NML

Annual Report

1975-76

National
Metallurgical
Laboratory

Jamshedpur, India

ANNUAL REPORT

1975-76

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

Design & Layout

P. K. Gupta
M. L. Sarkar

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INTRODUCTION

The National Metallurgical Laboratory, during the period under review, has maintained its stress towards the transfer of technology and industrial implementation of its various development projects. India's first sponge iron plant with a capacity of 25-30,000 tonnes per year based on the technology of solid reduction process as developed in the Laboratory has been commissioned at the plant site of M/s. Andhra Cement Company at Vijayawada where the technology was experimented on large scale. With the assistance of NML scientists, M/s. Andhra Cement Co. have modified a cement rotary kiln for production of sponge iron. The trial conducted by the NML scientists at the plant site have produced sponge iron over 90% metallization.

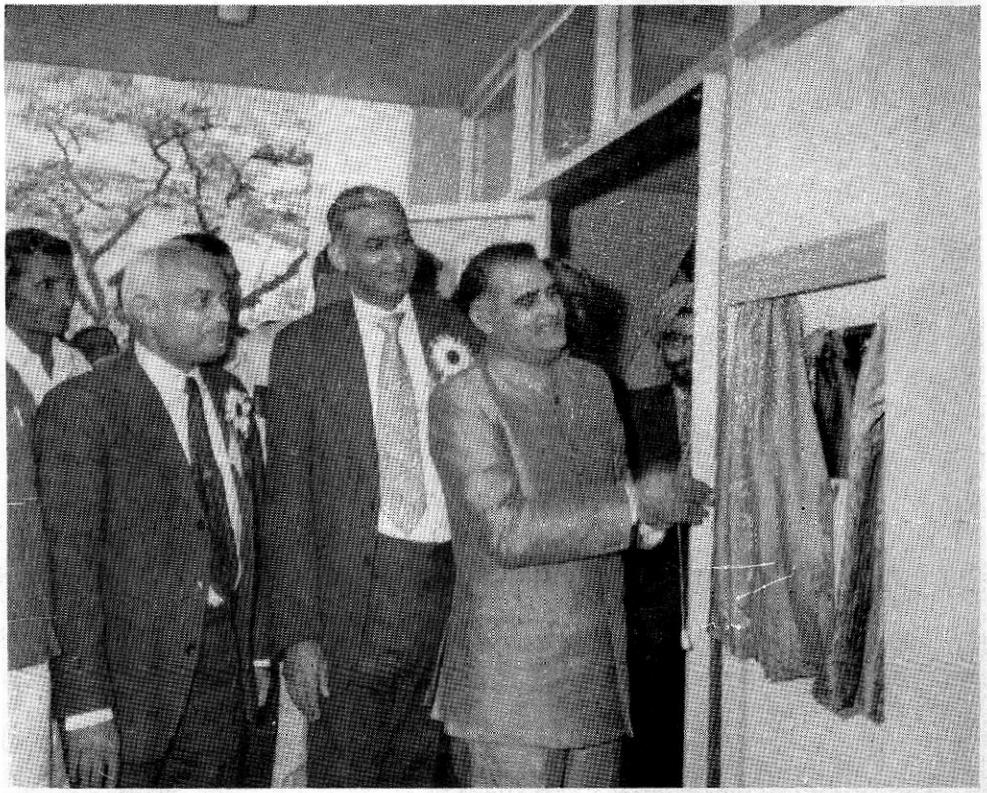
The Laboratory also succeeded in producing ferro-vanadium from the vanadiferous iron ores available near Bhadravati at the Visvesvaraya Iron & Steel Works in their 1500 KVA electric furnace with the NML developed know-how. A significant advantage of the process is that the principal by-product is a high grade pig iron low in phosphorus and silicon which is in great demand for the manufacture of malleable castings and S.G. iron.

The NML-PM2 electric grade alloy aluminium conductor is now produced on tonnage quantities by the various licencees. In recognition of the work on NML-PM2, the Cable & Conductor Manufacturers' Association have given an award to NML with the citation reading "Excellence in R&D on aluminium cables and conductors".

An alternate method of smelting lead concentrate to produce lead has given very encouraging results and it is under negotiation for release to industries. Phase I of Sukhinda Nickel Project for extraction of nickel from nickel ores has been successfully accomplished in collaboration with M/s. Chemical & Metallurgical Design Co. Ltd.

The technology of production of electrolytic manganese dioxide has been transferred to M/s. T. K. Chemicals, Bombay; who are setting up a plant at Trivandrum, Kerala, for its commercial production. Production of zinc dust, based on the laboratory's technology is now under commercial production.

For setting up of a Central Pelletization Plant in the Bihar-Orissa region, the Laboratory has conducted comprehensive studies on beneficiation and pelletization of iron ore fines from different areas at the instance of M/s. MECON. On behalf of M/s. Hindustan Copper Ltd.; Pyrites, Phosphate & Chemicals Ltd.; Gujarat Mineral Development Corporation; Tata Iron & Steel Co. etc. beneficiation studies have been conducted on low grade copper ore, iron ore, phosphate rock, kyanite, graphite, coal washery fines etc.



Shri Chandrajit Yadav, Union Minister for Steel & Mines, inaugurating the Building housing the Central Creep Testing Facilities.

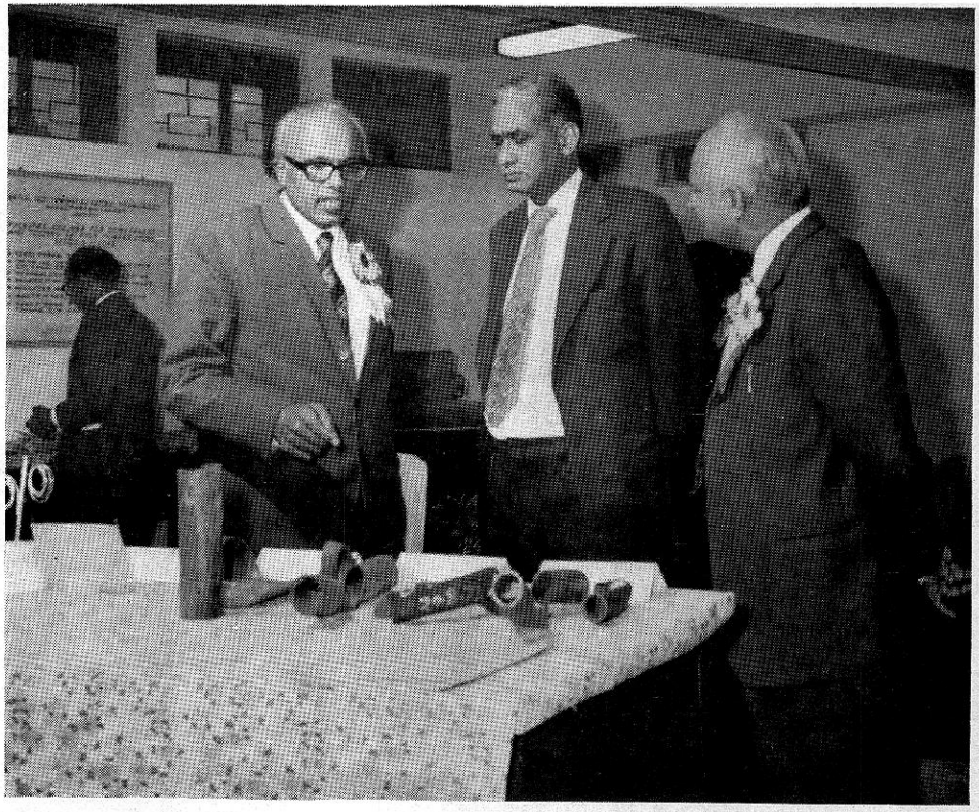
The Creep Testing Facility is being increasingly utilised by the consumer industries with the active co-operation of UNIDO experts and NML scientists working in the field. NML has entered into an agreement with M/s. Bharat Heavy Electricals Ltd. on a project of five years for the development of creep resistant steels.

Commencing from November, 1974 and ending in November, 1975, the National Metallurgical Laboratory observed its Silver Jubilee Year. During this period a number of seminars and technical conferences were held. The final function was held from 14th to 16th November, 1975, along with the 13th National Metallurgists' Day and 29th Annual Technical Meeting of the Indian Institute of Metals. The function was attended by State dignitories, Director-General, C.S.I.R., eminent scientists and technologists,

Prof. V. A. Altekar, Director, honouring Dr. B. R. Nijhawan, Senior Industrial Advisor, UNIDO & Ex-Director, NML; with a special NML Silver Jubilee Medallion.

industrialists, NML staff members and a large number of persons from different spheres of public life. Fortyeight staff members received 25 years service medallion. A special medallion was awarded to Dr. B. R. Nijhawan, Ex-Director, NML, for his outstanding contribution towards the growth and development of National Metallurgical Laboratory under his guidance.

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



Prof. Y. Nayudamma, Director-General, Scientific & Industrial Research, observing some product development work.

RESEARCH, INVESTIGATION & DEVELOPMENT PROJECTS

A. ORE DRESSING & MINERAL BENEFICIATION

1.0 Beneficiation of Iron Ore Fines from Bolani and Gua Mines Designated as Type III & IV Samples for Central Pelletization Project in the Bihar-Orissa Region. *Sponsored by M/s. MECON.*

The studies were aimed at finding a solution to the problems of surplus iron ore fines, huge stocks of which have accumulated over the years. The samples, designated as Type III and Type IV, were prepared by mixing proportionate quantities of fines from current arisings and old dumped fine samples. A concentrate assaying 62.5% Fe, and 2.28% Al_2O_3 with 85.5% yield was obtained from the Type III sample (Bolani fines) and 61.4% Fe, and 4.2% Al_2O_3 from the Type IV (Gua fines) samples.

1.1 Studies on Pelletization Characteristics of Iron Ore Fines Concentrates from Bolani and Gua for Central Pelletization Project in Bihar-Orissa Region. *Sponsored by M/s. MECON.*

Detailed pelletisation studies were undertaken on six concentrate samples of iron ore fines from the eastern region mixed with blue dust with a view to determine the characteristics and optimum parameters for producing pellets both for internal consumption as well as for export. The concentrates were produced after extensive beneficiation studies carried out with seven iron ore fine samples from the Barajamda area and six prepared composite samples. Pellets with good physical properties were prepared from these samples.

1.2 Comprehensive Studies on Beneficiation of Iron Ore Fines from the Barajamda Area for Central Pelletization Project in the Bihar-Orissa Region. *Sponsored by M/s. MECON.*

Optimum beneficiation flowsheets were developed for production of concentrates from a composite sample. A concentrate assaying 2.98% Al_2O_3, 62.2% Fe, 2.65% SiO_2 with an yield of about 74% and Fe recovery of 76.5% was produced. Further beneficiation of the washed sand produced an export grade concentrate assaying 2.66% Al_2O_3 with an yield of 44.1% and 49.5% Fe recovery.

1.3 Pilot Plant Studies on Beneficiation and Sintering of Kemmangundi Iron Ore, Karnataka State; (Part II—Sintering). *Sponsored by M/s. Visvesvaraya Iron & Steel Works, Bhadravati.*

Optimum conditions were determined to produce unfluxed as well as fluxed sinters. Tests on variation of MgO content in the sinter mix showed

that sinters with 4% MgO had good shatter size stability. Addition of blue dust in the sinter mix showed that with increase of blue dust, rate of sintering as well as sinter strength slightly decreased. Considering the amount of return fines produced, shatter size stability and the amount of—6.35 mm fraction produced after shatter, the optimum addition of blue dust in the sinter mix was determined.

1.4 Pilot Plant Studies on Beneficiation of Low-grade Lumpy and Fine Iron Ores from Codli Mines of M/s. Mingoa (P) Ltd. *Sponsored by M/s. Mingoa (P) Ltd.*

The concentrate produced from the lumpy ore assayed 60.3% Fe, 2.4% SiO_2 and 6.5% Al_2O_3 with a recovery of 36.0% Fe. The fine ore yielded a concentrate assaying 63.5% Fe, 2.8% SiO_2 and 3.7% Al_2O_3 with a recovery of 36.0% Fe.

1.5 Pilot Plant Studies on Beneficiation of High Grade Lumpy and High Grade Fine Iron Ores from Codli Mines of M/s. Mingoa (P) Ltd. *Sponsored by M/s. Mingoa (P) Ltd.*

A concentrate assaying 62.9% Fe, 2.0% SiO_2 and 4.8% Al_2O_3 with a recovery of 52.5% Fe was produced from the lumpy ore. The concentrate from the fine ore assayed 64.5% Fe, 1.7%, SiO_2 and 2.6% Al_2O_3 with a recovery of 65.3% Fe. The high grade fine ore as such was of good grade and may not require any treatment in the normal course.

1.6 Beneficiation of Iron Ore Slime received from the Noamundi Washing Plant. *Sponsored by M/s. Tata Iron & Steel Co. Ltd.*

Beneficiation technique by which improved iron value concentrate having a specified alumina-silica ratio of 2 could be produced with maximum yield was investigated and required grade of concentrate with maximum yield was produced.

1.7 Pilot Plant Studies on the Flowability and Screenability Characteristics of Iron Ore Samples from Meghataburu Mines. *Sponsored by M/s. National Mineral Development Corporation.*

Studies were conducted as per the test procedure laid down by National Mineral Development Corporation, and flowability and screenability characteristics were determined.

1.8 Beneficiation of a Composite Iron Ore Sample from Bailadila Deposit No. 4. *Sponsored by M/s. National Mineral Development Corporation.*

The composite sample was prepared by mixing five type-samples of

iron ore from Bailadila-4 of NMDC. Shatter test, bulk density, sp. gr., angle of repose, screen analysis etc. of lumps as well as fines at different stages were determined. Settling and filtration tests of slime and cyclone under flow have also been conducted. Further tests are in progress.

1.9 Beneficiation of Five Type Samples of Iron Ore from Bailadila Deposit No. 4. *Sponsored by M/s. National Mineral Development Corporation.*

Five type samples of iron ore were received for beneficiation studies. The samples were (i) massive steel grey hematite (ii) massive blue grey hematite (iii) laminated hematite with minor laterite (iv) mixed laminated and lateritic ore and (v) friable hematite with blue dust. Tests on these samples are in progress.

1.10 Beneficiation and Agglomeration Studies on a Low Grade Iron Ore Sample from Chandradinga, Assam. *Sponsored by Director of Geology & Mining, Govt. of Assam.*

The sample was beneficiated to 64.52% Fe with 79.0% Fe recovery. Pelletization studies were carried out and good quality heat hardened pellets having a compression strength of 325 kg/pellet was produced using suitable binder.

1.11 Sintering and Pelletization Studies on the Magnetite Concentrate from Low-Grade Ongole Magnetite Ore. *Sponsored by Dept. of Mines & Geology, Govt. of Andhra Pradesh.*

Optimum conditions were determined for the production of unfluxed as well as fluxed sinters. Pelletization studies were carried out to determine the optimum grind and select a suitable binder for producing pellets of good physical and chemical characteristics. Strong pellets were produced from the beneficiated sample. The properties of heat hardened pellets were considered satisfactory for transportation over long distance as well as smelting in blast furnace.

1.12 Studies on Iron Ore, Limestone and Char Coal Samples received from Nepal Bureau of Mines. *Sponsored bx M/s. M. N. Dastur & Co. Pvt. Ltd.*

Two samples of iron ore, one sample of limestone and one sample of char coal were received to study the physical and chemical characteristics of the samples, as well as the amenability for the beneficiation of iron ore samples, determination of reducibility characteristics of iron ore and dissociation characteristics of limestone. The desired grade of iron ore containing 62.64% minimum Fe with 3-4% maximum silica was produced. The samples were also subjected to various tests as specified and their physical and chemical characteristics were evaluated.

2.0 Batch and Pilot Plant Flotation Studies with a Sample of Copper Ore from Khetri. *Sponsored by M/s. Hindustan Copper Ltd.*

About 100 tonnes of low grade copper ore were received for carrying out batch as well as pilot plant flotation tests, employing the same flowsheet followed at present at the Khetri Copper Project, with a view to produce a copper concentrate analysing 14 to 16% Cu with high recoveries. Bench scale flotation tests under optimum conditions yielded a copper concentrate satisfying the grade requirements. Based on the batch test results, pilot plant flotation tests have been initiated.

2.1 Bench Scale Flotation Studies on a Sample of Low Grade Copper Ore from Chapri Deposit, Singhbhum Dist. *Sponsored by M/s. Hindustan Copper Ltd.*

A concentrate assaying 22.6% Cu with a recovery of 88.6% Cu was produced.

2.2 Beneficiation Studies on a Low Grade Complex Copper-Lead-Zinc Ore from Ambaji, Gujarat. *Sponsored by M/s. Gujarat Mineral Development Corporation Ltd.*

Since the results obtained with the first sample (Lode complex sample) were not satisfactory, attempts were made by hydrometallurgy methods for separation on a bulk concentrate containing Cu, Pb & Zn. The results obtained are being evaluated.

Studies are underway with the second sample (Dump sample) to establish optimum conditions for separation of different minerals from the bulk concentrate.

3.0 Beneficiation Studies with Lead-Zinc Ore from Romegangri, Bhutan. *Sponsored by Geological Survey of India.*

Bench scale investigation studies were undertaken. A zinc concentrate assaying 18.38% Zn with a recovery of 82.1% Zn was produced. Further tests are in progress.

4.0 Beneficiation of a Ferruginous Manganese Ore. *Sponsored by M/s. Rungta & Sons (P) Ltd.*

The sample was received for reducing the iron content. A non-magnetic fraction assaying 53.6% Mn and 9.9% Fe was obtained but Mn/Fe ratio could not be improved beyond 5.4 : 1 as there was intimate association of iron minerals with the manganese minerals.

5.0 Beneficiation of Phosphate Rock from Durmala, U.P. *Sponsored by M/s. Pyrites, Phosphates & Chemicals Ltd.*

A low grade phosphate rock sample from Durmala, U.P. was beneficiated to produce a concentrate assaying 31.8% P_2O_5 with a recovery of 43.1% P_2O_5. Although the recovery was low, the concentrate produced conformed to the specification.

5.1 Beneficiation Studies on Phosphorite Sample from Maldeota, Mussorie Area, U.P. *Sponsored by M/s. Pyrites, Phosphates & Chemicals Ltd.*

After preliminary sampling, mineralogical studies etc. on the sample, detailed discussion was held with the sponsor for the test procedures to be adopted. Work was conducted as desired and the sandy portion after desliming assayed 28.5% P_2O_5 with distribution of 73.5% P_2O_5 in it.

5.2 Beneficiation Studies on Phosphate Rock Sample from Jhamarkotra, Rajasthan. *Sponsored by Director of Mines & Geology Govt. of Rajasthan*

In consultation with the sponsor, a composite sample was prepared by mixing the different sample in specified proportions and bench and pilot plant beneficiation studies were undertaken on the composite sample. Large scale calcination tests are in progress.

5.3 Petrological Studies on Phosphate Rock Sample from Purulia, West Bengal. *Sponsored by M/s. Sadhana Enterprises, Delhi.*

A phosphate rock sample from Purulia was received for preliminary microscopic studies which indicated that apatite was the major mineral of economic interest and iron in the form of goethite, limonite and ochre were the main gangue materials. Methods were suggested for the reduction of iron minerals from the sample.

5.4 Bench Scale Floatation Studies for the Recovery of Apatite as a By-product from ICC Floatation Tailing Sample. *Sponsored by M/s. Indian Copper Complex, Ghatshila (M/s. Hindustan Copper Ltd.).*

Bench Scale beneficiation studies were conducted on three samples of mill tailings from Indian Copper Complex to recover apatite present as by-product. A concentrate analysing 27.3% P_2O_5 with a recovery of only 40% P_2O_5 could be obtained.

6.0 Beneficiation Studies with Low Grade Fluorspar Sample from Kahila & Mandokipal Mines. *Sponsored by Rajasthan State Industrial Mineral Development Corporation.*

Bench scale floatation studies on the individual as well as mixed sample have been completed. The following results were obtained :

(*i*) Kahila Fluorspar—A concentrate analysing 97.58% CaF_2, 0.40% $CaCO_3$ and 1.2% SiO_2 with a CaF_2 recovery of 71% was obtained.

(*ii*) Mandokipal Fluorspar—The concentrate obtained under optimum conditions did not meet the acid grade recruitment. The best grade obtained analysed 94.48% CaF_2 with 61.5% CaF_2 recovery.

(*iii*) Mixed Sample—Sample prepared by mixing Kahila and Mandokipal sample on the ratio of 2:1 yielded a final concentrate analysing 96% CaF_2 with 61-62% CaF_2 recovery which did not meet the acid grade specification.

7.0 Beneficiation of Low Grade Kyanite from Khamman District, Andhra Pradesh. *Sponsored by M/s. Lal Traders & Agencies (P) Ltd.*

A sample of low grade kyanite was received for beneficiation studies so as to produce a concentrate suitable for use in refractory industry. A concentrate assaying 60% Al_2O_3 with a recovery of 51% Al_2O_3 conforming to desired grade was produced.

7.1 Beneficiation of Low Grade Kyanite Sample from Lapso Buru Sample Designated as BT-4. *Sponsored by M/s. Hindustan Copper Ltd. (Indian Copper Corporation, Ghatshila).*

The low grade sample, designated as BT-4, was received for beneficiation studies so as to make it suitable for refractory use. Under optimum conditions, rougher floatation followed by three cleanings produced a final concentrate assaying 57.02% Al_2O_3 with a recovery of 39.7% Al_2O_3. Floatation tests with coarse and fine grind followed by five cleanings have been completed and assay results are awaited.

7.2 Beneficiation Studies on a Low Grade Sample of Kyanite from Lapso Buru (Sample Designated as BT-3). *Sponsored by M/s. Hindustan Copper Ltd. (Indian Copper Corporation, Ghatshila).*

The low grade kyanite sample, designated as BT-3, was received for beneficiation studies to make it suitable for refractory use. A concentrate assaying 51% Al_2O_3 was obtained. Further work is in progress.

7.3 Petrological Studies on a Low Grade Kyanite Ore Sample from Bharandiha Village, Chakradharpur, Bihar. *Sponsored by Bihar Mineral Development Corporation.*

A low grade kyanite sample was received for petrological studies and chemical analysis. Petrological studies revealed that kyanite was the economic mineral and quartz, the predominant gangue with subordinate

micas. Kyanite was found mostly liberated at a fairly coarse size. The sample assayed 24.3% Al_2O_3 with 65.6% SiO_2.

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

About eight tonnes of magnesite sample was received for beneficiation studies with a view to reducing the percentage of Fe, SiO_2 and CaO content in the sample, so that the final product could be used for refractory purposes. Preliminary washing, magnetic separation and floatation tests carried out with the sample did not yield satisfactory results. Further work is in progress.

9.0 Beneficiation of Amjhore Pyrite Employing Gravity Methods. *Sponsored by M/s. Pyrites, Phosphate & Chemicals Ltd.*

A sample of low grade pyrite from Amjhore was received to produce a concentrate at coarse size employing only gravity methods. A gravity concentrate assaying 38.19% S with a recovery of 63.7% S was obtained.

10.0 Batch and Pilot Plant Studies on Low Grade Graphite Sample from Banswara, Rajasthan. *Sponsored by Rajasthan State Industrial & Mineral Development Corporation.*

Bench and pilot scale beneficiation studies were conducted with individual as well as composite sample of low grade graphite from Tamtia, Sakakota and Kesharpur mines in Banswara district, Rajasthan. Floatation followed by several cleanings of the three samples, produced concentrates assaying 86.1%, 84.1% and 85% F.C. with recoveries of 77.0, 64.5 and 43% F.C. respectively. Pilot Plant studies with the composite sample under optimum conditions yielded a concentrate assaying 84.2% F.C. with a recovery of 78.5% F.C. in it. Batch results indicated that Tamtia graphite produced the best results out of the 3 samples tested while Kesharpura sample gave poor yield. Hence it might be advisable to use larger proportions of Tamtia graphite in the composite sample, for better plant performance;

11.0 Determination of Physical Characteristics of Five Limestone Samples. *Sponsored by M/s. Tata Robins Fraser Ltd.*

Specified tests were conducted on the physical characteristics of five limestone samples. The results have been furnished to the firm for their designing of crushers.

12.0 Reduction of Ash Content from the Coal Washery Fines of West Bokaro Colliery. *Sponsored by M/s. Tata Iron & Steel Co. Ltd.*

Bench and pilot plant scale tests were conducted on the West Bokaro

Coal Washery fines with a view to reduce the ash content to 16%. The concentrate produced averaged about 16% ash.

12.1 Reduction of Ash Content in a Jamadoba Coal Sample. *Sponsored by M/s. Tata Iron & Steel Co. Ltd.*

Beneficiation studies were conducted on a coal sample to reduce the ash content to 12%, 14% and 16% in three parallel set of tests specified by the sponsors. The required grades conforming to the specification were produced.

13.0 Determination of Work Index Values of Three Samples. *Sponsored by M/s. McNally Bharat Engineering Co. Ltd.*

Three different samples e.g. quartzite, calcined clay (chamosite) and magnesite were received for determining the work index value for open circuit grinding. The grinding tests indicated that the work index values of quartzite, calcined clay and magnesite were 29.95, 27.3 and 16.69 KWH/ tonne respectively.

14.0 Investigation on the Mineralogical Nature of Tungsten Ore Concentrate sample. *Sponsored by M/s. Sandvik Asia Ltd., Poona.*

A sample of tungsten ore concentrate was received to find out whether the ore material has been subjected to roasting in the process of selective mining or concentration of ore and if so, whether this treatment has altered the chemical structure of the basic compound.

The concentrate sample was subjected to mineralogical, D.T.A., chemical and *x*-ray diffraction studies which indicated that it had not been subjected to either roasting or chemical processing and there was no change in the chemical structure.

B. REFRACTORIES TECHNOLOGY

14.0 Castable Suspensions of Non-plastic Refractory Materials.

In order to develop high alumina slip cast ware, some kyanite thimbles were prepared and fired but were found not suitable for the purpose of determination of residues in crude and fuel oil. Therefore, some fused alumina shapes which were said to be more suitable for this purpose have been prepared by slip casting. A few samples of 2" diameter sintered alumina furnace tubes have also been prepared for use by manufacturing concern.

15.0 Welding Flux.

Further modifications to the wollostanite base composition were made.

In all, three compositions were prepared and one was tested for lead on plate test. The analysis of weld metal deposited with Modi No. 2 wire is given below.

	%
C	0.11
Mn	0.96
Si	1.11
S	0.03
P	0.04

Si in the weld metal is still on the higher side. The other two compositions are being tested.

16.0 Induction Furnace Linings.

50 Kg lining mix prepared earlier is being sent for field trials.

17.0 Development of High Alumina Refractories, using Kyanite as Raw Material.

This project is aimed at developing suitable high alumina refractory compositions for use in electric arc furnace roofs using kyanite on alumina rich mineral containing low percentages of impurities like iron oxide, alumina, titania etc. Samples containing different percentages of alumina were prepared and fired. Apparent porosities of the order of 22 percent were obtained in the fired samples. Other property determinations are in progress. After obtaining optimum properties on a reproducible basis, brick samples will be made.

18.0 Development of Zircon Refractories using Zircon Flour.

This project was undertaken with a view to develop a suitable zircon refractory brick from zircon flour comparable to an imported variety so as to eliminate any foreign collaboration for its manufacture in the country. The zircon flour was produced by M/s. Rare Earth Minerals Ltd., Quilon.

The physical properties of the imported zircon brick were determined and its microstructure was studied. The chemical analysis of the zircon flour as well as the imported brick was completed. Extensive bench scale investigation was carried out on the sintering characteristics of the zircon flour and the determination of physical properties after firing to different temperatures with variation in the forming pressures. The physical properties of the sinters were determined. Using the zircon flour as well as zircon sand, attempts have been made to obtain chemically bonded zircon brick with a view to attain the desired properties. Further work is in progress.

19.0 Development of Synthetic Carbonaceous Products as a Substitute for Petroleum Coke and Authracite.

In view of the increasing demand for petroleum coke in India for different carbon products such as carbon refractories, soderberg paste, cathode liners and variety of other products and the lack of indigenous resources of anthracite coal in India, the project was undertaken to develop suitable raw material from indigenously available low ash coals for the production of carbon products. A thermal balance study of one variety of coal was conducted. A close contact is maintained with Fuel Research Institute on the possible supply of natural low ash coal for use in carbon products.

20.0 Fused Rock Products and Methods of their Manufacture.

During the year under review, some more blocks have been made and their properties are under study.

21.0 Development of Sintered Fused Silica Products.

A sample of fused silica was ground and specimens were sintered at different temperatures and their physical properties are being determined.

22.0 Development of Tar Bonded Magnesite Blocks.

About 600 quarter sized bricks were tempered in an electric and gas fired furnaces and tested for their properties which are given in Table I.

Table 1

Properties of tar bonded magnesite blocks

Physical properties		
Porosity %	—	11.38
B.D. gm/cc	—	2.94
CCS Kg/sq.cm	—	33.48 (after tempering)
CCS Kg/sq.cm	—	52.38 (before tempering)
Chemical Analysis of dead burnt magnesite		
L.O.I.	—	2.59%
SiO_2	—	4.68%
Al_2O_3	—	1.01%
CaO	—	0.81%
Fe_2O_3	—	4.05%
MgO	—	86.6 %

23.0 Production of Magnesite Crucibles for High Frequency Induction Furnace.

Based on the technology developed, eighty magnesite crucibles of 3 kg. capacity have been produced for supplying to melting services section of the laboratory.

24.0 Testing of Binders and Raw Materials.

To fabricate suitable apparatus for testing the binders and raw materials, a carbon hydrogen ratio apparatus has been fabricated based on ISI standard specification. Efforts are also being made to design an abrasion resistance apparatus for studying the abradability of carbon and other refractory products.

Physical and chemical properties of pitches collected from Rourkela have been determined and given in Table 2. More samples of tar and pitches are awaited from Bhilai Steel Plant.

Table 2

Properties of Rourkela pitch

Pitch No.	Sp. Gr.	Moisture content %	Softening pt R & B
1	1.289	0.10	9.10
2	1.296	0.08	107.0

25.0 Development of Clay-Graphite Stopper Heads from Indigenous Raw Materials. *Sponsored by M/s. Patna State Graphite Mining Co., Titilagarh.*

M/s. Patna State Graphite Mining & Co. have sponsored a project for the development of clay graphite stopper head as import substitute. Chemical and physical properties of the imported stopper heads were examined. Using indigenous raw materials a few compositions have been calculated and a few test bodies were prepared for finding the physical and refractory properties. Some compositions were selected for preparation of stopper heads and further work is in progress.

26.0 Re-conditioning of Carbon Mass & Paste. *Sponsored by M/s. Bokaro Steel Ltd.*

M/s. Bokaro Steel Ltd. had imported long back carbon mass and paste for lining hearth and bosh wall of its blast furnaces. Due to aging, the

materials have lost their binding power and workability. Refractories engineers of M/s. Bokaro Steel Ltd. approached to find a solution for its effective use in the blast furnace construction which was urgently required.

By systematic investigation it was found that the carbon mass and paste could be utilised based on the results furnished.

27.0 Testing on Calcination Characteristics of Maharashtra Sillimanite. *Sponsored by M/s. Maharashtra State Mining Corporation.*

The Maharashtra State Mining Corporation sponsored an investigation for testing and evaluation of two sillimanite samples from Bhandara district. Chemical analysis on both the samples were determined. Investigation was carried out on the calcination characteristics study of the physical properties, apparent porosity, bulk density, specific gravity etc. and the refractoriness. From the study made it appeared that the raw material is a good source for sillimanite refractories and with judicious use it can be profitably utilised in the manufacture of high alumina refractories.

C. EXTRACTION & CHEMICAL METALLURGY

28.0 Extraction of Nickel and Cobalt from Lateritic Nickel Ores of Sukinda.

Programming is being done to carry out large scale experiments on continuous roast reduction and leaching basis.

28.1 Solvent Extraction for Recovering Nickel and Cobalt from Leach Liquors.

A laboratory scale mixer-settler unit designed and fabricated in the Laboratory for solvent extraction of nickel from the leach liquors with a propritory organic reagent is in operation. By this method, complete separation of nickel and cobalt is effected. Further improvement in solvent extraction of nickel has been made by designing and fabricating a new apparatus which works on a continuous basis and is based on hydrocyclone principle; the advantage of this new device is that it is much faster than the mixer settler unit and requires much less inventory of organic reagent to start and keep the unit in operation.

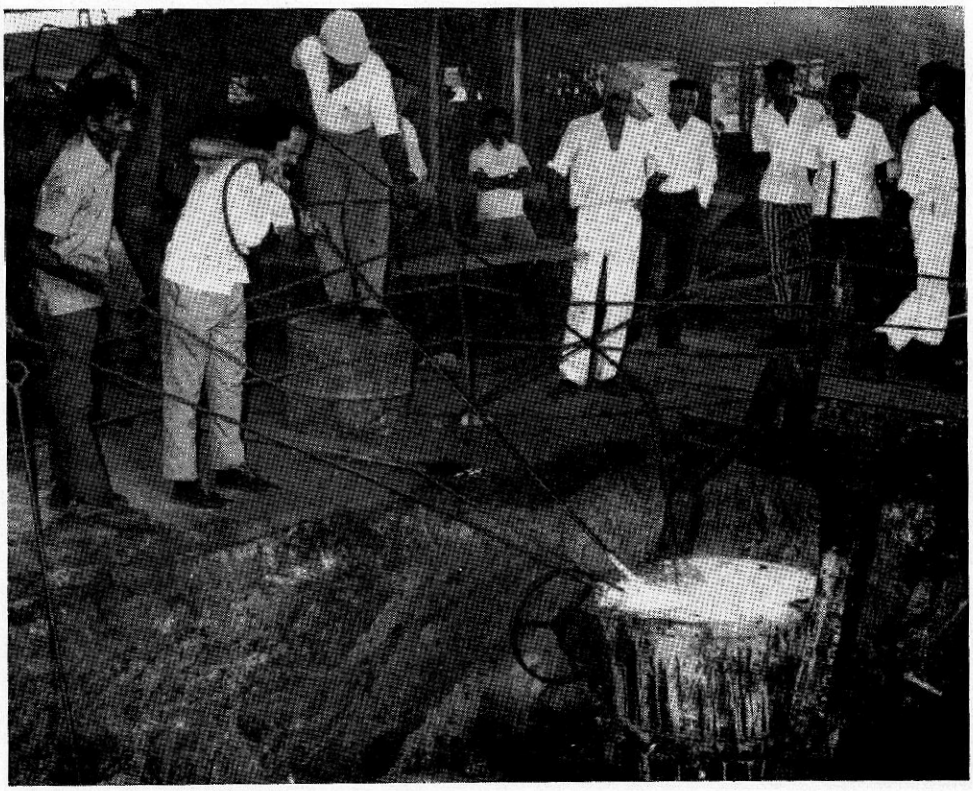
29.0 Bacterial Leaching of Copper Ore.

Bacterial leaching of copper from low-grade copper ore from Mosabani and Malhanjkhand were carried out in glass column of 10 cm. dia and 150 cm. height in 9K medium using Rakha mine water with a view to find out the acid consumption and relative rate of copper dissolution. Blank

experiments were also carried out in addition of bactericides to study the effect of bacteria on dissolution of copper. It was found that over 62% copper was leached out in 846 hours using Malhanjkhand ore containing 1% Cu, where as only 16.7% was leached out in presence of bactericides. Similarly only 14.8% Cu was leached in 940 hours in 9K medium in case of Mosabani copper ore containing 0.4% Cu using Rakha mine water.

30.0 Production of Vanadium Rich Slag/Ferro-Vanadium at Visvesvaraya Iron & Steel Works in Collaboration with M/s. Visvesvaraya Iron & Steel Works.

Industrial scale trials were conducted in a 1500 KVA submerged arc furnace in three different campaigns by smelting a total of 1500 tonnes of vanadium bearing ores containing 1.0% vanadium pentoxide. 400 kg. of vanadium rich slag was produced per day containing 20-25% vanadium pentoxide. In the second campaign the process was standardised and the optimum process parameters were obtained.



Production of ferro-vanadium from vanadiferous iron ore based on NML technology at M/s. Visvesvaraya Iron & Steel Works, Bhadravati.

30.1 Recovery of Vanadium Pentoxide from Iron and Steel Plant Slag. *Sponsored by M/s. Visvesvaraya Iron & Steel Works Ltd.*

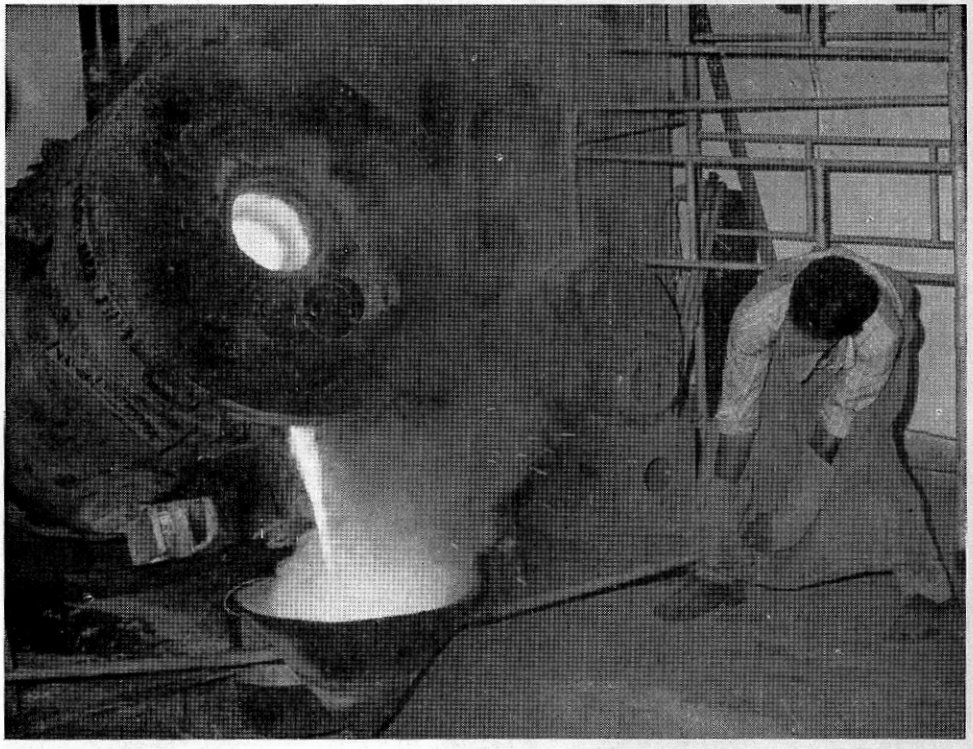
The slag supplied by M/s. VISL contained 14% V_2O_5. It was crushed and magnetic fraction was separated. The non-magnetic fraction was ground for further studies.

30.2 Recovery of Vanadium Pentoxide from Vanadium Sludge of Aluminium Plants.

Plant Sludge from M/s. Hindustan Aluminium Co. contains about 20% V_2O_5. On the laboratory scale experiment, 95% recovery was obtained. To confirm this result, bigger scale experiments were done in the scale of 100 kg. of sludge. The recovery was noted about 95%. The work is under progress on BALCO sludge containing 9% V_2O_5.

31.0 Recovery of Lead from Lead Concentrate from Bondulamutte by an Alternate Process.

The lead concentrate from Bondulamutte contains about 55 to 60%



Lead, produced by a new pollution free process and continually tried on 20 tonnes of concentrate, being tapped from furnace.

lead. Laboratory scale experiments were conducted to find out the optimum recovery of lead from lead concentrate. Laboratory scale experiments gave about 90% recovery and the purity of the metal was about 99.9%. On the basis of the laboratory work, bigger scale trials were done in Morgan type tilting oil fired furnace to confirm the above parameters. 100 kg. pellets were charged and recovery was about 90% with the purity of the metal about 99.9%. About 15 tonnes were treated during this campaign. The work is under progress on Sikkim lead concentrate which contains only 36% lead.

32.0 Liquid State Extraction of Magnesium in a Single Electrode Arc Furnace.

A single electrode arc furnace and condenser system to operate under vacuum has been designed and is under fabrication. The furnace is rated for 140 KVA and the expected output of the unit is 80 to 90 kg. of magnesium per day.

33.0 Production of Battery Grade Manganese-Dioxide by Decomposition of Manganese Carbonate Obtained from Low-grade Manganese Ore by NH_3-CO_2-H_2O Process.

Manganese dioxide was prepared on laboratory scale for chemical analysis and X-ray powder diffraction analysis. The percentage of manganese dioxide obtained was approximately 76%. X-ray analysis of the samples showed that they are Gamma manganese dioxide. For testing battery activity, sufficient quantity of manganese dioxide was prepared, which will be sent for testing.

34.0 Purification of Molybdenite Concentrate.

Laboratory scale experiments were carried out to enrich the molybdenite concentrate by leaching in ferric chloride solution with a view to remove the impurities such as nickel, copper etc. Over 92% Cu, and 76% Ni have been leached out from the concentrate with less than one percent loss of molybdenum present in the concentrate. The different parameters studied include the (*i*) effect of leaching temperature, (*ii*) period of leaching. The effect of concentration of ferric chloride in the presence of some oxidizing agents is in progress.

34.1 Roasting of Molybdenite Concentrate.

Molybdenite concentrate obtained from M/s. Uranium Corporation of India Ltd., Jadugoda, contains about 2.3% copper and 0.24% nickel. These high impurity levels make the concentrates unsuitable for its conversion of ferro-molybdenum for use in steelmaking industry. Attempts are being made for separating these impurities by roasting technique. It has been possible

to achieve removal of 65% of copper and 40% of nickel so far. Further work is in progress.

35.0 Static Bed Calcination of Maldeota Rock Phosphate, Uttar Pradesh. *Sponsored by M/s. Pyrites, Phosphates & Chemicals Ltd.*

M/s. Pyrites, Phosphates & Chemicals Ltd. sponsored a project for static bed calcination of rock phosphate from Maldeota region from Uttar Pradesh with a view to enrich the P_2O_5 content. A series of calcination tests were carried out in the temperature range of 800-1000°C for different periods using different size fraction of rock phosphate. The maximum P_2O_5 content in the product after calcination, quenching, desliming increased from 16.8 to 25.14%. A report was prepared and submitted.

35.1 Static Bed Calcination of Jhamarkotra Rock Phosphate. *Sponsored by Director of Geology & Mines, Govt. of Rajasthan.*

Phosphate rock samples of Jhamarkotra Block B area of Rajasthan contains 21.69% of P_2O_5. A series of calcination tests were carried out followed by hydration, scrubbing and desliming. Various parameters were studied for enrichment of rock phosphate which included (*i*) temperature of calcination, (*ii*) period of calcination and (*iii*) particle size of rock-phosphate. The maximum enrichment upto 36.5% P_2O_5 was obtained with the recovery of 88% of P_2O_5.

36.0 Granulation of Metals.

The project was initiated to make granules of light metals like that of Al, Mg and Ca. After repeated trials by using a number of devices, centrifugal dispersion method was found to be most suitable. Parameters such as the temperature of the molten aluminium, the speed of rotation of the rotating cup and the size of the nozzel which govern the size of the granules, have been studied.

37.0 Production of Zinc Dust.

The process know-how for the production of distilled zinc dust by the oil-fired retort process released by the NRDC earlier to Associated Pigments Limited of Calcutta was pursued and technology transfer completed to licencee for project implementation. Over 5 tonnes of product was successfully produced. Further production trials are underway.

38.0 Recovery of Zinc from Galvanizers' Dross.

The process know-how for the recovery of pure metallic zinc from

galvanizers' dross by atmospheric distillation was licensed to a local entrepreneur and transfer of technology will be taken up when the licencee comes forward.

38.1 Recovery of Zinc Values from Galvanizers' Zinc Ash and By-product Zinc Hydroxide from Sodium Hydrosulphite Industry.

A method has been developed to produce zinc oxide conforming to 'IS 3399 of 1965-zinc oxide for rubber industry' from galvanizer's zinc ash and by-product zinc hydroxide of sodium hydrosulphite industry. The zinc oxide produced on 2 kg. batch scale was sent to consumer industries for evaluation studies and it has been certified that the activating and compounding properties of zinc oxide produced at NML, by the developed method, closely matched to those zinc oxide samples currently in use by the consumer industries. The developed process has been referred to NRDC for release to interested entrepreneurs for commercial exploitation. An attempt is also being made to prepare a feasibility report on the above process with the collaboration of a reputed consultancy engineering firm.

39.0 Production of Atomized Metal Powder.

The process know-how for production of atomized powders of low melting non-ferrous metals ranging from lead to copper was licensed to two entrepreneurs and the technology transferred to them for project implementation. Development of a powder polishing mill was continued and a prototype was tested and is now under modifications.

40.0 Development of Contact Tips by Powder Metallurgy.

A technique was developed for coating particle graphite powder with copper and has been reported earlier. The work has been extended to develop contact tips for high voltage and medium voltage application. A literature survey report for contact tips is under preparation.

41.0 Adsorption Extraction of Cobalt with Lignite.

The extraction of cobalt from ammoniacal solutions by adsorption on granulated lignite was successfully investigated. It was found that over 98% recovery was possible. The adsorbed cobalt could be elutriated with acids and the solution treated further for precipitation, etc.

Further work on zinc, copper and other metals is under planning with the ultimate objective of evolving a method of selective adsorption for isolation of nickel from associated elements such as cobalt etc.

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

The influence of different variables on the recovery of copper and sulphur from chalcopyrite concentrate by direct leaching in ferric chloride

solution has been studied. A recovery of 99% copper and 92% chalcopyrite sulphur was obtained.

43.0 Preparation of Industrial Copper Chemicals from Low Grade Copper Ore Concentrate Containing Appreciable Impurities.

The work was extended to low grade chalcopyrite concentrate after successfully completing the work on high grade concentrate. Low-grade chalcopyrite concentrate was given various pretreatment and leached to remove pyrrhotite, sphalerite and galena. Though it was possible to remove 90% of total lead content, removal of zinc more than 30% causes simultaneous copper loss in appreciable quantity. Detailed work for removal of zinc and lead without much loss of copper value is in progress.

44.0 Preparation of Fluorine Chemicals for Metallurgical Use.

(*i*) Studies on the Preparation of Cryolite from Gujarat Mineral Development Corporation Fluorspar.

A lot of 8 tons of M/s. GMDC fluorspar was studied for its use for the preparation of aluminium grade cryolite. A selective leaching process for the purification of fluorspar suitable for preparing aluminium grade cryolite has been developed. Another 500 kg. sample called 'filter cake' has been received from M/s. GMDC which has been investigated. The cryolite product obtained from the purified fluorspar contained Fe_2O_3—0.09% and P_2O_5—0.05%.

(*ii*) Large Scale Trial Experiments on Preparation of Cryolite by Fluoboric Acid Process.

Eleven (100 kg. cryolite/batch) large scale experiments by recycling the spent liquor have been carried out for the product evaluation work. Already a ton of cryolite has been prepared and work is under progress to prepare 2 tonnes of cryolite needed for inplant trial.

45.0 Hydro-Electro Metallurgy Project.

Further layouts of process plant and equipment are being worked out. Constructions of the perimeter wall and two tubular site structures have commenced.

D. IRON & STEEL TECHNOLOGY

46.0 Study on Reduction Characteristics of Iron Ore Samples.

The following samples were studied during the period.

Sample description	*Name of sponsor*
(*i*) Iron ore sinters	M/s. Visvesvaraya Iron & Steel Works, Bhadravati.

(*ii*) Heat hardened pellets of Noamundi iron ores	M/s. Tata Iron & Steel Co.
(*iii*) Heat hardened magnetite pellets of Assam iron ore	M/s. State Geology & Mining, Govt. of Assam

The tests comprised of bulk reducibility based on Gakushin principle and swelling index based on Japanese method.

47.0 Appraisal of Raw Materials for Iron and Sponge Making.

The following investigations were completed during the period.

(*i*) Decrepitation characteristics of iron ores from Nepal Bureau of Mines and comparison of test results with that of Kiriburu iron ore.

(*ii*) Dissociation characteristics of limestone from Nepal Bureau of Mines.

48.0 Production of Sponge Iron in Rotary Kiln.

A technology of production of sponge iron in rotary kiln utilising Indian iron ore and solid reductant like non-coking coal has been developed. Extensive trials have been conducted during the period in a pilot rotary kiln of 10.7 mm long and 0.76 mm inside diameter with raw materials from M/s. Andhra Pradesh Industrial Development Corporation & Industrial Development Corporation of Orissa Ltd.

(*i*) Testing with APIDC Raw Materials. *Sponsored by M/s. Andhra Pradesh Industrial Development Corporation*

A second campaign was conducted in the rotary kiln with beneficiated Bayaram iron ore with Singareni coal to ascertain the possible improvement in the qualities of sponge iron produced as well as to confirm the results of previous campaign. Experiments were conducted with varying ore and coal sizes and ore to coal ratios using producer gas by replacing furnace oil. The average metallization was found to be 84.1%. By decreasing the coal size, the metallization decreased.

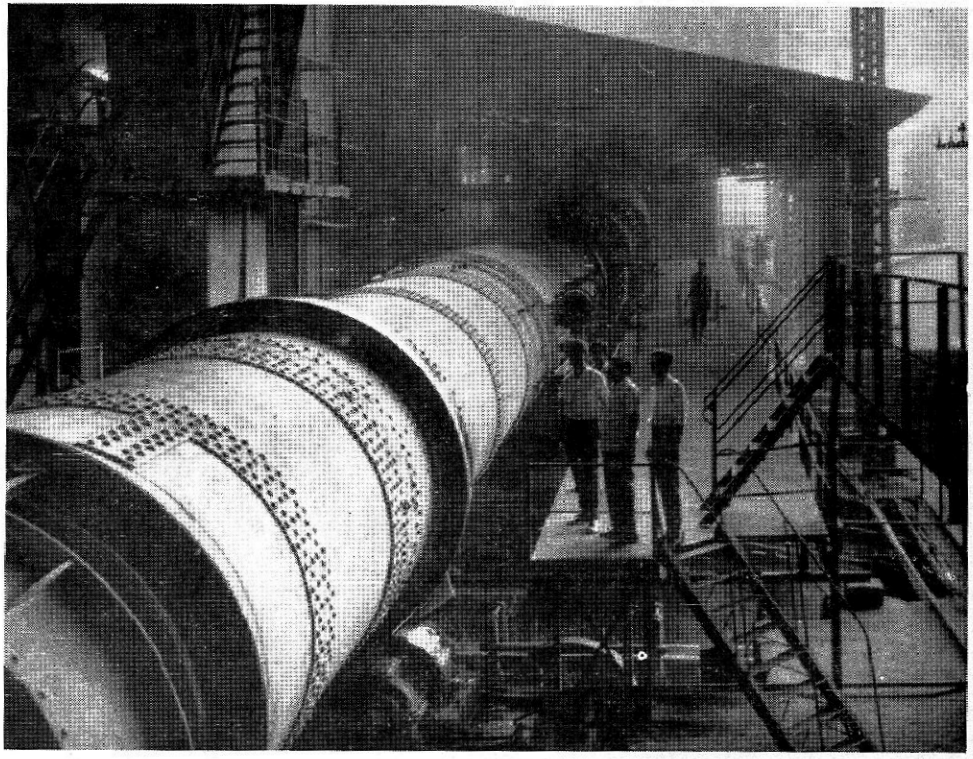
(*ii*) Testing of IDCOL Raw Materials. *Sponsored by M/s. Industrial Development Corporation of Orissa Ltd.*

Iron ore from Baripada mines were received for sponge iron production using Rampur and Samla coal. Four different sets of experiments were conducted with Rampur coal. The metallization was 84.7%. Accretion problems were found to be very acute. The degradation and decrepitation characteristic of the ore was high. The sponge iron produced was flaky

and soft. Trials conducted with Samla Coal did not yield better result than Rampur coal. Moreover Samla coal had comparatively lower ash fusion point in comparison to Rampur coal and was much softer in nature.

48.1 Sponge Iron Production Campaign in a Cement Kiln at Vijayawada, Andhra Pradesh.

The sponge iron process based on rotary kiln solid reductant proved viable and successful in most of the cases studied on pilot plant scale in the Laboratory. It was, therefore, planned to apply the process on a semi-commercial and industrial scale by utilising a cement rotary kiln as available. The authorities of M/s. Andhra Cement Co. Ltd., Vijayawada, A.P., came forward with a proposal to convert one of their old rotary kiln of 44.5 m long and 2.1 m internal dia. for sponge iron production. Necessary modifications of the kiln were taken up for the conversion of the kiln so as to make it suitable sponge iron production unit. A rotary cooler of 20 m. long with 1.2 m. internal dia. with proper water spraying arrangements was installed by replacing the planatory coolers. A central coal feeding system



Sponge iron produced commercially by NML developed technique in the rotary kiln of M/s. Andhra Cement Co., Hyderabad.

through the kiln shell was designed, fabricated and installed. The calcinator was suitably modified to use it as a preheating equipment for incoming iron ore. At the discharge end of the kiln, continuous vibrating screen, magnetic separators and storage cooler was installed with an arrangement to recirculate the char. A new instrumentation room was constructed to place the temperature recording instruments and the control switches of the entire sponge iron plant. With these modifications in the kiln, it was decided to utilise high grade iron ore from Hospet area and Singereni coal for sponge iron production. Six campaigns under different and modified conditions were conducted.

48.2 Use of Sponge Iron in Place of Steel Scrap for Steel Manufacture.

Industrial melting trials with sponge iron were conducted during the year at different electric steel manufacturing works.

(*i*) Sponge iron melting trials were conducted at M/s. Mukund Iron & Steel Co., Kalwe, Bombay, in a 10,000 KVA, 30 ton electric arc furnace. The sponge iron was supplied by M/s. Andhra Cement Co., Vijayawada. The trials were successful.

(*ii*) Industrial melting trials were also undertaken at M/s. Usha Alloys & Steels Ltd., Adityapur, Jamshedpur; in 8000 KVA, 25 ton electric arc furnace. Sponge iron for these trials was obtained from M/s. Andhra Cement Co., Vijayawada. Series of trials were made using 25% sponge iron in the charge which have shown that 25% sponge iron can be used in the charge with slight reduction in power consumption and no adverse effect on furnace refractories. Melting trials with 40% sponge iron in the charge are in process for which sponge iron produced at NML has been used.

49.0 Electric Smelting of Lohara Iron Ore.

M/s. Maharashtra Electro-Smelt Ltd., Bombay; has supplied iron ores from Lohara for evaluation in the production of standard grade basic pig iron for subsequent processing to steel in L.D. Converters. A continuous pilot plant trial in the 500 KVA smelting unit indicated feasibility of producing basic grade pig iron with the approximate composition of silicon 1.0%, manganese 0.6%, & carbon 3.6%.

50.0 Pneumatic Steel Making in Basic-Lined Side-Blown Converter.

The project for the development of the process of steel making in a basic-lined side-blown converter is completed. The only objective of the project is to demonstrate the technique to the interested parties. As such, a few experiments were conducted to demonstrate the process to the

representatives of M/s. MECON Ltd. one of the consultants for this process.

51.0 Alloy Steel Making in Top-Blown Converter.

In earlier experiments, it was established that in the existing 100 kg. capacity converter, the maximum recovery of chromium in the final metal was rather low to the extent of about 40-50%. Accordingly, it was decided that further experiments should be conducted in a 200 kg. capacity converter, the fabrication of which has been undertaken.

52.0 Special Steel Making in Basic-Oxygen Converter.

The installation of the oxygen pipe line extension was completed. Various other structural and fabricational work are in progress.

53.0 Development of Continuous Steel Making Process.

The launder furnace has been made ready with refractory lining. The electrical hoist and water cooled lances were processed and have been installed. Various other structural, electrical and mechanical installation work are in progress.

54.0 Electroslag Remelting.

Raw materials have been arranged for the manufacture of martensitic stainless steel in air induction melting furnace for electroslag remelting for further evaluation.

55.0 Commercial Trial Heats of Niobium Treated Steel.

In collaboration with Rourkela Steel Plant, two 50 ton heat of niobium treated steel were made at Rourkela Steel Plant and rolled into plates. Sub-zero temperature impact tests have been completed on these plates in the as rolled and normalised condition. Samples of the plates were sent to Research, Design & Standard Organization, Lucknow, and M/s. Bharat Heavy Electricals Ltd. for carrying out weldability tests and encouraging results have been obtained.

56.0 V-N Low Alloy High Strength Structural Steels.

In continuation of previous year's work, experiments were carried out to make V-N steels using the medium for introducing nitrogen. Several 10 kg. heats were made in the high-frequency furnace. The recovery of nitrogen in these steels was encouraging. Preparations have been made for making larger heats in the 0.8 ton electric arc furnace.

57.0 Carburizing of Grain Refined Steels at High Temperature.

In continuation with the previous work, steels with titanium and niobium were carburised at different temperatures for different periods of

time. All the specimens were allowed to cool to room temperature in the furnace. These specimens were quenched in water after reheating. The specimens were mock-carburised for the determination of impact toughness of the core. Grain size, case depth and hardness of the case and mechanical properties of the core are being determined.

E. DEVELOPMENT & STUDY ON ALLOYS

58.0 Development of Aluminium Cables and Conductors.—Electric Grade Aluminium Alloy NML-PM2.

The product development work on the NML-PM2 for the production of varieties of cables has been continued in collaboration with number of organizations. Notable amongst them are :—

(1) M/s. Indian Cable Co. Ltd., Jamshedpur.
(2) M/s. Universal Cable Co. Ltd.
(3) M/s. Premier Cable Co. Ltd., Cochin.
(4) M/s. Radiant Engg. Co., Hyderabad.
(5) M/s. Hindustan Cables Ltd., Rupnarayanpur.

Industrial Production of NML-PM2

The production of the NML-PM2 alloy has been continued at the works of the following licencees :

(1) M/s. Aluminium Cables & Conductors (UP) Pvt. Ltd., Calcutta.
(2) M/s. Galada Continuous Castings Ltd., Hyderabad.

Product Development

(*i*) PVC insulated and sheathed SOLIDAL cables have been produced from NML-PM2 alloy at Universal Cables Ltd. The properties of the cables made from NML-PM2 are superior to EC aluminium.

(*ii*) Enamelled wires from NML-PM2 alloy have found successful use in signal relay coil windings by R.D.S.O. Large quantities of the enamelled wires have been supplied to Southern Railway, Podanur; and N.E. Rly is also evaluating the use of NML-PM2 for the relay coil windings.

(*iii*) The processing of 50 Pairs dry core underground telephone cables at Hindustan Cables Ltd., Rupnarayanpur, has been completed. Processing of 100 pair cables are in progress.

(*iv*) Paper covered strips and rounds have been produced at Premier Cables Ltd. The properties are superior to EC aluminium.

(*v*) Welding cables made from NML-PM2 alloy supplied to various

user organizations in both public and private sector have given very encouraging performance.

59.0 Preparation of Master Alloys & Development of Inoculants for Aluminium & its Alloys.

The inoculants designated as PM-121 & PM-122 were prepared in the form of wire and their effects on the cast grain size and mechanical properties of aluminium and its alloys were determined. The average grain size and its variations were satistically calculated. The experimental results showed that these inoculants used in the wire form have certain advantages over conventional inoculants. Better mechanical properties were observed in IM series of alloys with low silicon after inoculating with these inoculants. Large quantities of these inoculants are under preparation for industrial trials.

60.0 Grain Refinement of Aluminium Alloys.

Effect of NML developed inoculants for aluminium and its alloys (PM-121 & PM-122) on the grain refinement of wrought Al-Zn-Mg alloys (7004, 7005, 7039) was studied. Effect of grain refinement in both cast (chill & sand) and wrought condition of the above alloys has been studied. The results were compared with that of indigenous and imported master alloys which are commercially used as grain-refiner. Mechanical properties and grain size measurement by linear-intercept method of the inoculated alloys in cast and wrought and heat treated conditions were determined.

61.0 Development of Grain Refiner for 3S Alloy.

The soaking temperature and intermediate annealing temperature are time and power consuming and it is proposed that by the addition of inoculant, the temperature can be brought down and crystallisation be achieved for better workability at lesser cost. With this view, two different compositions of the inoculant 3S alloy have been studied and extensive metallographic studies have been made with different heat treatments. Interesting results have been obtained and further work is in progress.

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

This investigation is aimed to develop aluminium alloy of increased ductility coupled with reasonably high strength. The aluminium alloy so developed will find immense practical implications in the areas where deep drawing qualities are required. Fifteen alloys with varying compositions (PM201-PM215) have been cast. They were rolled to obtain 3 mm thick sheet and 12.5 mm dia rod by forging and machining. Mechanical properties of the alloys in the sheet and rod form were determined under different heat

treated conditions. Metallographic work of the above samples under different heat treatment conditions was also carried out. Aging characteristics of the alloys have been studied by hardness measurement. Further work is in progress.

63.0 Study on the Phenomenon of Quench-Sensitivity on High Strength Al-Zn-Mg Base Alloys.

High strength aluminium alloys particularly Al-Zn-Mg-Cu are reported to be quench-sensitive. This phenomenon is undesirable for practical purposes because the alloys loose their hardening capability on subsequent aging when they are slowly cooled from solution treatment temperature.

Effect of chromium and manganese on the quench-sensitivity of high strength Al-Zn-Mg-Cu alloy has been studied. The samples were taken in the form of 1" dia and 8" long extruded rod. Effect of duplex aging on the quench-sensitivity has also been studied. Further work is in progress.

64.0 Effect of Inhomogeneities on the Mechanical and Physical Properties of Aluminium & its Alloys.

Properties of a series of Al-Si and Al-Mg alloys were determined. These alloys were prepared in a specially designed vacuum chamber with attachment for mechanical stirring when the materials are in molten state. The properties were compared with alloys of identical composition melted in ordinary atmosphere. In certain composition range, the alloy thus produced showed improved mechanical properties. Further experiments are in progress to study the effect of small alloying additions on the properties.

65.0 Production of Dense Casting of Aluminium and its Alloys.

Aluminium containing 2-16% Si were cast with and without application of pressure in cylindrical graphite moulds. Th emechanical properties of the alloys cast under pressure were determined and showed considerably higher value of tensile strength over the alloys cast under stationary conditions.

66.0 Development of Aluminium Base Welding Electrode Wire (MIG Wire).

The technology for the development of MIG wires corresponding to B.S. 2901 NG6 wire has been developed. The electrode wires have been evaluated for its welding characteristics and mechanical properties at various places and found satisfactory to meet the specific requirements. Most of this wire is used in the Defence Establishments for welding high strength Al-Zn-Mg alloys and is presently imported.

67.0 A study on the Physical and Mechanical Properties of Splat Cooled Aluminium and its Alloys.

Alloys of binary and quarternery Al-Si base were made and rapidly

cooled in the large scale splat cooling set-up, designed and fabricated in the laboratory. The rapidly cooled flakes were processed into rods. Metallography and mechanical property studies of the rods were carried out. Improvement in tensile strength and ductility was achieved in splat cooled alloys.

Experiments have been carried out to produce rapidly cooled Al alloys in strip form. Metallographic and hardness studies have been carried out after thermo-mechanical processing. Thermo-mechanical treatments were given to the rapidly cooled Al-Si and high strength complex Al alloy and metallographic, mechanical properties of the processed alloys were carried out. Al-Si alloy wires will be examined to determine their suitability as brazing filter metals. Another 5 kg. batch of rapidly cooled high strength Al alloy flakes has been prepared for further processing and evaluation of properties.

68.0 Production of Cu-Zn-Pb Alloys. *Sponsored by M/s. Nandan Brothers, Berilly.*

The alloy was produced and supplied to the party for the development of suitable alloy indigenously for application in musical instruments.

69.0 Development of Manganin Wire.

Several alloys in the manganin composition range were air induction melted. Due to air melting, control of composition was unsatisfactory. Future heats, are, therefore, planned to be made under controlled atmosphere as soon as the facilities are ready. Electrical resistivity studies on drawn wire showed very low temperature co-efficient of resistivity which improved considerably through annealing effect while the specimen was exposed to higher temperatures in the course of the measurements. Studies on annealed samples are in progress.

70.0 Thermostatic Bimetal.

A variety of thermostatic bimetals have been developed to suit various requirements. Production technology of all-ferrous thermostatic bimetals (i.e., the bimetal in which both the constituents are ferrous alloys) was developed and reported earlier. In the present phase of the work, high sensitive and special type of thermostatic bimetal involving non-ferrous alloys such as high expansion component have been developed and the production technology studied. Samples of special type thermostatic bimetal such as high sensitivity type and low resistivity type have been used by a number of equipment manufacturers and satisfactory performance reports of the bimetals have been received. Several requests have been received for the supply of thermostatic bimetals in bulk quantities. Further development work is in progress.

71.0 Nickel-Silver.

18% nickel-silver is mainly used as a spring material in telephone industries. During the year several heats were made in order to make lengthier strips which is required by the I.T.I. for the performance trials. Attempts were also made to make actual springs from the rolled strips for studying their service performance.

72.0 Dental Amalgam Alloy.

Dental amalgam alloy is a silver-base alloy with appreciable amount of tin and minor additions of copper and zinc. The alloy has been developed at NML as an import substitute. The samples made were sent to Tata Main Hospital for clinical performance trials.

73.0 Electrical Resistance Alloys.

Technical assistance was given to M/s. Cable Works to improve the workability of the alloy. The problem on wire drawing was mainly dealt with. In addition, to develop an alloy for high temperature application, eight heats were made in high frequency furnace. The ingots are dressed for further processing.

F. DEVELOPMENT OF MAGNETIC MATERIALS

74.0 Development of High Permeability Nickel-Iron Alloys.

Sponsored by M/s. Guest, Keen & Williams, Howrah.

Nickel-iron alloys are widely used in special type of transformers, inductors, magnetic amplifiers, switch cores, magnetic shields, tape recording heads and memory storage. These alloys are not manufactured in the country and the entire need of the country is met through import. The project was taken up on behalf of M/s. Guest, Keen & Williams to develop the indigenous know-how for their manufacture. The melting, rolling and heat-treatment schedules for these alloys were developed successfully to give magnetic properties as per the specification of the sponsoring authority.

75.0 Preparation of Magnetic Gamma Iron Oxide.

A 5 kg. lot of gamma iron oxide has been prepared by reduction of αFe_2O_3 to Fe_3O_4 and subsequent oxidation in air to γ Fe_2O_3. The gamma oxide thus prepared showed a coercive force of 230 oersted and a remanance of 920 Gauss. Gamma iron oxide has also been prepared by decomposing iron oxalate dihydrate in air and by reducing the αFe_2O_3 obtained from iron oxalate to Fe_3O_4 and then oxidising it αFe_2O_3. Gamma ferric oxide thus obtained had a coercive force of 230 Oe and a remanance of $\sim$940 gauss. Attempts have been made to incorporate Co^{2+} in the γ-Fe_2O_3 matrix for enhancing the coercive force. The preliminary investi-

gations on the cobalt-doped gamma iron oxide showed better properties than the pure oxide, i.e. a coercive force of 300-400 Oe and a remanance of 950 gauss.

76.0 Preparation of Anisotropic Ferrite Magnets.

A die was designed for pressing of anisotropic ferrite magnets for M/s. Scooter India and it is under fabrication. A solenoid was also designed to generate a magnetic field of 5000-8000 gauss and is being fabricated. Further sintering trials were carried on barium-ferrite magnets to have maximum density and energy product.

77.0 Development of Permanent Magnets Based on Crystalline Anisotropy and Exchange Anisotropy.

A solenoid was designed to generate a magnetic field of about 8000 gauss for pressing cobalt rare earth magnets in the magnetic field. The parts are under fabrication. A review on cobalt rare earth magnets has been completed.

78.0 Preparation of Low Carbon Soft Magnetic Iron.

(*i*) More than 1 ton of low carbon soft iron ingots produced in the laboratory was supplied to Southern Railway, Podanur, for further processing and subsequent use in signal relays. Southern Railway had been facing difficulties in the use and processing of these low carbon iron and they obtained very poor release values of 39% instead of 60%. The services of NML scientists were sought for actual study and discussions with their engineers at shop floor. The processing of the low carbon iron ingot to about one square inch bar was demonstrated by NML scientists. Subsequent test results from Southern Railway indicated that relays used with NML iron gave release values upto 55.11%, while with imported iron it is 60%.

(*ii*) Low carbon soft iron produced and processed into rods at NML were supplied to M/s. Bharat Electronic Ltd., Bangalore, against their request for testing its suitability for their work. The evaluation report given is as follows :

> "The soft iron rods sent by you have been used by us in the manufacture of solenoids and it is found that the performance of these solenoids is comparable to those manufactured using imported soft iron rods. However, long duration tests in bulk manufacture of solenoids have not been made".

(*iii*) 500 kg. of soft iron ingots were supplied to M/s. Bharat Heavy Electricals, Hardwar. It was a repeat order based on earlier supply of 100 kg.

78.1 Development of Soft Magnetic Iron.

Three trial heats were made and heat treated according to specifications.

In all three cases, the magnetic properties (coercive force, saturation magnetization, maximum permeability) conformed to the specifications laid down by the Indian Telephone Industries and the RDSO. The results were communicated to the Director of Electronics, Delhi. Further trials involving air induction melting of four heats with different combinations of deoxidation additions were made. Both chemical composition (gases and residuals including carbon) and inclusion distribution in some of the air melted samples compared favourably or better with respect to the previous three heats. Results from magnetic testings are awaited, while a 0.8 ton arc furnace heat is planned based on the findings so far of the air-melted heats

79.0 Development of Corrosion Resistant Electrical Steel.

The objective is to develop superior corrosion resistance without impairing unduly its magnetic properties for use in relay cores. Four heats with the same base composition equivalent to RSP 260: 50 were made and tested for magnetic and corrosion properties. Magnetic properties (core loss, coercive force, residual induction, maximum permeability and saturation induction) remain unaffected upto a specified amount of copper above which they deteriorate. Most of the improvement in the corrosion properties are known to take place within 0.1% Cu. However, corrosion results from marine and atmospheric exposures are yet to come.

G. HEAT TREATMENT & MECHANICAL WORKING OF METALS

80.0 Development of Heat Treatment & Casting Technique for the Production of High Speed Steel Cutting Tools.

Large number of heats of 18/4/1 type of H.S.S. were made for conducting heat-treatments on large scale production basis. Further work to study the effect of cobalt on cast and heat-treated structure of H.S.S. is in progress.

81.0 Extrusion Characteristics of Magnesium Base Alloys.

The melting technique of the magnesium base alloy A261 has been standardised. In order to study extrusion at higher speed, solution treated billets were extruded with various lubricants and modified toolings. It was possible to extrude the billets at a speed higher than 60/min in various sections.

82.0 Study of Cold Pressure Weld Characteristics of Aluminium & its Alloys During Extrusion.

This project has been undertaken with a view to study the possible causes of cracks and defects being developed at the aluminium joints in aluminium sheathing which is fast replacing the lead sheathing and also to study the characteristics of welded joints obtained in extrusion of aluminium and aluminium alloys. A number of Al and Al-Si alloy ingots

were made and the billets were extruded varying the extrusion parameters. Further work is in progress.

83.0 Development of Orthodontic Steel Wire.

The production technology of the alloy was developed. Wire was produced from the alloy with special wire-drawing technique. The wire stands well both in respect of properties and service trials. In connection with transfer of technology, a non-technical report and evaluation of pre-design cost data have been worked out.

84.0 Development of Clad Metals.

(*a*) *Copper Clad Aluminium Sheets.*

The production technology of this clad metal including cold rolling and annealing was developed and reported earlier. The project is being continued to produce and supply this clad metal to various users for their development work. Clad metals have been supplied to RDSO, Lucknow; who will use this clad metal for transition joint.

(*b*) *Stainless Clad Mild Steel.*

The production technology of stainless clad mild steel has been developed by 4-ply sandwitch pack rolling technique. Fabrication of the pack, development and application of appropriate separating medium as well as other parameters connected with the roll bonding of this clad product has been studied and standardised. The process is ready for commercial exploitation. Further development work is in progress.

(*c*) *Copper Clad Mild Steel.*

Sandwitch roll bonding technique for this combination was developed and reported earlier. The work has been extended to develop a substitute spring material for phosphor-bronze.

85.0 Mechanical Working Facilities.

Rolling, forging, wire drawing and extrusion facilities were extended to various divisions of the laboratory. Forming and shaping of the ingots were made as desired. This facility has given the opportunity to study the workability of various types of metals and alloys. Aluminium alloy, tubes and sections and a number of tubes and plates of magnesium base alloy were extruded.

H. TESTING OF MATERIALS

86.0 Central Creep Testing Facilities.

During the period, work on the following projects have been conducted :

A. Development, Testing & Evaluation of High Temperature Indigenous Creep Resistant Steels and Alloys.

(i) 1¼%Cr-1%Mo-3/4%V-Ti-B Bolting Steel.

High Temperature testing and evaluation of the 1¼Cr-1Mo-3/4V-Ti-B grade of bolting steel generally conforming to the original Russian specification GOST 2591, manufactured and processed indigenously for the first time in India by MUSCO, has made considerable headway.

On the basis of the high temperature test data including 10,000 hr. creep and stress rupture data collected to-date and from the trends of the tests still in progress, it can be stated that indigenous self-sufficiency in respect of this grade can be achieved shortly.

(ii) En20B Bolting Steel, Sponsored by M/s. Bharat Heavy Electricals Ltd.

Testing and evaluation of high temperature properties of 1¼%Cr-1/2%Mo bolting steel, generally conforming to the British Specification B.S. 970: En20B, has been sponsored by BHEL, Bhopal. Two casts of this steel have been received for high temperature tensile, creep, stress-rupture and stress-relaxation tests. Creep and stress-rupture tests are being carried out at 450°C and 500°C at the stress levels ranging from 47 Kg/mm² to 4 Kg/mm² to determine the stresses for 1% creep in periods upto 30,000 hr. and for rupture. The creep tests in progress at 450°C and 500°C have completed a total of 1,08,000 hr. and the stress-rupture tests have completed a total of 1,55,000 hr.

(iii) 1%Cr-1/2%Mo Steel Forgings. Sponsored by M/s. Bharat Heavy Electricals Ltd.

Samples from two casts of 1%Cr-1/2%Mo steel forgings were received from Bharat Heavy Electricals Limited, Tiruchirapalli and stress-rupture tests at 525°C at various stresses for expected test durations of 5000-20,000 hr. are in progress.

(iv) AISI 316 Grade Stainless Steel. Sponsored by Reactor Research Centre, Kalpakkam.

The Department of Atomic Energy is building a sodium cooled fast breeder test reactor at Kalpakkam. For most of the structural components of this reactor, AISI 316 grade stainless steels with rigorous specifications in chemical, mechanical and metallurgical properties, are used. Creep behaviour being one of the most important aspect of the quality control and design parameters; Reactor Research Centre, Kalpakkam, is interested to generate base line data, at the NML Central Creep Testing Facilities.

Steel Plates from four casts, procured by RRC from a French supplier will be tested at three temperatures 550°C, 600°C and 650°C and at three stress levels at each temperature to give expected rupture life in the range 1,000-20,000 hr. Out of the four casts of steel to be finally tested specimens from three casts have already been received and tests are in progress at 550°C & 600°C and a total test duration of 65,000 hr. have been completed.

B. Development of Ni-free Austenitic Creep Resistant Steels.

Work on austenitic steels containing Mn+N or Mn alone as austenitic stabilisers has been in progress. To some of them steels alloying additions of carbide and nitride forming elements such as Ti, Mo, W & V were made and creep tests were conducted on these experimental steels at 700°C at different stress levels ranging from 10-20 Kg/^{2}mm. Amongst the steels tested alloy C_{32} and A_5 with W and Mo additions showed promising high temperature strength compared to the standard AISI-316 and Esshete 1250 type alloys. Exploratory work is underway on the possible utilisation of this alloy for exhaust valves of automatic engines.

C. Development of High Temperature Bolting Steel.

High temperature steels of Cr-Mo-V type with high V-contents have recently been developed for modern power plants. These steels possess high creep strength but are prone to failure due to notch-embrittlement on prolonged aging under creep conditions. The present work is aimed to improve the creep ductility in these steels by minor alloying additions and by suitable heat treatment. Since resistance to stress-relaxation is important for a bolting material, it is also planned to evaluate the stress-relaxation behaviour of the experimental steels by both ring and tensile methods of testing.

Creep tests at 565°C and at various stress levels in the range 24-40 Kg/mm to give rupture lives of 100-10,000 hours have to be taken up on samples machined from heat-treated bars. Some of the tests have already progressed upto 10,000 hours. More data in respect of stress-rupture, stress-relaxation, aging embrittlement and high temperature tensile properties is awaited before any meaningful conclusion could be drawn.

87.0 Fatigue Testing.

The R.D.S.O., Ministry of Railways; referred a problem to determine the fatigue properties of aluminium caternary wires and copper caternary wires used for overhead transmission lines, samples of which were sent by them. Tests have been completed on the evaluation of fatigue properties of aluminium caternary wire (second set of samples) and the fatigue limit was determined by plotting the S-N curve. Most of the tests have been completed on the evaluation of fatigue properties of the copper

caternary wires supplied by the Railways. In addition to the above, the design of a compression joint for al-transmission cables is in progress.

88.0 Mechanical Testing Facilities.

During the period under review various types of mechanical testing of the specimens which comprised of tensile, compression, bend, cupping, hardness etc., were carried out in connection with the development work of NML and the outside parties. Calibration of several load cells belonging to laboratory was carried out.

I. METALLURGICAL INVESTIGATIONAL STUDIES ON METALS & ALLOYS.

89.0 Metallurgical Evaluation of Stainless Steel Materials for Tallex Mixing Unit. *Sponsored by M/s. Indian Explosives Ltd., Gomia.*

Metallurgical tests such as tensile test and corrosion test according to BS:18 and BS:1501 respectively on three sets of stainless steel materials belonging to their Tallex Mixing Unit were carried out and the materials were found to withstand the corrosion tests.

89.1 Metallurgical Investigation on Failure of Copper Profile Bars. *Sponsored by M/s. Bharat Heavy Electricals Ltd., Hardwar.*

Detailed metallurgical tests showed that inclusions and the presence of bismuth were responsible for the failure of the copper profile bars.

89.2 Metallurgical Tests on Boiler Tubes. *Sponsored by M/s. FCI Expansion Project, Namrup Division, of M/s. BHEL.*

Four samples of boiler tubes were subjected to metallurgical examination and the results of chemical analysis, hardness measurements, tensile tests, flatting tests, expansion test and metallographic examination were reported.

89.3 Metallurgical Investigation on the Failure of Superheater Tube. *Sponsored by M/s. DESU, I.P. Station, New Delhi.*

M/s. DESU, New Delhi, referred the repeated failures of super-heater tubes in the 29th coil of their Babcock & Wilcox boiler. The super-heater tube had undergone failure by 'ash corrosion'.

89.4 Investigation on the Failure of ERW Tube. *Sponsored by Oil & Natural Gas Commission, Sibsagar Project.*

Four tubes burst during hydraulic test were subjected to metallurgical

examination. Results showed that the material conformed to specification, but revealed a poor weld which could not stand the hydraulic test.

89.5 Micro-examination of Ferrous Samples. *Sponsored by M/s. Janjid Udyog, Jodhpur.*

Micro-examination showed the samples were pearlitic grey cast iron.

89.6 Substitute Shaft Material for Limestone Crushers. *Sponsored by M/s. Satna Cement Works, M.P.*

It was suggested that the shaft material which the firm desire to substitute in place of original shaft could be used after proper heat treatment.

89.7 Testing of Grinding Balls. *Referred by Central Excise Collectorate, Jaipur.*

The grinding balls sent for metallurgical examination were found to be alloy cast iron balls and not cast steel balls as reported.

89.8 Metallurgical Tests on Imported Aluminized Mild Steel Sheets. *Sponsored by Indian Posts & Telegraph Dept., Calcutta.*

Two imported aluminized sheets were received to test as per IS 3821 specification for aluminization. The tests showed that the sheets conform to specification.

89.9 Metallurgical Investigation of Wornout Bronze Impeller for 1000 H.P. Pump. *Sponsored by Executive Engineer, Tawi Canal Construction Division, Jammu.*

The investigation was required to be carried out because the bronze impeller was getting worn out much earlier than envisaged by the Tawi Canal Construction Division, Jammu. Along with water, the pump is also pumping some sand. During the investigation the impeller material was tested and other associated matter were studied. It was highlighted that along with water, pump is also pumping highly abrasive sand from the river Tawi which is causing excessive wear. Alternative material was also suggested for the impeller.

J. FOUNDRY TECHNOLOGY

90.0 Development of Heat Resistant Castings for Reduction Boxes.

Several castings of different shapes in high Al cast iron were made and tested for heat resistance at different temperature. Oxidation and growth test on machined specimens of these cast irons were carried out. From the

results obtained, three compositions which showed good results were selected for making carrier blade castings to be used in a reheating furnace in a production unit. The castings did not show any surface oxidation even after one month's continuous use and are continuing to give good service.

91.0 Development of Nickel Free Heat Resistant Alloy Cast Iron for High Temperature Application.

Work was conducted to develop alloy cast iron, free of nickel, for high temperature application. A number of test specimens were prepared by eliminating nickel and adding some alloying elements indigenously available. Based on the experiments conducted an optimum composition has been aimed at.

92.0 Wear and Abrasion Resistant Cast Iron.

Attempts were made to identify the entrepreneurs for the use of technology of production of "NML-Wearnot" to undertake the casting of components required in industry for wear and abrasion resistance applications. One firm has applied for the grant of license to NRDC, New Delhi; for utilising the technology.

93.0 Development of a New Mould Coating Process.

A large number of experiments with different coating and backing compositions were made. Backing of CO_2 sand, fluid sand and self setting sand etc. have been tried with slurry compositions with ethyl silicate, plaster of paris etc. Further experiments are in progress to arrive at the most suitable slurry composition and appropriate backing composition.

94.0 Development of Special Casting Methods.

Apparatus for determining the melting point has been fabricated. Some of the physical properties of five different types of waxes has been studied. Experiments to determine the slurry compositions suitable for investment castings has been taken up.

95.0 Production of Nodularising Agent.

Technical know-how has been developed for the production of following nodularising agents :

(*i*) *Iron-Silicon-Magnesium Alloy*

Technical know-how has been developed for the production of iron-silicon-magnesium alloy used for the production of nodular or spheroidal graphitic cast iron. The alloys have been produced in 4 kg. lots.

(ii) Nickel-Magnesium Alloy

Technical know-how is being developed for the production of nickel-magnesium alloy used for the production of nodular or spheroidal graphite cast iron. The alloy has been produced in 20 kg. lots.

96.0 Inoculation of Cast Iron with NML Developed Calcium-Silicide.

To obtain reproducible results, two heats of desired base composition of cast iron were made in 0.8 ton arc furnace. This base metal of desired quantity was remelted in induction furnace for inoculation studies. Ten such heats were made in induction furnace and the cast iron melts were inoculated with NML calcium-silicide and three other imported varieties of calcium silicide separately. Cast tensile test specimens and wedge specimens were made. Their tensile strengths have been determined and fracture of wedge was also studied for evaluation of the inoculation effect.

97.0 Development of Cupola Iron Melting.

A systematic study of the effects of using oxygen enriched hot air blast in cupola iron melting has been completed. Iron melting with hot air blast using Indian coke has also been completed.

98.0 Self-Setting Sodium-Silicate Bonded Sand.

Hot strength characteristics and breakdown properties of self-setting agent for sodium silicate bonded sand developed at NML has been studied. Industrial scale trials were completed at two different production centres. This project has now been completed and terms for its release through NRDC has been finalised. The work has now been extended to the study of other self setting agents being developed on similar lines.

99.0 Fluidized Sand Process.

After trials with all the mixers available in the laboratory, first with the existing ones and later with various modifications, it has been found that it is necessary to carry out trials with larger capacity mixers before conclusions can be drawn. One or two types of mixers are proposed to be tried on this basis.

K. CORROSION STUDIES ON METALS & ALLOYS

100.0 Atmospheric Corrosion of Metals & Alloys.

Studies on the behaviour of various inorganic surface coatings in the industrial atmosphere at Jamshedpur and the marine atmosphere at Digha were in progress. The coatings under test were (*i*) galvanised, (*ii*) alumi-

nised, (*iii*) Alclad, (*iv*) anodised, (*v*) aluminium (Alcoran treated) and plain mild steel. At MCRS, Digha; aluminised steel gave better performance at the end of 6 year period. Galvanised samples were severely corroded after 4 years period. Painted mild steel, Alclad, anodised aluminium and alcoran aluminium showed severe corrosion/pitting. At Jamshedpur, the samples showed no significant corrosion. The painted mild steel samples with and without scratches failed after 4 years period. Final report on the overall performance of all these coatings at Jamshedpur and Digha was under preparation.

101.0 Development of Aluminium Anode for Cathodic Protection.

'Superal' an aluminium based sacrificial anode highly suited for use in the cathodic protection of ship hull, buried and submerged pipelines, harbour installations, etc., has been developed. Electro-chemical data evaluated in laboratory tests were highly satisfactory. For large scale trial in the light of the consumers acceptibility test, normal size anodes for the installations in ship hull and underground pipelines have been prepared and some of them have been sent for actual field trial.

102.0 Temporary Protective Treatment for Copper and Copper base Alloys for Preventing Tarnishing.

Samples coated in the laboratory were tried in actual plant atmosphere and the performance was found very encouraging. A local cable manufacturing company is arranging for large scale trials in the plant itself for coating the conductors and testing the performance during the actual storage and transit conditions.

103.0 Utilization of By-product from a Chemical Industry for Formulating Acid Pickling Inhibitor.

A formulation of acid pickling inhibitor by utilizing the by-product has been successfully developed. The performance of the inhibitor as evaluated under laboratory testing condition was extremely satisfactory. Efforts are now being made to conduct a large scale trial to get feasibility data.

104.0 Studies on Phenomenon of De-alloying of Copper Base Alloys.

The first series of tests with different Cu-Mn and Cu-Zn alloys using 'potential shift' technique by galvanostat have been completed. The next series of tests with 'potential shift' techniqueby potentiostat havebeen started.

105.0 Joint Action of H_2S and Organic Compounds in Acid Pickling of High Carbon Steel.

The effect of different concentrations of HCL and H_2SO_4 at higher temperatures on the efficiency of the formulated inhibitor was ascertained

and it was found that there was not appreciable change in efficiency with rise of either temperature or concentration of acids. The inhibitor also gave good protection to different steels in acids saturated with hydrogen sulphide. The larger trials are under progress.

106.0 Studies on Stress Corrosion Cracking of Brass.

The mechanism of the stress corrosion cracking in alpha brass was studied in Mattson's solution by the technique of decreasing load. Mattson's solution of two different concentrations was used. In presence of more concentrated solution a tarnish layer was formed due to dezincification on the surface. The formation of a brittle layer was apparent due to active anodic dissolution along specific defect sites. The rate of crack propagation was of the same order of the brittle layer growth.

106.1 Studies on Stress Corrosion Cracking of Mild Steel.

Systematic studies on stress corrosion cracking of steel under decreasing load were taken up to correlate the intensity of attack with varied conditions of metallurgical treatments and environmental conditions. An experimental set-up was made and standardized for testing wire in contact with hot electrolytes under decreasing load. The stress corrosion susceptibility was found to increase at higher stresses. The pattern of corrosion attack (anodic dissolution) under stress was also examined metallographically and noted to be different from that obtained with brass. The formation of the oxide layer on the specimen surface during test appeared to have remarkable influence on the process of stress corrosion cracking. While conducting the experiment at lower *p*H value of the solution, the pattern of anodic dissolution particularly at the grain boundaries was found similar to the phenomenon observed in case of brass tested in Mattson's solution.

107.0 Studies on Hydrogen Embrittlement of Steels in Aqueous System.

In view of the greater susceptibility of high strength steel to hydrogen embrittlement, much care is needed for pickling of these grades so that the hydrogen pick up during pickling is minimum. Performance of some of the thio-compounds when added in pickling solution were studied. It was found that thio-compounds having lower molecular weight and unbranched chain resulted generally in loss in ductility, with high pickup of hydrogen. The work in this line is in progress.

L. SURFACE COATING ON METALS

108.0 Development of Tin Free Steel.

A process has been developed on bench-scale to deposit a fine layer of chromium metal-chromium oxide on steel surfaces having properties

required of a substitute material for tinplates. Starting with 10 cm^2 specimens, the process has been established with 400 mm × 350 mm black plates. The plated tin free steel specimens were sent to can industries for consumer acceptability studies and have been found to be comparable in properties to imported similar products such as 'Cansuper'.

A collaborative programme of work is being planned with Central Food Technological Research Institute for testing of tin free steel specimens as a canning material for fruit and vegetable products and examine the variant of chromium-chromium oxide composition and thickness for the purpose.

109.0 Electrolytic Copper Plating on Ferrous Materials.

Direct electrolytic copper plating on ferrous material from an acidic copper sulphate solution in presence of an inhibitor has been established. Copper coating is adherent to the base metal and bright in lustre. This process has application in wire industry for copper coating. The conventional cyanide copper plating is concurrently in use. Negotiations are in progress to utilise this technology.

110.0 Electroless Nickel Plating.

Experiments were conducted at different P_H. The hardness of the M.S. plate after plating was found to be increasing. After heat treatment there was no marked increase in the hardness, but the plating was uniform and adherent and shining. Plating on some complicated shapes were also done successfully. Experiments are again being repeated using other chemicals and varying the various parameters in order to improve the desirable properties.

111.0 Development of Continuous Copper Coating on Aluminium Wire.

The technology of copper plating on aluminium wire will extend the use and utility of copper coated aluminium wire in electrical industries for various purposes as follows :—

(*i*) House wiring.
(*ii*) Automobile wiring.
(*iii*) Coaxial cables connecting the antenna to television sets.
(*iv*) Contact wires for use in control and relay panels and switchgear panels.
(*v*) Winding wires in chokes, transformers, and fractional horsepower motors.

The work has recently been taken up.

112.0 Development of Acid Zinc Plating Solution.

To eliminate the hazards in cyanide solution and the difficulties in effluent treatment, an acid zinc plating solution as a substitute is being worked out. A composition for zinc plating solution has been standardised. The acidic zinc plating solution has given satisfactory results on performance in Hull Cell tests. A combination of brightner and leveller have been worked out to produce bright zinc plating from the acidic solution. Necessary arrangements are being made to utilise this process on a production plating practice.

113.0 Plastic Coatings (Vinyls) on Metals for Corrosion Prevention.

Samples were sent both for evaluation and exploitation by consumer industries. Test reports were obtained from Electronic Corporation of India, Hyderabad; Elico Pvt. Ltd., Hyderabad; M/s. Goodlass Nerolac Paints Ltd., Bombay and the reports are satisfactory. Samples of coated m.s. tubes were sent to M/s. Anand Steemet India Pvt. Ltd., Patna; at their request for assessing the possibility of utilizing such coatings in steel furniture manufacture.

113.1 Vinyl Coatings on Aluminium.

Samples of vinyl coated aluminium were sent to M/s. Goodlass Nerolac Paints Ltd., Bombay for evaluation of coating and test report was obtained which is satisfactory. Efforts are made to transfer the know-how of vinyl coatings on aluminium along with on steel.

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

Siliconizing, calorizing, chromising, chrome-aluminizing were carried on bench scale and the oxidation properties were evaluated. Coating thickness in each case and the concentration profiles of the elements in each case were evaluated.

114.1 Chromizing and Calorizing of Low Alloy Steel Parts for High Temperature Service.

Samples were made for initial experiments for pack calorizing.

M. STANDARD REFERENCE MATERIALS & ANALYTICAL WORK

115.0 Preparation of Standard Samples.

So far 25 different types of standard samples have been prepared which are now being sold to meet the demand of industries, educational and research organisations and instrument manufacturers etc. NML has

stared production of these specialised products on a modest scale which is intended to be expanded gradually covering production of more and more different standard samples of both ferrous and non-ferrous.

(*a*) *During the period the following samples were prepared*

(*i*)	Ferro-molybdenum	12 kg.
(*ii*)	Cast Iron	90 kg.
(*iii*)	Alloy cast iron	90 kg.
(*iv*)	1.0% C Steel	92 kg.
(*v*)	Silicon-Al alloy	26 kg.
(*vi*)	Brass 70/30	27 kg.
(*vii*)	0.3% C Steel	70 kg.

(*b*) *Each of the following samples were sent to seven different parties for analysis*

(*i*)	1.0% Carbon steel	92 kg.
(*ii*)	Silicon-Al alloy	26 kg.
(*iii*)	Alloy cast iron	90 kg.

(*c*) *The following new samples were released for sale during this period*

(*i*) 92 kg. 1.0% C steel No. 20.01
(*ii*) 70 kg. 0.3% C steel No. 13.01
(*iii*) 27 kg. Brass 70/30 No. 42.1
(*iv*) 90 kg. cast iron No. 1.4

(*d*) *Sample sold during the above period*

56.85 kg. of samples.

115.1 Preparation of Spectrographic Standard Samples.

After completing the series of plain carbon steel, preparation of low alloy steel standard was taken up. The composition of these standards have been adjusted in such a way that it would be possible to analyse the alloying elements in low alloy steels in the range given below by using emission spectrographs (both photographic and direct reading type) as well as X-Ray Fluorescence Spectrometer.

Si	0.05 to 2.0 per cent
Mn	0.05 to 2.0 ,,
Ni	0.1 to 5.0 ,,
Cr	0.1 to 3.0 ,,
Mo	0.05 to 1.5 ,,
V	0.05 to 1.0 ,,
Cu	0.05 to 0.5 ,,

Eight heats of variable composition of the above alloying elements have been melted and ingots have been cast. After ascertaining the composition of the different ingots by X-Ray fluorescence and emission spectrographic analysis, all the ingots have been forged. Samples in the form of discs have been sliced off from these forged ingots for homogeneity studies. Since homogeneity is very important for standard samples, spectrographic analysis is being carried out on different spots of the discs. Turnings from the forged ingots have also been taken up to carry out chemical analysis by several independent analysts. The work in this direction is in progress.

116.0 Analytical Work.

(*i*) *Chemical and Instrumental Analysis*

1909 samples containing 6898 radicals were analysed.

(*ii*) *Analysis of Gases in Metals by Vacuum Fusion & Vacuum Heating Methods*

134 samples were analysed for determination of O_2, N_2, H_2, CO, CO_2, CH_4 etc.

(*iii*) *Spectrographic Analysis*

(*a*) Qualitative Analysis—176 samples were completely analysed for major, minor and trace elements.

(*b*) Quantitative Analysis—118 samples were analysed for 583 radicals.

(*iv*) *X-Ray Fluorescence Spectrometer.*

The following work has been carried out in X-Ray Fluorescence Spectrometer.

(*a*) Standardization for determination of copper content in the range of 0.05 to 20 per cent in copper concentrates has been done and a total of 110 samples have been analysed.

(*b*) Standardization for determination of Pb, Zn, and Cu contents in Pb-Zn-Cu ore has been done in the following range and 75 samples have been analysed.

Cu	0.05 to 15.0 per cent
Pb	0.01 to 6.0 ,,
Zn	1.0 to 20.0 ,,

(*c*) Standardization for determination of Pb, Fe, and Zn contents in lead concentrate has been done in the following range and 10 samples have been analysed.

Pb	30 to 65 percent
Fe	1 to 16 percent
Zn	0.5 to 8.0 percent

(*d*) 25 samples of Fe ore samples for Fe content have been analysed.

(*e*) 15 samples of low alloy steel for 90 radicals have been analysed.

(*f*) Use of solution technique by X-Ray Fluorescence Spectrometer has been standardized for analysis of Al and Cu base alloys.

(*v*) *X-Ray Fluorescence Analysis by Autrometer*

A total of 350 samples were analysed for 515 radicals. The samples of investigations included (*i*) copper ore from Chapri, ICC, Ghatsila, (*ii*) fluorspar from Kahila and Mandokipal, Rajasthan, (*iii*) manganese ore from Rungta, Chaibasa, (*iv*) copper ore from Khetri and (*v*) copper-lead-zinc ore from Ambaji, GMDC.

(*vi*) *Differential Thermal Analysis, Thermogravimetric & Derivative Thermal Gravimetric Analysis of Ores & Minerals*

The following samples were studied :

(*a*) Iron ore slime from Noamundi.
(*b*) Six rock phosphate samples from Jhamarkota, Rajasthan.
(*c*) Magnesite from Pithorgarh.
(*d*) Iron Ore Type 4 from M/s. MECON.
(*e*) Wolframite ore concentrate from Thailand & Bankura.

(*vii*) *Petrological Studies on Ores & Minerals*

Forty two low grade ores and mineral samples received for beneticiation & other studies were studied and their detailed petrological reports were given which were included in the main investigation/project reports.

N. APPLIED BASIC PROJECTS

117.0 Liquid-Solid Transformation.

Splat cooled Al-Mg-Si alloy thin films were observed under scanning

dendrite followed by normal dendritic morphology. The results were interpreted by Link Energy Dispersive analysis. Similar work ni Al-Fe alloy of various Fe content is in progress.

118.0 Structure & Phase Transformation Studies of Rapidly Solidified Thin Films of Al-Cr Alloys from the Liquid State.

Two different compositions of Al-Cr alloys have been rapidly solidified and thin films obtained by the splat cooling technique have been studied by metallography and X-ray techniques. Further work is in progress.

119.0 Kinetics and Mechanism of Alkali Attack on Alumino-Silicate Refractories.

On the laboratory prepared samples, the progress of alkali attack and its mechanism was studied by X-ray diffraction studies of the attacked samples. The results indicated that the silicate glaze gradually depleted leaving behind mullite. The microscopic examination of the reacted samples also revealed gradual surface reaction by molten potassium carbonate.

In continuation of earlier work, some used and unused field samples of blast furnace stack bricks were collected. These bricks belong to the category of refractories over which extensive studies on the rates and mechanisms of alkali attack have been conducted earlier. Using these samples, the rate of attack with molten K_2CO_3, Na_2CO_3, Li_2CO_3 at appropriate temperatures was determined. The micro and macro structures were studied which show the dense impervious 44% alumino refractories made from naturally occurring alumina and silica bearing materials would resist best the alkali attack.

120.0 Studies on Sintering in the Presence of a Liquid Phase in Some Ceramic System.

During the period under review, work was done on the system containing alumino-silicates and varying percentages of magnesium carbonate. Experimental buttons were made and fired to determine the degree of sintering by measuring the physical properties such as linear and volumetric changes, porosity and bulk density. The results are being studied.

121.0 Fundamental Studies on Bentonites.

DTA of treated and untreated bentonite has been carried out. Electron diffraction studies have been made on some freshly mixed and also stored samples. Some calcium base lean bentonites were activated for study of the effect of gases. Further work is in progress.

PILOT PLANTS

122.0 Mineral Beneficiation Pilot Plant.

Pilot Plant investigations conducted on different types of low grade ores and minerals have been reported under item A "Ore Dressing & Mineral Beneficiation Studies".

123.0 Dense Carbon Aggregate Pilot Plant.

In order to evaluate the performance of soderberg paste made from dense carbon aggregate, M/s. Ferro Alloy Corporation requested for the supply of 30 tons of soderberg paste for industrial trials in all the three electrodes. With this objective in view, work was undertaken and 12 tons of paste was prepared on pilot plant scale in addition to the 10 tons already existed. About 10 tons of dense carbon aggregate is also in the process of its conversion to soderberg paste.

Initial trial runs on the operation of the electric tunnel kiln fabricated were highly encouraging and it was possible to reach desired temperatures of the order of 1300°C in the hot zone. A few design modifications were made in the heating zone and also other modifications to facilitate smooth working of the kiln are under progress. About 10 tons of pure calcium aluminate cement was produced and processed in the pilot plant for its end use in lining the kiln cars and making saggers. 30 tons of aggregate based on kyanite was calcined and graded for its use in the castables. A sample of laboratory's cement and castable was supplied to M/s. Instrumentation Kota Ltd. for their use.

124.0 Electrolytic Manganese and Manganese Dioxide Pilot Plant.

The NML developed technology for production of electrolytic manganese dioxide has been leased out to M/s. T. K. Chemicals Ltd., Bombay; who are setting up a 1000 tonnes per annum plant near Trivandrum in Kerala. M/s. T. K. Chemicals Ltd. sponsored a pilot plant suitability study of their proposed manganese ore and waste sulphuric acid from nearby Travancore Titanium Products for production of electrolytic manganese dioxide. The novelty of this plant is that it uses the waste liquor containing sulphuric acid and ferrous sulphate, from Travancore Titanium Products, instead of commercial sulphuric acid. NML is also actively collaborating with the Project consultants M/s. M. M. Suri and Associates Pvt. Ltd. to put up the above plant. The plant is expected to go into production in 1977.

M/s. M. L. Rungta, Chaibasa: also sponsored a suitability study of their manganese ore for production of electrolytic manganese metal and dioxide during this year. The medium grade manganese ore supplied by M/s. Rungta was found suitable for production of electrolytic manganese metal and dioxide.

125.0 Hot Dip Aluminizing Pilot Plant.

The strip aluminizing prototype plant installation was completed and commissioning trials have commenced. The furnace is being modified for top heat. The wire aluminizing pilot plant which was dismantled earlier is being renovated and re-installed for demonstration to licencees.

126. Sukinda Nickel Pilot Plant.

The pilot plant was commissioned and the first phase of the work has been completed.

A view of the pilot plant for treatment of Sukinda nickel ore, installed in collaboration with M/s. Chemical & Metallurgical Design Ltd., New Delhi.

NML FIELD STATIONS

NML Unit in CSIR Complex, Madras.

The NML unit in CSIR Complex, Madras, has conducted a number of investigations on beneficiation and agglomeration of low grade ores and minerals in Southern region, studies on expansion and modernisation of foundries, studies on plant corrosion as well as undertaking some inter-laboratory projects. Besides, technical assistance has been rendered to a large number of industries by way of furnishing information, specifications, queries on metallurgical processes, projects etc. Following are the various investigations conducted and underway in this unit.

(*i*) Beneficiation studies on a low grade magnetite sample (APU) from Geological Survey of India (Kerala).

(*ii*) Beneficiation studies on a low grade magnetite sample (APO) from Geological Survey of India (Kerala).

(*iii*) Beneficiation of a low grade sillimanite sample from M/s. Mineral Sales (P) Ltd., Hospet.

(*iv*) Beneficiation and pelletization studies on a limestone sample from M/s. Industrial Chemical Ltd., Tamil Nadu.

(*v*) Heavy media separation studies on a magnesite sample from M/s. Burn & Co., Salem.

(*vi*) Preparation of precipitated calcium carbonate. Referred by M/s. Gem International, Madras.

(*vii*) Washing of a clay sample from Ramnad district, Tamil Nadu.

(*viii*) Beneficiation studies on iron ore samples from Yerraballi and Chandoli areas of Karimnagar district—Referred by Director of Geology & Mining, Andhra Pradesh.

(*ix*) Beneficiation of two limestone samples from Andhra Pradesh (Karimnagar Project).

(x) Treatment of chrome sludge.

(*xi*) Project for expansion and modernisation of cast iron foundry of M/s. Singareni colliery.

(*xii*) Project Report for the establishment of electrolytic iron powder plant of M/s. Electro-Metallics, Cochin.

(*xiii*) Design of digital carbon analyser (joint project of NML, CEERI & CSIO).

(*xiv*) Design of high tension magnetic separator (joint project of NML & MERADO, Madras).

Field Stations at Batala, Howrah & Ahmedabad.

The technical services rendered by these Field Stations are being increasingly utilised by the regional metallurgical industry in general and foundry industry in particular. The Table 3 gives an account of the nature of technical assistance rendered by the field stations during the period. Technical guidance is furnished in the following fields.

(*i*) Selection of suitable raw materials—This includes facilities for the analysis of ferrous and non-ferrous metals and alloys, refractory materials, testing of sands, bentonites and other foundry raw materials.

(*ii*) Application of modern techniques of production, scientific methods of metal casting and testing.

(*iii*) To achieve quality control and improve productivity by elimination of moulding and casting defects.

(iv) To impart technical know-how and guidance to meet stringent export requirements.

Table 3

Nature of assistance rendered by Field Stations

Sl. No.	Nature of service	Batala	Howrah	Ahmedabad
1.	Chemical analysis. No. of radicals analysed	745	512	2216
2.	Mould and Core raw material testing. No. of tests	—	—	5
3.	Mechanical Testing. No. of tests	23	307	7
4.	No. of technical enqueries attended	482	233	413
5.	No. of foundry visits	71	77	25
6.	No. of sands and bentonites investigated	3	—	—

The testing facilities at the Field Stations are further being augmented to meet the increasing demand in the field of metallurgical analysis by establishing few instruments for supplying quick results.

The need for establishing microstructural studies for studying metals and alloys was also felt and subsequently the metallography facility has been planned to be established during the year 1976-77 for Field Station at Batala and Howrah and in 1977-78 for Field Station at Ahmedabad. The NML designed equiblast-cum-balanced blast cupola has been established in seven more foundries in the northern region.

Civil work pertaining to the proposed ore dressing and mineral beneficiation facility at Ahmedabad has been completed. The ore dressing facility is expected to be established during the year 1976-77. This will be of immense help to the mineral industry in the western region.

Small scale industries were given 50% rebate in testing charges so as to assist the small scale entrepreneurs in their efforts to maintain quality control. Field stations are represented in the local engineering and trade bodies and R&D committees.

Marine Corrosion Research Station, Digha.

The following investigations were conducted during the period.

(*i*) *Studies on Inhibition of Sea Water Corrosion*

Effect of chromate addition in sea water for reducing corrosion bimetallic joints has been studied. The influence of inhibitor additions was predominant on both anodic and cathodic metal from the point of wright less data and electro-chemical measurements.

(*ii*) *Behaviour of Metals and Alloys in Sea Water Under Laboratory Testing Conditions*

Various ferrous and non-ferrous metals and alloys have been tested in sea water under different exposure conditions. Brass and aluminium—2S showed greater resistance in fully and partially immersed conditions, whereas mild steel, copper, cast iron showed more corrosion than any other metals and alloys tested.

(*iii*) *Corrosion of Metals and Alloys under Marine Atmosphere*

Studies on behaviour of various inorganic surface coatings under marine atmosphere have been conducted and a final report is under preparation.

ENGINEERING ACTIVITIES

Mechanical Engineering

Fabrication & Service

(*i*) Modification and general alignment of strip aluminizing plant.
(*ii*) Furnace for electroslag remelting.
(*iii*) Feeder for lead smelting project.
(*iv*) Fluidized bed reactor.
(*v*) Creep specimen adapters.
(*vi*) Apparatus for polishing powder.
(*vii*) Reaction tube unit.
(*viii*) Attachment for creep testing machines.
(*ix*) Hoods & ducts.
(x) Preparation of various types of test specimens for different projects of the laboratory.

Electronics Engineering

A. Development Projects.

(*i*) *Solid State Thermogravimetric Balance.*

A FET differential amplifier using Bel BFW 10 was designed and fabricated.

(*ii*) *Proportional Temperature Controller* (*Thysistor Type*).

Firing circuit with UJT is under design as integrated firing circuit was not available.

B. Instrumentation of Projects.

(*i*) *Sukinda Nickel Project.*

Installation and commissioning of the following instruments were completed :

(*a*)	Rotameters (flow meter)	50 nos.
(*b*)	Potentiometric temperature indicators	4 nos.
(*c*)	Dial Thermometers	30 nos.
(*d*)	Pressure gauges	30 nos.
(*e*)	Sight glass gauge	20 nos.
(*f*)	Draught gauge	4 nos.

(*ii*) *Hydro-Electro Metallurgy Project.*

Testing and inspection of the following instruments were completed:

(*a*)	Variable dilutes	1 no
(*b*)	Spectro-colorimeter	2 nos.

C. Maintenance, Installation & Calibration.

Following jobs were done :

(*i*) Cambridge stereoscan S4-10.
(*ii*) Philips x-ray spectrometer PW 1410.
(*iii*) Philips x-ray diffractometer, PW 1130.
(*iv*) Pye-Unicam atomic absorption spectrophotometer SP 1900.
(*v*) Spectrophotometers.
(*vi*) Polarographs.
(*vii*) DTA units.
(*viii*) Recorder & controllers.
(*ix*) Nucleonic instruments.

Electrical Engineering

A. Development Projects.

(*i*) *Design and Development of Prototype Electroslag Refining Equipment—140 KVA capacity.*

The equipment was operated satisfactorily and a number of refining experiments were conducted. During the operation, it was observed that the provision of the facility for rapid travel of carriage is essential. In view of this, specification of an appropriate drive systems was worked out.

(*ii*) *Liquid State Extraction of Magnesium in a Single Electrode 140 KVA Electric Furnace.*

Design of a furnace based on electroslag heating was carried out. Efforts were made to get various components of the furnace fabricated.

(*iii*) *Design and Development of Electric Furnace for Multi-Specimen Creep Testing Machines.*

Electric furnaces of multi-specimen creep testing machines are provided with heat sinks of heat resistant material in order to satisfy very close temperature gradient in the furnace. In view of this, action was taken to develop heat resistant sink of certain composition to withstand the temperature of about 1000°C for long time.

(*iv*) *Development of 3-tonnes High Sensitivity Creep Testing Machine.*

Detailed drawings of various components of a prototype single specimen creep testing machine incorporating modern features were under preparation.

(v) *Studies on Electrical Resistivities of Slags and Mattes.*

The studies of resistivities of slags and mattes are essential for designing electrical furnaces to give practical shapes to processes for magnesium and lead development work in the laboratory. A set up was designed and fabricated to determine the resistivities of slags and mattes.

B. Engineering Monitoring and Project Management.

The remaining jobs of engineering services comprising of electrical substation, internal wiring and temperature and humidity control system of Central Creep Testing Facilities were completed.

C. Design & Fabrication.

A number of electrical heating and reheating furnaces were designed and fabricated for various research and development work in the laboratory.

D. Preventive Maintenance & Breakdown Repairs.

Preventive maintenance and break down repairs of electrical equipment comprising of power transformers, circuit breakers, rectifiers, motors, alternators, hoisting equipment, arc and resistance furnaces, high frequency furnaces, control devices etc. were carried out. A 20 KW high frequency alternator was repaired after designing special tackles for various operations such as opening, winding, vacuum impregnation etc.

Civil Engineering

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

1. Periodical painting and white washing (internal and external) Main Building of the Laboratory.
2. Periodical painting and white washing of pilot plant bays.
3. Periodical painting and white washing of technological block of the Laboratory.
4. Tarfelt treatment to the leakage roof of Laboratory building and cycle stand.
5. Making pandal & lighting etc. for NML Silver Jubilee function.
6. Replacement of damaged black or G.I. sheet with asbestos sheet at F.P.T.D.
7. Extension and modification of cooperative store building for opening State Bank Branch in NML.

TECHNICAL CONFERENCES

1. VII Annual Technical Convention of Indian Institute of Mineral Engineers.

The Indian Institute of Mineral Engineers in collaboration with National Metallurgical Laboratory held its VII Annual Technical Convention on 11th & 12th July, 1975.

The convention was inaugurated by Shri A. N. Banerjee, Chairman & Mg. Director, Hindustan Zinc Ltd. Shri P. C. Jain, Vice-President, IIME & Managing Director, McNally Bharat Engg. Co. Ltd. welcomed the attending delegates. Prof. V. A. Altekar, President, IIME & Director, NML, delivered the Presidential address. The key note address was delivered by Shri A. N. Banerjee. Altogether seventeen technical papers were presented and discussed in four technical sessions.

Shri A. N. Banerjee, Chairman & Mg. Director M/s. Hindustan Zinc Ltd., delivering key note address at VII Annual Technical Convention of Indian Institute of Mineral Engineers.

2. Seminar on 'Corrosion of Metals in Industries and their Prevention Techniques'.

A seminar on 'Corrosion of Metals in Industries and their Prevention Techniques' was held on 18th and 19th September, 1975, in collaboration with National Safety Council, Bombay. The seminar was inaugurated by Shri P. N. Gandhi, Ag. General Manager of M/s. Indian Tube Co. Ltd. Shri S. S. Kothari, Mg. Director, M/s. Hindalco presided over the inaugural function.

Prof. V. A. Altekar, Director, delivered the key-note address entitled "Corrosion protection—A joint responsibility of the scientists and engineers. Forty-two papers were presented and discussed in seven technical sessions.

3. Symposium on "Problems in Transfer of Technology from R&D Laboratory to Industries".

This Symposium was held as a part of the main function of NML

Prof. V. A. Altekar, Director, NML, delivering key-note address at the Seminar on 'Corrosion of Metals in Industries and their Prevention Techniques'.

Silver Jubilee on 14th November, 1975 which was inaugurated by Shri Chandrajit Yadav, Union Minister for Steel & Mines. The symposium was held in two technical sessions, which were presided by Prof. Y. Nayudamma, Director-General, CSIR and Dr. D. P. Antia, Mg. Director, Union Carbide Ltd. Ten papers from eminent scientists, technologists & engineering consultants from India and abroad were presented and discussed.

Mr. P. A. Woodrow, Chief of Production Technology, National Research Development Corporation, UK, presenting his paper at the Symposium on 'Transfer of Technology from R & D Laboratory to Industries'.

4. 29th Annual Technical Meeting of Indian Institute of Metals.

The 29th Annual Technical Meeting of Indian Institute of Metals was held in collaboration with National Metallurgical Laboratory on 15th & 16th November, 1975 as a part of NML Silver Jubilee function. Parallel sessions were held to present and discuss 164 papers covering various disciplines of metallurgy.

SILVER JUBILEE CELEBRATION

The National Metallurgical Laboratory stepped into twentyfifth years of its existence from November, 1974 and observed its Silver Jubilee year upto November, 1975 through a series of seminars, conference, etc. The final function was held from 14th to 16th November, 1975 along with the 13th National Metallurgists' Day and 29th Annual Technical Meeting of Indian Institute of Metals.

Shrimati Indira Gandhi, the Prime Minister and President of CSIR, who could not be present on the occasion sent her message in which she stated "Ancient India's metallurgical skills were world renowned. But feudalism and foreign rule prevented us from taking advantage of the industrial revolution and the discoveries of modern science. Only in the last three decades could we shape our own destiny. Our programme of economic regeneration assigns a crucial role to the development of our mineral resources. Through its fundamental and applied research, the

Shri Chandrajit Yadav, Union Minister for Steel & Mines, delivering inaugural address on the occasion of NML Silver Jubilee.

National Metallurgical Laboratory had made a significant contribution to the building up of key industries and to the attainment of technological self-reliance".

Shri P. N. Haksar, Deputy Chairman, Planning Commission and Vice President of CSIR, stated in his message "It is significant that this year the industries are seeking to utilize the sponge iron technology developed by this laboratory. With increasing demands for development and modification of technology to suit Indian conditions, I am sure the National Metallurgical Laboratory will be increasingly called upon by industries to come to their assistance."

Congratulatory messages were received from President and Vice-President of India, Governor & Chief Minister of Bihar. The President of Japan Iron & Steel Institute, Mr. Seita Sakui, in a communication stated

Shri Chandrajit Yadav, Union Minister for Steel & Mines, awarding 25 years service medallion to Shri G. C. Mishra, the oldest NML employee.

A view of the delegates attending the NML Silver Jubilee.

"Twentyfive years is not a long time from the point of history of steel industry, but this has been the most important period from the view point of the development of steel technology in the world. The National Metallurgical Laboratory is now celebrating its 25th anniversary, and Japan Iron & Steel Institute congratulates National Metallurgical Laboratory on its great achievements in these twentyfive years. The contribution of NML to the steel industry is highly appreciated not only by the people of India but also by those of the world."

The delegates and distinguished personnel attending the function were welcomed by Dr. Rajendra Kumar, Scientist. Prof. V. A. Altekar, Director, after paying a tribute to the Hon'ble Minister and distinguished gathering narrated the development of the Laboratory through twentyfive years and its contribution in the progress of metallurgical industries of the country. He outlined the expertise developed by the Laboratory in different facets of metallurgy, such as development of techniques of beneficiation and agglomeration of low grade ores and minerals, production of sponge

iron, NML-PM2, aluminium alloy conductor, special ferro-alloys, metal powders, vanadium extraction and ferro-vanadium production, nickel free heating elements, graphite crucibles, welding flux, electrolytic manganese metal, bright nickel plated materials etc. Prof. Altekar paid a special tribute to Dr. B. R. Nijhawan, former Director of the Laboratory and at present Senior Industrial Adviser, UNIDO; whose vision, foresightedness and continued interest has put the National Metallurgical Laboratory on the Metallurgical Research and Development Map of the World. In recognition of Dr. Nijhawan's service to the Laboratory: Prof. Altekar announced a special medallion to be bestowed on him on the occasion.

Prof. Y. Nayudamma, Director-General, CSIR, addressing the gathering said that National Metallurgical Laboratory which was founded twentyfive years ago has earned for itself the affection and trust from the industry through its technical competence and contributions in the metallurgical and allied subjects. He mentioned that some of the NML developed products and processes are now commercially utilized which has helped in utilizing the country's indigenous raw materials as well as minimizing the import of technology and products. Prof. Nayudamma indicated that considerable lacuna, however, still exists in the commercial implementation of the products and processes developed by the research laboratories and called upon the industrialists, entrepreneurs and research laboratories for greater and meaningful collaboration to meet this end. Prof. Nayudamma, on his own behalf and on behalf of CSIR offered warm felicitation to the Director and staff of NML and wished them continued success. He congratulated the winners of National Metallurgists Day awards and other award winners and also the NML staff who have been awarded the 25 years of service medallion.

Shri F. A. A. Jasdanwalla, President, Indian Institute of Metals, narrated the activities of Indian Institute of Metals and the part played by this Institution in spreading the metallurgical education and knowledge in the country. He complimented the award winners and thanked the Director and staff of the Laboratory of organizing the celebration in a befitting manner.

Shri Chandrajit Yadav, Union Minister for Steel & Mines, in his inaugural address said "The problem of finding an economic solution of India's endemic problem of poverty has to be sought on modern scientific lines. The conventional path will be of no use. Our indigenous talent in every discipline has to be effectively harnessed so that we can find our own Indian solutions to Indian problems. Borrowed technology will not help us; nor should we depend on them. It is this vision of harnessing our scientific and research talents to the solution of our problems that spurred Shri Jawaharlal Nehru to establish within a few years of our becoming free, a net work of scientific and research institutions throughout the country. Nehru conceived of it and with Bhatnagar as his ally, he

could achieve it in surprisingly short period. Sir C. V. Raman, once applauded this, as the 'Nehru-Bhatnagar' effect.

Continuing, he said that fundamental research is important but a much higher priority has to be accorded to the applied aspects of research. Let not the scientists, the engineers, the technologists and others forget that if today the Government is making available whatever resources it can spare, for promoting research, this is being done at the cost of continuing to deprive millions of our people of some of the basic necessities of life. This investment is made in the hope and confidence that, with these resources, country's scientific and engineering talent will be in a position to give the results of their labour which would enable us to satisfy the needs of the people speedily and at a lesser cost. NML during this short period of a quarter century has to its credit a number of indigenously developed processes which have successfully been translated to industrial implementation.Under the leadership of Prof. V. A. Altekar, the scientists are striving to make progress, to do better than before, in promoting the greater welfare of nation, thus setting fine example of the determination of India to produce her own technology by the use of her own technologists and scientists. Otherwise also, the country has now a well established technological base and the national laboratories, under the dynamic leadership of Prof. Nayudamma are doing excellent work. NML and its scientists have, of course, contributed much to the assessment of raw materials for use in metallurgical industry in the country, both in the private and public sectors. They have acquired the necessary expertise for setting up ore treatment plants. National Metallurgical Laboratory has shown exemplary courage in taking up the challenging initiative for promoting the direct reduction techniques in the production of sponge iron. This can result in establishing a large number of mini steel plants in the country which will serve the steel requirements of the areas nearby utilizing wherever possible, the deposits of iron are available. These mini steel plants, using sponge iron technique, will be able to provide 20 to 25% of the steel requirements in the years to come.

What is crucial is the establishment of close liaison between the research institutions and the production units. The results of research must be tested on production units. That will help us to gain confidence. It is in this context that the NML successfully carried out experiments with the Mysore Iron and Steel Works at Bhadravati recently. It was the drive of NML to develop the technology for the production of ferro-vanadium and the extraction of the vanadium from the vanadiferous ores in Karnataka State that goaded them to seek the collaboration of the Steel Works at Bhadravati. This technology yields high grade pig iron with low phosphorus and silicon, the latter being obtained as a by-product, much in demand by foundries. Similarly, the development of the alloy aluminium conductor NML-PM2 has bright prospects for use since it will help to replace copper in many electrical applications. The Central Creep Testing Facility set up at NML with UNDP assistance for testing and development

of high temperature materials for use in aeroengines, boilers, pressure vessels etc. is a significant addition. Messrs. Bharat Heavy Electricals and Kalpakam Reactor Research Centre are already utilizing these facilities by sponsoring long term investigations.

Shri Yadav paid a tribute to Jamshetji Tata whose vision and courage sixty years ago resulted in the establishment of the first steel plant in the country and called upon industrialists of today to emulate Jamshetji Tata's example.

The N. P. Gandhi Memorial Lecture of Indian Institute of Metals was delivered by Dr. P. L. Agarwala, General Manager, Rourkela Steel Plant. Dr. Agarwala gave an illuminating lecture on the fifteen years of experience of oxygen steel making in L-D converters at Rourkela Steel Plant.

Shri Parvez Mehta, President, Jamshedpur Chapter of Indian Institute of Metals proposed a vote of thanks.

The NML Silver Jubilee Celebration and 13th National Metallurgists' Day was marked by the award of Silver medallion to 47 staff members of NML who have completed 25 years of service and the National Metallurgists' awards of 1975 were received by four young metallurgists based on their contribution in the field of research, development, education and industrial production. In the afternoon a Symposium on "Problems in Transfer of Technology from R&D Laboratories to Industries" was held in which ten interesting papers including foreign papers were presented and discussed. On 17th & 18th November, 1975 the 29th Annual Technical Meeting of Indian Institute of Metals was held in which 164 papers covering various disciplines of metallurgy were presented and discussed in a number of parallel sessions.

On the occasion of NML Silver Jubilee, a well illustrated brochure on NML and Silver Jubilee Souvenir was brought out. Special supplements were published in 'Financial Express' and 'Engineering Times'.

A documentary film on 'National Metallurgical Laboratory' depicting the research and development work was produced on this occasion in collaboration with Films Division of India.

The budget statements on project basis of Fifth Plan Proposals covering R&D projects, pilot plant studies and infrastructural facilities were prepared showing the revised estimates for 1975-76 and budget estimates for 1976-77. These budget proposals are supported with project data for each project in which the type of project, priority rating, date of commencement, anticipated date of completion, objectives planned and achieved during 1974-75, objectives envisaged during 1975-76, work contemplated during 1976-77, etc. had been indicated along with the project requirements such as scientific and supporting staff, machinery and equipment, chemicals and other particulars.

Augmentation of Extraction Metallurgical Facilities at National Metallurgical Laboratory.

An appraisal UNIDO/UNDP joint mission visited NML from 11th to 17th March, 1975 and scrutinised the 'Project Document' prepared regarding UNDP project on "Augmentation of Extraction Metallurgical Facilities at NML".

PUBLICATIONS

During the period under review, the following publications were prepared, edited and brought out.

NML Technical Journal

The four issues of NML Technical Journal Vol. 17, 1971 were brought out. The November issue of the journal (Vol. 17, Nov. 4, 1975) was brought out as a special NML Silver Jubilee Number to commemorate the occasion of NML Silver Jubilee.

Brochure

A new illustrated brochure on National Metallurgical Laboratory depicting the current activities and achievements of the Laboratory was prepared and published on the occasion to NML Silver Jubilee.

NML Silver Jubilee Souvenir

A Silver Jubilee Souvenir was published on the occasion of NML Silver Jubilee. The souvenior contains the congratulatory messages from President, Vice-President & Prime Minister of India; Governor & Chief Minister of Bihar, Deputy Chairman Planning Commission & Vice-President of CSIR & Director-General of CSIR. The Souvenir gives an account of the twenty-five year activity of NML; year wise (since inception) figure of papers published, reports prepared with graphical representation, expenditure figure since inception, various national & international awards and honours received by staff members, NML processes and products under commercial production and sale value of products, patents, publications, social activities, etc.

Supplements on NML Silver Jubilee Celebration

Special supplements on 'NML Silver Jubilee, 13th National Metallurgists' Day & 29th Annual Technical Meeting of Indian Institute of Metals' were published in 'Financial Express' and 'Engineering Times' to commemorate the NML Silver Jubilee Celebration from 14th to 16th November, 1975.

Documented Survey on Metallurgical Development

The monthly issues of this publication were brought out.

Folders & Handouts

Folders and handouts for exhibition, get-together outling processes and technologies developed for commercial production were prepared.

Papers Published and Presented

Details furnished in Appendix I.

Research and Investigation Reports Prepared

Details furnished in Appendix II.

LIBRARY AND DOCUMENTATION SERVICES

Library & Documentation Services.

During the year under review, 1795 volumes were added to the stock of the main Library at the NML raising to its total holding to 32,160 bound volumes. In addition the reference holdings at the NML Field Stations, including the NML Unit at the Madras Complex, have gone up by another 1,660 books. The Library has also been receiving over 600 scientific journals in the field of metallurgy and allied disciplines.

The NML Library has been recognised as the National Branch Information Centre in the field of metallurgy. Metallurgists and research workers of several educational and research institutes, as well as from industries, have continued to use this Library. Comprehensive bibliographies on specific topics are prepared and made available to actual users.

Patent Index.

The NML is one of the inspection centres established by the Indian Patent Office and, therefore, gets supplies of all patents specifications filed with the Indian Patent Office. Patents relating to metallurgical and allied subjects are separated out and maintained in separately classified files so that these are more readily made available to the users. A patent index file covering both Indian and foreign patents has also been started and reference cards covering such patents are added to the main documentation card files.

INDUSTRIAL LIAISON AND RESEARCH CO-ORDINATION

Get-together and Exhibitions

In the get-together organised by RRL, Bhubaneswar; (13th & 14th April 1975) the pioneering work done by the NML on production of sponge iron was highlighted. Besides, NML also participated in the exhibition organised by the RRL. The processes/products developed at the NML were explained to various parties interested and the relevant literature was also given to them.

A technology exhibition of CSIR was organised by Birla Industrial & Technological Museum and was held from 27th April to 2nd May, 1975 at their premises. The NML participated in the exhibition by display of the various products/processes developed and R&D work at NML. An industrial get-together was also held on 27th and 29th April, 1975; wherein several

A view of the NML Stall of the CSIR Technology Exhibition organized by Birla Industrial & Technological Museum.

entrepreneurs/industrialists were informed of the processes developed at the NML. They were also informed of the economic and technical viability of the NML processes.

In the get-together held at Bangalore on 7th and 8th June, 1975, work done on the minerals of the Karnataka State such as iron ore, graphite ore, manganese ore etc. as well as scope of assistance which NML can offer for their copper project, refractories etc. was highlighted. During the meeting, numerous enquiries on the processes/products such as bimetallic strips, hot-dip aluminising, production of steel by side-blown converter process, silicon-carbide, crucibles etc. were attended to.

NML also participated in the exhibition organised by the Regional Institute of Technology, Jamshedpur, on 15th and 16th December, 1975 where the processes/products were displayed for the benefit of the local entrepreneurs.

Institutional Consultancy Services

The following advisory consultancy services were rendered :

(*a*) Selection of certain types of steels and one type of stainless steel for actual inplant development.

(*b*) Definition of terms relating to aluminium products and the relationship of ingots/wire bars with crude aluminium.

(*c*) Top-blown converter technique of making steel.

(*d*) Establishment of a graphite beneficiation plant (Based on sponsored investigation).

Collaborative Projects

A team of Professors from Indian Institute of Technology, Kharagpur, visited NML for discussions with the scientists of NML to identify areas of mutual collaboration and also examined the various facilities available to bridge the gaps in their requirements of equipments and facilities. Similarly, a team of scientists visited Kharagpur and discussed with IIT staff members. Areas of interaction and other aspects for smooth functioning of the mechanism were finalised.

A few projects were identified and to start with, a project on 'Development of high temperature materials having good creep and oxidation resistance at elevated service temperature' has been taken up for immediate consideration.

Transfer of Technology

(*i*) *Production of Sponge Iron*

India's first sponge iron plant with a capacity of 25-30000 tonnes

per year based on the technology of solid reduction process as developed at the NML was inaugurated by the Union Minister for Industry & Civil Supplies, Mr. T. A. Pai; on 2nd June, 1975 at the plant site of M/s. Andhra Cement Co. Ltd., Vijayawada. Mr. Pai warmly congratulated Prof. V.A. Altekar, Director, NML, and his colleagues who have helped in setting up the plant on the basis of 'our own technology, genius and abilities'.

(*ii*) *Ferro-vanadium from Vanadiferous Iron Ores at the Visvesvaraya Iron & Steel Ltd. (VISL), Bhadravati*

The NML's technology for production of vanadium bearing slag and therefrom ferro-vanadium utilising vanadiferous iron ores has been industrially implemented at the plant of VISL.

(*iii*) *Electrolytic Manganese Dioxide*

M/s. T. K. Chemicals Ltd., Trivandrum; has taken up the NML developed know-how for the production of electrolytic manganese dioxide.

Delegates/Mission Visits

(*i*) A high level Nigerian Steel Development Authority Delegation visited NML and its pilot plants to see the existing facilities available particularly in the fields of production of sponge iron and mineral beneficiation techniques. They held discussions with the senior scientists of NML and also explored the possibilities on the provision of training facilities for Nigerian steel engineers in NML.

(*ii*) A UNIDO/UNDP team visited NML for evaluation of the Central Creep Testing facilities at the NML and had discussions with NML experts regarding the progress made by the project. The evaluation team also held consultations with the user industries such as Bharat Heavy Electricals Ltd., Steel Authority of India; A.C.C. Vickers Babcock Ltd.; Durgapur Steel Plant, Alloy Steel Plant; Tata Iron & Steel Co. Ltd. and Indian Tube Co. Ltd.

(*iii*) A delegation consisting of five senior technical officials from the Andean Development Corpn. also visited NML and its pilot plants under the CSIR/UNIDO Technology Transfer/Familiarisation Programme with a view to exploring the possibility of technology transfer from the experience of India to the Andean Group. The delegation had very useful discussions with a large group of NML scientists drawn from different disciplines of the laboratory. There was a good deal of exchange of information and sharing of experience with the possibility of the transfer of suitable and viable technologies developed at the NML to the Andean Countries.

Visitors

Sixty-one distinguished visitors both from India and abroad paid

visit to the NML. The list includes a stream of foreigners from various countries such as UK, USA, Canada, Iraq, Nigeria, France, Bulgaria, Brazil, Andean countries etc.

Over 300 entrepreneurs visited NML and had technical discussions on various matters relating to metallurgical industries mainly on processes and products developed at the NML. The list includes licencees, technocrats, engineers, etc. A large number of students from various technical institutions also visited the laboratory.

Training at NML

Fortyone trainees deputed by various organisations such as Indian Institute of Technology, National Institute of Foundry & Forge Technology, Bharat Heavy Electricals, Indian Ordnance Factory and various other universities underwent training in multifarious disciplines of metallurgy such as physical/industrial/general metallurgy, alloy steel development, melting and metal working technology, foundry techniques, refractories, corrosion prevention techniques, ore dressing and beneficiation techniques, etc.

Photographic and Reprographic Services

Technical photographic and reprographic services as an aid to R & D work was continued. Wide photographic coverage was rendered for the Silver Jubilee Celebrations held in the month of November, 1975. A documentary film in collaboration with Films Division was produced to commemorate the Silver Jubilee covering the research and development activities as well as commercial utilisation of NML processes in different parts of the country. The film was screened throughout the country, by the Films Division network. 16 mm documentary film on different research projects as well as on Silver Jubilee Celebrations was also produced by the NML staff on this occasion.

Printing Services

In addition to various printing jobs that are normally undertaken; special bulletins, memos, circulars etc. for the various seminars held during the Silver Jubilee year of the NML and the main functions were attended to.

PATENTS AND PROCESSES

Patents Filed

	Title	*Inventors*
1.	Improvements in or relating to the manufacturing process of versatile aluminium/alloy aluminium conductor for multifarious electrical applications (corresponding to I. P. Application No. 2042/Cal/73 dated 6.9.73)	Rajendra Kumar and Manjit Singh.
2.	(a) New continuation in part application to already filed US Pat. No. 434,677 dated 18.1.74.	*Do*
	(b) Patent of addition filed Indian Pat. No. 2042/Cal/74.	*Do*
	The patent had also been filed in UK (Application No. 110044/74 dated 12.3.74)	
3.	Improvements in a relating to recovery of tellurium from copper refinery slimes (I. P. No. 1484/Cal/75 dated 29.7.75)	Narinder Singh & S. B. Mathur.
4.	An improved process for smelting of lead (I. P. No. 1725/Cal/75 dt. 10-9-75)	V. A. Altekar, Narinder Singh & S. B. Mathur.
5.	Improvements in or relating to preparation of manganese sulphate from manganese ores (I.P. No. 2339/Cal/75 dated 15.12.75)	V. A. Altekar, H. K. Chakrabarti, N. Dhananjayan & P. L. Sengupta, NML & S. K. Grover and P. C. Bhatia of M/s. M. M. Suri & Associates Pvt. Ltd., Delhi.
6.	An improved method and apparatus for making spherical aluminium particles (I.P. No. 66/Cal/76 dated 12.1.76)	D. D. Akerkar & A. K. Nayak.
7.	An improved process for electrothermal distillation of metals and alloys (I.P. No. 323/Cal/76 dated 24.2.76)	V. A. Altekar.

8. Improvements in or relating to smelting (electro-thermal) of lead from lead sulphide concentrates. V. A. Altekar.

Processes Ready for Release

Several processes such as self-setting sodium silicate sand for production of moulds and cores, silve based dental amalgam alloy, dental clips, an improved process for smelting of lead concentrates, iron-silicon-magnesium alloy, magnesium inoculant briquettes, for nodular iron production, recovery of vanadium from vanadium sludge, production of high alumina cement (CA) having 65-75% Al_3O_3 content, production of refractory castables suitable for different end uses process for prevention of tarnishing of copper and copper based alloys are ready for release and exploitation by the industry.

GENERAL

Recipient of Honours, Awards etc.

Forty-eight staff members were awarded twenty-five years service medallion on the occasion of NML Silver Jubilee. On this occasion, a special medallion was awarded to Dr. B. R. Nijhawan, former Director of NML, for his contribution towards the outstanding growth and development of National Metallurgical Laboratory under his guidance.

Japan Iron & Steel Institute has awarded a silver plaque to National Metallurgical Laboratory for its contribution in the field of research and development in metallurgy of iron and steel, on the occasion of Silver Jubilee of the Laboratory.

In recognition of the work done at NML on development of NML-PM2 alloy aluminium conductor, The Cable & Conductor Manufacturers' Association of India have given an award with citation "Excellence in R & D Aluminium Cable and Conductor". The award was presented by the President of India to NML which was received by Dr. R. Kumar, Scientist, on behalf of NML. The Executive Committee of NML has placed on record their appreciation for this work as well as for the various scientific & technical activities of NML.

Dr. R. Kumar, Scientist, has received the 2nd *Indranil* award for metallurgy from Mining, Geological & Metallurgical Institute of India for his book entitled 'Physical Metallurgy of Iron & Steel'.

Dr. R. V. Hargave, Scientist, has obtained Ph.D. degree of Ranchi University.

Shri J. P. Tewari, Scientist and Shri S. K. Gupta, S.L.A. have obtained the Degree of Master of Engineering (Met) from University of Roorkee. Shri S. K. Gupta has also been awarded a Gold Medal for standing first Class first.

Shri P. S. Nag, J.S.A., has obtained the Associate Membership of Indian Institute of Metals through examination.

Foreign Deputation/Training in India and Abroad

Shri N. K. Das, Scientist	Deputed to U.K. under Exchange Programme with British Council for training in the field of melting and casting techniques of reactive and special alloys.
Shri N. V. Nagaraja, S.S.A.	Deputed to Bulgaria under Exchange Programme for training in the field of agglomeration, pre-reduction and fluidised bed roasting of ore fine.

Dr. M. R. K. Rao, Scientist	Deputed to U.S.A. under Exchange Programme to study welding fluxes used in welding of low alloy steels, non-ferrous metals etc.
Dr. N. Dhananjayan, Scientist	Deputed to Romania under Scientific & Technological Co-operation between Govt. of India & Socialist Republic of Romania to study the latest methods in hydro-metallurgical techniques particularly on liquid-extraction and ion exchange.
Shri D. M. Chakrabarti, Scientist	Deputed to Bulgaria under Indo-Bulgaria Exchange Programme for advance training in ore-dressing techniques.
Dr. Inder Singh, Scientist	Deputed to USSR as a Member of the Indian Delegation under Indo-Soviet Agreement on Science & Technology, for the project on corrosion problems in tropical climate conditions including sea corrosion of structural steel.
Shri L. N. Das, Scientist	Deputed to U.K. for training in the field of creep testing under UNDP assistance project Creep Testing Facilities established at NML.
Shri Arjun Dev, S.T.A.	-do-
Shri K. N. Gupta, Scientist	Deputed to U.S.A. under Indo-US Exchange Programme for studying latest development in ferrous metallurgy.
Shri V. S. Sampath, Scientist	Attended a course on Research Management organised by Administrative Staff College, Hyderabad.
Shri P. K. Nag, Scientist Shri M. R. Kulkarni, Scientist	Attended Workshop-cum-Training Programme on Project Management conducted by CSIR Management Training Unit at National Institute of Oceanography, Goa.
Shri K. C. Ray, Scientist Shri T. K. Gangadharan, S.T.A.	Attended Refresher Course in Refractories organised by Indian Refractory Makers' Association, Calcutta.

Shri A. N. Mukherjee, Scientist	Attended a course on 'Corrosion of Metals and its Prevention' at Indian Institute of Science, Bangalore.
Shri P. P. Gupta, J.S.A.	Training in Instrumental Analysis in National Institute of Foundry & Forge Technology, Ranchi.
Shri S. K. Sinhababu, S.L.A.	Attended Refresher Course on 'Technology of Grey Iron Castings' organized by National Institute of Foundry & Forge Technology, Ranchi.
Shri R. N. P. Gupta, Scientist	Attended Advance Foundry Course organised by Indian Institute of Technology, Kharagpur.
Shri T. A. Beck, Scientist	-do-
Shri R. K. Mahanti, S.S.A.	Attended Short Term Course on 'Operation Management' at Xavier Labour Relation Institute, Jamshedpur.
Shri S. Pramanik, S.S.A.	Attended Refresher Course on Powder Metallurgy Organised by Indian Institute of Technology, Bombay.
Shri V. K. Gupta, S.T.A.	Attended a course on 'Information Storage and Retrieval systems' organised by SIET Institute, Hyderabad.

The following foreign scientists, technologists & dignitory visited the National Metallurgical Laboratory :—

	Name	*Country*
1.	Mr. U. Tintun Senior Scientist, Central Research Organization, Burma.	Burma
2.	Mr. P. A. Woodrow, Chief of Production Technology, National Research Development Corpn., U.K.	U.K.
3.	Prof. Dimitrov Erinin, Head of the Ferrous, Metallurgy Department of Bulgaria, Sofia.	Bulgaria

4.	Prof. L. Guiraldenq, Laboratoire De Metallurgie, Physique, France.	France
5.	Dr. R. P. M. Proctor, Corrosion & Protection Centre, Institute of Science & Technology, University of Manchester, U.K.	U.K.
6.	Dr. B. J. Meadows, Sr. Lecturer, Deptt. of Metallurgy, University of Aston, Birmingham.	U.K.
7.	Prof. B. B. Argent, Head of the Deptt. of Metallurgy, University of Sheffield, U.K.	U.K.
8.	Dr. W. E. Khadir, Director-General, Iron & Steel Co., Iraq.	Iraq
9.	Dr. E. V. Kulikov & Prof. U. P. Pulokhin, Tiazhpromexport, U.S.S.R.	U.S.S.R.
10.	Dr. D. J. Urquhart, Ex-Director, National Lending Library, for Science & Technology, Boston.	U.K.
11.	Dr. G. H. Watson, National Coal Board, Coal Research Establishment, Near Cheltenham, U.K.	U.K.
12.	Prof. James White, Dysore Professor of Refractories, University of Sheffield, U.K.	U.K.
13.	Dr. Oshuntoke, Principal Metallurgist, National Steel Development Authority, Nigeria.	Nigeria
14.	Mr. Olufemi Ojo, Nigerian Training Supervisor, Stationed at Bhila Technical Institute, Bhilai Steel Plant.	Nigeria

15. Mr. J. R. Maybee, Canada
Canadian High Commissioner to India,
Govt. of Canada.

16. A Joint Mission of UNIDO/UNDP.

Directorship, Chairmanship, Membership etc. on Outside Bodies

Prof. V. A. Altekar, Director	Director	Board of Directors of M.P. State Mining Corporation.
Dr. R. Kumar, Scientist	Convenor	Metals & Corrosion Committee of CSIR.
	Member	Central Boilers Board
	Chairman	Indian Institute of Metals, Jamshedpur Chapter.
	Member	Nation Council of Indian Institute of Metals.
Shri G. P. Mathur, Scientist	Hony. Secy.	Indian Institute of Mineral Engineers.
	Member	Academic Council, Indian School of Mines.
Dr. Ved Prakash, Scientist	Member	Indian Cryogenic Council.
	Member	Magnetic Society of India.
Dr. M. R. K. Rao	Member	Indian Institute of Ceramics.
	Member	Panel of Refractory Industry.
	Member	Panel of Carbon & Graphite, Industry.
Dr. Manjit Singh, Scientist	Hony. Secy.	Industrial Metallurgy Division Indian Institute of Metals.
Shri R. N. P. Gupta, Scientist	Member	Panel of Engg. Industries organised by R & D Committee of Gujarat State.
Shri C. R. Tewari, Scientist	Member	Magnetic Society of India.

Dr. Venkatesh Rao, Scientist	Member	Magnetic Society of India.
Shri S. Pramanik, S.S.A.	Member	-do-
Shri R. Jha, S.S.A.	Member	-do-
Shri D. Bandopadhaya, J.S.A.	Member	-do-
Shri Prakash Narayan, S.L.A.	Member	-do-

Lectures

A number of lectures were delivered by distinguished foreign and Indian metallurgists, technologists etc. during the period under review. The following special lectures were delivered by NML staff.

Name	*Subject*
Prof. V. A. Altekar, Director	Corrosion protection—A joint responsibility of the scientists and engineers; key-note address at the seminar on 'Corrosion of Metals in Industries and its Prevention Techniques' organised by NML and National Safety Council.
Dr. R. Kumar, Scientist	Principles of ingot solidification; at short term course on 'Ingot Defects' organised by Indian Institute of Metals, Jamshedpur Chapter.
Dr. P. R. Khangaonkar, Scientist	Iron & steel making—past & present, at SAEST (Madras Complex) Meeting.
Shri R. D. Gupta, Scientist	Wear resistant materials and hard facing at a course on Tribology organised by Foundry Division of TELCO.

Purchase & Stores

Purchase & Stores kept up their activities by procurement of capital equipment, raw materials, consumable stores for various research and development projects, construction and maintenance work etc.

Administration & Accounts

Administration & Accounts Section handled the administrative and budgetary affairs of the Laboratory. To streamline the preparation of the pay slips of different categories of staff 'Bradma' machine has been introduced and the payment is made through the State Bank of India, NML Branch.

Safety First and First Aid Section

Safety measures are taken for operating the various plants and equipments of the Laboratory, gas pipeline etc. and inspection of the safety measures is carried out regularly.

There was no major casualty during the period. The First Aid Section treated minor injuries and ailments 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 etc. to staff members.

NML Club maintained its sporting and social activities. The Club took part in local tournaments and also organized tournaments for NML staff and their families. Film shows are held regularly for the members of the Club. The NML canteen is supplying to staff member meals, snacks, tea & coffee etc. at reasonable price.

NML Welfare Committees at Agrico & Tuiladungri Colonies continued to look after cleanliness of the colonies, planting of trees inside the colony etc. Two kindergarten schools, one at each colony, are run for the children of the staff members. Music, dance, arts and craft classes are held regularly. Open-air film shows are organised periodically.

Staff Position

Scientific	197
Technical	453
Administration	151

Budget Figures

Recurring (Non-Plan)	*Figures in lakhs of rupees*
P-1 Pay of Officers	24.263
P-2 Pay of Establishment	27.988
P-3 Allowances	33.023

P-4 Contingencies		17.789
P-6 Maintenance		2.203
P-7 Chemicals		10.934
	Total	116.200
Capital (Non-Plan)		
P-5(4) Books		3.070
	Total	3.070
Capital (Plan)		
P-5(1) Works		4.874
P-5(2) Services		3.027
P-5(3) Apparatus & Equipment		16.753
P-5(4) Furniture		0.423
P-5(4) Vehicles		0.153
	Total	25.230
Pilot Plants (Plan)		
PP-1(I) Equipment		0.644
PP-1(II) Building		0.466
PP-2 Pay of staff		13.381
PP-3 Raw materials		0.240
PP-4 Miscellaneous		4.855
	Total	19.586
Hydro-Electro Metallurgy Projects (Plan)		5.576
	Grand Total	**169.662**

APPENDIX I

Papers Published, Communicated and Presented

1. Some problems of technology transfer in India—V. A. Altekar, NML Technical Journal, Vol. 17 (1975) 3 & 4—NML Silver Jubilee Number; Presented at the Symposium on 'Problems in Transfer of Technology from R & D Laboratory to Industries'—organised by NML & Ind. Inst. of Metals, 14th Nov. 1975.
2. NML-PM2 Conductor—A versatile aluminium Conductor—Why and for Whom?—R. Kumar; NML Technical Journal, Vol. 17 (1975) 3 & 4—NML Silver Jubilee Number.
3. Twentyfive years of dedicated service by National Metallurgical Laboratory to the mineral industries—G. P. Mathur & N. Chakravarty; NML Technical Journal, Vol. 17 (1975), 3 & 4—NML Silver Jubilee Number.
4. Anodizing of hot-dip aluminized mild and stainless steel improves corrosion and heat resistance—T. L. Sharma, A. Nag, S. M. Arora, Y. N. Trehan & V. A. Altekar; NML Technical Journal, Vol. 18 (1976) 1.
5. Some particulate properties of calcined petroleum coke—H. P. S. Murthy, B. Chatterjee & N. B. Sirkar; NML Technical Journal, Vol. 18 (1976) 1.
6. NML in retrospect—V. A. Altekar; Financial Express Supplement, 13th November, 1975.
7. NML—one link in the life line of the nation—R. Kumar; Financial Express Supplement, 13th Nov. 1975.
8. Twentyfive years of dedicated service by NML to the mineral industry—G. P. Mathur; Financial Express Supplement, 13th Nov. 1975.
9. NML's contribution to the development of mineral and metallurgical industries—V. A. Altekar; Engineering Times Supplement, 13th November, 1975.
10. A profile of NML-PM2 conductor—R. Kumar & Manjit Singh; Engineering Times Supplement, 13th Nov. 1975.
11. Spectro-chemical analysis of residual impurities in ferro-chrome by solution spark technique—M. K. Ghosh, S. V. Gopal Krishnan & H. K. Chakravarty—Metallurgia & Metal Forming—Vol. 42 No. 12 December, 1975.
12. Formation of metastable phases in Al-Mg-Si alloys by rapid solidification—R. Kumar & S. K. Bose—Proceedings of 2nd International Conference on Rapidly Quenched Metals, 1975; Massachusettes Institute of Technology, U.S.A.
13. Metallurgical evaluation of surgical implants—need for quality control—G. G. Nair, B. N. Haldar & Rajendra Kumar—ISI Bulletin, Vol. 28, No. 2, Feb. 1976.
14. Twentyfive years of service by National Metallurgical Laboratory to mineral and metallurgical industries—V. A. Altekar; Journal of Industry & Trade, March, 1976.

15. Inhibition of corrosion of aluminium alloys in sodium hydroxide solution—A. N. Mukherjee, Inder Singh & V. A. Altekar; British Corrosion Journal, Vol. 10, No. 3, 1975.
16. Inhibition of acid corrosion and hydrogen absorption in presence of some mercaptanes—Inder Singh, A. K. Lahiri & V. A. Altekar; Proceedings of the Fifth International Congress on Metallic Corrosion; pp. 570-574.
17. Transfer of sponge iron production technology from laboratory to industry—V.A. Altekar & V. S. Sampath ; Productivity Journal, July-Sept. 1975.
18. Technological innovations for improving productivity—V. A. Altekar & V. S. Sampath ; Specialist Administration, Oct. 1975, pp. 149-151.
19. NML's role in solving industrial problems—V. A. Altekar, Chemical Times.
20. Distribution of copper and magnesium between molten aluminium and lead—R. Kumar & C. S. Sivaramakrishnan ; Trans. of Japan Institute of Metals, Vol. 15 ; Nov. 5, 1975, pp. 319-323.
21. Thermo electric power and resistivity of Cu-Sn alloys at high temperature—Rajendra Kumar & T. H. D. Sinha ;—Indian Journal of Pure & Applied Physics ; Vol. 13, 1975, pp. 443-446.
22. Use of NML-PM2 as magnet wires in electrical machinery—R. Kumar & Manjit Singh ; Electrical India, 31.1.1976, pp. 5-12.
23. Electric grade aluminium alloy conductor, NML-PM2—R. Kumar & Manjit Singh, Invention Intelligence, Sept. 1975.
24. Analysis of alloys & salt solution by beta ray scattering—Mrs. A. Bahadur, K. D. Maji & R. Kumar ; Journal of Applied Chemistry & Bio-technology ; Vol. 25, 1975, pp. 515-522.
25. Metallurgical aspects of steam turbine materials—K. M. Chowdhury, R. Singh & R. Kumar ; Tool & Alloy Steel, Jan. 1976, pp. 7-21.
26. Potentialities in South India for the production of materials of strategic value—V. S. Sampath ; Kalaingyer International, Nov. 1975 (Industry & Power Number), pp. 14-22.
27. Corrosion study of NML-PM2 alloy—M. N. Singh, K. P. Mukherjee, R. K. Mahanti, Manjit Singh & R. Kumar ; Cable & Conductor News, August 1975.
28. Aluminium cable & conductor industries—prospects & periods—R. Kumar ; Proc. of the Seminar on "Aluminium Conductors & Cables".
29. Development of alloy aluminium conductors—G. K. Ghose, C. S. Sivaramakrishnan, Manjit Singh & R. Kumar ; Proc. of the Seminar on 'Aluminium Conductors & Cables'.
30. Effect of some industrial gase on gel and swelling properties of bentonites—R. R. Dash, R. Prasad & G. N. Rao—Indian Foundry Journal. Vol. 21 No. 12, Dec. 1975.
31. Fluid sand process—T. A. Beck, G. N. Rao & V. A. Altekar ; Indian Foundry Journal, Vol. 21, No. 11, Nov. 1975.
32. Foundry industry in India and the NML—G. N. Rao & V. A. Altekar —Indian Institute of Foundrymen Silver Jubilee Souvenir, Nov.-Dec. 1975.

33. Foundry experience with NML self setting sodium silicate process —G. N. Rao, T. A. Beck, A. Srinivasan & S. D. Deshnikar ; Proc. of International Symposium of I.I.F., New Delhi, 1975, pp. 65-68.
34. Non-metallic foundry raw materials for moulds and cores—G. N. Rao & V. A. Altekar ; Foundry Directory, Silver Jubilee Edition 1975, published by I.I.F. pp. 91-131.
35. Thermal expansion of some binary alloys—L. J. Balasundaran & A. N. Sinha ; Trans. of Ind. Inst. of Metals, Vol. 28, No. 2 April, 1975.
36. Inhibition of corrosion by thio-urea derivatives—Inder Singh ; Presented at the 6th International Congress on 'Metallic Corrosion' Sydney, 3-9th Dec. 1975.
37. X-ray fluorescence analysis and its application in a research laboratory with special reference to ores, minerals and their processing products. —A. Peravadhanulu, G. P. Mathur & V. A. Altekar ; sent for presentation at the International Confederation for Thermal Analysis (INTERAN '76) to be held at Prague, 23-27th August, 1976.
38. Recovery of tungsten oxide from tungsten carbide scrap—Prem Chand & V. A. Altekar ; Presented at the Seminar on 'Tungsten and its Products' organised by Powder Metallurgy Association of India, Hyderabad, July, 1975.
39. Analysis of some specific performance data obtained during rotary kiln operation for the production of sponge iron—B. L. Sengupta, K. N. Gupta, G. P. Mathur & V. A. Altekar ; Presented at the VII Annual Technical Convention of Indian Institute of Mineral Engineers, July, 1975.
40. Beneficiation of Amjhore Pyrites—P. D. Prasad Rao, S. K. Banerjee & G. P. Mathur ; Same as Sl. No. 39.
41. Sub-standard materials and their use in iron making—J. Goswami & A. N. Kapoor ; Same as sl. no. 39.
42. On some metallurgical considerations in iron ore sintering—H. Patnaik ; Same as sl. no. 39.
43. Manufacture of porous metal bearings by powder metallurgy—S. K. Singh ; presented at the Symposium on 'Sintered Products' organised by Ind. Inst. of Metals, Bangalore branch & Electrochemical Society of India, Bangalore, Sept. 1975.
44. Corrosion protection—A joint responsibility of the scientist and the engineer—V. A. Altekar; presented at the seminar on 'Corrosion of Metals in industries and its Prevention Techniques', organised by NML and National Safety Council, Sept. 1975.
45. Crystal growth in the oxidative corrosion of copper—Y. N. Trehan ; Same as sl. no. 44.
46. Role of different variables in stress corrosion cracking of metals—P. S. Nag & S. B. Chowdhury ; Same as sl. no. 44.
47. Inhibition of metallic corrosion—Inder Singh & M. K. Banerjee ; Same as sl. no. 44.
48. Some observations on service failure encountered in steam power plants—K. N. Chowdhury, B. N. Haldar, G. G. Nair and R. Kumar ; Same as sl. no. 44.

49. Role of some factors affecting atmospheric corrosion of metals in industrial and marine atmosphere—S. Rao Addanki, A. N. Mukherjee, A. K. Dey & M. N. Singh ; Same as sl. no. 44.
50. Hot-dip aluminizing of ferrous materials—a resume of two decades of R&D at NML—S. M. Arora ; Same as sl. no. 44.
51. Corrosion and protective coating—P. Prabhakaran ; Same as sl. no. 44.
52. Cathodic and anodic protection of metals—D. Das, K. P. Mukherjee & H. K. Chakravarty ; Same as sl. no. 44.
53. Some observations of corrosion of alloy steel by sulphurous gases—T. C. Dey ; Same as sl. no. 44.
54. Extraction of nickel and cobalt from oxide ores—B. N. Singh, M. S. Mahanty, D. D. Akerkar & V. A. Altekar ; presented at the Seminar on 'Non-ferrous Metals' organised by Inst. of Engineers (India), A. P. Centre, Oct. 1975.
55. Standardization for physico-chemical methods of testing of iron ores and pellets—K. N. Gupta & G. P. Mathur ; presented at the 16th I.S.I. Convention, Bhopal, Oct. 1975.
56. Use of electric grade aluminium alloy (NML-PM2) in transformers —a convention with standards—R Kumar ; Same as sl no 55
57. Area standards conducive for technology development ?—R Kumar ; Same as sl no. 55.
58. Research studies at NML on industry oriented minerals with special reference to Bihar State—A Pervadhanulu, S. K. Banerjee & G. P. Mathur ; presented at the Geological Symposium organised by State Geological Laboratory, Hazaribagh, Govt. of Bihar, Nov. 1975.
59. Development of wear and abrasion resistant cast iron for centrifugal shot blasting machine—R. D. Gupta & V. A. Altekar ; presented at the Silver Jubilee Symposium of Ind. Inst. of Foundrymen on "Innovation in Metal Casting Technology—Impact on Productivity", Nov. 1975.
60. Moulding properties and pH of gas treated bentonites—R. R. Dash & G. N. Rao ; Same as sl. no. 59.
61. Fluidized sand process—T. A. Beck, G. N. Rao & V. A. Altekar ; Same as sl. no. 59.
62. NML designed equi-blast-cum-balanced-blast cupola's performance. M. N. P. Verma, R. Kumar & V. A. Altekar ; Same as sl. no. 59.
63. Recent trends in the use of coke oven refractories—K. C. Ray & P. C. Sen ; Seminar on 'Coke Oven Refractories' organised by Indian Refractory Makers' Association, Nov. 1975.
64. Refractories for cupola furnace—N N Mathur, R. V. Hargave & M. R. K. Rao, Seminar on "Refractories for Iron Making" organised by Jamshedpur Section of Indian Ceramic Society, Nov. 1975.
65. Use of fused refractories in blast furnace and its ancillaries—K. C. Ray & P. C. Sen ; Same as sl. no. 64.
66. Examination of alkali resistance of blast furnace stack refractories—A. V. Subhramanyan ; Same as sl. no. 64.

67. Studies on clay-grog graphite refractory compositions for iron making—K. K. Singh ; Same as sl. no. 64.
68. Steel strategy with direct reduction electric furnace route—B. K. Paul ; presented at the 29th Annual Technical Meeting of Ind. Inst. of Metals, Nov. 1975.
69. Hot blast cupola iron melting with Indian cokes—R. Santokh Singh, P. S. Virdhi, A. N. Kapoor & R. Kumar ; Same as sl. no. 68.
70. Study of columnar crystallization in alnico-V alloys—Ved Prakash & C. R. Tewari ; Same as sl. no. 68.
71. Rapid solidification of Al-Mg-Si alloys from the liquid state—S. K. Bose & R. Kumar ; Same as sl. no. 68.
72. Effect of alloying additions on the structure and properties of Al-Si alloys—K. Lal & R. Kumar ; Same as sl. no. 68.
73. Development of grain refiner for aluminium alloys—C. S. Sivaramakrishnan, R. K. Mahanty, K. Lal & R. Kumar ; Same as sl. no. 68.
74. Thermostatic bi-metal production and applications—J. Bhattacharya, B. N. Ghose & S. K. Banerjee ; Same as sl. no. 68.
75. Sintering behaviour of Ni-Cu-Mo low alloy steels—J. P. Tewari & G. S. Upadhaya ; Same as sl. no. 68.
76. Investigation on centrifugal dispersion of molten metals for making spherical metal particles—A. K. Nayak & D. D. Akerkar ; Same as sl. no. 68.
77. Sulphitation studies of copper anode slimes—Narinder Singh & S. B. Mathur ; Same as sl. no. 68.
78. Some electrochemical aspects of corrosion behaviour of aluminised and galvanised steels—S. Rao Addanki, M. N. Singh, Inder Singh & V. A. Altekar ; Same as sl. no. 68.
79. Variation in mechanical properties of steels during acid pickling—M. K. Banerjee, Inder Singh & T. R. Soni ; Same as sl. no. 68.
80. Use of Cr_{51} in the study of the effect of chloride of passive films on mild steels—K. D. Maji, Inder Singh & R. Kumar ; Same as sl. no. 68.
81. Studies on de-alloying of Cu-Mn and Cu-Zn brasses in sodium chloride solution—A. N. Mukherjee, P. S. Nag & K. P. Mukherjee ; Same as sl. no. 68.
82. Studies on melting and extrusion characteristics of magnesium base wrought alloys—G. D. Sani, S. C. Dev, R. K. Dubey & R. Kumar ; Same as sl. no. 68.
83. Study into the manganese ore reduction—manganese dioxide to protoxide by solid reductants—A. M Pande & K. N. Gupta ; Same as sl. no. 68.
84. Development of a process for simultaneous electro-winning of zinc and manganese dioxide—A. M. Pande, K. N. Gupta & V. A. Altekar ; Same as sl. no. 68.
85. Same observation on chlorination of fly ash and flue dust to extract germanium—Narinder Singh ; presented at the 28th Annual Session of Ind. Inst. of Chemical Engineers, Dec. 1975.

86. Various grades of stainless steels and their properties—S. S. Bhatnagar; presented at the Seminar on "Application of Stainless Steel in Design, Process Development and Fabrication for Chemical and Process Industries" organised by Fertilizer Corporation of India, Sindri, Dec. 1975.
87. Electric potential—a tool of the corrosion engineer—Inder Singh & V. A. Altekar ; presented at the Seminar on "Corrosion Control" organised by National Productivity Council, Ahmedabad, Feb. 1976.
88. Stainless steel and stress corrosion cracking—S. S. Bhatnagar ; presented at the 4th Seminar on "Alloy Steel" organised by Alloy & Steel Producers Association of India, Feb. 1976.
89. X-ray spectrometric analysis of low alloy steel—S. C. Srivastava & M. K. Ghosh ; presented at the Seminar on "Metallurgical Analysis" organised by Dept. of Chemistry, Ravishankar University, Raipur ; Feb. 1976.
90. Separation of cadmium and zinc and their estimation in cadmium —zinc alloys—S. N. Jha, A. C. Biswas & H. P. Bhattacharya same as sl. no. 89.
91. Determination of zinc, silver, copper, iron and antimony in lead metal by atomic absorption spectrophotometry—L. P. Pandey, A. Ghose & P. Dasgupta ; same as sl. no. 89.
92. Rapid indirect volumetric method for determination of silicon in ferro-silicon—S. N. Jha, A. C. Biswas & H. P. Bhattacharya ; same as sl. no. 89.
93. Simultaneous sequential spectrophotometric method for the determination of silica and alumina in iron ores and sinter—A. C. Biswas, K. K. Padhi & H. P. Bhattacharya ; same as sl. no. 89.
94. Weldability of metals and potential application of explosive welding in modern industries—S. K. Banerjee, J. Bhattacharya & B. N. Ghose ; presented at the Seminar on 'Weldability of Metals and Alloys' organised by Indian Institute of Welding, March, 1976.
95. Extrusion characteristics of alumina refractory bodies—T. K. Gangadharan & A. V. Subrahmanyan ; Presidented at the 40th Annual Session of Indian Ceramic Society, March, 1976.
96. Studies on hydration resistance of sintered dolomite—K. C. Ray, P. C. Sen & M. R. K. Rao ; same as sl. no. 95.
97. Clay bonded graphite refractories—A review—K. K. Singh ; same as sl. no. 95.
98. Effect of chrome ore grade size on microstructure and properties of chrome—magnesite refractories—N. N. Mathur, M. R. K. Rao & P. C. Sen ; same as sl. no. 95.
99. Constitution and microstructure of indigenous basic bricks used in Indian steel plants—R. V. Hargave & M. R. K. Rao ; same as sl. no. 95.
100. An appraisal to beneficiation of some of the low-grade non-ferrous base metal ores at NML—M. V. Ranganathan, R. Ganesh, S. K. Banerjee & G. P. Mathur ; presented at the Seminar on 'Non-ferrous Metals' organised by Inst. of Engineers (India), A. P. Oct. 1975.

101. Beneficiation studies at NML on pyrite, pyrrhotite ore samples with special reference to Rajasthan and Bihar—P. D. Prasad Rao, A. Peravadhanulu, N. Chakravarty, S. K. Banerjee & G. P. Mathur ; presented at the Symposium on 'Pyrites & Phosphates' held at Udaipur, Nov.-Dec. 1975.
102. Investigation on phosphate rocks of India at NML—P. D. Prasad Rao et al, same as sl. no. 101.
103. Recent trends in the development of titanium alloys fo high temperature service—K. M. Chowdhury, R. Choubey & R. Kumar ; presented at the Seminar on 'Titanium Technology' held at Trivandrum, May, 1975.
104. Graphite and its refractory products—N. B. Sirkar, P. C. Sen & M. R. K. Rao ; presented at the Seminar organised by Industries Dept. Kerala State.
105. Relationship between corrosion and physical properties of refractories —A. V. Subhramanyan ; Trans. of Ind. Cer. Soc. May, 1975.
106. Fly ash and flue dust as source of germanium—V. S. Sampath & Narinder Singh ; presented at the Seminar on 'Coal Utilization for Power, Solid, Liquid Fuel, Fertilizers and Chemicals' organised by Indian Chemical Manufacturers and Allied Publications at I.I.T., Bombay.

APPENDIX II

Scientific Investigations Completed and Reports Prepared

1. A report on the tests on iron ores, limestone and charcoal sample received from Nepal Bureau of Mines (IR 826/75).
   Part I — *Beneficiation Studies.*
   Part II — *Reducibility Characteristics of Iron Ores.*
   Part III — *Dissociation Characteristics of Iron Ores and Limestone Sample'*
2. Beneficiation studies on a low grade magnetite sample (APO) from GSI, Kerala—K. Vijayaraghavan, C. Satyanarayan, R. Sreenivasan, P. V. Raman & P. R. Khangaonkar (IR 827/75).
3. Beneficiation studies on a low grade magnetite sample (ZPU) from GSI, Kerala—K. Vijayaraghavan, C. Satyanarayan, R. Sreenivasan, P. V. Raman & P. R. Khangaonkar (IR 828/75).
4. Hot-dip aluminizing of malleable iron castings—S. M. Arora, A Nag, T. R. Soni, S S. Bhatnagar, M. J. Shahani & V. A. Altekar (IR 829/75)
5. Pilot plant investigations on the production of sponge iron in rotary kiln with Bayaram iron ore and Singareni coal for Andhra Pradesh Industrial Development Corporation—B. L. Sengupta, S. R. Ghosh, K. N. Gupta & G. P. Mathur (IR 830/75).
6. Reduction of ash content in a coal sample received from M/s. Telco Ltd.—P. D. Prasad Rao, Joga Singh, S. K. Banerjee & G. P. Mathur (IR 831/75).
7. Beneficiation of phosphate rock from Durmala, U. P. (IR 832/75).
8. Pilot plant studies on beneficiation and sintering of Kemmangundi iron ore from M/s. Mysore Iron & Steel Works Ltd., Pt. II—Sintering —S. Prasad, P. K. Sinha, S. K. Banerjee & G. P. Mathur (IR 833/75).
9. Comprehensive studies on beneficiation of iron ore fines from the Barajamda area, sponsored by MECON for setting up of a Central Pelletizing Plant in the Bihar-Orissa region—N. Chakraborty, H. Patnaik, S. K. Banerjee & G. P. Mathur (IR 834/75).
10. Determination of work index values of three samples received from M/s. Mcnally Bharat Engineering Co. Ltd.—P. N. Pathak, Joga Singh & G. P. Mathur (IR 835/75).
11. Sintering and pelletising studies on the magnetic concentrate produced from low grade Ongole magnetite ore—R. K. Kunwar, S. C. Moulik, B. L. Sengupta. S. K. Banerjee & G. P. Mathur (IR 836/75)
12. Report on investigation of creep, stress-rupture and stress-relaxation properties of 1.1/4% Cr—1% Mo—3/4% V—Ti—B bolting steel—R. Singh, K. Prasad, S. C. Bose, R. Choubey & R. Kumar (IR 837/75).
13. Pilot plant studies on the flowability and screenability characteristics of iron ore lumps from Meghataburu works, NMDC Ltd.—R. K. Kunwar, P. K. Sinha, S. K. Banerjee & G. P. Mathur (IR 838/75).
14. Beneficiation of low grade kyanite from Khamman district, Andhra Pradesh—R. Ganesh, S. K. Banerjee & G. P. Mathur (IR 839/75).

15. Petrological studies on phosphate rock samples from Purulia, West Bengal—B. Banerjee, A. Peravadhanululu & S. K. Banerjee (IR 840/75).
16. Bench scale beneficiation studies for recovery of apatite as a bye-product from the I.C.C. mill tailing samples—M. V. Ranganathan, S. K. Banerjee & G. P. Mathur (IR 841/75).
17. Plan for expansion and modernisation of cast iron foundries—Singareni Collieries Ltd.—K. S. Vijayananayan & P. K. Khangaonkar (IR 842/75).
18. An investigation report on carbon mass and carbonpaste from Bokaro Steel Plant Ltd., Bokaro—B. Chatterjee, B. Mitra, M. C. Kundra & M. R. K. Rao (IR 843/75).
19. Batch and pilot plant studies on low grade graphite samples from Banswara, Rajasthan—R. Ganesh, S. K. Sengupta, N. Chakraborty, S. K. Banerjee & G. P. Mathur (IR 844/75).
20 Bench scale flotation studies on a sample of low grade copper ore (sulphide ore) from Chapri deposit for I.C.C. Ghatshila (HCL)—M. V. Ranganathan, S. K. Banerjee & G. P. Mathur (IR 845/75).
21. Beneficiation of Amjhore pyrite employing gravity method—Joga Singh, P. D. Prasad Rao, S. K. Banerjee & G. P. Mathur (IR 846/75).
22. Investigation on mineralogical nature of tungsten ore concentrate sample from M/s. Sandvik Asia Ltd., Poona—B. Banerjee.
23. Beneficiation of a low grade sillimanite sample from M/s. Minerals Sales (P) Ltd., Hospet—K. Vijayaraghavan, R. Srinivasan, C. Satyanarayan, P. V. Raman & P. R. Khangaonkar (IR 848/75-M).
24. On the suitability of the manganese ore supplied by M/s. Mangilal Rungta for production of electrolytic manganese dioxide and manganese metal—P. L. Sengupta, N. Dhananjayan & H. K. Chakraborty (IR 848/75).
25. Static bed calcination of Jhamarkata phosphate rock—A. K. Saha, A. K. Nayak & D. D. Akerkar (IR 849/75).
26. Beneficiation of iron ore slime received from the Noamundi Washing plant of Tisco Ltd.—R. K. Kunwar, N. Chakravarty, S. K. Banerjee & G. P. Mathur (IR 850/75).
27. Pilot plant studies on beneficiation of low grade lump and fine ores from Codli mines of M/s. Min Goa (P) Ltd.—Tirath Singh, J. S. Padan, S. R. Joti, P. K. Sinha, N. Chakravorty, S. K. Banerjee & G. P. Mathur (IR 851/75).
28. Recovery of vanadium from vanadium sludge from Bayer's alumina process—Narinder Singh, S. B. Mathur, D. D. Akerkar & V. A. Altekar (IR 852/75).
29 Reduction of ash content from the coal washing fines of West Bokaro Collieries of Tisco Ltd—R. K. Kunwar, P. D. Prasad Rao, S. K. Banerjee & G. P. Mathur (IR 853/76).
30. Moulding characteristics of sand sample No. 7 received from Directorate of Geology & Mining, Lucknow (U.P.)—R. C. Arora & M. N. P. Verma (IR 854/76).
31. Pilot plant studies on beneficiation of high grade fine iron ores from Codli mines of M/s. Min Goa (P) Ltd., Tirth Singh, J. S. Padan, S. R. Joti, P. K. Sinha, N. Chakraborty, S. K. Banerjee & G. P. Mathur (IR 855/76).

32. Test report on Maharashtra sillimanite—M. C. Kundra, T. K. Gangadharan & M. R. K. Rao (IR 856/76).
33. Report on investigation of creep stress rupture and stress-relaxation properties of 1% Cr—1% Mo—3/4% V-Ti-B bolting steel—Pt. III—R. Singh, M. Chowdhary, K. Prasad, M. R. Das, S. C. Bose, R. Choubey & R. Kumar (IR 857/76).
34. Report on investigation of creep stress-rupture and stress-relaxation properties of bolting steel En 20B, Pt I—R. Singh, M. Chowdhary, K. Prasad, S. C. Bose, R. Choubey & R. Kumar (IR 858/76).
35. Determination of physical characteristics of fine limestone samples for M/s. Tata-Robins-Fraser Ltd.—S. K. Sil, M. V. Ranganathan, A. Peravadhanulu & S. K. Banerjee (IR 859/76).
36. Beneficiation of iron ore fines from Bolani and Gua mines designated as Type III & IV samples for Central Pelletization Project on the Bihar-Orissa region, sponsored by MECON—H. Patnaik, S. K. Sengupta, N. Chakravorty & G. P. Mathur (IR 860/76).
37. Studies on pelletization characteristics of iron ore fines concentrate from Bolani and Gua mines, sponsored by MECON for Central Pelletization Project in the Bihar-Orissa region—N. Chakravorty, H. Patnaik, R. K. Kunwar & G. P. Mathur (IR 861/76).
38. Electric smelting of Lohara iron ore for the production of pig iron for M/s. Maharashtra Electro-Smelt Ltd.—D. D. Akerkar, N. N. Patra, B. V. S. Yedavalli, R. Santokh Singh, A. K. Saha, P. S. Virdi, Onkar Singh & M. S. Mohanty (IR 862/76).
39. Heavy media separation studies on a magnesite sample from M/s. Burn & Co., Salem—K. Vijayaraghavan, R. Srinivasan, C. Satyanarayan, P. V. Raman & P. R. Khangaonkar (IR 863/76).
40. Development of wear and abrasion resistant cast iron for centrifugal shot blasting machine—R. D. Gupta & V. A. Altekar (RR 348/75).
41. Removal of iron and phosphorus from fluorspar concentrate by selection leaching—Gurdail Singh, M. L. Dey, H. K. Chakravarty & V. A. Altekar (RR 349/75).
42. Pickling of malleable iron castings prior to galvanizing—R. M. D. Nayar, N. V. Naidu & P. R. Khangaonkar (RR 350/75).
43. Cupola iron melting with hot air blast—Pt I—R. Santokh Singh & & P. S. Virdhi (RR 351/75).
44. Cupola iron melting with hot air blast—Pt II—V. A. Altekar, R. Kumar, A. N. Kapoor, R. Santokh Singh & P. S. Virdhi (RR 352/75).
45. Cupola iron melting with oxygen enriched hot air blast—R. Santokh Singh, P. S. Virdhi, A. N. Kapoor & V. A. Altekar (RR 353/75).
46. NML-PM2 conductor—A versatile alloy aluminium conductor—why and for whom ?—R. Kumar (RR 354/75).