C and 2.09% volatile matter but with a lower recovery of 76.4% C. Regrinding the rougher float followed by four cleanings yielded a concentrate assaying 87.35% C with a recovery of only 67.8% C.

11.1 Beneficiation of Graphite Sample from Khepchisbi Hill, Bhutan. *Sponsored by Geological Survey of India.*

Beneficiation studies were undertaken on a low grade graphite sample from Khepchisbi hill of Bhutan, received from Director, Geological Survey of India, Bhutan Circle, Jalpaiguri Dt. West Bengal; with a view to produce a concentrate suitable for use in industry. The sample as received assayed 10.66% fixed carbon, 86.4% ash, 2.94 volatile matter, 0.66% moisture, 0.18% sulphur, 1.7% Fe in ash, 0.027% P_2O_5 and 1.1% TiO_2 . Rougher flotation using pine oil as collector frother followed by three cleanings of the rougher concentrate, yielded a graphite concentrate assaying 63.4% F.C. and 2.5% volatile matter, with a recovery of 78% C. The concentrate although very fine could perhaps be used for foundry facings and paint manufacturing purposes.

12.0 Purification of Zircon Concentrate from Kerala. *Sponsored by M/S. Hindustan Sanitaryware & Industries Ltd., Haryana.*

A sample of zircon sand concentrate was received from M/s. Hindustan Sanitaryware & Industries Ltd. with a request to study the possibility of up-grading it so as to make it suitable for manufacture of superior glaze. The sample as received contained some altered ilmenite, monazite, sillimanite and other grains as impurities together with some slightly coloured zircon grains constituting in all to about 2% of the total by weight. By a close sizing at 65 mesh or 100 mesh and high tension separation in two stages, a clean zircon product was obtained with 0.15% Fe, 0.39% Al_2O_3 and 0.01% soluble Fe with traces of TiO_2 and rare earth oxides. Magnetic separation, washing and gravity separation did not show any substantial improvement.

13.0 Beneficiation of a Kyanite-Sillimanite Sample from Dahagaon Area, Nagpur. *Sponsored by Directorate of Geology & Mining., Govt. of Maharashtra.*

A sample of the low grade kyanite-sillimanite designated D3S2 and received from the Director of Geology and Mining, Government of Maharashtra, Nagpur, was subjected to exhaustive beneficiation studies. The sample assayed 38.40% Al_2O_3 , 52.0% SiO_2 , 0.35% TiO_2 , 0.95% MgO , 0.37% Fe_2O_3 , 1.60% CaO , 1.27% $\text{Na}_2\text{O} + \text{K}_2\text{O}$ and 5% L.O.I. Muscovite and quartz were the major gangue minerals followed by minor amounts of tourmaline, rutile and opaques. Kyanite-sillimanite was fairly free from these minerals at about 100 mesh size. Gravity and flotation methods were employed for removal of the gangue minerals from kyanite. Tabling of the sample after hydro-classification at 65 and 100 mesh sizes did not produce a high grade kyanite concentrate. Tabling of a -65 mesh sample after close sizing also did not produce a satisfactory grade of kyanite concentrate. Air classification was also attempted for removal of muscovite from kyanite but without much success. Anionic flotation at a pH of 3.0, employing sodium sulfonate as collector for kyanite and citric acid and lactic acid as gangue depressants, followed by repeated cleanings yielded a kyanite concentrate assaying 59.90% Al_2O_3 , 36.6% SiO_2 , 0.71% TiO_2 , 0.4% MgO , 0.35% Fe_2O_3 , 0.7% CaO , trace % $\text{Na}_2\text{O} + \text{K}_2\text{O}$, with a kyanite recovery of 46%. Recirculation of the middlings is expected to improve the final kyanite recovery to about 66% for almost the same grade of concentrate. The concentrate satisfied the grade 'A' of ASTM requirements laid down for its use in refractories. Cationic flotation employing Aeromine 3037 at a pH of 5.5 for removal of muscovite followed by anionic flotation of kyanite using sodium sulfonate, produced a kyanite concentrate assaying 59.61% Al_2O_3 with a recovery of 52.80% kyanite.

14.0 Magnetic separation of Copper Tailings. *Sponsored by Indian Copper Corporation Ltd., Ghatsila.*

Attempts were made to recover magnetite from the I.C.C. tailings that contained upto 2.44% magnetite. Rougher wet magnetic separation employing drum separators followed by one cleaning had recovered upto 75% magnetite producing a magnetite concentrate assaying about 60% Fe.

15.0 Determination of Work Index and Rate of Settling and Filtration of Three Iron Ore Concentrates. *Sponsored by National Mineral Development Corporation.*

Grinding tests indicated that the work index values of three test samples varied between 23.81 KWH/tonne and 26.35 KWH/tonne. The settling tests

of the concentrates ground to —250 mesh size indicated the minimum area required for settling one tonne of dry solids to be varying between 0.058 and 0.08 sq. meter. The filtration tests of the concentrates ground to —250 mesh size and containing 60% solids indicated the filtration rates to be 879.7, 550.6 and 736.5 kg/hr/sq. meter of filter area of concentrates 1, 2 and 3 respectively.

16.0 Beneficiation of Low grade Magnesite from Ajmer, Rajasthan.

The sample as received assayed 41.6% MgO, 3.65% CaO, 43.8% CO₂, 9.2% SiO₂, 0.59% Al₂O₃ and 0.65% Fe. Few anionic flotation tests were conducted using oleic acid as collector for magnesite and sodium silicate as depressant for silica. The tests were conducted at different grinds to arrive at an optimum grind. The work is under progress.

17.0 Production of High Carbon Ferro-Manganese Using Low Temperature Carbonized Coke of Katkona Collieries of Madhya Pradesh.

Sponsored by Madhya Pradesh Audyogik Vikas Nigam Ltd.

Smelting studies were undertaken on the production of standard grades of high-carbon ferro-manganese using low temperature carbonization coke of Katkona Collieries of Madhya Pradesh with a view to limit the phosphorus content to less than 0.15% in the ferro-manganese. The smelting trials for the production of ferro-manganese by flux process was carried out in the 500 KVA submerged arc furnace.

From the various parameters studied in the production of high-carbon ferro-manganese in the pilot electric submerged arc furnace of 500 KVA capacity, the following conclusions were drawn.

- (i) Basic performance data were obtained in the production of high carbon ferro-manganese containing Mn 73.60—75.5%, Si 0.6—1.5% and C 6.0—7.0% using Durgapur coke as the reducing agent. A power consumption of 2878 KWH per tonne of ferro-manganese was obtained.
- (ii) The Durgapur coke was gradually replaced by 33%, 66% and 100% respectively by L.T.C. coke of Katkona seam No. 3 when comparatively good performance of the furnace was obtained. Ferro-manganese containing Mn 75.86—76.16%, Si 0.2—0.49% and C 6.8—7.2% was produced with a power consumption of 2733 KWH per tonne of ferro-manganese.

- (iii) The addition of Katkona L.T.C. coke required an additional excess of coke to account for its surface oxidation due to its higher reactivity.
- (iv). The phosphorus content of the ferro-manganese was 0.12 to 0.14%. Since 75% of the phosphorus input was derived from the manganese ore and the rest from the L.T.C. coke, the low P content of the coke was highly advantageous in keeping the P content of the ferro-manganese to less than 0.13%.
- (v) The use of L.T.C. coke of Katkona Seam No. 1 and No. 3 in the high carbon ferro-manganese production by electric smelting was found to offer many advantages viz smooth operation of the furnace with good tapping of metal and slag, low phosphorus content of the ferro-manganese. The comparatively lower Fe_2O_3 content of the ash of the L.T.C. coke would help in increasing the Mn/Fe ratio of the ferro-manganese. However this effect was off set by the lower Mn/Fe ratio of the manganese ore employed during this investigation. The extra additions of the L.T.C. coke required to compensate for air oxidation would decrease in full scale commercial units.
- (vi) Since the ore contained a lower amount of Al_2O_3 , the slag compositions during this investigation was found to be in the mellilite region within the 1400°C liquidus line in the $\text{CaO-MgO-SiO}_2\text{-10\% Al}_2\text{O}_3$ phase diagram and as a result, the slag was found very fluid and ferro-manganese containing low silicon content of 0.2—0.6% was produced with power consumption varying between 2733 KWH to 3290 KWH per tonne of ferro-manganese.
- (vii) 80% of the Mn fed to the furnace was recovered in the ferro-manganese, 15% was lost in the slag. 5% of Mn was lost in the form of dust, fume and metallic vapours.

18.0 Production of Ferro-Silico-Zirconium. *Sponsored by Alloy Steel Project, Durgapur.*

Work was taken up to produce one tonne of ferro-silico-zirconium at the instance of Alloy Steel Project, Durgapur.

Based on laboratory scale investigations on the production of ferro-silico-zirconium by alumino-thermic process, large scale production was undertaken to produce ferro-silico-zirconium containing 27.0—28.0% Zr, 16—18% Si, 4—6% Al. Zircon sand, iron ore and aluminium powder with energiser and

flux were the raw materials employed. One tonne of ferro-silico-zirconium was produced and supplied to Alloy Steel Project.

19.0 Production of Aluminium—10% Titanium Hardener Alloy. *Sponsored by Defence Establishment, Govt. of India.*

Work was taken up to produce 100 Kg of aluminium-10% titanium hardener alloy for Defence establishment.

Initially aluminium-titanium master alloys containing 55% titanium was produced by aluminothermic process using rutile, aluminium powder and an energiser. The master alloy was subsequently melted with aluminium at 1300°C, in an indirect arc furnace. The resulting aluminium titanium alloy contained 10—12% titanium.

20.0 Production of Nitrided Low Carbon Ferro-Chrome. *Sponsored by Alloy Steel Project, Durgapur.*

Work was taken up to produce 900 Kg of nitrided low carbon ferro-chrome at the instance of Alloy Steel Project, Durgapur.

Earlier, Laboratory scale investigations had shown that low carbon ferro-chrome can be nitrided with nitrogen gas in the solid state to pick up nitrogen from 4 to 6% depending on the particle size, temperature and duration of the nitriding.

21.0 Stabilisation of Ferro-Silicon Powder.

Ordinary ferro-silicon when used as a coating for the welding electrodes results in gaseous evolution during drying and storage and thus breaks the coatings. Studies were undertaken to stabilise ferro-silicon so that the welding electrodes do not break during manufacture.

A number of experiments were carried out using various gaseous and liquid reactants and it has been observed that ferro-silicon can be stabilised by heating the powder in presence of oxygen for 2 hours at 1050°C. Oxygen was found to be most suitable for stabilizing, since the same degree of stabilisation is attained in a shorter period in comparison to the other oxidising gases.

22.0 Fluo-Solid Roasting of Sikkim Complex Sulphide Concentrate.

Fluo-solid roasting of sulphide concentrates has been increasingly used as it helps in the production of high SO₂ containing flue gases coupled with uniformity in gas and calcine composition, and better heat transfer conditions

which prevail throughout the bed. Systematic studies were taken up on the roasting of complex sulphide concentrate from Sikkim.

From the continuous fluidisation experiments carried out at 750°—925°K, reported earlier, it was observed that maximum recovery of Cu and Zn was obtained in the temperature range of 875°—900°K. Further investigations were continued to study the kinetics of roasting for maximum dissolution of copper and zinc by roasting at 900°K.

The optimum values obtained with 6 cm dia. fluo-solid reactor are now being simulated on the 6 inch dia. Dorco-fluo-solid roaster to serve as pilot plant scale testing. Initial experimental runs carried out indicate good corroboration of data obtained from the bench scale continuous fluo-solid roasting tests. Further work is in progress.

23.0 Studies on the Extraction of Nickel from Low Grade Nickeliferous Limonitic Ore from Surabil—Sukharangi—Kumardah Sector, Orissa.

Several deposits of lateritic and serpentinous nickel ores have been discovered and explored during the recent years by Geological Survey of India. Owing to the strategic importance of nickel and cobalt, the recovery of Ni and Co from these ores is of paramount importance and systematic investigations are in progress to study the extraction characteristics of Ni and Co from the ore received from Surabil—Sukharangi-Kumardah sector of Orissa.

Light grade nickeliferous ore from Surabil—Sukharangi—Kumardah sector, Orissa, contained 1.36% NiO, 0.085% CaO, 0.067% Co, 53.76% Fe, 5.38% Cr₂O₃, 2.78% SiO₂, 0.20% Al₂O₃, 0.60% MnO, 1.124% MgO, with trace of Cu. The maximum nickel recovery of 88% was obtained by reducing the ore at 600°C for two hours, followed by preconditioning and ammonical leaching at room temperature at atmospheric pressure. Systematic study for Co recovery is under progress.

24.0 Utilization of Jadugoda Ni-Cu-Mo Concentrate.

Low grade nickel-copper-molybdenum deposits are found in Jadugoda area in Singhbhum district and in view of the strategic importance of nickel, copper and molybdenum, the recovery as well as separation of the metallic values from the concentrate is of great importance. Systematic investigations are being carried out to study the extraction characteristics of nickel, copper and molybdenum from the concentrate received from Jadugoda mines, Bihar, by sulphation and ammonical pressure leaching.

The concentrate containing 1.56% Ni, 0.94% Cu, 0.28% Mo, 54.12%

SiO₂, 9.88% Al₂O₃, 16.96% F₂O₃, 3.90% MgO, 0.56% CaO, 5.40% S and 1.40% P₂O₅ was roasted to extract Ni, Cu and Mo. It was found that 93.01% Ni, 88.53% Cu and 30.70% Mo could be recovered by pressure leaching at 100°C for 2 hours. By pressure leaching at 150°C for 2 hours molybdenum recovery increased to 69.6% but nickel and copper recovery decreased to 17.7% and 53.76% respectively.

25.0 Recovery of Vanadium from Vanadium Bearing Pig Iron by an Oxidising Slag.

Vanadium bearing titaniferous magnetites can be smelted to produce pig iron, transferring 80—85% of vanadium from the ore. Such pig iron can be treated under oxidising conditions to recover vanadium in the slag. Systematic studies were taken up to determine the optimum conditions to recover vanadium by treating the pig iron with oxidising slag.

The oxidation of vanadium from the pig iron containing 0.35—2.3% V was investigated by melting the same in a magnesia crucible in an induction furnace. The slag contained limestone, quartzite and varying amounts of iron oxides. Studies were made at 1350°C and it was observed that a maximum of 90% vanadium can be recovered from the pig iron (containing 0.35% V) by 200 gm of mill scale per kg of metal and 80% vanadium recovery was achieved at a slag basicity of 1.1.

26.0 Recovery of Selenium and Tellurium from Electrolytic Copper Slimes.

Anode slime of the electrolytic copper refinery is an important source of selenium and tellurium metals and with a view to produce these rare metals indigenously, systematic study on the recovery of selenium and tellurium from the slimes of the copper refinery of Indian Copper Corporation was taken up.

The slime used for recovering the metallic values analysed: Se—8.3%, Te—6.2%, Cu—14.2%, Ni—33.7%, Ag—1.58%, As—5.44%, Au—0.0928%, Fe—0.51%, SiO₂—6.5%, and S—3.76%.

Larger scale experiments using 100 to 500 gm of slime were carried out and the data obtained on laboratory scale experiments were confirmed. Experiments on 5 kg scale are being planned.

27.0 Recovery of Germanium from Coal Ash.

Germanium occurs as a minor constituent in coals and is generally discarded in coal ashes. In view of its increasing importance in the electronic

industry for making transistors, studies were undertaken for the extraction of germanium from coal ashes. Smelting of germanium with lime, soda and coke and copper oxide is being investigated. The regulus so obtained will be chlorinated to recover germanium as tetrachloride.

28.0 Preparation of Anhydrous Magnesium Chloride.

Anhydrous magnesium chloride is used as a fluxing material and as a feed material for electrolytic cells. Work was taken up with a view to examine possibilities of preparing anhydrous magnesium chloride from indigenous raw materials. The investigation is related with the work on preparation of metal halides and electro-chemical extraction of metals from fused salts.

The preparation of anhydrous magnesium chloride by chlorinating mixture of calcined Salem magnesite and calcined petroleum coke in the shape of briquettes and pellets was completed and the optimum conditions were earlier reported. Work was continued using mixture of uncalcined Salem magnesite with (i) calcined petroleum coke (ii) raw petroleum coke. The physical properties of the pellets prepared by varying (i) the quantity of binder and (ii) rolling time were measured and pellets then chlorinated in an externally heated furnace with silica tube reactor. Further work is in progress.

29.0 Production of Fluorine Chemicals for Metallurgical Use—Preparation of Synthetic Cryolite.

Studies on the properties and composition of synthetic cryolite and collection of relevant process data were continued. A scheme of experiments to determine material balance for each cycle, upto 20 cycles was undertaken. Reproducible data were obtained for six such cycles with fairly steady output of product having compositions within permissible range. Further work is in progress.

29.1 Preparation of Aluminium Fluoride.

Aluminium fluoride is a white crystalline solid. Its major use is in the manufacture and refining of aluminium as a component of the electrolyte. Nearly 58 lb of aluminium fluoride is consumed per ton of aluminium produced. To meet the growing needs of the indigenous aluminium industry, large quantities of this material are being imported at present.

Experiments were conducted for the decomposition of ammonium—aluminium—fluoride with varying time of decomposition, keeping the temperature constant. A high grade aluminium fluoride product was obtained containing small amounts of alumina which is not detrimental so far as it is used for the aluminium reduction cell. Further work is in progress.

30.0 Development of Stainless Steel.

Cr: Mn: N stainless steel heats at levels of Cr 17%, Mn 10% and 12%, nitrogen 0.4% and 0.3% and copper 3% were made in 6 KW high frequency furnace and hot-worked into slabs. Their hardness values were determined in the solution treated condition. A number of specimen were cut from the bars of different steels after forging and were solution treated at 1100°C. The solution treated specimen were aged at different temperatures and varying duration of time. The hardness of the specimen did not show any change after aging. Metallography samples were also prepared and they are being examined.

Four 10 kg heats of Cr: Mn: N stainless steels were made and were cast into moulds having different cooling rates. The ingots thus obtained were sectioned to study the distribution of blow-holes caused by nitrogen rejection during solidification of the ingot. All the ingots were cast with hot tops.

31.0 Development of Substitute High Strength Steel.

(i) Maraging Type Steel

The object of this investigation is to study the exact mechanism of strengthening of martensite in maraging steels and to study the effect on such reactions by replacing nickel, molybdenum and cobalt by manganese, titanium etc.

Six more alloys were prepared having 5—12% Ni, 5—12% Mn, 0—4% Mo, 0—8% Co, 0—4% Ti. X-ray diffraction, metallographic and electron microscopic studies on the maraging characteristics of these alloys were carried out on solution treated and 400° and 500°C aged samples. Mechanical properties of the aged samples were also examined. In this series of alloy only two alloys having 12% Ni, 5% Mn., 5% Mo., 8.5% Co and 12% Ni, 5% Mn, 3% Ti, 9.5% Co showed complete martensite structure on solution treatment and very high increase in hardness on ageing. The rest of the alloys, containing 5% Ni and 12% Mn with or without addition of molybdenum or titanium showed either austenitic or duplex structure on solution treatment. Studies carried out at subzero temperature (upto—180°C) on the transformation of martensite showed some interesting and encouraging results. Further work is in progress.

(ii) Low Cost Maraging Steels

The conventional maraging steels contain 18% nickel and other alloying elements such as molybdenum and cobalt which make the steel highly expensive. Development work was taken up on a low cost iron-copper base maraging

steel. In continuation of the previous work, strength and impact properties of five steels in the hardened and aged conditions were determined. Metallographic examination indicated the steel matrix to be of a mixed bainitic and martensitic structure. Electron micrographs revealed precipitation of epsilon copper in the matrix. Poor impact properties showed by the steels, which could not be improved by additions of molybdenum and niobium, was attributed to the mixed structure of the matrix. Further work is in progress.

(iii) *Thermo-mechanically Treated High Strength Low-alloy Steel*

Thermo-mechanical techniques developed recently aims at the production of substitute ultra high strength steels employing low alloy additions to reduce the high cost of expensive alloys. Work was taken up in this aspect on low alloy steels.

Detailed study on the structure and nature of the phases and their morphology was carried out on the thermo-mechanically treated low alloy steels containing 0.4% C; 3% Cr, 1.5% S, 4% Mn and 0.5% Mo. The electron fractography of the broken test pieces showed fine microcracks throughout the fine martensite structure which were assigned to be the cause of lower mechanical properties of most of the treated steels. Before carrying out further work on low temperature ausforming treatment (between 450°-500°C) investigations are being done on the prepared ingots for the cause of such defects.

32.0 Carburizing of Grain-refined Steels at Higher Temperature.

In recent years, an improved variety of mild steels with residual amount of Nb additions has come into existence as an important type of structural steels. These Nb-treated steels are fine-grained steels with yield stress higher than that of mild steels. These NbC(N) precipitates are very much resistant to growth and therefore it is believed that even after long carburising treatments the fine-grained structure with the associated toughness would be retained.

Six heats were made in basic lined high frequency induction furnace. The ingots were forged at 1200°C into $\frac{3}{4}$ " and 1 $\frac{1}{4}$ " sq. bars. The forged specimens were normalized at 900°C and grain sizes of these specimens were determined. Samples from the steels will be case hardened at temperatures between 930°C to 1100°C and mechanical properties and the mass effect of the core materials will be determined. Grain growth characteristics, transformation characteristics by continuous cooling of the steels and the structure and hardness of cementation layer will also be investigated.

33.0 Structure and Properties of 9 Percent Nickel Steel.

Work on the development of cryogenic steels for use at sub-zero tem-

perature was undertaken with a view to study (i) the mechanism by which the established cryogenic steels (especially 9% nickel steel) derive their cryogenic properties and (ii) to develop cryogenic steels based on indigenous alloying elements.

The work on (i) was carried out on 9% nickel steel which has gained prominence as a steel suitable for low temperature application. Structural features responsible for good sub-zero temperature impact properties of 9% nickel steels were studied. Further work is in progress.

34.0 Development of Cast Tools of 18-4-1 Type High Speed Steels.

This project aims at development of processes (i) to make cutting tools, die blocks etc. in as-cast condition in graphite and shell moulds, followed by various heat-treatments to get optimum conditions and mechanical properties for use as cutting tools, and (ii) to make cast milling cutters, cutters, reamers and other cutting tools by shell-moulding and Shaw processes.

The development of cast cutting tools is a two phase problem :

- (a) Casting of the cutting tools such as milling cutters, lathe tools etc. in the final shape; and
- (b) Heat treatment of the as-cast tools to achieve the required properties.

Different sets of parameters are under investigation to determine the optimum conditions for getting good surface finish of the cutter.

34.1 Development of Tool Steel.

After fundamental investigation essentially on the Fe-Ti system a few compositions were selected for the possible development into tool steels. Earlier their precipitation hardening characteristics were investigated with a view to define optimum heat treatment. The composition which yielded maximum hardening was designated as PM-501. During the year the stability of the structure after developing optimum hardness was investigated by keeping the specimens at 450, 500 and 550°C for periods upto 50 hours. It was observed that the structure was stable and hardness did not decrease on holding the specimens at elevated temperatures for periods upto 25 hours. Further work is in progress.

35.0 Ausforming of Spring Steel.

This work was undertaken with a view to achieve high strengths coupled with equivalent ductility in steels for applications in automotive industries.

Survey of literature on ausforming of different steels was completed and data on mechanical properties etc. were collected. Some ausforming treatments were carried out on Si-Mn steel. It was observed that it was possible to get only about 50% reduction in these samples. Samples (6-8" in length) of Cr-V steels were prepared and annealed for subsequent ausforming treatment.

36.0 Development of Low Alloy High Tensile Structural Steel.

This investigation was taken up to develop structural steels with improved mechanical properties, adequate workability, optimum corrosion resistance and favourable welding characteristics, based essentially on indigenous elements.

The previous experiments were made to improve the properties of the existing low alloy steels by modification in the percentages of the alloying elements so that the amount of pearlite was reduced while strength was increased.

Controlled temperature rolling of the vanadium bearing steel was conducted during the period under review. Rolling was carried out at 950°C and various deformation between 10 to 50% were given by a single pass.

From these rolled plates, tensile and impact test pieces were made from pieces cut parallel to the rolling direction. The tensile test results and the room temperature charpy impact values were determined. Micro structure study, sub-zero impact test and grain size measurements are being carried out. The results show almost no change in the L.Y.S. and U.T.S. values, but small increase in elongation % and RA % with the increase in draft % was observed. Room temperature impact values are quite satisfactory.

37.0 Improved Mild Steels for Structural Purpose.

The object of the investigation is to improve the properties of mild steels by adding residual quantities of alloying elements which while contributing little to the increase in the cost of production would impart pronounced strengthening effect. Strong dependence of yield strength and transition temperature of steels on grain size is well established and consequently among the various methods of strengthening of steels, grain refinement is the only technique which leads to simultaneous improvement of strength and toughness.

Of the various methods available for grain refinement of steels, the following techniques were taken up for study. (i) addition of grain growth restraining elements such as aluminium, titanium, vanadium, niobium etc. (ii) short austenitising treatment cycles.

Studies on grain refinement by the addition of grain growth restraining elements were completed. Studies on short austenitising for the improvement of strength properties are underway on three plain carbon steels of different carbon levels.

38.0 Development of Electrical Resistance Alloys.

The major development work of the project starting from the selection of alloy composition to the final stage of finished products has been already completed and the process has been released for industrial application. During the period under review, work was done to study the welding behaviour of the alloy.

38.1 Development of High Temperature Alloy.

The aim of the project is to develop high temperature alloy suitable for use above 1150°C upto about 1300°C as substitute to the conventional heating elements. Work on similar line under the title 'Electrical Resistance Alloys' has lead to the successful development of one class of heating elements which could be safely used up to the maximum temperature of 1150°C. The present work is also based on Fe-Cr-Al system and is aimed at modifications so as to cover higher temperature range.

Attention has been focussed on the selection of alloy composition which is directed in the range of high Cr and low Al content. The percentage of Cr was chosen above 20% and Al below 5%. With the selected composition range, some heats were prepared in 41b. high frequency furnace. Besides, the straight Al-Cr heats, minute quantity of some other elements i.e. Zr, misch metal, Mg, Nb, W, etc. were added to see the effect on workability.

39.0 Development of Aluminium Base Bearing Alloy.

The project was taken up with a view to develop suitable aluminium base bearing alloys which will replace the conventional hard copper base bearing alloy used as cast and machined and also soft tin or lead base bearing alloy which is bonded to hard backing material.

The work on the development of suitable compositions and their mechanical properties was reported earlier. The Indian Railways have shown interest in this alloy for the manufacture of floating bushes used in locomotive engine and have sent a drawing for the purpose. Suitable experimental alloys were selected on the basis of the working condition of floating bushes in railway engines according to their physical property requirements. Several small heats were made with the selected composition and their antifricition and other

properties, were studied. After achieving the required bearing properties with the composition, several heats of floating bushes, according to the drawing, were made utilising the above composition using gas fired furnace and sand mould. As no casting completely free from blow holes could be made even after adjusting the pouring temperatures and using different kinds of de-oxidiser, the casting procedure was changed. Experiments are being carried out to standardise a technique which will give all the castings free from any casting defect. Experiment on extrudability of the alloy was carried out with success.

40.0 Development of Aluminium Alloy Conductors.

Efforts were directed to develop alloy conductors utilising commercial aluminium and possessing adequate strength and conductivity. In such conductors the strength increases at the expense of conductivity.

Aluminium of 92.2 to 99.3% purity was selected for making the alloy conductors and alloys containing silicon, magnesium and zinc in various amounts, designated PM-51, 52, 53 and 54 were made on laboratory scale. The cast ingots were forged and drawn into 0.36 cm and 0.05 cm dia. wires. Their electrical and mechanical properties were investigated in the cold drawn condition. The study of the effect of heat treatment is in progress.

40.1 Development of Aluminium Cables.

Since laboratory and semi-commercial scale working of the PM-2 conductor has demonstrated its technical superiority over electrical grade aluminium, its commercial production was attempted at the Hirakud Works of the Indian Aluminium Co.; at Kundara and at the Electrical Manufacturing Company, Calcutta. The former employs the Properzi method of casting and rolling of aluminium and the latter employ semi-continuous method of casting ingots which are subsequently hot extruded. In both cases, the products of the Properzi mill or of hot extrusion were successfully drawn into wires.

41.0 Development of Magnetic Materials.

- (i) *To Study the Effect of Application of Magnetic Field During Compacting on the Magnetic Properties of Ferrite Magnets.*

The work has recently been taken up with a view to develop the technical know-how of anisotropic ferrite magnets based upon barium, lead and strontium-ferrite compositions. Two small electromagnets were built to supply the magnetic field to the ferrite powder compaction in a stainless steel die.



A typical heap of PM-2 aluminium Cables developed at NML produced on semi-commercial scale in an aluminium plant.

(ii) *To Study the Effect of Directional Crystallization on the Magnetic Properties of Alnico Alloys.*

The project was recently taken up. A literature report on the subject is under preparation. Necessary raw materials required for the project are being collected.

(iii) *To Study the Magnetic Properties of High Coercivity Ductile Alloys of the Cu-Ni-Fe and Co-Cr-Fe Type.*

Cunife alloys are well known permanent magnet materials which can be rolled into sheets and drawn into wires. Co-Cr-Fe alloys are of more recent origin and have comparatively lower properties. An investigation of preliminary nature was carried out on these alloys with a view to study their workability, and magnetic properties.

(iv) *Magnetic Properties of Co-Al Alloys.*

The specimens of alloys were quenched from a solution temperature of 1380°C, tempered at 525°C for durations upto 200 hours and tested ballistically. In general, the effect of manganese additions was to decrease the coercive force, increase the saturation induction, remanence and energy product. The latter increased from 1.8 mgo for Co-14% Al alloy to 2.0 mgo for Co-14% Al-3.76% Mn alloy. The effect of tempering for increasing durations was to increase the coercive force and energy product upto 100 hours of tempering. The remanence values decreased gradually as tempering time was increased.

42.0 Light Metals and their Alloys.

(i) *Aluminium-Magnesium Alloys.*

The work on the development of high strength, stress corrosion resistant aluminium alloy was continued. More heats of Al-7/8% Mg alloys were prepared with addition of chromium in the range 0.1 to 0.3%, and misch metal in the range 0.3 to 1.6%. The hot working characteristics of the prepared alloys were studied by hot forging and hot rolling in the temperature range of 430°C to 400°C after homogenizing the billets.

Further studies are being continued by making bigger heats to confirm the reproducibility of the results. A prototype stress-corrosion testing machine was designed and fabricated for stress-corrosion studies of the alloys.

(ii) *Aluminium-Silicon Alloys.*

During the course of some experiments of Al-Si alloys, it was observed that samples of sulphur received from different sources behaved differently in

their efficiency of modification. This aspect is being comprehensively pursued with regard to their chemical purity, physical forms by X-ray studies etc.

(iii) *Universal Bath for Electro-Polishing of Aluminium and Aluminium Alloys.*

A bath containing perchloric acid, butyl cellosolve and ethanol has been comprehensively studied for its suitability for electro-polishing of the following :—

1. Super purity aluminium
2. Commercial purity aluminium
3. Duralumin type, Al alloys
4. Al-Mg-Zn alloys
5. Al-Mg-alloys
6. Al-Cu alloys
7. Al-Cr-Ni alloys.

The polishing conditions viz., bath temperature, current density and cell voltage were worked out for each of the alloys mentioned above. Standard voltage/current graphs were prepared for use in the electro polishing of these alloys.

(iv) *Integral Colour Anodizing of Al and Al-alloys.*

With a view to develop a process for the integral colour anodizing of aluminium and its alloys, which would avoid separate colouring of the anodized product, work was initiated to study the various anodizing baths for obtaining different colours during anodizing itself. A preliminary study was made of three different baths. The materials studied for integral colour anodizing were :—

1. Super purity aluminium
2. Commercial aluminium
3. Al-Cr-Ni alloys
4. Al-Si alloys
5. Al-Mg alloys
6. Al-Mg misch metal alloy.

43.0 Production of Copper Powder.

In continuation of the work done earlier, experiments were carried out with a view to study (i) the effect of different acid and copper concentrations on powder characteristics (ii) to produce higher apparent density (2.8 g/cc onward) so that it can disengage automatically from the cathode and (iii) to dry the fine grade copper powder which gets tarnished very quickly.

43.1 Production of Iron Powder by Atomisation.

A comprehensive investigation has been undertaken for production of iron powder by atomisation by suitable atomising agents like water, air, gases and steam. Molten pig iron was employed in the trials to produce iron powder containing 99% Fe.

Different compositions of pig iron were tried. The temperature of the molten metal was maintained at about 1280°C. The chemical analysis of the iron powder obtained was Fe% 90, FeO% 2.16, T.C. 2.48%, Si 4.82%, Mn trace, S% 0.07, P% 0.23. The particle size distribution of the iron powder produced was +7 mesh 1.6%, 7-16 mesh 10.4%, 16-30 mesh 16.9%, 30-60 mesh 14.4%, 60-100 mesh 19.00%, 100-200 mesh 19.3% and -200 mesh 18.1%. The grain shape of 60-100 mesh fraction was mostly rounded with some oval, enlarged and rod like particles. The 100-200 mesh fraction composed of mostly oval, elongated, rod like and curved grains with rounded edges. The -200 mesh size fraction comprised of more rod like, elongated and curved grains.

44.0 Production Technology of Nickel-Silver for Electrical Purposes.

Nickel-silver springs are widely used and has been specially developed with closely controlled constituents, to meet the exacting requirements in the telecommunication industries. The entire requirement of nickel-silver is being made through import. This can be attributed primarily due to the lack of know-how on melting, casting and working techniques. The objective of this project is to develop the technical know-how to study the foundry technology as well as the working by hot and cold rolling. The first phase of this project was devoted in evolving the technique to achieve a sound casting involving close control in the selection of raw-materials, fluxing, deoxidation, pouring temperature etc.

45.0 Development of Electrode Materials for Resistance Welding.

The aim of the project is to develop suitable alloys for use as welding electrodes in resistance welding machines. The essential properties of such an alloy are (a) good electrical conductivity (b) good mechanical strength and hardness at high temperature so that pressure can be applied to the work without deformation at working temperature. Copper and copper alloys in the hardened condition are the materials generally selected for the electrodes. The alloying elements suitable for introducing the desirable properties are known to be Ag, Te, Cd, Cr, Zr, etc. depending on the specific application.

The work was started with copper rich copper-silver alloy. Several

castings were made having various percentages of silver. Hardness values of the alloys were determined and their micro-structures were studied. During the last six months, age-hardening characteristics of the alloys were studied. The alloys were given different cold reductions in order to obtain satisfactory hardness values. The softening temperatures of these alloys in cold worked conditions were determined.

46.0 Brazing Alloy Clad Aluminium.

Brazing of aluminium is one of great industrial importance in joining the assemblies of two or more parts together. To have too many brazed joint (as in heat exchanger etc.) in close proximity is troublesome and costly. In such cases braze alloy clad materials are used where low melting brazing alloy is clad on either on one side or on both side of aluminium base metal.

Work was taken up to develop (i) technique for fabrication of aluminium/aluminium-silicon clad sheet with different component ratio and (ii) a flux necessary for furnace brazing and dip-flux brazing.

Few heats were prepared having 5% Si, 10% Si and 12% Si, according to the specifications. The ingots were forged and rolled upto the final optimum thickness after the optimum rolling parameters of these alloys were established. These were then clad with aluminium by hot-rolling. Brazed metal was clad on one side and the thickness of the brazing material was 10% of the composite thickness. After producing the brazing alloy clad sheets, conditions for brazing were established.

47.0 Study on the Indigenous Foundry Moulding Materials.

This long term project was taken up with a view to assess the moulding characteristics of Indian foundry sands, bonding clays and other binding materials, such as dextrine, resin, etc. and to determine their suitability for various types of castings. The following investigations were conducted during the period.

(i) The Effect of Heat on the Bonding Properties of Some Indigenous Bentonite.

Three sodium base bentonites (Kutch, Sc and MI) were examined for their suitability as bonding material while in service. Heat treatment on bentonites was done by heating constant quantity of bentonite at different temperatures ranging from 100—500°C for three hours. The changes that took place as clays were heated progressively to higher temperatures were noted which lead to further infer that the clay used in foundries with high green strength but poor heat resisting capacity would be less economical than those with moderate

green strength but high heat resistance capacity. Also, the removal of used sand clay mixture and addition of fresh clay would largely depend upon the size and type of castings which is responsible in heating up the clay associated with the mould.

(ii) *Suitability of Shellac Compounds as Core Binders. Sponsored by Indian Lac Research Institute.*

The Indian Lac Research Institute, Ranchi, has developed some shellac compounds which may be used in foundries as core binders and with their sponsorship two series of shellac compounds were evaluated as core binders. From the tests conducted, it was found that the shellac binders could be used satisfactorily as core binders in the foundry.

48.0 Development of Wear and Abrasion Resistant Cast Iron.
Sponsored by Tata Engineering & Locomotive Co.

The project was taken up at the instance of M/s. Tata Engineering & Locomotive Co. Ltd. who had been importing the impeller blade castings for their shot blasting fettling machines. The object is to develop suitable composition and heat treatment technique for producing wear and abrasion resistant cast iron suitable for such machines. The basic requirements of impeller blades is specified in terms of hardness and in imported blades it had been found as Rc 66; but hardness alone does not qualify to give satisfactory castings unless a proper service life is obtained.

More impeller blade castings were made and subjected to service trials. Very encouraging results were obtained. Some more blades are under test to obtain reproducibility and confirm the previous results.

49.0 Appraisal of Raw Materials for Iron Making.

(i) *Physical and Chemical Characteristics of Iron Ore.*

In view of the importance of the physical and chemical characteristics of the raw materials for efficient iron smelting further studies were conducted. Reducibility of Orissa Mineral iron ore was determined at reaction temperature of 500°C with H₂ gas as reductant with the variation in the grain size from -25+13, -13+6 to -6+3 mm.

It was observed that in 30 min. time, the % reduction at 900°C was 92% whereas at 500°C, the % reduction amounted to only 22%.

(ii) *Reducibility Under Conditions of Blast Furnace Stack.*

The reducibility tests with H₂ gas as reductant cannot simulate the blast

furnace stack condition and therefore the data may be debatable. Reducibility apparatus is being fabricated to determine reducibility in a gas mixture of CO: CO₂: N₂ in desired proportions.

(iii) *Decrepiation Characteristics.*

Decrepiation characteristics of six iron ore (NMDC) were determined in a stagnant atmosphere. The decrepiation temperature varied between 425°C and 480°C.

(iv) *Dissociation Characteristic of Limestone.*

Dissociation characteristic of Satna limestone was determined at isothermal temperatures of 700°C, 800°C and 900°C in the particle size ranges of —25+13 and —13+6 mm. The amounts of CO₂ evolved at 800°C and 900°C were not very much different, but at 700°C no dissociation took place.

50.0 Study on the Reduction Mechanism of Iron Ores in Relation to the Gas Utilisation Co-efficient.

This work was taken up to study the reduction mechanism in finely divided iron ore bed in relation to the gas utilization co-efficient which is denoted by $\frac{\text{CO}_2}{(\text{CO} + \text{CO}_2)}$ for carbon monoxide and $\frac{\text{H}_2}{(\text{H}_2 + \text{H}_2\text{O})}$ for hydrogen.

Further studies were conducted with Bolani and Barajamda iron ores to find the gas utilisation coefficient percentage which is denoted by $\frac{\text{CO}_2}{\text{CO} + \text{CO}_2} \times 100$ for carbon monoxide. The rate of flow of CO was kept constant at 500 ml/min. at NTP and the temperature of ore bed at 950° ± 10°C. It was observed that with increase in the weight of ore the CO utilisation co-efficient was higher for the same reduction degree percentate indicating thereby better utilisation of CO at the above noted rate of flow. It was also observed that the rate of CO utilisation coefficient calls at a lower rate for increased ore weight over the entire 150 minutes of the reduction process.

51.0 Study on the Reduction Mechanism of Iron Ore by Solid Carbon.

The reduction of iron ore can be obtained by carbon by direct or indirect reactions. A great deal of experimental work has been done and various theories have been advanced on the different aspects of gaseous reduction or indirect reduction but relatively little has been confirmed for direct reduction (solid-

reduction). It is with this in view the investigation was taken up to study the interactions of carbon and iron oxides occurring by the two known mechanisms and also to compare the reduction mechanism when ore bed is heated with coke/carbon along with small amounts of carbon monoxide.

Further work was done on Bailadila, Bolani and Kiriburu iron ores by keeping ore to carbon ratio about 1.5, 1.75, 2 and 3 and maintaining a temperature of $975^{\circ} \pm 15^{\circ}\text{C}$ and flow rate of nitrogen inside the reaction tube at 1 cm/sec. Results so obtained indicated variation in the rate of oxygen removal over different periods of the entire experiment for 200 minutes.

52.0 Reduction of Metallic Minerals by Naphtha.

Earlier investigations were conducted on reduction of iron ores by naphtha, a petroleum product, to produce sponge iron or iron powder. The work was further enlarged to use the set up for the reduction of metallic mineral oxides by the hydrocarbons to their lower oxides or to the metallic form. The first to be tried out was MnO_2 to MnO . This is important in not only upgrading the manganese ores but also to use the MnO reduced from MnO_2 for its subsequent treatment in the production of electrolytic manganese. Work is in progress to obtain the optimum conditions for efficient reduction.

53.0 Determination of Porosity of Iron Ores and Sinters.

It is well known that porosity of iron ores and sinter plays an important role in their reduction in a blast furnace. Higher the porosity, higher is the rate of reduction due to increased surface area. It is with this in view an apparatus was fabricated for the determination of macro and micro porosities of iron ores and sinters, collected from various ore occurrences in India. With this apparatus, the porosities of 18 more iron ores were determined with argon gas as penetrant. The porosity values were also correlated to reducibility etc.

54.0 Thermal Conductivity of Indian Iron Ores.

In order to assess the efficiency of heat transfer and thermal exchange between the descending burden and the ascending gases in a blast furnace, the determination of coefficient of thermal conductivity of iron ore is important. An apparatus for determining the coefficient of thermal conductivity was designed and fabricated in this Laboratory, using the principle of comparative method. The results of Barsua and Kiriburu iron ore samples were earlier reported. Further work on Bolani and Bailadila iron ore was done to determine the thermal conductivity values from 50° — 350°C . An attempt is being made to replace the silver cubes with refractory cubes for higher temperature thermal conductivity determination.

55.0 Influence of Associated Ingredients on Mechanism of Gaseous Reduction of Hematite.

The kinetics of gas-solid reducing reactions decides the efficiency of iron smelting in blast furnace. It is considered that the minerals associated with hematite may significantly influence the reaction rate. A comprehensive investigation has been undertaken to study the effects of various associated ingredients on the mechanism of gaseous reduction of hematite.

In continuation of the work reported earlier, the sintered pellets having (i) 2% CaCO_3 , (ii) 4% CaCO_3 and (iii) 10% CaCO_3 and the balance ferric oxide were reduced in purified hydrogen (1000 cc/min) at temperature of 600–900°C. The mathematical analysis of reduction mechanism was applied to samples with calcium carbonate. It was accepted that the sample was therodynamically stable during the reduction experiment. The equations adopted take into consideration the dimensions, composition of sample, effective volume of gas flow around the particle, diffusivity of gases and equilibrium ratio at the ambient temperature. Reaction rate and diffusivity were calculated from the known data.

56.0 Reactivity of Solid Fuels Employed for Iron Smelting in Low Shaft Furnace.

Reactivity of the fuel greatly influences the gaseous reduction in the stack of the blast furnace and thereby reflects on the fuel consumed. It is of greater significance in a low shaft furnace as the limited stack height requires fuel of optimum reactivity.

Further experiments were carried out to study the effect of inorganic additions such as sodium hydroxide, barium carbonate and ferric chloride on the reactivity. The experimental details and conditions for the test were mentioned in the earlier report.

It was observed that with the increase in the concentration of NaOH , the reactivity was increased. The addition of BaCO_3 and ferric chloride also increased the reactivity. The combined addition of $\text{NaOH}(2\text{N})$ and BaCO_3 (10%) did not have marked effect. The results, however, were not identical as in case of pearl coke (Bhilai) and L.T.C. (Ghughus). The combined addition lowered the reactivity slightly, as compared to the presence of one of these additions. Apart from the study of the effect of chemicals on reactivity, reactivity of several fuels used in low-shaft furnace was determined.

57.0 Study of Sulphide Capacities of Slag.

In continuation of the previous work, the distribution of sulphur between

molten pig iron saturated with carbon and slag of different basicity degrees were studied in a temperature range of 1450 to 1550°C in a reducing atmosphere. Several melts containing same amount of sulphur were equilibrated with synthetic slags of high basicity degree. It was found that the partition of sulphur between the slag and the metal depended upon the basicity degree of the slag. Further work with high alumina slags is proceeding.

58.0 Study of Kinetics of Malleabilization.

Low phosphorus pig iron made with low temperature carbonized coke from fully non-coking coals, leads to the production of low phosphorus pig iron which is more suitable for malleabilization. It is also known that certain elements like copper, boron, aluminium affect the malleabilization cycle. With a view to reduce the malleabilization cycle, the effect of addition of varying additions of aluminium and boron was studied dilatometrically. Twenty heats having same base composition with variation in alumina and boron contents were made. The apparatus was made studying the dilatation of 25 cm long $\times$ 6 cm dia. specimen at a temperature of 950°C in a salt bath of sodium chloride/barium chloride. Samples were also withdrawn from the bath at predetermined time intervals to ascertain kinetics of malleabilization. The examination of microstructure disclosed the morphology of graphite precipitation. Hardness measurements corroborated the completion of malleabilization cycle. The variation of boron at a definite level of aluminium did not materially affect the kinetics of malleabilization. With increase of aluminium, however, the period of malleabilization was lowered. Further work is in progress.

59.0 Structure of Liquid Metals.

(i) Cadmium-Antimony System.

In order to study the liquid state structure of a binary alloy system which exhibits compound formation in solid state and retains strong cohesion between solute and solvent atoms in liquid state, the cadmium-antimony system was chosen because x-ray, electrical and thermodynamic observations by other workers have shown that the Cd-Sb interaction is not suddenly destroyed on melting but is significantly retained in the liquid state as well.

Alloys containing 7, 29, 50, 57 and 79 at. % Sb were examined in the range of 350–650°C. The results of the sedimentation equilibrium set up by the centrifugal force were statistically evaluated to give correlation coefficient and confidence range of the results. The cluster radii were calculated by the sedimentation equilibrium equation. The results show that the liquids corresponding to eutectic composition in the Cd-Sb system have clusters of smaller size and the cluster size increases on the pre-antimony sides of both the eutec-

tics. An important observation was that in liquid of stoichiometric composition corresponding to Cd-Sb, no concentration gradient could be established during centrifuging. This indicates that short range order predominates in the liquid. When these results are examined along with the published values of viscosity, it was observed that short range order was not merely confined to the stoichiometric composition but extended over a considerable composition range.

(ii) *Study of Interaction in Liquid Aluminium-Silicon Alloys.*

Five aluminium-silicon alloys containing respectively 1, 4, 7, 11 and 17% silicon were prepared in the unmodified condition. Their structures in liquid state were investigated in the temperature range 600—750°C by the liquid metal centrifuging technique developed earlier in the Laboratory under a centrifugal force 63g. All the samples were chemically and micrographically examined. Since considerable difference was observed in the behaviour of hypo- and hyper-eutectic alloys, experiments were repeated a large number of times to establish the observations on firm footing. The results are being statistically evaluated.

(iii) *Studies of Thermodynamic Properties of Pb-Sb System.*

Earlier work on the structure of lead-antimony alloys had shown the existence of clusters and had indicated the existence of a region of incipient immiscibility in the composition range corresponding to the inflection in the liquidus. But earlier thermodynamic work on the lead-antimony system was done at temperatures considerably above the liquidus and above the temperature of investigations of the structure of liquid lead-antimony system. Such thermodynamic observations do not indicate the existence of a region of incipient immiscibility. In order to find thermodynamic corroboration of observations of the liquid structure, the thermodynamic properties of the lead-antimony system are being investigated in the temperature range upto 500°C.

Five alloys containing respectively 6, 11.2, 17, 38 and 45% antimony were prepared under vacuum for a preliminary determination of thermodynamic parameters by the e.m.f. techniques. The thermodynamic results confirmed the need of detailed investigation of this system in this temperature region.

(iv) *Liquid Metals and Solidification.*

Earlier investigation on the structure of liquid aluminium-copper alloys in this Laboratory had shown that copper rich clusters exist in liquid aluminium-copper alloys. In this investigation, the influence of such clusters on the cast morphology and its structural stability was studied. During the year, work was extended to alloys containing 5.4 and 9.4 atomic % copper. Films were exa-

mined metallographically and by x-ray diffraction techniques for structures. The nature of solid solution in the as cast condition and after annealing were studied and the observations are being explained on the basis of the stability of the copper rich clusters within and outside the spinel.

(v) *Unidirectional Solidification.*

It is now generally known that the production of two phase microstructure in which the hard phase is aligned by unidirectional solidification considerably enhances the tensile properties. In order to study the unidirectional solidification of (i) essentially eutectic type of structures and (ii) where an inter-metallic phase solidifies in minor quantities but not in the eutectic manner, apparatus was fabricated. Its essential features are that it permits various growth rates by adjusting the speed of the movement of furnace. Work is in progress on aluminium-manganese system.

(C.0.0 Co-efficients of Thermal Expansion of Ferrous Metals and Alloys.

To study variation of ferro-magnetic coupling with thermal expansion co-efficients, measurements of co-efficients of thermal expansion were made with the same iron-aluminium and iron-silicon alloys which were earlier used for curie temperatures measurements. To understand a similar relationship between antiferro-magnetic coupling and thermal expansion co-efficients, the work was critically extended to copper-manganese alloys. Alloys of copper and manganese in the range 25—90 at. % manganese were made and after suitable heat treatment in the γ range, co-efficients of thermal expansion were measured (in the temperature range 20°—400°C). The co-efficients of thermal expansion showed a maximum at about 35 at. % manganese and a minimum at about 25 at. %. The work is now being extended (i) to lower percentages of manganese and (ii) for measuring co-efficients of expansion in α composition range.

61.0 Fundamental Alloying Characteristics of Iron.

In earlier reports, it was pointed out that a change over of ferro-magnetic coupling to antiferro-magnetic coupling would give rise to complex crystal structures and with this hypothesis the occurrence or absence of sigma phase in binary alloy systems of transition metals was accounted for. Application of this idea to Nb-Al, Ta-Al systems, in which occurrence of sigma phase has been reported, suggested that cesium chloride type structure would additionally occur in these alloy systems. Nb-Al and Ta-Al alloys were prepared and further work is in progress.

Extension of the above idea to pure iron suggests that iron should exhibit complex crystal structures in the temperature range 770 to 910°C, but no such

complex crystal structure has been observed. Absence of such complex crystal structures in iron between 770—910°C has been suggested to be due to the fact that iron probably exhibits Fe_3Al type of structure in this temperature range with lattice sites having differing atomic magnetic moments.

62.0 Grain Size Control of Non-ferrous Metals and Alloys.

Earlier work on the solidification of aluminium had shown that nucleation of solidification is promoted by presence of Al-Ti clusters in the liquid metal or heterogeneously by surfaces provided by titanium carbide. Both kinds of nucleation catalysts require the presence of titanium in some form. An attempt was therefore made to develop the inoculant (PM-120) and to compare its performance with one at present industrially used and marketed by a foreign company. The inoculants were added at 780°C to 1 Kg melts of aluminium or its alloys. The relative efficiency of the two inoculants was judged by casting cylindrical and wedge-shaped specimens under identical conditions. Average grain sizes and the variations in grain size in the different alloys were statistically determined. The results indicate that PM-120 is particularly more efficacious in refining grain size in case of commercial aluminium and LM-14. The statistically evaluated co-efficient of variation is either less than or equal to that for alloys inoculated with the presently available inoculant; when it is less it indicates a more uniform cast grain size.

63.0 Preferred Orientation in Extruded Rods.

This project was taken up with a view to study the preferred orientation developed during extrusion as a function of (i) temperature of extrusion (ii) speed of extrusion and (iii) position in the rod and to study the influence of preferred orientation developed during extrusion on (a) mechanical properties and (b) preferred orientation to be developed on subsequent cold drawing of the extruded rod.

During the period under review, the duralumin and commercially pure aluminium ingots were chillcast and machined to 3 inch dia. by 10 inch long extrusion billets. Each of the duralumin and commercially pure aluminium billets was extruded at 360°C with exit speed of 60 ft/min. to a rod of 0.785 inch dia. Variation of the textures from the surface to the centre of the above duralumin and commercially pure aluminium extruded rods was studied.

64.0 Study on Creep.

(i) Development of Nickel-Free Austenitic Creep Resisting Steel.

In the first phase of the work on development of nickel-free creep resist-

ing steels based on Cr-Mn-N-C steel, it was found that the solution treatment temperature and the nitrogen to carbon ratio and the precipitation behaviour under stress in these steels exercised considerable influence on creep strength and rupture ductility of the alloys. Based on this study N/C ratio of about 1 and solution treatment temperature of 1075°C was arrived at in the basic alloy composition. The creep fracture was found to originate from matrix precipitate interface and thereby it could be possible to improve the rupture life by modifying the precipitation structure by suitable prior ageing treatment. This aspect is being further studied.

In order to further strengthen the alloy it was considered to study the effect of alloying elements like Al, Ti, W and Mo with a view to strengthen the matrix as well as to have precipitation of carbides and nitrides and inter-metallic compounds which should be stable under the high temperature creep conditions.

- (ii) *Study of Creep-rupture and Other Related Properties of 1/2 Cr-Mo-V Steel from M/s. Bharat Heavy Electricals Ltd., Hyderabad.*

Creep stress rupture tests on cast valve steel samples from B.H.E.L. are in progress at 525°C aiming the test duration of at least 10,000 hours which is the minimum requirement as per the international standard. Studies of structural changes and notch embrittlement due to long-time aging at elevated temperature are also in progress.

- (iii) *Establishment of a Creep Testing Laboratory with 150 Test Point.*

With the assistance of UNDP Special Fund, and Ministries of Industrial Development, Department of Iron & Steel, Govt. of India; action is being initiated to set up a 150 test point Creep Testing Laboratory, to meet the increasing demand of the industries for the high temperature metals and alloys as well as their creep data for design and fabrication of high temperature materials.

65.0 Radio-Isotope Research.

A Radio-Isotope Research Laboratory has been started in the National Metallurgical Laboratory with a view to use radio-active isotopes as tools in metallurgical research problems.

Determination of the percentage of U_3O_8 equivalent present in Jadugudah active ore samples and other active ores received from the Ore Dressing Division of the Laboratory, was made using the standards from Bhabha Atomic Research Centre, Trombay, with the Geiger counting set up. A number of electronic instruments and accessories were set up during the period.

66.0 Development of Basic Refractories from Indigenous Sources.

This project was taken up to assess the suitability of Almora magnesite for basic brick manufacture. The present work deals with its suitability for the manufacture of chrome-magnesite and magnesite-chrome refractories.

In continuation of the work reported earlier, some more experiments were performed to see the effect of iron oxide addition to magnesite on the direct bonding. Samples were made with Dewaldhar magnesite (sintered with 5 and 10% iron oxide additions) and Tulloch's chromite. 70/30, 60/40 and 50/50 chrome-magnesite samples were made and were fired at 1700°C. Physical properties and microstructure of the fired samples were studied. It was observed that both 5 and 10% iron oxide additions to the magnesite improved the direct bonding of chromite and periclase. The direct bonding also improved with the increase of magnesia content of the samples.

67.0 Studies on Carbon Refractories.

The objective of this project is to study carbonaceous materials from the point of view of their ultimate utilization as raw materials for the production of carbon products for diverse application in metallurgical and chemical industries.

Two aspects under study during the period were (i) development of a substitute for petroleum coke and (ii) preliminary studies on binders. Under the first head, physical properties of the Digboi and Gauhati petroleum cokes as well as their calcination characteristics were examined. The work on binders included setting up of apparatus for (a) solvent extraction (b) viscosity at various temperatures (c) swelling point determination and (d) workability determinations.

68.0 Study on Clays and Bauxitic Clays from Jammu & Kashmir.

The objective of this study is to find the possibility of utilising the clays from Jammu for the manufacture of refractories. Earlier studies, made on the physico-chemical properties of these clays indicated that these clays could be used for the manufacture of superduty type fireclay refractories. On the basis of their mineralogical constitution these clays can be classified into two categories (i) kaolinitic clays and (ii) bauxitic clays with kaolinitic and diaspore intimately mixed in varying proportions. Out of these, the four kaolinitic clays and one of the bauxitic clays were further investigated for their suitability for the manufacture of superduty fireclay refractories. Results on physical properties of some of the selected composition made from these clays, which

showed promise for their utilisation were reported earlier. During the period under review large batch of bauxitic clay BC_4 and BC_5 were taken and crushed and briquetted to prepare the grog at $1500^\circ C$. Bricks were formed under total load of 200 tonnes *i.e.* nearly $11,000 \text{ lb/in}^2$ pressure. These bricks were fired to $1500^\circ C$. The study of the physical and mechanical properties of the bricks is under progress.

69.0 Development of Ramming Mixes for Lining Induction Furnaces—High Alumina Ramming Mixes.

Objective of this investigation is to develop suitable refractory ramming mix compositions from indigenous raw materials, for lining low and high frequency induction furnaces melting ferrous and non-ferrous metals and alloys.

Based on extensive laboratory investigation reported earlier, a high alumina ramming mix composition (HA_3) was developed in this laboratory using indigenously available natural corundum as the base material, with appropriate addition of suitable bond clays etc. A large quantity of this ramming mix was prepared and a number of trials were carried out on 25 lb. Ajax Wyatt—Coreless type, high frequency induction furnace, using the segmented lining test for evaluating its service performance. In this method of testing one half of the lining was rammed with an imported high alumina ramming mix and the other half with the laboratory developed HA_3 ramming mix. After 25 intermittent trial meltings of cast iron, copper and its alloys, the results indicated the HA_3 ramming mix is quite comparable to imported ramming mix in its service performance.

70.0 Development of High Alumina Cement.

The object of this investigation is to develop suitable composition and properties for the manufacture of high alumina cement from Indian raw-materials. Such cements are normally made either by melting or by sintering together bauxite and limestone in suitable proportions. As a first step towards this direction, work was carried out to find out the suitability of some bauxites and limestones from different parts of the country. Some of the raw materials examined in this study showed considerable promise for their utilisation in the manufacture of these cements employing the above two manufacturing method. During the course of this investigation, the effect of some of the constituent oxides of the cement, particularly MgO and SiO_2 in the cementing characteristics were also studied. Optimum ratio of Al_2O_3/CaO in the final mix while using different bauxites and limestones were fixed. The next phase of this investigation is to extend the results of the earlier studies in fixing con-

dition for large scale production of these cements both by the melting and sintering technique.

71.0 Development of Submerged Arc Welding Fluxes.

During the period under review, further development and testing work was carried out on welding fluxes for submerged arc welding.

As required by the DGTD, NML licensee was asked to test the flux produced by them, as per the NML know-how, at Walchand Industries, Walchandnagar. Using Modi No. 2 wire, the mechanical properties of the all weld test piece were as follows: U.T.S. 56.82 Kg/mm₂; elongation 37.7% and reduction in area 48.98%. M/s. Walchand Industries certified that these tests results were satisfactory. The same wire-flux combination was tested again by M/s. A.V.B. Ltd., Durgapur, in the presence of Inspector of Boilers and Lloyds Inspector and the properties of the weld were found to conform to the rigid specifications for welding pressure vessels and boilers. Further work was carried out on the development of fused fluxes containing high MnO. A gas fired furnace was designed and built for melting the flux compositions upto 30 Kg. The furnace was successfully operated and fused flux compositions containing high and low MnO could be successfully melted. A quenching tank with continuous supply of water was designed and fabricated. Work was also initiated on the development of agglomerated fluxes for submerged arc welding. Samples of Fe-Mn slag were used as one of the ingredients and some preliminary experiments were made to agglomerate the components.

72.0 Development of Silicon Carbide Heating Elements.

This project was undertaken with a view to examine the possibilities of manufacturing silicon carbide heating elements for use in electric furnaces in the country.

Representative samples of silicon carbide of—80 mesh from sources like Regional Research Laboratory, Hyderabad, Norton (American) and from Germany, were prepared. Mixed with suitable bakelite powder, cylindrical buttons were pressed and polished. Using microscopic method, the count of the particles was done on the polished surface measuring 1 sq. cm. on each specimen. The shape and distribution of the particles was found to be more regular in the Norton and German specimens than in the case of the R.R.L. Knowing the microscopic counts of the particles and their individual sizes, the histograms were prepared. Standard deviations were calculated and plotted to determine the amount of scatter around the arithmetic mean. It was found to be identical in the case of R.R.L. and the foreign specimens. The hardness tests con-

ducted on the polished particles of the above specimens gave the following values:

(a)	Vickers Hardness	(Hv)	
	Norton	=	4645 Kg/mm ²
	RRL	=	4620 Kg/mm ²
(b)	Knoop Hardness	(Hk)	
	Norton	=	4310 Kg/mm ²
	RRL	=	4120 Kg/mm ²
	German	=	4215 Kg/mm ²

Oxidation experiments were conducted on silicon carbide samples of RRL in the Pt-Rh wound tubular furnace. Temperature of weighed SiC samples was raised to 1100°C and maintained there for two hours. Oxygen was bubbled at the rate of 140–160 bubbles/min. Percentage gain in weight was found to be in the range of 0.002 to 0.20.

Oxidation characteristics were also observed in the thermal gravimetric balance. Contrary results were however obtained, as the samples of SiC on oxidation showed loss in weights of the order of 0.002 to 0.0045% in the case of RRL and about 0.7% in the Norton SiC. This is probably due to the draughts of air, and hence needs further check up.

73.0 Development of Tar Bonded Basic Refractories for L.D. Converter.

Tar bonded basic refractories for L.D. furnace lining has a vast commercial potential in the steel industries in India as a consequence of the use of L.D. process of steel making. At present Rourkela Steel Plant, HSL (which is the only steel plant using L.D. process in India) manufacture tar bonded dolomite blocks for their own use. The steel plant to be set up at Bokaro is also expected to use pneumatic process of steel making (L.D.) This is expected to create need for data on indigenous raw materials as well as systematic study of lining that can be developed from them. With this end in view a project for the development of tar bonded basic refractories has been taken up under the following heads.

- (i) Literature review of the most recent developments in this field.
- (ii) Study of the indigenous raw materials, dolomites, magnesites, tars and pitch etc.
- (iii) Development of suitable compositions of the refractory tar bonded basic bricks.

- (iv) To make pilot plant scale studies.

In continuation of the earlier report for developing tar bonded basic refractories, a literature review of the recent development in this field was prepared. Samples of dolomite, magnesite, tar and pitches were collected. Physical properties of the dolomite and magnesite were studied and sample preparations for the microscopic studies are under way.

74.0 Investigation on Hot Top.

This project was taken up with a view to develop hot top for ingot moulds from indigenous materials. At present all the steel plants in India are using hot tops which reduce the shrinkage pipe in the steel ingots thereby increasing the yield of ingots which may be of the order of 5 to 10% depending on the efficiency of the hot tops.

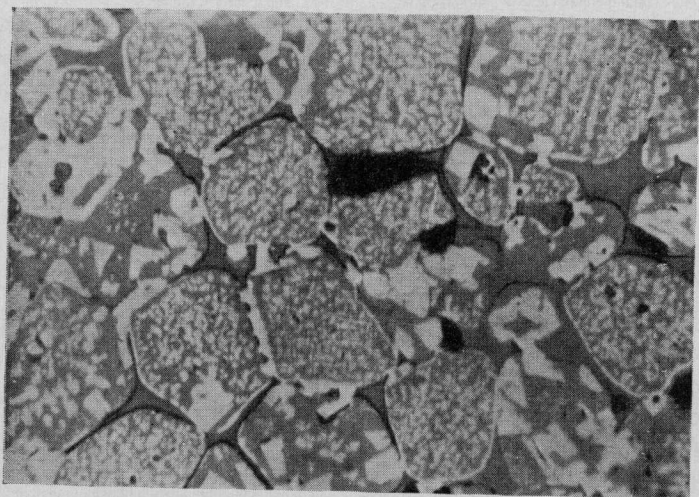
Samples of various sizes of hot top moulds at present used in Indian Steel Plants have been studied for their physical properties like bulk density, porosity and thermal conductivity. Chemical analyses were also done. Details of various patented processes of making this hot tops have also been collected from the literatures. Insulating hot top compositions have been formulated from indigenous raw materials. The properties of some of the experimental bodies of hot tops thus studied are comparable to the products already in use in steel plants. Larger slabs of these compositions are being made to study their behaviour in actual factory floor trial.

75.0 Fabrication Methods of Special Refractory Shapes for Oxide Materials.

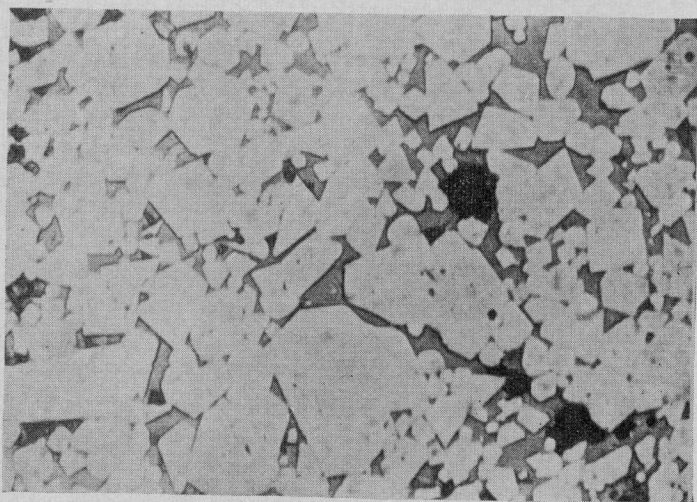
During the period under review certain wooden patterns were made to make plaster moulds for slip casting. By rough experiments, it was found that low temperature calcined alumina may be used for slip casting, by producing a powder of suitable fineness, adding acid thereby arriving at pH of about 3, and water to get a specific gravity of about 1.8. The solids in the slip are around 65%. The slip cast furnace tubes thus obtained can be hardened by sintering at about $1650^{\circ}C$ if proper precautions are taken. Further work to do this sintering and produce a number of sample tubes is in progress.

76.0 Mineralogical Constitution of Metallurgical Slags.

During the period under review, the work on the constitution and mineralogy of Indian blast furnace and open hearth slags were completed and considerable progress was made in determining the liquidus of Indian blast furnace slags.



Magnesite brick showing periclase with precipitates of magnesio-ferrites forsterite and monticellite × 500



Mag-chrome brick showing secondary spinel crystallisation × 500

In all more than 20 samples of blast furnace slags from different steel plants were studied. The highest liquidus temperature recorded among all the slags was from Tisco having 1538°C while the lowest from Rourkela having 1356°C . Apart from determining the liquidus temperature, the crystallisation history movement of crystals in the liquid, rate of crystal growth and the optical properties of primary and secondary phases were noted.

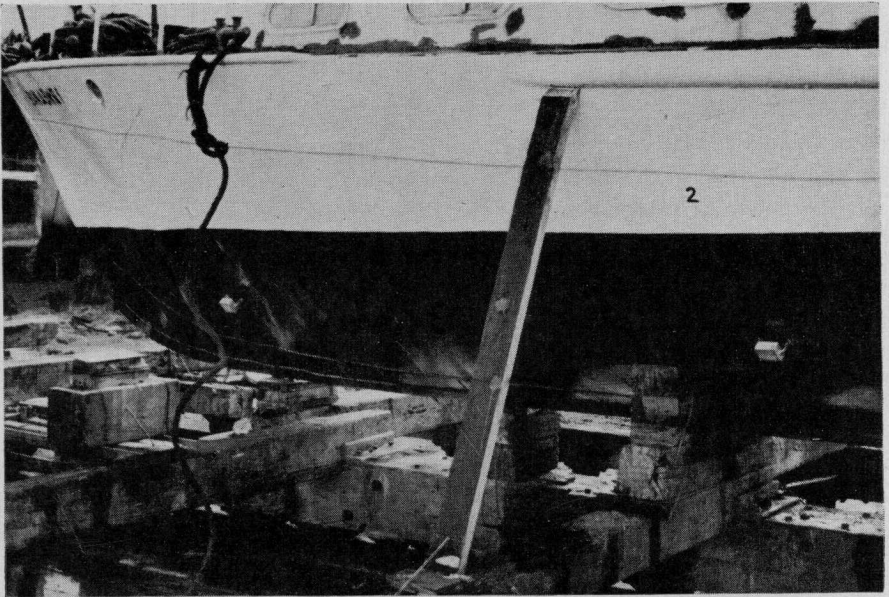
77.0 Microstructure of Basic Refractories and Related Physical & Mechanical Properties.

During the period under review, several polished and thin sections of basic bricks received from different Indian manufacturers and users were studied. In most of the bricks, periclase was predominant phase. In many of the samples fine precipitates of magnesio-ferrite in periclase were also present. Almost in all magnesite bricks studied, where forsterite matrix is predominant, the periclase grains were bigger in size with somewhat irregular outline. In areas where more silicate matrix specially monticellite was present periclase grains were smaller in size and well rounded with occasionally large grains. Monticellite and forsterite in the matrix could easily be distinguished as monticellite has got higher relief with greyish colour whereas forsterite has lower relief with light grey colours.

In chrome-magnesite bricks also, texture was not uniform and grain sizes were variable. In general, phases present were chromite, periclase, forsterite and monticellite. Direct bonding was not very common. Amongst all bricks studied samples from Belpahar Refractories seem to have more direct bonding than others. In some samples secondary angular spinel also occurred sometimes interlocking with periclase grains. Magnesite-ferrite occurred as precipitates in periclase.

78.0 Development of Aluminium Base Sacrificial Anode for Cathodic Protection.

The use of sacrificial anodes for cathodic protection of sea going vessels and underground pipelines is receiving increasing importance. Magnesium and zinc are commonly used metals for such purpose but both of them have their own limitations. From the theoretical point of view aluminium is a very much attractive metal but its use as active anode is not possible unless the tendency of the metal to develop passivity is checked by suitable alloying. On the basis of work carried out in this line it has been possible to successfully develop aluminium alloys to be used as sacrificial anode. The production technique and properties of the alloy were tested both on laboratory scale and on large scale. The alloy has been fitted in steam launch operating in river estuaries for field trial.



Launch fitted with aluminium alloy developed at NML for cathodic protection purpose.

Another novelty of the alloy is that it can be processed using commercial grade of aluminium and can be worked to fine rod or ribbon without any adverse effect on the electrochemical properties of the alloy. The alloy can therefore be used for protection of small pipelines by housing this alloy in ribbon form.

79.0 High Temperature Oil-Ash Corrosion of Alloy Steel.

Studies on oil-ash corrosion carried so far indicated the importance of the following factors in controlling the accelerated oxidation.

- (a) Presence of V_2O_5 or some of its specific compounds in liquid form.
- (b) A high concentration of vanadium near the metal/oxide interface.
- (c) Porous nature of the oxide layer to permit easy access of oxygen to the metal/oxide interface.

With a view to study the role of various factors on the accelerated corrosion of high alloy steels by oil-ash, the investigation was continued on the three alloys, namely Cr/Ni stainless steel (S), Inconel (I) and Ni-free stainless steel (N_3). X-ray, X-ray fluorescence and electron microprobe analysis of oxides of the alloys were carried out to determine the composition and nature of oxide layers.

(i) In alloy S, which has a poor resistance to V_2O_5 attack, the concentration of vanadium in the oxide scale increased with depth reaching a maximum value at the oxide/metal interface. (ii) The vanadium concentration in the scale of alloy N_3 was highest at the top surface decreasing with depth. Just at the metal/adherent scale interface a sudden high increase in vanadium concentration was observed. (iii) No compounds of metal vanadates could be definitely detected in scales of alloys S and N_3 . This however does not mean that none are formed. It is probable that their amount is too low to be detected. (iv) The marked difference in corrosion rates of S and N_3 is probably due to the nature of the oxide growth which alters the porosity of the scale, thus hindering the rapid diffusion of oxygen to the oxide/metal interface.

80.0 Studies on Atmospheric Corrosion of Metals and Alloys Exposed at Jamshedpur and Digha.

Studies on atmospheric corrosion of metals and alloys were further extended to determine in greater detail the effect of different variables in influencing the rate of corrosion both at Jamshedpur and Marine Corrosion Research Station, Digha. A brief account is furnished in the following page.

- (i) Studies were undertaken to understand the mechanism involved in the improvement of atmospheric corrosion resistance of steel by small additions of copper (0.050%, 0.25% and 0.6%). Samples cut from hot rolled sheets were heated at 850°C for 4 hours followed by quenching. While a part of the samples were exposed in quenched condition, others were tempered at 200°—300°C for 24-72 hr. prior to exposure. While quenching increased the corrosion resistance, tempering decreased it. This indicated the effect of copper in solution in controlling the corrosion rate. The tests are being continued to determine the effect of longer period of exposure on the degree of corrosion.

(ii) *Long Term Exposure Tests at Jamshedpur & Digha.*

Long term tests on corrosion resistance properties of copper, nickel, brass, zinc and monel are being continued. The above metals and alloys, including aluminium and aluminium alloys were also exposed at Marine Corrosion Research Station, Digha. Periodical observations and collection of meteorological data are being carried out.

(iii) *Effect of Distance from Sea Coast on Corrosion Rate of Mild Steel (Exposure Tests at Digha).*

In the coastal locations, salinity of the atmosphere primarily affects the corrosion rates. The salinity of the atmosphere is usually highest near the sea-shore and falls off as the distance from sea increases.

(iv) *Monthly & Yearly Atmospheric Corrosion Tests.*

Monthly and yearly corrosion tests were continued at Digha, to understand the effect of initial exposure period and seasonal fluctuation in temperature, humidity and atmospheric pollution on corrosion rate.

At Digha, the monthly corrosion rate of mild steel was lowest during the winter period and highest during summer. In the case of yearly exposure tests, it was however, observed that samples exposed during the winter time corroded more, compared to those exposed during summer.

(v) *Exposure Tests on Protective Coatings.*

The Committee on Inorganic Coatings of the Corrosion Advisory Bureau decided in its 3rd meeting, that exposure tests should be

carried out to evaluate the protective properties of inorganic coatings at different places in India. Under this scheme, exposure tests on the following specimens with and without painting were started both at Jamshedpur and Digha. Periodical observations are being made to study the performance of the coating.

- (i) Alclad
- (ii) Anodised aluminium
- (iii) Galvanised sample
- (iv) Aluminised sample
- (v) Mild Steel
- (vi) Aluminium (Alcrom treated)

81.0 Development of Electrolytic Metal/Metal Oxide Coating as Substitute Tin Plate.

The shortage and high price of tin in the world market has led to the search for an alternate material specially as a substitute for tin plate. This is all the more important in India as it has to depend totally on the import of tin. In countries like U.S.A. and Japan extensive researches have been carried out to develop an alternate to tin plate specially for packaging of comparatively less corrosive items. The NML has undertaken work on similar lines to develop metal/metal oxide coating which can economically be used for the replacement of tin coated steel.

During the period, number of experiments were carried out to get thin deposit of chromium and chromium oxide coating by single and double step process. The studies have indicated that it is possible to obtain a thin composite coating of chromium/chromium oxide and work is underway to determine the composition, corrosion resistance and toxicity of the coating.

82.0 Role of Heterocyclic Group of Compounds in the Acid Dissolution of Iron and Its Alloys.

The investigation was undertaken with a view to study the kinetics of metal dissolution and hydrogen absorption by mild steel in the presence and absence of polar organic inhibitors of heterocyclic base group. In the present study, three compounds namely quinoline, acridine and acriflavine were studied in detail. These inhibitors were found to reduce the corrosion rate and hydrogen absorption by the mild steel to a considerable extent. Amongst these inhibitors, acriflavine was found to be most efficient. All the inhibitors were found to be anodic type at lower concentrations whereas at higher concentrations they behaved as cathodic inhibitor.

83.0 Corrosion Problems Referred to by Industries.

The following corrosion problems were referred to by industries. Based on spot survey followed by investigational work, remedial measures were suggested.

- (i) Corrosion of boiler tubes
- (ii) Corrosion of steel plates during storage
- (iii) Corrosion in stainless steel valve in recovery and purification block of the antibiotics plant at Rishikesh.

84.0 Development of Plastic Coatings.

Conditions for satisfactory deposition of zinc phosphate coating of low costing weight per square foot on cold rolled steel in dip process were studied and optimum conditions were evaluated. At 80°C, zinc phosphate deposit of about 500 mgm to 800 mgm. wt. per sq. foot was obtained in 4 minutes by dipping in a bath of 30 points. The deposit consisted of dendritic crystals of zinc phosphate and the surface was very smooth. This phosphate coating served as a good base coat for subsequent adhesion of the PVC organosols.

Relative viscosities of PVC in a mixture of DOP and MIBK were determined at 20°C. The viscosities were also determined at different proportions of thinner so as to evaluate the suitable consistency for spraying. At a relative viscosity of 50 sp with a corresponding flow time of 17-18 sec. with A_{10} flow up the material could be satisfactorily sprayed. Similar experiments were carried out with PVC/PVA and mixtures of PVC and PVC/PVA with the plasticizer DOP, solvents and thinners.

As PVC and PVC/PVA need thermal stabilization a few stabilizing agents such as basic lead carbonate, Ca-bentonite and Na-bentonite were tried and it was found that the basic lead carbonate is the best on the basis of HCl retained by the resin sample and the stabilizer on heating at 180°C for 35 minutes.

Primer compositions based on PVC, PVC/PVA, acryloid, pigments, DCP, DICP, solvents and thinners consisting of MIBK, toluene, xylene etc. were made and cut down to spraying consistency. Similarly top coat compositions consisting PVC, PVC/PVA and blends, pigments, plasticizers, solvents and thinners were made. Cold rolled steel panels were degreased and coated with the primers and top-coats developed and the panels were baked in the range 160°—190°C. The physical properties of the coatings such as rocker hardness, scratch hardness, flexibility and distensibility were evaluated.

85.0 Gases in Metals.

More than 150 samples of metals and alloys were analysed for hydrogen, nitrogen and oxygen by vacuum technique. Detailed analytical work leading

to the identification of the state of nitrogen present in a number of creep resisting steels was carried out by electrolytic method also.

86.0 Electroplating.

(i) Plating of Bright Nickel.

The investigation was taken up to identify brightener compositions and study their characteristics in application.

One composition based on double ring aryl sulphonic acids has been developed fully, on bench scale and tried in commercial plating tanks. It was found satisfactory for plating cycle rims in preference to usual dull nickel technique. Work is being extended with alternative compositions.

(ii) Stripping Composition for the Removal of Nickel from Rejected Nickel Plated Goods.

A process for stripping nickel from nickel plated rejects was standardised and is currently utilised by an industrial firm. One of the ingredients of the stripping composition is cyanide.

Investigation was undertaken to work out an alternative non-cyanide and non-cyanide and non-toxic composition to eliminate hazards during use. Studies are being continued to establish yield of recovered nickel for a given quantity of stripper composition.

(iii) Gold and Gold Alloys Platings.

In the studies on the plating of Au-Cu and other alloy combinations on watch straps, it was observed that the colour of the alloy plating viz Au-Cu can be improved, but the tarnish resistance of the coating was not satisfactory. Even by incorporation small amount of antimony, in alloy Au-Cu coating, the tarnish resistance property was not altered.

Hence further investigations with the collaboration of Bentex India Ltd. who initiated this project is under way.

(iv) Production of Electrolytic Iron-Powder.

A process for the production of high purity electrolytic iron powder was standardised. The iron powder is on the average 150—350 mesh having carbon content of the order of 0.03 to 0.05.

87.0 Study on Techniques of Electrolytic Deposition of Metal-Ceramic Composite Materials and Their Properties.

The object is to study the possibility of electro-depositing composite materials. Coatings and components of composite materials exhibit many interesting properties *e.g.* resistance against wear, abrasion, high temperature oxidation, impact resistance, sulphur attack etc. Such compositions can furnish self lubricated bearing surfaces also.

After determining the optimum conditions, and the effect of different variables on the electro-deposit ion of nickel-alumina-composite, its physical and mechanical properties are being studied.

88.0 Preparation of Metal Catalysts for Use in Organic Reaction Processes.

A technique for producing silver catalyst was developed in the laboratory. It consists of two main steps namely (i) Electrodeposition of fine silver powder (ii) Agglomeration of the silver powder into porous granules.

89.0 Development of Standard Metals.

(i) Standard Samples Prepared.

One sample of ferro-chrome and one sample of alloy cast iron were fully standardised and certified. These are now available for sale.

(ii) PL-480 Scheme.

A Project for the preparation of three standard samples of ferro-alloys was sanctioned under PL-480 scheme. Necessary arrangements for recruitment of staff and procurement of raw materials for the project are under way. Preliminary work on fixing a crushing schedule for the ferro-alloys was chalked out.

90.0 Analysis of Metals, Alloys, Minerals etc.

(i) Chemical Analysis.

3654 samples containing 10472 radicals were analysed for different divisions of the Laboratory.

(ii) Spectrographic analysis.

370 samples were qualitatively analysed and 16 samples were quantitatively analysed during the period.

(iii) *Petrological and Ore-microscopic Studies on Low Grade Ores and Mineral Samples.*

Comprehensive petrological and ore microscopic studies of the various low grade ores received for beneficiation studies were undertaken. The scope of investigations included the physical mineralogical characteristics of the ores, textural relationship, interlocking and model analysis of the mineralogical constituents. In addition to this, a continuous support was provided to the ore-dressing investigations by microscopic examination of the test products of the beneficiation processes so that the effectiveness of a process could be adequately judged. Detailed petrological study of a large number of ore samples was conducted during the period.

(iv) *X-ray Fluorescence Analysis of Ores, Minerals and Metals.*

The non-destructive, highly sensitive, selective and very rapid method of X-ray fluorescence analysis is in use since past six years to expedite analysis of routine test and processing products of various divisions of the laboratory as well as for specialised analytical problems. The results of analysis obtained were highly satisfactory in their degree of accuracy as well as to the rapidity of the method, as compared to the other conventional time consuming analytical techniques.

(v) *X-ray Diffraction Analysis.*

X-ray diffraction analysis was done on different samples received from various divisions of the Laboratory for determining the different phase and crystal structures.

91.0 Recovery of Metallic Values from Metallurgical Wastes.

(i) *Brass Dross.*

A sample of brass dross received from a Plant in Bombay contained fine metallics intimately associated with slag flux and oxides of Cu & Zn. By the melting and agglomerating technique developed, about 17.5% of the weight of the dross could be recovered. This showed 75.5% of Cu and 11.52% Zn recovery of the metallics in the dross. Further work is in progress.

(ii) *Recovery of Aluminium from Aluminium Dross.*

Two more samples of Al dross were treated during the year:

- (a) The sample received from Kundara, Kerala, contained 45.50% metallic aluminium and was associated with flux and oxides. The sample contained large sized metallic pieces that could be easily separated by hand picking and melted by the conventional methods. The dross sample remaining after hand picking of the coarse Al pieces was further treated by the patented process and an overall recovery of 75% metallic Al was obtained.
- (b) Another sample received from Jagadhri passed through 7 mesh B.S.S. and was intimately associated with fluxes, oxides and other gangue materials. The metallic content was 56% and was in the form of fine particles. The sample was subjected to pretreatment for upgrading the metallic content and then agglomerated. A recovery of 70% Al was obtained from the treated product.

(iii) *Treatment of Zinc Dross.*

During galvanizing considerable quantities of waste products are obtained in the form of zinc dross, ashes, skimming and blowing which do not directly find any application. Generally in galvanising of tubes about 25% of zinc is lost as zinc dross. The investigation aims at the recovery of the metallic values from the zinc dross. It was observed that maximum recovery obtained so far from 100 kg sample for distillation at 750°C for 12 hours was 74%.

92.0 Recovery of Secondary Metals from Scrap by Filtration.

The conventional processes of recovery of secondary metals from dross involve a series of operations from crushing and grinding to melting. As crushing and grinding of metallic values are difficult problems, an attempt was made to develop an alternative processes of recovering metals from dross by melting and filtration in liquid state, so that the crushing and grinding operations are eliminated. Experiments were done to recover the metals from dross or to purify metals of the following types: (i) Recovery of metallic zinc from zinc dross (ii) Recovery of metallic aluminium from aluminium dross, (iii) Purification of aluminium containing more than 1% Fe, (iv) Purification of aluminium of 99.6% purity.

Zinc dross analysing 95% Zn was melted and filtered in the specially designed filters. The filtered zinc contained greater than 99% zinc. These experiments were repeated a large number of times on laboratory scale involving about 220—250 gm of metal at a time.

The aluminium dross in the as received condition contained a lot of fines and its average metallic aluminium content was 8—10%. The metallic values

from this dross were initially hand picked to analyse 60—70% metallic aluminium. This enriched dross was melted and filtered in the temperature range 700—800°C. Specially designed filters were used and the purity of the metal recovered was 98—99% at a recovery level of 90%. No aluminium could be recovered from the residual fines. Aluminium scrap containing more than 1% Fe was also filtered and the iron content could be reduced to 0.4—0.5%.

PILOT PLANTS

93.0 Low Shaft Furnace Project.

During the period under review further investigations on the smelting of iron ore fines, with low-temperature carbonised coke made from wholly non-coking coals, or sub-size coke were undertaken with variations in the operational parameters. The investigations on iron smelting conducted during the period under review comprised of the following campaigns:

(i) Fortythird Furnace Campaign.

Smelting trials were conducted with two varieties of iron ores from Orissa (S. Lal) and Andhra Pradesh with limestone (Satna), dolomite (Assam) employing low temperature carbonized coke made from wholly non-coking coal (Singarini Colliery, Andhra) with the object of assessing the effect of the different particle size of the iron ores on the fuel rate and productivity.

(ii) Fortyfourth Furnace Campaign.

Smelting trials were conducted with a good grade iron ore (Orissa Minerals) using a mixed fuel burden comprising of sub-size nut coke and low-temperature carbonized coke in the ratio of 50:50 limestone (Satna) and dolomite (Assam) with the object of obtaining maximum production rate with desired chemical analysis of the pig iron.

94.0 Scrap Oxygen Steelmaking in Basic Oxygen Converter.

Extensive investigations are underway to develop a suitable technique for conversion of solid iron and steel scrap of assorted sizes generated in iron and steel foundries to molten steel of desired chemical compositions by a modified basic top-blown oxygen steelmaking technique.

95.0 Experimental Baby Blast Furnace.

The objective of iron smelting in the baby blast furnace is to comprehensively evaluate the effect of burden preparation, oxygen and fuel injection on the fuel rate and productivity and to study the kinetics of reactions involved in the reduction of iron ore during the use of such auxiliary fuels.

Further trials were conducted in an experimental blast furnace with effective height of 130 cm, hearth diameter of 25.4 cm, bosh diameter of 33 cm, throat diameter of 23 cm having four tuyeres of 2.54 cm diameter. The blast was preheated to 280°C in a metallic tube recuperator. Employing iron ore fines and various solid fuels, the effect of different degrees of oxygen enrichment of the blast on the smelting efficiency was comprehensively studied. Further investigations will be conducted with prepared burdens and pellets of smaller size with simultaneous enrichment of the blast with oxygen.

96.0 Investigation on Cupola Melting Practice.

With the object of utilizing sensible and chemical heat contents from the effluent gases, a simple heat exchanger was designed, fabricated and installed at the top of one tonne/hr cupola. In the base period, with cold blast the coke in the split charge amounted to 12.5% by weight for hot metal temperature of 1300°C. With the incorporation of the heat exchanger, a hot blast temperature of 230–250°C was available. The amount of coke in the split charges was determined. It was established that with the preheated air blast of 230–250°C coke consumption decreased from 12.5% to 10%, the decrease amounting to 20% for hot metal of identical temperature.

97.0 Investigation on Agglomeration.

Pre-reduced self-flux pellets.

With a view to incorporate metallurgical wastes like flue dust and sludge from wet gas cleaning plant, further investigations were conducted on pelletising iron ore fines (Orissa Minerals). Pellets were prepared with addition of 1% bentonite, 15% moisture, 5, 10, 15 and 20% coke fines respectively.

The pellets were reduced at temperatures of 800, 900 and 1000°C for one hour in N₂ gas atmosphere. The reduced pellets were subjected to shatter test. It was observed that the physical strength of the reduced pellets decreased with the increase in addition of coke fines. Further investigations on the reduction of iron ore pellets were conducted in gas fired laboratory rotary kiln with different types of solid fuels. The maximum temperature in the kiln was between 1000–1100°C. However, the design characteristics of the kiln did not yield high degree of reduction.

The pelletisation of flue dust was conducted with the incorporation of 5 and 10% flue dust with iron ore fines with the addition of 1% bentonite, 15% moisture. The grain size of the flue dust was below 200 mesh B.S.S.

The green strength of the pellets was not satisfactory. The pellets were heat hardened for 30 minutes at different temperatures in N₂ gas atmosphere.

After heat hardening the shatter test was performed at room temperatures. It was observed that the physical strength of the pellets containing 5% and 10% flue dust after heat hardening at 1000°C was satisfactory.

98.0 Production of Pig Iron from Run-of-mine Iron Ore, Limestone Fines and Coke or Coal Breeze in a Rotary Furnace.

With the objective of obtaining molten pig iron utilising fine grained raw materials such as iron ore, limestone and solid fuel, further smelting trials were conducted in basic lined rotary furnace to control sulphur and phosphorus content in the pig iron produced. The furnace was lined with dead burnt magnesite using sodium silicate as binder. After sintering of the lining, investigations were conducted by obtaining a pool of molten pig iron in the hearth of the revolving furnace. Following it, the burden consisting of iron ore fines, limestone fines and solid fuel fines in appropriate quantities intermittently fed into the furnace, and the carbon monoxide liberated due to the reduction of iron oxide with carbon was burnt inside the furnace by consumable oxygen lance. Severe wear of the refractory lining of the furnace seriously affected the continuous iron smelting trials and it was concluded that the design of the furnace, its revolution and other aspects are to be suitably modified for further trials with this particular process.

99.0 Production of Alloy Steels by Basic Oxygen Steelmaking Process.

Investigation was undertaken to produce 10 to 15% chromium steel in a basic-lined experimental L.D. converter employing pig iron and high carbon ferro-chromium.

From a thermo-dynamic consideration of the oxidation of carbon vis-a-vis the oxidation of chromium at a certain temperature, it was felt that the basicity degree of the slag will greatly affect the oxidation behaviour of chromium and consequently synthetic slags of high basicity degrees were initially prepared having basicity degree of 2.8 to 3. Initially ferro-chromium at room temperature was added, but after the refinement treatment, it was found that the maximum amount of chromium absorbed was only 5%.

Further experiments were conducted with the addition of pre-heated ferro-chromium and raising of the temperature of the bath to about 1600°C. The relation between the oxidation of carbon with regard to chromium is being studied under various operational conditions and it was found that the recovery of chromium decreased with increase in ferro-chrome. Further work for determining the operational conditions for promoting the oxidation of carbon and lowering the oxidation of chromium are being conducted.

100.0 Hot-dip Aluminising.

(i) Continuous Hot-Dip Aluminising of Mild Steel Strips.

Initial trial experiments were conducted on continuous aluminising of mild steel strips. The existing continuous hot-dip aluminising plan for wire was modified for aluminising mild steel strips upto 8" wide. The process is continuous except for degreasing. Degreasing was done by burning the greasy material and slightly oxidizing the steel surface. In the continuous operation the strip passes, from the feed reel, through the pickling tank, washing tanks, fluxing tank, drier and preheater, and then enters the aluminium bath through a wiper made of asbestos pad. After cooling, the strip is coiled up on the taken up reel.

The aluminised strips had good finish. The metallographic study and the mechanical tests gave encouraging results. During these experiments, zircon lined mild steel pot was put on a trial for holding the molten aluminium.

(ii) Aluminising of Fasteners.

Aluminising of fastener by the centrifuge technique is being developed. Preliminary experiments were conducted for designing the aluminising basket. Bolts and nuts of 5/8" dia. and above have been aluminised with encouraging results.

(iii) Aluminising of Mild Steel Panels.

Three hundred numbers of mild steel panels (6"×8") were aluminised. These panels were descaled by shot blasting prior to aluminising. The aluminised panels were required by the Inorganic Surface Coating Committee of the Corrosion Advisory Bureau for conducting exposure tests in various places throughout India.

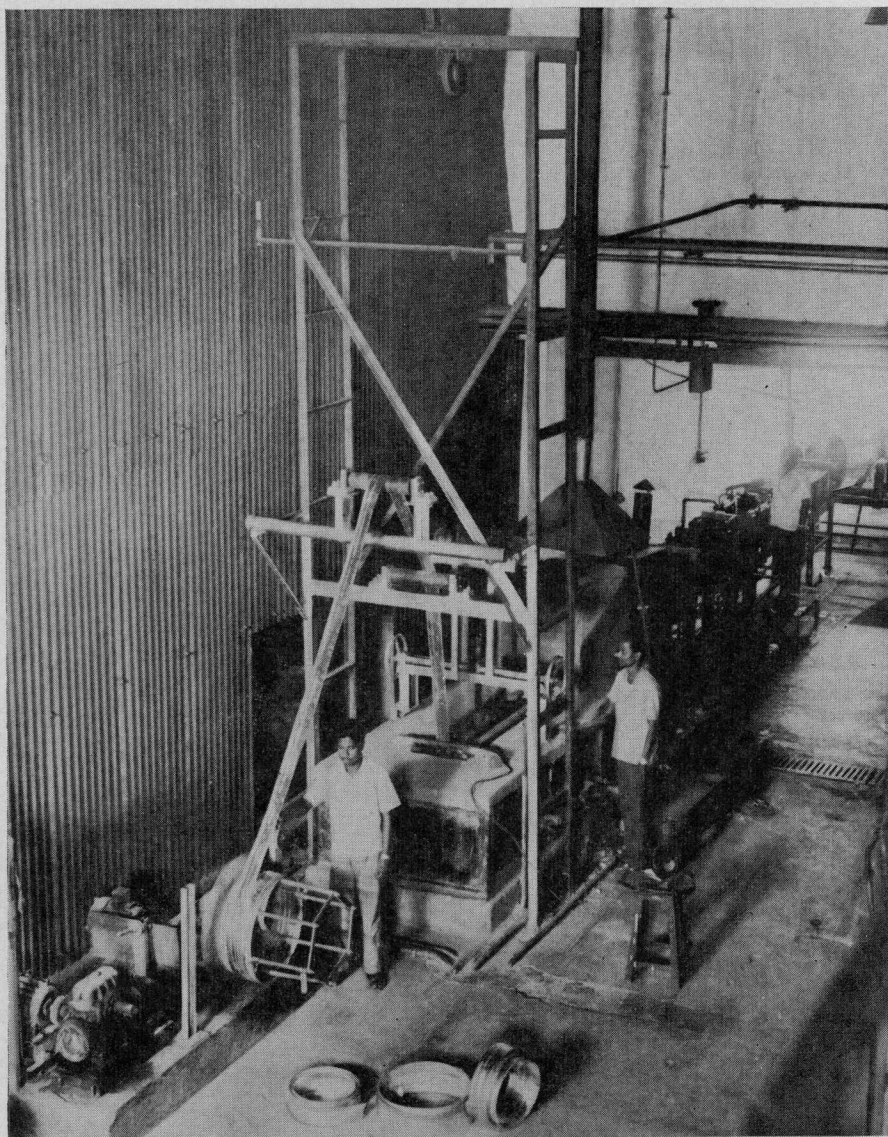
(iv) Demonstration & Training to Licencees.

Demonstration and training were given to M/s. Standard Alumino-Ferrous Pvt. Ltd., Calcutta, one of the licencees in the technique of aluminising.

101.0 Electrolytic Manganese Metal Pilot Plant and Manganese Dioxide Pilot Plant.

During the year the following investigations were carried out:

- (i) Studies on the reduction of manganese ores with solid and liquid fuels viz. charcoal and fuel oil.



The Modified plant for strip aluminizing.

- (ii) Suitability studies of manganese ores from Sandur Manganese and Iron Ore Ltd., Mysore and production of electrolytic manganese metal.
- (iii) Operation of 100 lb/day electrolytic manganese metal plant with a view to collect operational data as well as production of manganese metal for research purposes and sale of surplus to outside organisation.

102. **Pilot Plant for Production of Carbon Refractories.**

During this period, Refractories Pilot Plant has done considerable work for planning layout, erection, installation of machines and equipments and construction of furnaces in the dense carbon pilot plant, (an extension of Refractories Pilot Plant) with a capacity of 1/2 ton of dense carbon aggregate per day.

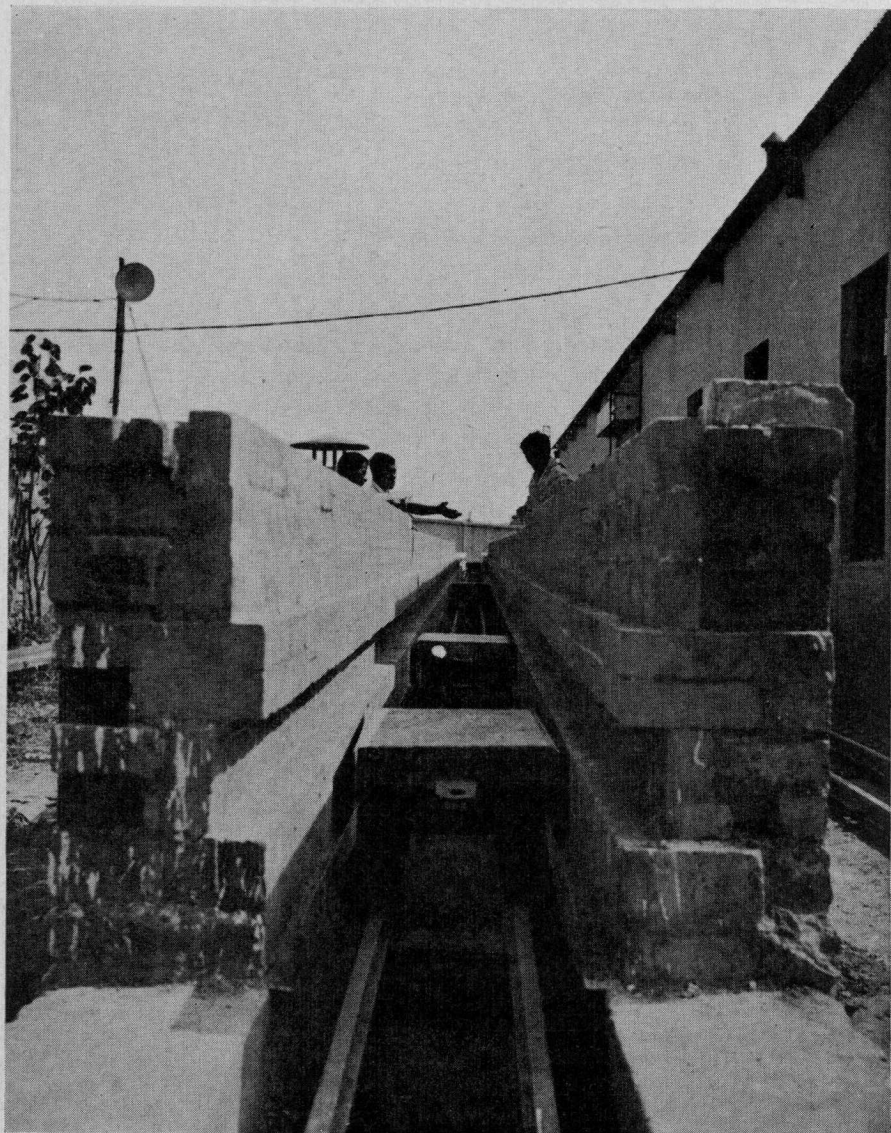
Before starting construction of furnaces *i.e.* D. D. Kiln and tunnel kiln, primary need was high alumina refractories for holding heating element coils, roof blocks and some other special shapes etc. The above requirements were costly as well as subjected to heavy delay by the suppliers. Therefore work was undertaken in the pilot plant to fabricate these refractories in the Laboratory to meet the demand on the following lines:

- (i) To produce high alumina cement.
- (ii) Calcination of kyanite at 1500°C and its crushing and grading etc.
- (iii) Formulating certain castable and rammable mixes.

About 10 tonnes of high alumina cement were made in the pilot plant for the construction of high alumina castable refractories. Two wagon loads *i.e.* 40—45 tonnes of 'D' grade kyanite were calcined at 1500°C in the D. D. kiln putting 3.5 to 4 tonnes in one lot. The calcined material was crushed and graded to yield an optimum powder density mix. Different types of ramming and castable mixes were formulated using CA cement and calcined kyanites for the construction of required refractories and their physical properties were studied to assess the suitability for the above purpose.

Installations of Machines and Equipment for Dense Carbon Aggregate Pilot Plant.

Most of the machines *i.e.* jaw crusher, roll crushers, bucket elevators, ball mill, hot blade sigma mixer, coke heater and hydraulic press etc. were put into position and installed. The plant is expected to start working in the near future and will produce 1/2 ton of dense carbon aggregate per day. In the beginning it will utilise raw-petroleum coke as base material. In the later stage processed Bhilai pitch and bituminous coal will be used as base material. These aggregates are expected to replace anthracite coke and imported low ash metallurgical coke which are being employed by the aluminium industry in its cathode lining.



Construction of Electrical Tunnel Kiln for Dense Carbon Pilot Plant.

ENGINEERING SERVICES

Design & Mechanical Engineering.

A. DEVELOPMENT PROJECTS UNDERWAY.

(i) *Strip Aluminizing Prototype Plant.*

The rotary melting furnace foundations were completed and the furnace installed. The coating furnace walls and foundations were completed. Lining of these is underway. The fabrication of the melt pot was also completed and its installation into the coating furnace is underway.

(ii) *Vanadium Pentoxide Plant.*

The draft project feasibility report for this plant was prepared and sent to the concerned Ministry.

(iii) *Continuous HCl Pickling.*

Research-cum-development work on this process was carried out which has a direct bearing on the pre-treatment of steel strip in the Strip Aluminizing Prototype Plant.

(iv) *Sukhinda Nickel Project.*

Design work, particularly related to the modification of existing equipment at NML such as rotary kiln, and sulphuric acid injection system was initiated. The objective is the procurement of process data amenable to scaling up for industrial use.

(v) *Multipurpose Pilot Plant.*

A flow sheet was under development for a multipurpose Metal Extraction Plant.

B. DESIGN AND FABRICATION PROJECTS COMPLETED OR UNDERWAY.

(i) *Corrosion of Moving Bodies.*

Design work was continued for an apparatus capable of determining corrosion in moving bodies.

(ii) *Micro Manipulator.*

A precision device for micro manipulation is being designed for the FPT Division.

(iii) *Electro Thinning Apparatus.*

Design was completed and fabrication is underway.

(iv) *Stress Corrosion Rig.*

Design and fabrication was completed.

(v) *Single Crystal Growth Apparatus.*

Design was completed.

(vi) *Raft for Corrosion Studies.*

Design of a raft for use at the Marine Corrosion Research Station at Digha was underway.

C. MISCELLANEOUS JOBS.

(i) *Workshop Section.*

This section comprising of Machine Shop, Fitting Shop, Fabrication Shop and Mechanical Maintenance Shop completed some 538 items of fabrication, 99 jobs involving over 800 test specimens and 175 breakdown/repair jobs for various research divisions of the Laboratory.

(ii) *Drawing Office Section.*

Tracings/drawings amounting to 550 were made for various research/development projects.

(iii) *Pattern Shop Section.*

Some 60 wood working/pattern jobs were completed.

Electronics Engineering.

A. DEVELOPMENT WORK.

(i) Precision Temperature Controller.

Modification work on the precision temperature controller developed earlier (Indian Patent No. 91134) was carried out to substitute imported components with components manufactured in India.

(ii) High Current Electronic Potentiostat.

Several types of direct-coupled amplifiers were tried out. Design of a suitable amplifier is under progress for use with saturable core reactor, using cold-rolled grain-oriented silicon steel laminations.

(iii) Solid State Automatic Thermogravimetric Balance.

The thermogravimetric balance developed earlier (using electron tubes) is being modified using solid state devices such as transistors and photoresistors.

(iv) Displacement Actuated Electronic Trigger for High Temperature Creep Testing.

The project was undertaken with a view to develop an electronic trigger for closing the armature circuit of a continuously excited D.C. shut motor. The motor reduces the applied load by means of gearing to the handwheel of the creep machine. As soon as the original value of strain is reached by this reduction of load, electrical contact is broken and the loading gear comes to rest. Design of a schmidt trigger circuit is under progress.

B. MAINTENANCE, INSTALLATION, TESTING AND CALIBRATION WORK.

Among the major maintenance, installation, testing and calibration work the following may be mentioned:—

- (i) Repair of electron beam melting furnace
- (ii) Repair of Philips x-ray diffractometer
- (iii) Repair of Philips autometer
- (iv) Repair of AEI electron microscope
- (v) Repair and installation of Magna research potentiostat
- (vi) Repair of derivatograph (D.T.A.)

- (vii) Repair of Radyne high frequency generator
- (viii) Maintenance of FPTD, MBPP and MCRS (Digha) instruments.
- (ix) Set up for testing of mu metal tubes.

Electrical Engineering.

A. MAJOR ELECTRICAL INSTALLATIONS.

(i) Electrical installation in Dense Carbon Pilot Plant.

Two parallel underground cables were installed from Mineral Beneficiation Pilot Plant Substation to Dense Carbon Pilot Plant to carry a power of 400 K.W. These cables have terminated to a main distribution board comprised of incoming air circuit breaker and out going H.R.C. fuse switch units. Power is then distributed to various control centres. Various electrical equipment for a jaw crusher, roll crusher, elevators, ball mill, coke powder heater, pitch heater, 400 Ton Hydraulic press, etc. were installed.

(ii) The following major electrical installations for several new equipment were made during the period.

- (a) Installation of one laboratory type arc furnace and three silicon carbide furnaces.
- (b) Installation for lathe, milling machine, polishing machine and surface grinder.
- (c) Installation of power points in new laboratory of Alloy Steel Division.
- (d) Installation for standby diesel generator and its control panel for existing creep laboratory.

B. DESIGN JOBS.

(a) Design and Fabrication of Electric Kiln in Dense Carbon Pilot Plant.

The kiln was divided into a number of zones in order to give a smooth gradient of temperature. Considering the temperature in each zone constant, power requirements of each zone and thus that of the entire kiln were calculated. The total power load comes to about 300 K.W. According to the power load in each zone, the heating elements were designed. Design of refractory supports for heating elements and their power terminals were completed.

(b) Design of Electrical Sub-station and Power Distribution.

The design of electrical substation and power distribution of new creep laboratory was carried out and estimate of expenditure was prepared. The sub-station will comprise of one 500 K. V. A., 6600/410 Volt stepdown transformer, H.T. and L.T. circuit breakers, voltage stabilizes and power distribution boards.

(c) Design and Fabrication of Resistance Furnaces.

Several electric resistances of low medium and high temperatures were designed and fabricated to meet the demand of various research and development work in National Metallurgical Laboratory. The heating elements used in these furnaces were nichrome, kanthal, platinum, platinum-rhodium and silicon carbide.

(d) Major Repairs of Electrical Equipment.

A number of major repairs were made which included extra high voltage transformers ; modification of the circuit of 0.87 arc furnace ; repairs of 3000 amps. 0-12 volt rectifier etc.

Civil Engineering.

Various civil engineering Jobs relating to maintenance and erection of plant and equipment, building, extension of building, etc. were conducted during the period under review.

INDUSTRIAL LIAISON, INFORMATION AND EXTENSION SERVICES

Liaison, Information and Extension services of the National Metallurgical Laboratory continued to play an important role in the field of dissemination of research results, commercial exploitation of the techniques and processes developed in the laboratory, providing consultancy work etc.

A number of 'Get-together' were held in different states with industrial organization, department of industries etc. to acquaint them the processes and techniques available for exploitation as well as to understand and undertake problems of the industries. A very encouraging response has been received from the industries and the state governments in this direction.

A brief account of the activities is furnished below:—

Consultancy Work.

During the period under review, metallurgical industries both in public and private sector continued to call on heavily the assistance of the National Metallurgical Laboratory in diversified subjects of metallurgical research, pertaining to production, process control etc.

A fluorspar beneficiation plant of the Gujarat Mineral Development Corporation having a capacity of treating 500 tons of low grade fluorspar per day, based on the process developed by the NML, Jamshedpur has been commissioned this year at Kadaipani, Ambadongar (Gujarat). This plant is cent per cent Indian in design, fabrication, erection and commissioning. The NML assisted the G.M.D.C. in the preparation of the plant lay out, scrutiny of tenders, selection of equipment etc. and finally in the commissioning of the plant for full production. The plant has a rated capacity for producing Rs. 40 million worth of fluorspar annually.

The National Metallurgical Laboratory had been carrying out beneficiation studies for several years on low grade pyrite samples from Amjhore, Shahabad Dist. Bihar; with a view to produce concentrate suitable for manufacture of sulphuric acid. During the period under review, batch heavy media separation tests with four pyrite samples from Amjhore supplied to Pyrites, Phosphates and Chemicals Ltd. were conducted to produce a concentrate

suitable for sulphuric acid manufacture in the Sindri Fertilizer Plant. Pilot Plant scale tests was also undertaken in the Heavy Media Separation Plant of NML on low grade pyrite from Amjhore and based on the results and data obtained from pilot plant run, a flow sheet was developed and specifications of equipment for setting up of a 1600 tonnes per day beneficiation plant along with the cost of beneficiation had been supplied to the sponsored organisation. M/s. Pyrites, Phosphates & Chemicals Ltd.

Pilot Plant flotation studies have been carried out with run-of-mine ore sample from Jaduguda Mines sent by Uranium Corpn. of India Ltd., with a view to recover copper, nickel and molybdenum minerals from the uranium bearing ore prior to uranium extraction. The objective is to set up a mineral byproduct recovery plant for treating 1,000 tonnes of run-of-mine uranium ore per day at Jaduguda. The studies were completed and report had been submitted.

Among the major work relating to ore preparation, extraction etc. referred to NML during the current period, mention may be made of (i) the project on United Nations Industrial Development Organisation's proposal for beneficiation studies on Asswan Iron Ore for United Arab Republic. The National Metallurgical Laboratory has been awarded an international assignment to undertake pilot plant scale investigations for the production of pig iron from low grade iron ores from Asswan (UAR) after beneficiation, agglomeration and pre-reduction. Based on these pilot plant studies, the NML will submit to UNIDO a technical feasibility report. This is the first international assignment which the NML has received in recognition of the outstanding work done in the field of mineral beneficiation and processing. (ii) Another special project on bench and pilot plant scale studies on Sukhinda deposits in Orissa has been taken up on behalf of M/s. Chemical & Metallurgical Design Co. P. Ltd. in order to evaluate and provide the data required for the design and setting up of a plant for the extraction of nickel and cobalt.

Technical Aid to Industries.

Over two hundred enquiries on different subjects pertaining to process details, raw materials, quality, production etc. were attended to during the period under review. The majority of the enquiries originated from private industries as well as individuals. Detailed technical notes were furnished whenever necessary. About sixty short-term investigations and testings were conducted out of which about 43 percent related to government and semi government organisations and 57 percent from private industries and individuals.

Industrial Surveys and Collection of Statistical, Economic and Market Data.

Statistics relating to latest production and consumption figures of different types of raw materials, ferrous and non-ferrous metals and alloys of Indian and other countries of the world were collected. Scanning of technical news of the industry and research development in home and overseas press was done. Data thus collected were classified and catalogued and made available to research workers of the laboratory as well as made use of in connection with enquiries from outside organizations.

Training.

Instructional and training facilities were extended to twenty eight students of metallurgy from the I.I.T., Madras and special lectures were arranged on (i) Ore dressing technique for Indian iron and manganese ore (ii) Modern physico-chemical methods of metallurgical analysis and (iii) Manufacture of iron in low shaft furnace.

Besides, many technical personnel from engineering colleges, universities and students from technical institutes, universities and engineering colleges were given training in heat treatment, induction melting, mechanical testing, refractories, ore-dressing techniques, foundry technology etc.

Visitors.

During the period under review, the following important visitors visited the Laboratory. Besides, a large number of visitors from industries, universities, technical institutions etc. visited the Laboratory.

1. Dr. G. Mikeldaze, Institute of Metallurgi, Georgian S.S.R. Tbilis, U.S.S.R.
2. Mr. J. Greenhill, British Cast Iron Research Asscn., Birmingham, U.K.
3. Mr. K. T. Chandy, Chairman, Hindustan Steel Ltd.
4. Mr. R. P. Billimoria, Director, Hindustan Steel Ltd.
5. Officers of National Defence College, Dehradun.

NML FIELD STATIONS & MARINE CORROSION RESEARCH STATIONS

Field Stations

The field stations have been rendering useful service to the local foundry industries in selection of proper raw materials by offering testing facilities for the analysis of metals and alloys, testing of sand samples etc. which are essential for quality control and elimination of rejects in the day to day working of a foundry. The field stations have been receiving requests for technical guidance and help from local foundrymen and other industrialists in increasing number of diverse aspects of foundry technology which include proper selection of foundry raw materials, application of modern techniques of production, use of scientific methods of metal melting and casting, quality control and elimination of defects, production techniques to meet export requirements etc.

It is now proposed to diversify the activities of the field stations depending on regional demands. As there is no facility for undertaking studies on mineral beneficiation and ore dressing in the Western part of the country, it has therefore been decided to diversify the activities of the field station at Ahmedabad and provide facilities for carrying out investigations and studies related to mineral beneficiation. A refractories testing laboratory where investigation and testing can be taken up on refractory raw materials and products has been the long felt need of the Southern Region. There is also need for providing facilities for ore dressing especially in view of the rich mineral resources of the Southern region. The proposed expansion programme of the Field Station, Madras, therefore consists in providing facilities for refractories testing and ore dressing. In view of the large number of metal working and metal forming industries in North India, heat treatment and general metallurgical facilities for the development of metal working industries is essential. It is, therefore, proposed to expand the facilities of the Field Station, Batala, to include heat treatment, mechanical testing and metallurgy Division.

Marine Corrosion Research Station.

The Marine Corrosion Research Station at Digha on the coast of Bay of Bengal in West Bengal has initiated a number of research projects on the corrosion and protection of metals under marine environmental condition. The details of work have been furnished in main body of the report.

LIBRARY, DOCUMENTATION, TRANSLATION & REPROGRAPHIC SERVICES

Library & Documentation Services.

During the period, the library subscribed 500 Journals and received 109 Journals on exchange programme. Documentation service is provided by scanning and classifying the published information from current journals. A monthly publication covering the abstracts from current periodicals is being brought out.

Translation Service—Publication of Survey of Metallurgical Developments.

To avoid the language difficulties for French, German and Russian technical Journals, action has been initiated to prepare comprehensive and fully informative abstracts of all the articles of these Journals in English and publish the same in the form of a monthly bulletin.

In addition to the above publication, the routine translation services were continued. French, German & Russian articles of direct interest to research projects of the Laboratory were translated into English. Oral translations were also rendered for the benefit of the research workers.

Reprographic Service.

Photostat, reflex prints and micro-films were made from scientific papers of interest for research staff. Micro-photographs, X-ray photographs, photographs of apparatus and equipment etc. of various projects of the Laboratory were also taken.

PUBLICATIONS

NML Technical Journal.

NML Technical Journal has entered into twelfth year of publication. The journal is continuing to be received with much interest by scientists, technologists and industrialists both in the country as well as abroad. Exchange agreement has been arrived with a large number of Indian and Foreign journals. The leading abstracting services of the world are regularly publishing the abstracts of the papers of NML Technical Journal. One hundred and nine journals were received in exchange programme established with NML Technical Journal.

Proceedings of the Symposia.

The Proceedings of the Symposium on "Recent Developments in Non-ferrous Metals Technology" is under publication during the period. The Proceedings covered three volumes *e.g.* Volume I—Aluminium and its Alloys; Volume II—Copper and its Alloys; Volume III—Other Non-ferrous Metals & Alloys. The first volume of the Proceedings was published during the period and the publication of the other two volumes are underway.

Monograph.

A Monograph on "Structure of Electro-deposited Manganese Metal" was published. Another Monograph entitled "Atlas on Transformation Diagrams of Low Alloy Steels" is under publication.

Special reports.

Many special reports were prepared to meet the need of the industries and government organizations. To discuss problems of interest to iron and steel plants with public and private sector iron and steel industries, a report was prepared and circulated covering industrial investigations of interest to iron and steel plants conducted in the laboratory and facilities available in the Laboratory for undertaking industrial investigation. The report evolved considerable interest amongst the iron and steel plant executives and technical personnel resulting in a series of discussions and referring of problems to the laboratory. Reports were also prepared on work done and that can be conducted in different fields of study *e.g.* non-ferrous metallurgy, mineral beneficiation, refractories etc. for fruitful discussion with industrial and other organizations.

Press Releases.

Periodic press releases were issued to appraise the general public about the important activities and contribution of the National Metallurgical Laboratory.

Hand outs & Notes.

Hand outs and notes on the processes of the laboratory developed for commercial exploitation were prepared and circulated to interested industrial organizations.

Papers Published and Presented.

Fifty three papers were published and presented during the period. The details are furnished in Appendix I.

Research & Investigation Reports.

Seventy five research and investigation reports were prepared during the period. Details are furnished in Appendix II.

GENERAL

Prof. V. A. Altekhar, joined as Director, National Metallurgical Laboratory in August 1969. Shri P. I. A. Narayanan, Officer-in-Charge (Ore-Dressing) & Ex-Scientist-in-Charge retired in January 1970.

The following staff of the Laboratory were nominated to various Committees.

(i) Prof. V. A. Altekhar, Director—Governing Council for establishment of laboratory connected with research in Defence Research & Development Organisation.

(ii) Shri P. I. A. Narayanan, Officer-in-Charge (Ore-Dressing)—Board of Directors of the Pyrite & Chemicals Development Corp. Ltd.

(iii) Dr. A. B. Chatterjea, Scientist—Standing Committee & Committee of the Coal Advisory Council (Ministry of Steel, Mines & Metals, Govt. of India).

(iv) Shri R. M. Krishnan, Scientist,—Panel for Steel Casting Industry (Ministry of Industrial Development, Internal Trade & Co. Affairs, Govt. of India).

Besides the above, the staff of the Laboratory, worked in various Committees of Indian Standard Institution.

Shri H. R. Thilakan, Scientist, went on deputation to Poland under Exchange Programme to study advance techniques and methods of corrosion and its protection.

Purchase and Store Section kept up their activities for procurement of capital equipment, raw materials, consumable stores etc. Administration & Accounts section handled the general administration and budgetary accounts with speed and efficiency.

The NML Staff Co-operative Credit Society continued its good work and handled transaction amounting to nearly Rs. 2 lakhs. Co-operative Stores of the Laboratory is supplying ration, food-stuffs, stationery articles. The Canteen continues to supply to the staff meals and snacks at reasonable price.

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

Safety First & First aid Section.

Periodic inspections to safety measures were carried out during the period. Safety materials and garments were supplied to workers who are exposed to various hazards. There was no major casulaty during the period.

PATENTS AND PROCESSES

Patents

	Ind. Patent No.	Title
Applied for	126062	An improved method for the removal of vanadium from vanadium pig iron.
Accepted	119958	Development in or relating to the production of aluminium alloy anodes for cathodic protection.
	118916	A process for stabilisation of ferro-silicon.
	116520	An improved and modified process for the manufacture of ferrite magnets.
Sealed	114500	Improvements in or relating to welding flux compositions and methods of making the same.
	112574	A simple process for pre-heating the air blast in a cupola.
	110814	Improvements in or relating to the production of fluoboric acid.

Processes Released.

The following process was released during the period to the firm as mentioned :

	Process	Firm
1.	Hot-dip aluminising of ferrous materials.	Standard Alumino-Ferrous Industries Ltd., Calcutta.

APPENDIX I

Papers Published, Communicated and Presented.

1. Smelting of iron ore fines with non-metallurgical fuels and blast additives: Experimental trials for ten years in Low-Shaft Furnace—A. B. Chatterjea—NML Technical Journal, Vol. XI, No. 4, 1969.
2. Smelting of iron ore with raw lumpy non-coking coals—A. B. Chatterjea, J. Goswami, S. K. Biswas, R. Santokh Singh, J. S. Padan & S. R. Ghosh—NML Technical Journal, Volume XI, No. 4, 1969.
3. Heat balance for iron making in experimental Low-Shaft Furnace.—S. Prasad & A. B. Chatterjea.—NML Technical Journal, Vol. XI, No. 4, 1969.
4. Effect of inhibitors on the permeability and diffusion co-efficient of hydrogen in steel—Inder Singh, NML Technical Journal Vol. XII, No. 1, 1970.
5. Studies on the precipitation of ALN in Steel—J. K. Mukherjee, NML Technical Journal, Vol. XII, No. 1, 1970.
6. Viscosity of blast furnace slag and its effects on their application—Narinder Singh, V. Muthukrishnan & T. Rogozinski. NML Technical Journal, Vol. XII, No. 1, 1970.
7. Evaluation of manganese-copper-nickel alloys for use in thermal bi-metals.—J. Bhattacharya & B. N. Das. NML Technical Journal, Vol. XII, No. 1, 1970.
8. Beneficiation of graphite with particular reference to sample from Andhra Pradesh.—P. V. Raman, S. K. Banerjee & P. I. A. Narayanan.—NML Technical Journal, Vol. XII, No. 1, 1970.
9. Hardening of silicon-spring steel.—S. K. Tiwary & P. K. Gupte.—NML Technical Journal, Vol. XII, No. 1, 1970.
10. Studies on the inhibitors for packaging and storage.—K. V. Srinivasan & V. A. Altekar—NML Technical Journal, Vol. XII, No. 2, 1970.

11. Investigation on molybdenum concentrate obtained from Rakha mine.—H. P. Bhattacharya, A. K. Lahiri & T. Banerjee.—NML Technical Journal, Vol. XII, No. 2, 1970.
- ✓12. Stainless steel corrosion—a case study.—K. P. Mukherjee, A. K. Lahiri & T. Banerjee. NML Technical Journal, Vol. XII, No. 2, 1970.
13. Design of risers by the cooling curve method.—G. N. Rao. NML Technical Journal, Vol. XII, No. 2, 1970.
14. Phase transformation in thermal copper-tin alloys.—G. Basu, J. K. Mukherjee & T. Banerjee. NML Technical Journal, Vol. XII, No. 2, 1970.
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24. Treatment of complex lead, copper and zinc sulfides—P. V. Viswanathan, B. V. S. Yedavalli, S. R. Srinivasan & P. P. Bhatnagar. Proc. of the Symposium on Non-ferrous Metals Technology, Vol. II—Copper.
25. Brittleness in copper.—S. M. Arora and P. K. Gupte. Proc. of the Symposium on Non-ferrous Metals Technology, Vol. II—Copper.
26. Study of micro-structure of chill cast aluminium bronze (Cu-Al-Fe-Mn)—R. D. Gupta, D. P. Chakravarty, R. Chakravarty & P. K. Gupte. Proc. of the Symposium of Non-ferrous Metals Technology, Vol. II—Copper.
27. The applicability of size-factor and electron concentration concepts to alloying behaviour of copper.—L. J. Balasundaram. Proc. of the Symposium on Non-ferrous Metals Technology, Vol. II—Copper.
28. Nickel resources in India and their exploitation.—R. N. Misra & P. P. Bhatnagar. Proc. of the Symp. on Non-ferrous Metals Technology, Vol. III.
29. Polarographic analysis of zinc ore concentrates for the determination of lead, copper, cadmium and zinc.—H. P. Bhattacharya & P. C. Debnath. Proc. of the Symp. on Non-ferrous Metals Technology, Vol. III.
30. Studies on Nundydroog gold ore with a view to improving gold recovery.—P. V. Raman & P. I. A. Narayanan. Proc. of the Symposium on Non-Ferrous Metals Technology, Vol. III.
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38. Simulation studies on steel ingot casting and solidification—K. N. Gupta & A. N. Kapoor. Presented at the Annual Convention of Ind. Inst. of Foundrymen, held at Bombay, February 1970.
39. Iron melting in cupola with arrangement for pre-heating the air blast by effluent gases—S. Santok Singh & A. B. Chatterjea. Presented at the Annual Convention of Ind. Inst. of Foundrymen, held at Bombay in February 1970.
40. Structural changes in as-cast high speed steel—R. K. Dubey, P. S. Nag & P. K. Gupte. Presented at the Annual Convention of Ind. Inst. of Foundrymen, held at Bombay, February, 1970.
41. Wear and abrasion resistant cast iron for centrifugal abrading machine—R. D. Gupta & P. K. Gupte. Presented at the Annual Convention of Ind. Inst. of Foundrymen, held at Bombay, February, 1970.
42. Recovery of metallic values from foundry wastes—N. G. Basak, V. S. Sampath & P. P. Bhatnagar. Presented at the Annual Convention of Inst. of Ind. Foundrymen, held at Bombay, February, 1970.
43. Increasing in casting yield by use of exothermic riser—G. N. Rao & P. R. Prasad. Presented at the Annual Convention of Inst. of Ind. Foundrymen, held at Bombay, February, 1970.
44. The structure and properties of 9 percent nickel steel.—R. Chattopadhyaya, J. P. Tewari & S. S. Bhatnagar. Trans. of Ind. Inst. of Metals, Vol. 23 No. 1, 1970.

45. Structure of electro-deposited manganese Pts. I & II.—N. Dhananjayan. Trans. of Indian Inst. of Metals, Vol. 23 No. 1, 1970.
46. Diversity in industrial failures due to corrosion a few case studies.—K. P. Mukherjee, S. Rao Addanki, H. R. Thilakan, A. N. Mukherjee & A. K. Lahiri.—Proc. of the Symp. on Corrosion Fundamental.
47. Microstructure and properties of chrome-magnesite refractories made from indigenous raw materials.—U. N. Mathur, M. R. K. Rao & P. C. Sen. Communicated for Annual General Meeting of Indian Ceramic Society.
48. Technology of barium ferrite magnets—Ved Prakash. Communicated for Annual General Meeting of Ind. Cer. Society.
49. Beneficiation of low-grade ores and minerals of Rajasthan.—P. V. Raman & G. P. Mathur. For presentation at the Symp. on Prospects of mineral based industries in Rajasthan.
50. Measurement of low-temperatures. L. J. Balasundaram.—For presentation at the Seminar on "Cryogenics—its research & Application in India".
51. Behaviour of metals and alloys at low-temperature.—Ved Prakash, Rajendra Kumar. For presentation at the Seminar on "cryogenics—its research & application in India.
52. Influence of associated ingredients on the mechanism of gaseous reduction of hematite Pt. I—Calcium carbonate.—T. C. De & A. B. Chatterjea. Communicated for Annual Technical Meeting of Indian Inst. of Metals.
53. Mould and core coatings for copper base alloys.—G. N. Rao, R. N. P. Gupta & R. M. Krishnan. For presentation at the Seminar organised by Indian Copper Information Centre.

APPENDIX II

Scientific Investigations Completed and Reports Prepared.

1. Studies on crushing and washing of a mixed iron ore sample from Kiriburu Mines of N.M.D.C. for supply of ore to Bokaro Steel Plant.—R. K. Kunwar, P. K. Sinha, G. P. Mathur & P. I. A. Narayanan (I.R. 511/69).
2. Beneficiation of a low grade phosphate rock from Kataria hill mine, Udaipur Dt. Rajasthan.—S. K. Dhar, P. V. Raman & P. I. A. Narayanan (I.R. 512/69).
3. Batch heavy media separation tests with the four pyrite samples from Amjhore, Shahabad Dist. Bihar.—M. V. Ranganathan & P. I. A. Narayanan (I.R. 513/69).
4. Beneficiation studies on a low grade nickeliferous laterite from Sukinda, Orissa.—S. Prasad, P. V. Raman & P. I. A. Narayanan (I.R. 514/69).
5. Investigation on powder resin received from M/s. India Cements Ltd. (Foundry Division), Madras.—H. P. Singh, T. A. Beck & P. K. Gupte (I.R. 515/69).
6. Lax Bond—TD 300, and "Yellow Dextrine" as Core Binders.—S. K. Sinhababu, T. A. Beck & P. K. Gupte (I.R. 516/69).
7. Beneficiation of phosphate rock sample from Kanpur Block of Udaipur Dist. Rajasthan.—K. N. Rakshit, S. K. Banerjee & P. I. A. Narayanan, (I.R. 517/69).
8. Concentration of low-grade galena from Bandalamottu block, Agnigundala area, Andhra Pradesh.—S. K. Banerjee & P. I. A. Narayanan (I.R. 518/69).
9. Petrological study of five limestone samples from Bhadiguda mines of Mysore Iron & Steel Ltd. Bhadravati.—B. Banerjee, A. Peravadhanulu, M. S. Chopra, & P. I. A. Narayanan (I.R. 519/69).
- ✓ 10. Corrosion of stainless steel valve in the recovery and purification block.—K. P. Mukherjee, A. K. Lahiri (I.R. 520/69).

11. Petrological studies on the two phosphate rock samples A and B received from Director of Mines and Geology, Udaipur, Govt. of Rajasthan.—B. Banerjee, A. Peravadhanalu, M. S. Chopra and P. I. A. Narayanan (I.R. 521/69).
12. Moulding characteristics of Rajmahal Sand (Coarse).—S. K. Sinhababu, T. A. Beck & P. K. Gupte (I.R. 522/69).
13. Flotation studies for the recovery of molybdenum, copper and nickel minerals from the uranium ore from Jaduguda Mines—Part II.—R. Ganesh, G. S. R. K. Rao, P. I. A. Narayanan (I.R. 523/69).
14. Moulding characteristics of sand sample No. KS-3 received from Punjab State Industries Dept. Chandigarh.—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 524/69).
15. Moulding characteristics of sand sample No. KS-2 received from Punjab State Industries Dept. Chandigarh.—R. C. Arora, M. N. P. Verma & G. N. Rao (IR 525/69).
16. Moulding characteristics of sand sample No. KS-20 received from Punjab Industries Dept. Chandigarh.—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 526/69)
17. Moulding characteristics of sand sample No. KS-5 received from Punjab State Industries Dept. Chandigarh.—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 527/69).
18. Moulding characteristics of sand sample No. KS-1 received from The Punjab State Industries Dept. Chandigarh.—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 528/69).
19. Beneficiation of low grade kyanite-sillimanite sample No. D₂S₁ from Dahagaon Area, Nagpur.—A. K. Khatry, R. Ganesh, & P. I. A. Narayanan (I.R. 529/69).
20. Study into the cause of failure of some turbine blades—P. Basak & B. N. Das (I.R. 530/69).
21. Production of silico-chrome by single stage process with the raw materials supplied by M/s. Ferroalloy Corporation Ltd., Garividi—P. P. Bhatnagar, M. Subramanian, R. G. Gangully, N. Subrahmanyam, B. V. S. Yadavalli & S. S. Bhorey (I.R. 531/69).

22. Moulding characteristics of sand sample No. GSP-8 (natural moulding sand) received from Punjab State Industries Department, Chandigarh. R. C. Arora, M. N. P. Verma & G. N. Rao (I. R. 532/69).
23. Moulding characteristics of sand sample No GSP-18 received from Punjab State Industries Department, Chandigarh.—R. C. Arora, M. N. P. Verma and G. N. Rao (I. R. 533/69).
24. Failure of shafts from return drums of endless belts.—B. K. Saxena & C. Sharma (I.R. 534/69).
25. High strength of low alloy steel to IS : 961.—C. Sharma (I.R. 535/69).
26. Testing of B & W. boiler tubes.—C. Sharma (I.R. 536/69).
27. Failure of heat resisting steel castings.—C. Sharma (I.R. 537/69).
28. Manufacture of alloy steel liners for presses used in making bricks.—C. Sharma (I.R. 538/69).
29. Bucket tooth for excavators.—C. Sharma (I.R. 539/69).
30. Results of observations on ancient iron ingots and crucibles sent by Metals Committee.—J. K. Mukherjee, A. K. Lahiri (I.R. 540/69).
31. Pilot Plant beneficiation studies of a low grade phosphate sample from Maton Block, Udaipur Dist. Rajasthan.—Joga Singh, G. Radhakrishnan, P. D. Prasad Rao, B. L. Sengupta, G. P. Mathur & P. I. A. Narayanan (I.R. 541/69).
32. Petrological studies on the two limestone sample No. 1 and 2 received from M/s. Travancore Electro-chemical Industries, Chingavanam Kottayam Dist. Kerala—B. Banerjee, A. Peravadhanulu, M. S. Chopra & P. I. A. Narayanan (I.R. 542/69).
33. The corrosion of cast iron pipes used in the manufacture of sulphuric acid.—H. R. Thilakan, A. K. Lahiri (I.R. 543/69).
34. Fluidized bed roasting of zinc sulphide concentrates—some equilibrium considerations.—S. R. Srinivasan & P. P. Bhatnagar (I.R. 544/69).
35. Pilot plant flotation studies for the recovery of molybdenum, copper and nickel minerals from uranium ore received from Jadujuda Mines—Part III.—R. Ganesh, K. Vijayaraghavan, G. S. Ramakrishna Rao, G. P. Mathur & P. I. A. Narayanan (I.R. 545/69).

36. Moulding characteristics of sand sample No. GSP-11 received from The Punjab State Industries Depart. Chandigarh.—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 546/69).
- ✓ 37. Failure of stainless steel pumps parts in the production of electrolytic zinc.—H. R. Thilakan & A. K. Lahiri (I.R. 547/69).
38. Moulding characteristics of sand samples No. GSP-13 (natural moulding Sand) received from Punjab State Industries Department, Chandigarh.—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 548/69).
39. Moulding characteristics of sand sample No. BTL-6 (natural moulding sand) received from the Department of Industries, Govt. of Punjab.—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 549/69).
40. Pilot Plant studies on washing and pelletization of Donimalai iron ores for N.M.D.C.—P. K. Sinha, N. Chakravorty, G.S.R.K. Rao, G.P. Mathur and P. I. A. Narayanan (I.R. 550/69).
41. Corrosion of steel plates during storage.—Inder Singh & A. K. Lahiri (I.R. 551/69).
42. Batch and pilot plant beneficiation studies on a low grade limestone sample from Tal, Garhwal Dist. U.P. and proposals for setting up of a 1200 t.p.d. beneficiation plant.—B. L. Sengupta, C. Satyanarayana, G. Radhakrishnan, S. K. Banerjee, G. P. Mathur & P. I. A. Narayanan (I.R. 552/69).
43. Studies on beneficiation of a complex copper-lead-zinc ore from Dariba-Rajpura area, Rajasthan.—P. V. Raman, S. K. Sengupta & P. I. A. Narayanan (I.R. 553/69).
44. Purification of zircon concentrate from Kerala for M/s. Hindustan Sanitary-ware & Industries Limited. Haryana.—N. Chakravorty & P. I. A. Narayanan (I.R. 554/69).
45. Beneficiation of Low grade graphite from Sitampalli Mines, Andhra Pradesh.—C. Satyanarayana, S. K. Banerjee & P. I. A. Narayanan (I.R. 555/69).
46. Pilot Plant Studies on beneficiation of Amjhore pyrite employing H.M.S. and jigging and proposals for setting up of a 1600 Tonnes/day treatment plant.—M. V. Ranganathan, P. D. Prasada Rao, R. K. Kunwar, K. Vijayaraghavan, S. K. Banerjee, G. P. Mathur & P. I. A. Narayanan (I.R. 556/69).
47. Production of high carbon ferro-manganese using low temperature

carbonization coke of Katkona collieries of Madhya Pradesh.—P. P. Bhatnagar, M. Subrahmanian, R. G. Ganguly, N. Subrahmanayam, B. V. S. Yedavalli & S. S. Boray (I.R. 557/69).

48. Moulding characteristics of sand sample No. K.S.S. 1—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 558/70).
49. Moulding characteristics of sand sample No. GSP-19.—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 559/70).
50. Moulding characteristics of sand sample No. BTL-18—R. C. Arora, M. N. P. Verma and G. N. Rao (I.R. 560/70).
51. Moulding characteristics of sand sample No. BTL-16—R. C. Arora, M. N. P. Verma, G. N. Rao (I.R. 561/70).
52. Moulding characteristics of sand sample No. GSP-14—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 562/70).
53. Moulding characteristics of sand sample No. BTL-8—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 563/70).
54. Moulding characteristics of sand sample No. BTL-15—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 564/70).
55. Moulding characteristics of sand sample No. LSS-1—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 565/70).
56. Moulding characteristics of sand sample No. BTL-19—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 566/70).
57. Moulding Sands available near Batala & their suitability for copper alloy casting.—R. N. P. Gupta, M. N. P. Verma & G. N. Rao (I.R. 567/70).
58. Beneficiation studies on a low grade kyanite-sillimanite sample (D_3S_2) from Dahagaon Area, Nagpur.—P. V. Raman & P. I. A. Narayanan (I.R. 568/70).
59. Moulding characteristics of sand sample No. GSP-16 received from The Department of Industries, Govt. of Punjab.—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 569/70).
60. Moulding characteristics of sand sample No. KS-6 received from the Department of Industries, Govt. of Punjab.—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 570/70).

61. Moulding characteristics of sand sample No. KS-7, received from the Department of Industries, Govt. of Punjab.—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 571/70).
62. Moulding characteristics of sand sample No. BTL-14 (natural moulding Sand) received from the Department of Industries, Govt. of Punjab.—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 572/70).
63. Beneficiation of a pyrite-pyrrhotite sample from Saladipura Area, Dist. Sikar, Rajasthan.—B. L. Sengupta & G. P. Mathur (I.R. 573/70).
64. Petrological studies of fourteen core samples of bore holes D-9A, D-10 and D-14 of Kanjamalai magnetite deposits, Salem, Govt. of Tamil Nadu.—Bhaskar Banerjee, A. Peravadhanulu, M. S. Chopra, G. P. Mathur (I.R. 574/70).
65. Calcination characteristic of Indian petroleum cokes—Study by polarised light microscopy.—R. V. Hargave & H. P. S. Murthy (R.R. 264/69).
66. Structure and stability of liquid aluminium-zinc alloys.—Rajendra Kumar & C. S. Sivaramakrishna (R.R. 265/69).
67. Grain size control of magnesium—Rajendra Kumar & R. K. Mahanty (R.R. 266/69).
68. Embrittling effect of manganese on Fe-20% Ni type Maraging steels.—R. Kumar & C. S. Sivaramakrishna (R.R. 267/69).
69. Structure and stability of Pb-Sb-liquid Alloys.—Rajendra Kumar & C. S. Sivaramakrishnan (R.R. 268/69).
70. Kinetics of reaction between barium carbonate and iron oxide—S. K. Bose & Ved Prakash (R.R. 269/69).
71. Phase changes in $Mn_{1.11} Al_{0.89}$ alloy.—C. R. Tiwari & Ved Prakash (R.R. 270/69).
72. Tempering of die-steels based on indigenous materials.—R. K. Dubey, S. P. Chakravarty & P. K. Gupte (R.R. 271/69).
73. Hardening of silicon-spring steel.—S. K. Tiwary & P. K. Gupte (R.R. 272/69).
74. Fluidized bed roasting of zinc sulphide concentrates—some equilibrium considerations.—S. R. Srinivasan & P. P. Bhatnagar (R.R. 272A/69).
75. Increase in casting yield by use of exothermic riser.—G. N. Rao & P. R. Prasad (R.R. 273/70).

APPENDIX III

Major Sponsored Projects

Sl. No.	Title	Sponsor
1.	Studies on crushing & washing of a mixed iron ore sample from Kiriburu mines of N.M.D.C. for supply of ore to Bokaro Steel Plant.	National Mineral Development Corpn. Ltd., New Delhi.
2.	Pilot Plant studies on washing and pelletisation of Donimalai Iron ores for N.M.D.C.	National Mineral Development Corporation Ltd., New Delhi.
3.	Batch and pilot plant beneficiation studies on a low grade lime-stone sample from Tal, Garhwal Dist. U.P. and proposals for setting up of a 1200 t.p.d. Beneficiation Plant.	Directorate of Geology & Mining, Govt. of U.P. Lucknow.
4.	Production of high carbon ferro-manganese using low temperature carbonization coke of Katkona collieries of Madhya Pradesh.	Madhya Pradesh Audyogik Vikas Nigam Ltd., Bhopal.
5.	Pilot Plant studies on beneficiation of Amjhore pyrite employing H.M.S. and jigging and proposals for setting up of a 1600 tonnes/day treatment plant.	Pyrites, Phosphates & Chemicals Ltd., Dehri-On-Sone, Dist. Shahabad.
6.	Beneficiation studies on a low grade nickeliferous laterite from Sukinda, Orissa.	Geological Survey of India, Calcutta.
7.	Beneficiation of a low grade phosphate rock from Kataria Hill Mine, Udaipur Dt., Rajasthan.	Director of Mines & Geology, Udaipur, Rajasthan.

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| 8. | Concentration of low grade galena from Bandalmottu Block, Agnigundala Area, Andhra Pradesh. | Geological Survey of India, Southern Region, Hyderabad. |
| 9. | Beneficiation of phosphate rock sample from Kanpur Block of Udaipur Dt., Rajasthan. | Geological Survey of India, Jaipur, Rajasthan. |
| 10. | Purification of zircon concentrate from Kerala for M/s. Hindustan Sanitaryware & Industries Ltd., Haryana. | Hindustan Sanitaryware & Industries Ltd., Rahtok, Haryana. |
| 11. | Studies on beneficiation of a complex copper-lead-zinc ore from Dariba-Rajpura area, Rajasthan. | Geological Survey of India, Jaipur, Rajasthan. |
| 12. | Beneficiation of low grade graphite from Sitampallimines, Andhra Pradesh. | S. Lal & Co. Pvt. Ltd., Calcutta. |