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National Metallurgical Laboratory

Jamshedpur, India

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NATIONAL METALLURGICAL LABORATORY

COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH

JAMSHEDPUR, INDIA

Compiled, Edited & Produced by
P. K. Gupta

Secretarial Assistance
Afzal Ahmed
P. V. K. Iyer
T. Radhakrishnan

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

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INTRODUCTION

The research and development work of the National Metallurgical Laboratory, during the period under review, have been geared up to generate a continuous dialogue between the researchers, planners, users and industries for identification and solution of problems pertaining to various disciplines of metallurgy against the background of industrial and national needs. As a result, the laboratory is receiving an increasing number of investigations sponsored by metallurgical and mineral industries who are also keen in exploiting the processes and products developed by the laboratory. In the field of beneficiation and utilization of low grade indigenous ores and minerals, the contributions made by the laboratory have helped the industrial concerns, both in public and private sectors, in determining the suitability of their raw materials for industrial applications. Apart from the detailed investigational work done on batch as well as pilot plant scale, feasibility reports have been prepared and submitted for implementation. Thus work has been done on behalf of M/s. Hindustan Steel Ltd.; Tata Iron & Steel Co.; Bokaro Steel Ltd.; Hindustan Copper Ltd.; Industrial Development Corporation of various States; State Governments; Manganese ores of India; Ferro Alloys Corporation of India; Pyrites, Phosphates and Chemicals Ltd.; Fertilizer Corporation of India; Tinplate Co. of India; Dunlop India Ltd.; Bharat Heavy Electrical Ltd., etc.

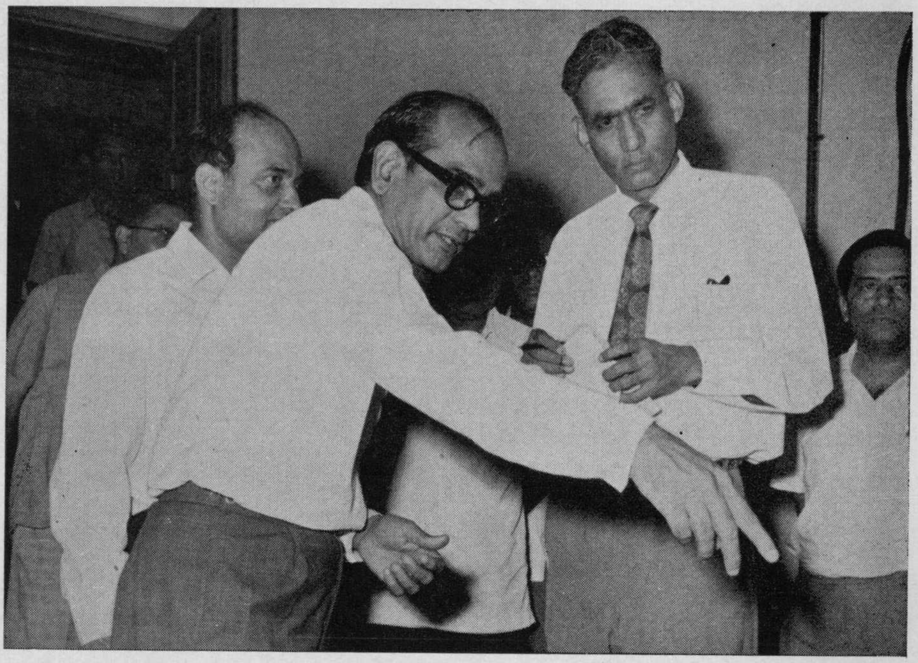
Regarding the processes and products developed by the laboratory, it is significant to mention that negotiations are under way to lease out the technical know-how on the production of steel by side blown basic converter, electrolytic manganese metal and manganese dioxide, synthetic cryolite, extra fine zinc dust etc. besides releasing the processes like production of carbon free ferro-alloys and metal powders for commercial production. A plant is being set up by M/s. Cable Works (I) Ltd., Faridabad, to manufacture electrical resistance heating elements based on the NML developed technique.

The field trials of the telecommunication cables made from aluminium alloy conductor developed by the laboratory has given highly satisfactory performance and action is under way for its commercial scale production and application in place of the copper cables. The first phase of work relating to the development of a suitable lining material for L-D converter of Rourkela Steel Plant is over and the findings have been communicated to the Rourkela Steel Plant authorities. Active consultancy services were provided to Andhra Pradesh Industrial Development Corporation who are interested in the setting up of a graphite beneficiation plant for manufacture of graphite crucibles. In connection with the construction of Tube Railway System at Calcutta, Metropolitan Transport Authorities (Railways) have approached the Laboratory to act as Consultant in connection with the underground corrosion problems due to current leakage.

The laboratory has made considerable progress in setting up the (150 test point) Central Creep Testing Facilities with the assistance of UNDP. The building is coming up rapidly and orders for major items of equipment have already been placed. Work on the establishment of

Hon'ble Shri S. Mohan Kumarmangalam, Union Minister for Steel & Mines, delivering the inaugural address on the occasion of NML Open Day on 26th November, 1972.

Prof. V. A. Altekar, Director, National Metallurgical Laboratory, welcoming the delegates to the Symposium on 'Science and Technology of Sponge Iron and its Conversion to Steel'.



Dr. Y. Nayduamma, Director-General, Scientific & Industrial Research, at the National Metallurgical Laboratory.

Adityapur Complex has been taken up and already hundred acres of land for housing the complex has been obtained in the industrial area of Adityapur, about 16 kilometers from the laboratory. The complex will comprise of semi-commercial industrial plants of sponge iron, rupees one crore hydro-electro-metallurgy facilities, submerged are electric smelting furnace and mineral beneficiation facilities.

The laboratory organized two 'Open Days' one in August and the other in November. The Open Day in August was meant for general public and students, while the Open Day in November was specially meant for the teaching staff, industrialists, technologists, researchers etc. Both the 'Open Days' drew a record number of visitors who evinced keen interest in the work of the laboratory and its contribution towards the progress of mineral and metal industries of the country.

During the year, the laboratory organized a highly successful international Symposium on "Science and Technology of Sponge Iron and its Conversion to Steel" which was attended by a record number of delegates both from overseas countries and India. The proceedings of the Symposium is now being published. Besides this Symposium, the laboratory held a seminar on 'Bacterial Leaching' which subject has now come to the forefront and has attracted the attention of a number of research institutions and organizations.

A well illustrated colourful brochure depicting the activities of the laboratory was brought out to commemorate the Silver-Jubilee Independence Year of the country. The 'NML Technical Journal' has entered its fourteenth year of publication. The 'Documented Survey on Metallurgical Developments' is another publication, brought out monthly and has stepped into its 4th year of publication.

A number of 'Get-togethers' were held in the different state capitals to appraise the state industries about the products and processes developed by the laboratory as well as the assistance that can be rendered to the metallurgical and mineral industries of the States. The 'Get-togethers' roused considerable interest amongst the state industrial departments and respective industrial concerns.

The Field Stations of the laboratory continued to serve the industries located in their respective areas. The Marine Corrosion Research Station at Digha has been continuing its valuable studies on marine corrosion problems.

NML participated, as a constituent of CSIR, in the 'ASIA-72' exhibition. The different products and processes developed by the laboratory and the assistance that has been and can be rendered were exhibited through samples and well illustrated charts, models etc. A special folder on the activities of the laboratory was brought out on the occasion which was considered to be of very high quality.

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

RESEARCH & INVESTIGATION PROJECTS

A. SPONSORED PROJECTS

1.0 Pilot Plant Studies on Beneficiation of SICOM Iron Ore. *Sponsored by SICOM.*

The sample as received assayed 60.1% Fe, 5.2% SiO_2 and 6.3% Al_2O_3. As the ore was of a low grade, it was beneficiated before its use for sponge iron production experiments. The iron content was improved with a total iron recovery of 93.0%.

1.1 Pilot Plant Studies on Beneficiation and Sintering of Donimalai Composite Iron Ore Sample. *Sponsored by CEDB, HSL, Ranchi.*

Studies were undertaken with a composite iron ore sample from Donimalai mines of M/s. National Mineral Development Corporation. The ore as received analysed 66.1% Fe, 1.6% SiO_2 and 2.07% Al_2O_3. The sample assayed 67.2% Fe, 0.8% SiO_2 and 1.0% Al_2O_3 after washing.

Sintering characteristics of the classifier sand mixed with cyclone underflow were studied for making unfluxed as well as fluxed sinters. Good quality sinters were produced.

1.2 Grinding of Iron Ore Fines from Bailadila for Slurry Tests. *Sponsored by Engine ersIndia Ltd.*

Four samples of Bailadila iron ore fines were received for grinding to 75% and 85%—325 mesh sizes for slurry tests.

1.3 Pilot Plant Studies on the Beneficiation of Iron Ore Sample I received from M/s. Bolani Ores Ltd., Orissa. *Sponsored by M/s. Bolani Ores Ltd., Orissa.*

Detailed beneficiation studies on a 60 tonne sample of soft iron ore from Bolani, were undertaken along with the determination of physical characteristics of the original sample as well as of the crushed product.

Three different campaigns were conducted with the sample. In all cases suitable grades of lumps and classifier sands were obtained.

1.4 Pilot Plant Studies on the Beneficiation of Iron Ore Sample II received from M/s. Bolani Ores Ltd..—*Sponsored by Bolani Ores Ltd., Orissa.*

Studies were made on 60 tonnes sample, run of mine ore, under three campaigns. The 1st campaign gave the best performance. Product from campaign I assayed 61.0% Fe, 1.78% SiO_2, and 4.87% Al_2O_3.

1.5 Pilot Plant Studies on Beneficiation and Sintering of Five Types of Iron Ore Samples from Donimalai Mines. *Sponsored by CEDB, HSL, Ranchi.*

Beneficiation and sintering studies on five different types of samples of iron ore from Donimalai Mines, Mysore, are in progress. The tests are being conducted under the optimum conditions obtained earlier with a composite sample received from Donimalai mines.

1.6 Pilot Plant Studies on the Beneficiation of Khondband Hard Iron Ore Sample from M/s. Tisco. *Sponsored by M/s. Tata Iron & Steel Co. Ltd.*

At the instance of M/s. Tata Iron & Steel Co. Ltd., beneficiation studies on hard iron ore sample from their Khondband mines, Orissa; were carried out. The original sample assayed 63.0% Fe, 2.9% SiO_2, 4.0% Al_2O_3 0.10% S and 0.08% P. The sample consisted mostly of hematite in a compact-massive variety with an admixture of hydrated iron oxide minerals such as goethite, limonite, laterite etc. By suitable treatment the quality of the products were enriched.

1.7 Pilot Plant Studies on Beneficiation of Noamundi Iron Ore (Hard) from Tisco. *Sponsored by M/s. Tata Iron & Steel Co. Ltd.*

The sample was received from Tisco Ltd., from its Noamundi mines to study its washing characteristics at two sizes viz. —50 mm and —30 mm. The run of mine ore analysed 63.3% Fe, 1.86% SiO_2 and 4.1% Al_2O_3. After treatment, Fe content was increased by 3%, SiO_2 decreased by 0.2 to 0.3% and Al_2O_3 by 4.0 to 0.5% in washed lumps.

1.8 Pilot Plant Studies on the Beneficiation of Joda Flaky Iron Ore Sample from Tisco. *Sponsored by M/s. Tata Iron & Steel Co. Ltd.*

100 tonnes of Joda flaky iron ore were received from M/s. TISCO Ltd. for beneficiation studies. The original sample assayed 62.92% Fe, 3.40% SiO_2, 4.0% Al_2O_3, 0.044% S and 0.054% P. The samples consisted of massive hematite ore as well as laminated variety with an admixture of hematite with altered oxides of goethite etc.

Suitable grade of washed lumps and classifier sand for use in the blast furnace and for sintering or pelletizing was obtained.

1.9 Studies on Production of Fluxed Sinters with —10+3 mm. Iron Ore Fines from Kiriburu Iron Ore Mines for Bokaro Steel Project. *Sponsored by Bokaro Steel Project.*

Comprehensive studies were made on sintering characteristics of —10+3 mm iron ore fines from Kiriburu iron ore mines for the production of fluxed sinters and optimum conditions were determined.

1.10 Studies on Production of Fluxed Sinter with the Classifier Sand (—3 mm+65 mesh) from Kiriburu Iron Ore Mines for use in Bokaro Steel Plant. *Sponsored by Hindustan Steel Ltd.*

Comprehensive studies were made on sintering characteristics of the classifier sand obtained from Kiriburu Iron Ore Mines. Optimum conditions for production of fluxed sinters were determined.

1.11 Studies on Production of Fluxed Sinters using —10 mm+65 mesh composite Iron Ore Fines from Kiriburu Iron Ore Mines for Bokaro Steel Project. *Sponsored by Hindustan Steel Ltd.*

Bench scale studies were conducted on —10 mm+65 mesh composite sample from Kiriburu Iron ore mines for the production of good quality fluxed sinters for use in Bokaro Steel Plant.

1.12 Beneficiation of Studies on a Low Grade Magnetite Sample Marked "M" from Kavuthimalai Deposit, Tamil Nadu. *Sponsored by the State Dept. of Geology, Tamil Nadu.*

The sample assayed 34.51% Fe and 45.9% SiO_2 and constituted principally, martite, magnetite, hematite and quartz.

Concentrates assaying 61.5% Fe and 64.2% Fe with recoveries of 93.67% and 91.16% respectively were obtained. A two stage method produced a magnetite concentrate assaying 64.59% Fe with 89.50% recovery.

1.13 Beneficaition Studies on a Low Grade Magnetite (Sample 'C') Sample from Kavuthimalai Deposit, Tamilnadu. *Sponsored by State Dept. of Geology, Tamilnadu.*

The ore analysed 34.63% Fe, 43.57% SiO_2, 1% Al_2O_3, 0.36% S, 0.10% P and 0.10% TiO_2 and contained principally magnetite, followed by hematite and traces of hydrogoethite. Quartz was the principal non-metallic gangue.

A two stage method after grinding it to —65 mesh produced concentrate assaying 64.9% with 91.36 % Fe recovery.

1.14 Studies on Physical Characteristics of —40+10 mm Size Lumpy Iron Ores from Jajang, Jhilling and Ghatkuri Mines and a Comparative Study with the Characteristics of Kiriburu Iron Ore. *Sponsored by Bokaro Steel Project.*

A comparative study of the physical properties of —40+10 mm iron ore sample from Kiriburu mines of National Mineral Development Corporation and three reference samples from Jajang, Jhilling and Ghatkuri iron ore mines, was made at the instance of the Bokaro Steel Project.

The chemical analysis of the four samples showed that the iron content in the Kiriburu sample was higher than those of Jhilling and Ghatkuri ores but lower than that of Jajang ore. However, the silica and alumina contents in the Kiriburu ore were lower than those of the three samples.

Shatter size stability, tumbling and abrasion indices and crushing strength were also determined. They indicated that the Kiriburu iron ore was softer than the Jajang iron ore but harder than the Jhilling and Ghatkuri iron ore samples.

1.15 Determination of Settling Rate of Barsua Iron Ore Slime using Various Types of Flocculants. *Sponsored by Rourkela Steel Plant.*

Settling tests were carried out in 500 cc graduated cylinders with the pulp as received (containing 14.5% solids) using different flocculants like Separan, Flocal T-214, Flocal F/C-214, Flocal TN-40 and Polytex-60. Tests were also carried out without the addition of any flocculant. From the results, it was concluded that in comparison with other flocculants, Flocal T-214 was the most active flocculant for the pulp as the average settling rate improved considerably.

2.0 Jigging and Tabling Studies on Manganese Ore Sample 'A' from Tirodi. *Sponsored by M/s. Manganese Ore (India) Ltd., Nagpur.*

A low grade low phosphorus sample designated as sample 'A' received from M/s. Manganese Ore of India Ltd., was subjected to jigging and tabling processes with a view to producing a lumpy size concentrate assaying 46-48% Mn with high manganese recoveries. The sample, as received, assayed 39.95% Mn, 10.65% Fe and 16.81% SiO_2. A concentrate assaying 46.9% Mn with 89.9% recovery was obtained. The Mn/Fe ratio could not be improved to more than 3.7 because of the presence of iron bearing manganese minerals in the sample.

2.1 Jigging and Tabling Studies on Manganese Ore Sample 'B' from Tirodi. *Sponsored by M/s. Manganese Ore (India) Ltd., Nagpur.*

A low grade, low-phosphorus manganese ore sample designated as sample 'B' received from Manganese Ore (India) Ltd., was subjected to jigging and tabling processes with a view to producing a concentrate assaying 46-48% Mn with satisfactory Mn recoveries. The sample as received assayed 29.7% Mn, 13.8% Fe and 25.4% SiO_2. Jigging test results showed that the sample could not be upgraded to the desired grade due to the finely disseminated siliceous gangue and due to the presence of manganese minerals high in Fe. Even after suitable crushing and close sizing before jigging operation, the concentrate analysed only 43% Mn and represented a recovery of 80.5% Mn.

2.2 Beneficiation Studies on Low Grade Manganese Ore Sample 'C' from Tirodi. *Sponsored by M/s. Manganese Ore (India) Ltd., Nagpur.*

Beneficiation studies were taken up on a low grade, high phosphorus manganese ore sample designated as sample 'C' from Tirodi area with a view to produce a concentrate assaying over 46% Mn suitable for export. The sample as received analysed 35.8% Mn, 9.5% Fe, 17.35% SiO_2 and 0.34% P.

A concentrate having a wt. % 55.3 w.r.t. the feed and assaying 45.02% Mn with a distribution of 69.6% Mn was obtained. Treatment after close sizing of the sized products yielded Mn concentrates, which when mixed, had a wt. % of 61.8 and assayed 45.4% Mn with 79.5% Mn recovery. Crushing of the sample to suitable size, followed by close sizing and treatment produced a Mn concentrate weighing 54.8% and assaying 48.1% Mn with 74.5% Mn recovery. But for the poor Mn/Fe ratio, the concentrate fulfilled the grade requirements laid down by M/s. Manganese Ore (India) Ltd.

2.3 Beneficiation Studies on a Low Grade Manganese Ore Sample 'D' from Tirodi. *Sponsored by M/s. Manganese Ore (India) Ltd., Nagpur.*

A low-grade, high-phosphorus manganese ore designated as sample 'D' and assaying 29.5% Mn, 9.5% Fe, 30.3% SiO_2, and 0.33% P received from M/s. Manganese Ore (India) Ltd., was subjected to beneficiation studies with a view to producing a manganese concentrate of 46-48% Mn, suitable for export purposes.

A concentrate weighing 48.3% and assaying 45.0% Mn was obtained. Close sizing the sample followed by treatment of the various size products produced a combined Mn concentrate weighing 46.1% and assaying 46.1% Mn with 73.6% Mn recovery.

Crushing the sample to suitable size followed by close sizing and required treatments yielded a combined Mn concentrate of 47.7% by weight and assaying 47.89% Mn with 74% Mn recovery. But for an unfavourable Fe/Mn ratio, the concentrate fulfilled the grade requirement laid down by M/s. MOIL. Presence of iron bearing manganese minerals in the sample indicated that a manganese content of standard Fe/Mn ratio is rather difficult to obtain by gravity methods.

2.4 Beneficiation and Agglomeration Studies on Manganese Ore Fines Sample from M/s. Khandelwal Ferro-Alloys Ltd. *Sponsored by M/s. Khandelwal Ferro-Alloys Ltd., Nagpur.*

The ore fines rejected at M/s. Khandelwal Ferro alloys Ltd., Kamptee, carry considerable amount of manganese values. It is reported that for every 100 tonnes of manganese ore processed nearly 7-10 tonnes of -3 mm fines analysing 30-35% Mn, 8-9% Fe, 18-20% SiO_2, 3-5% Al_2O_3 and 0.16 to 0.2% P are produced and discarded at present. The firm referred the problem for improving the quality of these fines to a grade suitable for ferromanganese production and also for producing sinters or pellets of quality and strength.

The sample received for investigation analysed 36.0% Mn, 9.04% Fe, 17.62% SiO_2, 3.68% Al_2O_3, 1.37% BaO, 0.125% P and 0.27% S. Various methods were investigated to improve the ore quality.

Pelletization studies undertaken on a manganese concentrate analysing 48.0% Mn established that pellets of good quality and strength could be produced with usual binders. Optimum conditions were also established to produce Mn sinters of good quality and strength from the table concentrate.

From the results of this investigation it may be stated that ore fines analysing 36% Mn could be successfully upgraded to 47-48% Mn and agglomerated to yield sinters or pellets of quality and strength.

3.0 Batch and Pilot Plant Beneficiation Studies on a Low Grade Copper Ore from I.C.C. *Sponsored by Indian Copper Corporation, Ghatsila.*

A sample of copper ore, (weighing about 100 tonnes) was received from M/s. Indian Copper Corporation for conducting batch and pilot plant beneficiation studies. The sample assayed 1.8% Cu, 0.08% Ni and 2.6% S.

Bench scale studies were undertaken so as to establish optimum grind, quantity of frother and collector and reflotation conditions for flotation of a bulk sulphide float from the sample. The copper concentrate produced under optimum conditions analysed 22.95% Cu, and 42% Ni with satisfactory recoveries of copper and nickel. The concentrate fulfilled the grade specifications laid down by the sponsors.

Comprehensive pilot plant flotation studies undertaken on a 100 tonne sample revealed that the flowsheet presently employed at ICC could be adopted with success for production of bulk copper concentrate analysing 20-22% Cu with satisfactory recoveries of Cu, Ni and S.

3.1 Benefication of Core Sample of Low-grade Copper Ore from Malanjkhand, Balaghat Dist. Madhya Pradesh. *Sponsored by M/s. Hindustan Copper Ltd., Khetrinagar.*

Beneficiation studies were carried out on a mixed core sample of low grade copper ore from Malanjkhand, Balaghat District, Madhya Pradesh assaying 0.645% Cu, 2.73% Fe, 0.86% S, 72.24% SiO_2, 4.49% Al_2O_3, 2.37% CaO, and 1.40% MgO. A copper concentrate assaying 25.8% Cu with a Cu recovery of 92.17% was obtained.

3.2 Beneficiation Studies on a Low Grade Copper Ore from Bhogani Area, Alwar Dist. Rajasthan. *Sponsored by Geological Survey of India.*

A sample of low grade copper ore from Bhogani area, Alwar Dt., Rajasthan, assaying 1.16% Cu, 1.51% S, 7.56% Fe, 23.58% SiO_2, 4.40% Al_2O_3, 14.34% MgO, 16.45% CaO, 27.80% LOI was subjected to intensive bench scale beneficiation studies with a view to determine conditions for production of a copper concentrate suitable for smelting. Mineralogical studies revealed that the chief copper bearing mineral in the sample as chalcopyrite with minor amounts of azurite and malachite. Calcite, dolomite and minor amounts of quartz and other silicates constituted the gangue. A concentrate assaying 22.30% Cu representing a recovery of 86.7% Cu was obtained.

Since the tailings contained considerable amounts of calcite and dolomite, these were recovered as valuable by-products. The calcite-dolomite concentrate obtained, analysed 30.52% CaO, 20.28% MgO, 2.57% insolubles, and was of a grade suitable for refractory use.

3.3 Batch & Pilot Plant Studies on Beneficiation of Rakha Copper Ore. *Sponsored by M/s. Hindustan Copper Ltd.*

The original sample as received for pilot scale studies assayed Cu 0.92%, Mo 0.015%, Ni 0.025%, Fe 9.5%, S 1.35%, SiO_2 67.25% and U_3O_8 0.013%. The optimum grind obtained in the batch tests was 54%—200 mesh. A concentrate assaying Cu 16.2% with 99.5% Cu recovery, Mo 0.254% (90% recovery) was obtained. The concentrate obtained was differentially treated for molybdenum recovery. A final molybdenum concentrate assaying 34.6% Mo and Cu 1.13% was obtained. The batch tests were completed and pilot plant tests are in progress.

4.0 Beneficiation Studies on a Low-Grade Complex Cu-Pb-Zn Ore from Dariba, Rajasthan. *Sponsored by M/s. Hindustan Zinc Ltd.*

Beneficiation studies were undertaken on a sample of low grade copper-lead-zinc ore received from Dariba-Rajpur area, Rajasthan, analysing 0.42% Cu, 1.72% Pb, 6.2% Zn, 3.03% Fe, 6.29% S, 36.6% SiO_2, 0.40% Al_2O_3, 13 56% CaO, and 10.02% BaO. Mineralogical examination identified chalcopyr ite, galena, sphalerite and pyrite as the chief sulphide minerals and the gangue was mostly contributed by quartz followed by barite, calcite, dolomite and fluorspar. Though the copper, lead, and zinc minerals were fairly free from siliceous gangue at about 150 mesh size, they were in intimate association with each other.

Bulk flotation of copper lead minerals yielded copper and lead concentrates assaying 19.1% Cu and 60.6% Pb with recoveries of 66.4% Cu and 87.1% Pb respectively. Silver constituted an important by-product in the concentrates assaying 364.0 gm Ag/ton and 504.0 gm Ag/ton of copper and lead concentrate respectively. Activation of sphalarite from the copper-lead rougher tailings yielded a sphalerite concentrate analysing 52.9% Zn with a recovery of 73.5% Zn. A barite concentrate constituting 9.5% by wt., analysing 90.1% BaSO and representing a recovery of 56.6% barite was also recovered from the tailing. The barite concentrate was snow white in colour and can be used in paper, paint or textile industries.

4.1 Heavy Media Separation Studies with the Zinc Ore from Balaria, Rajasthan. *Sponsored by M/s. Hindustan Zinc Ltd.*

Pre-concentration employing batch heavy media separation was undertaken on a zinc ore from Balaria area of Rajasthan, assaying 5.1% Zn and 0.006% Pb. Three different size ranges of feed were fractionated at specific gravities ranging from 2.70 to 3.00 with a gravity differential of 0.05. The coarsest feed yielded the best results after rejecting 20% by weight of material as float at 2.70 sp. gr. with a loss of about 8% zinc in it.

4.2 Batch & Pilot Plant Studies for the Concentration of Galena from a Low-Grade Lead Ore from Bandalamottu Block, Agnigundala Area, Andhra Pradesh. *Sponsored by M/s. Hindustan Copper Ltd.*

Batch as well as pilot plant beneficiation studies were undertaken on a sample of low grade lead ore from Bandalamottu block, Agnigundala area, Andhra Pradesh, to develop a flow-sheet for producing a concentrate assaying about 70% Pb, with satisfactory recoveries. The sample as received assayed 3.2% Pb, 0.04% Cu, 0.03% Zn, 12.2% SiO_2, 2.54% Al_2O_3, 18.42% CaO, 17.0% MgO, 0.8% S and 4.9% Fe. Galena was the predominant sulphide mineral with negligible amounts of pyrite, chalcopyrite and sphalerite. The gangue comprised mostly of dolomitic limestone, quartz and chert.

Optimum flotation conditions were established to produce a galena float with maximum recoveries. Flotation tests yielded a rougher concentrate assaying 33.9% Pb with a lead recovery of 94.6%. Three cleanings of the rougher float improved the grade to 72.5% Pb but with a recovery of 82% Pb. Based on the batch test results, continuous pilot plant flotation tests were carried out and a flowsheet was developed to produce a concentrate assaying 71.5% Pb with a recovery of 89.3% Pb.

5.0 Beneficiation of Low Grade Graphite from Chammua, Sidhi Dist, Madhya Pradesh. *Sponsored by Directorate of Geology & Mining, Madhya Pradesh.*

A low grade graphite from Chammua, Sidhi district, M.P. received for beneficiation studies assayed 7.67% FC, 85.41% ash, 5.11% volatile matter and 1.81% moisture. Graphitisation in the sample was not complete and thus resulted in the presence of only minor amounts of free crystalline graphite. The rest of the material might be graphitised anthracite or other type of coal intimately associated with argilaceous and arenaceous material. A high grade concentrate suitable for commercial utilisation by ore dressing methods could not therefore be produced.

5.1 Beneficiation of Low Grade Graphite from Gidher, Sidhi Dist. Madhya Pradesh. *Sponsored by Directorate of Geology & Mining, Madhya Pradesh.*

Beneficiation studies were carried out on a low grade graphite sample assaying 4.86% fixed carbon, 87.34% ash and 6.69% vol. matter. Quartz, feldspar, and carbonates were the principal gangue in the sample. It was a poor variety of partially graphitised coal like material in intimate association with quartz, calcite, feldspar etc. and as such, did not warrant detailed beneficiation studies. A few flotation tests were however, carried out and as anticipated did not yield encouraging results.

5.2 Beneficiation Studies on a Low Grade Graphite Sample from Jhab-Radhana Mine of G.M.D.C. *Sponsored by Gujarat Mineral Development Corpn.*

The low grade graphite sample collected from Jhnab-Radhan Mines, Panchmahal Dist. assayed 7.1% fixed carbon, 80.0% ash, 11.29% V.M., 1.65% moisture, 0.47% total S, with 3.65% Fe in the ash. Calcite, quartz, felspar, mica and pyroxene were the chief gangue minerals followed by traces of goethite, magnetite and pyrite. Graphite grains were extremely fine and were found to be disseminated in calcitic and silicate gangue. Rougher flotation followed by four cleanings after regrinding yielded a refloat concentrate analysing 41.65% F.C. with a recovery of 76.6% F.C. Acid leaching of the refloat concentrate obtained after seven cleanings improved the grade to 58.02% C, with a recovery of only 27.0% F.C.

5.3 Beneficiation of Graphite Samples G-1 to G-4 from Khammam Dist., A.P. *Sponsored by Andhra Pradesh Industrial Development Corporation.*

Six samples of low grade graphite, designated as G-1 to G-6 from Jeddikuppa and Kavarigundla Area, Khammam Dist. A.P. were beneficiated with a view to produce graphite concentrates suitable for crucible manufacture as well as for other industrial uses like batteries, carbon brushes, paint manufacture etc. The samples assayed 10.4% to 64.35% fixed carbon with ash contents varying between 81.7% and 31.64%.

A combined graphite concentrate assaying between 69.5% C and 87.37% C with an overall graphite recovery of 87 to 88% was obtained.

6.0 Beneficiation Studies on a Limestone Sample received from M/s. Travancore Electro-Chemical Industries. *Sponsored by M/s. Travancore Electro-Chemical Industries, Kerala.*

A representative sample of limestone from Chingavanam, Kottayam Dt., Kerala assaying 49.23% CaO, 4.41% SiO_2, 2.234% Al_2O_3, 0.36% MgO, 1.06% Fe_2O3, 0.05% P, 0.092% S, 40.44% CO_2 and 8.41% total insolubles, was received for beneficiation studies. The object of the investigation was to bring down the SiO_2 and P contents of the sample to less than 1.5% and 0.02% respectively so that the material after beneficiation and suitable agglomeration could be used for clacium carbide manufacture.

The sample essentially consisted of crystalline calcite followed by minor amounts of magnesite, phlogopite, copper and iron pyrites, graphite, wollastonite, apatite, quartz, feldspars and talc.

Techniques for the removal of quartz and apatite from limestone were studied. An apatite concentrate assaying 52.59% CaO, 0.16% SiO_2 and 0.23% P with a distribution of 8.1% CaO and 33.4% P was obtained. But for the slightly high P content, the calcite concentrate was of a grade suitable for CaC_2 manufacture. By subsequent treatment the bulk of the phosphorus in the coarse fraction was removed. The fine sand and the slime fractions representing 70.8% by weight, analysed 0.016% P only. This product fulfilled the grade requirements laid down for calcium carbide manufacture.

7.0 Beneficiation of Wolframite from Bankura, West Bengal. *Sponsored by M/s. Gouripur Industries, Calcutta.*

Wolframite containing 0.14% WO_3 was investigated for beneficiation in view of the difference in sp. gr. between the gangue and the mineral. The grade was improved to 42% WO_3 from 38%. The product was further enriched to give an improved grade containing 53% WO_3. The final product is being further enriched to 60% WO_3 by magnetic separation.

8.0 Beneficiation of Saladipura Pyrite. *Sponsored by M/s. Pyrites, Phosphates & Chemicals Ltd.*

Two samples of pyrite-pyrrhotite from Saladipura deposit in Rajasthan and designated as level 1 and 2 samples were received for intensive bench scale beneficiation tests, so that the material after beneficiation could be used for sulphuric acid manufacture. It was stipulated by M/s. PPCL that the sulphur content in the sample should be upgraded to 39-40% S with high sulphur recoveries.

Level II Sample : Intensive bench scale beneficiation studies on the sample designated 'Level 2' analysing 31.3% S established that it could be easily processed to produce concentrate suitable for sulphuric acid manufacture, with recoveries ranging from 89 to 92% S.

Level 1 sample : Studies undertaken on level 1 sample analysing 15.81% S established that it could not be processed easily. However, a concentrate analysed 40% S with a recovery of 87% S could be obtained.

9.0 Beneficiation of Baryte from Madhya Pradesh. *Sponsored by Dept. of Mining & Geology, Govt. of Madhya Pradesh.*

Two samples of low grade baryte designated 586A and 586B were received from the Dept. of Mining and Geology, Govt. of M.P. for beneficiation studies. The samples were mixed as desired and the composite sample analysed 67.21% $BaSO_4$, 31.2% SiO_2, with traces of Fe_2O_3, CaO, MgO etc.

Mineralogical examination revealed that the mixed samples essentially consisted of baryte followed by quartz which constituted the chief gangue with traces of muscovite, magnetite, hematite, goethite, chalcopyrite etc. Lock liberation studies revealed that fair liberation of baryte from quartz took place at about 35 mesh size.

The concentrate obtained was snow white in colour and satisfied the specifications of various grades laid down for its use in paint manufacture, ceramics, chemical, paper, and leather industries. The concentrate could as well perhaps be employed as a wetting agent in oil well drilling, but only after grinding to —200 mesh size.

10.0 Beneficiation of Low Grade Chrome Ore from Garividi, Srikakulam Dist. Andhra Pradesh. *Sponsored by M/s. Ferro-Alloy Corporation, Garividi.*

A low grade chromite sample was received for beneficiation tests with a view to produce a concentrate suitable for standard grade ferrochrome manufacture. The sample as received assayed 43.80% Cr_2O_3, 21.51% FeO, 14.28% SiO_2, 8.32% Al_2O_3, 1.04 CaO, 10.98% MgO. Mineralogical studies revealed that gangue minerals associated with chromite were orthopyroxenes followed by minor to trace amounts of plagioclase feldspars, biotite, muscovite, antigorite and quartz. The metallic minerals hematite, goethite and ilmenite occured in traces. Metallurgical grade of concentrate could not be produced from this sample by conventional ore dressing methods.

11.0 Reduction of Lime Content of a Bauxite Sample from Saurashtra. *Sponsored by M/s. Carborandum Universal.*

A sample of bauxite received from M/s. Carborandum Universal analysing 59.29% Al_2O_3 and 1.63% CaO was subjected to detailed laboratory studies with a view to reducing its CaO content to less than 0.6%. Mineralogical studies revealed that the ore was of lateritic nature. The aluminous laterite matrix constituted chiefly of gibbsite, bohemite and cliachite along with minor amounts of kaolinite, montmorillonite, illite and allophane.

Froth flotation yielded a concentrate assaying 61.55% Al_2O_3 with a 57% recovery of alumina. Leaching produced a concentrate assaying 62.18% Al_2O_3 with 98.80% recovery of alumina. Calcination and slacking tests could procure only marginal reduction in the CaO content of the sample.

12.0 Reduction of Iron Content in a Quartz Sample from Hazaribagh, Bihar. *Sponsored by Indo Asahi Glass Works, Hazaribagh.*

The sample as received assayed 99.22% SiO_2, 0.51% Al_2O_3 and 0.17% Fe_2O_3. Besides quartz, which was the predominant mineral, the sample contained some opaques such as hematite, goethite and magnetite and other non-metallic minerals such as felspars, chlorites, spene and tourmaline. The clayey and ferruginous matter were generally present as ocherous, brownish yellow and rosy colour surface coatings. Some washing tests as well as leaching tests have been completed.

13.0 Beneficiation of Flourspar from Kohila Mines, Rajasthan. *Sponsored by Rajasthan State, Ind. Dev. Corpn., Jaipur.*

The sample assayed 24.6% CaF_2. Quartz constituted the predominant gangue mineral. Work is in progress.

14.0 Crushing Tests on a Dolomite Sample from Kovilpatty Mine, Salem. *Sponsored by M. N. Dastur & Co., Industries & Commerce, Mining & Geology Branch, Madras.*

Five tonnes of L.D. dust sample was received from Rourkela Steel Plant of M/s. Hindustan Steel Ltd., for carrying out agglomeration studies. Various processes of agglomeration were employed. Sintering appeared to be the most promising method for agglomeration and subsequent utilization of the sample.

15.0 Agglomeration Studies on L.D. Dust from Rourkela Steel Plant of Hindustan Steel Ltd. *Sponsored by Hindustan Steel Ltd., Rourkela.*

Five tonnes of L.D. dust sample was received from Rourkela Steel Plant for carrying out agglomeration studies. Various processes of agglomeration were employed. Sintering appeared to be the most promising method for agglomeration and subsequent utilisation of the sample.

16.0 Testing of Pine Oils received from M/s. Camphor & Allied Products. *Sponsored by M/s. Camphor and Allied Products, Ltd., Bareilly.*

Performance of two pine oil samples received from M/s. Camphor & Allied Products Ltd., during the flotation of chalcopyrite and other sulphides from a low grade copper ore was studied in a Denver Sub-A flotation cell and the metallurgical results were compared with those obtained from a test using a standard pine oil (imported variety). Both the pine oil samples tested exhibited no collecting power and produced fragile and short lived froths. The frothers tested were also found to be insensitive to pH in the alkaline range. The copper recovery and flotation selectivity of the frother designated ES-IL 141271, compared well with that of standard pine oil. As regards Frother 181271, flotation was found to be less selective and copper losses in the tails were also somewhat higher.

17.0 Determination of Bond's Work Index of (i) Bauxite and (ii) Calcined Petroleum Coke from M/s. Aluminium Corporation of India, Calcutta. *Sponsored by the Firm.*

Work index values of a bauxite and calcined petroleum coke samples received from M/s. Aluminium Corporation of India Ltd., Calcutta, were determined based on the method of F. C. Bond and were found to be 7.48 KWH/tonne and 83.3 KWH/tonne respectively, at 250% circulating load.

18.0 Dolomite Lining for L. D. Converters. *Sponsored by M/s. Hindustan Steel Ltd., Rourkela.*

The objective of the project was to examine the rather poor performance of the converter linings in Rourkela as compared to the performance of similar linings in other countries. Till a couple of years ago, the average lining life in Rourkela was 180 heats with a record performance of 250 heats. Within the last two years, however, the average lining life has fallen to as low as 140 heats.

According to the calculations of the steel plant authorities, if campaign lives of even 220 heats can be assured, they could break even and maintain the targetted rate of production of steel. The situation is therefore, one, in which planning of a steady steel output has become considerably difficult.

In a joint meeting held on 29th Dec. 1971, between NML Scientists and Rourkela Steel Plant Officers, for defining the problem, it was agreed that a complete study of all the variables namely (i) raw material quality, (ii) processing of the raw material into the blocks (iii) installation of lining in the converter itself, (iv) its after treatment and (v) the manner in which the regular steel production operations are conducted, should be made. Since such a study would encompass, a very large area, it was decided that the programme should be phased, starting with the variables inherent in the refractory raw material and its processing into the final block.

Accordingly, the first phase of study was drawn up to include (i) visits of NML scientists to the plant for preliminary observations, (ii) examination of data made available from the dolomite brick plant and steel melting plant records for last 3 years at Rourkela (iii) preliminary experiments at NML with Rourkela raw materials and products (iv) inplant data collection, concerning current practice over a period of 6 weeks, (v) further experiments at NML on the raw material as well as sinter and tar to determine the quality of the product that could be normally obtained from these materials and a critical evaluation of the process parameters as found in Rourkela practice, in order to suggest alternatives, if any, for bringing out significant improvement.

During the year under review, the programme has been completed and the data collected as well as the experiments conducted at NML have been reported to the Rourkela Steel Plant by way of three comprehensive investigation reports, of which part-I deals with studies on process variables in the tar-dolomite block making, part-II deals with laboratory studies on raw dolomite and dolomite sinter and part-III deals with experiments to evaluate as well as to suggest quality norms and process parameters for the production of tar dolomite blocks.

The photographs of raw dolomite and the wear in used linings are given in Figures 1 to 3.

19.0 Protective Scheme for Underground Steel Pipes from Boirdih Dam to Dali Industrial Site, Bhilai. *Sponsored by M/s. Bhilai Steel Plant (HSL).*

This problem was referred with a view to formulating a comprehensive protective scheme for the proposed underground steel pipes of 45 cm dia, 30 km long from Boirdih to Dali Industrial Site for the transportation of water.

Soil samples were collected at various places along with the alignment

Fig. 1 Photomicrograph of raw dolomite ×125

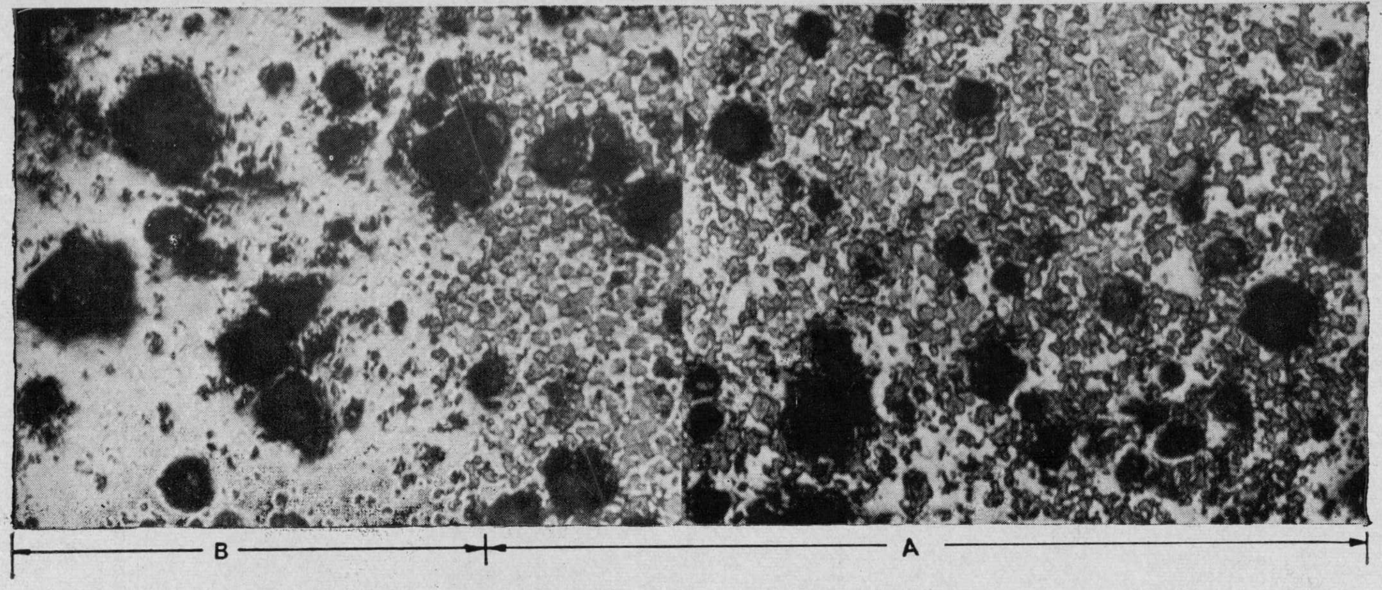


Fig. 2 Serial photomicrograph of sinter dolomite showing reacted zone (A) depleted of lime and unreacted zone (B). Etched with distilled water 20 seconds.

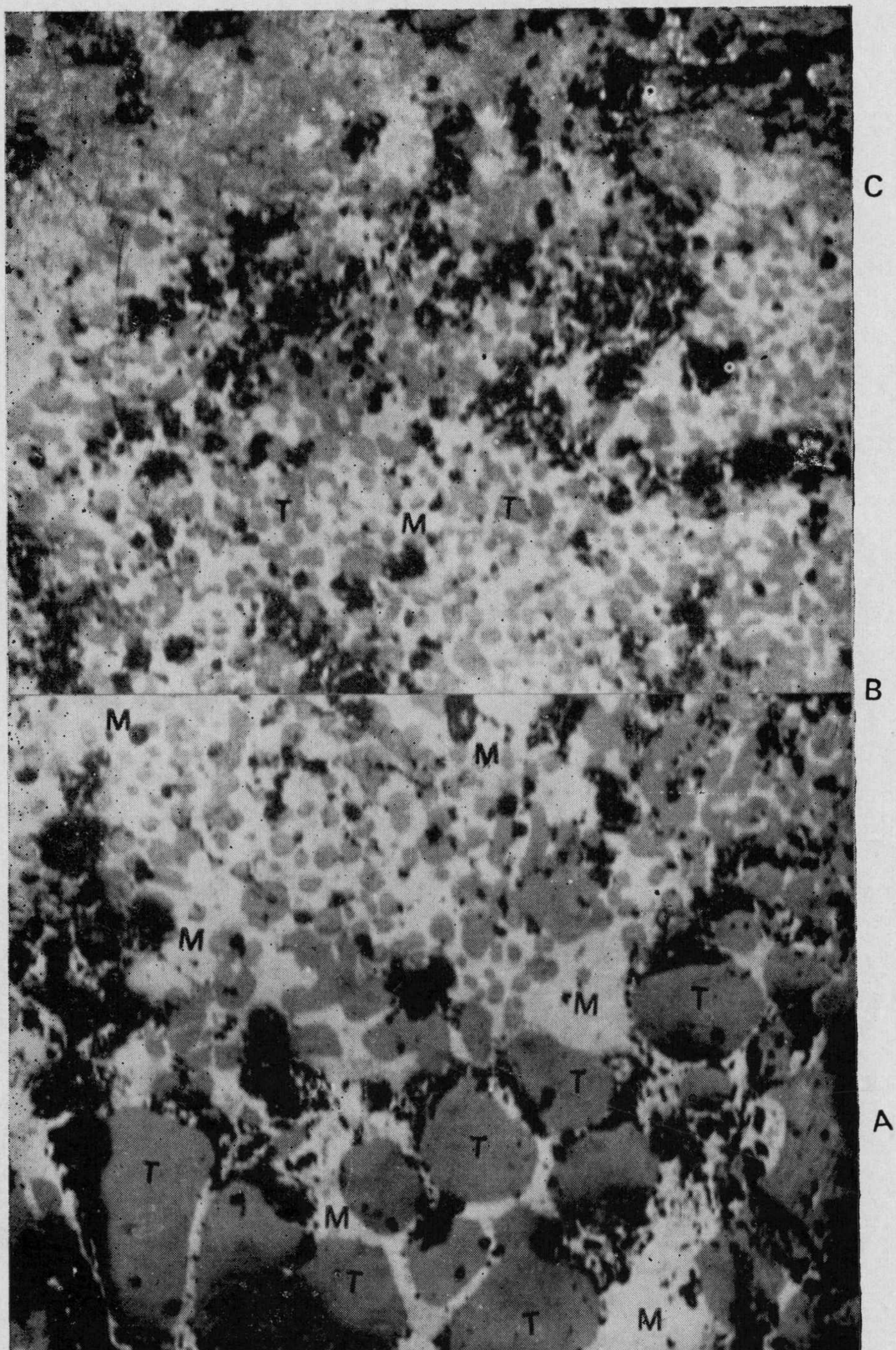


Fig. 3—Serial photomicrographs of slagged brick showing different zones ×750

A *Slag rich zone consisting of coarse tricalcium silicate (T) in magnesiowustite (M) matrix*

B *Decarburized zone consisting of finely crystallized tricalcium silicate (T) in magnesiowustite (M) matrix*

C *Unreacted zone showing lime (dark) and periclase (grey)* of the pipes and analysed for their chemical compositions, specific resistance, etc. Results indicated that the soil condition around the proposed depth of the pipe can be considered as mildly corrosive and on this basis recommendation were made to protect the pipe surface from underground corrosion.

19.1 Scientific Evaluation for the Installation, Testing and Commissioning of the Cathodic Protection for the City Filter Water Pipe Line in Calcutta. *Sponsored by Calcutta Metropolitan Water & Sanitation Authority.*

The Calcutta Metropolitan Water and Sanitation Authority, Calcutta decided to cathodically protect the city water mains from underground corrosion. To work out the feasibility of such installations in a conjested city like Calcutta, it was decided to instal at the first instance two cathodic protection pilot stations to ensure the effectiveness of the system as well as to get field data on economy of the process. M/s. Corrosion Control Services of Bombay was the contractor and necessary consultancy services are provided by NML.

Proper system for cathodic protection has been suggested, designed and installed in two places. These installations could successfully protect the pipelines at reasonably low cost. The attenuation curves for the installations are shown in Fig. 4.

19.2 Corrosion of Steam Header of Power Plant at Barauni Refinery. *Sponsored by M/s. Barauni Oil Refinery.*

This problem was referred to investigate the early failure of steam-header at the thermal power station of the firm. The problem was investigated and the result showed that early failure of super-heated steam header was primarily connected with the inadequate precaution against corrosion during the long idle hours, thermal fatigue-creep acted conjointly with corrosion to cause the failure. Radiograph indicating the nature of cracking propagated throughout the thickness of the metal is shown in Fig. 5. Methods of preventing such failures by introducing proper system for corrosion protection during idle hours were suggested.

19.3 Corrosion of the Structural Parts in the Fertilizer Plant. *Sponsored by Fertilizer Corporation of India Ltd., Namrup.*

The Fertilizer Plant at Namrup although recently commissioned has been experiencing severe corrosion problems specially on the structural members in the ammonium sulphur plant. The services of the Laboratory was called for on-the spot study of the problem to suggest possible remedial measures. On the basis of the survey on-the-spot, suggestions were made to protect the vital assemblies which are exposed to the severe corrosive conditions and also for the assemblies in less severe areas. It was emphasised that a rigid control on the supervision and maintenance work will be necessary to fight such rapid corrosion of the structural members.

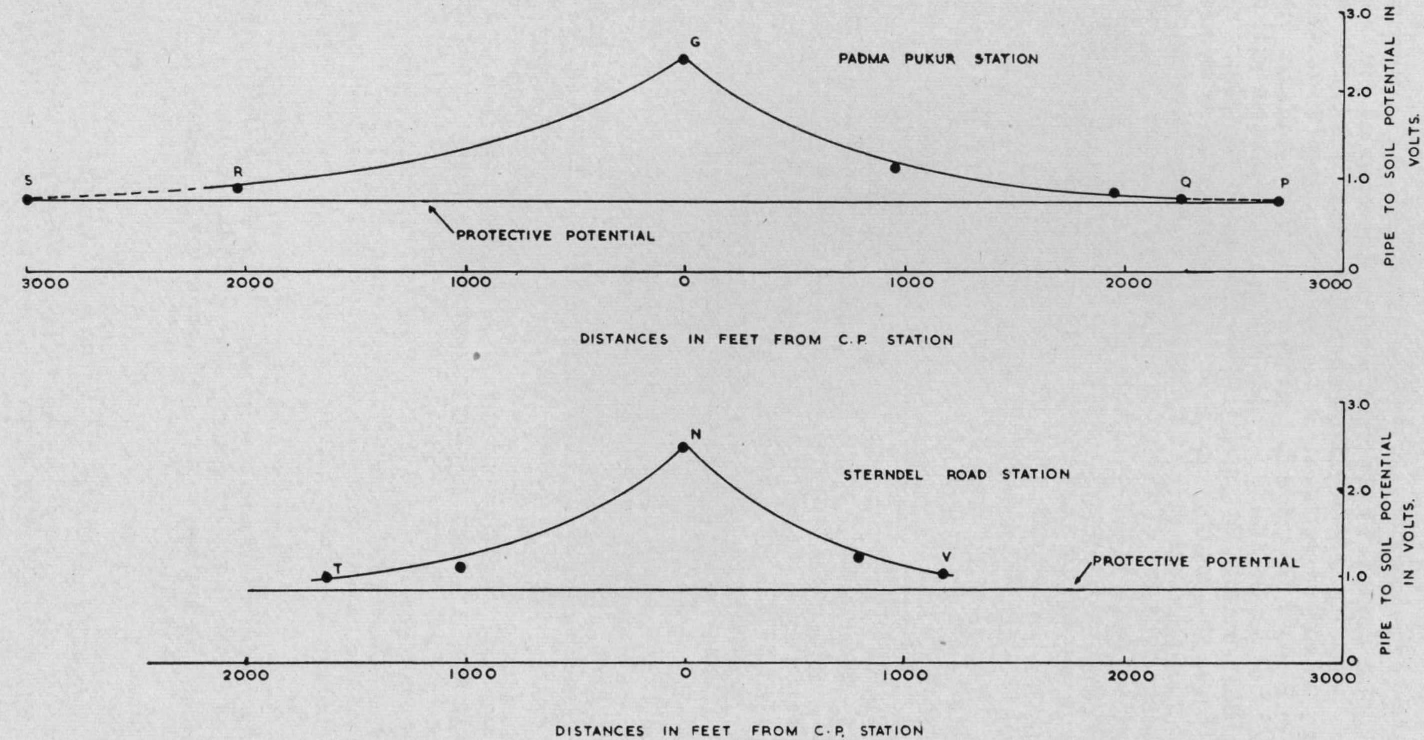


Fig. 4—Attentuation curves for the cathodic protection installations in Calcutta

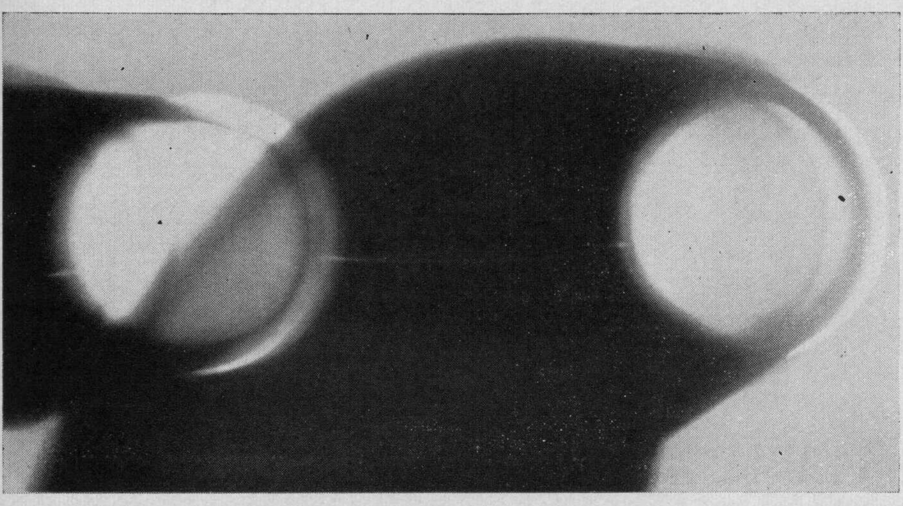


Fig. 5—Radiograph showing the nature of cracking of steam-header at Barauni Oil Refinery Ltd.

19.4 Proposed Consultancy Work in Connection with the Stray Current Corrosion Problems of Underground Tube Railway System at Calcutta.

Metropolitan Transport Authorities (Railways) at Calcutta have approached NML to act as consultants in connection with the underground corrosion problems due to leakage currents.

The Laboratory is in correspondence with the above authorities, regarding the various data required for undertaking the consultancy work. Literature survey work in this connection is under progress.

20.0 Recovery of Iron Powder from Waste Sulphuric Acid Pickle Liquor of Tinplate Co. of India Ltd., Jamshedpur. *Sponsored by the firm.*

Tinplate Co. of India, Jamshedpur, is producing 2-3 tons of pickle liquor per day in their works containing 250-300 gm $FeSO_4$/litre and the firm desires to utilize this waste, for the production of iron powder and referred the problem to the Laboratory. It has been found possible to produce iron in the form of powder or flakes from the waste pickle liquor. Further work on the project is contemplated.

21.0 Bright Nickel Plating on Cycle Rims. *Sponsored by M/s. Dunlop India Ltd.*

Dunlop India Ltd., has taken 'NML' process for bright nickel plating in their factory at Sahaganj, West Bengal. The firm is utilizing the process in production practice on their cycle rims for more than two years. The firm by implementing the process in their works has considerably brought down the production cost. Fig. 6 indicates the process in operation.

22.0 Preliminary Trials on Fluo-Solid Roasting of Saladipura Pyrites. *Sponsored by M/s. Pyrites, Phosphate & Chemicals Ltd.*

A sample of pyrites analysing Fe 35.84%, sulphur 38.31% and rest inerts was received from M/s. Pyrites, Phosphates and Chemicals Ltd. Laboratory scale fluid bed roasting experiments were carried out in a 6 cm dia. reactor with R.O.M ore, hand picked, crushed to 50%-200 mesh at temperatures between 750 °C and 820 °C for a retention time of 2 hours with varying amount of air. The products are being analysed for evaluation of the roasting mechanism.

23.0 Macro & Micro Porosity of Jajang, Dhatkuri and OMDC Iron Ore. *Sponsored by Bokaro Steel Ltd., Bokaro.*

For selecting the right type of ores for direct charging or blending for blast furnace, macro & micro porosity of Jajang, Dhatkuri and O.M.D.C. iron ores have been determined in an apparatus designed and fabricated at NML. Hydrogen gas was used as a penetrating fluid as it can give a better correlation of the penetration or diffusion of hydrogen in iron ore lumps during reduciblity determinations with hydrogen.

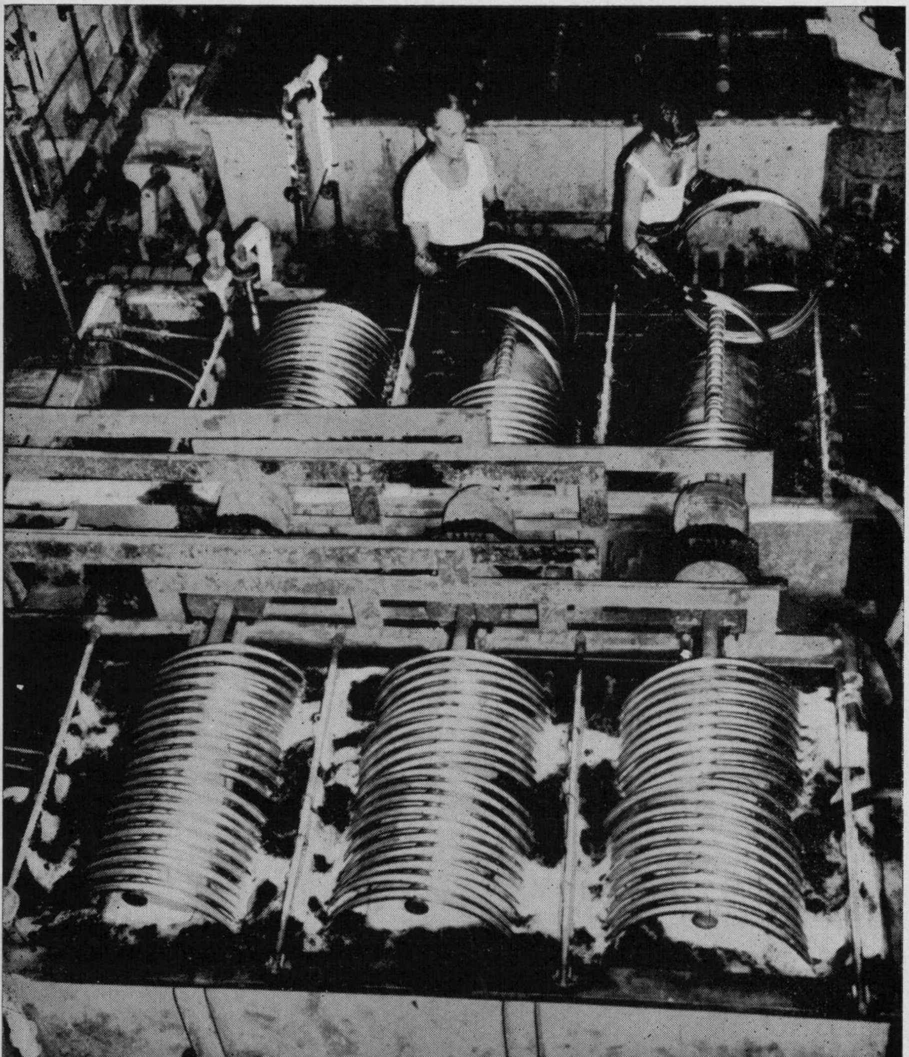


Fig. 6—Bright nickel plating of cycle rims by NML process at M/s. Dunlop India Ltd.

23.1 Matching Tests for the Studies on the Pre-reduction Characteristics of Iron Ores from Industrial Development Corporation of Orissa Ltd., with Non-metallurgical Coals. *Sponsored by IDCOL, Bhubaneswar, Orissa.*

An investigation was sponsored by IDCOL to conduct matching bench scale tests for pre-reduction of iron ore and coal supplied by them. After experimenting with various combinations of iron ores and coals in a static bed reactor a set of two best suited combinations were indicated. The sponsors have been advised to get these raw materials tested for their suitability in the rotary kiln experiments.

23.2 Reduction Characteristics of Joda Iron Ore. *Sponsored by Tisco. Ltd., Jamshedpur.*

In order to expand the steel capacity of TISCO to 4 million tons, several new iron ore deposits are being explored for charging into their new blast furnaces. TISCO has sponsored an investigation to determine the reducibility characteristics of Joda iron ore for this purpose. The reduction characteristics of this ore were determined by using a synthetic gas mixture containing 35% CO, 15% CO_2, 10% H_2 and 40% N_2 at temperature of 800, 900 and 1000 °C, at a flow rate of 2-4.8 lit/min. The results have been communicated to the sponsor on the two Joda iron ore sample viz. —50 mm+10 mm & —30 mm+10 mm size lump iron ores. The experimental set up for reducibility determination by gaseous mixture is shown in Fig. 7.

23.3 Reduction Characteristics of Donimalai Iron Ore. *Sponsored by CEDB, Hindustan Steel Ltd., Ranchi.*

An investigation was sponsored by Central Engineering and Design Bureau of Hindustan Steel Ltd., Ranchi ; for testing the Donimalai iron ore. Reduction characteristics of this ore was determined by using —40 mm+10 mm particle size of the ore, with gaseous mixture containing CO, CO_2, H_2 & N_2 at a flow rate of 3-8 lit/min. at temperatures of 800, 900 and 1000 °C. The reducibility results have been conveyed to the sponsor.

23.4 Reduction Characteristics of Khondobond Iron Ore. *Sponsored by TISCO, Jamshedpur.*

An investigation was sponsored by TISCO for determining the various properties of Khondobond iron ore in assessing its suitability for charging into blast furnace. The reduction characteristics were determined by reducing the iron ore with gaseous mixture containing CO, CO_2, H_2 & N_2 at a flow rate of 2-4.8 lit/min. at temperatures of 800, 900 & 1000 °C, for the two particle sizes viz., —50 mm+10 mm and —30 mm+10 mm. The reducibility results have been conveyed to the sponsor.

23.5 Reduction Characteristics of Twenty One Iron Ore Samples from TISCO by Gaseous Mixture. *Sponsored by TISCO, Jamshedpur.*

An investigation was sponsored by TISCO to find the reduction

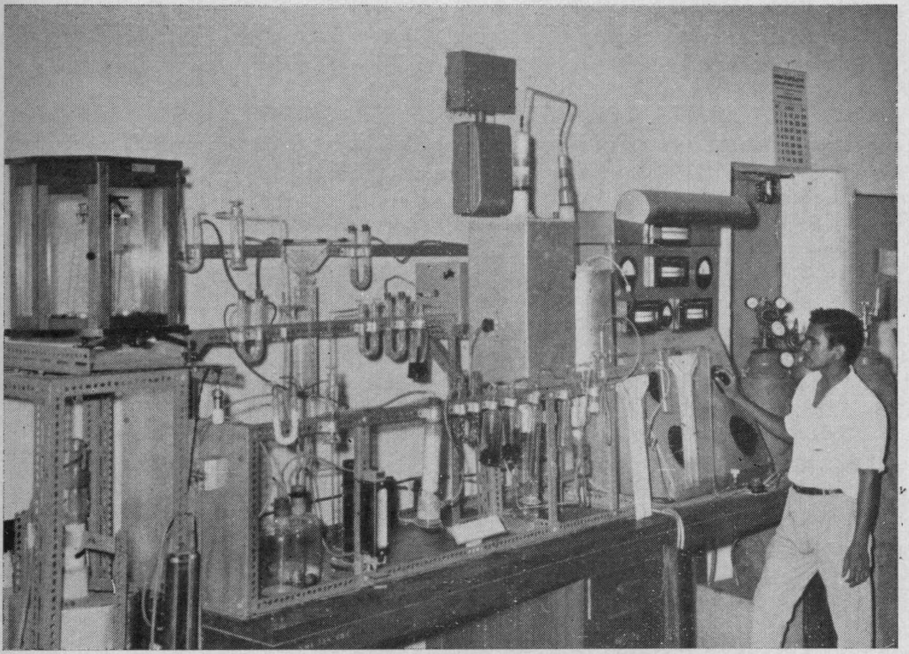


Fig. 7—Reducibility determination apparatus for the reduction of iron ores by the gaseous mixture consisting of carbon monoxide, carbon dioxide, hydrogen and nitrogen.

characteristics of 21 iron ore samples taken from different outcrops at the Khondobond iron ore deposit. The iron ore sample are being tested at 900 °C, the flow rate of the gaseous mixture at 4.8 lit/min. with the particle sizes —30 mm+10 mm. The experiments are under progress.

23.6 Swelling Index of Donimalai Iron Ore. *Sponsored by CEDB, Hindustan Steel Ltd., Ranchi.*

An investigation was sponsored by Central Engineering Design Bureau, Hindustan Steel Ltd., Ranchi, for determining the various properties of Donimalai iron ore. A specially designed apparatus, evolved on Japanese standard for swelling index of iron ore, has been rigged up for this purpose. Some preliminary experiments have shown 3-5% swelling during reduction. Further experiments are under way.

24.0 Matching Bench Scale Tests for the Suitability of Banke and Jamuna Coal for Sponge Iron Production with Rajhara Iron Ore. *Sponsored by HSL, Bhilai.*

An investigation was sponsored by Hindustan Steel Ltd., Bhilai; for sponge iron production with Rajhara iron ore and a suitable coal. The preliminary experiments were designed to find out the suitability of Banke and Jamuna coal for sponge iron production with Rajhara iron ore. Several static bed matching bench scale tests were conducted to determine the suitability of Banke and Jamuna coal. It was found that Jamuna coal was a better reductant than Banke under identical condition of time and temperature.

24.1 Bench Scale Matching Tests in a Static Bed on Reducibility of Noamundi Pellets by Singareni Coal. *Sponsored by TISCO.*

TISCO is producing heat hardened pellets at their pelletization plant at Noamundi. About 200 tons of heat hardened pellets were received for assessing their suitability for sponge iron production in a rotary kiln. To determine some of the basic parameters like residence time, ore-coal ratio, temperature and pellet quality, several bench scale static bed tests were conducted by using heat hardened Noamundi iron ore pellets and Singareni coal. For the static bed experiments pellets/coal ratio was maintained at 1:1, temperature at 1000 °C, residence time between 60 and 90 minutes. It was found that the reducibility of the pellets was relatively poor in comparison to Donimalai pellets produced at the NML. It was also observed that the pellets decrepitate during reduction and at times 70-80% decrepitation was also observed.

25.0 Failure of Cylinder Heads of Nuovo Pignone Gas Engine. *Sponsored by M/s. Oil India Ltd.*

Investigation was conducted on the cause of failure of the cylinder heads of the engine which had run only for 2200 hours. Detailed metallurgical examinations of the failure parts was conducted and from the results of different tests it could be concluded that the failure of the cylinder head might have occured due to localised higher hydrogen concentration, combined with high inclusions content and sharp graphite flakes which resulted in the development of cracks and subsequent failure.

25.1 Failure near a Welded Plug Joint of One Heat Exchanger in a Catalytic Reforming Unit of Gujarat Refinery. *Sponsored by M/s. Indian Oil Corporation.*

Investigation was conducted on the cause of failure near the plug joint of one heat exchanger shell cover of catalytic reforming unit of Gujarat Refinery. Chemical, spectrographic and metallographic examinations were conducted. It was revealed that the material did not contain chromium or molybdenum. The failure might have been due to hydrogen attack. Suitable steel composition and to give better service life were suggested.

25.2 Metallurgical Investigation on Cold Forming Steel for Dynamo Casing. *Sponsored by M/s. Pratap Steel Rolling Mills, Amritsar.*

Samples of steel plates reported to be developed by the firm for dynamo casing in automobile industry were sent for metallurgical examination. Chemical analysis of the material has shown that all the elements except phosphorus are within the specified range. Micro-structure showed typical annealed mild steel structure consisting of ferrite and pearlite, consistent with the tensile strength and hardness values obtained.

25.3 Failure of Boiler Quality Plate. *Sponsored by M/s. Kalyanpur Lime & Cement Works Ltd., Banjani.*

Examination carried out with the available material revealed that the failure might have occurred due to combined effect of heavy non-metallic inclusions in the heat affected zone and a sharp change in the micro structure between the weld metal and heat affected zone having a coarse crystalline structure which could have been avoided by a post weld heat treatment.

26.0 Studies on Creep Properties of Materials received from Industries.

Considerable progress has been made in the last three years in conducting creep and stress-rupture tests on domestic high temperature steels with the existing battery of creep testing machines (26 test points). Already over 250,000 hours of creep and creep rupture tests have been completed on materials from various industries.

B. INDUSTRIAL PROJECTS

27.0 Extraction of Nickel & Cobalt from Low-grade Lateritic Ore by Amchlor Process.

Semi pilot scale experiments carried out in the vertical moving bed reactor have given consistently 80% and 75% recoveries of nickel and cobalt respectively. Two thirds of the ammonia in the charge was found to get volatilised in the roaster gases at the operating temperatures of 275-300°C. Leaching and washing by counter current decantation has yielded overall nickel recovery of 84%. The product liquor analysed 7-8 g/l Ni, 0.3-0.4 g/l Co, 0.2 g/l Fe, 2.5-3.0 g/l Al and 4.5-5.0 g/l Mn. To test the feasibility of the process a pilot plant is proposed to be set up. A suitable roaster to process 0.5 to 1.0 tonne of laterite per day is under development.

Both NML and RRL, Bhubaneswar, are collaborating on the nickel project. NML will develop suitable roaster for NH_4Cl-HCl roasting of laterites, while RRL, Bhubaneswar; will evolve a suitable flowsheet for the recovery of nickel and cobalt from the leach liquors.

27.1 Resistance Heating of Nickel Ore

The aim of the project is to make a suitable reactor for roasting the ore with NH_4Cl or HCl. Some experiments were carried out in a glass reactor with a mixture of ore (mixed with NH_4Cl/HCl) and coke in different ratios. Nickel recoveries have been found to be low due to uneven distribution of heat. Further work is under progress in a graphite reactor.

27.2 Production of Ferro-Nickel from Lateritic Nickel Ores

As ferro-nickel is being accepted as an alloy in the production of stainless and alloy steels, the production of ferro-nickel by smelting Indian lateritic nickel ores is under investigation. The nickel, iron ratio in the ore being very low, efforts are being made to improve upon the grade of ferro-nickel produced by selective reduction techniques for its commercial acceptance. The success of the project would contribute towards saving in foreign exchange by minimising the import of nickel.

28.0 Bacterial Leaching of Copper Ores

Studies have been undertaken to apply the technique of bacterial leaching to low grade copper ores to extract copper from it. A Seminar was arranged on this topic at the National Metallurgical Laboratory.

29.0 Production of Silicon Metal in a 500 KVA Sub-merged Arc Furnace

There is no production of silicon metal at present in the country. From the studies carried out in the 500 KVA sub-merged electric arc furnace in this Laboratory, suitable design data can be developed for a commercial unit of 10,000 KVA to 24,000 KVA capacity. The technology can be released for industrial process control.

30.0 Production of Mg-Fe-Si Alloy

Magnesium is introduced in the form of nickel base alloy or as magnesium-ferro-silicon (with or without cerium) to make nodular spheroidal graphite iron in foundries. With a view to avoiding nickel which is scarce in India, the production process for obtaining Mg in an alloyed form upto

10% with ferro-silicon as the base has been attempted. Even higher Mg containing alloys could be produced with good recoveries of Mg.

31.0 Spray Roasting of Lead Sulphide Concentrate from Zawar Mines

The aim of this project is to overcome the conventional blast furnace method of lead making. The object is to roast the concentrate fully to its oxide form and then to mix the roasted product with fresh PbS concentrate and melt them together to get molten lead. Some experiments have been carried out on roasting of the concentrate at different temperatures in order to get PbO but formation of some sulphate could not be avoided. Work is in progress to minimize the sulphate and total sulphur contents of the oxidised product.

32.0 Studies on the Adsorption Extraction of Non-Ferrous Metals.

Work is under way on the bench scale development of adsorption techniques for extraction of nickel from nickel bearing solutions utilizing Indian lignites as an adsorbent.

Batch studies have shown recoveries upto 99% of nickel. Continuous studies in packed columns is now underway. Concurrently, work is also being carried out on selective absorption studies.

33.0 Production of Atomized Metal Powders.

Two processes for the production of metal powders are ready for transfer of the technology to industry. One is the production of extra fine non-ferrous atomized metal powders covering aluminium, copper, lead, tin, zinc and pigment/lithographic grades upto and below —325 mesh sizes. The other is the production of atomized bimetallic powders covering copper-lead and leaded bronzes for the bimetallic bearings industry.

The processes are under release to industry. Each involves an investment of Rs. 10 to 15 lakhs on equipment depending on the degree of sophistication of plant. Conversion costs have been estimated around Rs. 6.00 for atomizaton and Rs. 8.00 for flaking.

Further work on improvements in process techniques and process economics is progressing.

33.1 Fluidized Bed Drying/Annealing of Metal Powders.

The processing of raw atomized or electrolytic powders to the specifications of powder metallurgy requirements involves drying and annealing of these powders.

A fluidized bed column utilizing hydrogen gas has been set up to initiate studies on drying/annealing of atomized bimetallic powders, atomized and electrolytic copper powders, electrolytic iron powders.

34.0 Production of Zinc Dust.

Technology for the production of zinc dust to ISI chemical grade specifications is under transfer to industry. The technique involved is that of shock cooling zinc vapours to yield dust which is below-325 mesh containing metallic zinc upto 98%. Lead content in the zinc dust to meet sodium hydrosulfite manufacture requirements was also successfully achieved. Over 200 Kg. of dust was supplied to M/s. Cominco-Binani of Kerala and found to be of proper specifications. Samples have also been sent to other interested users such as Indian Dyestuffs Ltd., Armament Research Estt. etc. The process is based on three alternate raw materials viz., primary zinc metal, galvanizer's dross, hard zinc & Zamak diecasting scrap.

Recoveries of over 90% have been achieved with cost of conversion estimated at Rs. 1.25 to 1.50 per kg. involving equipment costs of upto 15 lakh rupees for a 10 tonnes/day cap. plant.

34.1 Recovery of Zinc Metal from Galvanizer's Dross by Atmospheric Distillation.

Technology for the recovery of zinc metal of purity exceeding 99.90% from galvanizer's dross has been developed and is ready for transfer to industry.

Over 18,000 tonnes of galvanizer's dross is estimated as the annual turnover in the country and with this technology over 93% of the zinc content can be recovered at an estimated cost of less than Re. 1.00 per kg with a total capital invesment of around seven lakh rupees.

34.2 Recovery of Zinc as Chemical Grade Zinc Dust from Galvanizer's Dross.

Techniques for the recovery of zinc metal from galvanizer's dross have been carried forward to produce high quality chemical grade zinc dust to ISI specifications for use in the sodium hydrosulphite industry.

34.3 Utilization of Zinc Ash for Production of Virgin Zinc Metal.

Work was initiated to utilize the zinc ash produced at electrowinning zinc plants in India for the production of Zinc metal. This zinc ash contains 3-4% chlorine which renders it unsuitable to return to the leaching circuit for production of zinc metal.

A technique has been developed to remove 98-99% of the chlorine present in the ash with only 2-3% loss of zinc. The treated zinc ash contains around 78% zinc and 0.03% chlorine which is quite comparable to the imported zinc concentrates containing 52-56% zinc and 0.04-0.07% chlorine. Laboratory scale experiments were carried out on leaching the treated ash in sulphuric acid, purification of the leached solution and electrolysis of the purified solution. Further it has been found by experiments that there is no build up of chlorine on continued leaching of the treated zinc ash in the spent liquor coming from electrolyte zinc cell.

34.4 Manufacture of Zinc Oxide from Waste Byproduct Zinc Hydroxide.

For every kg of sodium hydrosulphite produced using zinc dust, 0.6 kg of zinc hydroxide is produced which needs to be purified for application in chemical industries. A method has been developed to produce pure zinc oxide from the impure zinc hydroxide. Zinc oxide has been prepared on bulk quantities for consumer acceptability tests.

34.5 Recovery of Zinc Values from Galvaniser's Zinc Ash.

The zinc ash formed as a byproduct in the galvanizing plants, contains metallic zinc and zinc oxide totalling to about 60-80% zinc. The object of this project is to separate out the metallic zinc portion from the ash by selective leaching and to produce pure zinc oxide from the rest of the available zinc content in the ash which is dissolved.

A method has been developed to separate the metallic zinc from the ash which could be agglomerated into zinc slabs. Pure zinc oxide meeting the rigid specifications of the zinc oxide for rubber industries (ISI 3399-1965) is produced from the rest of the zinc content in the leached medium. Zinc oxide produced on laboratory scale has been examined by compounding tests by a reputed rubber manufacturing firm and the compounding and activation properties of the zinc oxide have been found to closely match with their standard material in current use.

35.0 Recovery of Cadmium - Tin from Spray Booth Powder.

In the manufacture of selenium rectifiers, a 40% tin. 60% cadmium alloy is used as a spray and significant quantities of spray booth are collected as a waste in cake form containing upto 38% tin and 54% cadmium with traces of iron.

Recovery techniques were successfully developed to yield over 80% of the tin and 75% of the cadmium in the waste cake. It was estimated that recovery treatment on a basis of 50 kg per day of waste cake, material worth over Rs. 5 lakhs per annum could be recovered at a cost of Rs. 3.50 /kg with a total capital investment of less than one lakh rupees. The process is ready for transfer to industry.

36.0 Recovery of Tungsten from Tungsten Carbide Scrap.

Methods which have been tried, consist of oxidizing the scrap at 1000°C in presence of oxygen and fusing the oxidized mass with Na_2CO_3 and Na_2O_2. The fused mass is leached with water and then hydrolysed to tungstic acid precipitate and finally dried at 700° C to get pure tungstic at oxide WO_3 99.9%. This is again reduced to tungsten powder 800 to 900°C in a stream of hydrogen. Other method which is in progress involves direct chlorination of scrap to finally obtain tungsten powder.

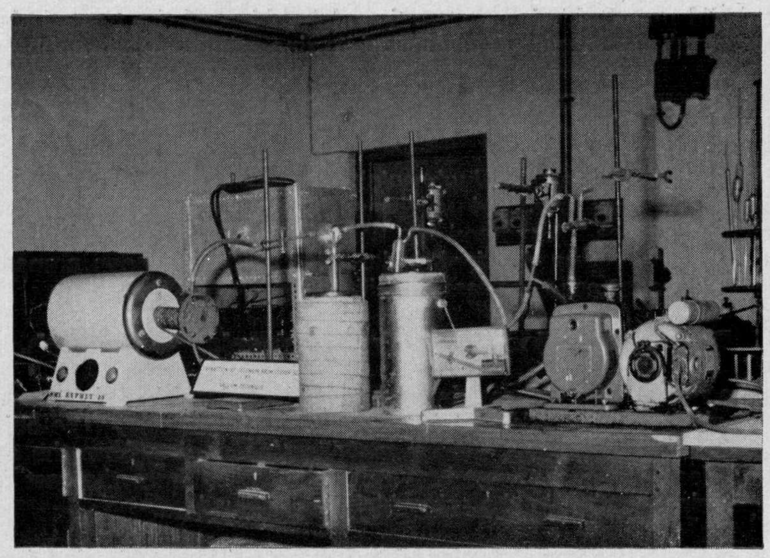


Fig. 8-Set up for recovery of selenium and tellurium from electrolytic copper slimes by vacuum sublimation.

37.0 Recovery of Germanium and Gallium from Coal Ash.

Recovery of germanium and gallium from coal ash is being continued. The germanium bearing fly ashes and flue dusts have been found and located after detailed study of these from various sources. Smelting and chlorination trials to concentrate and then recover germanium have been taken up on laboratory scale.

38.0 Recovery of Selenium and Tellurium from Electrolytic Slime.

The bench scale studies have been completed successfully and various optimum conditions have been determined. Work on separation of copper sulphate and nickel sulphate from the leach solution has been taken up by electrolysis with a view to design a full flow sheet for the recovery of almost all metals from slime.

On the basis of flow sheet developed, a scale up of small plant is being designed with a view to test the data obtained on laboratory scale.

38.1 Recovery of Selenium and Tellurium from Electrolytic Copper Slimes by Vacuum Sublimation.

A new approach of extraction of selenium and tellurium from electrolytic copper slimes by vacuum sublimation has been studied and important parameters determined. Experimental set up of the apparatus is shown in Fig. 8. The work on laboratory scale has been completed.

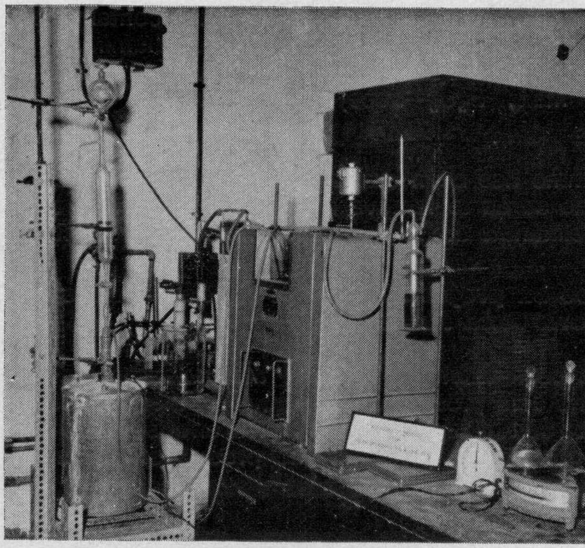


Fig. 9-Set up for recovery of mercury from the gases of sulphide ores by roasting and smelting.

39.0 Recovery of Mercury from Waste Gases of Sulphide Ores Smelting.

The optimum conditions for recovery of mercury from the flue gases of sulphide ore roasting and smelting have been determined. The object of the project is to avoid atmospheric pollution by mercury if the sulphur dioxide is sent to atmosphere or to make the sulphuric acid free from mercury in case the SO_2 present in the flue gases is used for making sulphuric acid. Mercury may be present in the sulphide ores as impurity. Experimental set up is shown in Fig. 9.

40.0 Preparation of Silver Catalyst.

Work was taken up to prepare and regenerate silver catalyst from organic materials for use in chemical industries. Currently the supply of the material depends mostly on foreign sources.

The product obtaned on laboratory scale experiments has been tested and found effective in converson reactions. Currently large scale experiments have been undertaken with a view to evaluate consumer acceptability of the product as well as to confirm the laboratory scale data of the process parameters.

41.0 Studies on the Preparation of Cryolite from G.M.D.C. Metallurgical Grade Fluorspar.

The G.M.D.C. fluorspar contains high percentages of Fe_2O_3 and

P_2O_5. The cryolite prepared from this fluorspar is contaminated with Fe_2O_3 and P_2O_5 rendering the cryolite unsuitable for aluminium industry. The objective is to prepare specification grade cryolite (I.S.I. specification—Fe_2O_3 0.10% max; P_2O_5—trace) from G.M.D.C. metallurgical grade fluorspar.

A programme has been drawn up to upgrade G.M.D.C. fluorspar by chemical means so as to remove P_2O_5 and Fe_2O_3 from the raw material rather than to eliminate the impurities from the end product.

41.1 Studies on preparation of 50 Kg/day Synthetic Cryolite by Fluoboric Acid Process.

Work has been taken up to study the various parameters for scaling up the fluoboric acid process of preparing synthetic cryolite developed in the laboratory to 50 Kg/day production. The efforts will be directed towards setting up a commercial plant for the production of this material with indigenous know-how.

Several experiments were conducted with the set up made for 50 Kg/day production. Cryolite obtained analysed Fe- 52.45; Na—21.21; Al—19.49; SiO_2-0.02; Fe_2O_3—0.06; P_2O_5—0.06; SO_4—1.06; Ca—1.58; combined water 1.66 per cent, Pb was not found. More work is underway.

42.0 Development of a Process for the Production of Electrolytic Iron Powder.

Based on the laboratory scale investigations conducted earlier, work has been undertaken to standardize conditions for production of iron powder of sufficient purity for use in powder metallurgy.

The process has been found suitable for continuous operation in plastic lined mild steel vats producing roughly between 3-4 Kg iron powder per day (Fig. 10). The process parameters in this scale have also been established by continuous running of the cell. The trials are still being continued to produce iron powder.

43.0 Development of Aluminium Cables and Conductors.

Work was continued on the industrial development of NML-PM2 conductor for different electrical applications. The NML-PM2 conductor wire was used to produce 20 pair dry-core underground telephone cable in active collaboration with M/s. Hindustan Cables Ltd., and has satisfied all the requirements of Post and Telegraph Deptt. for equivalent grades of copper. The lead sheathed cable produced with the NML-PM2 conductor is shown in Figure 11. It is significant that conventional continuous processing mill, wire-drawing units and cable making machines have been used in these commercial trials.

The NML-PM2 conductor wires have undergone extensive and exhaustive tests at the Telecommunication Research Centre (P & T Board)

Fig. 10-Production of electrolytic iron powder'

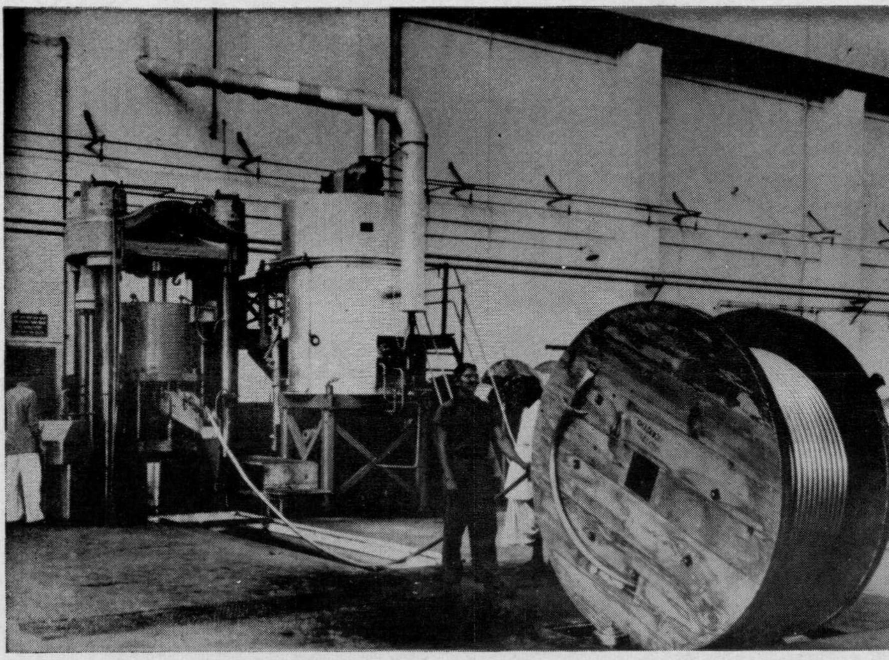


Fig. 11-Lead sheathed cable produced with NML-PM2 conductor at Hindustan Cable Ltd.

and the results obtained are very encouraging. The ductility of these wires in terms of 180° reverse bend test is as good as that of copper.

The NML-PM2 conductor has also been successfully produced on industrial scale into fine size wires upto 0.364 mm dia and the drawing of still fine size wires of 30-34 SWG size is in progress in collaboration with industry.

The electrical and mechanical properties of the NML-PM2 conductor material in terms of electrical conductivity, ductility and tensile strength suggest that the conductor material is suitable for multifarious electrical applications like underground telephone cables, covered conductors, automobile cables, fexible cables, welding cables, magnet wires, enamelled winding wires, mining cables, fine size wires, ACSR conductors etc. The use of this conductor material will save considerable amount of foreign exchange spent on the import of copper used for these applications.

43.1 Development of Alloy Aluminium Conductor.

Development work on a suitable alloy aluminium conductor, possessing suitable combination of electrical and mechanical properties has been continued. Based on the laboratory scale results obtained on the mechanical working characteristics of alloy compositions designated PM51, PM52, PM53 and PM54, the semi-commercial sizes of ingots of these alloy compositions were produced in the laboratory. The hot rolling of PM51, 53, and 54 was successfully done. The wires of the size equivalent to 2.10 mm dia of cadmium-copper from the hot-rolled rods have been produced with a thermo-mechanical treatment. Further work is in progress to obtain suitable combination of electrical and mechanical properties by appropriate thermo-mechanical treatments suitable for use as catenary wires for over-head railway electrification in place of cadmium-copper conductor.

44.0 Al-Mg Mischmetal-Chromium Wrought Alloys.

Laboratory scale trials were made for determining the hot-workability of the alloys under development. The composition range of the alloys is Al-(7-8.5%) Mg-(0.5-2.5%) misch metal —(0.15-0.3%) Cr. The alloys were prepared in gas fired furnace and high frequency induction furnace. The alloys prepared in high induction furnace, contained less gas and pin hole porosity was reduced. Also the composition at the top and bottom of the ingots was more uniform than in the ingots prepared in gas fired furnace.

The effects of Ti and Cr on the grain refinement were studied. It was possible to hot forge the ingots (size 50 mm×50 mm×250 mm) and hot roll the billets to sheets of 3 mm thickness. Rolling trouble and failure like edge cracking and crocodiling were experienced.

45.0 Studies on Stress-Corrosion Characteristics of Al-Mg alloys.

Specimens of Al-Mg mischmetal—Cr alloy were tested for stress corrosion susceptibility in 3.5% NaCl solution in the Distington Stress Corrosion testing machine and NML fabricated spring loaded jig. Specimens testes at 60% of proof stress has a life of over five months in typical case. Work has been initiated to fabricate a battery of twelve such machines.

46.0 Development of Self-Lubricating Bearing Materials.

Studies were made to evaluate the influence of various material and process parameters on the impregnation of a sintered porous iron skeleton by graphite. It was found that size and shape of iron powder, the size of the volatile filler used during compaction, size and shape of graphite powder and the viscosity of suspension have significant effect on the degree of pore filling. The optium conditions for impregnating a porous sintered metallic skeleton by a solid lubricant (such as graphite) has been established. Under optimum conditions about 3 to 3.5 wt% graphite (i.e. 10 to 12 Vol%) can be impregnated in porous skeleton with 50% porosity.

The next stage of work includes the evaluation of wear and antifriction properties and the mechanical properties of these impregnated skeleton prepared under various conditions.

47.0 Pneumatic Steelmaking in Basic-Lined Side-blown Converter.

The following compaigns were conducted during the period in continuation of the four compaigns conducted earlier.

(i) Fifth campaign : The fifth campaign was undertaken with a view to study the effect of primary slagging on phosphorus and sulphur removal of the steel.

(ii) Sixth campaign : The sixth campaign was done in order to study the operational behaviour for continuous number of blows.

(iii) Seventh & Eighth campaign : Both seventh and eighth campaign were done in order to determine the position of corrosion in lining.

(iv) Ninth campaign : The ninth campaign was done to study the behaviour of chemically bonded refractory tuyers block.

48.0 Special Steelmaking in Top Blown Converter by B.O.F. Process.

Trials were conducted in 100 kg capacity top blown converter to standardise the consistency of the process. The same trials were continued with the addition of alloying elements. A number of heats were made to observe the replaceability of scraps by sponge iron.

From the results, it was observed that chromium pick up in some heats is in the range of 45-50%, but in some heats it is very low. The slag analysis shows that the FeO content in some heats is high, though in most of the heats it is within the limit. Also it was evident from the results, that quite a good percentage of consistancy in performance was achieved.

Trials were conducted with the addition of sponge iron gradually increasing from 2, 4, 6 and 9 percent to observe what level it can replace scraps and its trends. From the results it was observed that the sulphur content of the blown metal increased slightly with the addition of sponge iron. The FeO content of the slag increased though the consistency in performance was achieved.

49.0 Continuous Steelmaking.

After completing the literature survey on continuous steelmaking and spray refining process as developed by BISRA, experimental programmes were worked out to conduct preliminary trials in order to study various aspects which do influence to a greater extent the techno-economics of a process. To achieve this end, a launder furnace has been designed and fabricated. Necessary equipments are being procured.

50.0 Setting up of a L-D Unit having 220-230 Kg. Capacity

After having worked with 100 kg. converter it was observed that heat losses are excessive and control of the operation is quite difficult. It was, therefore, decided to set up a slightly bigger converter of 200-230 kg. capacity having modern technical devices. Accordingly a converter was designed, fabricated and installed. Controlling equipment and measuring devices are being procured.

51.0 Development of Nickel Free Heat Resistance Cast Iron for High Temperature Applications

The investigation was undertaken with the object of producing high chromium content cast iron for using as a heat resistance material in the high temperature range and also to study the various parameters of properties like growth oxidation resistance etc.

At the initial stage of the investigation, experiments were conducted to observe the melting characteristics of ferro-chrome in pit furnace with basic pig iron.

52.0 Production of Ferro-Phosphorus in the Low Shaft Furnace.

To determine the possibilities of production of ferro-phosphorus in the low shaft furnace, about 26 tonnes of phosphate rock was sent by a party from a quarry near Chakulia in Bihar State. After heating the furnace upto desired temperature by using fire wood logs, initially iron ore was used utilising nut coke from Tisco as fuel and Satna limestone and Assam dolomite as fluxes. Later on the phosphate rock charge was included in the burden in two stages. The smelting of the phosphate ore in both the stages was very smooth. The chemical analyses of the ferro-phosphorus produced and the corresponding slag analysis is shown in Table 1.

TABLE 1

Chemical analyses of the ferro-phos and corresponding slag

Analyses of	5 kg phosphate rock in the the charge		10 kg phosphate rock in the charge	
	47 M_4	47 M_8	47 M_{17}	47 M_{18}
Ferro-Phos.				
% P	1.56	—	3.70	4.16
% C	2.68	2.62	—	—
% Si	4.17	2.60	2.89	3.36
% S	0.105	0.11	—	—
% Mn	—	—	—	—
	47 S_8	47 S_{14}	47 S_{21}	
Slag :				
% CaO	37.08	35.37	35.10	
% SiO_2	30.84	31.60	30.10	
% FeO	2.16	2.32	5.20	

53.0 Effect of Oxygen Enriched Hot Air Blast in Cupola Iron Melting.

Experiments were conducted by enriching the hot air blast in different temperature ranges by 1 to 4% of oxygen. In all the experiments the coke rate was kept as 10 kg of coke per 100 kg of metallic charge, except when steel scrap was melted with 33%. The other operational variables like airblast pressure, its volume, bed coke weight, soaking time etc. were kept same in all the experiments. It was observed that for every one percent increase in the enrichment of the air blast by oxygen at a particular hot air blast temperature range, the molten metal temperature increased by an average of 20 to 25 °C. The rate of increase of the hot metal temperature was proportional to the rate of increase of the oxygen in the air blast upto 3%, after which it decreased probably indicating 3 to 3% as the optimu m working range so far as the oxygen enrichment is concerned. In the top gases, the percentage of the oxygen increased as the enrichment of the air blast increased stage wise.

The increase in the molten metal temperature vis-a-vis the enrichment of the hot air blasts at three different ranges, by oxygen ranging from 1 to 4 by volume of the air blasts used is shown in Fig. 12.

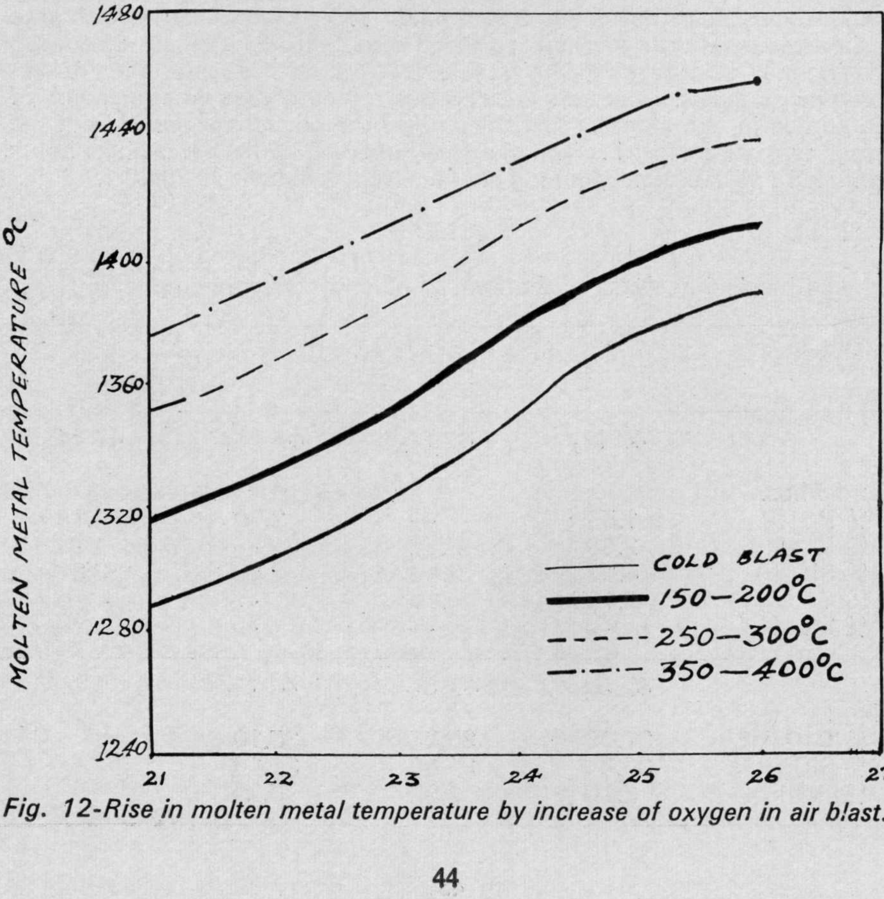


Fig. 12-Rise in molten metal temperature by increase of oxygen in air blast.

54.0 Appraisal of Raw Materials for Iron Making.

In order to find the suitability of raw materials for iron making, it is necessary to conduct various physical and chemical tests, such as reducibility, decrepitation, porosity, shatter and abrasion etc. and calcination of limestone.

The following investigations were completed during the period.

(i) Decrepitation test on iron ore and pellets from TISCO.

(ii) Decrepitation test on iron ore from Donimalai.

(iii) Decrepitation test on iron ore from Orissa Mineral Corporation Ltd. (Daitri Iron Ore Project).

(iv) Physical Characteristics and reducibility of Maharashtra iron ore (SICOM).

(v) Calcination test on Salem limestone.

55.0 Continuous Reactor for the Reduction of Iron Ores with Naphtha.

After obtaining the preliminary success of producing sponge iron by reducing iron ores directly with naphtha, several campaigns were undertaken to obtain the optimum process parameters. It was also attempted to obtain the maximum naphtha efficiency while producing sponge iron with over 96% metallization. This process has got potentiality for commercially producing sponge iton in localities of naphtha abundance or coastal location of sponge iron plant wherein the naphtha will be imported from neighbouring countries and sponge iron can be exported. The design work on the pilot plant based on this process has been undertaken for a scaled up capacity of about 12 tons/day of the sponge iron.

56.0 Parametric Investigations for the Reduction of Manganese Ore with L.T.C. Coke in a Continuous Shaft Reactor.

This investigation was undertaken with a view to find out alternative reducing agents other than the coke oven gas for the efficient reduction of manganese ore, which is the first step, for production of electrolytic manganese. Several series of experiments were performed by varying particle size, the type of reductant, reductant/ore ratio, temperature and duration of the experiment. It was found that efficient reduction, of MnO_2 to MnO of manganese ore, can be obtained by using about 10% by weight of low temperature carbonized coke, in about 20 minutes. Recoveries of about 95% were obtained by choosing the above experimental conditions. The experiments were repeated with low grade manganese ore and it was found that about 7% L.T.C. coke, as reductant, was enough to yield about 94% manganese recovery in about 20 minutes. The report is being made ready for using these parameters in a continuous vertical shaft furnace.

56.1 Continuous Vertical Shaft Reduction of Manganese Ore on Large Scale (250 Kg/day).

After obtaining the desired recoveries of manganese in the reduction of MnO_2 to MnO by maintaining the optimum experimental conditions in a batch process, it was decided to instal a continuous vertical shaft furnace of a capacity 250 kg/day. The installation includes a continuous screw charging and discharging system with external electrical heating and simultaneous leaching of reduced manganese ore. The whole equipment is under fabrication and is likely to be installed shortly.

57.0 Vanadium-Nitrogen Low Alloy High Strength Structural Steels.

Six 10 kg heats of vanadium-nitrogen low alloy high strength structural steels were made in the 30 KW high frequency induction furnace in the following range of composition :

C —0.15%
Mn —1.5
V —0.10 to 0.20%
N —0.012 to 0.015%

The ingots are awaiting forging.

58.0 Ferritic Stainless Steels.

Six 8 kg heats of 17% chromium ferritic stainless steel were made in the 20 KW high frequency induction furnace with additions of niobium ranging from 0.03 to 0.5%. The ingots have been forged into slabs which are awaiting rolling into sheets. Metallographic and ageing studies have been carried out on samples from the forged slabs. Further work is in progress.

59.0 Cr-Ni-Cu Austenitic Stainless Steels.

Seven 8 kg heats of Cr-Ni-Cu austenitic stainless steel have been made in the 20 KW high frequency furnace in the following range of composition.

Cr —17%
Ni —5 to 8%
Cu —3 to 4%

The ingots are awaiting forging.

60.0 Carburising of Grain Refined Steels at High Temperature.

Four 10 kg heats of grain refined carburising steels were made in the 20 KW high frequency induction furnace with titanium and titanium plus chromium. The ingots are awaiting forging. Carburising characteristics of standard carburising steels with and without titanium additions are being investigated.

61.0 Development of Nickel-free Austenitic Creep Resistant Steels.

With a view to improve elevated temperature creep strength properties of Cr-Mn-N-Cu austenitic stainless steels, several alloys with additions of alloying elements such as W, Ti, Al and Mo were made. The alloys were made in 10 Kg induction melting furnace and ingots, 64 mm square, were reduced to 34 mm square by hot-forging in the temperature range 900°-1200°C. Several reheats to the forging temperature 1200°C were necessary. After forging, solution treatment of the alloys with additional alloying elements was carried out at relatively higher temperature (1250°C) to bring back as much carbides and nitrides into solution as possible. It was found that no appreciable grain coarsening occurred during solution treatment of these alloys even after longer soaking periods upto 4 hr at 1250°C. This confirmed that these alloying elements inhibited grain coarsening. The results obtained indicated significant improvement in creep properties of Cr-Mn-N-C steels in presence of these alloying elements (Fig. 13).

Further work is underway to develop Mn-Cr type austenitic steels and the possibility of improving the creep and oxidation resistance of these steels by minor alloying addition being explored.

62.0 Cryogenic Steels.

Few more heats of low carbon steels with 7 to 9% Mn and suitable grain refiner were made and studied. The microstructures were quite favourable for low temperature toughness. Much progress could not be made due to trouble of melting and forging etc. Further studies are in progress.

62.1 Development of Tool and Die Steel

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

1. High hardness (650 VPN) and abrasion resistance.
2. Dimentional and structural stabilities of structure.
3. No distortion during heat-treatment.
4. Good tensile strength.

62.2 Electro-Slag Remelting.

Industrial evaluation work is in progress on the following steels :—

(a) Ball bearing steel.
(b) Air hardening steel for high temperature applications.
(c) High speed steels.

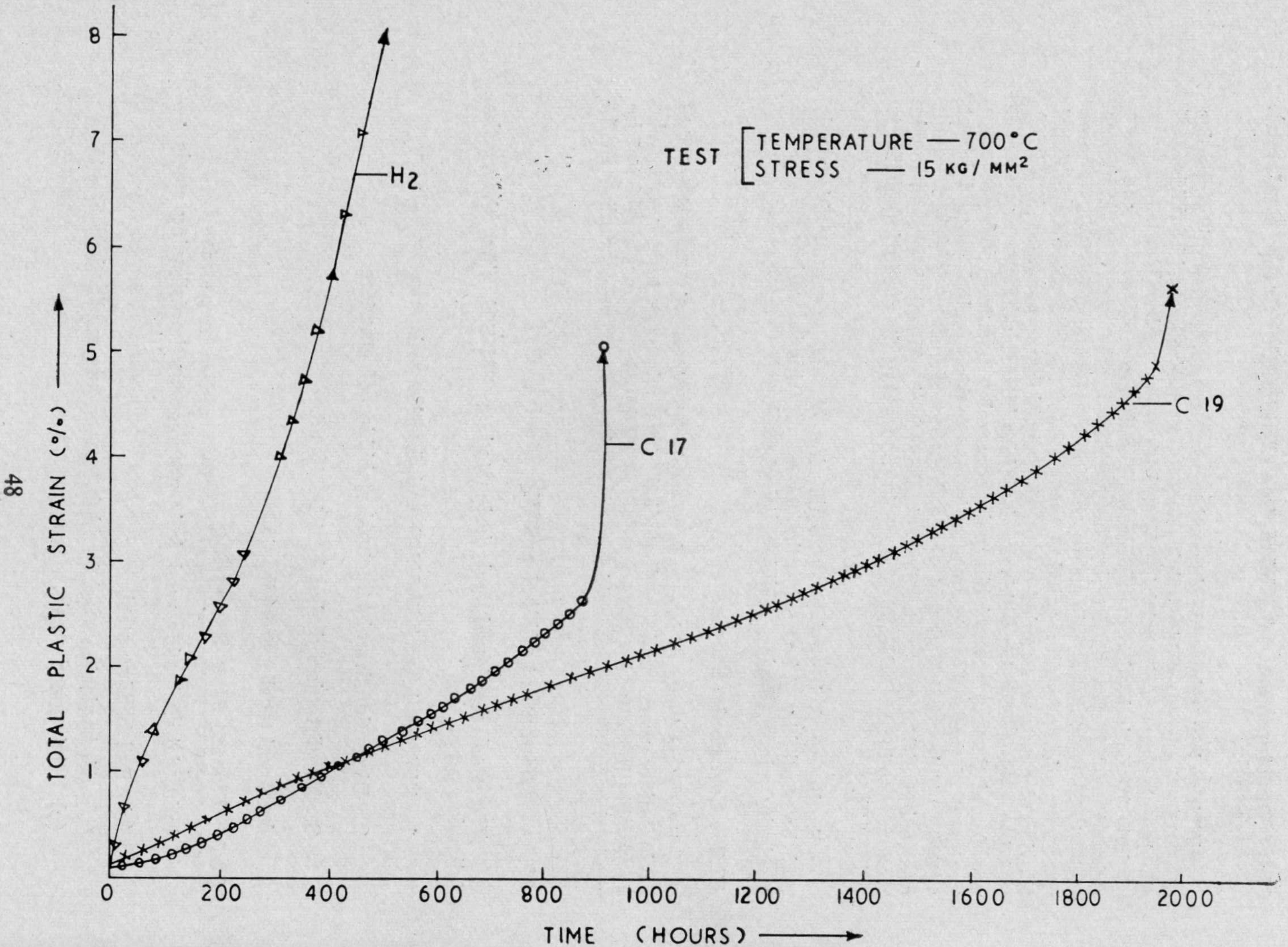


Fig. 13-Creep curves of alloys H2, C17 & C19.

Most of the electrical accessories of the new electro-slag remelting set up have been received and fabrication is in progress.

62.3 High Strength Fe-Al-Si Alloys.

In continuation of previous work, the effect of ageing treatments on the mechanical properties has been studied. Corrosion studies on five alloys having different compositions of Al and Si are Al and Si are being carried out.

63.0 Commercial Trial Heats and Subsequent Rolling Schedule of Niobium Treated Steel at Rourkela Steel Plant.

A 50 ton L/D heat of low-carbon manganese steel was made at Rourkela steel melting shop. The ladle analysis of the melt was as follows :

Element	*wt. per cent.*
C	0.16
Mn	1.28
P	0.017
S	0.016
Si	0.080

Ferro-niobium was added at two different levels to two moulds. The soaked ingots were sent to roughening mill, where a total number of 21 passes were given so as to produce 145 mm thick slabs. The tensile properties were determined on specimens both in longitudinal and transverse direction to rolling. Also charpy V-notch impact values were evaluated at both longitudinal and transverse direction. The microstructure was studied under optical microscope.

It was observed that excepting where mixed grain sizes were produced, it was possible to obtain a good combination of high yield strength and low transition temperature.

64.0 Stainless Steel for Safety Razor Blade.

Safety razor blade is an important item of consumer product, with considerable export potential. An investigation was carried out with a number of stainless steel safety razor blades available in the market. Detailed investigation revealed that there was no material difference between the strips used in the manufacture of stainless steel safety razor blades in the country and those used by the manufacturers abroad. Metallurgically both Indian and Foreign brands attain the same excellence in terms of microhardness and microstructure.

65.0 Isotropic Ferrite Magnets Based upon Mixed Compositions.

The effect of small additions of divalent and trivalent oxides on the properties of barium ferrite composition were further studied after sintering at various temperatures between 1050 to 1750 °C. Some of the composition were found to be associated with energy product of 1.4 mgO.

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

During the period under review experiments were carried out to produce columnar crystals in loud speaker magnets of 25.0 mm dia. and 15.0 mm length varying casting temperatures, size of the runners, exohtermic mixtures and hot tops. It was observed that variations in these conditions resulted in 10 mm length of the columnar crystals. Further experiments in this direction are in progress.

The effect of different moulding materials and conditions were also studied on the surface finish of the alnico alloys. The materials studied were silica, zircon and sillimanite sand of various mesh sizes with sodium silicate/bentonite/dextrine as binders in various proportions.

65.2 Growing Single Crystals of Ferromagnetic Oxide.

Single crystals of ferrites are used for numerous industrial applications as in Video recording heads and microwave applications. Due to the industrial importance of these crystals, work was undertaken to grow crystals of appropriate size and shape. As a first step, a literature report on growing of single crystals was prepared. Out of the various methods suggested the flux-melt technique was considered appropriate to get some experience on the growth of crystals. A furnace going upto 1300°C was fabricated for melting the fluxes and oxides. The furnace had a uniform temperature zone of four inches. A platinum crucible was also fabricated for melting the fluxes etc.

65.3 Preparation of γ-Fe_2O_3

γ-Fe_2O_3 is used for recording sound in tape recorders. Due to immense future requirements of this material in India a project on developing the know-how of γ-Fe_2O_3 was undertaken. It was found that it is possible to produce γ-Fe_2O_3 by wet oxidation of magnetite. The method however suffered from the defect that the final particle size was difficult to control. This difficulty is minimised if Fe_3O_4 is precipitated from its constituant salts, (ferrous and ferric salts) under controlled conditions. Preliminary tests showed that γ-iron oxide so produced was accicular in nature with saturation induction of 67 gauss/cm^3/gm. Further studies to optimise the conditions are in progress.

66.0 Production of Chromium Coated Steel to Replace Tin Coated Steel.

During the period under review, bigger size samples of 30 cm×30 cm were prepared and sent for consumer acceptability test to a reputable firm. Studies on the various changes produced in the bath during electrolysis and the replenishment of the bath by the addition of fresh constituents are in progress. Design of cell and accessories for the preparation of still bigger size of samples (60 cm×80 cm) are being made.

67.0 Corrosion Studies on Nickel-free Stainless Steel Developed at NML.

A few compositions of the nickel-free stainless steel which showed very good resistance in 65% boiling nitric acid test were checked for their performance in various other neutral and acidic media. The B_2 composition showed high resistance to corrosion in a number of media. Further tests using potentiostatic techniques are in progress to assess the corrosion resistance properties of B_2 composition in comparison to 304 and 316 stainless steel are in progress.

68.0 Atmospheric Corrosion of Metals and Alloys.

Long term exposure studies using various ferrous and non-ferrous metals such as mild steel, low alloy steel, copper, brass, monel, aluminium etc., which were started in the year 1964 are being continued. Non-ferrous metals such as copper, brass, zinc, aluminium etc. were removed after eight years exposure for the assessment of corrosion rate. Low alloy steel samples were also removed after exposure for eight years for studies on the properties of the rust formed on the samples. The report on electro-probe micro-analysis, x-ray diffraction and metallographic studies of the rust showed a remarkable variation on the corrosion products from the base metal to the periphery. Further studies, such as chemical analysis for the constituents present, polarisation, etc., are in progress.

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

Successful coating compositions based on vinyls and suitable primers for the same were developed. Necessary metal pre-treatment procedures were developed for imparting good adhesion of the coating to the base metal. The coatings possess good ductility and excellent corrosion resistance as evaluated by accelerated corrosion testing procedures and also electrochemical methods. Their resistance to ultra-violet light is poor but they showed excellent performance under indoor conditions. Coated samples of larger dimensions are being prepared for consumer acceptability tests.

70.0 Evaluation of the Corrosion Resistance Properties of Plastic Coatings by Electrochemical Method.

A number of compositions were tested using an A.C. bridge circuit for measurement of electrical resistance and capacitance of coated panels with time while the coated samples are immersed in 1% sodium chloride solution. Two compositions were found to be extremely good from the data obtained in these experiments. The A.C. bridge set-up used in the investigation of vinyl coatings can be utilised for the study of any other organic coatings.

71.0 Vinyl Coatings on Aluminium.

Chromate passivation treatment for aluminium was developed in order to improve adhesive of the vinyl coatings to aluminium and also prevent decomposition of vinyls in contact with pure aluminium. The successful compositions developed for steel were tried on aluminium and they are found to possess excellent adhesion. A number of large panels have already been made for consumer acceptibility tests.

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

Further experiments were carried out on chromising of sheet and rod samples of steel and some of them were subjected to aluminising also after chromising. The depth of diffusion zone was found to be about 250 microns. Experiments were carried on aluminising and effect of annealing after aluminising was also studied. Annealing is found to improve the uniformity of the coating. The diffusion coated samples were sent to Defence Metallurgical Research Laboratory for analysis of Si, Cr, Al etc. at different depths in the coating zone.

73.0 Effects of Alternating Currents on Corrosion Behaviour of Metals in Aqueous Media.

Studies on the dissolution rate of mild steel in hydrochloric acid solution with A.C. of different frequencies and current densities was carried out. Results obtained indicated that the rate of corrosion decreased with increasing frequency, and dissolution rates were higher at higher current densities. The explanation suggested for decrease in corrosion rates at higher frequencies was that at higher frequencies, current was not actually made available for the Faradic process due to interference from hydrogen ions.

74.0 Evaluation of Inhibitor Efficiency and Hydrogen Pick-up by Steel During Pickling.

Further work on hydrogen embrittlement in 1N H_2SO_4 containing thiocompounds such as hydrogen sulphide, NN' diethylthiourea, diphenyl thiourea, isobutylmercaptan, secondary butylmercaptans were carried out at 40°C. The data on corrosion rate, potential change and cracking time were collected. The results indicated that corrosion cracking susceptibility of high carbon steel (0.86%C) was influenced markedly by the concentration of the inhibitors. An interesting phenomenon observed in the case of hydrogen sulphide was that the concentration of H_2S in between 0.6-0.8 ppm in 1N H_2SO_4 could give inhibition in between 40-60% with maximum shift in potential in negative direction, and with highest cracking time. Below and beyond that concentration, the cracking time and percent inhibition efficiency were comparatively loss;

Effect of cathodic charging on the inhibition efficiency of isobutyl mercaptans, secondary butyl mercaptan, T-octyl mercaptan, 2-mercapto-benzothiazole, quinoline and acriflavine was studied. The result indicated that cationic inhibitor with cathodic charging showed synergistic effect whereas anionic inhibitor with cathodic charging behaved antagonistically.

75.0 Studies on Stress Corrosion Cracking of Copper Base Alloys.

Effect of polarisation on cracking susceptibility in Mattsson's solution, fractographic studies, electron micro-probe analysis of Cu-Zn, Cu-Mn, and Cu-Al alloys showed interesting results. Various parameters of the stress corrosion cracking behaviour of austenitic stainless steels were studied in boiling magnesium chloride solution. At various operating test conditions the mode of cracking, time of failure and detailed nature of the cracked surface by fractography were studied.

76.0 Use of B.F. Slag as Rail Ballast.

Results on field trials and laboratory tests indicated that air cooled B.F. slag can be used as rail road ballast in place of stone ballast from the point of view of corrosion properties. At a joint meeting held at Research Design & Standard Organisation, Ministry of Railways, it was decided to draw up a specification for B.F. slag ballast for the use on rail road. Specification of stone ballast now in use for Railway is not available. Data relating to the use of standard ballast in different parts of rail road in India are being collected which will help to draft a specification for the B.F. ballast.

77.0 Use of Silico-chrome Slag as Railroad Ballast.

Laboratory tests on lump density, pH of the water extract of the ballast, corrosion rate of rail steel in the water extract were performed. Field trial with these ballast in situ are being planned.

78.0 Testing for the Performance of the Various Inorganic Coatings on Steel Exposed to Industrial Atmosphere at Jamshedpur.

Work was taken up to obtain atmospheric corrosion data which will be helpful for selecting suitable protective scheme for structural material.

It was proposed under the above scheme to conduct atmospheric corrosion tests at different exposure sites in India, on the under mentioned protective schemes :

1.	Alclad	painted and unpainted.
2.	Anodised	-do-
3.	Galvanised	-do-
4.	Aluminised	-do-
5.	Mild Steel	-do-
6.	Aluminium (Alcoran treated)	-do-

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

79.0 Stress Corrosion Cracking of High Strength Aluminium Alloys.

The project is associated with the development of high strength Al-Zn-Mg & Al-Zn-Mg-Cu alloys which are very susceptible to stress corrosion cracking in chloride atmosphere. Overageing treatment of these alloys improves resistance to s.c.c. on the expense of strength. The aim is to achieve resistant against s.c.c. in these alloys by adding alloying elements, performing typical heat treatments and mechanical workings without the loss of mechanical strength. An apparatus has been fabricated to study the s.c.c. behaviour of plate specimen in plain or pre-cracked form.

80.0 Development of Oxidation Resistant Chromium Steel.

In high temperature oxidation resistant alloy series Fe-Cr-Al alloys are the cheapest. The main requirement for these alloys are low carbon steel containing maximum 0.02% P; low carbon ferro-chrome and some other alloying elements like Al, Si, rare earths etc. By proper improvement, the Fe-Cr-Al alloys can surpass chromium-nickel steel in oxidation resistance. A steel based on Fe-Cr-Al system has been developed in USSR which oxidised at 1100°C at the rate of 0.03 mm/year. This steel surpasses titanium stabilized 25% Cr steel in sulphurous atmosphere, 23% Cr-18% Ni steel and 25% Cr-20 Ni-2% Si steel in oxygen pre-heater. The project aims to develop such steel utilizing cheap resources to substitute nickel containing alloys for oxidation resistant purposes. Further the project aims to improve creep strength of ferritic Fe-Cr-Al alloys by dispersion hardening. An apparatus has been designed and fabricated to study the high temperature oxidation of metals. Literature survey has been made and based on that a review report on the subject has been drafted.

81.0 Development of High Alumina Refractories from Indigenous Bauxite.

Work on the evaluation of indigenously available bauxite for development of high alumina refractories was completed. Part I dealt with the evaluation of bauxites namely Shevaroy white and red, Katni white and red and Jammu and Kashmir bauxite. Physical and chemical and mineralogical (including D.T.A., microscopy and X-ray analysis) studies indicated that these are generally suitable and are expected to yield good quality high alumina refractories.

Part II pertained to the development of high alumina refractories from the above. Grog mixes were made from the bauxites with and without the addition of clays. In some gorg mixes fused alumina made locally in NML was added to scale up the alumina contents. Grog specimens were fired at high temperature to remove all shrinkage (the shrinkage ranged from 15% for Jammu and Kashmir bauxite to about 50% in case of Shevaroy red variety). Topaz and rock phosphate were added as mineralisers to no effect.

Some service tests done at a local engineering firm on a 60% high alumina brick made from red variety of bauxite showed them to be quite suitable for the skid rails of a block and billet reheating furnace, where they were exposed to heat and radiation.

82.0 Production of High Alumina Cement and Castables.

The object of this project is to provide high alumina cement and castables for making special refractories and shapes to be used for the construction of 180 ft long electrical tunnel kiln & other furnaces for the carbon plant to facilitate and economise the plant set up.

Calcination of about 45 tons of kyanite was done in D.D. kiln at a suitable temperature with a 3 ton batch every time and a soaking of 8-10 hours to have uniformity in the calcined product. After determining physical properties such as apparent porosity, bulk density and true specific gravity, the material was crushed through jaw and roll crushers to have aggregate of known physical characteristics to be utilised for making high alumina castables.

About 60-65 tons of high alumina castables were made for the following purposes :

1.	Tunnel kiln sagger base along with side wall slabs size	70 pcs	35 tons
2.	Slabs for holding heating elements	200 pcs	5 tons
3.	Roof slabs of size $40' \times 18' \times 1\frac{1}{2}'$ for tunnel kiln.	150 pcs	5 tons
5.	Saggers for D.D. kiln and bogey kiln	30 pcs	15 tons
6.	Special shapes for tunnel as well as DD kilns		8 tons

83.0 Work on Castable Suspensions of Non-plastic Refractory Materials.

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

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

84.0 Studies on Clay Bonded Graphite Refractories.

A literature review was carried out on clay bonded graphite refractories. A sample of fireclay (Bommur) was received from The Andhra Pradesh Mining Corporation Ltd. with a view to evaluate its suitability for refractory purposes. Different properties of this fire-clay were studied to examine its mineralogical characteristics and its usefulness as a refractory material. Further work is in progress.

85.0 Submerged Arc Welding Flux.

During the period under review work was continued on basic fluxes. Three compositions were prepared and bead on plate tests were conducted. Initial trials showed poor performance such as pitted appearance of the weld deposit formed and porosity in the slag with poor flow properties. Readjustment of compositions gave encouraging results. Drillings were taken from the weld bead and sent for analysis. The flux compositions still need some improvement as regards the weld metal analysis. These improvements are being worked out. Some compositions have even higher basicities are also being prepared.

86.0 Development of Welding Technology.

Keeping in view the needs of the industries, the following projects have been initiated.

(i) Study of the welding characteristics of ferritic and austenitic stainless steels with a view to develop suitable techniques of welding these special types of steels.

(ii) Study of the welding characteristics of non-ferrous metals and alloys such as aluminium and its alloys, copper and its alloys.

(iii) Development of hard facing electrodes and suitable techniques for their application.

87.0 Fluidized Moulding Sand Mixtures.

After standardizing the fluid sand mixture in the laboratory scale experiments, foundry floor trials were carried out by making large size cores measuring 18″×15″. These trials have given indication regarding the possible difficulties that may be encountered when using the process for production of castings. These include difficulties in stripping pattern and core boxes, cracking of moulds and cores, adjustment of setting time etc. Experiments are in progress to overcome such difficulties. After suitable remedial measures are developed, actual testing trials will be taken up.

88.0 Development of Analytical Techniques of Metals, Alloys, Minerals etc.

(i) *Rapid Spectrographic Method for the Simultaneous Determination of Silica and Alumina in the Iron Ores.*

Existing spectrophotometric methods are unsuitable for the determination of alumina and silica from the same solution of ferrous samples. In the present work, determination of silica has been tried by the silico-molybdate method from a solution of iron ore from which alumina had already been estimated. The results are found satisfactory.

Typical data on silica content of a few iron ores estimated by the method developed is given in the next page.

		Percentage of SiO_2 (present)	Percentage of SiO_2 (found)
(a)	Iron ores (NML Standard sample)	3.49	3.48
(b)	Iron ores (BS)	8.13	8.09
(c)	Dhatkuri iorn ores	1.22	1.16

(ii) *Rapid Indirect Volumetric Method for the Determination of Silicon in Ferro-Silicon.*

It has been observed during the analysis of a very large number of ferro-silicon samples that the total percentage of iron and silicon in different grades of ferro-silicon comes to 98%. The remaining 2% invariably accounts for impurities. Thus, if only iron is determined volumetrically and deducted from 98, percentage of silicon should be available. It has been shown this does make out in practice.

Results of analysis of a few typical samples bear out the above contention.

	Percentage of Silicon: Indirect volumetric method	Percentage of Silicon: Conventional method
1. Fe-Si (19-79)	78.94	78.84
2. Fe-Si (24-74)	74.04	74.12
3. Fe-Si (27-71)	70.99	70.96
4. Fe-Si (29-69)	69.14	69.07
5. Fe-Si (33-65)	64.92	64.82

The method is helpful where chemical analysis is wanted in batches or in production scale. It saves time as well as costly materials like platinum vessel, nickel crucible, sodium peroxide etc.

(iii) *Separation of Cadmium and Zinc and their Complexometric Determination in Cd-Zn Alloys.*

Cd and Zn can be determined complexometrically in presence of each other. But it is better if they are separated first and then each is estimated in absence of the other.

The classical method of separation of Cd from Zn by hydrogen sulphide (H_2S) at controlled pH is tedious and clumsy. In the present work, Cd and Zn were separated by alkali treatment and estimated separately by EDTA titration.

A synthetic mixture of Cd and Zn of different ratios were taken and analysed by this method. The results obtained were found satisfactory.

(iv) *Development of Technique for Rapid Determination of Oxygen in Liquid Steel by Electro-chemical Probe Method.*

During the period under review, a comprehensive literature survey report has been prepared on the various investigations on development of probes for oxygen in liquid steel bringing out the merits and demerits of operation of probes. It has been possible to prepare fully stabilised zirocnia. Attempts are being made to reduce the level of impurities.

(v) *Routine Chemical Analysis.*

1680 samples containing 5390 radicals were analysed during the year for different research divisions of the laboratory and sponsored investigations.

(vi) *Routine Spectrographic Analysis.*

Qualitative analysis—180 samples were analysed for major and trace elements.

Quantitative Analysis—One sample for six radicals was analysed.

(vii) *Analysis of Gases in Metasl.*

About 100 samples of ferrous and non-ferrous metals and alloys were analysed for different research projects of the Laboratory and from outside parties, for metal gas analysis by vacuum fusion method. Besides about 200 samples of gas mixture were analysed for CO, CO_2, O_2, H_2, N_2 and CH_4 in connection with sponge iron project.

89.0 Preparation of Standard Samples.

During the period, the following standard samples were undertaken for preparation.

(a) Ferro-Silicon
(b) Brass (60-40)
(c) Brass (70-30)
(d) Nickel steel

The analytical result of standard ferro-silicon sample prepared & analysed is as follows :

Silicon	..	74.92%
Aluminium	..	0.477%
Phosphorus	..	0.025%
Calcium	..	1.99%

Samples of ferro-silicon have been sent to various institutions for analysis and analytical results are awaiting.

Standard sample of brass (60% Cu, 40% Zn) was prepared and it analysed as follows :

Copper	..	58.26%
Zinc	..	38.74%
Lead	..	2.64%
Iron	..	0.098%

Brass (70% Cu, 30% Zn) was obtained from M/s. Binani Metal Works, Calcutta. Analytical results of final sample obtained in this laboratory, is given below :

Copper	..	70.48%
Zinc	..	29.36%
Iron	..	0.070%

Preparation of nickel-steel (3% Ni) is under progress.

The following standard samples were sold during the period.

(a)	Steel Sample No. 12.2	..	10.2 Kg.
(b)	Steel Sample No. 13.2	..	14.6 Kg.
(c)	Steel Sample No. 14.1	..	0.3 Kg.
(d)	Low Alloy Steel No. 25.2	..	4.5 Kg.
(e)	Iron Ore No. 61.1	..	0.9 Kg.
(f)	Mn-Ore No. 66.1	..	0.6 Kg.
(g)	Lime stone No. 71.1	..	0.4 Kg.
(h)	Alloy Cast Iron No. 7.1	..	3.9 Kg.
(i)	Alloy Cast Iron No. 7.2	..	3.6 Kg.
(j)	Ferro-Chrome No. 30.1	..	0.6 Kg.
(k)	Cast Iron No. 1.4	..	1.4 Kg.

C. APPLIED BASIC PROJECTS

90.0 Structure of Liquid Metals.

(*i*) *Al-Si-Mg Alloys.*

It was reported earlier that in the Al-Si system the nature of clustering in the hypo-eutectic region is different from that in the hypereutectic region. Clusters in the former are of like atoms and in the latter of unlike atoms. The effect of Mg which forms strong intermetallic compounds with silicon was studied during this year. Aluminium alloys containing 7%, 12% and 16% silicon were chosen to which 2% and 6% Mg were added separately and the melt was centrifuged at a centrifugal force of 63.5 g for varying periods of time at 750°C. The chemical analysis and metallographic studies of the centrifuged specimens revealed that :

(a) In hypo-and hyper-eutectic alloys the clusters are of Al-Si and Si-Si types respectively.

(b) Additions of increasing amounts of Mg either destroys clustering due to the formation of inter-metallic compounds or forms ternary compounds of nearly identical density as that of liquid aluminium.

(*ii*) *Liquid Metal & Solidification.*

Studies on the effect of rapid solidification of Al-Si alloys from the liquid state were continued. It was observed that the limit of primary solid solubility of Si in Al is extended almost to the eutectic composition after solidifying the alloy rapidly from the liquid state, resulting in the formation of super saturated solid solution. The large super saturation thus generated is relieved on raising the annealing temperature in the range of 110-450 °C. Work is now in progress of Al-Si-Mg alloys.

91.0 Coefficient of Thermal Expansion of Metals and Alloys.

Coefficient of thermal expansion of some binary alloys were measured by dilatometric method. Binary systems involving wide range of factors influencing thermal expansion like ferro-magnetic element Fe (Fe-Al & Fe-Si) antiferromagnetic element Mn (Cu-Mn), some low temperature melting alloys (simple eutectics and complete solid solution systems) like Pb-Sn, Pb-Cd, Bi-Sn, Bi-Pb, Bi-Cd, Cd-Sn, Bi-Sb, Al-Sn and Al-Sn were investigated. Attempt has been made to correlate the factors and nature of variation of thermal expansion of these alloys in view of the above investigations. Results of the work on the Cu-Mn Al-Zn & Al-Sn systems are shown in Figs. 14 & 15.

92.0 Preferred Orientation in Extruded Rods.

Studies on variation in the preferred orientations developed in extruded rods of duralumin of the L65 (BS) type and commercial aluminium from the centre to the surface region in the radial direction and from front end to back end at different fabricating conditions of extrusion have been completed.

The results show that there are three different zones—(1) central (2) intermediate and (3) surface zones in the extruded duralumin type of alloy rod and two different zones, (1) central and (2) surface zones in the extruded commercial aluminium rod.

93.0 Development of Beta-ray Back Scattering Technique for Chemical Analysis.

The dependence of the beta ray back scattering being very sensitive to the atomic number of the scatterer, the detection of high atomic ions in a medium of low atomic number may easily be done using beta ray back scattering.

This property of the back scattered data radiation has been utilised to determine the unknown concentrations of solutions of lead-nitrate, lead acetate, barium acetate, silver nitrate, barium chloride, cadmium chloride, ferric chloride, copper nitrate and copper sulphate.

This method has also been extended for the analysis of alloys and ores. On the same principle, further work on alloys and ores is in progress.

94.0 The Effect of Inhomogeneities on the Mechanical Properties of Aluminium and Its Alloys.

Based on the encouraging results obtained on preliminary experiments with Al-Mg alloys, an equipment was designed and fabricated to melt these alloys under special conditions. Al-Mg alloys are prone to heavy oxidation and much of the loss, in materials, is due to defective, 'cauliflower' structures. The present studies are in the direction to eliminate such defective structures and to obtain sound ingots.

95.0 Solidification of Binary Aluminium Alloys.

In continuation of the work published on Al-Cu alloys, study of marphological & crystallographic characteristics of Al-Mn alloy was taken up. Various commercial pure and superpure Al-Mn alloys were isothermally and anisothermally cast from different pouring temperatures and the grain and cell size was determined with the help of anodic oxidation technique. Intermetallic phases were extracted electrolytically from various alloys and identified by X-ray diffraction photograph. A study of the effect of addition of silicon and iron is in progress.

96.0 Use of Flocculant for Settling Slurries Containing Manganese Sulphate.

Work was taken up to identify a commercially available flocculating agent for reducing the time of settling of a slurry containing insoluble solids and manganese sulphate solutions.

Experiments with leach slurry at pH 2-5 show that additions of polymers vary in their effect on the settling rate of the slutty. One of the flocculant was found to be very effective. Same flocculant and several others were found effective at pH 6.8. Investigation on the effect of flocculant with sulphide slurry has given good results at pH 7.

97.0 Electrical Resistivity of Iron Ore Pellets Reduced to Various Degrees.

A project was initiated to determine the primary electrical properties such as resistivity of iron ore pellets reduced to various degrees and at various temperatures. This was done with a view to study the behaviour of pre-reduced iron ore pellets particularly during smelting of the reduced pellets in an electric arc furnace. It was observed that the electrical resistivity varied from 1.5 meg. ohm. to 8.0 meg. ohm. for different degrees of reduction (10-100%) and temperatures from 30-1000 °C. All the series of experiments have now been completed and the report is being made ready.

98.0 Electrical Conductivity of Ferro-alloy Burden Material.

As the electrical conductivity of the reducing agents used in sub-merged arc smelting of ferro-alloys play an important role in the specific power consumption of the ferro-alloy produced, the various reducing agents

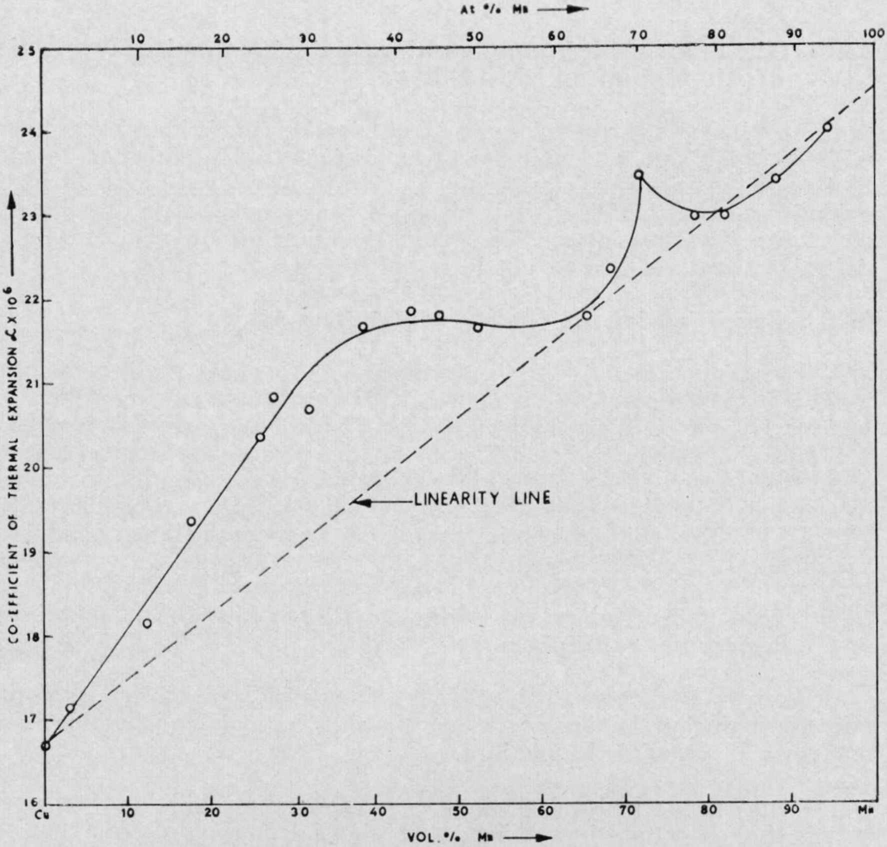


Fig. 14 Variation of thermal expansion co-efficient of copper-manganese alloys with volume percent manganese.

used in the pilot plant for the production of high carbon Fe-Cr, Si-Cr, Fe-Mn, were taken and the values of electrical conductivity were arrived at using the wheatstone bridge.

98.1 Effect of Silicon Carbide in the Production of Ferro-Alloys.

The formation of silicon carbide is inevitable in the production of high silicon containing ferro-alloys. The formation is being traced by microscopic study on the samples collected while the furnace is in operation as well as from the cooled furnace hearths while digging the hearth at the end of the campaign. The extent of its formation and its effect on the production rate of the alloy are being correlated.

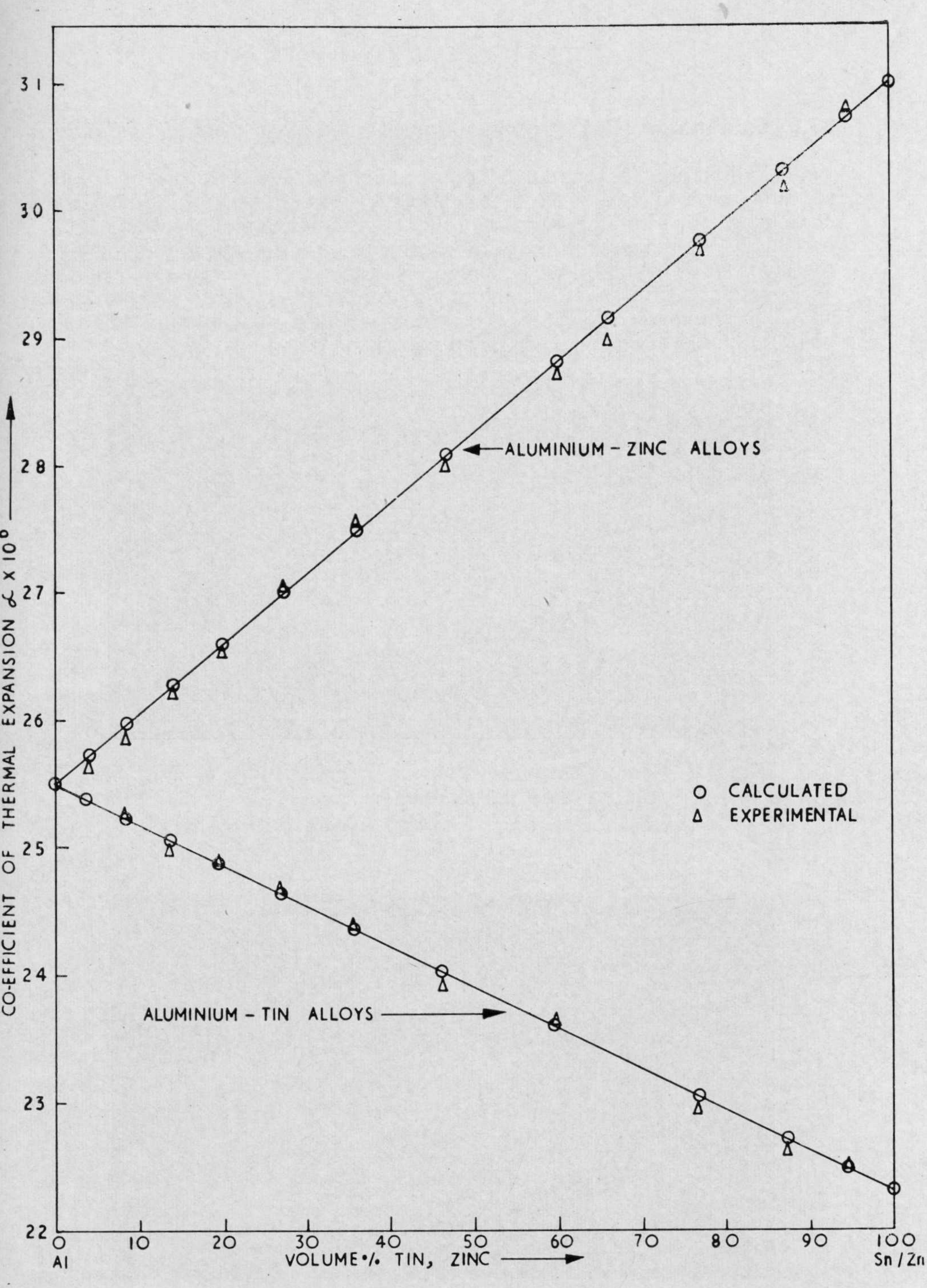


Fig. 15 Thermal expansion co-efficients of aluminium-tin and aluminium-zinc alloy.

99.0 Studies on High Alumina Slag (*Liquidus and Phase Equilibrium*)

Liquidus studies on the 64 compositions which were planned with alumina levels of 24% to 30% basicities varying between 0.9 to 1.3 were completed. The liquidus temperature of these slags varied between 1353° to 1550°C. Melilite occured as most common primary phase but some of the slags having higher MgO content had spinel as primary and melilite as secondary phases. Photomicrograph showing primary melilite and spinel is shown in Figs. 16. and 17 respectively. An interim report is being prepared and results are being compiled.

Fig. 16 Photomicrograph showing a primary spinel in high alumina blast furnace slag.

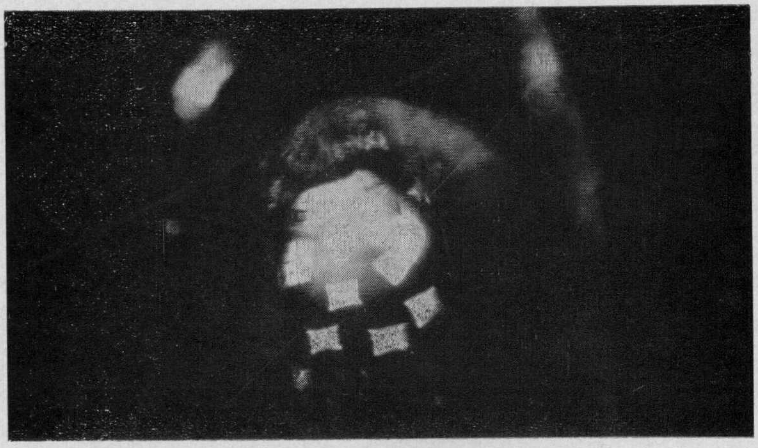


Fig. 17 Photomicrograph showing several rectangular melilite crystals in blast furnace slag (crossed nicols).

SPECIAL PROJECTS

100.0 Production of Sponge Iron.

Production of sponge iron in rotary kiln was continued with raw materials received from M/s. NMDC, SICOM & TISCO. Large scale trials were also conducted in 0.8 ton electric furnace on the melting of sponge iron. The melting characteristics were studied and the method of feeding the sponge was standardised. Different grades of steel with sulphur and phosphorus in the specified range were produced.

101.0 Production of Calcium Metal.

A number of campaigns were conducted at the Magnesium Project site using the facilities available to determine the scale up factors and to optimize operating parameters in an actual plant trial. The recovery of the metal in some of the campaigns were less than 50% because of defective operation and raw material preparation.

102.0 Bacterial Leaching of Low-grade Ores.

A Seminar on 'Bacterial Leaching' was organised by the Laboratory to discuss the various facets of the subject matter and the assignment to be taken up by different organizations connected with the project. More report about this seminar has been furnished in the Chapter 'Symposia & Seminar' in this report.

103.0 Setting up of Central Creep Testing Facilities.

For housing the Central Creep Testing Facility, a separate building adjacent to the existing main building of the National Metallurgical Laboratory is under construction. The floor area of this laboratory building will be adequate to finally accommodate about 400 creep test points. In the construction of this building several special design features have been incorporated. The foundation has been specially made of a floating raft type and it has been isolated from the walls and the main columns in order to make it free from any extraneous vibrations in the area where high sensitivity creep testing machines are to be installed. For the same reason the heavy equipment likely to cause excessive vibrations viz. equipment for temperature and humidity control and diesel generator are being housed in a separate plant room in which the electrical sub-station is to be installed.

In order to fully ensure the safety of the uninterrupted long-term creep tests, an automatic stand-by diesel generator which will get energised and will generate full load within about ten seconds has been provided. The entire creep testing bay will be fully air-conditioned round the clock, to maintain the ambient temperature and humidity within a close tolerance in order to avoid their adverse influence on the long-term high sensitivity creep and stress-relaxation tests. The work of building construction and provision of the various services are proceeding as per schedule programmed and the building and services will be completed before the equipment are received for installation.

The orders for the major items of equipment as given below have already been placed by the UNIDO. This will make up for about 150 creep test points to be established in the first phase of the project to meet the immediate requirements of industries. A 500 channel data-logger will enable automatic recording of temperature and strain readings from the creep testing machines. The data will be recorded on a teletype.

	List of Equipments	*Quantity*
(i)	High sensitivity single specimen creep testing machines.	55
(ii)	Multi-specimen creep testing machines with 12 test points each.	6
(iii)	Extensometer calibrating deviatull balance type.	1
(iv)	Thermocouple secondary calibrating device.	1
(v)	Instron high temperature tensile testing machine.	1
(vi)	Central measuring console.	1

For subsequent expansion of this facility to about 400 test points the requirement of creep testing equipment is aimed to be met indigenously. Further there is likely to be demand for creep testing machines from several other organisation's in the country.

A scheme has been jointly taken up by the National Metallurgical Laboratory, Central Mechanical Engineering Research Institute and National Aeronautical Laboratory for designing and development of indigenous creep testing machine and its control equipment which is to conform to the precision and reliability of corresponding grade imported equipment.

The design specifications of the creep testing equipment to be indigenously produced have already been finalised by the collaborative effort of the three sister laboratories. It has been decided, in the first phase to fabricate six complete units for a proper evaluation and calibration of the equipment and its control and measuring devices at the three laboratories. Based on this study, a production model will be evolved.

104.0 Nimonic Alloys.

A few 10 kg heats of niomic 80A were made in vacuum induction melting and casting furnace to specification. The hot working characteristics are under study. Arrangement are being made to make other grades of nimonic alloys. The heats will be used to fabricate components exposed to high temperatures in the proposed indigenous creep testing machines.

105.0 Multipurpose Hydro-Electrometallurgical Large Scale Testing Facilities.

Preliminary project planning on this one crore facility is well under way. Layouts are under preparation alongwith detailed equipment specifications for indigenous and foreign procurement under UNDP auspices.

Adityapur Complex.

The Adityapur Complex comprising one hundred acres of land is located about 16 KM from NML. The land has been allotted to NML and actual possession is being taken followed by surveying and contour mapping. Preliminary site layouts have been prepared and reputable architects are being contacted for architectural conceptions of a master plan for this two crore rupees complex.

In the first phase, the complex will comprise of the followng:

(i) Sponge Iron Project.
(ii) Hydro-Electro Metallurgy Facilities.
(iii) Submerged Arc Furnace.
(iv) Mineral Beneficiation Facilities.

PILOT PLANTS

106.0 Mineral Beneficiation Pilot Plant.

Pilot plant investigations conducted on different types of low grade ores and minerals have been reported under sponsored projects.

107.0 Dense Carbon Aggregate Pilot Plant.

During the year under review, the pilot plant set up for the production of dense carbon aggregate came on regular production and not only dense aggregate but also soderberg paste suitable for use in ferro-alloy furnaces have been under regular production throughout the year. A major supply of 10 tons of soderberg paste intended for tests in Mysore Iron & Steel Works is now ready in the plant for despatch. The plant has fulfilled almost all the design expectations and except for the electrical tunnel kiln, all the other equipment have been put on run and standardised. The electrical kiln had some teething troubles which are now under rectification. It is also expected to go into operation very shortly as soon as the electricity shortage ceases.

The properties of the soderberg paste ready for supply to Mysore Iron & Steel Limited are given in Table 2.

TABLE 2

Properties of soderberg paste.

Green	NML paste	Sample of imported paste supplied by one of the ferro-alloy manufacturers.
Flowability	140°C-25% 180°C-30% 220°C-36%	140°C-29% 180°C-32% 220°C-38%
Bulk density gm/cc	1.71	1.62
Baked at 1000°C		
Volume change %	—05. to +1.5	—.2 +1.5
Bulk density gm/cc	1.49	1.37
Apparent porosity	23%	24%
Cold crushing strength kg/cm	250-280	180-210
Modulus of rupture kg/cm	75-80	40-45
Electrical resistance ohm mm^2/M	80-85	85-90
Oxidation loss (oxygen flow 1 lit/mt. sample 1″ sq.×2″) after 2hours at 900°C.	71%	78%

In connection with the design of soderberg paste, a comprehensive study on the methods for testing and evaluation of carbon pastes in general has been undertaken and a number of tests for determining properties such as, flowability, swelling, oxidation resistance, electrical conductivity, thermal conductivity, thermal expansion and strength have been standardised.

Arrangements have also been completed to set up a full fledged laboratory for testing both raw materials and finished products of carbon industry. The equipment envisaged includes apparatus for ultimate analysis of the carbonaceous raw materials, for solvent extraction, for studies on viscosity and low temperature properties of binders as well as for plastometric studies. Arrangements for evaluating baked carbon products have also been planned.

108.0 Hot-dip Aluminising Pilot Plant.

At the request of Heavy Machine Building Plant of Heavy Engineering Corporation, Ranchi, the laboratory developed the technology for coating aluminium on cathodes and anodes for the aluminising plant of Bharat Aluminium Co. The aluminium coated anodes and cathodes were subsequently welded to the aluminium strips successfully by the HMBP, Ranchi and met the rigid specifications of the collaborators of Bharat Aluminium Company. The aluminium coated cathodes and anodes are shown in Fig. 18. The laboratory has agreed to train the staff of HMBP, Ranchi.

150-200 lb/mile quality m.s. wire was aluminised from different baths. Metallographic examination of transverse sections has shown that silicon reduces the alloy layer thickness by retarding diffusion as also the outer aluminium layer thickness by reducing the viscosity of bath so that less of coating metal is carried over. Excess metal which remains fluid for a longer time falls back into the bath from wiping pads. Wiping with a block of graphite instead of asbestos pads was also tried as the latter wear out quickly and have to be replaced. Graphite blocks were made from waste broken electrodes of the arc furnaces.

108.1 Tube Aluminising.

Investigations were conducted on the feasibility of hot-dip aluminising of mild steel tubes (2.3 cm I.D.; 2.8 cm O.D) analysing C 0.15, Si 0.05, Mn 0.47, P 0.06, S 0.05 from a commercial aluminium bath at different temperatures for different dipping times. Bath composition also varies due to iron pick up caused to tube-bath diffusion reactions and by intentional Si additions. 0.15 mm to 0.20 mm thick coating weighing 4.5 to 5.5 gm/sq. dm were obtained from commercial aluminium bath. 1% Si in the bath reduced coating weight to 2 to 2.5 gm/sq. dm. Increase in dipping time and bath temperature both increased the coating weight. Few 1 metre long samples were also prepared. To minimise dross formation dipping time as well as temperature should be kept as low as possible.

108.2 Aluminising of Stainless Steel.

Stainless steel panels of 18 : 8 type were hot-dip aluminised for

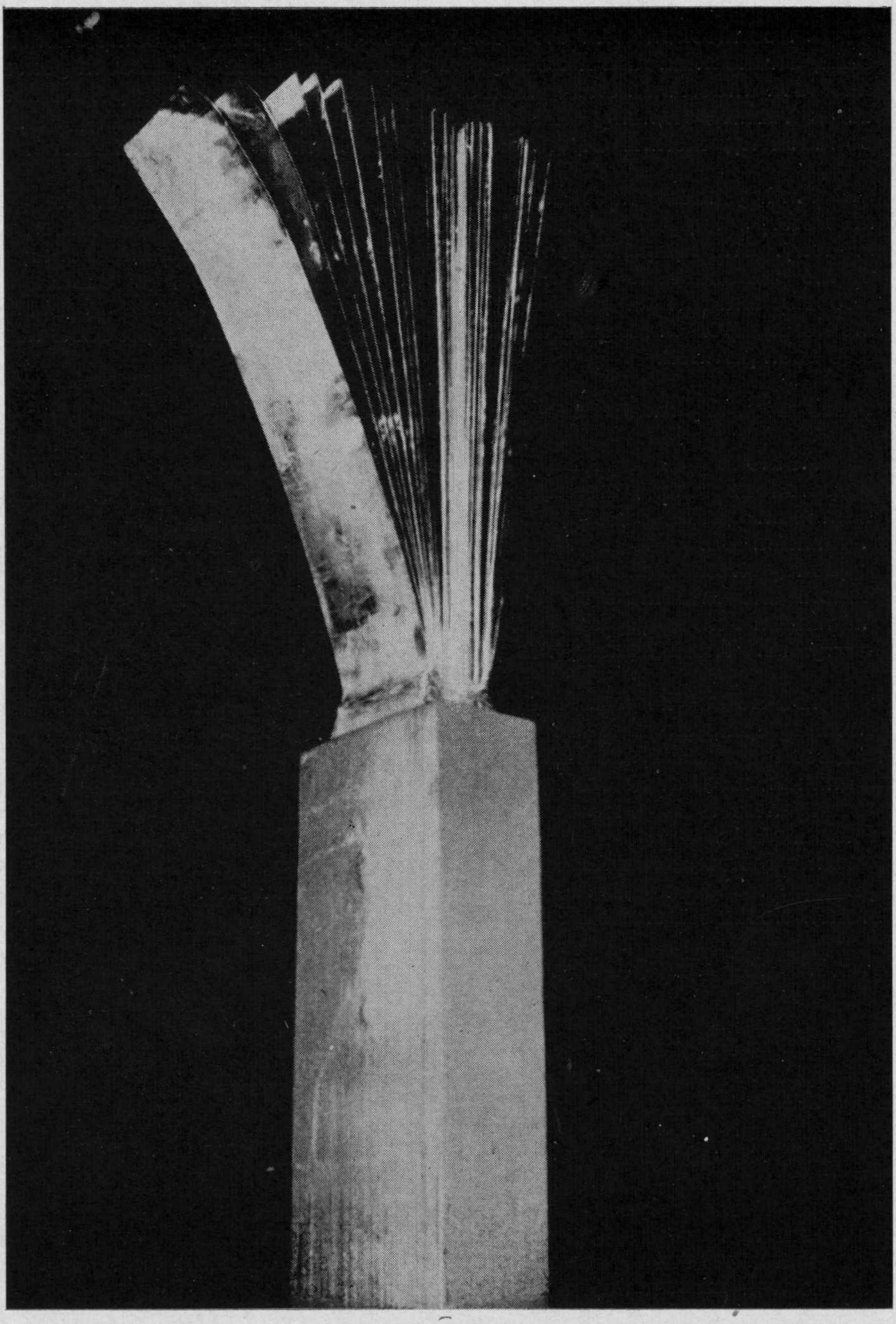


Fig. 18 Photograph of cathode developed by Heavy Machine Building Plant, HEC, Ranchi in collaboration with NML for use in aluminium extraction cell of the aluminium plant of Bharat Aluminium Co. Ltd., Korba (M.P.)

improvement in their heat, oxidation and scaling resistance. Tests at 1100°C showed that uncoated stainless steel scaled heavily. The scales were dark grey and spalled off and were of blister type. In comparison aluminised stainless steel developed a thin, adherent light grey oxide film and there was no scale formation. Further studies are in progress.

108.3 Strip Aluminising.

With the successful development of the know-how for aluminising of steel wires and ferrous hardware products by hot-sip aluminising at NML, a project for designing and fabrication of strip aluminising plant was taken up by NML.

Erection work of the aluminising furnace was completed. The aluminising pot was lined with silicon carbide. Further work in connection with the commissioning of the plant is in progress.

109.0 Electrolytic Manganese and Manganese Dioxide Pilot Plant.

The pilot plant for production of electrolytic manganese was run successfully in several organised campaigns to collect operations data on reduction, leaching, purification and electrolysis with low and high grade ores. During these runs about 500 Kg of electrolytic manganese metal was collected. After meeting the internal demand of manganese metal for research activities, more than 1500 Kg of manganese metal was sold to outside organisation.

A new PVC lined reactor vessel and a small electrode steam boiler have been installed in the manganese and manganese dioxide pilot plant.

The manganese dioxide cell was put into operation on experimental runs for collection of necessary design data for a larger commercial plant.

110.0 Semi Pilot Plant for Preparation of Synthetic Cryolite.

Several experiments were carried out with 50 Kg/day set up. Typical data of one such experiment are given below.

Material used for one leaching experiment :

Sulphuric Acid, commercial	.. 170 Kg.
Boric Acid, commercial	.. 120 Kg.
Sodium sulphate, commercial	.. 25 Kg.
Water	.. 1000 Kg.
Fluorspar	.. 130 Kg.
(CaF_2-96.81, $CaCO_3$-0.49, Fe_2O_3-0.14, Al_2O_3-0.06, MgO-0.43, SiO_2-0.59, L.O.I. 1.42 in percentage)	
Total leach liquor recovered	.. 985 Litres

Materials used for precipitation of cryolite :

Hydrated Alumina	.. 52.6 Kg.
Sodium carbonate	.. 61.2 Kg.
Dry cryolite produced	.. 99 Kg.

Composition of the Cryolite :

F-52.45, Na-21.21, Al-19.49, SiO_2-0.02, Fe_2O_3-0.06, P_2O_5-0.06, SO_4-1.06, Ca-1.58, Comb. water-1.66, Pb-not found (all in percentage)

Overall fluorine recovery—84.7%.

The experimental set up is working quite satisfactorily except some teething troubles which have been overcome to an extent.

The leaching and precipitation vessels are working nicely except a few microholes in leaching which are plugged. The vacuum rotary drum filter and the centrifuge are working excellently. The heating system to the reactor vessels is quite efficient. The 50 Kg/batch set up is shown in Fig 19.

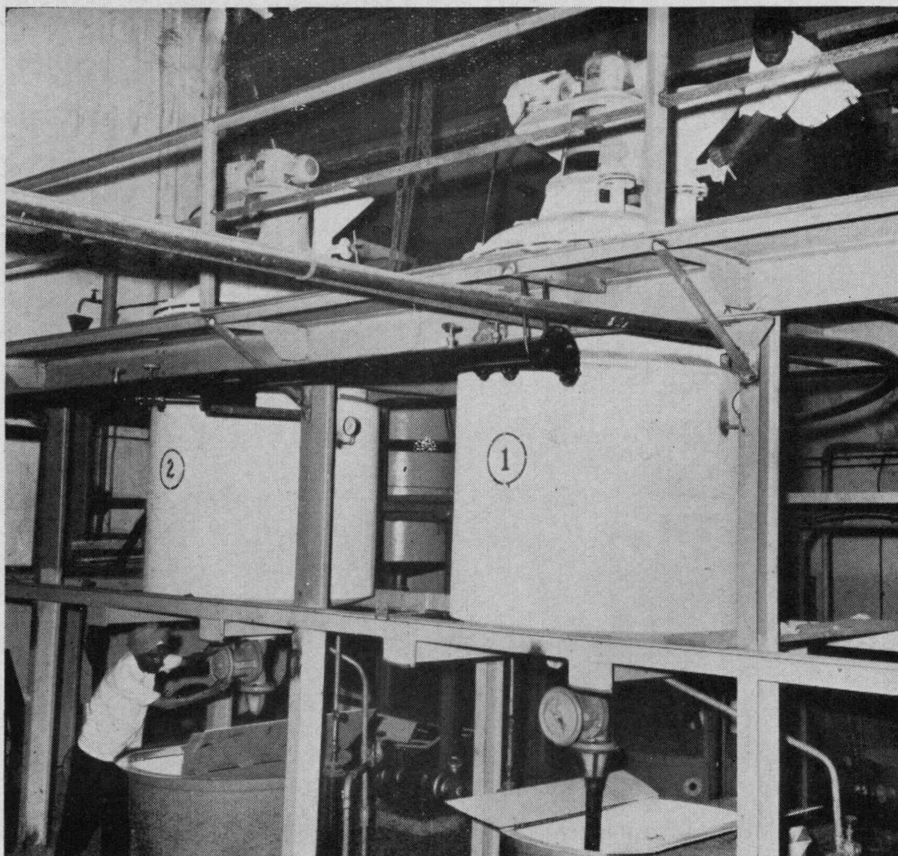


Fig. 19 A view of the set up for 50 Kg/day production of synthetic cryolite.

ENGINEERING ACTIVITIES

Design & Mechanical Engineering.

A. The following major jobs were undertaken.

Design and fabrication of atomisers for producing extra-fine metal powders—The atomisers have been successfully used for producing powders of the following metals/alloys.

(i) Aluminium
(ii) Copper
(iii) Brass/Bronze
(iv) Copper-Lead Bimetallic Powder
(v) Zinc
(vi) Tin
(vii) Lead.

Preliminary trials for producing Al-Si alloy powder for powder metallurgy applications were also conducted.

B. Engineering consultancy services were provided in respect of the following projects undertaken by NML.

(i) Production of iron powder from waste pickle liquor with simultaneous regeneration of sulphuric acid from pickle liquor of Tinplate Company of India, Jamshedpur.

(ii) Conversion of hot dip tinning lines at H.S.L. Rourkela to aluminising/tin free steel lines.

C. A process for elimination of short circuits in the bus bars of the electrolytic tinning line at H.S.L. Rourkela was suggested and demonstrated to representatives of HSL, Rourkela. The process is now being tried out for its adoption as a standard practice.

D. Bench scale experiments to study the feasibility of producing iron powder from workshop scrap using different baths were carried out. The sulphate bath gave most promising results.

E. Some Major Fabrication Work on Projects :

(i) Vertical reduction furnace for sponge iron.
(ii) Atomisation nozzles for powder metallurgy.
(iii) Toolings for extrusion of magnesium alloy for the joint project of NML & BARC.
(iv) Lead anodes, stirrer etc., for Manganese Pilot Plant.
(v) Cable guiding arrangement and installation of 50 KVA Arc Furnace for Extractive Metallurgy.

Fabrication work is almost completed on electroslag melting, strip aluminising plant and cryolite pilot plant.

F. Fabrication of instruments, equipment and accessories for research.

(i) Accessories for testing creep specimens.
(ii) Reactor cells of different materials.
(iii) Different types of furnaces.
(iv) Work under progress;
  (a) Rotating crucible furnace.
  (b) Vertical furnace.

550 pieces of various types of test specimens are made for destructive and metallurgical tests for research projects as well as out side investigations.

G. Major repair/maintenance work carried out on :

(i) Hydraulic press
(ii) Extrusion press
(iii) Pneumatic hammer
(iv) Rolling mill
(v) E.O.T. Crane
(vi) Hot blast cupola
(vii) Installation of 500 cft. compressor is also under progress.

Electronics Engineering.

A. Development Projects.

(*i*) *Solid State Temperature Controller.*

A thyristor temperature controller (proportional type) is under design and fabrication. For firing circuit an unijunction transistor is proposed to be used.

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

Light dependent resistor (such as ORP 61) has been successfully tried out. Suitable d.c. amplifier has been designed and is under fabrication. Studies have been made to incorporate a rate controller for TGA work.

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

Various trigger circuits have been designed and simulation tests have been carried out.

(*iv*) *High Current Electronic Potentiostat.*

Design of a saturable reactor using CRGO sheets is under progress.

(*v*) *Development of a Capacitor Circuit for Precision Spot Welding of a Fine Strip and Wires for Resistivity Studies.*

By charging and discharging of a capacitor the following materials can be welded. The method is relatively better than other methods.

(a) Chromel/Alumel thermocouple wires
(b) Platinum/Platinum-Rhodium thermocouple wires
(c) Tantalum and tungsten to iron-aluminium alloys.

(*vi*) *Study of Bellows or Flexible Diaphragm for Bin Level Solid Measurement (New Project)*

The method of bin level solid measurement with bellows or flexible diaphragm is simple and its range is very wide. The unit can be developed from materials available in India thus saving some foreign exchange.

B. Maintenance, installation etc.

Following are the major maintenance, installation, testing, repair, calibration and modification jobs carried out :

(i) Repair of Philips X-ray diffractometer, Autrometer and Deltatherm
(ii) Repair of electron microscope EM6
(iii) Testing, repair and calibration of various types of temperature recorders and controllers.
(iv) Installation of arc spark generator, nucleonic instruments, oscilloscopes, potentiostat, gas chromatograph, in-situ universal bridge, digital wheatstone bridge, colorimeter etc.
(v) Maintenance of electronic and process control instruments of FPTD, MBPP, Carbon Plant, Mag. Plant, Creep Laboratory and NML Field Stations.

Electrical Engineering

A. Development Projects.

(*i*) *Furnace for Creep Testing.*

The prototype, designed, fabricated and commissioned in the laboratory is under life expectancy trial. One such furnace has also been supplied to National Aeronautical Laboratory for their use of developing a suitable solid state temperature controller to match this furnace.

(*ii*) *Electro-Slag Refiner*

Design of various components, such as column, electrode arm, water cooled electrode holder, water cooled mould etc., of an electro-slag refiner, were under active progress. Their fabrication has also commenced.

(*iii*) *Electrical Vertical Shaft Reduction Furnace*

The work on design of one vertical shaft reduction furnace, electrically heated was undertaken for the reduction of manganese ore on laboratory scale.

(*iv*) *Automatic Power-input Controller for High Temperature Resistance Furnace*

The performance of this developed equipment is under observation.

B. Design, Fabrication and Installation.

(i) Several electrical resistance furnaces were designed and fabricated to meet the requirement of research and development work of the Laboratory.

(ii) Specifications of various equipments for electrical sub-station, internal wiring and temperature and humidity control system for the central creep testing facilities have been finalized, tenders have been invited and are under scrutiny for awarding the work.

(iii) Installation and commissioning of several equipments, machineries and power distribution systems were planned and executed.

C. Preventive Maintenance and Repairs.

A number of break-down repairs of various electrical equipments, control systems and power supply and distribution net work were carried out. Preventive maintenance of electrical equipments viz., power transformers, circuit breakers, rectifiers, motors, cranes, electric arc and resistance furnaces, control devices etc., were carried out.

Civil Engineering.

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

1. Office and control rooms for dense carbon plant.
2. Extension of library building, NML.
3. Concrete passage in front of mechanical stores.
4. Construction of room for the installation of air compressure foundation etc.
5. Conversion of B/46 Bungalow at C.H. Area into NML Guest House.

The following jobs were taken up and are in progress :

(i) Construction of connecting road to Meter House at FPTD (NML) and from the existing main road.

(ii) Sanitary and water supply for office and control rooms including sewer lines to septic tank.

(iii) Central Creep Testing Laboratory's offices and auditorium.

(vi) Construction of room at the back side of technical block for electrical sub-station.

NML FIELD STATIONS

Foundry Stations.

The foundry field stations continued their progress on investigations on indigenous foundry sands and bentonites. The number of region-wise investigations are as follows:—

Batala	..	2
Madras	..	6
Howrah	..	6
Ahmedabad	..	13

Technical Services

The NML Foundry Field Stations have been rendering useful service to the industries located in the respective regions by way of offering technical guidance on the diverse aspects of foundry technology such as:

(i) For selection of proper raw materials. This includes facilities for the analysis of ferrous and non-ferrous metals and their alloys, testing of sands, bentonite and other foundry raw materials.
(ii) For the application of modern techniques of production, scientific methods of metal testing and casting etc.
(iii) To achieve quality control and improve productivity by elimination of casting and moulding defects.
(iv) Regarding production technique to meet export requirement etc.

This has been possible due to on the spot assistance given by the field staff to a number of foundries in their respective regions. Extensive work has also been carried out by the field stations in exploiting and investigating the regional resources with regard to foundry raw materials in collaboration with the Geological Survey of India and the respective State Geology and Mining Departments. Table 3 gives an account of nature of assistance rendered by individual field station.

TABLE 3

Assistance rendered by different field stations

	Batala	*Madras*	*Howrah*	*Ahmedabad*
1. Chemical analysis-No. of radicals analysed.	437	190	387	709
2. Sand Testing: No. of samples tested.	22	14	124	28
3. Mechanical Testing No. of samples tested.	7	50	112	—
4. No. of Technical Enquiries attended.	234	124	102	215
5. No. of Foundry visits	58	20	82	6
6. No. of sand samples investigated.	2	6	6	13

Marine Corrosion Research Station, Digha.

Atmospheric Corrosion of Metals and Alloys under Marine Atmosphere at Digha.

Long term atmospheric corrosion tests with aluminium 2S, aluminium 3S, aluminium M57S, brass, copper, nickel, monel and zinc were started in the year 1964 and data on their corrosion rates have been collected upto 6 years of exposure. The last set of samples will be removed after ten years of exposure in the year 1974.

One of the most important factors in atmospheric corrosion is the amount of moisture in the atmosphere and the period of its retention on the metal surface. Another aspect is the mass of the sample which will influence the period of retention of heat and moisture as metal surface. Studies on the effect of mass of the sample on atmospheric corrosion using mild steel were continued. The results obtained showed that while there was a straight decrease in the corrosion of mild steel with increase in mass and exposure in the winter months (when the corrosion is low), the corrosion of mild steel at first showed a decrease and then an increase with increase in mass.

Exposure of high conductivity aluminium wires along with INDAL and HINDAL aluminium wires are being continued. Atmospheric corrosion tests of some low alloy steels containing Al and Si have been initiated.

Testing of various inorganic coatings on Steel Exposed to Marine Atmosphere at Digha.

In order to evolve suitable protective scheme for structural materials, painted and unpainted panels of mild steel, galvanised steel, aluminised steel, Cu-clad steel, anodised aluminium and aluminium (alchrome treated) are under exposure at Digha for over three years. Periodic observations and weight loss data are being collected.

Sea Water Corrosion of Different Metals and Alloys.

Studies on the effect of chromate inhibitor in sea water on corrosion of galvanic couples of mild steel with zinc, aluminium and copper in different area ratios were continued. The results obtained showed that corrosion rate of the active metal reduced considerably with increase in the amount of chromate inhibitor and this reduction was more pronounced when the area ratio is high.

Sodium benzoate was found to be not a good inhibitive agent in sea water corrosion of mild steel. Studies were, therefore, taken up to see the effect of chloride ions on corrosion of mild steel in benzoate solutions. The concentration of benzoate and chloride ions were varied between 0 and 10,000 ppm. The results obtained so far have shown that for each concentration of benzoate ions there is a critical chloride ion concentration at which the active-passive region was found and beyond which the corrosion of mild steel remained constant.

PUBLICATIONS

During the period under review, a number of publications relating to the research, development and other activities of the National Metallurgical Laboratory were prepared and published. Such publication cover a wide spectrum ranging from periodic press releases to scientific journal, special technical reports etc. Following will give a brief account of the various publications prepared and brought out.

NML Technical Journal.

NML Technical Journal entered into fourteenth year of publication and continued to be in much demand by metallurgical research & technological organization, scientists, technologists, research workers and industrialists. During the current period 121 exchange agreement with India and foreign publication were established and the journal was subscribed by 162 institutions and individuals.

Brochure.

A special well illustrated coloured brochure giving a cross section of the latest activities and achievements of the laboratory was prepared and published on the occasion of the silver jubilee of India's Independence. The brochure has been written in popular style suitable for understanding by intelligent public, industrial enterprenuers and persons interested in the metallurgical and allied fields. The brochure has been highly commended both from the point of view of the subject matter dealt with as well as its get up and presentation.

Folder.

For the 'ASIA-1972' Exhibition at New Delhi in December 1972, a special folder covering the activities of the Laboratory was prepared. The folder was written in a style suitable for catering to different types of visitors to the exhibition pavilion. The folder has been acclaimed to be of very high quality regarding the mode of style and presentation of the subject matter.

Special Reports.

A special report covering the various important work and achievement of the Laboratory since its inception in 1950 was prepared. The Annual Report of 1971-72 was published. The 5th Five Year Plan Report of the Laboratory was prepared.

Press Releases & Broadcast Talk.

Periodic press releases were issued to appraise the general public about the function and contribution of the Laboratory. Besides, broadcast talk relating to NML activities were prepared for broadcasting through AIR.

Documented Survey on Metallurgical Development.

Issues of the monthly publication 'Documented Survey on Metallurgical Development' were continued to be published which was well appreciated by the research and other organizations interested in the subject matter.

Bibliography on Sponge Iron Making.

A bibliography on sponge iron making covering approximately four hundred references grouped under appropriate process heading was prepared and published.

Handouts & Notes.

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

Papers Published and Presented.

Details of paper published and presented during the period are furnished in Appendix I.

Research & Investigation Reports.

Details of research and investigation reports prepared during the period are furnished in Appendix II.

SYMPOSIUM AND SEMINAR

(i) Symposium on Sponge Iron.

With a view to focussing attention on the diverse aspects of the production of sponge iron and its conversion to steel, an international Symposium on "Science and Technology of Sponge Iron and its Conversion to Steel" was organized by the National Metallurgical Laboratory from 19th to 22nd February, 1973.

The scope of the Symposium covered the following facets of the subject matter.

1. Physical and chemical characteristics of iron ore and solid fuels, such as raw non-coking coal, and lignite for direct reduction;
2. Fundamental aspects of reduction of iron oxide by solid reductants with particular reference to reduction in rotary kiln;
3. Short-time laboratory tests for ascertaining the suitability of raw materials for undertaking further trials in pilot plants;
4. Pilot plant trials on reduction of size-graded lumpy iron ore with raw non-coking coal, operational and engineering design data to evolve commercial prototypes, and factors to be considered for the design of industrial plants;
5. Design characteristics and limitations of rotary kilns for reduction of iron oxide;
6. Experience of operation of commercial rotary kilns for reduction of iron oxide with solid reductants, operational difficulties in continuous operation and yield, and techno-economic assessment;
7. Future of direct reduction processes based on the use of solid reductants;
8. Fundamental aspects of electric arc steelmaking with sponge iron;
9. Concept and advantages of ultra-high power electric arc steelmaking;
10. Operational characteristics of steelmaking with sponge iron on industrial scale;
11. Comparative evaluation of steelmaking with scrap and optimum amount of sponge iron and scrap.
12. Techno-economic appraisal of steelmaking by the conventional blast furnace/basic oxygen steelmaking processes and alternatives such as sponge iron/electric-arc steelmaking;
13. Techno-economic evaluation of ironmaking in blast furnace with pre-reduced ferrous burden; and
14. Utilization of sponge iron in basic oxygen steelmaking processes.

The Symposium drew a large gathering of nearly three hundred delegates from all over the world. Forty two papers were presented in the following six technical sessions.

(i) Introductory session.
(ii) Sponge-iron-fundamental aspects, present status and future development.

(iii) Fundamental and operational aspects of sponge iron production in rotary kiln.
(iv) Gaseous reduction of iron ore to sponge and submerged arc furnace smelting.
(v) Steelmaking with sponge iron.
(vi) Pre-reduced burden in pig iron production and pre-reduction in shaft furnace.

At this symposium the consensus was that developing countries in particular should adopt the proper technique of sponge iron making and its subsequent melting into steel. So far India is concerned, the limited availability of coking coal and the enormous cost involved in utilizing the blast furnace technology pose problems for the development of iron and steel industry in the country. In view of the abundance of good grade iron ore and non-metallurgical coal, adoption of direct reduction technology based on rotary kiln or vertical retort operation using solid reductant like coal and the use of electric arc furnace for production of quality steel, could be an answer to the situation preventing in India.

(ii) Seminar on Bacterial Leaching.

Bacteria have been identified to play a role in the leaching of low grade ores. Bacterial leaching methods are adopted in a number of countries for the treatment of low grade ore deposits and rejected waste dumps of copper and uranium.

In view of these developments in this field, and for the possible augmentation of the production of copper by the application of this method in this country, an inter-laboratory project on 'Bacterial Leaching' was taken up involving the following laboratories : National Metallurgical Laboratory, Jamshedpur; Central Mining Research Station, Dhanbad; National Chemical Laboratory, Poona; and Regional Research Laboratory, Bhubaneswar.

For proper identification of the problems, a seminar on 'Bacterial Leaching' was held at NML on 21-22 December, 1972.

The scope of the seminar broadly covered the following aspects :

1. Assessment of low grade deposits of non-ferrous metals such as copper, cobalt. nickel, molybdenum and uranium for their suitability for bacterial leaching;
2. Bacterial leaching as an alternative process for conventional processes for extraction;
3. Economic viability of bacterial leaching of low grade ore as compared to conventional methods;
4. Recovery of metallic values from dilute solutions with special reference to copper using cementation, ion exchange and solvent extraction techniques;
5. Role of bacteria in the dissolution of minerals; and
6. Isolation and identification of bacteria responsible for leaching of ores, etc.

In three technical sessions twenty papers covering the various facets of the subject were presented. At the end of technical sessions, panel and inter-laboratory group discussions were held.

The following recommendations were made :

(1) Basic research will be undertaken by NCL, Bhabha Atomic Research Centre, Trombay; Atomic Minerals, Delhi and RRL, Bhubaneswar.
(2) Heap leaching and in situ leaching studies will be undertaken at NML, CMRS, Atomic Minerals, Delhi, and Uranium Corporation of India Ltd., Jadugoda.
(3) Recovery studies of metals from dilute solutions will be taken up at NML, BARC, Atomic Minerals, Delhi and RRL, Bhubaneswar.

LIBRARY AND REPROGRAPHIC SERVICE

Library Service.

During the current year along with the usual increasing annual additions of books, periodicals and other forms of literature on metallurgy and other allied subjects, the Library has set up an unit of linguaphone record and tape recorder for learning different foreign languages. The continued growth of the Library necessitated the extension and replanning of space by rearranging the shelving system, reading-room, and also an annexure for the scientists to have study-cum-discussion with their group leaders. The facility to the readers also has been augmented by allowing three hours extra in the evening at least four days in a week.

The Central Information File, because of its dynamic growth was also demanding the new system of maintenance. Library, has, therefore, installed an unit of 'Kardveyer' an electrically operated machine to facilitate the handling of pin-pointed information. This was particularly urgent in view of necessity to dovetail the entries in Central Documentation System with macro data in the Library, in order to afford a firmer foundation to the system which now has been operating more than twelve years.

Reprographic Service.

Preparation of photostat and reflex prints as well as micro-films from scientific papers of interest for the research scientists has been continued. Photomicrographs, X-ray photographs and photographs of apparatus and equipments, as also of the progress on different projects were also made.

INDUSTRIAL LIAISON & RESEARCH CO-ORDINATION

The NML has continued to make all-round progress in its pursuit of multiple research and development activities and has been actively called upon to tackle various mineral and metal problems of the industries both in public and private sectors. A significant development has been the growing utilisation of the facilities and expertise available at the NML. The industrial investigations sponsored at the NML during the year, has shown a greater and progressively increasing inter-action with the industries.

With a view to forging close links with the industry and to make them aware of the R&D facilities and expertise available at the NML, the programme of organising 'Get-togethers' and joint technical meetings with the representatives of metallurgical industries has been continued. A very successful Get-together was organised at Calcutta in collaboration with the Indian Chamber of Commerce. The experience has shown that such direct contacts with the industries have been very useful resulting in increased sponsored work as also better appreciation of the processes and technologies developed by the NML and their exploitation by the industry.

More than a hundred foreign collaboration applications from various Indian firms were examined with respect to the know-how envisaged against the expertise on products/processes available at the NML.

The visitors to NML for technical discussions continued to be many for acquainting themselves with the research and development activities and the utilisation of Laboratory's expertise. These include production of extra-fine non-ferrous metallic powders, bi-metals, magnetic materials, foundry products, utilisation of ores and minerals, reclamation of non-ferrous metals from their wastes, refractories, steel production technology, basic-lined side-blown converter technique, ferro-alloys etc.

Technical Aid and Services.

The quantum of technical enquiries from government, govt. undertakings and private sector industrial organisations relating to processes/ patents of the laboratory and technical information/data was almost same as in previous years. In addition a number of new sponsored projects were undertaken.

Industrial evaluation trials on products developed at NML were carried out and these relate to Al/alloy Al conductors, high hardness steel, ramming mix for Ajax Wyatt low frequency induction furnace, refractory cement for nickel sulphate plant evaporator, high alumina cements.

The NML is being increasingly called upon to act as technical consultants to the industry. The consultancy service assignments related to examination of the feasibility of providing protection to the Calcutta city water mains from corrosion, operational efficiency of Govt. Mint, Alipore, Calcutta, critical evaluation of a project report for manufacture of graphite crucibles received from Maharashtra State Industrial & Investment Corpn.

Ltd., vacuum melting of alloys for production of electrical resistance alloys based on the NML know-how to the licencee M/s. Cable Works (I) Ltd., Faridabad; Rakha Copper Project of Hindustan Copper Ltd. corrosion of structural parts in the Namrup Fertilizer Plant etc. Besides, technical service was rendered to a number of industrial units, govt. institutions, large and small scale units by undertaking testing work.

Training facilities provided at NML.

The training facilities at the laboratory were provided during the year to the candidates deputed from various organisations such as IIT, Madras; Small Industry Training Institute, Hyderabad; Punjab Engg. College; Armament Research and Dev. Establishment, Poona; M.S. University, Baroda; Banaras Hindu University, Varanasi; Birla Institute of Technology, Ranchi; Regional Engineering College, Rourkela etc. The training related to beneficiation of graphite, physical and mechanical properties of metals and alloys, heat-treatment and special investigation techniques, spectro-chemical analysis of metals and their alloys, high temperature oxidation of alloys, refractory mineralogy and X-ray diffraction, methods for testing of metals and alloys including creep resistance properties etc.

Training of NML Staff.

A number of scientific staff members have been deputed for training in various organisations and establishments in the country. The field of training covered workshop materials management, sophisticated instrumental analysis, modern foundry practice, welding supervisory course, applications of operational research, corrosion and its prevention, appreciation programme on method study—a powerful tool for cost reduction, coal sampling and analysis, heat and mass transformation of metallurgical processes, non-ferrous alloys technology etc. which included refresher courses as well.

Extension Services.

The NML participated in the Mineral Convention organised by the Kerala State Industrial Development Corporation, Trivandrum in May 1972, where discussions on the processes developed and expertise available at NML were held.

The NML had also prepared brief notes on the sponsored research and development work carried out on mineral and metal industries utilising the resources of the States concerned and such brief notes were sent to various State Agencies of Bihar, Rajasthan, Kerala etc.

Get-Together.

A 'Get-together' was arranged at Calcutta in Sept. '72 in collaboration with Indian Chamber of Commerce, Calcutta, (on 20th Sept. 72). Representatives of industries who attended the get-together were appraised of the techniques and facilities available at NML that can be best utilised by industrialists and entrepreneurs for rapid industrial progress. Consequent upon this get-together the Indian Chamber of Commerce have requested

NML for opening a technical liaison centre in the Chamber premises so that the Centre could work as a zonal liaison office as well as clearing house for information for processes developed by the NML and also make available periodical hand-outs for circulation amongsts all the interested industries with the developmental activities in NML and also display the products and processes at the Centre for the use of the members of Chamber of Commerce and business community in general. The Chamber of Commerce have generously made available an area of 1000 sq. ft. free of charges to accommodate the NML's Regional Liaison Centre in their premises at India Exchange building.

NML Open Day.

In celebration of the Silver Jubilee of Indian Independence and with a view to securing closer identification of the common people with the activities of the NML, an 'OPEN DAY' was organised at the NML on 20-8-1972. The 'Open Day' was a great success in as much as the NML had to cope up with about 25,000 visitors as against the anticipated number of about 5,000.

A 2nd 'OPEN DAY' was organised on 26-11-72 which was limited to special invitees. This was inaugurated by Hon'ble Shri S. Mohankumar-mangalam, Union Minister for Steel & Mines. Senior students of the metallurgy department of Regional Institute of Technology, Jamshedpur, staff and senior students of the Science Faculty in the local colleges, Heads of other academic institutions, technical personnel from local industries visited the labratory. Nearly 350 members were conducted round the laboratory and the work was explained to them and it was very much appreciated by them.

AIR Broadcast.

The A.I.R., Ranchi prepared features in English and Hindi on the activities of the NML in the service of the mineral and metal industries in India, on 9-2-73 and on 2/3-3-73 respectively. A report on the NML 'Open Day' was also broadcast on 20th August and 26th Nov. 1972 by the Ranchi Station of A.I.R. and also by some other regional stations of AIR.

University Students' Competition.

18 students from Engineering Institutions such as the IIT, RIT, universities etc. were invited to spend a week from 23rd to 28th Oct. 1972 at the NML and its pilot plants. The students were given an insight into the working of the laboratory, its research projects and development programmes. Finally at the end of the week, an essay competition was organised on 'Impact of NML on the development of metallurgical industries in India' and three prizes were given to the best three entries.

Asia Fair 1972.

The NML actively participated in the third Asian Trade Fair 1972 held at New Delhi in Nov. 1972 and exhibits were displayed in order to show the contribution of the NML and development work pertaining to the economic growth and self-reliance in metallurgical and allied fields. The NML stall in the CSIR Pavilion in the Hall of Sciences and Technology attracted lot of visitors and technical informative bulletins were made available to visitors and the processes/products developed and projected were explained by our staff members to the visitors.

Visitors.

During the period under review, the following distinguished visitors visited the Laboratory. Besides a large number of visitors from industries, universities and technical institution visited the Laboratory.

1. Shri S. Mohan Kumarmangalam, Union Minister for Steel & Mines.
2. Dr. Y. Nayudamma, Director-General, Scientific and Industrial Research, New Delhi.
3. Shri M. A. Wadud Khan, Chairman, Steel Authority of India Ltd. and Secretary, Dept. of Steel, Govt. of India, New Delhi.
4. Shri H. Bhaya, Chairman, Hindustan Steel Ltd., Ranchi.
5. Shri G. B. Nawalkar, Chairman, Maharashtra Mineral Dev. Corpn., Bombay.
6. Shri M. M. Suri, Member, National Council of Science & Tech., New Delhi.
7. Dr. Brahm Prakash, Director, Indian Space Research Organisation, Thumba (accompanied by other members).
8. Dr. S. Ramachandran, General Manager, Research and Development, HSL, Ranchi.
9. Dr. C. V. S. Ratnam, Mg. Director, National Research Development Corpn. of India, New Delhi.
10. Mr. D. K. Kahan, Metallurgist, National Bureau of Standards, USA.
11. Dr. V. G. Alkov, Dean of Technology Faculty, Siberia, USSR.
12. Prof. Niels Engel, School of Chem. Engg., USA.
13. Dr. D. S. Crowe, The Australian Mineral Development Laboratories, Australia.
14. Prof. A. Dernyttere, Catholic University of Lenven, Belgium.
15. Dr. A. De, Director, CMERI, Durgapur and party.
16. Mr. O. Ozoro, Scientist, Nigeria.
17. Mr. Sabah Kchari, Ministry of Planning, Govt. of Iraq and other delegates.
18. Mr. S. M. Mermerski, Scientist, Bulgaria.
19. Prof. O. A. Bannyh, USSR Academy of Sciences.
20. Madam Dr. M. P. Matveeva, USSR Academy of Sciences
21. Madam Prof. L. A. Petrova, USSR Academy of Sciences
22. Mr. F. Everard, Toranto, Canada.
23. Mr. W. M. Burton, Toranto, Canada.
24. Dr. Mahmoud A. Hassan, Chairman, Egyptian Organisation for Metallurgical Industries and Chairman, Industrial Research & Technology and Member, Academy Board, Cairo, (ARE)—Leader of the Delegation accompanied by Dr. A. A. Kamal, Dr. Mustafa Hafez and Mrs. Hieleya A. E. Elkerim.

25. A team of Overseas delegates to the International Seminar on Technology Transfer—Asia 1972.
26. Shri K. K. Srivastava, Industrial Development Commissioner, Govt. of Bihar, Patna.
27. Shri D. K. Sahay, Additional Director of Industries, Chotanagpur, Ranchi.
28. Sri Kedar Pandey, Chief Minister of Bihar.
29. Delegates to the Symposium on 'Science and Technology of Sponge Iron and its Conversion to Steel'.

PATENTS AND PROCESSES

Patents filed in India.

1. Improvements in or relating to plating on steels with a fine layer of metallic chromium and chromium oxide—V. A. Altekar, N. Dhananjayan and A. C. Sinha Mahapatra.
2. An improved method for the extraction of metals from solution by solid state absorption technique—A. K. Saha, M. J. Shahani and V. A. Altekar.
3. A process to coat steel surfaces with vinyl compositions and the products thus coated—P. Prabhakaram, S. R. Addanki and A. N. Mukherjee.
4. A process and equipment for producing sponge iron—V. A. Altekar, K. N. Gupta.

Processes Released for Commercial Utilisation

During the period under review, demonstration cum training of the following processes was arranged and the technical know-how, vital informa tion and practical data were given to the representatives of the licencees.

Processes	*Firms*
Production of carbon-free ferro-alloys by alumino-thermic reactions.	1. M /s. T. K. Industries, Kurukshetra. 2. M/s. Industrial Minerals & Chemicals Co. Pvt. Ltd., Bombay. 3. M/s. Stemet Alloys Pvt. Ltd., New Delhi.
Production of metal powders by atomisation of molten metals (coarse powders of low melting metals such as Al+Zn of size range +60 upto 200 mesh)	M /s. Industrial Minerals & Chemicals Ltd., Bombay.

GENERAL

Chairmanship, Membership, Examinership etc. on Outside Bodies.

Prof. V. A. Altekar, Director.	Member	Board of Governors of National Institute of Foundry & Forge Technology, Ranchi.
Dr. R. Kumar, Scientist.	Chairman	Board of Assessment for Technical and Professional Qualifications, Ministry of Education and Social Welfare, Govt. of India.
	Member	(i) Academic Council of National Institute of Foundry & Forge Technology, Ranchi. (ii) Material and Process Panel of the Aeronautics R & D Board, Ministry of Defence.
Shri M. J. Shahani, Scientist.	Member	(i) NCST Panel 6. Heat Treatment Equipment. (ii) NCST Panel 7. Powder Metallurgy. (iii) Planning Sub-group for Nickel & Copper, Dept. of Mines, Ministry of Steel & Mines. (iv) Technical Committee on Sukhinda Nickel Project. Dept. of Mines, Ministry of Steel & Mine.
Shri S. K. Banerjee, Scientist.	Examiner	B.Sc. Mining Pt. II. Indian School of Mines, Dhanbad.
Shri K. N. Gupta, Scientist.	Examiner	Graduate & Post Graduate Examinations in Metallurgy, Ranchi University.

Honours, Awards etc.

Shri G. P. Mathur, Scientist.	National Mineral Awards (1970) by Ministry of Steel & Mines, Govt. of India; for outstanding contribution in the field of mineral benefication.
Dr. N. Dhananjayan, Scientist.	Binani Gold Medal of Indian Institute of Metals for best contribution in Non-ferrous metallurgy.
Shri A. N. Mukherjee, Senior Scientific Assistant.	L.I.M. of Institution of Metallurgists (London).

Foreign Deputations/Training in India and Abroad.

Prof. V. A. Altekar, Director.	(i) Attended the Working Group on "Resent Advances in Mining and Processing of Low-grade Mineral Deposits" organised by the United Nations in New York, April 3-7th 1972 and visited various Research & Development Centres in Pittsburgh, Socorro, Washington etc.
	(ii) Visited various Research & Development Centres in U.K. in April 1972.
	(iii) Visited Bulgaria as a Member of the Scientific Delegation to participate in the 2nd Session of Indo-Bulgarian Joint Commission for Scientific & Technical Corporation in October 1972.
	(iv) Visited Vienna in October 1972 for discussion with UNIDO authorities on Creep Project, Asswan Iron Ore etc.
Dr. R. Kumar, Scientist.	Attended the Second International Conference on Liquid Metals in Tokyo in September 1972 for presentation of the papers (i) Structure of Liquid Aluminium-silicon Alloys and (ii) Immiscibility in Binary Alloys of Group Two Metals.
Shri G. P. Mathur, Scientist.	Visited Bulgaria under Indo-Bulgaria Technical Exchange in May 1972.
Shri H. B. Barari, Scientist.	(i) To work with M/s. R.T.Z. Consultants Ltd., London, U.K. in connection with preparation of feasibility report for Saladipura Pyrite Project in October 1972. Sponsored by M/s. Pyrites, Phosphates & Chemicals Ltd.
	(ii) Visited Royal School of Mines & Chessington Laboratories, London.
	(iii) Visited Lavadore Plant and Rio Tinto Patino Plant, Sivella, Spain.
	(iv) Visited Scarlino Plant of Montecatini Edision, Follorica, Italy.
Shri J. S. Padan, Scientist.	Poland for six months for training in assessment of raw materials and on the production of iron and steel.
Shri Upkar Singh, Scientist.	Attended POWTECH '73 Conference on Powder Metallurgy at Harrowgate, U.K.
Shri D. M. Chakravorty, Scientist.	Attended course for three months at the Computer Centre of the Cabient Secretariat including.

	(i) Assembly system and COBOL—compiler programme. (ii) Operations. (iii) System analysis and design.
Shri A. Ghosh, Scientist and Shri M. M. Sahai, Scientist.	Training in industrially oriented course on Instrumental Analysis at National Institute of Foundry & Forge, Ranchi, for a period of three months.
Shri K. N. Gupta, Scientist.	Attended a special course on "Method study—a powerful tool for cost reduction, organised by Skill for Progress, Bangalore (SKIP) in association with the Indian Institute of Industrial Engineering, Jamshedpur Chapter and Singhbhum Institute of Technology, Jamshedpur.
Shri T. A. Beck, Scientist and Shri R. Prasad, Scientist	Attended "A short course on modern foundry practice" at Indian Institute of Technology, Kharagpur; for a period of 12 weeks.
Shri R. Prasad, Scientist.	Attended 4 weeks course in advance foundry practice at Indian Institute of Technology, Kharagpur.
Shri B. K. Saxena, Scientist and Shri P. Basak, Scientist.	Attended a training course on "Tungsten inert gas argon arc welding, hard surfacing" and supervisory welding training course at Indian Oxygen Welding training Centre for a period of about two months.
Shri A. K. Dey, S.L.A. and Shri M. N. Singh, S.L.A.	Participated in the refresher course on 'Corrosion and its prevention' at C.E.C.R.I., Karaikudi for 5 weeks.
Shri N. Ghosh, Scientist and Shri K. K. Padhi, S.S.A.	Training on "Coal samples and analysis" at C.R.F.I., Jealgora, for a period of two weeks.

Lectures & Colloquia.

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

Purchase & Stores.

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

Administration & Accounts.

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

Safety First & First Aid Section.

No major casulaty was reported during the year. Regular inspection to safety measures was carried out and effort was directed to maintain accident free records at different pilot plants; workshops etc. The First Aid Section treated minor injuries, indispositions caused to staff members on duty.

Activities of Societies/Club and Canteen.

NML Staff Co-operative Credit Society continued its good work and handled transactions annually to nearly rupees two lakhs. Co-operative Store is supplying rationes, food-staffs, stationery articles to the staff members.

NML Club maintained its sporting and social activities. The club participated in the S.S. Bhatnagar Tournament and was runners up in volley-ball and table tennis.

NML Canteen continued to supply to staff members meals and various snacks at reasonable price.

Staff Position

Scientific

Gazetted	..	116
Non-Gazetted	..	88
Research Fellows	..	6

Technical

Gazetted	..	18
Non-gazetted	..	288
Class IV	..	73

Administrative

Gazetted	..	6
Non-gazetted	..	143
Class IV	..	111

Apprentice

Graduate Apprentice	..	28
Trade Apprentice	..	52

Budget Figures

Figures in Rupees.

Recurring		
P-1	Pay of Officers	13,31,750
P-2	Pay of Establishment	13,09,830
P-3	Allowances	20,92,350
P-4	Contingencies	10,58,320
P-6	Maintenance	1,63,070
P-7	Chemicals etc.	9,48,580
		Rs. 69,03,900
Capital		
P-5	Works	
	Services	
	Apparatus & Equipment	24,35,680
	Miscellaneous	
	Creep Project	9,06,100
		Rs. 33,47,780
Pilot Plants		16,46,150
Construction of Quarters		7,77,060
	GRAND TOTAL	Rs. 1,26,68,890

APPENDIX I

Papers Published, Communicated and Presented.

1. Studies on ammonical pressure leaching of bulk Ni-Cu-Mo sulphide concentrate—D. S. Tandon, A. K. Saha, M. S. Mohanty and P. P. Bhatnagar; NML Technical Journal Vol. 13, No. 4, 1971.

2. Utilization of indigenous steel scrap for iron powder production—a study of dissolution rates of scraps in hydrochloric acid—A. K. Saha, A. Kumar, D. D. Akerkar and M. J. Shahani; NML Technical Journal, Vol. 13, No. 4, 1971.

3. Spectrographic method for determination of niobium in steel—M. K. Ghosh, S. V. Gopalkrishna and H. K. Chakravarty; NML Technical Journal, Vol. 13, No. 4, 1971.

4. Chemical aspects of shell moulding resin and its use as a binder—R. N. P. Gupta, G. N. Rao and P. K. Gupte; NML Technical Journal, Vol. 13, No. 4, 1971.

5. Cracking of brass tubes in sugar juice evaporators—a case study—A. K. Lahiri and U. C. Bhakta; NML Technical Journal, Vol. 13, No. 4, 1971.

6. Scrap-oxygen steel making in top-blown converter—S. K. Biswas, S. B. Ghosh and A. B. Chatterjea; NML Technical Journal, Vol. 14, No. 1, 1972.

7. Studies on vapour phase deposition of chromium on graphite—A. K. Saha, R. N. Misra and P. P. Bhatnagar; NML Technical Journal, Vol. 14, No. 1, 1972.

8. Establishment of the temperature range of accidental overheating of precipitation hardened aluminium—copper alloys—Rajendra Kumar & C. S. Sivaramakrishnan; NML Technical Journal, Vol. 14, No. 1, 1972.

9. Infrared study of adsorption of mixed collectors on galena and anglesite—M. S. Prasad; NML Technical Journal, Vol. 14, No. 1, 1972.

10. A short communication on role of different variables on atmospheric corrosion in marine environment—effect of proximity to sea—D. K. Basu & D. K. Khan; NML Technical Journal, Vol. 14, No. 1, 1972.

11. Beneficiation studies with a pyrite-pyrhotite sample from Saladipura, Rajasthan—P. D. Prasad Rao, C. Satyanarayana, K. Vijayaraghavan & G. P. Mathur; NML Technical Journal, Vol. 14, No. 2, 1972.

12. Beneficiation studies on low grade molybdenite samples from Tamil

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15. An investigation on the metallurgical characteristics of stainless steel safety razor blades—B. K. Guha, M. R. Kulkarni & S. S. Bhatnagar, NML Technical Journal, Vol. 14, No. 3, 1972.

16. Observations on high temperature oxidation behaviour of some Fe-Cr-Al alloys—R. K. Haldar and A. K. Lahiri; NML Technical Journal, Vol. 14, No. 3, 1972.

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20. Heavy media hydrocyclones in mineral beneficiation—D. M. Chakraobrty; NML Technical Journal, Vol. 14, No. 4, 1972.

21. An analysis of procedure for acceptance creep testing of ferritic low alloy steels for high temperature service—R. Choubey and M. R. Das; NML Technical Journal, Vol. 14, No. 4, 1972.

22. Sponge iron technology-Efforts at NML—V. A. Altekar; presented at the Symposium on "Science and Technology of Sponge Iron & its Conversion to Steel" and also published in the Souvenir of the Symposium, Feb., 1973 (NML).

23. Operational aspects of sponge iron production in rotary kiln—B. L. Sengupta, A. B. Chatterjea, G. P. Mathur and V. A. Altekar; Presented at the Symposium on 'Science and Technology of Sponge Iron and its Conversion to Steel"—Feb., 1973 (NML).

24. On some fundamental aspects of operational parameters of direct reduction in a rotary kiln—A. B. Chatterjea; Presented at the Symposium on 'Science and Technology of Sponge Iron and its Conversion to Steel'; Feb., 1973 (NML).

25. A study of ring formation in the production of sponge iron in the rotary kiln—M. R. K. Rao; Presented at the Symposium on 'Science & Technology of Sponge Iron and its Conversion to Steel'; Feb., 1973 (NML).

26. Naphtha reduction of iron ores to sponge iron in continuous vertical reactor—V. A. Altekar, K. N. Gupta, B. K. Paul, & V. K. Soni; presented at the Symposium on 'Science & Technology of Sponge Iron and its Conversion to Steel'; Feb., 1973 (NML).

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28. Sponge iron production in a vertical shaft furnace—A. B. Chatterjea, T. C. De and V. A. Altekar, presented at the Symposium on 'Science and Technology of Sponge Iron and its Conversion to Steel'; Feb., 1973 (NML).

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30. Beneficiation of graphite by differential grinding and screening—C. Satyanarayana, S. Raghunadha Rao, S. K. Banerjee & G. P. Mathur; presented at the 5th Annual Convention of Ind. Inst. of Mineral Engineers; March, 1973.

31. Sponge iron from iron ores—K. N. Gupta & V. A. Altekar; presented at the 5th Annual Convention of Ind. Inst. of Mineral Engineers, March, 1973.

32. Studies in the macro and micro porosities of some Indian iron ores and its effect on the reducibility—B M Dutta, K N Gupta & A N. Kapoor; Trans. of Ind. Inst. of Metals, June, 1972.

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34. Activity of carbon in iron-chromium-carbon alloys containing 4.3 and 6.4 wt. percent chromium at 1000°C—A. K. Nayak & P. P. Bhatnagar; Trans. of Ind. Inst. of Metals, Sept., 1972.

35. Distribution of antimony alloys using radio active tracers—K. D. Maji and H. R. Tipler; Trans. of Ind. Inst. of Metals, December, 1972.

36. Production of tin free steel—A. K. Sinhamahapatra, N. Dhananjayan and V. A. Altekar; under publication in Trans. of Ind. Inst. of Metals.

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N. V. Nagaraja, K. N. Gupta, and V. A. Altekar; presented at the 26th Annual Technical Meeting of Ind. Inst. of Metals; Dec., 1972.

38. Thermodynamic properties of liquid Pb-Sb alloys—C. S. Sivaramakrishnan, R. Kumar & G. Mishra; presented at the 26th Annual Technical Meeting of Ind. Inst. of Metals, Dec., 1972.

39. Structure of liquid metals and alloys—R. Kumar; presented at the Symposium on 'Recent Developments in Metallurgical Science & Technology' of Ind. Inst. of Metals, 1972,

40. Thermal expansion of some binary alloys—L. J. alasundaran & A. N. Sinha—presented at the 26th Annual Technical Meeting of Ind. Inst. of Metals, Dec., 1972.

41. Co-efficient of themral expansion of Cu-Mn alloys—A. N. Sinha & L. J. Balasundaram; Trans. of Ind. Inst. of Metals, April, 1973.

42. Immiscibility in binary alloys of group 2 metals—R. Kumar; presented at the International conference on the 'Structure & Properties of Liquid Metals'; Tokyo, Japan, Sept., 1972.

43. Structure of liquid aluminium-silicon alloys-Manjit Singh & R. Kumar; Journal of Materials Science, 1973, 8(3), 371.

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45. Immiscibility in binary alloys of group IA metals (lithium, sodium and potassium)—R. Kumar; Journal of Material Science, 1102.

46. Structure of rapidly solidified Al-Si alloys—R. Kumar & S. K. Bose; under publication with Journal of Materials Science.

47. Grain size control of magnesium and Mg-Al alloys—R. Kumar & R. K. Mahanty; Journal of British Foundrymen.

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49. A study of solidification of Al- and Al-Cu alloys by anodic oxidation technique—R. Kumar & Mrs. A. Bahadur; Metallography.

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51. Structure of liquid Al-Si-Mg alloys—R. Kumar, C. S. Sivarama-Krishnan & R. K. Mahanty; presented at the 2nd International Conference on 'Liquids', 3-8 Sept., 1972; to be published in 'Advances in Physics'.

52. Metal powders—status of technology in India—R. G. Ganguly, Upkar Singh, MJ Shahani & V. A. Altekar; Presented at 'POWTECH' March 1973 conference, Horrowgate, U.K.

53. Electro-deposites nickel-aluminium composites—P. K. Sinha, N. Dhananjayan & H. K. Chakravorty—Plating, January, 1973.

54. Effect of 2-mercaptobenzothiazole on acid dissolution and hydrogen absorbtion of steel—Inder Singh & T. Banerjee; Corrosion Science, 1972, Vol. 12, 503-515.

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57. Stress corrosion cracking of homogeneous copper alloys—A. K. Lahiri & U. K. Chatterjea; Proc. of 2nd South American Conference on 'Metallic Corrosion', Sau Paulo, Brazil, Nov., 1972.

58. Stress corrosion cracking of alpha brass in ammonium sulphate solution—U. C. Bhakta & A. K. Lahiri—under publication with British Corrosion Journal.

59. Failure of a turbine blade due to corrosion fatigue—S. M. Arora & P. K. Gupte; communicated to 'Praktische Metallographic', West Germany.

60. Hydrogen adsorption by cold rolled steel in inhibited sulphuric acid—Inder Singh, A. K. Lahiri & T. Banerjee; Ind. Jr. of Technology, Vol. 10, June, 1972.

61. Preferred Orientation in extended aluminium alloy and aluminium rods—K. D. Maji, Communicated to Ind. J. of Technology.

62. Bacterial leaching—an alternative method of extraction of non-ferrous metals—Narinder Singh, S. R. Srinivasan, M. J. Shahani & V. A. Altekar; presented at the Seminar on 'Bacterial Leaching' Dec., 1972 (NML).

63. Recovery of copper from dilute solutions—C. Sankaran, S. R. Srinivasan & D. D. Akerkar; Presented at the Seminar on 'Bacterial leaching', Dec. 1972 (NML).

64. Economic viability of bacterial leaching—a management research view point—B. V. S. Yedavalli. Presented at the Seminar on 'Bacterial Leaching', Dec., 1972 (NML).

65. Effect of cathodic charging on the inhibition and efficiency of polar organic compounds—Inder Singh & V. A. Altekar; Proc. of 'Corrosion on Chemical Process Industries', Calcutta, Nov., 1972.

66. Underground corrosion and cathodic protection—S. Rao Addanki, K. P. Mukherjee & H. K. Chakravorty; Proc. of 'Corrosion on Chemical Process Industries', Calcutta, Nov, 1972.

67. Atmospheric Corrosion of mild steel in industrial and marine atmospheres—H. R. Thilakan, A. K. Dey and M. N. Singh; Proc. of 'Corrosion in Chemical Process Industries; Calcutta, Nov., 1972.

68. Selective Corrosion of stainless steels in the process industry—M. N. Singh, A. N. Mukherjee, K. P. Mukherjee & V. A. Altekar—Proc. of 'Corrosion in Chemical Process Industries' Calcutta Nov. 1972.

69. Rapid assessment of barrier type organic coatings by electro chemical investigations—P. Prabhakaran, S. Rao Addanki & A. N. Mukherjee; presented at the Symposium on 'Surface Coatings' organized by Colour Society, Bombay, March, 1973.

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71. Tarnishing of copper during storage and transit and its prevention—A. N. Mukherjee & A. K. Lahiri—Communicated to Journal of Institution of Engineers.

72. Wet and dry methods of limestone benefication—S. Raghunadha Rao & G. P. Mathur; Presented at the Symposium on 'Limestone and Dolomite Industries in India' at Rourkela.

73. Tin free steels—A. K. Sinha Mahapatra, N. Dhananjayan, & V. A. Altekar; Eastern Metals Review, Annual Number, April, 1972.

74. Studies on suitability of Rampur sand for steel foundry use—A. Dass, A. Dutt, G. N. Rao, & P. K. Gupte; Foundry News, March, 1972.

75. How to reduce scrap casting—G. N. Rao & P. K. Gupte; Indian Journal of Engineers.

76. Aluminizing of steel sheet and strip—S. M. Arora—Presented at the Symposium on 'Coatings of and on aluminium' June 10, 1972; Organized by Society for the Advancement of Electrochemical Science and Technology.

77. Feasibility of hot-dip aluminizing of steel tubes—A. Nag, S. M. Arora & P. K. Gupte; presented at the seminar organized by Ind. Inst. of Metals and Inst. of Engineers at Jamshedpur, Dec., 9, 1972.

78. Loh ispat padarthon ka aluminikaran (Hindi)—S. M. Arora; Communicated to Vigyan Pragati.

79. Development of soft magnetic materials—R. D. Gupta & P. K. Gupte; presented at the Symposium on 'Electrical, Electronics & Magnetic Materials' organized by BARC at Madras, Dec. 1972.

80. Some binary alloys for magneto mechanical applications—L. J. Balasundaram & A. N. Sinha; presented at Symposium on 'Electrical, Electronics & Magnetic Materials' organized by BARC at Madras, Dec., 1972.

81. NML Aluminium Conductor—its impact on national economy;-Rajendra Kumar & Manjit Singh; presented at the Symposium on 'Electrical, Electronics & Magnetic Materials' Organized by BARC at Madras, Dec., 1972.

82. Germanium—its source and recent trends in its extraction from coal mines—Narinder Singh, S. B. Mathur, & V. A. Altekar; presented at the Symposium on 'Electrical, Electronics & Magnetic Materials' organized by BARC at Madras, Dec., 1972.

83. Special methods of vacuum melting—N. K. Das & L. J. Balasundaram; presented at the RDOEI seminar on 'Engineering Materials' Bhopal, Feb., 1973.

84. Aluminium in electrical and telecommunication industry—R. Kumar & Manjit Singh, presented at the RDOEI Seminar on 'Engineering Materials' Bhopal, 1972.

85. Thermal expansion of Bi-Pt & Bi-Sn alloys—L. J. Balasundaram & A. N. Sinha; Current Science, March 20, 1972.

86. High strength Fe-Al-Si alloys—N. K. Das and L. J. Balasundaram; presented at the Silver Jubilee Symposium of Indian Institute of Science, Bangalore, May, 1972.

87. Impact of some recent metallurgical developments on the technology of aluminium—R. K. Mahanty, C. S. Sivaramakrishnan, Manjit Singh & R. Kumar; under publication in anniversary issue of Indian & Eastern Engineers.

88. Structure of liquids and freezing—R. Kumar; a chapter in the book published by Prof. H. D. Merchant, IIT, Kanpur.

APPENDIX II

Scientific Investigations Completed and Reports Prepared.

1. Study of the creep-rupture properties of three casts of 1% Cr, 1% Mo, 1% V steel (corresponding Czech. material C.S.N. 422744) for Steam Turbine Valves—R. Choubey, K. M. Chowdary & K. Prasad (I.R. 671/72).

2. Determination of microhardness and angularity of quartz samples A & B received from M/s Shevaroy (P) Ltd, Yercaud, Salem Dt., Tamilnadu.—A. Peravadhanulu, Fhaskar anerjee & S. K. Banerjee (I.R. 672/72).

3. Final report on testing of Kiruburu lumpy iron ore for Bokaro Steel plant employing Thakur Prasad ore (Barajamda) as reference sample—Inter Divisional Project (I.R. 673/72).

4. Moulding characteristics of Teka/sand sample (No. 'B') received from Department of Industries, Govt. of Haryana.—R. C. Arora, M. N. P. Verma, G. N. Rao & P. K. Gupte (I.R. 674/72).

5. Moulding characteristics of Teka sand sample (No. 'C') received from the Department of Industries, Govt. of Haryana.—R. C. Arora, M. N. P. Verma, G. N. Rao & P. K. Gupte (I.R. 675/72).

6. Moulding characteristics of Quartzite sample, Kathasiris, District Mayurbhanj, Orissa—Ashimesh Dutt, G. N. Rao, P. K. Gupte (I.R. 676/72).

7. Moulding characteristics of Quartzite sample from Balimundi, District Mayurbhanj, Orissa—Ashimesh Dutt, G. N. Rao & P. K. Gupte (I.R. 677/72).

8. Moulding characteristics of Quartzite sample from Dublabera, District Mayurbhanj, Orissa—Ashimesh Dutt, G. N. Rao & P. K. Gupte (I.R. 678/72).

9. Investigation of failure of shoes for conveyanance KQ-783 for Folax Grate Cooler for cooling—Raghubir Singh, J. P. Tewari & H. C. Singh (I.R. 679/72).

10. Laboratory scale tests on compatibility of iron ores and non-coking coals undertaking further trials in Rotary Kiln for production of sponge Iron—(I.R. 680/72).

11. Investigation report on batch and Pilot Plant Benefeciation Studies on a low grade copper ore from Indian Copper Corporation Ltd., Ghatsila (Bihar)—M. V. Ranganathan, C. Satyanarayana, P. V. Raman & G. P. Mathur (I.R. 681/72).

12. Studies on production of fluxed sinters with the-10+3 mm iron ore

fines from Kiruburu iron ore mines, for Bokaro Steel project—P. K. Sinha, B. L. Sengupta, P. V. Raman, S. K. Banerjee & G. P. Mathur (I.R. 682/72).

13. Studies on production of fluxed sinters using-10 mm+65 mesh composite iron ore fines from Kiruburu iron ore mines for Bokaro Steel project—R. Ganesh, B. L. Sengupta, S. K. Banerjee & G. P. Mathur (I.R. 683/72).

14. Jigging & tabling studies on a low grade manganese ore sample (sample A) from Tirodi, Maharastra, received from M/s Manganese Ore (India) Ltd. Nagpur—C. Satyanarayana, P. D. Prasad Rao, P. V. Raman, S. K. Banerjee & G. P. Mathur (I.R. 684/72).

15. Jigging & tabling studies on a low grade manganese ore sample (Sample B) from Tirosi, Maharastra, received from M/s Manganese Ore (P) Ltd., Nagpur—P. D. Prasad Rao, C. Satyanarayana, P. V. Raman & G. P. Mathur (I.R. 685/72).

16. Recovery of Iron powder from waste pickle liquor of Tinplate Co. Ltd., Jamshedpur—S. N. Sinha & S. K. Ray (I.R. 686/72).

17. Investigation on the calcination characteristics of kyanite samples supplied by Maharastra Mineral Corporation Ltd., Bombay (I.R. 687/72).

18. Determination of Bond's Work Index of (i) Bauxite & (ii) calcined Petroleum coke, from M/s. Aluminium Corporation of India Ltd., Calcutta—K. Vijaya Raghavan, P. V. Raman, S. K. Banerjee & G P. Mathur (I.R. 688/72).

19. Beneficiation and Agglomeration studies on Manganese ore fines sample from M/s. Khandelwal Ferro Alloys Ltd., Nagpur (I.R. 689/72).

20. Protective Scheme for the underground steel pipes—Dr. Indra Singha & K. P. Mukherjee (I.R. 690/72).

21. Beneficiation studies on a low grade Manganese ore (sample C) from Tirodi area, M.P., from M/s. Mangenese Ore (I) Ltd.—P. D. Prasad Rao, P. V. Raman & G. P. Mathur (I.R. 691/72).

22. Washing studies with a lime stone sample from Purna-pani HSL, Rourkela—P. D. Prasad Rao, R. K. Kunwar, S. K. Banerjee & G. P. Mathur (I.R. 692/72).

23. Beneficiation of core samples of low grade copper ore from Malanj-khand, Balaghat Dist., M.P.—M. S. Prasad, G. P. Mathur & V. A. Altekar (I.R. 693/72).

24. Beneficiation studies on a low grade manganese ore received from M/s. Manganese Ore (I) Ltd., Nagpur—P. D. Prasad Rao, P. V. Raman & G. P. Mathur (I.R. 694/72).

25. An Investigation on Dolomite Linings for L.D. Converters at HSL., Rourkela, Part 1: Studies on Process variables in the Tar-Dolomite Block Making (I.R. 695/72).

26. Testing of Pine oils received from M/s. Camphor & Allied Products Ltd., Bombay—Sachidanda Prasad, P. V. Raman, S. K. Banerjee (I.R. 696/72).

(I.R. 696/72).

27. Reduction of Lime content of Bauxite Sample from Saurashtra—D. M. Chakrabarti, P. V. Raman & G. P. Mathur (I.R. 697/72).

28. Corrosion of steam-header of power plant at Barauni oil refinery—P. S. Nag & A. K. Lahiri (I.R. 698/72).

29. The Scientific evaluations for the installations, testing and commissioning of protection to the city filter water pipe lines in Calcutta—K. P. Mukherjee (I.R. 699/72).

30. Beneficiation of lowgrade chrome ore from Garividi, Srikakulam Dist., A.P. (M/s. Ferro Alloys Corporation, Shreeramnagar)—S. K. Banerjee & G. P. Mathur (I.P. 700/72).

31. Agglomeration studies on L.D. dust from Rourkela Steel Plant of Hindustan Steel Ltd.—H. Patnaik, B. L. Sengupta, S. K. Banerjee & G. P. Mathur (I.R. 701/72).

32. Studies on production of fluxed sinters with the classifier sand —3 mm+6 mesh from Kiriburu iron ore mines for use in Bokaro Steel Project—H. B. Barari, B. L. Sengupta, S. K. Banerjee & G. P. Mathur (I.R. 702/72).

33. Beneficiation studies with pyrite-pyrrhotite samples from Saladipura area of P.P.C.L.—K. Vijaya Raghavan, M. L. Viswakarma, P. V. Raman & G. P. Mathur (I.R. 703/72).

34. Beneficiation studies on a low grade copper ore from Bhogani area, Alwar Dt., Rajasthan—S. N. Prasad, P. V. Raman & S. K. Banerjee (I.R. 704/72).

35. Beneficiation studies on a lime-stone sample received from M/s. Travancore Electrochemical Industries, Chingavaram, Kottyam—S. Prasad, P. V. Raman, S. K. Banerjee & G. P. Mathur (I.R. 705/72).

36. An investigation on dolomite linings for L.D. converters at HSL, Rourkela Part 2—Laboratory studies on raw dolomite and dolomite sinter (I.R. 706/72).

37. Pilot plant studies on the beneficiation of Joda flaky iron ore sample from M/s. Tata Iron & Steel Co.—R. K. Kunwar, S. C. Maulic, N.

Chakravarti, B. L. Sengupta, S. K. Banerjee & G. P. Mathur (I.R. 707/72).

38. Beneficiation studies on low grade complex Copper-Lead-Zinc ore from Dariba-Rajapura, Udaipur, Rajasthan—S. K. Sengupta, P. V. Raman & G. P. Mathur (I.R. 708/72).

39. Batch scale and pilot plant studies for the concentration of galena from a low grade lead ore from Bandalamottu block, Agnigundala area, A.P.—C. Satyanarayana, P. V. Raman, S. K. Banerjee & G. P. Mathur (I.R. 709/72).

40. Beneficiation of graphite sample from Rajasthan State Industrial Mineral Development Corporation, Jaipur—Joga Singh, P. V. Raman, S. K. Banerjee & G. P. Mathur (I.R. 710/73).

41. Beneficiation of Lowgrade Graphite from Chammuna, Sidhi Dt., M.P.—S. Ranganatha Rao, S. K. Banerjee & G. P. Mathur (I.R. 711/73).

42. Studies on physical characteristics of—40+10 mm size lumpy iron ores from Jajang-Zhilling and Ghatturi mines and a comparative study with characteristics of Kiruburu Iron ore—P. K. Sinha, B. L. Sengupta, S. K. Banerjee & G. P. Mathur (I.R. 712/73).

43. Beneficiation of Baryte from M.P.—K. Vijaya Raghavan, P. V. Raman, S. K. Banerjee & G. P. Mathur (I.R. 713/73).

44. Beneficiation of low grade graphite from Gidher, Sidhi Dist., M.P.—S. Ranganatha Rao, S. K. Banerjee & G. P. Mathur (I.R. 714/73).

45. Dry and wet screening tests with a limestone sample from Purnapani H.S.L., Rourkela—P. D. Prasad Rao, R. K. Kunwar, P. V. Raman, S. K. Banerjee & G. P. Mathur (I.R. 715/73).

46. Corrosion of the structural parts in the Fertilizer Corporation of India Ltd., Namrup—A. N. Mukherjee, Indra Singh & K. P. Mukherjee (I.R. 716/73).

47. Determination of settling rate of Barsua Iron ore slime using various types of Floculants—S. K. Sil, S. K. Sengupta, S. K. Banerjee & G. P. Mathur (I.R. 717/73).

48. Preliminary trials on fluo-solid roasting of Salsipura pyrites received from Pyrites, Phosphates & Chemicals Ltd.,—P. V. Viswanathan & B. V. S. Yedavalli (I.R. 718/73).

49. A report on comprehensive test on Joda Iron ore for the Tata Iron & Steel Co. Ltd. (I.R. 719/73).

50. Pilot Plant Studies on the Beneficiation of Iron ore sample received from M/s. Bolani Ores Ltd., Orissa—R. N. Kunwar, V. K. Sharma, S. C. Maulik, B. L. Sengupta & G. P. Mathur (I.R. 720/73).

51. Pilot plant studies on the Beneficiation of Khondobond hard Iron ore sample from Tisco Ltd.—R. K. Kunwar, S. C. Maulic, B. L. Sengupta, S. K. Banerjee & G. P. Mathur (I.R. 721/73).

52. The Reduction Characteristics of Khondobond Iron Ore—N. V. Nagaraja & K. N. Gupta (I.R. 722/73).

53. Pilot plant investigations on the production of sponge iron from iron ore lumps and pellets using solid reductants—B. L. Sengupta, G. P. Mathur & V. A. Altekar (I.R. 723/73).

54. Spectrographic analysis of residual elements in ferrochrome—M. K. Ghosh, S. V. Gopalkrishna & H. K. Chakravarti (R.R. 308/72).

55. Preparation of anhydrous magnesium chloride in fluidized bed—S. K. Roychowdhury, P. K. Som and H. K. Chakravarti (R.R. 309/72).

56. Studies in chlorination of magnesites—S. K. Roychowdhury, S. C. Aush and P. K. Som (R. R. 310/72).

57. Metallographic studies of precipitation in Iron—5% Titanium—S.P. Mukherjee and Rajendra Kumar (R.R. 311/72).

58. Aluminium in electrical and telecommunication industries—Rajendra Kumar and Manjit Singh (R.R. 312/72).

59. Structure of liquid Aluminium—Silicon—Magnesium alloys—Rajendra Kumar, C. S. Sivaramakrishnan and R. K. Mahanty (R.R. 313/72).

60. Immiscibility in Binary Alloys of Group II Metals—a semi-emperical approach—Rajendra Kumar (R.R. 314/72).

61. The NML aluminium conductor—its impact on national economy—Rajendra Kumar and Manjit Singh (R.R. 315/72).

62. Thermodynamic properties of liquid Lead-Antimony alloys—C. S. Sivaramakrishnan, G. Misra and Rajendra Kumar (R.R. 316/72).

63. The solid state nitrogenation of carbon free ferro-chromium—N. Subrahmanyam, R. G. Ganguly and M. Subrahmanyam (R.R. 317/72).

64. Final report on Operational efficiency of India Govt. Mint, Alipore, Calcutta—Rajendra Kumar (R.R. 318/73).

65. Preferred orientation in extruded aluminium alloy and aluminium rods—K. D. Maji (R. R. 319/73).

66. Feasibility of hot-dip aluminising of steel tubes—A. Nag, S. M. Arora and P. K. Gupte (R.R. 320/73).

67. 17% Cr-Mn-N stainless steels—S. S. Bhatnagar and B. R. Nijhawan (RR 321/73).

APPENDIX III

Sponsored Investigations Completed

	Title	*Sponsorer*
1.	Beneficiation of core samples of low grade copper ore from Malanjkhand, Balaghat Dist., M.P.	Hindustan Copper Ltd.
2.	Batch and pilot plant studies for the concentration of a tailing from a low grade lead ore from Bandalamottu block, for Agnigundala Project.	Hindustan Copper Ltd.
3.	Beneficiation studies on a low-grade copper ore from Bhagoni area, Alwar Dist., Rajasthan.	Geological Survey of India.
4.	Beneficiation studies on low-grade complex copper-lead-zinc ore from Dariba-Rajpura, Udapur.	Hindustan Zinc Ltd.
5.	Production of fluxed sinters with (i) —10+3 mm iron ore fines, (ii) —10 mm+65 mesh composition ore fines and (iii) classifiar sand —3 mm+6 mesh from Kiriburu iron ore mines for use in Bokaro Steel Plant.	Bokaro Steel Plant.
6.	Testing of Kiriburu lumpy iron ore from Kiriburu employing Barajamda ore supplied by M/s. Thakur Prasad, as reference sample.	Bokaro Steel Plant.
7.	Pilot Plant studies on beneficiation, decrepitation and reducibility studies on (i) Joda Flaky iron ore ore sample and (ii) Khondbond hard iron ore sample.	The Tata Iron & Steel Co. Ltd.
8.	Investigations on a limestone sample from Purnapani (a) washing studies with one sample and (b) dry and wet screening tests on a 2nd sample.	Rourkela Steel Plant, H.S.L.
9.	Investigation on dolomite linings for L.D. converters at H.S.L., Rourkela : Part I—Studies on process	Rourkela Steel Plant, H.S.L.

	variables in the tarsolomite block making and Part II : Laboratory studies on raw-dolomite and dolomite sinter.	
10.	Agglomeration studies on L.D. dust.	-do-
11.	Protective scheme for the underground steel pipes.	Bhilai Steel Plant, H.S.L.
11.	Protective scheme for the underground steel pipes.	Bhilai Steel Plant, H.S.L.
12.	Preparation of samples of Donimalai iron ore, coke, coal, limestone, dolomite and bentonite samples for despatch to U.S.S.R.	Ministry of Steel & Mines, Govt. of India, New Delhi.
13.	Appraisal of raw-materials for sponge iron making.	Industrial Development Corporation of Orissa Ltd.
14.	Beneficiation of low-grase graphite samples (1) from Gider, Sidhi Dist. and (2) from Chammuna, Sishi Dist., M.P.	Director, Geology and Mining, M.P.
15.	Bench scale beneficiation studies on a baryte sample.	Director of Geology and Mining, Raipur, M.P.
16.	Preliminary trials on fluosolid roasting of Saladipura pyrites.	Pyrites, Phosphates & Chemicals Ltd., Dehri-on-Sone.
17.	Beneficiation Studies with Pyrite-pyrrhotite Sample from Saladipura area.	-do-
18.	Beneficiation of a graphite sample from Rajasthan.	Industrial Mineral Development Corporation, Jaipur.
19.	Beneficiation studies on a manganese ore sample and jigging and tabling studies on two samples from Tirodi Mines.	Manganese Ores (I) Ltd., Nagpur.
20.	Beneficiation and agglomeration studies on manganese ore fines.	Khandelwal Ferro Alloys Ltd., Nagpur.
21.	Studies on calcination characteristics of kyanite samples.	Maharashtra Mineral Corporation Ltd., Bombay.
22.	Beneficiation of a limestone sample.	Travancore Cochin Electro-

		chemical Industires, Chingavaram, Kottayam.
23.	Determination of micro-hardness and angularity of quartz samples.	Shevaroy (P) Ltd., Yercand, Tamilnadu.
24.	Determination of Bond's Work Index of (i) Bauxite and (ii) Calcined petroleum coke.	Aluminium Corporation of India, Jaykaynagar.
25.	Study of creep-rupture properties of three cast 1% Cr—1% Mo—1% V Steel for steam turbine valves.	Bharat Heavy Electricals Ltd., Tiruchirapalli.
26.	Recovery of iron powder from waste pickle liquor.	Tinplate Co. of India Ltd., Jamshespur.
27.	Testing of pine oil.	Camphor and Allied Products Ltd., Bombay.
28.	Corrosion of steam-header of a power plant.	Barauni Oil Refinery, Barauni.
29.	Corrosion of structural parts.	Fertiliser Corporation of India Ltd., Namrup.
30.	Scientific evaluation for the installation, testing and commissioning of cathode protection to city filter water pipe lines in Calcutta.	Calcutta Metropolitan Water and Sanitation Authority, Calcutta.
31.	Failure of super heater tubes.	Singareni Collieries Co. Ltd., Kothagudam, A.P.
32.	Causes of failure of aluminium detonator shell.	Indian Detonators, Hyderabad.
33.	Aluminising of I.D. fan impeller liner tips.	Thermal Power Station, Talcher, Orissa.
34.	Investigations on bentonite sample.	Steel Cast Corporation, Bhavnagar.