# NML

## Annual Report

## 1973-74

National
Metallurgical
Laboratory
Jamshedpur, India

# ANNUAL REPORT

## 1973 - 74

**NATIONAL METALLURGICAL LABORATORY**

COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH

JAMSHEDPUR, INDIA

Compiled, Edited & Produced by
P. K. Gupta
A. N. Kapoor

Secretarial Assistance
T. K. Ghose
K. V. Easwar

Design & Layout
P. K. Gupta
M. L. Sarkar

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# INTRODUCTION

The National Metallurgical Laboratory, during the period under review, has continued its efforts towards the industrial implementation of its various development projects as well as finding of solution of assignments sponsored by the industry. A number of major public and private sector industries as well as medium and small scale industries have continuously called at NML with metallurgical problems in their respective fields, culminating in the shape of sponsored research, investigation and development work. Thus work has been conducted on behalf of M/s. Hindustan Steel Ltd., Tata Iron & Steel Co., Ltd., Hindustan Copper Ltd., Hindustan Zinc Ltd., National Mineral Development Corporation, Nepal Minerals Supply, Rajasthan Industrial Mineral Development Corporation, M. N. Dastur & Co., MECON, etc.

The Laboratory has offered its services regarding infrastructure facilities for the extraction of nickel from the Sukhinda nickel ores based on the tests carried out in the Laboratory. This project is sponsored by the Ministry of Steel & Mines, Govt. of India, through their consultants M/s. Chemical & Metallurgical Design Co. The Laboratory will be setting up a pilot plant in their first phase of work.

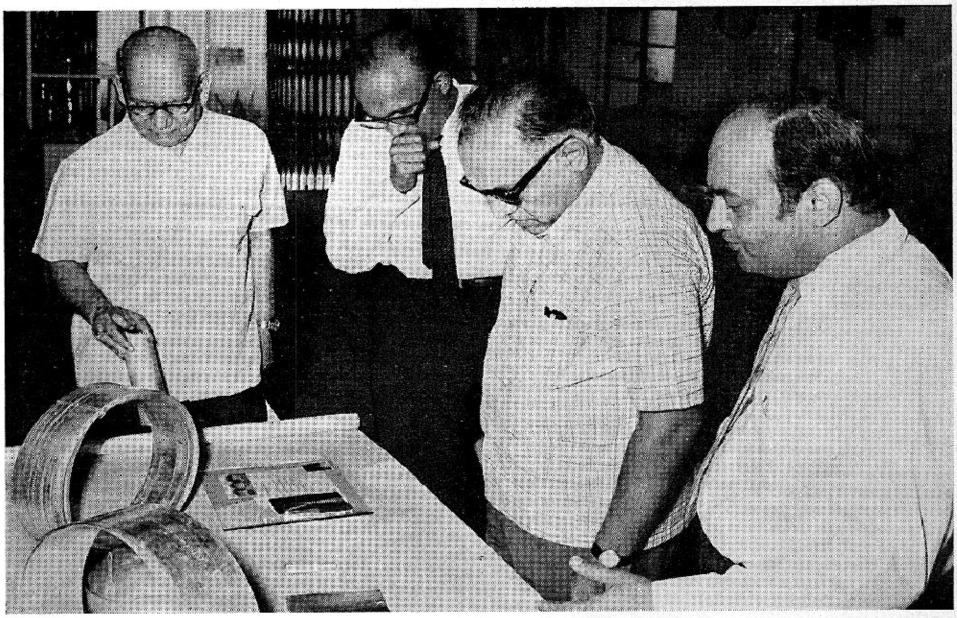
The Laboratory continued to undertake investigations on tonnage scale raw materials supplied by M/s. Andhra Pradesh Industrial Development Corporation Ltd. and Industrial Promotion and Investment Corporation of Orissa Ltd., on production of sponge iron. A technical feasibility report for production of sponge iron of 100 tonnes/day was prepared and sent to Steel Authority of India Ltd.

Work was continued on the product development and market promotion of the multifarious electrical applications of the electric grade aluminium alloy NML-PM2. It is significant that the first ever production of telecommunication cables in India was from NML-PM2 in the form of twenty pair cable. The cable has been laid in the Model Town Area of Delhi by the Post & Telegraph Department. Encouraged by the satisfactory results obtained after extensive and exhaustive evaluation, P & T Department have placed repeat orders for the production of fifty and hundred pair dry core cables from the NML-PM2 alloy. These cables are now under processing at M/s. Hindustan Cables Ltd., Rupnarayanpur.

During the year, the technology of the NML-PM2 alloy was released to M/s. Aluminium Cables & Conductors (U.P.) Pvt. Ltd. and M/s. Bharti Smelting and Refining Corporation Ltd., Bombay. The production of the alloy has also commenced at the works of M/s. Aluminium Cables & Conductors (U.P.) Pvt. Ltd.

Processes on production of extra-fine non-ferrous metal powders by atomization and production of extra fine zinc dust have been released to industries for commercial production. M/s. Cable Works (I) Ltd., Faridabad, have set up commercial plant and started production of electrical resistance heating elements based on NML technology which was licensed out to them earlier.

Considerable progress has been maintained on the setting up of the Central Creep Testing Facility with the assistance of UNDP. The building to



*Mr. Wadud Khan, Chairman, Steel Authority of India Ltd., (2nd from right) being explained by Prof. V. A. Altekar, Director, NML (Extreme right) some product development work of NML.*

house the facility has been completed and a number of equipments have been installed and work has been initiated. M/s. Bharat Heavy Electricals Ltd. have sponsored investigations on the development of indigenous creep resistant steels.

The NML Annual Day-cum-Get Together was held on 26th November, 1973, synchronizing with the inaugural day of the Laboratory twenty three years before. The Laboratory participated in the 'Get-togethers' at Barbil (Orissa) and Hyderabad. In an effort to build linkages at the State level, the Director-General, Scientific & Industrial Research, nominated NML to make systematic study of the Bihar State Fifth Five Year Plan to identify major areas of thrust for industrial, economic and social development by holding a 'Get-Together' at the State Capital, Patna.

The Laboratory has set up a Regional Liaison Centre at Calcutta to bridge the 'Communication gap' between the Laboratory and the Industry. This centre will appraise industrialists and entrepreneurs about the scope of technical assistance that the Laboratory can offer for setting up mineral based and other metallurgical industries.

The Field Stations at Batala, Madras, Howrah & Ahmedabad continued to render useful services to the regional foundry and engineering industries. The Field Stations are now being expanded phase by phase to increase their activities in different directions such as ore-dressing, refractories, metallographic work etc. so as to meet the regional demands. The Marine Corrosion Research Station is conducting a number of valuable projects on the marine corrosion problems of metals and alloys.

The preparation of the Proceedings of the Symposium on 'Science & Technology of Sponge Iron and its Conversion to Steel' was taken up and papers were edited and sent for publication. The Symposium was organized by the Laboratory in February, 1973. An illustrated folder depicting the various priced publications of the Laboratory was brought out.

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

# RESEARCH & INVESTIGATION PROJECTS

## A. SPONSORED PROJECTS & INVESTIGATIONS

### 1.0 Pilot Plant Studies on Beneficiation and Sintering of Five Types of Samples of Iron Ore from Donimalai Mines. *Sponsored by MECON.*

Washing and sintering studies were undertaken with five individual types of iron ore samples from Donimalai mines of M/s. National Mineral Development Corporation, at the instance of MECON.

Washing tests were carried out to separate the fines. Iron values were recovered from slimes which were subsequently mixed with the respective classifier sands and used for sintering. It was observed from the test results that the overall sintering characteristics of the composite sample was better than those of the individual samples under identical conditions.

### 1.1 Pilot Plant Studies on Beneficiation of Iron Ore Sample II from M/s. Bolani Ores Ltd., Orissa. *Sponsored by M/s. Bolani Ores Ltd., Orissa.*

About 60 tonnes of iron ore sample from M/s. Bolani Ores Ltd., Keonjhar Dist., Orissa were subjected to beneficiation studies in order to improve its grade for utilisation in the blast furnace.

Three different campaigns were undertaken with the sample. In all cases, the grades of washed lumps and those of classifier sands did not improve to a considerable extent mainly due to the lateritic material contained in the sample. Tests conducted with the washed lumps obtained from all the three campaigns indicated that the sample under investigation was of soft nature.

### 1.2 Pilot Plant Studies on Beneficiation of Joda Hard Iron Ore Sample from TISCO. *Sponsored by M/s. Tata Iron & Steel Co. Ltd.*

At the instance of M/s. Tata Iron & Steel Co., Ltd. detailed washing studies and subsequent physical tests on washed products were carried out on a hard iron ore sample from Joda mines, Orissa. Tests conducted showed that the ore under investigation was compact and hard in nature.

### 1.3 Pelletizing of Iron Ore Fines from Rajhara Mines and Comparison of Properties with Cold Bonded Pellet Made by Regional Research Laboratory, Jorhat. *Sponsored by MECON & RRL.*

Rajhara iron ore fines as received from the mines was ground and pellets were prepared. The green pellets were heat hardened. The crushing strength, tumbling test and reducibility of these pellets prepared were compared with those of the seven batches of cold bonded pellets received from R.R.L., Jorhat. It was concluded that one of the cold bonded pellets, sample No. 2 made from run-of-mine sample had comparable strength as heat hardened pellets. Strict comparison could not be done with other samples as they were partly beneficiated.

**1.4 Pelletization of Tisco Iron Ore from Noamundi.** *Sponsored by M/s. Tata Iron & Steel Co. Ltd.*

Three samples of iron ore fines were received from Noamundi mines of TISCO, comprising of (*i*) Classifier sand, (*ii*) Flaky ore and (*iii*) Blue dust. Two composite samples of the three samples were prepared and detailed pelletising tests were carried out. The optimum method to produce good pellets was determined. The results have been discussed in a joint meeting with TISCO and adopted by them for improving pellet plant performance.

**1.5 Studies on Meghataburu Iron Ore Samples from N.M.D.C.** *Sponsored by National Mineral Development Corporation.*

Five types of samples of iron ores were received for beneficiation studies and preparation of sized and final products to meet the requirements of Bokaro Steel Plant. The objective of the investigations was to conduct studies with a composite sample prepared by mixing the ores in specified proportions and to determine the optimum flowsheet.

The composite sample was prepared by mixing the sample. An optimum flowsheet was obtained to meet the requirements. Different tests were also conducted to determine the physical and chemical characteristics of the sample as received, as well as, of different products obtained at different stages.

**1.6 Studies on Physical and Chemical Characteristics of Iron Samples from Deposits 4 and 5 of Bailadila Iron Ore Mines.** *Sponsored by M/s. M. N. Dastur & Co. (P) Ltd.*

Eight samples of different types of iron ores were received from deposits 4 and 5 of Bailadila Mines. The samples were received for determining the following characteristics:—

(*i*) Sieve analysis and chemical analysis of the sieve fractions of the sample as received.
(*ii*) Crushing to —40 mm size and wet screening using 10 mm screen.
(*iii*) Mineralogical studies.
(*iv*) Reducibility studies with —40 plus 10 mm fractions.
(*v*) Decrepitation studies with —40 plus 10 mm fractions.

Studies on (*i*), (*ii*) and (*iii*) have been completed. It was observed from the tests that in case of lateritic and limonitic ores, the iron content can be improved by about 2% and reject a considerable amount of $SiO_2$ and $Al_2O_3$.

**1.7 Screenability of Daitari Iron Ore from Orissa Mining Corporation, Bhubaneswar.** *Sponsored by M/s. Orissa Mining Corporation.*

Screenability tests were conducted on a sample of iron ore from Daitari mines. The results indicated that screenability deteriorated with the increase in moisture content, reached a minimum at a certain percentage and then gradually started improving.

**1.8 Beneficiation Studies on a Low Grade Magnetite Sample Marked 'M' from Kavuthimalai Deposit near Tiruvannamalai, Tamil Nadu.** *Sponsored by State Geologist, Govt. of Tamil Nadu.*

At the instance of State Geologist, Govt. of Tamil Nadu, beneficiation studies on a low grade magnetite sample marked 'M' were conducted. Different methods were attempted to upgrade the Fe content to 63.0%. It was found a concentrate analysing 63% Fe with a recovery as high as 92% could be produced. The concentrate fulfilled the grade requirements laid down by the sponsors.

**1.9 Beneficiation Studies on a Low Grade Magnetite Sample 'C' from Kavuthimalai Deposit, Tamil Nadu.** *Sponsored by State Geologist, Govt. of Tamil Nadu.*

The sample marked 'C' is one of the three samples sent by State Geologist, Tamil Nadu for beneficiation studies. A concentrate analysing 63.5% Fe with 91.43% Fe recovery was obtained. A better grade of concentrate could be obtained at the same size but the recovery was low.

**1.10 Beneficiation Studies on ONGOLE Magnetite.** *Sponsored by Director of Geology, Andhra Pradesh Government.*

A concentrate assaying 64% Fe with a recovery of about 80% Fe was obtained.

**1.11 Mineralogical & Davis Tube Studies on Lohara Iron Ore.** *Sponsored by State Industrial and Investment Corporation, Maharashtra.*

The two samples designated (*i*) Main ore body and (*ii*) Stack were of a high grade. The high iron content in both the samples indicated that these require no beneficiation treatment and can be used as such for iron smelting. Davis Tube tester produced concentrates analysing 67-67.5% but the recoveries of iron in the magnetic product was only of the order of 75-80%.

**2.0 Batch & Pilot Plant Studies on Low Grade Copper Ore from Malanjkhand, Madhya Pradesh.** *Sponsored by M/s. Hindustan Copper Ltd.*

Beneficiation studies on a composite low grade copper sample were carried out. Pilot Plant studies indicated that a concentrate assaying 27.9% Cu with 96.8% Cu recovery could be produced. The flowsheet developed after pilot plant tests was confirmed by the Russian Consultants, who are preparing the project report for Hindustan Copper Ltd. after independent tests carried out by them in Mechanobr Laboratories, Leningrad.

**2.1 Beneficiation Studies on a Complex Copper-Lead-Zinc Ore from Mahabharat Area, Baraghani District, Nepal.** *Sponsored by M/s. Nepal Minerals Supply Co., Kathmandu.*

Beneficiation studies were undertaken on a sample of complex Cu-Pb-Zn ore from Mahabharat area in Nepal. A copper concentrate analysing 22.82% Cu and 1.02% Pb with 76.70% Cu distribution and a Pb concentrate analysing 65.21% Pb and 2.0% Cu with 80.1% Pb distribution was obtained. Separation of Zn minerals was almost impossible due to very fine association of the same with other iron sulphide and siliceous minerals.

**2.2 Batch and Pilot Plant Studies on the Recovery of Copper, Molybdenum and Nickel Minerals from the Low Grade Copper Ore.** *Sponsored by M/s Hindustan Copper Ltd.*

A sample of low grade copper ore was received from Rakha Mines of Hindustan Copper Ltd. for recovering copper, molybdenum and nickel minerals. This investigation was for their Phase II planning of the Rakha Project. Bench scale tests were conducted to determine the optimum flowsheet for recovering copper, nickel and molybdenum present in the sample in the form of copper-nickel concentrate and molybdenum concentrate. Studies were aimed at recovering the $U_3O_8$ from the primary tails. 94.5% Cu, 60.0% Ni and 90.00% Mo present in the test sample could be recovered from the combined concentrate under the optimum conditions. Based on the optimum test results obtained by the batch scale tests, continuous pilot plant tests were undertaken with a view to reproducing the laboratory test results and collect the necessary data useful for the designing of a concentrator. Continuous pilot plant run indicated the feasibility of recovering about 61.6% Mo, 91.6% Cu and 33.1% Ni present in the Rakha ore producing a Mo concentrate assaying 41.8% Mo and a copper-nickel concentrate assaying 25.4% Cu, 0.26% Ni and 0.144% Mo. An optimum flowsheet for the recovery of copper, nickel and molybdenum from Rakha copper ore along with the material balance has been recommended.

**3.0 Studies on Production of High Quality Sinters from Galena Concentrates for M/s. Hindustan Zinc Ltd.** *Sponsored by M/s. Hindustan Zinc Ltd.*

Detailed sintering studies on the production of good quality sinters using updraft sintering system, were undertaken with galena flotation concentrate; reclaimed slag and flue dust received from M/s. Hindustan Zinc Ltd., Tundoo. After proper proportioning of the charge materials good quality sinters were produced without addition of any fluxing material with low residual sulphur.

**4.0 Heavy Media Separation Studies with Zinc Ores from Balaria, Rajasthan.** *Sponsored by M/s. Hindustan Zinc Ltd.*

A low grade zinc ore was received from the Hindustan Zinc Ltd., for pre-concentration employing heavy media separation. The best grade of concentrate assayed 23.0% Zn with a distribution of only 10.88% Zn in it.

**5.0 Beneficiation of Low Grade Fluorspar Sample.** *Sponsored by M/s. Rajasthan Industrial Mineral Development Corporation.*

Beneficiation studies were undertaken on two low grade fluorspar samples received for producing acid grade concentrate. Investigation conducted on the first sample produced an acid grade concentrate assaying 98.0% $CaF_2$, 0.40% $CaCO_3$ and 1% $SiO_2$ with a fluorite recovery of 82.0% in it. Beneficiation studies with the second sample (S.No. 2) received from them under optimum conditions established for Sample No. 1 are in progress. A plant is being contemplated to be put up by The R.S.M.D.C. for treating the low grade fluorspar deposit using the above test data.

**6.0 Beneficiation Studies on a Low Grade Run of Mine Wolframite Sample from Chandapathar Mines, Bankura, W. Bengal.** *Sponsored by M/s. Gouripur Industries, Calcutta.*

Beneficiation studies were carried out with a low grade run-of-mine wolframite sample from Chandapathar Mines, Bankura District. Different series of tests were carried out with a view to produce a good grade concentrate with high recovery. The successful test yielded a concentrate assaying 59.1% with a recovery of 49.07% $WO_3$.

**7.0 Beneficiation of a Low Grade Kyanite Sample from Bihar.** *Sponsored by M/s. S. Lal & Co., Calcutta.*

Bench scale beneficiation tests were undertaken on a low grade sample of kyanite from Sirbali Mines, Bihar. A kyanite concentrate assaying 60.1% $Al_2O_3$ with an $Al_2O_3$ recovery of 57.6% in it was obtained which satisfied the grade requirements laid down for use in refractory industries.

**8.0 Beneficiation of Magnesite Sample from Pithorgarh (U.P.).** *Sponsored by M/s. Orissa Industries Ltd., Rourkela.*

A magnesite sample from Pithorgarh (U.P.) was received from the Orissa Industries Ltd., Rourkela for beneficiation studies. Conventional beneficiation techniques were attempted to reduce the iron content present in the sample. However, results were not encouraging due to the fact that the siderite was found to be in solid solution with magnesite. Separation of calcium minerals from magnesite could not be achieved by the flotation methods.

**9.0 Determination of Physical Characteristics of Dolomite and Limestone Samples from Tamil Nadu for Salem Steel Plant.** *Sponsored by M/s. M. N. Dastur & Co.*

Dolomite and limestone samples were received for conducting chemical analysis and physical tests such as bulk density, compression strength, sieve analysis etc. Petrological studies, D.T.A. studies were also conducted and the data supplied to the sponsorers for incorporation in their project report.

**10.0 Beneficiation Studies on a Low Grade Graphite Sample from Jhab-Redhana Mine of G.M.D.C. Ltd.** *Sponsored by Gujarat Mineral Development Corporation.*

A low grade graphite sample collected from Jhab-Redhana mine, Panchamahal dist., Gujarat, was received for batch beneficiation studies. A concentrate analysing 41.65% Fe with a recovery of 76.6% F.C. was obtained. The concentrate was of a grade suitable for foundry use.

**11.0 Determination of Bond's Work Index of Open Hearth Slag.** *Sponsored by Mr. B. A. Yashanoff, Calcutta.*

An open hearth slag sample was received from M/s. Tisco, Jamshedpur, through Mr. B. A. Yashanoff of Calcutta for determining the Work Index value. The sample as received contained metallic pieces. These were first removed. The results indicated that the sample was hard in nature and the Work Index value was 20.55 KWH/tonne at 250% circulating load.

**12.0 Studies on Reduction of Iron Content and Production of Sized Quartz Sand for Indo-Asahi Glass Co. Ltd., Hazaribagh.** *Sponsored by M/s. Indo-Asahi Glass Co.*

A sample of quartz was received from Maganpur Mines of the Indo-Asahi Glass Co. Ltd., Hazaribagh, for bench-scale studies to establish optimum conditions for production of a sand with maximum recovery and having minimum amount of impurities, particularly iron so as to make it suitable for use in glass manufacture. A sized silica sand conforming to chemical specifications for use in glass manufacture was obtained.

**13.0 Dolomite Lining for L-D Converter.** *Sponsored by M/s. Hindustan Steel Ltd., Rourkela.*

The third and final report of the studies undertaken in collaboration with H.S.L., Rourkela was submitted to Rourkela Steel Plant. Based on the data collected, the report makes certain specific recommendations to be verified in trials at the plant.

**14.0 Investigations on Some Physical Properties of Castables.** *Sponsored by M/s. Indian Oil Corporation Ltd., Haldia Refinery Project.*

Physical properties like bulk density, linear change, modulus of rupture, cold crushing strength and thermal conductivities at various temperatures of insulating castables were determined.

**15.0 Investigation on Kovilpatti Dolomite.** *Sponsored by Director of Industries & Commerce, Mining & Geology Branch, Govt. of Tamil Nadu.*

A dolomite sample low in silica and other impurities but coarsely crystalline with some ferro-magnesian gangue minerals was received and its properties were evaluated.

**16.0 Investigation on the Thermal Conductivity of Insulating Brick.** *Sponsored by M/s. New Kem Products Corporation.*

The thermal conductivity tests of two varieties of Insulating bricks at various temperatures were conducted.

**17.0 Reduction Characteristics of Cold Bonded Pellets.** *Sponsored by Ministry of Steel & Mines, Govt. of India.*

An investigation was undertaken for testing the cold bonded iron ore pellets produced by RRL, Jorhat for their reducibility and other characteristics. Reduction characteristics of these pellets were determined. The results have been conveyed to the sponsor in a composite report. Reducibility characteristics of cold bonded pellets, heat hardened pellets of NML and iron ore of Rajhara were compared for relative assessment. Heat hardened pellets were found to be the poorest among the three. Both the pellets showed negligible degradation during reduction.

**18.0 Static Bed Bench Scale Tests for the Pre-reduction of Iron Ores with Coals.** *Sponsored by Industrial Development Corporation of Orissa Ltd.*

This investigation was conducted to study the static bed reduction characteristics of three iron ores namely, Gandhamardan, Khondobond and Baripada using coals from Talcher, Samla and Rampur collieries. Three series of tests using (*i*) Talcher coal with Gandhamardan iron ore; (*ii*) Samla coal with Khondobond iron ore and (*iii*) Rampur coal with Khondobond iron ore have so far been completed. Two more series of tests using (*i*) Samla coal with Baripada iron ore and (*ii*) Rampur coal with Baripada ore are being carried out.

**19.0 Reduction Characteristics of Bailadila Iron Ore.** *Sponsored by M/s. MECON.*

These tests are being carried out to determine the reducibility of iron ores from deposit Nos. 4 and 5 of Bailadila.

**20.0 Reduction Characteristics of Noamundi Iron Ore by Gaseous Mixture.** *Sponsored by M/s. Tata Iron & Steel Co. Ltd.*

As desired, the tests were carried out in two different ranges of particle size with variation of temperature and flow rate of gaseous mixture.

**21.0 Reduction Characteristics of Joda (Hard) Iron Ore by Gaseous Mixture.** *Sponsored by M/s. Tata Iron & Steel Co. Ltd.*

Two samples of washed Joda (Hard) iron ore were tested in two different particle sizes. A series of isothermal tests were conducted at different temperatures and with different flow rates of the gaseous mixture.

**22.0 Reduction Characteristics of Outcrop Iron Ore Samples from Khondobond Area.** *Sponsored by M/s. Tata Iron & Steel Co. Ltd.*

Tests are being carried out for determining reduction characteristics of eleven iron ore samples from Khondobond area using a gaseous mixture.

**23.0 Reduction Characteristics of Donimalai Iron Ore and Its Sinter.** *Sponsored by M/s. MECON.*

The reduction characteristics of Donimalai iron ore as well as sinters made from the same ore were determined by using a gaseous mixture. The ore was reduced to 76% whereas the sinter was reduced to less than 65% under the same experimental conditions and time. Both ore and sinter exhibited negligible decrepitation and cracking during reduction.

**24.0 Reduction Characteristics of Lohara Iron Ore.** *Sponsored by State Industrial and Investment Corporation of Maharashtra.*

In this investigation, the reduction characteristics of two samples of Lohara iron ore were determined under three different sets of conditions. All the tests were carried out.

**25.0 Reduction characteristics of Three Iron Ore Samples from HSL, Rourkela by Bulk Reducibility Test.** *Sponsored by M/s. Hindustan Steel Ltd., Rourkela.*

This investigation was sponsored for determining the reduction characteristics of iron ore samples from Barsua, Kalta and Barajamda by bulk reducibility test. The tests were carried out in five ranges of particle size.

**26.0 Reduction Characteristics of Bayaram Iron Ore.** *Sponsored by Andhra Pradesh Industrial Development Corporation.*

Reducibility of Bayaram iron ore was determined. Under the conditions of the experiments the ore could not be reduced to more than 60% in 3 hours and to 75% in 5 hours.

**27.0 Bench Scale Compatibility Tests in Static Bed on Bayaram Iron Ore with Singareni Coal.** *Sponsored by Andhra Pradesh Industrial Development Corporation.*

This investigation was sponsored for ascertaining the optimum ore: coal ratio retention time, effect on partic e size and temperature for reduction. The work has been completed.

**28.0 Evaluation of Surgical Instrument for Corrosion Resistance.** *Referred by Indian Standards Institution.*

The Indian Standards Institution has specified copper sulphate test (IS:3643, 1966) for corrosion resistance which from the viewpoint of the manufacturers of the surgical tools does not ensure dependable results and need to be substituted by an alternative test. The issue of introducing the boiling and autoclaving being followed in Federal Republic of Germany has come up. It was decided that a comparative study on both the tests should be conducted before a final decision is taken. Such tests were conducted on samples of dissecting forceps made from ferritic stainless steel and supplied by M/s. Surgical Instruments Plant, Madras, and the results were reported to ISI.

**29.0 Failure of Super-heater Tubes.** *Sponsored by M/s. Singareni Collieries, Ramagundam Power House, Andhra Pradesh.*

The problem was referred to investigate the causes leading to the repeated failure of super-heater tubes in the secondary section of the water tube type radiant heat boiler.

A systematic study of the various factors involved in the operation of the boiler revealed that the tubes failed due to improper tube material to withstand the said operating conditions. Corrosion and metallographic examinations revealed that it was a case of overheating associated with creep failure. Composition of steel and precautions to be taken were recommended to prevent and minimise such failures.

## B. INDUSTRIAL PROJECTS

**30.0 Extraction of Nickel and Cobalt from Lateritic Nickel Ores of Sukinda by Amchlor process.**

Further experiments were done in continuation of the previous work of ammonium chloride roasting. It was found that almost all the iron could be suppressed.

**30.1 Production of Ferro-Nickel from Lateritic Nickel Ores of Sukinda.**

Experiments were carried out extensively in a 50 KVA submerged arc conducted in the 500 KVA submerged arc furnace and it was observed that attack on lining was very severe.

### 31.0 Bacterial Leaching of Copper Ores.

During the year, samples of copper ores and mine water samples were collected from Rakha and Mosabani Mines and sent to NCL, Poona; for identification of bacteria.

### 32.0 Production of Silicon Metal in 500 KVA Submerged Arc Furnace.

Semi-continuous smelting trials were executed in the 500 KVA submerged arc furnace for production of Si metal. Silicon metal of 94% Si was prepared. It is further planned to have large scale continuous trials in the 500 KVA submerged arc furnace.

### 33.0 Production of Calcium Metal.

A campaign was conducted at the magnesium plant using the facilities available there. Further studies has now been discontinued on the aluminothermic reduction, because of the low yield and the impurities in the product and the difficulties experienced in this work. It has been thought over to study the liquid state reduction process. Further a rotating cup technique has also been developed for making metal chips. Preliminary experiments were done successfully for making aluminium and aluminium alloy chips.

### 33.1 Production of Calcium-Silicide.

Large scale trial was conducted in the 500 KVA submerged arc furnace. An alloy of ISI grade was produced except for a little higher aluminium content. The trial report has been prepared. Calcium silicide so produced has been sent to industries for conducting trials for use as an inoculant (in foundry) as well as deoxidant.

### 34.0 Production of Magnesium-Zirconium Master Alloy.

Work was taken up to prepare zirconium tetrachloride and further making magnesium-zirconium master alloy containing 30-40% zirconium metal. This alloy is used in the preparation of magnesium based wrought alloys for application in aircraft industry and other areas where high strength to weight ratio is desired.

### 34.1 Development of Aluminium-Zirconium Alloys.

Some master alloys have been made from $ZrO_2$ and samples with large variation up to 11% Zr were obtained.

## 35.0 Studies on Adsorption Extraction of Non-Ferrous Metals.

The extraction of nickel from ammonical solutions by adsorpion on granulated lignite (Neyveli source) was investigated. It was found that over 99% recovery was possible using a multistage technigue. The adsorbed nickel could be elutriated with acids and the solution treated further for nickel precipitation etc. It was also possible to directly recover nickel metal from the absorbent by ignition and melting in an induction furnace with appropriate fluxes.

## 36.0 Production of Atomized Metal Powders.

The process know-how for production of atomized powders of low melting non-ferrous metals was released for licensing through NRDC and active negotiations were underway with several interested entrepreneurs for both unalloyed non-ferrous powders as well as bi-metallic powders. Work was continued for the development of aluminum pastes as well as lithographic gold bronze powders.

## 37.0 Production of Zinc Dust.

The process know-how for the production of distilled zinc dust by the oil-fired retort process was released for licensing through NRDC and negotiations with Associated Pigments Limited, Calcutta, are in the final stage of conclusicn.

Transfer of technology preparations were initiated involving the experimental 0.75 tonnes per day furnace unit which was virtually the size of a commercial unit (1 tonne per day). Design of an improved condenser was finalized and fabrication was initiated. Process yields of over 94% of metallic zinc charged were stabilized using galvanizers' dross or slab zinc. Quality of product was tested by several actual users and found to be of required specifications.

## 37.1 Recovery of Zinc Metal from Galvanizers' Dross.

The process know-how for the recovery of pure metallic zinc from galvanizers' dross by atmospheric distillation was released for licensing through NRDC and active negotiations were underway with an entrepreneur for the process know-how.

## 37.2 Production of Zinc Oxide from Galvanizers' Zinc Ash and Zinc Hydroxide.

The method developed enables the separation of metallic zinc from galvanizers' zinc ash by a selective leach. The separated oxide is produced from the leached zinc content by precipitation as zinc carbonate.

The zinc oxide produced from galvanizers' ash and zinc hydroxide has been tested by reputed rubber manufacturing concerns and has been certified as follows :-

(*i*) "The activating property of the zinc oxide sample produced at NML closely matched with that of the approved material in current use."

(*ii*) "As regards its behaviour in activation is concerned, it is found to be comparable to the standard zinc oxide sample."

A non-technical note and pre-design cost estimate have been prepared and the process is being referred to NRDC for release of the know-how. A scheme for production of zinc oxide from zinc hydroxide has been prepared and sent to Kerala State Industrial Development Corporation.

### 37.3 Simultaneous Electro-Winning of Zinc and Manganese Dioxide.

In commercial zinc plants the electrolyte often contains manganese in appreciable quantities which gets precipitated at the anode as $MnO_2$ and settles at the bottom as sludge requiring frequent cleaning of the cell. The aim of this project is to get this manganese out of the electrolyte as anodic deposit of good battery grade manganese dioxide and simultaneously deposit zinc at the cathode. Also, it may be possible to recover sulphur. Good adherant deposit of about 82% $MnO_2$ has so far been obtained. The deposited zinc has the purity of 99.88%. Further parametric studies on bench scale are in progress.

### 38.0 Recovery of Mercury from Effluents.

Bench scale studies were initiated on the use of zinc powder/dust for the removal and possible economic recovery of mercury from effluents such as chlor-alkali wastes, zinc and copper smelter gases, etc.

### 39.0 Recovery of Tungsten from Tungsten Carbide Scrap.

(*a*) *Fusion Process*

The work done by the fusion process has been referred to India Hard Metals Pvt. Ltd., Calcutta, for large scale trials in their plant.

(*b*) *Anodic Dissolution of Tungsten Carbide in Aqueous Sodium Hydroxide Bath*

Tungsten is dissolved anodically in NaOH bath as sodium tungstate. This is again precipitated to tungstic acid and then to 99% pure tungstic oxide.

### 39.1 Recovery of Tungsten Trioxide from Tungsten Carbide Tool Bit Scrap.

Two approaches have shown success so far: (*i*) combination of pyro-cum-hydro-metallurgical technique and (*ii*) anodic dissolution in aqueous bath. Out of the two approaches, anodic dissolution of cobalt from tungsten carbide scrap is better, as the Co is only 10% in the available scrap as compared to the amount of tungsten present. Feasibility report, indicating the cost of recovery of tungsten oxide/carbide from the scrap is being prepared.

### 40.0 Recovery of Germanium and Gallium from Flue Dust and Fly Ashes.

One tonne flue dust containing 200 ppm Ge was briquetted and smelted in the 50 KVA submerged arc electric furnace. Regulus containing Ge was collected and analysed to 200 ppm. Regulus was again smelted to further concentrate germanium. Further work is in progress.

## 41.0 Recovery of Selenium and Tellurium from Electrolytic Copper Slime.

On the basis of bench scale results, large scale experiments were conducted using 500 gm slime for digestion and roasting. The recovery of Se was about 90 to 95% and the purity of recovered selenium was 99.0%. It is proposed to do semi-pilot plant designing work.

## 42.0 Recovery of Elemental Sulphur and Copper, Lead and Zinc from Respective Sulphide Mineral Concentrator.

Optimum conditions for maximum percentage recovery of copper and elemental sulphur on ferric chloride leaching of copper concentrates have been determined. Further studies are in progress on the concentration of copper and rate of flow of solution to achieve a higher cathodic current efficiency and a maximum ferrous to ferric oxidation in the anode chamber.

## 43.0 Preparation of Fluorine Chemicals for Metallurgical use.

The Gujarat Mineral Development Corporation fluorspar contains high percentages of $Fe_2O_3$ and $P_2O_5$. As various approaches to prepare cryolite from the G.M.D.C. fluorspar concentrate as it is, did not yield specification grade cryolite; it was decided to upgrade the fluorspar itself by chemical methods. A process has been developed for the removal of $P_2O_5$ and $Fe_2O_3$ simultaneously from the G.M.D.C. fluorspar.

## 43.1 Studies on the Preparation of 50 kg/day Synthetic Cryolite by Fluoboric Acid Process.

A set of ten experiments on large-scale recycling the process liquor has been carried out with G.M.D.C. metallurgical grade purified fluorspar.

Average analysis of cryolite obtained in the large scale experiments is %F—52.84; %Al—18.88; %Na—23.15%; %$SiO_2$—0.02; %$Fe_2O_3$—0.100; %$P_2O_5$—0.047; %$SO_4$—2.68; %Ca—0.85; %Comb.water—0.83.

It may be mentioned that the leachability of the fluorspar was about 86% against 96.7% in the case of acid grade fluorspar. The products from batches were mixed and a representative sample have been sent to two firms for chemical analysis.

## 44.0 Preparation of Industrial Chemicals from Off-grade Copper Concentrates.

Some off grade sulphide concentrates containing chalcopyrite could not be utilized for extraction of copper by the conventional pyrometallurgical process due to the complex nature (sulphidic) and grade (low copper with high level of associated impurities) of the material. The investigation was taken up to explore the possibility of utilizing off grade sulphide concentrates for production of industrial chemicals by small scale operation. Emphasis has been on developing a non-pollution and economically feasible process flowsheet. Non-polluting roasting of the concentrates with admixture of ingredients and subsequent leaching gave encouraging results. Further work is under progress.

### 45.0 Production of Electrolytic Iron Powder from Scrap Iron Using Insoluble Anode.

A process is being worked out for the electrolytic production of iron powder using steel scrap and turning as the cheap source of raw material. A special diaphragm cell has been designed and fabricated for the purpose with a continuous flow circuit. The process is made continuously operated by controlling the flow of the feed and anolyte liquor. Satisfactory results have been obtained.

### 45.1 Production of Iron Powder from Mill Scale.

By varying different parameters it was attempted to determine the optimum experimental conditions for obtaining the desired grade iron powder. Results so far obtained are encouraging and some desired grades powders could be successfully produced. Further experiments with pre-oxidized mill scale are being carried out.

### 46.0 Development of Aluminium Cables and Conductors.

Work has been continued on the product development and market promotion of the multifarious electrical applications of the electric grade aluminium alloy NML-PM2. The unique combination of electrical and mechanical properties have made the NML-PM2 alloy an ideal conductor for a variety of applications as a substitute of copper such as :-

1. Welding cables.
2. Enamelled wires/strips for motor and transformers.
3. Underground telephone cables.
4. PVC insulated flexibles.
5. Control cables.
6. Glass covered conductors.

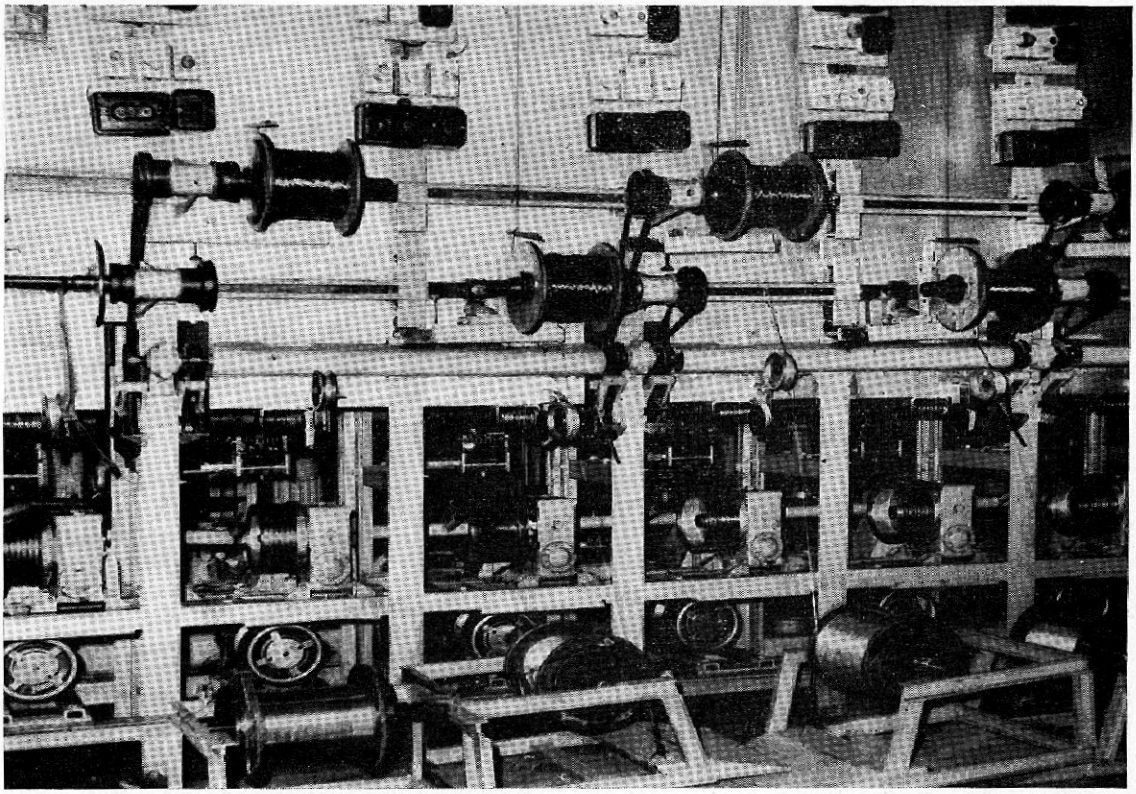
INDUSTRIAL PRODUCTION

(*i*) *Telecommunication Cables*

It is significant that the first ever production of tele-communication cables in India was from the NML-PM2 alloy in the form of 20 pair cable. The cable has been laid down in the Model Town Area of Delhi by the P&T Deptt. Encouraged by the satisfactory results obtained after extensive and exhaustive evaluation, the Post & Telegraph Department have placed repeat orders for the production of 50 and 100 pair dry core cable from the NML-PM2 alloy. The cables are now being processed.

(*ii*) *Welding Cables*

1161/0.3 mm dia. welding cables have been produced with the NML-PM2 alloy in collaboration with cable industry and has satisfied all the requirements.



*Enamelling of electric grade aluminium alloy (NML-PM2) magnet wires developed in NML at the M/s. Hiracable Works Ltd., Hirakud.*

The electrical conductivity of the processed wire is 62-63% IACS which is higher than the specified value. The cables (0.3 mm dia.) have been sent to a number of user organisations against their educational orders for field trials. The fine size (0.3 mm) wires for these cables have been successfully drawn at relatively much greater speed using indigenous wire-drawing machine.

(*iii*) *PVC Insulated and Sheathed Flexible Cables*

Large quantities of single core, two core and three core PVC insulated and sheathed flexible cables have been successfully produced from NML-PM2 in the cable industry. The extensive field trials have been planned in collaboration with leading fan producers of the country.

(*iv*) *Winding Wires for Motors and Transformers*

Wires down to 38 SWG (0.15 mm) dia. have been industrially produced and enamelled to the International Specifications. It is significant that the spring back on these wires was minimum and well within the specifications of copper. Typical results obtained on enamelling the NML-PM2 wires in industrial quantities are as follows:-

Test Results on enamelled NML-PM2 wires

| | | |
|---|---|---|
| 1. | Elongation | 25-32% |
| 2. | Adherence | O.K. |
| 3. | Breakdown Voltage (KV) | 5.3—7.8 |
| 4. | Pin hole test | O.K. |
| 5. | Heat shock | O.K. |

Large quantities of NML-PM2 enamelled wires of different sizes have been sent to Research, Design & Standards Organisation, Lucknow; and fan producers and other electrical machinery producing concerns in the country for field trials and evaluation. Results obtained so far are very encouraging.

(*v*) *Field Cables for Defence*

Copper is used for the production of field cables. Encouraged by the high ductility of the NML-PM2 alloy, the Ordnance Cable Factory, Chandigarh, is collaborating with NML to produce field cables. Two Km length of the cable has been produced and further quantities have been supplied.

(*vi*) *Transfer of Technology*

The technology of the NML-PM2 alloy has been released through National Research Development Corporation to the following organizations.

(*a*) M/s. Aluminium Cables & Conductors (U.P.) Pvt. Ltd., Calcutta.
(*b*) M/s. Bharti Smelting & Refining Corporation Ltd., Bombay.

The commercial production of the alloy has started at the works of M/s. Aluminium Cable & Conductors (U.P.) Pvt. Ltd. Commercial quantities are available from NML or the licencee. The cable industries can also get their EC grade aluminium converted into NML-PM2 from the NML licencee.

## 47.0 Inoculants for Grain Refining Aluminium and its Alloys.

PM-121 and PM-122 inoculants in the form of wire for grain refinement in continuous casting have been developed. Trials on 1 Kg. heats with low silicon LM series have shown improved mechanical properties and refinement of the grain size. The data of properties are compiled.

## 47.1 Development of Grain Refiners for Al-Mn Alloys.

The industrial important 3S(Al-Mn) alloy requires extensively long time for homogenisation at 610°C and also intermediate annealing in the process of rolling to final product. The annealing temperature is also reasonably high thereby making the process costly in view of power shortage etc.

Hence, it is proposed to lower down the time temperature parameters by adding a suitable inoculant which will help recrystallisation of the rolled elongated grains to finer size at lower temperature annealing itself. The inoculent was made in rocking arc furnace. Non-inoculated & 0.4% inoculated alloys are under study. Different parameters of homogenisation, rolling, and annealing procedures are being examined along with metallographic studies of recrystallisation and grain size.

## 48.0 Development of Self-Lubricating Bearing Materials.

A novel technique was developed for making porous bearing of iron powder by impregnating solid lubricant inside the pores of sintered metallic skeleton under controlled vacuum. This type of bearing having self lubricating facilities can be used in many engineering components where external application of lubrication is undesirable or disadvantageous such as drug, machinery, food and textile machineries. In this investigation, influence of various parameters on the impregnation of the skeleton by graphite were studied. Optimum conditions were achieved and 3 to 3.5 wt% graphite can be impregnated.

## 48.1 Iron-Copper-Graphite Bearing Material.

Conventional method of mixing elemental iron, copper and graphite followed by compaction and sintering leads to poor mechanical properties. Graphite at higher temperature of sintering forms a brittle compound, hence it was aimed to coat graphite with copper to overcome the difficulties in producing iron-copper-graphite sintered bearing material.

Electrochemical methods of copper coating over graphite powder were studied and encouraging results were obtained. Process standardization is in progress.

## 49.0 Development of Copper Clad Aluminium Sheet.

Copper clad aluminium combines the properties of both aluminium and copper and possesses good electrical and thermal conductivity. The clad metal in sheet form can replace copper in a variety of uses and may contribute towards conservation of copper.

The production technology of copper clad aluminium sheet was thoroughly investigated and different parameters were studied on laboratory scale. Indian

Railways have placed an order for 6 sq. meters of the clad metal for use as transition joint for their R & D work.

## 50.0 Study on the Effect of Alloying Additions and Heat Treatment on the Mechanical Properties of Al-Si Alloys.

The objective of the project is to develop high ductility wrought aluminium alloys having tensile strength upto an acceptable limit utilising commercial aluminium with some alloying additions. Fifteen alloys have been made with varying alloying additions. Tensile testing of all these alloys in the as-cast condition have been carried out. Mechanical properties under different heat treated conditions are in progress. Microstructural studies have also been carried out. In order to explore one of the practical applications of the alloys under development which have high extrudability, efforts are being made for tube making by extrusion.

## 51.0 Study of the Phenomenon of Quench-Sensibility in the Al-Zn-Mg Type Alloys.

The objective of the project is to develop high strength Al-Zn-Mg type alloys having reduced quench-sensitivity. Efforts are being made to study the quench-sensitivity phenomenon with varying alloying additions and modified heat-treatments. Studies of the effect of grain size, Zn/Mg ratio, different alloying additions and heat-treatment on quench-sensitivity of Al-Zn-Mg type alloys are in progress.

## 52.0 Appraisal of Raw Materials for Iron Making.

Various physical, chemical and metallurgical poperties of raw materials are determined before the same could be employed successfully in blast furnace for making pig iron or in a rotary kiln for making sponge iron. Some of the most important properties which should be considered seriously are physical strength, reduction strength, reducibility, decrepitation, porosity, softening point and calcination etc.

The following investigations were completed during the year:

(*i*) Decrepitation characteristics of 25 Khondbond iron ore samples from Tata Iron & Steel Co. Ltd.

(*ii*) Decrepitation characteristics of Noamundi (ROM) iron ore from TISCO.

(*iii*) Decrepitation and thermal degradation of iron ores for Rourkela Steel Plant (HSL).

(*iv*) Decrepitation characteristics of iron ores for Chandrapur Iron & Steel Project, SICOM, Bombay.

(*v*) Decrepitation characteristics of iron ore from Andhra Pradesh Industrial Development Corporation.

(*vi*) Decrepitation characteristics of Tiruchirapally limestone for Salem Steel Plant.

(*vii*) Detailed study on decrepitation at various experimental conditions viz. at different temperature, time and initial particle.

## 53.0 Continuous Vertical Shaft Reduction of Manganese Ore on Large Scale.

A vertical shaft reactor with continuous charging and discharging arrangement was fabricated and used for reduction of manganese ore with solid reductant coke. The preliminary working of the reactor gave only 88.7% manganese recovery but by increasing the retention time about 94% Mn recovery could be easily attained.

## 54.0 Study of the Controlled Oxidation Characteristics of Naphtha.

The aim of the project is to partially burn naphtha in a furnace with controlled amount of air/oxygen and produce a gas rich in carbon monoxide and hydrogen. To study the reactors, a furnace has been designed. This test furnace will be provided with a number of sampling points for taking out product gases at different points along its length. The furnace shell has been fabricated and refractory work is in progress.

## 55.0 Pneumatic Steel Making in Basic-Lined Side-blown Converter.

The work was continued. (1) To demonstrate the technique of steel making by the side-blown converter process to interested parties, and (2) To study the life of the refractory by using different refractory ramming masses.

The process developed has been leased out to the following three parties and demonstrated:

(*i*) M/s. Kartar Iron & Steel Co. Ltd., Jamshedpur.
(*ii*) M/s. Mehra Ferro Alloys (P) Ltd., Amritsar.
(*iii*) M/s. Partap Steel Ltd., Amritsar.

The following consulting engineering firms attended demonstration:-

(*i*) M/s. Davy Ashmore (India) Ltd., Calcutta.
(*ii*) M/s. M. M. Suri & Associates, New Delhi.

ECON Steels & SAIL were also shown this process of steel making. Besides demonstration, study was made on the life of the refractory tuyere block.

## 56.0 Special Steel-making in Top Blown Converter by BOF Process.

Use of sponge iron was made to find out its suitability and other benefits in place of steel scrap conventionally used. Experiments were also done in order to determine the composition of the bath during the blow specially C% and P% at different stages of the blowing cycle. From the experimental results it was observed that considerable amount of phosphorus was removed. Further experiments with Fe-Cr addition are under progress. Simultaneously a bigger size vessel of capacity of 20/25 kg was designed and fabricated.

## 57.0 Development of Cr-Ni-Cu Austenitic Stainless Steel.

A number of heats of the compositions were made in high-frequency induction furnace. The compositions were so adjusted as to give a stable austenitic structure. All the alloys made are found to be non-magnetic after rolling into sheets and solution-treatment. The steels are being examined for their structural stabilities and corrosion resistance properties.

## 58.0 Commercial Trial Heats of Niobium Treated Steels at Rourkela Steel Plant and Evaluation of Properties.

Commercial trials on the production of high strength low alloy structural steels were carried out at the Rourkela Steel Plant and highly encouraging results were obtained from the controlled rolled carbon-manganese-silicon steels with minute additions of niobium. An improvement in yield strength from 30 kgf/$mm^2$ for plain carbon-manganese-silicon steel to 40 kgf/$mm^2$ for the control-rolled niobium treated steels were obtained. The ductile to brittle impact transition temperature of —30°C at 5.5 Kgfm was recorded.

The same steel plates on further treatment showed an improvement in ductile-to-brittle transition temperature and yield strength.

## 59.0 Development of Tool and Die Steel.

The steel developed and designated as PM-501 alloy shows the following properties :

1. High hardness (650 VPN) on heat-treatment,
2. Wear resistance,
3. Dimensional and structural stabilities,
4. No distortion on heat-treatment.

Although the steel showed the above desirable properties it lacked the impact and elongation. These additional properties would widen its field of application in engineering industries. With this in view certain further alloying elements to PM-501 alloys individually and in combination were chosen. It is being visualised that these elements would contribute towards improving the percentage elongation and impact values.

## 60.0 Fe-Al-Si High Strength Steel.

In continuation of the previous work, it was observed that two compositions of Fe-Al-Si showed good ductility and also good forging and rolling behaviour. It also appears to have good atmospheric corrosion resistance capacity. Investigation on corrosion resistance property of these alloys are being carried out.

For further developmental work to assess some of its mechanical properties such as (*i*) impact values and transition temp., (*ii*) elongation on 2" gauge length and (*iii*) weldability test, heats of the different compositions were made.

## 61.0 Continuous Steel Making Process.

After completing the job of making a tapping pit for the launder, work on the construction of a control cabin was taken up which would house equipments and instruments. The work has been completed except the flooring, which will be taken up shortly. Simultaneously control panel is also at the point of completion.

## 62.0 Electro-Slag Remelting of Steels.

Electro-slag remelting of martensitic stainless steels was undertaken. Remelted ingots were processed by mechanical working. The product was analysed before and after electro-slag remelting. Further work on mechanical properties is in progress. Ball bearing steel made in electric arc furnace was successfully electro-slag remelted.

## 63.0 Low Carbon Soft Magnetic Iron.

Low carbon iron was supplied for industrial use and evaluation to following parties for their development work pertaining to import substitution.

1. N.E. Rly.—Gorakhpur.
2. Southern Rly.—Podanpur.
3. Kirloskar Electric Engineering Co., Bangalore.
4. University of Poona.

## 64.0 Hot Blast Cupola—Developments in Cupola Iron Melting.

According to the contemplated programme, the development work in determining the effects of oxygen enriched hot air blast on various parameters by enriching the hot air blast temperature was completed. Work on other stages has been taken up.

## 65.0 Preparation of Self Setting Sodium Silicate Bonded Sand.

Laboratory scale work has been completed except for a few tests on high temperature properties. The main findings are:-

(*i*) The variation in chemical analysis of the residues does not substantially affect its use as a hardner.
(*ii*) The residue is reactive with water and once it is wet it is unsuitable for use as a hardner.
(*iii*) The residue can be used quite effectively as a hardner for sodium silicate bonded sand.
(*iv*) Certain additives are to be incorporated to obtain the desired properties of the sand mix.
(*v*) It offers considerable scope within certain limits of obtaining desired rate of hardening and bench life by suitably adjusting the ingredients of sand mix.

*Inplant Trials*

Trials were conducted both in TISCO and Heavy Engineering Corporation for making cores and moulds which usually are made by $CO_2$ process. The results obtained were satisfactory from moulding and core making point of view. Also shake out properties were good.

From the knowledge gathered at TISCO and Heavy Engineering Corporation, the process would be more economical as compared to $CO_2$ process.

## 66.0 Fluid Sand Moulding Process.

The fluid sand moulding process which is in use in developed countries is still to be introduced in this country. Work has been taken up to develop the process using indigenous raw materials.

Bulk of the laboratory scale work has been completed. A composition has been arrived at which gives optimum results. Large scale laboratory experiments are under progress.

## 67.0 Preparation of Foam Aluminium.

Work was taken up to develop the know-how for the production of cellular metal having different void size which may find application in many fields such as (*a*) composite material (*b*) metallic filter (*c*) exhaust muffle (*d*) energy absorption material (*e*) electronic packaging material etc.

## 68.0 Development of Aluminium-Cast Iron.

The project was taken up to develop Al-cast iron compositions having good mechanical properties. Al-cast iron can substitute conventional heat resistant cast irons which normally contain Cr, Ni, Mo, etc.

## 69.0 Nickel Free Heat Resistant Cast Iron for High Temperature Applications.

The objective is to produce high chromium cast iron for use as heat resistant material in the high temperature range.

Alloy cast iron free from nickel was prepared and cylindrical test specimens were made. The weighed specimens were tested in stagnant atmospheric condition at different temperature ranges. Same experiments were undertaken under constant flow of air and the results were compared with under stagnant air condition. Further work is in progress.

## 70.0 Development of Heat Resistant Boxes.

The project has been taken up to develop a suitable composition for heat resistant boxes for use at high temperature for the production of iron powder. Boxes of different alloy cast iron and steel compositions were cast in actual size required for the manufacture of iron powder. The dimensions of the boxes were $10'' \times 8'' \times 11''$ and weighed 25 kg to 30 kg. The boxes were tested at different temperatures for their life and heat resistance. In the case of high aluminium cast iron practically no oxidation of the boxes was observed, only a thin and adherent layer of oxide was noticed. But the boxes were found to crack after few cycles of heating. Further work is in progress.

## 71.0 To Study the Effect of Directional Solidification on the Magnetic Properties of Alnico V Alloy.

During the period under review, the effect of small additions of sulphur on the growth of columnar crystals in Alnico V alloys were studied. The sulphur content was varied using hot moulds and chill plate and casting the molten alloy. It was observed that the heats killed gave columnar crystal of 40 mm length. Sulphur increased the columnar crystal from 40 mm to 50 mm. It was also observed that this small beneficial effect of sulphur was confined to a certain amount. Increasing the concentration of sulphur beyond it had no effect upon the crystal growth. The optimum properties were obtained in specimens having columnar structure throughout the length and breadth of the casting and crystals were always straight. The properties decreased somewhat when the columnar crystals grew at an angle to the base of the casting.

## 72.0 Development of Ductile Permanent Magnets from Fe-Co-Cr and Fe-Co-V Alloys.

A number of heats of Fe-Co-Cr, Fe-Co-V alloys were made in 2 kg high frequency induction furnace to study their magnetic, electrical and mechanical properties. X-ray and metallographic studies have been carried out for the identification of different phases responsible for their magnetic properties. The vicalloy in the optimum heat treated condition consisted of two phases: (1) b.c.c. phase having d=2.857 Å, (2) phase having d=3.572 Å. Phase (1) was highly ferromagnetic while phase (2) was feebly ferromagnetic. Further experiments are in progess.

## 73.0 Growing Single Crystals of Ferri-Magnetic Oxide.

Trials were conducted to grow single crystals of barium ferrite. The mixture was melted in a platinum crucible inside a double chamber furnace and cooled slowly. The matrix was leached for several days to remove the reacted mass. 2-3 mm size single crystal plates having thickness of about 0.5 mm size were found to have grown. They were separated, washed with water. The X-ray photographs indicated that only a few crystals were really single crystals. Others had shown defects.

## 74.0 Preparation of Gamma Iron Oxide.

It was established that gamma-iron oxide can be prepared by oxidation of $Fe_3O_4$. A series of experiments were performed to prepare $Fe_3O_4$ from thermal decomposition of ferrous salts and precipitation of ferrous and ferric hydroxide from aquous salts. It was found that it is easier to decompose iron salt to first form $\alpha$-$Fe_2O_3$ and then reduce this $\alpha$-oxide to $Fe_3O_4$ which can be re-oxidized to $\gamma$-iron oxide.

## 75.0 Production of Chromium Coated Steel to Replace Tin Coated Steel.

A process for deposition of chromium-chromium oxide coating on steel to replace tin-coated steel has been developed. A few pieces of 20″×15″ tin free steel sheets were made from a larger experimental cell and they were sent to can manufacturers for evaluation studies at their end. They were found to be similar to that of imported 'Hi-top' and 'Cansuper' sheets in respect of corrosion resistance, lacquerability and lacquer adhesion and cooling.

## 76.0 Corrosion Studies on Nickel Free Stainless Steel Developed at NML.

The corrosion resistance of nickel-free Cr-Mn-N austenitic stainless steels was evaluated in the laboratory by performing (*i*) Huey test, (*ii*) Strauss test, (*iii*) Total immersion test in various chemical media, (*iv*) Studies on high temperature oxidation, and (*v*) Polarisation studies.

The corrosion resistance of these alloys was affected by chromium and manganese addition. While chromium showed a tendency to increase the passivation of the steel, manganese appeared to counteract this effect. Steels containing 21.0% Cr, 14.0% Mn showed corrosion resistance similar to the 18/8 austentic stainless steel in a number of media.

## 77.0 Atmospheric Corrosion of Metals and Alloys.

Long term exposure studies on various ferrous and non-ferrous metals in the industrial atmosphere of Jamshedpur are being continued. The trend in corrosion rates of various metals showed that the characteristics of the rust layer formed on the surface contribute remarkable influence on ultimate corrosion rate. Corrosion resistance of low alloy steels was superior to that of mild steel specially during longer period of exposure, indicating that the alloying additions modify the properties of the rust.

## 78.0 Plastic Coatings (Vinyls) on Metals for Corrosion Protection and Metal Finishing.

Samples were sent for assessment and detailed test report received so far is encouraging, keeping in view that these coatings are recommended for indoor applications.

## 79.0 Diffusion Coatings on Steel with Special Reference to Corrosion and Oxidation Resistant Coatings on Steel.

Siliconizing, chromizing, aluminizing and chrome—aluminizing of mild steel were carried by pack cementation process and the different parameters for obtaining adequate thickness of coating, such as temperature, duration of time, composition of the pack etc. were evaluated.

It is inferred from the studies that chromizing and chrome-aluminizing of mild steel will impart to mild steel oxidation resistant surface properties superior to 18/8 stainless steel and inconel and such treated steels can be utilized in place of alloy steels where oxidation resistance is needed.

## 80.0 Evaluation of Inhibitor Efficiency and Hydrogen Pick-up by Steel During Pickling Studies on the Performance of Mercaptans as Inhibitors.

The influence of some mercaptans and sulphides on the cracking susceptibility of cold rolled high carbon steel (0.86% C) in $H_2SO_4$ was thoroughly investigated. The results showed that with increase in inhibitor concentration, the % inhibition efficiency increased in all cases excepting a few which-were found to decrease the % inhibition efficiency. All compounds studied showed predominantly cathodic inhibition.

## 81.0 Joint Action of $H_2S$ and Organic Compounds in Acid Pickling of High Carbon Steels.

The action of thiourea, allylthiourea, NN'diethylthiourea, a compound NML-NOCORR-1, diamylamine, dicyclo-hexylamine, N-ethylaniline and

N-diethylaniline on the cracking susceptibility of cold rolled high carbon steel wire in $H_2SO_4$ containing $H_2S$ has been studied. Inhibition efficiency increases in all cases with increase in concentration of inhibitors. Amongst the inhibitors studied NML-NOCORR-1 proves to be best inhibitor considering inhibition efficiency, cracking susceptibility of wire etc. The large trials with NML-NOCORR-1 is being conducted. The formulation of NML-NOCORR-1 to suit the consumers and storage capability is under progress.

### 82.0 Studies on Stress Corrosion Cracking of Copper Base Alloys.

The importance of metallurgical and electrochemical factors on stress corrosion cracking susceptibility of copper base alloys have been studied in greater detail. The electrochemical studies on Cu-Zn and Cu-Mn system have revealed that a close range of potentials exists where the metal becomes more susceptible to cracking. The nature of the crack developed on the surface also changes as it penetrates deeper and deeper into the metal until failure. Fractography studies have indicated that the crack at the point of initiation is brittle which turns to a ductile one at the middle of its path and again becomes brittle at the brink of fracture.

Studies on the stress corrosion susceptibility of austenitic steels including the Ni-free steels developed in NML are also in progress. Under similar experimental conditions in 40% boiling magnesium chloride solutions, nickel free steels took prolonged time in comparison to 18 : 8 Cr-Ni steel for the cracking failure to occur.

### 83.0 Stress Corrosion Cracking of High Strength Aluminium Alloys.

The fabrication of the stress corrosion testing apparatus utilising cantilever beam specimen was completed. Four aluminium alloys belonging to high strength group were prepared. The specimens having particular shape and dimensions were made out of the rolled plate. Another testing procedure using double cantilever beam specimens was conceived and four aluminium alloys having basic composition of 7075 were prepared. The specimens were prepared and experiment was started by dipping the specimens in NaCl solution.

### 84.0 Testing of the Performance of the Various Inorganic Surface Coatings on Steel Exposed to Industrial Atmosphere at Jamshedpur.

The work was initiated to obtain atmospheric corrosion data which will be helpful for selecting suitable protective schemes for structural materials.

It was proposed under the scheme to conduct atmospheric corrosion studies at different exposure sites in India (at least 6 years duration) on the undermentioned protective schemes.

1. Alclad — painted and unpainted
2. Anodised — painted and unpainted
3. Galvanised — painted and unpainted
4. Aluminised — painted and unpainted
5. Mild steel — painted and unpainted
6. Aluminium (alchrom treated) — painted and unpainted

Tests on the above panels are being continued and periodical observations are being made.

## 85.0 The Development of Oxidation Resistant Chromium Steel.

A thermogravimetric type apparatus was fabricated to study oxidation characteristics. Ten chromium steels having different compositions were prepared in electron beam melting unit. Alloys were homogenised, hot forged and hot rolled to a thickness of 2 mm. The specimens weighing between 200 to 500 mg were prepared from the rolled sheet after annealing, grinding and polishing.

Six chromium steels were exposed to oxidation at 900°C in air and flowing oxygen atmosphere. Encouraging results were obtained.

## 86.0 Developmental Studies on Surface Coating of Aluminium Alloys—Hot Dipped and Power Coating Systems.

Investigations are being carried out with aluminium based alloy products. Preliminary observations indicated that some of the aluminium alloy products can give equal or better protection to steel from the point of view of corrosion resistance. Further work in this regard is under progress.

## 87.0 Development of Heat, Oxidation and Scaling Resistant Materials by Surface Alloying with Aluminium.

Aluminising of 18 : 8 type stainless steel 10 cm × 15 cm × 16 gauge panels was carried out at different bath temperatures and dipping times with Si bath additions. Spangles have been observed at a specific Si level. Coating weight of 2-3 gm/sq.dm. (both sides) was observed. Bend tests on 1/2″ × 4″ strips of aluminised stainless steel show best results with a strip coated at a speciic temperature. Salt spray corrosion test on 4 × 6 × 16 gauge stainless steel uncoated and aluminised panels showed a loss in weight of 150 and 505 mg respectively in 120 hours. This means that aluminium coating which had a weight of 2-3 gm/sq.dm. is still available for sacrificial protection on aluminised sample of sheet whereas the uncoated sample looses the basis metal. Aluminised and uncoated stainless steels panels tested show negligible gain in weight. Oxidised samples are being subjected to electron diffraction study to determine the nature of oxide film formed.

## 88.0 Anodizing of Hot-dip Aluminized Mild and Stainless Steel Panels.

Anodizing from oxalic acid bath gives pale oxide film while that from tartaric acid bath gives irridescent bluish-yellowish-greenish views depending upon angle from which the sample is viewed.

Metallographic examination of transverse section shows uniform anodic oxide film formed on the outer aluminium layer produced by aluminising the ferrous materials. The anodising of hot-dip aluminised mild and stainless steel samples has been found to improve salt spray corrosion resistance and also heat, oxidation and scaling resistance of the aluminised steel.

## 89.0 Bright Nickel Plating on Cycle Rims.

M/s. Dunlop India Ltd. is utilising "NML" Bright Nickel Plating Process for production of cycle rims for more than three years. The same "NML" process has been demonstrated at the plating plant of Road Master Industries of India Pvt. Ltd., Ghaziabad at their request. The party is interested to take up the process in their production unit.

## 90.0 Studies on Clay Bonded Graphite Refractories.

A sample of plastic fireclay (Bommur) was received from the Andhra Pradesh Mining Corporation Ltd. with a view to evaluate its suitability for the manufacture of clay bonded graphite refractories. Different properties of this plastic fire-clay were studied regarding its physical, chemical, mineralogical, thermal and mechanical characteristics.

Further, crucible grade graphite (Madagascar) was taken and preliminary studies were done regarding its nature of particles, sieve analysis and chemical analysis. 'Bommur' plastic fire-clay was used both for the purposes of grog and binder. A typical mix was prepared. Buttons of 150 gm. and 200 gm. mix. were made at different pressures. A detailed compact studies was further made on these buttons. Further investigation is being carried out on different compositions of the mixes.

## 91.0 Investigation on Cement Fondu.

The investigations were based on the raw materials supplied by M/s. Ishwar Industries Ltd., from the Katni area. The programme extended from the determination of chemical analysis of raw-materials to bench scale and pilot scale investigations on the production of cements with various $Al_2O_3$ to CaO ratios. A number of batches were prepared and heat treated at various temperature in order to establish the effect of various parameters on the qualities of the final product. As a result of these investigations, a number of compositions have been perfected and the process parameters have been so designed as to yield cements of acceptable quality. A preliminary feasibility report on NML process has been prepared.

## 92.0 Work on Castable Suspensions of Non-plastic Refractory Materials.

During the period, work has been continued on the study of parameters for conditioning calcined Bayer alumina and Maharashtra kyanite into workable suspensions. Their density, electrolyte concentrations, viscosity, and pH relationships have been studied. Casting rate as well as the effect of particle size variations on the suspension characteristics have also been assessed.

Thermocouple sheaths of 25 mm dia. as well as furnace tubes of slightly larger dia. have also been cast to find out the castability of these suspensions. The work is continuing on Lapsaburu kyanite.

## 93.0 Development of Refractory Lining for Induction Furnace.

During the period under review a 98% $Al_2O_3$ lining material was prepared for lining a 12 Kg H.F. vacuum induction furnace. This material has so far given 6 heats and is still being used after minor repairs.

## 94.0 Development of Products Similar to Basalt Tiles.

Kolar gold field sands from the Walkers dump at Kolar gold fields have been utilised as the base material for this investigation. The idea is to extend these studies to other such metallurgical and mineral wastes.

The investigation was aimed on the production of abrasion resistant tiles that could be used as lining materials for slurry ducts in thermal power stations and steel plants. In the series of experiments, the sintering method was tried for which purpose the mineral waste was mixed with a binder and pressed into shape in hydraulic press. The shapes were later set in furnace and heat treated at various temperatures. While some tiles came out of such treatment sound and adequately abrasion resistant, in many cases there was considerable warpage.

## 95.0 Welding Fluxes.

During the period under review, some of the agglomerated fluxes prepared earlier were tested. Bead on plate tests were conducted using different welding wires. Table 1 gives the weld metal analysis for different flux-wire combinations.

**TABLE I**

Weld Metal Analysis for Different Flux-wire Combinations

| Flux | Weld metal analysis % | | | | | Welding wire used |
|---|---|---|---|---|---|---|
| | C | Mn | Si | S | P | |
| 1. | 0.13 | 0.39 | 1.3 | 0.02 | 0.04 | SA-1 |
| 2. | 0.11 | 0.42 | 1.59 | 0.02 | 0.08 | SA-1 |
| 3. | 0.17 | 2.28 | 0.75 | 0.06 | 0.035 | Modi-2 |
| 4. | 0.12 | 1.02 | 0.72 | 0.024 | 0.035 | Modi-2 |

With flux 1 & 2, Si content of the deposit is high whereas with 3 & 4 the S content is high. These compositions were, therefore, modified and are being tested.

## 96.0 Preparation of Spectrographic Standard Samples.

Preparation of plain carbon steel standards having constituents such as C, S, P. Si and Mn have been taken up at the initial stage. The samples have been tested by few steel plants as in plant trial to assess its suitability for use in direct reading spectrographs. To ascertain the composition of the materials, the samples have been sent to different reputed organisations for independent chemical analysis. The results obtained are satisfactory, and conditions of preparation have been standardised. Next phase of work will be to prepare the above samples on a large scale for supply to parties.

## 97.0 Preparation of Standard Samples.

The following materials were taken up for preparation of Standard Samples:-

(*a*) Low Carbon Ferro-manganese
(*b*) Carbon Steel No. 15.1
(*c*) Carbon Steel No. 12.03
(*d*) Carbon Steel No. 12.2
(*e*) Steel No. 14.2
(*f*) Low Carbon Steel
(*g*) Nickel Steel No. 21.1

All the above samples were analysed carefully in the laboratory. The samples have been sent to various reputed outside parties for analysis. Some of the results have already been received and are in close agreement with NML results. After getting all the results they will be certified and released for sale.

The following samples have been released for sale after certification.

(*a*) Brass No. 41.2
(*b*) Fluorspar No. 72.1

All the analytical results of Ferro-silicon have been received from outside parties. It is being finalised for using the certificate of analysis. Most of the analytical results of Brass (70/30) and Ferro-molybdenum Standard Samples have been received, and only a few are awaited. As soon as the complete lists are available the samples will be certified. Weight of samples sold during the period is 86.75 Kg.

## 98.0 Analytical Work.

(*i*) *Chemical and Instrumental analysis.*
2095 samples and 6438 radicals were analysed.

(*ii*) *Spectrographic analysis.*
(*a*) Qualitative—244 samples were completely analysed for major, minor and trace elements.
(*b*) Quantitative—75 samples for 237 radicals were determined.

(*iii*) *Gases in Metals.*
120 samples of ferrous and non-ferrous metals were analysed for oxygen, nitrogen and hydrogen by vacuum fusion method. Besides 150 samples of gas mixtures were analysed for determination of CO, $CO_2$, $O_2$, $H_2$, $N_2$ and $CH_4$.

(*iv*) *Autrometer* (*X-ray fluorscence*) *Analysis.*
The autrometer is mainly used for analysis of different types of beneficiated mineral products produced in the Mineral Beneficiation Pilot Plant and Ore-Dressing Division. Different samples such as iron ore, copper ore, fluorspar, kyanite, wolframite etc. have been analysed.

## 99.0 Petrological Study of Ores, Minerals etc.

All the low grade samples of ores and minerals received for beneficiation studies were petrologically examined to determine the irmineral constituents for further carrying out the beneficiation work.

# C. APPLIED BASIC PROJECTS

## 100.0 Liquid Metals and Solidification.

Studies upon the metastability of rapidly solidified Al-Si supersaturated solid solution has been completed. The results show that the equilibrium solid solubility limit of Si in Al can be extended by six fold upto the eutectic composition by the help of rapid solidification from the liquid state. Further the degree of supersaturation could be relieved by isochronal annealing the thin films at elevated temperature.

Similar studies have been extended to ternary Al-Mg-Si alloys. In this case about four such alloys of varying $Mg_2Si$ content has been prepared. Lattice parameter and microhardness of the splat cooled films have been measured. The variation of 'a' and micro-hardness shows the non-extensibility of the solid solubility limit in pseudo binary Al-$Mg_2Si$ system as was obtained in Al-Si alloys. The work is in progress.

## 101.0 Thermodynamic Properties of Liquid Metals.

(*a*) *Measurement of Heats of Fusion of Pure Metals and Alloys.*

A simple thermal analysis calorimeter has been designed and constructed to determine heats of transformations of pure metals, eutectic alloys and congruently melting intermediate phases of binary metallic systems. The apparatus is calibrated by using pure lead and pure aluminium for which heats of fusion are known. Heat of fusion of aluminium-silicon eutectic alloy is measured. The thermal data obtained are reproducible which confirms the reliability of the Calorimeter.

(*b*) *Thermodynamic Study of Liquid Metals by a Vapour Pressure Technique (Transpiration Method).*

An apparatus based on transpiration method is assembled to measure vapour pressure of liquid metals. The calibration of the equipment is in progress.

## 102.0 Determination of Concentration of Water Solutions of Salts and Analysis of Alloys by Beta Ray Back Scattering.

The results of investigations on the binary alloy systems of (Zn-Cd) and (Pb-Sn) and aqueous salt solutions of elements potassium, iron, copper, zinc, silver, cadmium, barium and lead having atomic numbers in the range of 19 to 82, show that despite the linearity of the variation of the intensity of beta ray back scattering with concentration, the technique of beta-ray back-scattering cannot be used on the basis of any reliable analytical technique for solid alloys, but can be adapted for aqueous solutions where $Z_{eff} > 16$.

It also confirms that the acid radical contributes to the back-scattering and its effect can be incorporated in the calculation of Z.eff. Effect of the geometry of specimen arrangements on the intensity of betaray back-scattering was also studied. The project has been completed.

## 103.0 Studies on the Corrosion Inhibition Mechanism using Radio Active Tracers.

Preliminary work has been undertaken. Cell to be used is under fabrication. Literature survey is also being carried out.

## 104.0 Determination of Sulphur in High Alumina Slags by Radioactive Tracer Technique.

The experimental technique first employed was perfected on the basis of the results obtained from the preliminary experiments in high frequency furnace for the studies of transfer of sulphur in slags using thirteen radioactive standards. Encouraging results have been obtained.

## 105.0 Liquidus and Phase Equilibrium Studies on High Alumina Slag.

With the completion of experimental work on 64 synthetic blast furnace slag compositions, the data obtained were analysed and compiled. The study gave some interesting results regarding optimization and viscosity of synthetic blast furnace slags of different compositions.

Melilite was primary phase in most of the slags but compositions with higher magnesia had spinel as primary melilite as secondary phase. In most of the slags no difficulty was encountered in recrystallising the slags but some slags having low $CaO/SiO_2$ ratio and lower magnesia content were difficult to crystallise.

Observation of crystal movement and its growth in the slag samples near liquidus point gave an approximate idea of viscosity of slag. Behaviour of the slag samples varied from sample to sample near liquidus temperature. In general, the liquidus temperature at any given magnesia level increased with increasing $CaO/SiO_2$ ratio for all the four alumina levels studied. At any given magnesia content, with few exceptions, increase of alumina increased the liquidus temperature. Slag compositions having higher magnesia had spinel as primary phase in most of the samples but near with 5% MgO and below. Whenever spinel occured as primary phase liquidus temperature was comparatively high. The study on high alumina slags indicated that a basicity ratio of 1.15 to 1.20 would be more favourable for high alumina blast furnace slag practice in present Indian conditions.

## 106.0 Production of Sponge Iron in Rotary Kiln.

(*i*) Investigation was conducted with low grade iron ore and coal from Andhra Pradesh Industrial Development Corporation. The iron ore was first beneficiated and then used for sponge iron making. In this case Bayaram iron ore, Singareni Coal and Surajgarh limestone were used for sponge iron making in rotary kiln.

The objectives of the investigations were to determine the following :-

1. Optimum size of raw materials.
2. Behaviour of finer raw materials during reduction.
3. Maintenance of proper temperature gradient inside the kiln.
4. Optimum metallization that could be achieved.
5. Materials and heat balances obtainable from the operation.

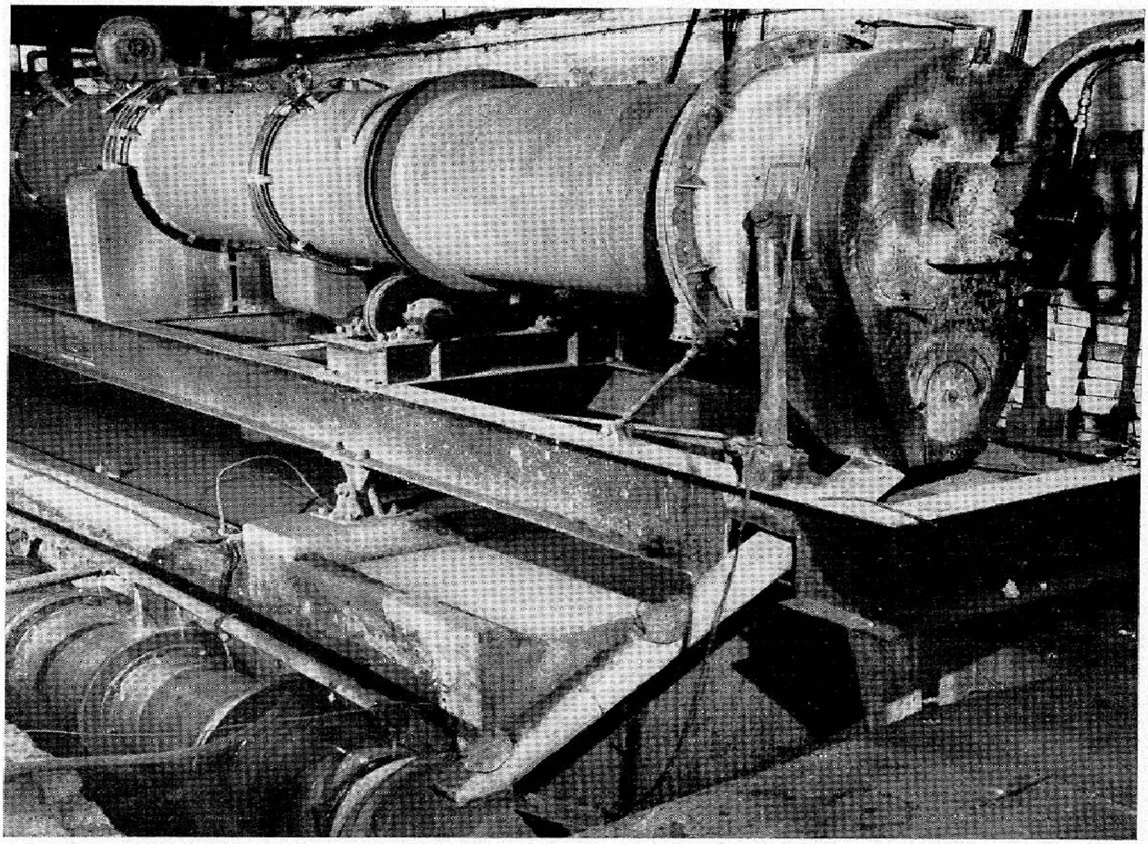
Six separate experiments were conducted with beneficiated Bayaram iron, Singareni Coal and Surajgarh limestone using different sizes of iron ore and non-coking coal in oil fired rotary kiln. Encouraging results were obtained. The average metallization was 85-87%. The average compression strength of the sponge iron was 136-138 kg per pellet with a tumbling index 94-96% plus 8 mesh. The total iron recovery in the products was in between 95-96% of the feed to the rotary kiln.

(*ii*) IDCOL raw material consists of high grade iron ore and non-coking coals. The investigations of sponge iron were conducted in two campaigns with Gandhamardhan iron and Talcher coal, and Khondband and Samla coal. In both the cases limestone from Birmitrapur was used.

Six separate experiments were conducted with Gandhamardhan iron ore and Talcher coal iron ore campaign and Khondband iron ore and Samla coal in the other campaign using different sizes of iron ore and non-coking coal. Good results were obtained. The metallization was 89-91%. The compression strength of the sponge iron in both the cases were (95-100) kg/pellet with a tumbling index of (88-90)% plus 8 mesh. The total iron recovered in the product in both the cases was 96% of the feed to the rotary kiln.

## 106.1 Modification of Vertical Shaft Reactor for Sponge Iron Production Using Non-Coking Coal as Reductant.

Based on the findings and experience of a small vertical shaft reactor with a capacity of 150 kg/day, a bigger reactor is being designed. In view of the difficulties faced with the small reactor, i.e. insufficient height of the reaction zone, high-temperature corrosion of metallic reactor, leakage of atmospheric air in the reactor and a poor heat profile in the furnace etc. etc., suitable modifications are being incorporated in the new design.



*A view of the rotary kiln with cooler for production of sponge iron (2-3 tons/day) installed at NML.*

## 106.2 Design of 1.7 $M^3$ Sponge Iron Plant Based on Naphtha as Reductant.

After successful production of sponge iron using naphtha as reductant in a continuous vertical reactor, having a capacity of 100 kg. of sponge per 24 hours, it has been decided to further scale up the process to a capacity of 10-12 tonnes per day. Accordingly, the designing of the reactor, furnace for heating, charging and discharging systems, naphtha feed line and injection equipments etc. have been taken up and are in progress. It is also proposed to try retorts made of different materials to find out a suitable retort material both from the point of view of operation, as well as economy.

## 106.3 Sponge Iron by Gaseous Reduction.

This is an Inter-Laboratory Collaborative Project between NML and CFRI, Jealgora. The project aims to utilize products of gasification of coal for the purpose of reduction of iron ore and pellets to sponge iron per day. For speedy implementation of the project a joint team of scientists of both NML and CFRI has been formed. The team is finalizing the design of the reactor and the ancillaries to be required for the purpose.

## 107.0 Production of Steel from Sponge Iron in Electric Arc Furnace.

Sponge iron was used for making different grades of plain carbon steel in 0.8 ton arc furnace unit at NML for testing their processing and mechanical properties. Sponge iron was also used to produce low carbon grade for soft magnetic applications. The material was processed and tested for magnetic properties after annealing and stress relieving. The properties obtained are given below:-

*Magnetic properties*

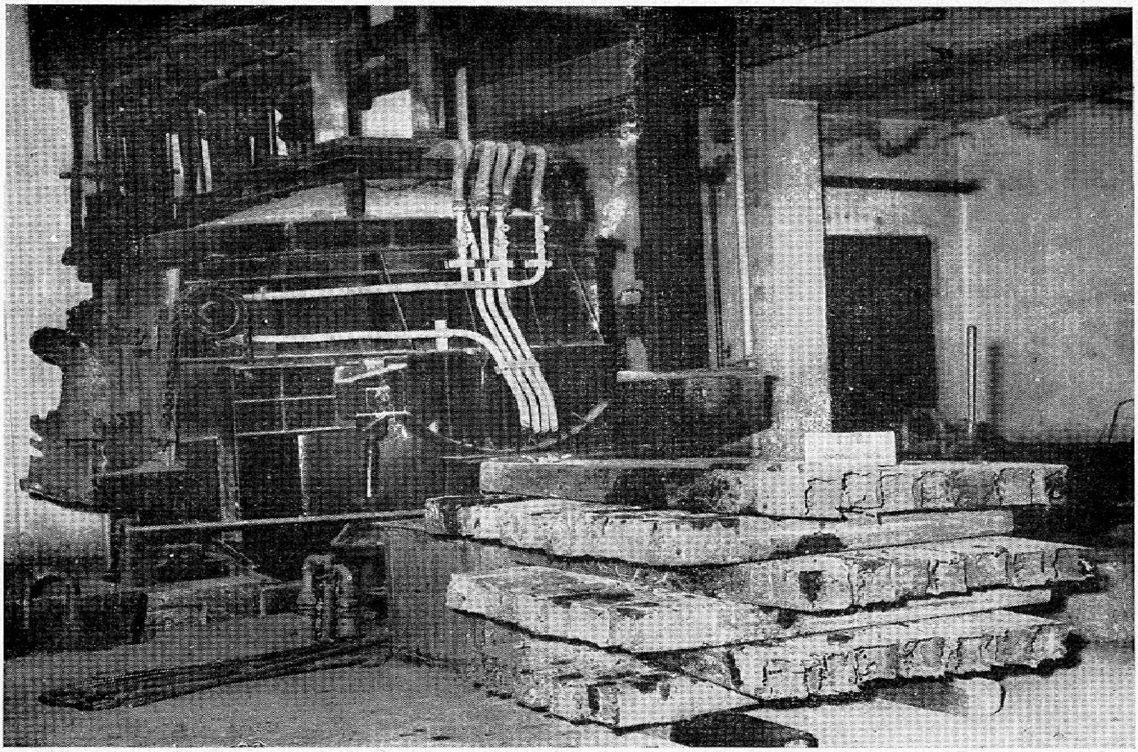
| | | |
|---|---|---|
| 1. | Saturation magnetisation in gauss | 19,500 |
| 2. | Maximum permeability | 6,900 |
| 3. | Coercive force in oersted | 0.60 |
| 4. | Remanence in gauss | 6,500 |

*Industrial Inplant trials*

Industrial inplant trials were held during the year at Foundry Forge Plant of Heavy Engineering Corporation, Ranchi and at Bhilai Steel Plant, Bhilai. Plain carbon and alloys steels of casting grade were made at HEC using up to 30% sponge iron of the total steel scrap charge in 10-ton electric arc furnace. Plain carbon steels of casting grade were made at Bhilai using up to 20% sponge iron of the total steel scrap charge in 5 ton electric arc furnace. Trials at both places were successful and steel could be made to specification.

## 108.0 Multipurpose Hydro-Electrometallurgical Large Scale Testing Facilities.

The project will be located at the NML Adityapur Complex, situated



*Steel prepared in the 0.8 ton electric arc furnace from sponge iron produced at NML.*

approximately 20 kilometers from Jamshedpur, where 100 acres of land is under acquisition from the Adityapur Industrial Development Authority.

Planning of land development including purchase of requisite machinery was completed. Layouts of process plant and equipment are actively underway. The central materials handling and storage facilities are being finalized.

**109.0 Sukinda Nickel Project.**

Work is underway in setting up of the pilot plant for processing Sukinda nickel ores.

**110.0 Setting up of Central Creep Testing Facilities.**

The building of the Central Creep Testing Facility was constructed and installation of the equipments carried out. The following equipments have been installed :-

12 Nos. 5000 kg-Single Specimen High Sensitivity Extensometer Creep Testing Machines for temperature upto 1000°C.

55 Nos. 3000 kg-Single Specimen High Sensitivity Extensometer Creep Testing Machines for temperatures upto 1000°C.

1 No. 3000 kg-Single Specimen High Sensitivity Extensometer Creep Testing Machine for temperatures upto 900°C with facility for optical recording of creep-strain/time curve.

7 Nos. 3000 kg-Multi-Specimen Stress-Rupture Testing Machines having 12 test points (4 loading strings, each for 3 specimens in tandem) for testing temperatures upto 1000°C.

1 No. Stress-Relaxation Testing Unit designed for Ring-Type Specimen for temperatures upto 1000°C.

1 No. 25,000 kg-Instron Universal High Temperature Tensile Testing Machine with precision Strain Rate Control Device for testing temperatures upto 1200°C.

**111.0 Nimonic Alloys.**

The ingots previously made could not be forged satisfactorily. Arrangements are in progress to obtain proper raw materials for making fresh heats.

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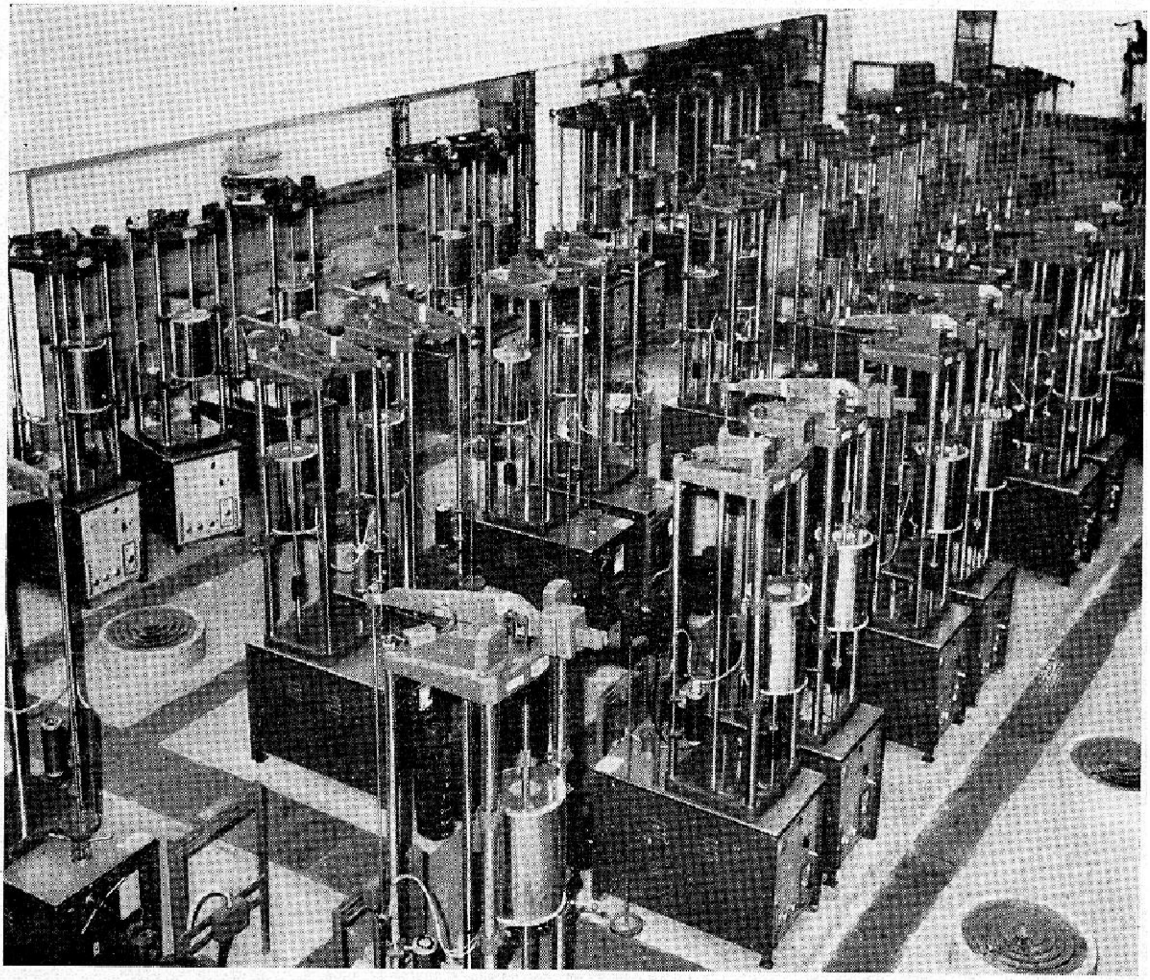


*Battery of creep testing equipment installed at the Central Creep Testing Facility of NML.*

# PILOT PLANTS

## 112.0 Mineral Beneficiation Pilot Plant.

Pilot Plant investigations conducted on different types of low grade ores and minerals have been reported under Sponsored Projects.

## 113.0 Dense Carbon Aggregate Pilot Plant.

During the year under review, the pilot plant continued its production. Bulk quantities of Soderberg paste compounded from dense carbon aggregate were supplied to ferro alloy manufacturers in tonnage quantities. These pastes have been tried in the electrodes of industrial furnaces and excellent reports about their performance have been obtained.

A combined team of CSIR, NRDC and DGTD visited NML mainly to assess the developmental work carried out in this field. The team was much impressed by both the quantum as well as the quality of work conducted and underway.

## 114.0 Electrolytic Manganese and Manganese Dioxide Pilot Plant.

The process for production of electrolytic manganese dioxide is now being actively considered for commercial exploitation. The process was demonstrated in several organised campaigns in presence of representatives of M/s. M. M. Suri & Associates. Besides, 100 lb cell was run continuously for twenty days. Valuable data for the rotary kiln reduction, leaching and purification of spent liquor, and running of the cell were collected and supplied to M/s. M. M. Suri & Associates. During these runs about 1 ton of electrolytic manganese dioxide was collected. The product after post treatments was sent to different parties to study the suitability for making dry cell battery. During the year, electrolytic manganese metal was supplied for internal experiments in different divisions.

# NML FIELD STATIONS

## Foundry Stations

The Field Stations at Batala, Madras, Howrah and Ahmedabad were rendering useful services to the regional foundry and engineering industries. The testing facilities offered in the field of metallurgical analysis, mechanical testing, moulding materials evaluation are being increasingly utilised by the industry, which was evident from the 2025 tests conducted during the period. The awareness of quality control is fast picking up among the small and medium scale entrepreneurs and they are approaching the field stations for technical guidance in large numbers. About 680 parties have been benefitted by such consultations. About 140 foundries were visited to impart on-the-spot technical guidance to solve problems encountered in moulding and core practice and melting and casting techniques. Through the above services, field stations are helping the local industry in selecting the suitable raw materials and in modernising the production techniques, which lead to a better quality control and ultimately lesser rejections. As per the previous programme, Field Stations are being expanded phase by phase. NML Field Station at Madras has been shifted from its present location at Guindy to the CSIR Madras Complex at Adayar. Ore dressing wing of the unit has started functioning. Civil work required for the ore dressing facility at NML Field Station at Ahmedabad has started.

## Marine Corrosion Research Station

Following work was done during the period under review.

(*i*) *Atmospheric Corrosion of Metals and Alloys Under Marine Atmosphere at Digha.*

Long term exposure tests on various metals such as Al (2S), Al (M57S), Brass, Copper, Nickel, Monel, Zinc, etc. are being continued. The results obtained so far showed that aluminium and its alloys were most resistant to the atmospheric corrosion. Exposure of high conductivity aluminium wires and a series of low alloy steels containing Al and Si has also been started.

(*ii*) *Testing of Various Inorganic Coatings on Steel Exposed to Marine Atmosphere at Digha.*

A countrywide test programme has been drawn up by the Corrosion Advisory Bureau to evaluate various surface protective schemes under different climatic conditions. In connection with this project samples of galvanised steel, aluminised steel, Al-clad steel, anodised aluminium are under exposure at Digha for over three years. Periodical observations and weight loss data are being collected.

(*iii*) *Sea Water Corrosion of Different Metals and Alloys.*

Studies on sea water corrosion was undertaken to obtain sufficient data with the common engineering materials such as aluminium, copper, brass, monel, mild steel, etc. from the corrosion point of view. The results obtained so far indicated copper and brass exhibited higher resistance under alternate immersion condition whereas monel and nickel showed greater resistance under totally immersed condition. Tests with different inhibitors showed higher efficiency of chromate for providing protection to metals in sea water under various testing conditions.

# ENGINEERING ACTIVITIES

## Design & Mechanical Engineering

### A. Design & Development

*Metal Powders*

(*i*) Design and development work on atomizer for producing atomized non-ferrous powders has been completed. The atomizer can handle up to 5 kg/min. of aluminium and 8-10 kg/min of brass, bronze etc.

(*ii*) Design drawings for equipment for zinc dust production in connection with transfer of technology to licencee has been completed.

### B. Service and Fabrication.

(*i*) Fabrication of instrument/equipment/components for various research and development work of the laboratory.

(*ii*) Repair and maintenance work on plants and equipments.

(*iii*) Preparation of various types of test specimen for destructive and metallurgical tests of the laboratory as well as for outside investigations.

(*iv*) Supply of tracings for graphs, figures etc.

(*v*) Preparation of ammonia prints.

## Electronics Engineering

### A. Development Projects.

(*i*) Development of a Capacitor Circuit for Precision Spot Welding of a fine strip and Wires for Resistivity Studies.

The circuit developed was fabricated into a prototype and was utilised for development work of some research project.

(*ii*) Thermogravimetric Balance.
A differential d.c. amplifier was fabricated and tested. Further work is in progress.

(*iii*) Proportional Temperature Controller.

Suitable firing circuit has been designed with unijunction transistor having thysistor in the control circuit.

### B. Instrumentation of Projects.

Instrument ation of sponge iron and hydro-electro-metallurgy projects were planned and schemes prepared. For creep project the pre-installation work for data logger and the temperature controllers were completed along with creep project staff.

### C. Maintenance, Installation etc.

Following major jobs were done.

(*i*) Electron microscope EM6.
(*ii*) Philips diffractometer.
(*iii*) Deltatherm.
(*iv*) Polarographs.
(*v*) Potentiostats.
(*vi*) Rolling mill controls.
(*vii*) Spectrophotometers.
(*viii*) Gas chromatograph.
(*ix*) Various types of recorders and controllers.
(*x*) Radio frequency and vacuum furnace controls.

## Electrical Engineering

### A. Development Projects.

(*i*) *Electro-Slag Refining Equipment.*

Fabrication of various components, such as column, electrode arm, water cooled electrode holder, water cooled mould etc. of an electro-slag refiner of 140 KVA capacity were carried out. Various parts were assembled and installed. Transformer, regulator circuit breaker, trip unit and electrode drive unit were also installed and commissioned.

(*ii*) *Design and Development of Electrical Isothermal Furnaces of 2.00 KW for Creep Testing of Metals and Alloys.*

The furnace designed and fabricated by NML and supplied to National Aeronautical Laboratory for field trial gave trouble free service as reported by National Aeronautical Laboratory.

(*iii*) *Electrical Furnace for Vertical Shaft Reduction Unit.*

The performance of a furnace of a particular design was studied and the modifications required in the design were noted.

### B. Engineering Monitoring and Project Management.

Engineering monitoring and project management of contractual work on electrical sub-station, internal wiring and temperature and humidity control system of Central Creep Testing facilities involving very specialised electrical engineering services were undertaken.

### C. Design, Fabrication and Installation.

(*i*) Design of power supply systems and their installations were carried out for several equipment such as 500 cft air compressor, Sukinda Nickel Project, Cryolite Plant, Heat treatment bay etc.

(*ii*) A number of electrical resistance furnace were designed and fabricated to meet the specialised needs of research and development work of the laboratory.

**D. Prevention Maintenance and Breakdown Repairs.**

Fault shooting and repairs of a number of electrical equipment such as extrusion press, arc furnace, high frequency furnace, temperature and humidity control systems, machine tools etc. were carried out. Preventive maintenance of electrical equipment comprising of power transformers, circuit breakers, rectifiers, motors, hoisting equipment, arc and resistance furnaces, control devices etc. were carried out.

## Civil Engineering

Other than the normal maintenance and modification of gas, water and other service lines at various installation places of equipment, the following major jobs were completed during the period.

1. Construction of room at the back side for the extension of the sub-station of Technological Block.
2. Construction of bus garage.
3. Construction of room for installation of air compressor.
4. Connecting road from Ferrous Production Technology Division Office to First Aid room.
5. Extension of sample room for storing ores in Mineral Beneficiation Pilot Plant.
6. Tarfelt treatment over the roof of NML Main Building.

The following jobs were taken up and are in progress:

Sanitary, plumbing and other civil work in offices and auditorium of Central Creep Testing Facilities.

# PUBLICATIONS

During the period under review, a number of publications were brought out, a brief account of which is given below.

## NML Technical Journal

NML Technical Journal entered into fifteenth year of publication.

## Proceedings of Symposium & Seminar

The papers presented at the Symposium on "Science & Technology of Sponge Iron and its Conversion to Steel" were edited and sent for publication.

The papers presented at the seminar on "Bacterial Leaching" were edited and published as "Bacterial Leaching Seminar Number 1" in NML Technical Journal, November, 1973 issue.

## Folder

An illustrated folder was brought out depicting the various priced publications of the Laboratory.

## Press Releases

Periodic press releases were issued to appraise the general public about the function and contribution of the laboratory.

## Documented Survey on Metallurgical Development

Issues of this monthly publication were brought out.

## Handouts & Notes

Handouts and notes on processes of the laboratory developed for commercial utilization were prepared and distributed to interested persons and organizations.

## Papers Published and Presented

Details furnished in Appendix I.

## Research and Investigation Reports

Details furnished in Appendix II.

# INDUSTRIAL LIAISON & RESEARCH CO-ORDINATION

## Consultancy Service

A number of major public and private sector industries including small scale industries have continuously called at NML with metallurgical problems in their own development fields, culminating in the shape of sponsored research investigation/development work. The NML continued to render its consultancy services to the Gujarat Mineral Development Corporation, whenever any problem was referred to the Laboratory.

The consultancy services are being offered by the NML to M/s. Hindustan Copper Limited, Calcutta, for setting up of a copper ore beneficiation plant of 1000 tonnes per day at Rakha Mines, Bihar. The NML will be investigating tonnage lot samples etc. The NML has also been negotiating for large scale industrial trials of the sponge iron technology by rotary kiln process by utilising the old cement rotary kiln of a firm which would be suitably modified as far as practicable for its adoption to the NML developed technology.

The NML has offered its services for infrastructure facilities for the extraction of nickel from the Sukhinda Nickel Ores based on the tests carried out at NML. This project is sponsored by the Ministry of Steel & Mines through their consultants M/s. Chemical & Metallurgical Design Co., the NML shall be setting up a pilot plant in their 1st phase of work.

Consultancy services had also been offered to M/s. Hindustan Copper Ltd. for their project on Bundalamutu galena. The NML has been closely associated in the investigations continued on Bundalamutu ores both on batch and pilot plant scales and is actively collaborating with M/s. Engineers India Ltd., consultants to M/s. Hindustan Copper Ltd., for this project.

The technical feasibility report for production of sponge iron of 100 tonnes per day had been prepared and forwarded to the Ministry of Steel & Mines (Steel Authority of India Ltd.).

## Get-Together

'Get-togethers' were held at Barbil (Orissa) and Hyderabad and the NML participated in the meeting with the Ministry of Steel & Mines, especially with reference to problems on non-ferrous minerals and metals. The NML has initiated a dialogue with the Kerala State Industrial Development Corporation, Kerala Minerals & Metals etc. for the role, the NML can play in achieving the minimum objectives of the State Government's Five Year Plan as well as some long term objectives. These get-togethers have proved of immense value in the sense that a few problems of mutual interest were able to be identified in these get-togethers where NML can undertake the necessary investigations on sponsored basis, besides offering their consultancy services and expertise on the technologies developed at the laboratory.

## NML Annual Day 1973

The NML Annual Day-cum-Get-Together was held on 26th November, 1973, synchronising with the date of opening of this laboratory 23 years ago.

*Prof. V. A. Altekar, Director, NML, addressing a press conference and acquainting the press about the activities of NML.*

A representative gathering of industrialists/entrepreneurs/mineral producers participated in the function and got acquainted with the expertise available at the NML for starting new mineral based and other metallurgical industries. The meaningful dialogue also helped to identify new areas where NML can provide necessary inputs. Minister of Industries & Technical Education and State Minister for Industries of the Govt. of Bihar also attended the function which was inaugurated by the former.

In an effort to build linkages at the State level, the Director-General, Scientific & Industrial Research, has recently nominated NML to make systematic study of the Bihar State Fifth Five Year Plan to identify major areas of thrust for industrial, economic and social development of the State by holding a get-together at the State capital, Patna.

## National Mineral Convention

The National Mineral Convention organised by Mining, Geological & Metallurgical Institute of India and co-sponsored by Mining Engineers' Association ; Institution of Engineers (India) ; NML ; Indian Mine Managers' Association and Birla Industrial & Technological Museum was held on 24th and 25th November, 1973. It was largely attended by mineral, mining and metallurgical engineers from all over India as well as representatives from the mineral industries both in private and public sectors.

## High Power Committee

Representatives of the High Power Committee, constituted by the Govt. of Bihar to suggest the various measures for promoting the development of mineral based industries in Bihar held its first meeting on 14-15th January, 1974 to discuss the expertise available at the NML on sponge iron production ; aluminium/alumina/refractories etc.

## Technical Aid and Services

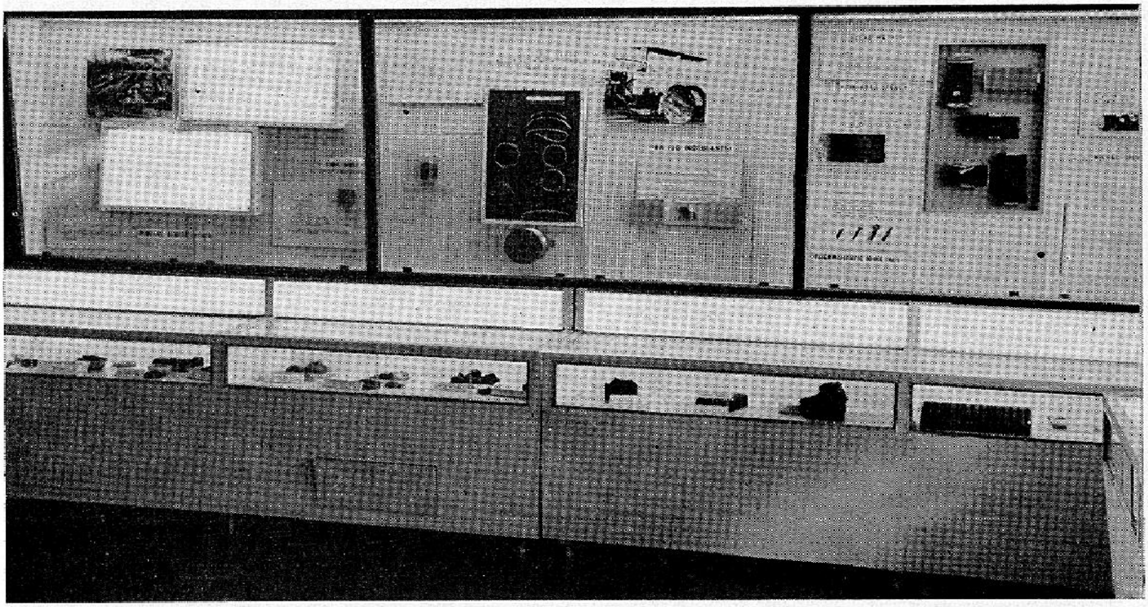
Over 150 technical enquiries from various government, semi-government, public and private organisations, 200 enquiries pertaining to the details of the processes/patents of the laboratory and to provide latest technical information data were attended to. Technical services by way of analyses and testing of over 75 samples on short term ad hoc testing basis, besides metallurgical failure investigations were undertaken.

## Exhibition

Wholly Indian exhibition (through Indian Council of Trade Fairs & Exhibitions) was held in March 1974 at Caracas (Venezuela). To project the image of the laboratory, NML participated in this exhibition thro' CSIR by way of sending (*a*) NML brochures (*b*) priced publication e.g. NML Technical Journal, Monographs, Symposium/Seminar proceedings, (*c*) other literature materials.

## Air Broadcast

In collaboration with AIR Ranchi, a full length radio feature programme in English and other regional languages was prepared on the salient achieve-



*A view of the NML Regional Liasion Centre at Calcutta.*

ments of NML towards the goal of self-sufficiency and broadcast on the national hookup on 13.9.73.

**Extension Services**

The National Metallurgical Laboratory has set up a Regional Liaison Centre at Calcutta. This Centre will appraise industrialists and entrepreneurs of the scope of technical assistance the Laboratory can offer for setting up new mineral based and other metallurgical industries. Housed at the India Exchange Place, the Liaison Centre exhibits the products and processes developed by NML. The space for the Centre has been made available free of charge by the Indian Chamber of Commerce, Calcutta.

Proposal for the establishment of Testing & Development Centres at Agra and Kanpur in order to cater to the need of the foundry industries was prepared and sent to UP Government for their confirmation.

**Training Facilities At NML**

Candidates deputed from various organisations such as Board of Practical Training, Eastern Region, Calcutta (under practical training stipendary scheme); NMDC; the Fertilizer Corporation of India Ltd.; I.I.T.s; Indian School of Mines, Dhanbad; B.H.U.; Small Industry Extension Training Institute; Birla Institute of Technology, Mesra; Andhra University; Regional Engineering College, Rourkela; etc. were provided with training facilities in various disciplines of metallurgy viz. metallurgical testing including analysis of ores, minerals, metals and alloys; mineral beneficiation and ore dressing techniques; extraction of metals; production of iron and steel; sand testing; heat treatment; metallography; mechanical testing; physical metallurgy; crystallography and X-rays; refractories; pelletization studies and corrosion studies etc.

**Visitors**

Over 200 visitors called on NML and had technical discussions regarding utilisation of Laboratory's expertises.

# PATENTS AND PROCESSES

## Patents Field

1. Improvements in or relating to non-sludge forming zinc phosphating compositions—H. R. Thilakan, K. P. Mukherjee & A. K. Lahiri (IP 2247/Cal/73).
2. Improvement in or relating to manufacturing process of versatile aluminium/alloy aluminium conductor for multifarious applications—R. Kumar & Manjit Singh (IP 2042/Cal/73, UK 11044 dt. 12.3.74; USA 434677 dt. 18.1.74).
3. Improvement in or relating to removal of phosphorus and iron from fluorspar—Gurdail Singh, M. L. Dey, P. V. Raman, H. K. Chakrabarty & V. A. Altekar (IP 2614/Cal/73).
4. A device for the position control of the electrodes of electric furnaces—Hawalder Singh (IP 185/Cal/74).
5. An improved process for production of zinc dust—V. A. Altekar & B. V. S. Yadavalli (IP 245/Cal/74).

## Processes Released

| *Processes* | *Firms* |
|---|---|
| Production of extra-fine non-ferrous metal powders by atomization. | M/s. Nalco Metal Products Ltd., Madurai, Tamil Nadu. |
| Production of extra-fine zinc dust (distilled zinc dust). | M/s. Associated Pigments Ltd., Calcutta. |
| Electric grade alloy aluminium conductor | (*i*) M/s. Aluminium Cable & Conductors (U.P) Pvt. Ltd., Calcutta.<br>(*ii*) M/s. Bharti Smelting & Refining Corporation, Bombay. |

# GENERAL

## Recepients of Honours, Awards etc.

| | |
|---|---|
| Prof. V. A. Altekar, Director. | Distinguished Alumnus Award of Banaras Hindu University. |
| Dr. R. Kumar, Scientist | Distinguished Alumnus Award of Banaras Hindu University. |
| Shri R. M. Krishnan, Scientist | Distinguished Alumnus Award of Banaras Hindu University. |

## Foreign Deputation/Training.

| | |
|---|---|
| Prof. V. A. Altekar, Director. | Visited Japan to attend the IVth International Conference on Vacuum Metallurgy and IVth International Symposium on Electro-Slag Remelting Process during 4-8th June, 1973. Visited various research institutes and industries in Japan. Also visited Bangkok in June, 1973. |
| Shri D. D. Akerkar, Scientist. | Deputed to 3 months study/training in non-ferrous metal production under UNDP programme at Dept. of Energy, Mines & Resources and Ontario Research Foundation, Canada. |
| Shri P. K. Sinha, Scientist. | Deputed to Poland for training in the field of iron ore agglomeration. |
| Shri P. V. Raman, Scientist. | Deputed to Czechoslovakia for training in the field of Ore-dressing. |
| Shri N. Subramanian Scientist | Deputed to Poland for training in the field of production of ferro-alloys and electric arc furnace. |

## Directorship, Chairmanship, Membership etc. on Outside Bodies

| | | |
|---|---|---|
| Prof. V. A. Altekar, Director. | Director | Board of Directors of U.P. State Mineral Development Corporation. |
| | President | Indian Institute of Mineral Engineers. |
| | Chairman | Industrial Metallurgy Division of Indian Institute of Metals. |
| | Vice-President | National Council of Indian Institute of Metals. |
| | Member | (*i*) American Institute of Mining, Metallurgy & Petroleum Engineers. |

| | | |
|---|---|---|
| | | (*ii*) National Council of Institute of Indian Foundrymen. |
| | | (*iii*) Editorial Board of the Journal 'Mineral Processing'. |
| | | (*iv*) Editorial Advisory Board of the Journal 'Indian Chemical Manufacturer'. |
| | | (*v*) Editorial Board of the Journal 'Tool & Alloy Steels'. |
| | | (*vi*) Corresponding Member in India for 11th International Mineral Processing Congress. |
| | | (*vii*) 'Working Group Industries' Constituted by Bihar State Planning Board. |
| | | (*viii*) 'Task Force for Large & Heavy Industries' of the Bihar State Planning Board. |
| | | (*ix*) 'Task Force for Intermediate Industries' of the Bihar State Planning Board. |
| Dr. R. Kumar<br>Scientist | Member | (*i*) Study Group on Power & Gas Turbine of the Energy Research Committee of CSIR. |
| | | (*ii*) Corrosion Research Committee of CSIR. |
| | | (*iii*) Materials Process Panel of the Aeronautics R & D Board, Ministry of Defence. |
| Shri A. Peravadhanulu<br>Scientist. | Member | Aluminium Ores Sub-Committee of National Mineral Development Corporation. |

**Lectures & Colloquia**

A number of lectures were delivered by distinguished metallurgists, technologists and industrialists during the period under review. The staff of the laboratory presented and discussed papers on subjects in respective fields in the colloquia. The following special lectures were delivered by NML staff.

| | |
|---|---|
| 1. Prof. V. A. Altekar, Director. | Key note address on "Electro-thermal smelting—present status and future prospect—At ELKEM Seminar, January 1974, New Delhi. |
| 2. Dr. R. Kumar, Scientist | Key note lecture on "The challenge of aluminium for application in electrical and telecommunication industries"—At Golden Jubilee Celebration of Banaras Hindu University. |
| 3. Shri K. P. Mukherjee Scientist. | "Corrosion of metal and its prevention"—Special Meeting organised by Jamshedpur Productivity Council. |

### Purchase & Stores

Purchase & Stores kept up their activities by procurement of capital equipment, raw materials, consumable stores for the various research projects, pilot plant activities, constructional work etc.

### Administration & Accounts

Administration and Accounts Section handled the general and overall administration and budgetary accounts.

### Safety First and First Aid Section

No major casualty took place during the year. Regular inspection to safety measures were carried out. The First Aid Section treated minor injuries, indisposition caused to staff members on duty.

### Activities of Societies, Club and Canteen

NML Staff Co-operative Credit Society operated its transactions worth over rupees two lakhs with efficiency. NML Co-operative Stores continued to supply rationed food stuff, stationery articles to the staff members.

NML Club maintained its sporting and social activities. It took part in local tournaments in Cricket, Table Tennis, Cards etc. and also organized tournaments for NML staff and their families. A number of film shows were organised by the club. The NML Canteen is supplying to staff members meals, snacks etc. at reasonable price.

NML Welfare Committees at Agrico & Tuiladungri colonies continued to look after the cleanliness of the colonies, running of kindergarten school, arranging cultural and film shows etc.

### Staff Position

| | |
|---|---|
| *Scientific* | 193 |

| | |
|---|---|
| *Technical* | 536 |
| *Administrative* | 268 |

**Budget Figures**

| | | |
|---|---|---|
| *Recurring* | | *Figures in Lakhs of Rupees.* |
| P-1 | Pay of Officers | 15.992 |
| P-2 | Pay of Establishment | 14.443 |
| P-3 | Allowances | 24.437 |
| P-4 | Contingencies | 10.680 |
| P-6 | Maintenance | 1.137 |
| P-7 | Chemicals etc. | 8.812 |
| *Capital* | | |
| P-5 | Works | 25.009 |
| | Services | 0.074 |
| | Apparatus & Equipment | 26.248 |
| | Miscellaneous | 1.658 |
| *Pilot Plants* | | 17.304 |
| *Construction of Quarters* | | 11.692 |
| | GRAND TOTAL Rs. | 157.486 |

# APPENDIX I

## Papers Published, Communicated and Presented

1. Studies on manganese—nickel system—S.S. Sachdeva, J. K. Mukherjee & T. Banerjee; NML Technical Journal, Vol. 15 (1973) 1, pp 1-9.

2. Solid state nitrogenation of carbon-free ferro-chromium—N. Subramanyam, R. G. Ganguly & M. Subramanian; NML Technical Journal, Vol 15 (1973) 1, pp 10-16.

3. Refining of selenium—A review—Narinder Singh, S. B. Mathur & D. D. Akerkar; NML Technical Journal, Vol. 15 (1973) 1, pp 17-23.

4. Spectrophotometric studies on the reduction of vanadium & molybdenum by glucose & fructose—L. P. Pandey, NML Technical Journal, Vol. 15 (1973) 1, pp 24-27.

5. Reactivity of some low temperature carbonized coke made from non-coking coals—Sidheswar Prasad & A. B. Chatterjea; NML Technical Journal, Vol. 15 (1973) 2, pp 29-35.

6. Production of molten pig iron from fine grained iron ore, fuel & limestone—R. Santokh Singh, P. S. Virdhi & A. B. Chatterjea; NML Technical Journal, Vol. 15 (1973) 2, pp 36-41.

7. Survey of indigenous coals, fly ashes & flue dusts as a potential source of germanium—Narinder Singh & S. B. Mathur; NML Technical Journal, Vol. 15 (1973) 2, pp 42-48.

8. Utilization of secondary zinc—G. Basu, P. K. Sinha, S. C. Aush, N. Dhananjayan & V. A. Altekar; NML Technical Journal, Vol. 15 (1973), 3, pp 49-58.

9. Bearing materials—A general appraisal—C. S. Sivarama Krishnan; NML Technical Journal, Vol. 15 (1973) 3, pp 69-75.

10. Raw materials for iron making & their testing—J. S. Padan, Onkar Singh & A. N. Kapoor; NML Technical Journal, Vol. 15 (1973) 3, 59-68.

11. Role of micro-organisms in minning metals from low grade ores—Narinder Singh, S. R. Srinivasan, M. J. Shahani & V. A. Altekar; NML Technical Journal, Vol. 15 (1973) 4, pp 16-24.

12. Economic viability of bacterial leaching—A management research view point—B. V. S. Yedavalli; NML Technical Journal, Vol. 15 (1973) 4, pp 28-31.

13. Recovery of copper from dilute solutions—C. S. Sanbaran, S. R. Srinivasan & D. D. Akerkar; NML Technical Journal, Vol. 15 (1973) 4, pp 32-41.

14. Industrial scale trials on niobium treated high strength low alloy structural steel—N. S. Datar, S. C. Reddy, R. Chattopadhyay, B. K. Guha & S. S. Bhatnagar; NML Technical Journal, Vol. 16 (1974), 1 & 2, pp 1-4.

15. Proper methods of testing for selection of iron ore for iron making—A. N. Kapoor & J. S. Padan; NML Technical Journal, Vol. 16 (1974), 1 & 2 pp 5-9.

16. Effect of aluminium & boron on the kinetics & morphological of graphite precipitation during malleablization—S. K. Palit & A. B. Chatterjee; NML Technical Journal, Vol. 16 (1974) 1 & 2, pp 10-17.

17. Vacuum heating hydrogen determination in aluminium & aluminium alloys—J. Konar & N. G. Banerjee; NML Technical Journal, Vol. 16 (1974) 1 & 2, pp 18-19.

18. Powder metallurgical aspects of alloy steels—J. P. Tewari & G. S. Upadhyaya; NML Technical Journal, Vol. 16 (1974) 1 & 2, pp 23-26.

19. Sponge Iron technology—V. A. Altekar; Proc. of Symp. on Science & Technology of Sponge Iron & its Conversion to Steel.

20. Operational aspects of sponge iron production in a rotary kiln—B. L. Sengupta, A. B. Chatterjea, G. P. Mathur & V. A. Altekar; Proc. of Symp. on Science & Technology of Sponge Iron & its Conversion to Steel.

21. A study of ring formation of sponge iron in the rotary kiln—M. R. K. Rao, Proc. of Symp. on Science & Technology of Sponge Iron & its Conversion to Steel.

22. On some fundamental aspects of operational parameters of direct reduction in a rotary kiln—A. B. Chatterjea; Proc. of Symp. on Science & Technology of Sponge Iron & its Conversion to Steel.

23. Naphtha reduction of iron ores to sponge iron in continuous vertical reactor—V. A. Altekar, K. N. Gupta, B. K. Paul & V. K. Soni; Proc. of Symp. on Science & Technology of Sponge Iron & its Conversion to Steel & Engineering World 7th Oct. 1973., pp 135-143.

24. Relevance of sponge iron technology to India—P. K. Gupta, Commerce, October 6, 1973.

25. Sponge iron—a challenging alternative, V. A. Altekar, Science Today, April, 1973.

26. Sponge iron—its past, present and future—V. A. Altekar, Banaras Hindu University Seminar.

27. Sponge iron production in a vertical shaft furnace—A. B. Chatterjea, T. C. De & V. A. Altekar; Engineering World 7th Oct., 1973, pp 93-100.

28. Use of sponge iron in the production of low-carbon iron for soft magnetic applications—R. D. Gupta, & V. A. Altekar; Steel Furnace Monthly, Vol. VIII, No. 12, Dec. 1973, pp 695-696.

29. Direct reduction process for steel making—V. S. Sampath and V. A. Altekar—Golden Jubilee Number of Institute of Engineers, 1973, pp 91-95.

30. Role of NML for small/medium scale industries—V. A. Altekar & K. N. Srivastava; Paper for circulation at the ECAFE Committee on Industries & National Resources (Sub-Committee on Metal & Engg.) 12th Session, August 1973 at New Delhi.

31. Indian iron in antiquity—A. B. Chatterjea & V. A. Altekar; Eastern Metals Review, Mid-Year Special Number, 1973, pp 77-87.

32. The NML of India—A case study of the development of a R & D institute—V. A. Altekar; presented at the 3rd International Symposium on the Iron & Steel Industry held in Brasilia, Brazil, 14th—21st Oct. 1973.

33. Application of aluminium and alloy aluminium conductors in electrical industries—V. A. Altekar & V. S. Sampath; Engineering News of India Annual Number, October 1973.

34. Role of NML in research and development of non-ferrous metals—V. A. Altekar; Eastern Metals Review, Silver Jubilee Number. Vol. 26 No. 23, June, 1973, pp 241-245.

35. Structural Steels—S. S. Bhatnagar & V. A. Altekar; Tool & Alloy Steel Annual Number, 1973, pp 9-13.

36. Development of 'SUPERAL'—An aluminium anode for cathodic protection; Symposium on 'Cathodic Protection'; organised by Defence Research Laboratory, Kanpur, December 1973.

37. The deep anode bed system for cathodic protection of underground structure—H. R. Thilakan, K. P. Mukherjea, A. K. Lahiri and V. A. Altekar; Symposium on 'Cathodic Protection'; organised by Defence Research Laboratory, Kanpur, December 1973.

38. The protection of super-alloys from oxidation and hot corrosion—S. N. Prasad & V. A. Altekar; Seminar on 'Metallurgy of High Strength High Temperature Alloys' organised by Roorkee University.

39. Stress Corrosion cracking in high strength Al-Zn-Mg alloys—A review—S. N. Prasad & V. A. Altekar; Symp. on 'Environmental Effects on the Properties of Materials' held at Thumba, Trivandrum.

40. Embrittlement of high carbon steel in sulphuric acid containing thio-compounds—A. K. Dey, Inder Singh & V. A. Altekar; Symp. on 'Environmental Effects on the Properties of Materials' held at Thumba, Trivandrum.

41. Studies on atmospheric corrosion of non-ferrous metals at NML—H. R. Thilakan, A. K. Dey & K. P. Mukherjee; Symp. on 'Environmental Effects on the Properties of Materials' held at Thumba, Trivandrum.

42. Diffusion coating on steel—A. N. Mukherjee & P. Prabhakaran; Symp. on 'Environmental Effects on the Properties of Materials' held at Thumba, Trivandrum.

43. Polar-organic inhibitors—Mechanism and phenomenology—Inder Singh; Symp. on 'Environmental Effects on the properties of Materials' held at Thumba, Trivandrum.

44. Application of chlorine and chlorides in extraction metallurgy—V. S. Sampath & V. A. Altekar; Golden Jubilee Number of Banaras Metallurgist, Banaras Hindu University, December 1973.

45. Electrical resistivity of pre-reduced iron ore pellets and its impact on electric smelting—B. K. Paul, K. N. Gupta & V. A. Altekar; Golden Jubilee Number of Banaras Hindu University, December 1973.

46. Highly reducing gases from hydro-carbons—a pre-requisite to gaseous reduction—V. K. Soni, K. N. Gupta & V. A. Altekar; Golden Jubilee Number of Banaras Metallurgist, Banaras Hindu University, December, 1973.

47. Thermo-chemical testing of iron ores/pellets for their suitability to blast furnaces or DR processes—N. V. Nagaraja, B. M. Dutta, K. N. Gupta & V. A. Altekar; Golden Jubilee Number of Banaras Metallurgist, Banaras Hindu University, December, 1973.

48. Prospects of developing nickel industry in India—V. A. Altekar & V. S. Sampath; Eastern Metals Review, Silver Jubilee Number.

49. Production of tin-free steel—A. K. Sinha, N. Dhananjayan & V. A. Altekar; Trans of Ind. Inst. of Metals Vol. 26 No. 6, December, 1973 pp 51-55.

50. Adsorption of nickel by lignite—V. A. Altekar, M. J. Shahani & A. K. Saha; Fuel, Vol. 53, January, 1974, pp 29-31.

51. Role of NML in the development of mineral based industries in India—V. A. Altekar; Silver Jubilee Souvenir, Indian National Mine Workers' Federation, New Delhi, March, 1974.

52. Impact of some recent metallurgical developments on the technology of aluminium—R. K. Mahanty, C. S. Sivaramakrishnan, Manjit Singh & R. Kumar; 114th Anniversary Number. The Indian and Eastern Engineer, pp 35-40.

53. Development of NML—PM2 aluminium alloy conductor for electrical and telecommunication applications—R. Kumar & Manjit Singh; Symposium on 'Use of Aluminium in Electrical Energy' organised by Institution of Engineers, December, 1973.

54. Electric grade aluminium alloy (NML—PM2)—An ideal substitute of copper for electrical industry—R. Kumar & Manjit Singh, 27th Annual Technical Meeting of Indian Inst. of Metals.

55. High strength Fe-Al-Si alloys—N. K. Das & L. J. Balasundaram; Indian Journal of Technology, Vol. 11, No. 12, Dec., 1973, pp 628-634.

56. Structure of rapidly solidified Al-Si alloys—S. K. Bose, and R. Kumar—Journal of Material Science 8 (1973), pp 1795-1799.

57. Extraction of vanadium from vanadium bearing pig iron by an oxidising slag containing mill scale, lime and silica—K. K. Gupta, A. K. Nayak & P. P. Bhatnagar; Trans. of Ind. Inst. of Metals, Feb., 1973, pp 35-41.

58. Calcium metal—Scope for production in India—A. K. Nayak & M. J. Shahani; Chem. Age of India, May, 1973, pp 298-301.

59. Thermal and quantitative thermal analysis of Al-Zn alloys and determination of the equilibrium diagram of the binary system—A. K. Nayak; Journal of Inst. of Metals. 101 (1973), pp 309-314.

60. Powders of Copper and its alloys—R. G. Ganguly, Upkar Singh & M. J. Shahani—Seminar on 'New Vistas for Small Scale Copper Base Industries' Bangalore, May, 1973.

61. Recovery of Zinc metal from galvanizers' dross by atmospheric distillation—G. Basak, R. N. Lahiri, V. Srinivasan & M. J. Shahani; Chemical Age of India, Nov., 1973, pp 757-759.

62. Instrumentation on corrosion study of metals and their surface protection in industry—P. K. Bagchi & A. P. Chowdhury; Seminar on 'Instrumentation and Automation in Metallurgical and Engineering Industries' organised by Inst. of Engineers, Jamshedpur Sub-Centre, Feb., 1974.

63. Instrumentation of a rotary kiln in a sponge iron plant—B. K. Choudhury & A. P. Chowdhury; Seminar on "Instrumentation and Automation in Metallurgical and Engineering Industries' organised by Inst. of Engineers, Jamshedpur Sub-Centre, Feb., 1974.

64. An electro-hydraulic automatic gauge control in cold rolling mills using solid instrumentation system—A. P. Chowdhury; Seminar on 'Instrumentation and Automation in Metallurgical & Engineering Industries' organised by Inst. of Engineers, Jamshedpur, Sub-Centre, Feb., 1974.

65. Maintenance of process control instruments for power plant—B. K. Chowdhury; Seminar on 'Instrumentation and Control in Steam Generation and Utilization' organised by Inst. of Engineers, Mysore Centre, June, 1973.

66. Refractory raw materials for electric melting furnace—P. C. Sen, R. V. Hargave & M. R. K. Rao—Steel Furnace Monthly, Vol. IX, No. 2, Feb., 1974 (Presented at the Seminar on 'Refractories for Electric Melting Furnace' organised by Indian Ceramic Society, Jamshedpur Section, Feb., 1974).

67. Developments in the refractory practice for electric melting furnace—A. V. Subhramanyan & K. K. Singh—Steel Furnace Monthly, Vol. IX, No. 2, Feb., 1974 (Presented at the Seminar on 'Refractories for Electric Melting Furnace' organised by Indian Ceramic Society, Jamshedpur Section, Feb., 1974).

68. Development of indigenous refractory lining for vacuum induction furnace—R. D. Gupta, N. N. Mathur & M. R. K. Rao—Steel Furnace

Monthly, Vol. IX, No. 2, Feb., 1974 (Presented at the Seminar on 'Refractories for Electric Melting Furnace' organised by Indian Ceramic Society, Jamshedpur Section, Feb., 1974).

69. Electric arc as a factor in the service life of the arc furnace lining—A review—H. P. S. Murthy—Presented at the Seminar on 'Refractories for Electric Melting Furnace' organised by Indian Ceramic Society, Jamshedpur Section, Feb., 1974.

70. Phase equilibria, raw materials, development and uses of high alumina refractory cements—A. K. Bose, M. C. Kundra, M. R. K. Rao & H. P. S. Murthy—Presented at the Third Cement Industry Operation Seminar, March, 1973.

71. Blast furnace slags—a study of chemical and mineralogical composition and utilization in cement industry—R. V. Hargave, S. P. Dasgupta & M. R. K. Rao—Presented at the Third Cement Industry Operation Seminar, March, 1973.

72. Investigation on the possibility of production of fosterite refractories from talc—M. C. Kundra & H. P. S. Murthy—Presented at the Third Cement Industry Operation Seminar, March, 1973.

73. Evaluation of Nattam dolomite from Tamil Nadu as a raw material for the production of refractories—M. R. K. Rao, P. C. Sen & K. C. Ray—Presented at the Annual Session of Indian Ceramic Society held at Madras, Feb.-March, 1974.

74. Fe-Ti Steel—An indigenous high hardness steel—S. P. Mukherjee & Rajendra Kumar—Presented at the Seminar on 'Metallurgical and Engineering Aspects of Tool Materials' organised by Indian Institute of Metals, Jamshedpur Chapter & M/s. Hind Tools & Dies (P) Ltd., Jamshedpur, April, 1973.

75. New strides in the manufacture of high speed steels—R. D. Gupta, Tool & Alloy Steels, Annual No. 1973 (Nov.-Dec. 1973), Vol. 7, No. 7, p. 51.

76. Role of sponge iron in arc furnaces for mini-steel plants—R. D. Gupta—Presented at the Symposium on 'Prospects of Mini Steel Plants in Gujarat' organised by Baroda Chapter of Ind. Inst. of Metals, Dec., 1973.

## Scientific Investigations Completed and Reports Prepared

1. Beneficiation studies on a low grade graphite from Jhab-Redhana mine of GMDC Ltd.—S. K. Sengupta, P. V. Raman & G. P. Mathur (I.R. 724/73).

2. A comprehensive report on Khondbond iron ore for Tata Iron & Steel Co. Ltd. (I.R. 725/73).

3. Beneficiation Studies on a low grade magnetite sample marked 'M' from Kuvuthivalai deposit near Tiruvannamalai. Pt. II—J. P. Srivastava, P. V. Raman, S. K. Banerjee & G. P. Mathur (I.R. 726/73).

4. Beneficiation studies on a low grade magnetic sample 'C' from Kavuthimalai deposit, Tamil Nadu—J. P. Srivastava, P. V. Raman, S. K. Banerjee & G. P. Mathur (I.R. 727/73).

5. Heavy media separation studies with the zinc ore from Balaria, Rajasthan—P. N. Pathak, S. K. Banerjee, D. M. Chakrabarti and G. P. Mathur (I.R. 728/73).

6. Moulding Characteristics of sand sample no. 'A' received from Department of Industries, Govt. of Haryana—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 729/73).

7. Moulding Characteristics of sand sample No. 1 received from the Directorate of Geology & Mining, Lucknow (U.P.)—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 730/73).

8. An interim investigation report on study of creep rupture properties of 1% Cr. 1/2% Mo steel seamless tubes for high temperature service sponsored by M/s. Indian Tube Co. Ltd., Jamshedpur—R. Choubey, K. Prasad & S. C. Bose (I.R. 731/73).

9. Investigation on failure of superheater tubes—referred by Singareni Colleries, Ramagundam Power House, A. P.—S. Rao Addanki & P. S. Nag (I.R. 732/73).

10. Determination of Bond's Work Index and crushing strength of six uranium ore samples from M/s. Uranium Corporation of India Ltd., Jadugoda —M. L. Viswakarma, K. Vijayaraghavan, P. V. Raman & S. K. Banerjee (I.R. 733/73).

11. Studies on bore holes and bulb samples of magnetite from Salem—M. L. Vishwakarma, B. Banerjee, C. Satyanarayan, P. V. Raman, A. Peravadhanulu, S. K. Banerjee & G. P. Mathur (I.R. 734/73).

12. A report on comprehensive tests on Noamundi hard iron ore from TISCO. (I.R. 735/73)

13. Investigation on a dolomite lining for L.D. converters of HSL Rourkela, phase III—Laboratory studies on dolomite sintering and tar bonding of sinter—N. B. Sarkar, N. N. Mathur, A. K. Bose, R. V. Hargave, K. C. Ray, P. C. Sen, M. R. K. Rao & H. P. S. Murthy (I.R. 736/73).

14. Beneficiation studies on a low grade magnetite sample marked 'F' from Kavuthimalai deposit near Thiruvannamalai, Tamil Nadu—J. P. Srivastava, P. V. Raman, S. K. Banerjee & G. P. Mathur (I.R. 737/73).

15. Pilot Plant studies on beneficiation and sintering of a composite sample of iron ore from Donimalai, C.E.D.B., HSL,—P. K. Sinha, B. L. Sengupta, S. K. Banerjee & G. P. Mathur (I.R. 738/73).

16. Pilot Plant studies on the beneficiation of Noamundi hard iron ore sample from M/s. Tisco Ltd.—H. Patnaik, R. K. Kunwar, V. K. Sharma, B. L. Sengupta & G. P. Mathur (I.R. 739/73).

17. Pilot plant studies on the beneficiation of iron ore sample II from M/s. Bolani Ores Ltd., Orissa—S. C. Maulik, R. K. Kunwar, B. L. Sengupta & G. P. Mathur. (I.R. 740/73)

18. Studies on production of high quality sinters from galena concentrates for M/s. Hindustan Zinc Ltd.—B. L. Sengupta, H. Patnaik & G. P. Mathur (I.R. 741/73).

19. Reduction characteristics of Noamundi iron ore for Tisco—N. V. Nagraja & K. N. Gupta (I.R. 742/73).

20. A report on comprehensive test on Joda hard iron ore for Tisco (I.R. 743/73).

21. Beneficiation studies on a complex copper-lead-zinc ore from Mahabharat Area, Baraghani Dist, Nepal from M/s. Nepal Minerals Supplies Co., Kathmandu—P. D. Prasad Rao, P. V. Raman & G. P. Mathur (I.R. 744/73).

22. Moulding characteristics of sand samples no. 2 received from Directorate of Geology & Mining, Lucknow (U.P.)—R. C. Arora, M. N. P. Verma & G. N. Rao (I.R. 745/73).

23. Reduction characteristics of Joda hard iron ore from Tisco—N. V. Nagaraja & K. N. Gupta (I.R. 746/73).

24. Pilot plant studies on beneficiation and sintering of five type samples of iron ore from Donimalai mines—P. K. Sinha, B. L. Sengupta & G. P. Mathur (I.R. 747/73).

25. Pilot plant studies on the beneficiation of Joda hard iron ore sample from M/s. Tata Iron & Steel Co. Ltd.—S. C. Maulik, R. K. Kunwar, B. L. Sen Gupta & G. P. Mathur (I.R. 748/73).

26. Screenability of Daitari iron ore from Orissa Mining Corpn., Bhubaneswar—S. K. Sil & S. K. Banerjee (I.R. 749/73).

27. Studies on reduction of iron content and production of sized quartz sand for the Indo-Asahi Glass Co.—R. Ganesh & G. P. Mathur (I.R. 750/73).

28. Beneficiation of magnesite sample from Pithargarh, U.P.—K. Vijayaraghavan, M. S. Prasad, P. V. Raman & G. P. Mathur (I.R. 751/73).

29. Investigation on liquid resin received from M/s. Chowgule & Co. (P) Ltd., Calcutta—S. K. Sinhababu, T. A. Beck & G. N. Rao (I.R. 752/73).

30. Determination of physical characteristics of dolomite (Pt. I) and limestone (Pt. II) sample from Tamil Nadu for Salem Steel Plant—S. K. Sengupta, S. K. Banerjee & G. P. Mathur (I.R. 753/73).

31. Batch and pilot plant studies on the recovery of copper, molybdenum and nickel minerals from the low grade copper ore from Rakha Mines (Phase II) of Hindustan Copper Ltd.—P. N. Pathak, S. N. Prasad, C. Satyanarayana, M. S. Prasad & G. P. Mathur (I.R. 754/73).

32. Investigation report on conversion of pig iron to steel on a basic lined side-blown converter supplied by M/s. Utkal Automobiles Ltd., Jamshedpur—A. N. Kapoor, S. K. Biswas & R. Santokh Singh (I.R. 756/73).

33. Investigation on bentonite received from M/s. Steel Cast Bhavnagar (P) Ltd., Gujarat—S. K. Sinhababu, T. A. Beck & G. N. Rao (I.R. 756/73).

34. A report on tests on small lot samples of Khondbond iron ore for Tata Iron & Steel Co. Ltd.—Staff of Ferrous Production Technology Division & Director's Laboratory (I.R. 757/73).

35. Determination of specific surface of iron ore powder received from M/s. Chowgule & Co. Goa—Joga Singh & S. K. Banerjee (I.R. 758/73).

36. Beneficiation studies on a low grade run of mine wolframite sample from Chandapathar mines, Bankura, W. Bengal—S. K. Sengupta, S. Raghunath Rao, S. K. Banerjee & G. P. Mathur (I.R. 759/73).

37. Determination of Bond's Work Index of open hearth slag from Mr. B. A. Yashanoff, Calcutta—P. N. Pathak, S. K. Banerjee & G. P. Mathur (I.R. 760/73).

38. Mineralogical and Davis Tube studies on Lohara iron ore—B. Banerjee, A. Peravadhanulu, H. Patnaik, P. V. Raman & G. P. Mathur (I.R. 761/73).

39. Failure of super heater tubes at Patratu Thermal Power Station—S. C. Bose, K. M. Chowdhury, R. Choubey & R. Kumar (I.R. 762/74).

40. Beneficiation of low grade kyanite sample from Bihar for M/s. S. Lal & Co., Calcutta—P. N. Pathak, M. V. Ranganathan, S. K. Banerjee & G. P. Mathur (I.R. 763/74).

41. Report on the manufacture of soil pipe castings by foundries in Howrah region—M. N. P. Verma, A. Dutta, G. N. Rao & R. Kumar (I.R. 764/74).

42. Reduction characteristics of Lohara iron ore from SICOM (I.R. 765/74).

43. Reduction characteristics of Bayaram Iron Ore of APIDC—N. V. Nagaraja & K. N. Gupta (I.R. 766/74).

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45. Investigation into the failure of boiler quality plate for Holtee Engineering (P) Ltd., Patna—G. G. Nair, B. N. Halder & R. Kumar (I.R. 768/74).

46. Metallurgical investigation on boiler tubes, Tisco—G. G. Nair, B. N. Halder & R. Kumar (I.R. 769/74).

47. Testing of boiler tube, Power House No. 4, Tisco—G. G. Nair, B. N. Halder & R. Kumar (I.R. 770/74).

48. Metallurgical investigation on surgical inplants for Ministry of Steel & Heavy Engineering, Govt. of India—G. G. Nair, B. N. Halder & R. Kumar (I.R. 771/74).

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50. Investigation on the failure on IF—3 vacuum transfer line for Madras Refineries Ltd., Madras—G. G. Nair, B. N. Halder & R. Kumar (I.R. 773/74).

51. Metallurgical investigation of failed heater tube of coking unit, Barauni Refinery, Indian Oil Corporation—G. G. Nair, B. N. Halder & R. Kumar (I.R. 774/74).

52. Metallurgical investigation on the failure of aluminium brass condenser tube pertaining to 15 MW turbo-alternator No. 8 Ahmedabad Electricity Co., Ahmedabad—G. G. Nair, B. N. Halder & R. Kumar (I.R. 775/74).

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