Annual Report

1971-72

National Metallurgical Laboratory

Council of Scientific & Industrial Research
Jamshedpur, India

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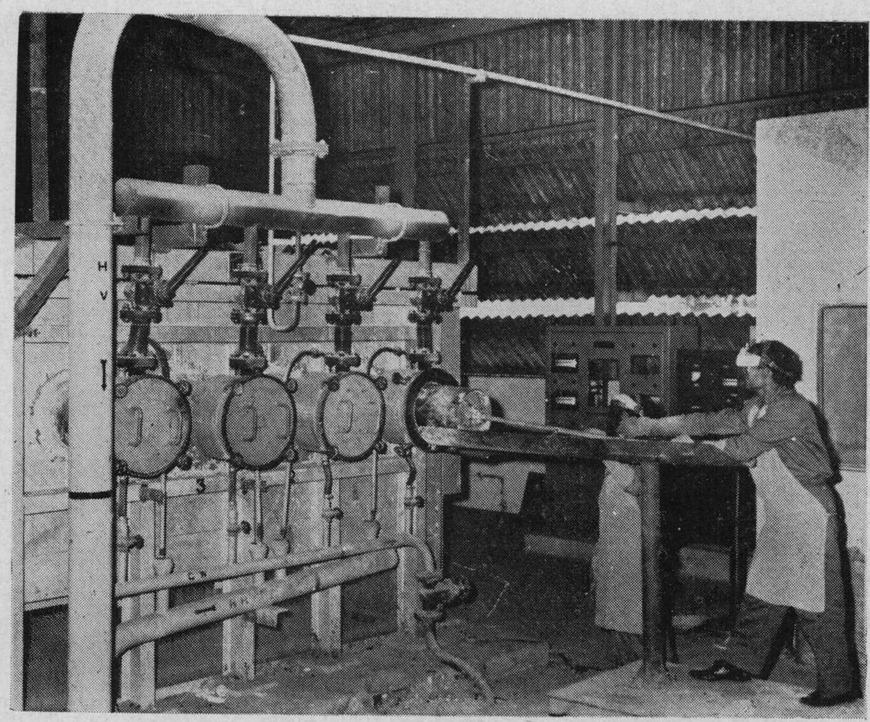


Magnesium crown being removed from the retort at the 200 tonnes/annum Magnesium Plant, Jamshedpur set up with NML developed known-how.

A group discussion during a Technical Session of the UNIDO Workshop on 'Creation and Transfer of Metallurgical knowhow' at NML (7th December 1971)

INTRODUCTION

During the period under review, the National Metallurgical Laboratory has undergone a further reorientation of its activities in the various research and development projects and has maintained close and purposeful relations with mineral and metal industries both in the public and private sectors. During the hostilities of December 1971 and emergency, the NML as usual rose to the occasion and offered all facilities at their command to meet urgent Defence needs. A significant development has been the completion of the Magnesium Plant and the commencement of successful trial runs. It was a happy augury that the commissioning the entire plant was completed by the month of February 1972 as scheduled. An equally heartening feature has been the production of tonnage quantities of low phosphorus steel from Indian Pig Iron in the basic-lined side-blown converter developed at the NML. The consumer acceptibility tests on 'Tin free steels' developed at the Laboratory have been highly encouraging and it is now planned to undertake in plant trials for the production of 'TFS' on a large scale.

Despite the disturbed conditions and dislocation of services, the Workshop on 'Creation and Transfer of Metallurgical Know how' organized by UNIDO was succesfully held at NML from 7th to 11th December 1971 in which experts, fellows and observes from various developed and developing countries participated. The principal conclusions and recommendations which emanated from the five day workshop were that increasing technical self sufficiency should be achieved progressively by the developing countries for the growth and development of their metallurgical industries; imported technology should be improved and modified to indigenous conditions in order to develop local talent, and UNIDO should act as an antenna to transfer the metallurgical know-how and to develop technical consultancy services in the develpoing countries themselves.

The laboratory has been laying greater emphasis to develop interaction with industries and to build 'customer-contractor' relationship through Get-together, Seminars and Symposia. Such interaction with industry has not only bridged the credibility gap between research and industry by identification of plant and industrial problems to be fed back

Sri C. Subramaniam, Union Minister fer Planning, Science & Technology, at the Magnetic materials room of the Laboratory. Prof. V. A. Altekar, Director NML is on extreme right (11th February 1972).

to the Laboratory but has also made the industry conscious and aware of the R & D facilities and expertise available at the laboratory which they can utilize profitably, so that the work of the laboratory could be purposeful and relevant to the requirements of the industry.

Joint task forces have been constituted for identification of urgent R & D problems and for uudertaking development projects, viz at Rourkela Steel Plant.

(1) Inplant trials for Aluminising by NML process.

(2) Inplant trials of Tin-free Steel production.

(3) Establishment of a 5 tonnes experimental L-D converter.

(4) Manufacture of Low Alloy High Strength Steels.

Work on improving the life of the L-D converter lining at Rourkela Steel Plant has already been assigned to the Laboratory. It has also been possible to identify the problem of setting up a custom benefication plant for the graphite ores for Andhra Pradesh and setting up the industrial unit for the manufacture of graphite crucibles in collaboration with the NLM.

The researches carried out at the Laboratory have been recognised both in India and abroad and have created confidence amongst public and private sector metallurgical and mineral industries culminating in the engagement of NML as their technical consultants. Hindusthan Copper Ltd., have appointed NML as their consultant for their Rakha Copper Project for setting up and commissioning their 1000 tonnes/day concentrator plant at Rakha mines. The Calcutta Metropolitan Water and Sanitation Authority has assigned consultancy services to the Laboratory for providing technical advice in designing and commissioning of ground beds for cathodic protection to steel water mains under the supervision of NML scientists and for evaluation of data obtained from studies and examination of final report of the contractor. The Dept. of Economic Affairs, Ministry of Finance, Govt. of India has recently assigned to review the present operational efficiency in coinage production in Alipore Mint, Calcutta. M/s. Manganese Ore (India) Ltd. have also approached the NML for technical advice in modernising and mechanising their operations at Balaghat and other mines.

NML has been entrusted with the task of testing raw materials for the projected steel plants at Salem, Vishakhapatnam and Vijayanagar. Kiriburu lumpy iron ores as well as fines after sintering have been

Shri S. Mohan Kumarmangalam, Union Minister for Steel & Mines, (centre) with Prof. V. A. Altekar, Director NML (right) and Shri N. A. Palkhiwala, Vice-Chairman TISCO (second from left) at the Alluminising Pilot Plant. (19th January, 1972).

evaluated to determine their suitability for use in the Blast furnace of the Bokaro Steel Plant.

The foundation stone of the Central Creep Testing facility was laid on 22nd April 1971 by Dr. Atma Ram, Director General, Scientific & Industrial Research. The detailed design of the building were finalised in consultation with U.N. consultant (Planning) and the detailed drawings and estimates submitted by the Architects have been scrutinised by the Expert Building Advisory Committee. Construction of the building has already started. UNIDO has floated enquiries for the purchase of the required equipment.

After successful bench scale trials with the Asswan iron ores (UNIDO sponsored project), pilot plant scale investigations on bulk samples including beneficiation, agglomeration (pelletising, sintering and heat hardening) and pre-reduction of beneficiated ore have been completed. Smelting of both heat-hardened and pre-reduced pellets has been done in submerged arc electric furnace producing tonnage quantities of pig-iron. The final report containing the consolidated test data is under preparation.

Long-term, tonnage scale, investigations with respective regional raw materials from IDCOL, Bhilai, SIICOM, APIDC, etc. are being sponsored at the laboratory for testing their suitability for the production of sponge iron.

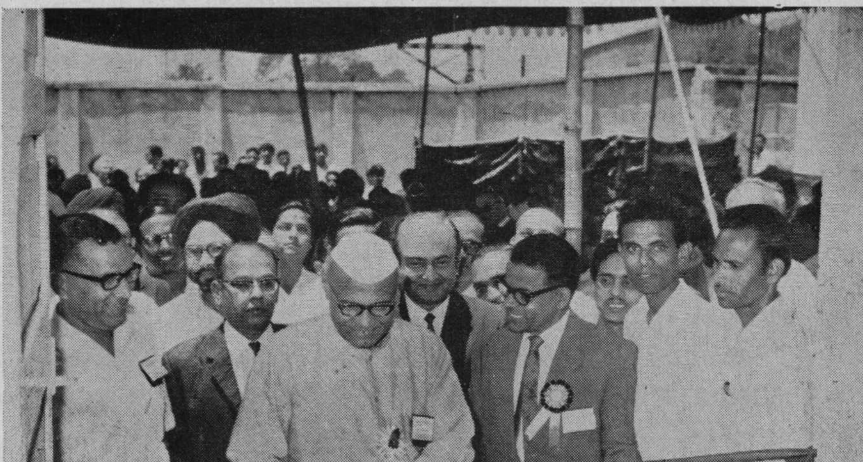
PM-2 aluminium conductor, developed at the Laboratory, showed improved strength, electrical conductivity and ductility in the fully drawn condition in industrial scale trials. It compares favourably with the imported grade of aluminium conductors.

The laboratory has done significant work on the development of refractory materials and a scientist of the Labratory working on refractory mateials has been awarded one of the 9th National Metallurgists' Day award for 1971.

The aid to electroplating industry has been recognised by the Inventions Promotion Board by conferring a Republic Day award on a scientist of the Laboratory.

The total number of projects handled during 1971-72 was 152 of which 47 were sponsored (2 under international organisation), 105 projects were undertaken on the initiative of scientists including 44 projects on basic rsearch. 59 projects were completed.

Dr. Atma Ram, Director-General, Scientific & Industrial Research, laying the foundation stone of the Central Creep Testing facility at NML (22nd April, 1971).



Dr Atma Ram, Director-General, Scientific & Industrial Research, inaugurating the Dense Carbon Aggregate Pilot Plant, at NML. (22nd April, 1971).

The activities of Laboratory during the period under review are presented in subsequent chapters. One hundred and eleven research papers were published, presented or communicated for publication during the year. Details are furnished in Appendix I. Details of Reserch and Investigation reports are given in Appendix II. A list of completed Sponsored projects is given in Appendix III. The earning of the Laboratory during the financial year was over 12.2 lakhs for the differnt services rendered to the industry and to other research institutions. Considerable amount of foreign exchange could be saved by the adoption of the processes and products developed by the Laboratory. It is hoped that laboratory will continue the lead in stimulating new developments in processes and products and solving multidiscipline problems of metallurgical and mineral industries of the country in the years to come. The facilities at the Labortory are at the disposal of the industry and it is invited to make good use of these in solving their problems.

Sri H. C. Sarin, Secretary, Dept of Steel, Ministry of Steel & Mines, Govt of India, cutting the tape to symbolise the opening of the Heavy Media Seperation Plant at NML. Standing left to him is Sri S. Moolgaokar, Vice-Chairman, TISCO and Prof. V. A. Altekar, Director NML (5th May 1971).

1.0 RESEARCH INVESTIGATIONS

1.1 Sponsored Projects.

1.1.1 Asswan Iron Ore from the Arab Republic of Egypt.
(Sponsor : UNIDO)

1.1.1.1 *Beneficiation*

In order to evolve an economic flow-sheet and to select a process for optimum beneficiation of the Asswan Iron Ore, bench scale and pilot plant scale beneficiation studies were carried out. The studies included sieve and chemical analyses of the samples, dry magnetic separation, washing followed by reduction roast, wet magnetic separation, calcination followed by magnetic separation, flotation tests, agglomeration of the beneficiated product by sintering or pelletization, pre-reduction of pellets etc. The most economic and optimum method for beneficiation has been found to be magnetizing roasting of the lumps followed by grinding to 85% below 200 mesh size and wet magnetic separation. A concentrate assaying 51.7% Fe, 15.84% FeO, 11.3% SiO_2, 5.23% Al_2O_3 with recovery of 77% from the original bulk sample having 41.2% Fe, 17.88% SiO_2 and 7.54% Al_2O_3 was obtained. The wet magnetic concentrate was pelletized, using 1% bentonite as binder to 9-12 mm size. The green pellets had the average compressive strength of 1.5 to 1.7 kg. and these were then subjected to pre-reduction using a highly volatile non-coking coal as a solid reductant. The operating parameters of prereduction were evaluated. The kiln discharge was subjected to magnetic separation. Pre-reduced pellets obtained attained 85% average degree of metallization with 92.4% Fe in the product, equivalent to 87.5% Fe recovery with respect to the original sample. The products were found to be suitable for electric smelting to produce pig-iron.

1.1.1.2 *Reduction characteristics*

1.1.1.2.1 Reduction characteristics of Asswan Iron Ore were determined by hydrogen and a mixture of carbon monoxide and hydrogen separately, at different flow rates and temperatures. Bolani ore of India was used as reference and reducibilities were compared under identical conditions. It was observed that reduction is faster by hydrogen than by a mixture of carbon monoxide and hydrogen.

1.1.1.2.2 Reduction tests of Asswan ore by using varying amounts of Naphtha was studied at 1000°C. The sponge iron obtained showed 90-97% metallization.

1.1.1.3 *Pre-reduction characteristics of fluxed and unfluxed beneficiated iron ore pellets from Asswan iron ores with non metallurgical coals in a static bed.*

To obtain primary date about retention time, ore/coal ratio and temperature of reduction static bed reduction tests were conducted at 1000°C with fluxed and unfluxed beneficiated Asswan iron ore pellets. It was found that though the pellets could be reduced to 96-97% metallization, very little agglomeration of the reduced pellets was obtained during reduction with or without limestone. The agglomeration was more pronounced with lime than without it. Tests conducted at 900°C showed that the agglomeration of reduced pellets was completely eliminated at the cost of decreased metallization of 1 to 2%. Results were suitably used in rotary kiln trials.

1.1.1.4 Macro and micro porosities of the Asswan iron ores were determined in a special test apparatus designed and fabricated for the purpose. Argon and hydrogen were used as penetrant fluid. 39 to 42% porosity values and 3.35 to 3.45 gm/cc density of the ore were obtained.

1.1.1.5 Decrepitation test were conducted on the Asswan iron ore under stagnant and flowing CO, CO_2, and N_2 atmospheres. Shatter strength of the iron ores was also determined in all cases. The average decrepitation temperature under stagnant and flowing CO, CO_2, and N_2 atmosphere was 390° and 305°C respectively.

1.1.1.6 *Electro-Smelting*

Trial campaigns were conducted on the Asswan iron ores and ore pellets of various grades in the 500 KVA submerged arc furnace. Initial trials were conducted using Andhra ores for furnace stabilization and familarization. The Asswan pre-reduced ores could be successfully smelted to pig-iron.

1.1.2 Calcination of Limestone from Asswan.

(Sponsor : UNIDO)

The calcination characteristics of the Asswan limestone were determined at constant rate of heating up to 930°C and the results were compared with those of Bisra (India) limestone. CO_2 evolution in 60 minutes for Asswan limestone of $-25+12$ mm size and $-12+6$ mm size was slightly higher than that of Bisra.

1.1.3. Beneficiation Studies on Bolani Iron ore fines.

(Sponsor : M/s. Bolani Ores Ltd.)

The investigations were undertaken to eliminate the sticky constituents such as clayey and acherous gangue from the fines. The sample as received assayed 42.8% Fe. Scurbbing and wet screening of the fines yielded a product assaying 63.8% Fe and 3.98% insolubles with recovery of 77.1% Fe. The cyclone concentrate obtained from slime treatment assayed 63.2% Fe and 2.7% insolubles with a recovery of 15% Fe. A final concentrate of 63.6% Fe and 4.2% insolubles was produduced by mixing the screen and cyclone concentrate with 92.2% Fe recovery. The free flowing characteristics of the concentrate were confirmed.

1.1.4. Studies on Production of Fluxed sinter with Iron ore fines from Kiriburu.

(Sponsor : Bokaro Steel Ltd.)

1.1.4.1. *Iron ore fines* : Comprehensive studies on sintering characteristics of the ore fines designated as grain size (-10+3 mm size) for production of fluxed sinters were carried out. Under optimum conditions coke consumption could be minimised to the extent of 20% by introducing fuel gas during sintering.

1.1.4.2. *Iron ore fines :* Bench scale studies were carried out to determine the optimum conditions for good quality sinter with composite iron ore fines (-10 mm $+$ 65 mesh). Addition of manganese, did not improve the size stability, but gave a higher degree of oxidation. However, inerease in the MgO content in the sinter mix from 3 to 5% improved the sinter strength.

1.1.5. Studies on Physical characteristics of Six lumpy Iron ore samples.

(Sponsor : Industrial Development Corpn. of Orissa Ltd.)

1.1.5.1. Six iron ore sample received from 'IDCOL' for comparative study of the physical properties, were designated (i) Khondbad (KB-OMC) (ii) TK (OMDC) (iii) Jajang (Jin) (iv) Jhilling (S. Lal & Co.) (v) Gandhamardan mines (G.M) and (vi) Barapada mines (B.P). Shatter, tumbling and crushing strength tests showned that the samples from Khondbad, Gandhamardan and Barapada mines were harder than those from Jajang, Jhilling and 'TK' mines. 'TK' mine sample was the softest.

1.1.5.2 *Studies on physical characteristics of lumpy iron ore from Kiriburu and Barajamda.*

(Sponsor : Bokaro Steel Ltd.)

Lumpy iron ore samples (—40+10 mm size) from Kiriburu Mines (NMDC) and a reference sample of same size from Barajamda mines (M/s. Thakur Prasad & Co.) were tested for their comparative evaluation. Chemical analyses indicated that the Kiriburu sample was slightly better in quality. Shatter, tumbling and crushing testes indicated that the Kiriburu sample was harder than the Barajamda ore. Swelling index test indicated that the Kiriburu ore was desner of the two.

1.1.5.3 *Reduction characteristics*

The reducibility of Kiriburu iron ore with reference to Barajamda iron ore was determined with hydrogen and gaseous mixture of carbon monoxide, carbon dioxide, hydrogen and nitrogen in a special set up, On compairing the results Kiriburu iron ore behaved better than Barajamda ore under identical reduction conditions.

1.1.5.4 Macro and Micro porosity tests were determined with a view to corelate the Blast furnace behaviour of known Barajamda ore with unknown Kiriburu ore.

1.1.6 Appraisal of Raw materials for Iron-marking.

1.1.6.1 (Sponsor : Bokaro Steel Ltd.)

1.1.6.1.1 Decrepitation tests were conducted between 325° and 400°C temperature on two lots of iron ore supplied by Bokaro Steel

Ltd. In the first lot, Barajamda and Kiriburu (test samples) iron ore and in the second Barajamda (Orissa minerals) Kiriburu (NMDC), Ghatkuri and Jajang (Rungta mines) were tested. Test results showed that the Jajang ore decrepitated comparatively more than the other ores.

1.1.6.1.2 The reduction characteristics of Jajang, Dhatkuri and Orissa mineral samples with gaseous mixture of carbon dioxide, carbon monoxide, hydrogen and nitrogen at varying flow rates and temperatures were compared. The respective reducibilities are under compilation.

1.1.6.1.3 Macro and micro porosity of the above ore samples were also determined using hydrogen as the penetrant fluid.

1.1.6.2 (Sponsor : Industrial Development Corp. of Orissa Ltd.)

1.1.6.2.1. Decrepitation tests under CO, CO_2 and N_2 atmosphere at temperature between 315 to 410°C and reducibility with hydrogen were carried out on the iron ores supplied by IDCOL Ltd, which were Jhilling (S Lall), Jajang (Rungta), Thakurani, Khondbad, Gandhamardhan and Barapada (OMDC). Jajang descrepitated to a greater extent than the other ores. Practically all ores could be reduced upto 80% and in the case of Jajang, Jhilling and Thakurani ores reduction was somewhat higher (85-90%) than other ores.

1.1.6.2.2 Matching tests on pre-reduction of six iron ore samples and three non metallurgical coals from Orissa and Raniganj coal field supplied by the sponsor were carried in static bed to find out the suitable combinations for obtaining maximum reduction of iron ores and also to ascertain the amount of reduced ore of definite size retained after reduction. A suitable combinations of ores and coals having optimum conditions for sponge iron production were indicated to the sponsor.

1.1.7 Beneficiation of low grade Manganese ores.

(Sponsor : Manganese Ores India Ltd.)

Four samples marked A, B, C & D of low grade Mn ore were received for beneficiation by jigging only to obtain concentrate assaying 46—48% Mn.

1.1.7.1 For the bulk sample A, a processing schedule was evolved whereby the original Mn. ore sample assaying 39.95% Mn, 10.65% Fe and 16.81% SiO_2 could be up graded to a combined concentrates assaying 47.5% Mn, 12.9% Fe and 6.66% SiO_2. Mn/Fe ratio could not be brought down as the bulk of the sample contains iron bearing manganese mineral.

1.1.7.2 The bulk sample B, containing lower Mn and assaying 27.9% Mn, 13.8% Fe and 25.4% SiO_2, could not be concentrated to the required grade due to (i) fine dissemination of siliceous gangue in the ore and (ii) the presence of Braunite. Work on samples C and D is in progress.

1.1.8 Beneficiation and Agglomeration of Oriental mixture Manganese ore fines.

(Sponsor : Khandelwal Ferro-Alloys Ltd., Khanhan, Kamptee, Nagpur)

The sample of Mn ore was subjectod to reduction roast followed by magnetic separation. The concentrate analysed 47.72% Mn, 8.5% Fe and 12.3% SiO_2 while the original sample contained 36% Mn 9.04% Fe and 14.62% SiO_2. Attempts to reduce the Fe content did not yield satisfactory results. Studies on the agglomeration of the concentrates are in progress.

1.1.9 Beneficiation of low grade Wolframite ores.

1.1.9.1 *From Degana (Rajasthan).*

(Sponsor : Director of Mines & Geology, Rajasthan)

The bulk sample assayed 0.052% WO_3. Assay of screen fractions from —10 mesh to —200 mesh did not show any preferential seggregation of wolfram value in particular sieve fraction. A number of treatment combinations were tried. The final flow sheet developed used tabling, hydrocycloning, high tension magnetic separation, roasting followed by magnetic separation with—48 mesh feed. Retreating the middlings yielded a final concentrate assaying 36% WO_3; total W recovery being 69%. The ore is characterised by its extremely low grade and a propensity to form ferruginous alterations along cracks and cleavage planes. These alterations are being intimately dispersed. For this reason it is not feasible to devise an entirely physical method to beneficiate the ore to commercial grade.

1.1.9.2 *From Bankura, (W. Bengal).*
(Sponsor : Gouripur Industries Ltd., Bankura)

Low grade mine samples assayed 0.143% WO_3, 0.0987% Cu and 91.67% SiO_2. Wolframite and Scheelite were the important tungsten bearing minerals and quartz was the predominant gangue followed by muscovite, lapidolite; sericite and tourmaline in smaller quantities. Tabling the ore after grinding to -35 mesh produced a rougher concentrate assaying 9.0% WO_3 with 40.1% recovery of WO_3. Magnetic seperation of this concentrate after roasting at 650°C improved the grade to 54.42% WO_3 with a low recovery of 20.6% WO_3. Rost reduction followed by magnatic separation of the table concentrate yielded a better concentrate of 59.7% WO_3 grade with recovery of only 26.6% WO_3. It has been concluded that there was only a remote possibility of producing a marketable grade concentrate, with high recovery from the ore sample supplied.

2.1.9.3 *Pilot Plant Studies for beneficiation of low grade Wolfram ores*
(Sponsor : Gouripur Industries Ltd., Bankura)

The Wolfram ore fines, usually 12 mm size, collected from the dumps after handpicking and sorting at the mines were beneficiated to produce an industrial grade concentrate and to suggest a flow sheet. The dumped rejects as received assayed 1.5 to 1.8% WO_3. Petrological examination showed that the tungsten bearing minerals were free only below 48 mesh. Tabling followed by three cleanings of table rougher concentrate yielded a product assaying 65% WO_3. Cyclone treatment of the slime which contains 20-25% WO_3, is under progress.

1.1.10 Beneficiation of low grade Molybdenite (L-1) from Karadikuttam, Madurai, Tamilnadu.

(Sponsor : G. S. I., Tamilnadu Circle)

As reported earlier, industrial grade Molybdenite concentrate could be obtained from sample (L-2), where as, the grade obtained from sample (L-3) was still poorer. During the period under review, a third sample, (L-1), assaying 0. 169% Mo has been subjected to bench scale beneficiation studies. The molybdenite was fairly free at about 65 mesh size. Rougher flotation after grinding to 21.4% –200 mesh, and using fuel oil and cresylic acid yielded a concentrate assaying 30.2% Mo with 91.2% Mo recovery.

Two cleanings of the rougher float using sodium cyanide yielded a cleaner concentrate assaying 54.7% Mo with recovery of 57%. Regrinding the tailing and recleaning yielded a second concentrate assaying 54.6% Mo, with additional recovery of 23.4%. The combined final concentrate assayed 54.7% Mo and 0.61% Cu with overall recovery of 80.4% Mo. The concentrate has been found suitable for commercial ues.

1.1.11 Beneficiation of low grade Copper ore.

1.1.11.1 *From Bhagoni, (Rajasthan).*
(Sponsor : Geological Survey of India)

A representative portion of -10 mesh original sample was sieve analysed after preliminary crushing and grinding. Petrological study revealed cale-granulite schist, calcareous biolite schist and calcareous quartzite. Pyrite and Pyrrhotite were other metallic sulphides. Chalcopyrite was well liberated from the non metallic gangue at about 65 mesh. Preliminary flotation tests are under progress.

1.1.11.2 *Complex Cu-Pb-Zn ore from Dariba, (Udaipur).*
(Sponsor : Hindusthan Copper Ltd.)

Petrological studies, after crushing and grinding the samples, on -10 mesh representative samples revealed that the ore was a complex sulphide with quartz as the chief gangue material followed by barite, fluorspar, carbonates (calcite, cerussite, dolomite etc), with traces of anglesite, apatite etc. Microscopic examination of the various sieve fractions indicated a fair degree of liberation of the mettalic sulphides from gangue at about -150 mesh size and that the bicomponent (two sulphides) and tri-component (three sulphides) minerals would still be interlocked to some extent even at 200 mesh size. Flotation tests, using various combination of reagents are in progress.

1.1,11.3 *Batch and Pilot Plant Benefication Studies on a low grade Copper ore.*
(Sponsor : Indian Copper Complex, Ghatsila, Hindusthan Copper Ltd.)

Comprehensive laboratory and pilot plant studies were undertaken on a low grade copper ore sample assaying 1.8% Cu, 0.08% Ni & 2.6% S. The results indicated that mechanically agitated flotation cells were quite suitable for producing a copper concentrate of 20-26% Cu with 96% recovery of Cu. Sulphur content raised between 24.92 to 27.88% in the concentrate and nickel recovery was of the order of 40-45%.

When coarser grind, around 40% -200 mesh, was used for flotation, the concentrate grade was between 21-22% Cu with recovery of 95% Cu and tailing loss was 0.096%. The power consumption, for grinding only, was 8-9.1 KWH per tonne of ore, depending on the fineness of the grinding.

1.1.12 Beneficiation of low grade Chrome-ore.

(Sponsor : M/s. Ferro-alloys Corpn. Ltd. Shreeramnagar, Srikakulam, A.P)

The ore was crushed to -10 mesh size and then the tabling tests were carried out at -28 and -48 mesh sizes. The reduction roast followed by magnetic seperation have been completed. Further work is in progress.

1.1.13 Beneficiation of Beach sand sample.

(Sponsor : Director of Mines & Geology, Gujarat)

Beach sand samples from Gujarat have been beneficiated to study the possibility of recovering ilmenite. The sample was well worn and derived from calcareous sedimentary rocks consisting mainly of quartz in different form, with calcified and fossil fragments. Heavy minerals of interest were mainly iron oxide and some magnetite-limonite grain and occassionally, zircon and monazite grains. Gravity, magnetic and high-tension seperation gave slight concentration of Fe value with no significant recovery of $Ti0_2$. Since ilmenite was very finely disseminated and interlocked with monazite grains and occured as inclusions in the magnetic grain in submicroscopic range, it was not possible to recover it economically.

1.1.14 Beneficiation of Phosphate rock, Karbaria block, Udaipur.

(Sponsor : G.S.I., Rajasthan circle)

Flotation of crushed samples 75% -200 mesh, yielded a concentrate with 31.9% P_20_5 content, already reported. The tests are being continued to improve the grade. Regrinding the rougher float in rod mill to 98%, -200 mesh and subjecting it to 3 cleanings, yielded a concentrate assaying 34% P_20_5 with 76.9% P_20_5 recovery. The grade is suitable for super phosphate manufacture. As the sample was calcitic in nature another flow sheet has been attempted. Calcination of the sample to about

980°C followed by quenching and desliming produced a sand fraction which when subjected to flotation after wet ground to 75.4% —200 mesh, yielded a concentrate assaying 34% P_2O_5 with recovery of 57.1% P_2O_5. Though the grade is acceptable for fertilizer manufacture, the recovery of P_2O_5 was low compared to that by straight flotation.

1.1.15 Beneficiation of raw Bauxite.

(Sponsor : M/s. Carborundum Universal Ltd., Madras)

Acid leaching, flotation and decrepetitation tests were carried out with a view to reduce the CaO content below the 0.6% level. The results are encouraning and the work is in progress.

1.1.16 Beneficiation and Calcination of low grade Kyanite.

(Sponsor : Maharashtra Minerals Corpn. Ltd.)

1.1.16.1 *Beneficiation*

The present low grade sample is the third in a series received for detailed bench scale beneficiation. The sample contained muscovite and quartz as major gangue with minor amounts of chlorite and tourmaline. Kyanite-Sillimanite got fairly liberated from gangue at about 65-100 mesh size range. Spiral concentrate when subjected to flotation assayed 61.1% Al_2O_3 with 76.3% kyanite recovery. Regrinding followed by flotation of the cleaner tails enhance the recovery by 3.4%, and final kyanite-sillimanite concentrate assaying 61.02% Al_2O_3 with 80% recovery was obtained. The concentrate satisfied thc grade required for refractory manufacturer.

1.1.16.2 *Calcinatin :* Calcination characteristics of kyanite were evaluated with respect to time and temperature for establishing a 5000 tonnes/year capacity plant, most of whose produce is slated for export. Negotiations are under way for a fuller involment of NML upto commissioning the plant.

1.1.17 Removal of P_2O_5 from Fluorspar concentrate.

(Sponsor : G.M.D.C.)

The Gujarat Mineral Development Corporation had found substantial amounts of P_2O_5 in both the acid and metallurgical grade fluorspar concentrates. Investigations have been carried out to reduce the amount of P_2O_5 from the concentrate by using various depressants at pH 8 with sodium oleate as collector.

1.1.18 Beneficiation of Baryte samples.

(Sponsor : Dept. of Mining & Geology, M.P.)

Petrological examination of the—10 mesh sieve fractions revealed that baryte was the major mineral. The other minerals found were quartz, traces of muscovite, magnetite, chalcopyrite, pyrîte etc and fair liberation of baryte from quartz could be obtained at about—35 mesh size. Gravity concentration by such methods as hcavy media separation, jigging, tabling etc. are under progress.

1.1.19 Beneficiation studies on Limestone.

(Sponsor : M/s. Travancore Electrochemical Industries, Chingavanam, Kottayam, Kerala)

The sample, as received, assayed 49.23% Ca0, with 8.41% total insolubles and 42.11% loss on ignition and consisted essentially of calcite followed by magnesite, The siliceous gangue could mostly be freed at about—65 mesh size, while apatite minerals could be seperated at about 150 mesh size. Flotation, after grinding to 65.5%—200 mesh with sodium silicate and oleic acid emulsion produced a rougher concentrate assaying 53.3% Ca0, 0.063% P with a Ca0 recovery of 91.2%. Attempts made to refloat apatite from calcite concentrate keeping calcite depressed by using Katha (an extract of tanin) did not yield encouraging results. Pelletization studies were carried out with low phosphorus limestone concentrate without further grinding. Good green pellets could be produced by using 5% molases and 9.17% moisture. Heat hardening at 110°C yielded pellets with compressive strength of 16.3 kg/pellet. When dextrine was used as binder, the compressive strength was lost on storage of the pellets.

1.1.20 Manganese metal.

1.1.20.1 *Suitability of low grade Mn ore for production of electrolytic Manganese.*

(Sponsor : Mysore State Industrial Development Corpnl)

Four representative samples of Manganese ore received from the sponsor weae tested and was found quite suitable for the production of electrolytic Mn metal, indicating recoveries of 95-96%. Losses of manganese were found to be very low during reduction, leaching and purification of the electrolyte.

1.1.20.2 Utilization of Ferromanganese Slag.

(Sponsor : Tata Iron & Steel Co. Ltd., Joda)

Suitability of ferro-manganese slag for the production of electrolytic manganese with regard to leaching recovery, essential purification step, acid consumption and electrolytic behaviour of the purified solution have been examined in detail. Since the manganese is present in the slag as silicate it could be directly dissolved in the spent liquor from electrolytic cells and required no pre-reduction as is the case with manganese ore. The advantage was offset due to filtration difficulties of the gel formed by the leach liquor. The slag which is usually low in manganese, and high in calcium contents, resulted in additional sulphuric acid consumption. Technically, it is possible to produce electrolytic Mn from slag, but uneconomical compared to the production from Mn ore especially in India, where Mn ores are cheap.

1.1.21 Utilization of Wastes

1.1.21.1 *Recovery of Iron powder from waste Pickele liquor.*

(Sponsor : Tinplate Co. of India, Jamshedpur)

Disposal of huge quantities of pickele liquor produced during tin-plate manufacture and sanitation of the locality had become a problem.

Investigations are in progress to ascertain the influence of various parameters for the production of iron powder and regeneration of sulphuric acid from the weste pickle liquor.

1.1.21.2 *Utilization of waste Zinc ash.*

(Sponsor : Cominco Binani Zn. Ltd., Alwaye)

A process previously developed at NML, has been used for the recovery of zinc metal from zinc ash resulting from cathode sheet melting in electrowinning of zinc. It was possible to remove 98-99% of chlorine, with 2-3% loss of zinc. The calcined ash contained around 78% Zn and 0.03% chlorine, compared to the imported zinc concentrates which contain 52-58% Zn and 0.04-0.07% chlorine. Bench scale trials were also carried out for leaching the calcined ash in the spent liquor obtained from electrolytic zinc cells, purification of the leached solution and electrolysis of the same. No build up of chlorine was observed in the electrolyte on the continued use of the calcined zinc ash.

1.1.22 Mangesium-base alloys.

(Sponsor : Dept. of Defence Production, Ichapur)

In order to cast certain Mg–base alloys for extrusion at the defences laboratories, a few trial heats were made to asses the quality of castings etc. utilising ingot magnesium and crowns from the Magnesium project. Further trials are continuing to perfect the process.

1.1.23. Basic lined Side blown converter

(Sponsor : Utkal Automobiles (P) Ltd., Jamshedpur)

As reported last year, preliminary trials on the production of pneumatic steel using high-silicon pig iron did not yield encouraging results. Experments were conducted with low silicon basic pig iron as supplied by the sponser to study and to standardise the various parameters for producing usable quality of steel. Sulphur and phosphorus contents could not be appreciably lowered by using powdered lime as flux and single slagging. Addition of various amounts of lime powder did not yield any favourable results; 30-40% of the powdered lime used was lost during blowing. Active slag with lumpy lime and higher basicity factor could affect adeqate removal of phosphorus and to some extent of sulphur. Double slagging with lumpy lime gave satisfactory results and certain specifications of steel, viz. 0.04 -0.067% C, 0.017 -0.048% P and 0.012% -0.07% S could be produced.

1.1.24 Production and characteristics of Sponge iron in Rotary kiln.

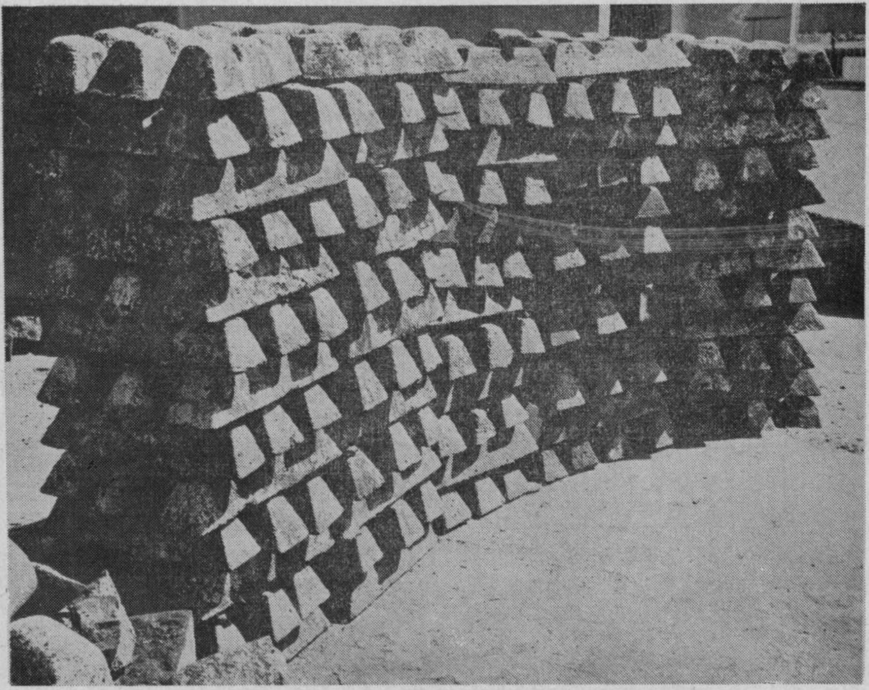
(Sonsor : IDCOL, APIDC, UNIDO Etc.)

1.1.24.1 The following raw materials were under testing/completed for sponge iron production in a rotary kiln.

(i) Bailadila iron ore pellets,

(ii) Barajamda iron ore lumps (-25+12mm size from Orissa minerals),

(iii) Asswan iron ore pellets (UNIDO), (bentonite as binder)



Asswan Pig iron produced in Submerged Arc furnace from pre-reduccd unfluxed pellets at NML under UNIDO assignment.

Basic Lined Side Blown Converter in operation.

(iv) Ghughus coal (Maharastra) as solid fuel.

1.1.24.2 The physical properties with respect to shatter, abrasion, porosity and bulk density for both pre-reduced iron ore and pellets were also determined.

1.1.24.3 The oxidation characteristics of pre-reduced pellets stored at room temperature were also determined at intervals of 7 days upto 63 days. The changes in physical properties of the metallized pellets with lapse of time were ascertained. There was no marked change in the iron content between the initial and final stages when these samples were stored in a room or under a shed on a cemented floor but they were prone to oxidation when stored in open air with severe metallic losses and abrupt fall in strength were also observed.

1.1.25 Investigation on L. D. Lining.
(Sponsor : Rourkela Steel Plant)

The possibility of increasing the service life of the L-D converter lining at Rourkela Steel Plant from the present low average of 156 heats per lining to 200-220 heats level is being studied by inplant trials at the Rourkela Steel Plant. The work has been phased into two parts : The first is to study the variables in the raw materials and their processing into the final block. The second phase envisaged a detailed study of the construction and the effect of the operational parameters on the lining life. Detailed experiments have been conducted on raw materials as well as sinter. Detailed inplant operative data of the dolomite brick plant at Rourkela have been examined and statistically analysed with the assistance of statisticians of the Rourkela Plant.

A comprehensive report embodying the various parameters examined and conclusions drawn from the data thus collected, is now under preparation. Investigations on phase two of the study are in progress.

1.1.26 Study of Creep-rupture properties.

1,1.26.1 *Steel Castings for high pressure boilers.*
(Sponsor : Bharat Heavy Electricals Ltd., Tiruchirapalli)

From the three cast steel samples produced in India conforming to creep specification CSN 422744, specimens free from visual defects were selected and creep rupture tests were carried out at three stress levels of 18.5, 20 and 22 kg/mm^2, at a temperature of 525°C. The lowest stress level was chosen to give a rupture time of about 10,000 hours. The results obtained from these three Indian melts fall within the scatter band indicated in the Czech specifications. However, data on some casts were below the mean Czech values.

1.1.26.2 *Cr-Mo seamless steel tubes for Super-heaters.*
(Sponsor : Indian Tube Co. Ltd., Jamshedpur)

The chaemical analysis and mechanical properties at ambient temperatures of the rolled and heat treated (normalised and tempered) steel samples corresponding to BS 3059/620, from the tube walls as supplied by the Indian Tube Co., were determined, Elevated temperature tensile tests to determine 0.2% proof stress in the temperature range 400-500°C at 50°C interval have beeu carried out. The creep and creep rupture tests at 500° and 525°C for 3000, 5000 and 10,000 hours of duration are under progress. Tests at 550°C will also be undertaken.

1.1.26.3 *Stress-relaxation properties of high temperature bolting materials.*
(Sponsor : Bharat Heavy Electricals Ltd., Hardwar)

Steel samples of Russian Specification (20 Cr, 12 Mo, 95 V, 85 Ti, B), were first examined for inclusion and grain size studies. The ring method of testing, as used in Russia and East European countries, was established and used for a preliminary study of the same steel samples. The results were compared with those obtained by the constant strain/stress-relaxation tests using conventional tensile creep test specimens as used in the western countries. Experiments were also conducted on samples of mild steel and stainless steel in the high sensitivity creep testing machines maintaining a constant strain by manually reducing the load. The Ring method, which is the simplest of all the methods, gives fairly accurate results and enables carrying out of large number of tests without much expenditure. An extensive investigation on study of long-term creep, creep rupture, stress-relaxation behaviour and elevated temperature tensile properties of 1% Cr-1% Mo—$\frac{3}{4}$% V steel with small addition of Ti and B have been initiated.

1.1.27 Investigation on the failure of High temperature steel castings.

(Sponsor : M/s, Orissa Cement Co. Ltd., Rajgangpur, Orissa)

The causes of failure of high temperature steel shoes in the conveyer system of the Folax-grate cooler, used for cooling of cement clinkers, were extensively investigated by metallographic study and microhardness tests.

The failure was attributed to the presence of (i) large strinkage cavities of sizes upto 225 mm length and 12 mm dia and blow holes (ii) net work of carbide and ferrite impairing the mechanical properties and (iii) substantial amounts of sigma phase.

1.1.28 Metallurgical Studies for evaluation of Hammer bit.

(Sponsor: Hindusthan Steel Ltd., Ranchi)

The poor crushing capacity and fast wear of hammer bits used for crushing coal at Bhilai, Rourkela & Durgapur were metallurgically investigated. Results showed that the hammer bits were not properly heat-treated in most cases. A suitable heat treatment and suitable addition of special alloying elements required to improve the properties and service life of the hammer bits have been suggested.

1.1.29 Metallurgical Study of Shear blade for cutting Molten glass.

(Sponsor : Vazir Glass Works Ltd., Bombay)

In view of the import difficulties of the shear blades used in glass industry for cutting molten glass at 1200°C, metallurgical examination of these blades were initiated to examine the possibility of the indigenous manufacture. The investigation is in progress.

1.1.30 Metallurgical Studies of C.I. pipe failure.

(Sponsor : Bhandara Explosive Factory, Ministry of Defence)

A number of pipes burst almost in the centre when the C.I. pipe line of 24″ dia laid for mains water supply was put to test, even though a number of air and scour valves were provided. The metallurgical tests conducted showed that the pipes did not conform the specifications, especially with regard to tensile strength and lacked suitable heat treatment. The white cast iron layer, regarded as inherently very brittle and detrimental in service, was formed during solidification in the course of pipe manufacture and mainly contributed to the failure of the pipes during testing.

1.1.31 Cracking of Brass tubes used in sugar evaporators.

(Sponsor : M/s. Multimetals Ltd., Kota)

70/30 brass tubes were used in sugar cane juice heater. These tubes were found to crack within one year of service. Their failure was investigated in detail. It was concluded that the presence of SO_2 and/or ammonia environment and internal stresses in the tubes caused the cracking. A stress releaving treatment has been recommended for as a remedial measure.

1.1.32 Corrosion in the water side of the Economiser tubes.

(Sponsor : Indian Drugs & Pharmaceutical Ltd., Rishikesh)

The problem of frequent failures of economiser tubes due to perforation from the water side was investigated. It was observed that the premature failure of the tubes was due to the combined effects of the corrosive action due to the flow of water inside the tube and the presence of corrosive constituents in the water. It was suggested that the production and maintenance of the magnetite film on the inside surface of the tube should be minimised. Modifications in the economiser tube design have been recommended to minimise the turbulence of water inside the tube.

1.1.33 Cathodic protection.

(Sponsor : Calcutta Metropolitan Water & Sanitation Authority)

Technical consultancy service has been rendered to the Calcutta Metropolitan Water and Sanitation Authority for commissioning two pilot stations for providing cathodic protection to the city water mains.

1.1.34 Nehru Time Capsule.

(Sponsor : Ministry of Education & Social Welfare, New Delhi)

Technical consultancy service has been rendered to the Ministry of Education and Social Welfare, New Delhi for the selection of the material of construction for the 'Nehru Time Capsule' which has been recently laid underground at Shantiban, Delhi.

1.1.35 Inorganic coatings on Steel exposed to Marine atmosphere at Digha.

(Sponsor : Inorganic Sub-Committee of Corrosion Advisory Bureau, Metals Research Committee)

The study was undertaken with a view to certify the performance of various inorganic coatings on steel under exposure to different climatic conditions of India and to provide ready made information regarding various corrosion preventive methods for marine structure. 18 sets of pannels with different metalllc coatings were exposed to marine atmosphere for 2 years, weighed and reexposed. The performance of each set of pannels has also been assessed. It is proposed to conduct such atmospheric corrosion tests at different exposure sites in India embracing the different climatic conditions. The work is in progress.

1.2 Industrially Oriented Projects.

1.2.1 Development of High Alumina cement.

In continuation of the previous work, the sintering charactertstics of Saurastra bauxite and Tamilnadu limestone mix has been studied at 1350°C for 4 to 12 hours maintaining a constant Al_2O_3/CaO ratio. The cement product obtained at 8 hour sintering has good properties. High alumina cements and refractory castable from an Indian manufacturer were tested as per B.S. and German specifications. Semi-pilot plant scale work has been envisaged based on above results, modifying the furnace lining by alumina. Bulk materials are under collection.

1.2.2 Effect of additives on the Strength and Workability of Refractory plastics.

Rajharah fireclay was chosen for aggregate as well as plastic bonding agent. The clay crushed ground and formed into bricks. These bricks were fired at 1300 to 1500°C for three hours in three seperate batches and grog of different gradings were made. Raw clay was ground to -100 B.S. mesh for use as plastic bond.

Work has been temperarily suspended.

1.2.3 Evaluation of Sponge iron as charge in Electric arc furnace.

Industrial scale smelting was carried out in 0.8 tonne direct arc electric furnace. Plain carbon scrap and sponge iron in equal proportion formed the starting materials. Melting was smooth and a recovery of 85-86% of total iron from the sponge was obtained, Carbon content varying from 0.1 to 0.56% in the steel ingots. Further Trials are in progress to study iron recovery by varying the proportions of sponge and scrap in the charge and also the suitability of producing other types of steel.

1.2.4 Production of Ferro-silicon, 75% grade.

The production trials carried out in the 200 KVA submerged arc furnace were highly successful. The results are being compiled.

1.2.5 The folloing new projects have been initiated for trial in the 50 KVA Submerged arc furnace under installation.

(i) production of Calcium-Silicon alloy

(ii) production of commercial 91 to 98% purity silicon metal

(iii) production of Ferro-Nickel from lateritic ores.

1.2.6 Pneumatic Steel making.

1.2.6.1 *Basic oxygen converter* : As mentioned last year, satisfactory chromium pick up could not be obtained using highsilicon pig iron. Further experiments were carried out with desiliconised pig iron (desiliconisation being affected by injecting oxygen into the melt in a ladle containing briquetted burnt lime). The basicity of the melt did not improve even by adding burnt lime to the extent of 32-35% of the hot metal. Lumpy limestone along with burnt lime dust were added to increase the basicity. From slag basicity it was clear that chromium pick up would not be encouraging until phosphorus was effectively removed. A slight improvement was observed by adding chrome ore along with the flux, before Fe-Cr addition, due to the reduction of chromium loss by oxidation,

1.2.6.2 *Setting up a converter unit of 200-220 Kg capacity* : In order to control the influencing factors vital for Basic Oxygen steelmaking process, a new set up with modern technical devices is under construction for development work in the field.

1.2.7 Continuous Steel making.

An experimental programme to conduct preliminary trials has been initiated in order to develop indigenous know how on the technology of continuous steelmaking and spray-refining. Various techno-economic factors which influence the process are proposed to be studied under the programme.

1.2.8 Production of Manganese metal.

Experiments with fuel oil did not show promising results in small vertical kiln since the oil mixed ore was observed to cause hanging in the kiln. It was decided to study the reduction in a bigger furnace having oil injection facility. Leaching characteristics of the reduced ore were studied in the as reduced condition and after grinding. It was observed that in all cases the ground ore gave a better leaching recovery.

1.2.9 Nickel extraction.

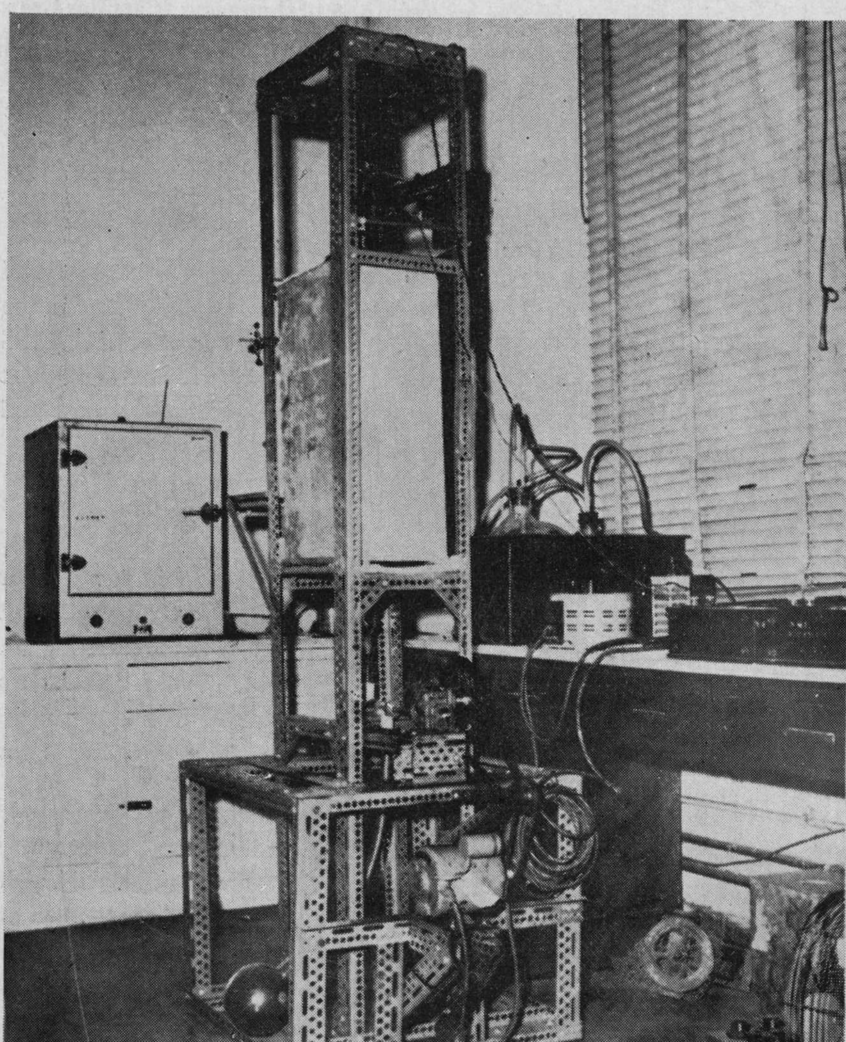
1.2.9.1 *Roasting and leaching of Nickel ore pellets*: After completing the bench scale work, a small vertical roasting unit was built for continuously processing the nickel ore pellets. On leaching the roasted pellets yielded over 80% Ni recovery. The data obtained on the small scale unit is to be utilised for setting up a unit to handle 500 kg to one tonne of 0.5 to 1.0% Ni bearing Sukinda ores per day to either metallic nickel or its salts.

1.2.9.2 *Amchlor Process :* After extensive modification to the rotary kiln, semi pilot scale trials were carried out to suit the processing of nickel bearing ores by roasting. It was desirable to effect further modifications to prevent (ammonia) losses and their recovery.

1.2.10 Rare metals extraction.

1.2.10.1 Recovery of Germanium and Gallium oxide from Coal ash is being continued.

1.2.10.2 A flow sheet has been developed for the production technology of Selenium and Tellurium from electrolytic copper slime on the basis of successful bench scale studies to design a scaleup unit.



Set up for extraction of Nickel from Lateritic ores by AMCHLOR process developed at NML

1.2.11 Recovery of Mercury from Smelter waste gases.

Experiments have been initiated using synthezised mercury containing gas mixture to develop proper detection and analytical methods for removal and recovery of mercury, recyciing the gas itself for acid making prior to the work on actual smelting gases.

1.2.12 Removal of Vanadium from Pig iron.

A rotating type furnace has been designed and under fabrication to tackle the problem of removing Vanadium from pig iron.

1.2.13 Recovery of Metallics from scrap by filtration :

In an attempt to scale up the work, efforts were made to develop newer filtering media for oxides, non-metallics and suspended impurities.

1.2.14 Recovery of Tin-Cadmium from Spray Booth waste.

Samples of spray booth powder, a waste product in rectifier manufacture, containing 60 Cadmium—40 Tin were investigated and over 70% of the individual metals were successfully recovered by a multistep process of fluxing and melting. After completing the laboratory scale investigation the work was temporily suspended.

1.2.15 Preparation of Anhydrous metal halides.

1.2.15.1 *Chlorination :* Having established the conditions for pellet preparation from raw magnesite and untreated as reccived petroleum coke with additives and the chlorination characteristics in a laboratory scale batch operation, a few long duration experiments at an overage temperature of $880° \pm 20°C$ with all the raw materials (viz Almora, Salem, Ajmer and Mysore magnesites) were carried out to ascertain if the physical properties of the prepared pellets and chlorine efficiency were sufficient and adequate enough under such conditions. 5-7% increase in efficiency over that of batch operation were obtained. The product was found quite suitable as electrolyte feed and for the preparation of fluxes.

Impure magnesite has been found amenable to the production of anhydrous magnesium chloride synthetically and some important steps of conventional processes were eliminated.

1.2.15.2 *Fluidized bed :* The dehydration without decomposition of hydrated magnesium chloride clearly indicated several distinct steps which could only be achieved when the formation of decomposition products were suppressed by contact with gaseous HCI, one of the decomposition products. To this end a fluidized reactor has been utilized using magnesium chloride dihydrate as the feed material. The influence of temperature, composition of the gaseous heat transfer media and the quality of the product obtained from commercial hydrated magnesium chlorides, a by-product of the salt industry, has been examined in details. The effect of impurities in the original feed materials on the final composition of dried products has also been studied. From heat efficiency considerations, the process should be operated in 3 stages for continuous operation.

1.2.16 Fluorine chemicals

1.2.16.1 *Preparation of Aluminium fluoride :* A fluoboric acid process for prepapation of Aluminium fluoride has been developed through the intermediate formation of ammonium aluminium cryolite. The proeess has been standardised to obtain high grade fluoride which satisfies the specifications set by the aluminium industry.

1.2.16.2 *Iron free Cryolite :* Removal of iron from the process liquor by ion exchange resins before precipitation of cryolite did not prove feasible. The iron content of the cryolite prepared from iron containing fluorspar (from GMDC) by the conventional fluoboric acid process was slightly higher than the ore. Washing with dilute fluoboric acid and sulphuric acid, increasing the acid concentration and/or temperature of washing did not improve the yield, while 8-20% of cryolite was lost in the process. The loss was minimum on washing with 1% by vol. sulphuric acid at room temperature. It also brought down the $Fe_2 0_3$ content to 0.34%.

1.2.17 Tin free steel.

A two-step and a single step processes have been developed on laboratory scale for chromium/chromium oxide deposition on steel substrate. The product has been exhaustively tested in the laboratory for flexibility, porosity and corrosion resistance properties. The developed product was found to be at par with the imported tin-free steel. Consumer acceptibility of the NML product was also certified by different Can manufacturers, who have now demanded larger size samples for undertaking actual service trials. The preliminary reports from Can manufacturers were encouraging.

1.2.18 Production of Zinc & Zinc oxide.

1.2.18.1 *Atmospheric Zinc distillation* : Active work has been carried out in a 100 kg vaporizing unit and parameters have been evolved with the object of establishing the know- how for design and economic operation of units upto 10 tonne/per day utilizing galvanizer's dross and other zinc metal bearing wastes. Further work is in progress.

1.2.18.2 *Zinc dust production:* Successful experiments were carried out on a 30 to 50 kg scale, in a vaporizing furnace to ascertain process feasibility on the larger scale for preparing chemical grade zinc dust (extra fine -325 mesh) required for the sodium hydrosulfite industry. Useful data have been collected for designing a simplified set-up for full scale production.

1.2.19 Production of Metal powders.

1.2.19-1 *Iron powder by atomisation* : After a thorough study of the various factors viz atomising agents, air pressure, temperature of molten metal, metal flow rate, tundish orifice diameter etc. which influence the atomisation and the physical and chemical properties of the powders as a whole, the following conclusions have been deduced :

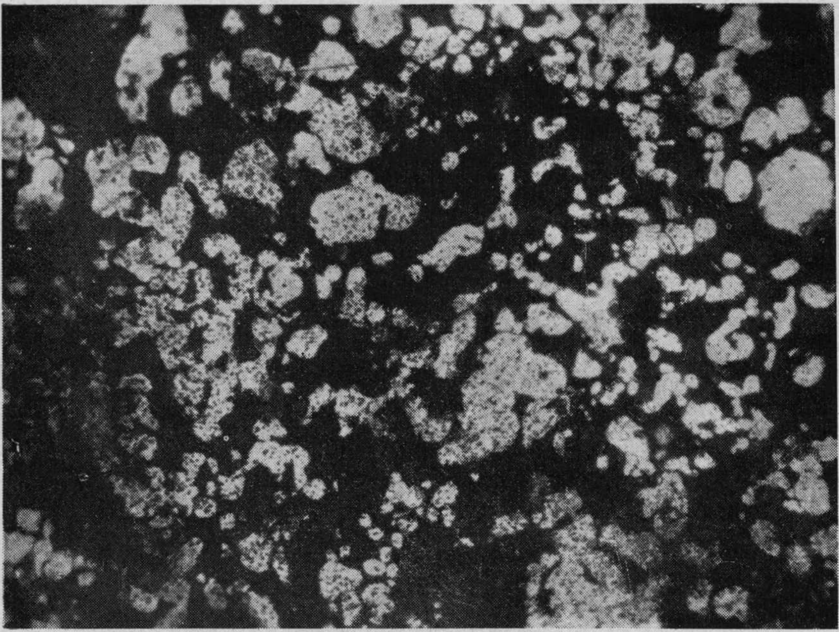
(i) pressures below 2.5 atmos did not give satisfactory atomisation.

(ii) higher pressures and temperatures yielded finer particles in the powder which also necessiates a smaller orifice of the tundish.

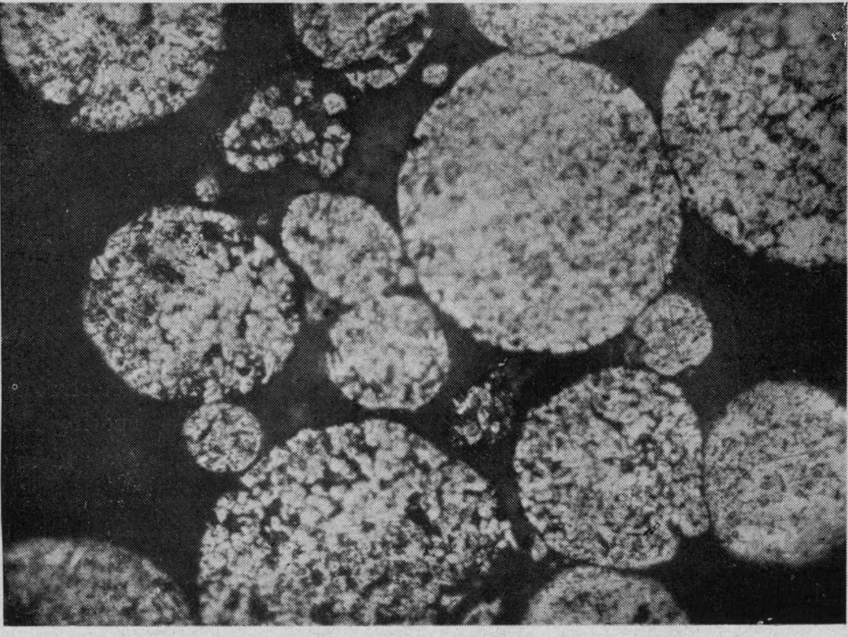
(iii) flat type rectangular nozzle and circular type tundish orifice appeared to be more effective.

(iv) Preheated air (200-300°C) give better atomisation results.

1.2.19.2. *Production of electrolytic Iron Powder:* An electrolytic process has been investigated and various parameters for preparing iron powder were established. The iron powder which was fine grained and dendritic in form, has also been tested for fabrication of articles by powder metallurgy technique. The bulk density of the powder was 3045 Kg/cu meter, with an angle of repose of 34°. A patent application has been filed.



Fe powder from ferrous chloride, NML process (×400)



Atomized Cu-Pb (bi-metallic) powders (process ready for release) (×400)

1.2.19.3. *Iron powder from Ferrous chloride* : Encouraging results were obtained after extensive bench scale work for preparation of pure iron powder by reduction of ferrous chloride (with hydrogen). The feasibility report is under preparation.

1.2.19.4. *Production of Zn powder* : Electrolytic deposition of Zn powder has been studied on a laboratory scale using stainless steel cathodes and different acidic and alkaline electrolytes. Preliminary experiments were also carried out to recover Zn-dust from the spent liquor from the hydrosulphite industry. The work has been temporary suspended.

1.2.19 5. *Extra fine Metal powders* : A process has been developed using the atomizing technique to produce the extra fine metal powders with particle sizes finer than -325 mesh, from such metals as copper, tin, lead, zinc, aluminium and brasses. Flaky grades of metal powders used in lithographic, pyrotechnics and similar uses have also been developed.

The process know-how has been consolidated for release to industry.

1.2.19.6. *Bimetallic Powder* : Pre-alloyed copper, lead and leaded bronze powders are required for heavy duty bearings in dissel and other auto engines. The process know how has been developed and now ready for industrial use. This will reduce the current import of nearly 300 tonnes of powder per year.

1.2.20. Nickel plating and stripping.

1.2.20.1 *Bright Nickel plating* : A process flow sheet has been established for bright nickel plating. Its feasibility in a commercial production line was demonstrated in the bright nickel plating on cycle rims. The process has been relessed for exploitation to a commercial firm.

1.2.20.2 *Alkaline stripping solution for Nickel from nickel plated steel substrates* : Studies have been under taken to develop a process for recovering nickel from nickel plated sitrps, rejected for various reasons, thus enabling reuse of the base metal and the nickel. The process is very economical and does not entail the use of electric current, usually required in the current stripping practice. The base metal is also recoverable undamaged.

The process has won an Inventions Promotion Board award.

1.2.21 Silver catalyst.

Exploratory work has been initiated to ascertain the industrial applicability of the silver catalyst produced at NML after the processes of preparation of silver powder and its agglomeration and regeneration of used silver catalyst had been developed on a bench scale. The operational parameters, equipment and byproduct recovery are also under investigation. An alternative method of obtaining the silver powder by electrodeposition from silver hydroxide and simultaneous reduction of the same to metallic powder has been carried out in single cell. Further work is in progress.

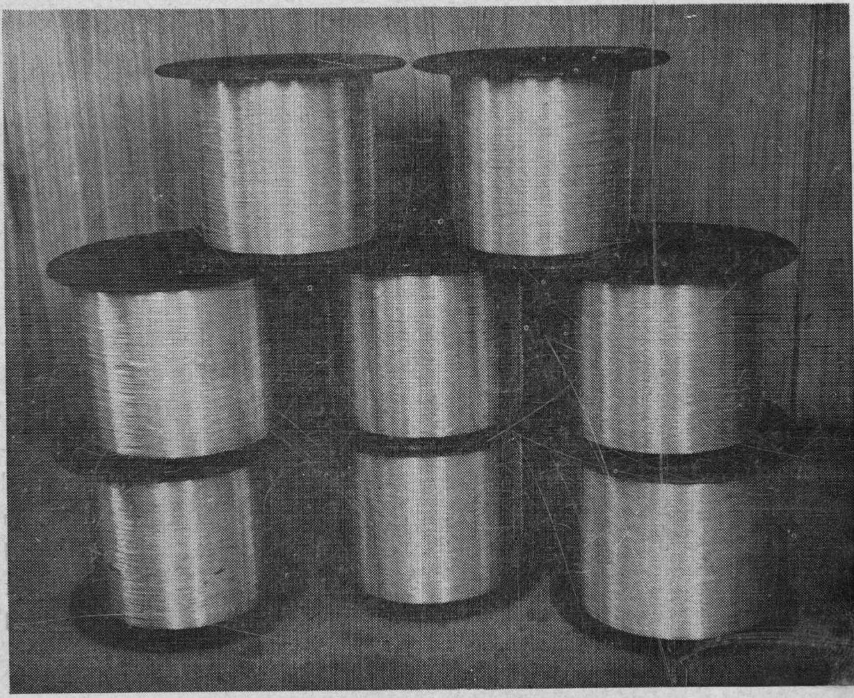
1.2.22. Experimental Small Cupola

1.2.22.1 *Improvement in Cupola operation (with oxygen enriched air)* : In continuation of the earlier work on the use of a simple heat exchanger device, the effects of using hot air blast at different temperatures, up to 400°C, oxygen enrichment, melting rate and composition of cast iron produced have heen investigoted. Enrichment of hot air blast with 1-4% extra oxygen increased the metal temperature, as also the top gas temperature.

1.2.22.2 *Use of calcium carbide :* Effect of addition of 1-3 wt% calcium carbide on the melting of 50, 75 and 100% steel scrap was studied. The rise in the temperature of the tapped metal due to carbide addition was nearly proportional to the amount of carbide added, the maximum increase being 60 -70°C. The carbide addition results in increased metal temperature, higher carbon saturation of the melt and increased lime content of the slag. The data obtained are being compiled.

1.2.23 Development of Aluminium Cables and Conductors

1.2.23.1 *Aluminimm cables* : Work has been continued on the development of ACSR overhead transmission and telecommunication cables in tonnage scale based on the aluminium conductor alloy developed at NML, in association with leading cable manufacturers, using the conventional facilities of melting, Properzi casting, wire drawing and heat treatments.



Alloy Aluminium wires (size 0·813 mm) for telecommunication cables developed at NML. (Sheathed cables are now undergoing field trials).

1.2.23.1.1 *ACSR conductors* : The characteristics of ACSR conductors in the hard-drawn condition are :

Electrical conductivity (% IACS at 20°C)	61.5
Breaking load (for 2.36 mm conductors) (kg)	81.0
Wrapping test (6 Wraps round on its own dia)	Good

The values of breaking load could be increased at the cost of electrical conductivity.

1.2 23.1.2 *Telecommunication cables* : A twenty pair dry core communication cable has been successfully manufactured in kilometer lengths in association with the cable manufacturing industry. It has passed the rigid test specifications of the Post and Telegraphs Dept. Aluminium communication cables meet all the requirements of physical and mechanical properties of an equivalent grade copper conductor as per Indian Standard 1753-1967. The cable is now under extensive trials in association with Telecommunication Research Centre, New Delhi.

1.2.23.2 *Alloy-aluminium conductor :* Development work on a suitable alloy aluminium conductor, possessing suitable combination of electrical and mechanical properties has been continued. The mechanical working characteristics of some of these alloys have been tested in semi-commercial operation and found to be satisfactory. The electrical and mechanical properties of the alloy developed (PM-52) in the hard drawn condition have been found to be better than those of the heat-treated conventional alloy (50S) containing 0.5% Si and 1% Mg. Further work is in progress to obtain suitable combinations of electrical and mechanical properties by appropiate heat-treatments.

1.2.24 Copper-clad-Aluminium Sheet.

Production technology for copper clad aluminium sheet materials has been fully developed on laboratory sale. Cold roll bonding of copper-aluminium composite demands a degree of cold reduction, adequate surface preparation and holding time. For commercial roll bonding about 68% cold reduction has been found adequate. However, warm roll bonding has an edge over cold roll bonding. Appropriate annealing conditions have been established for rerolling the clad metal and also for fabrication purposes.

1.2.25 Development of Nickel-Silver alloy electrical contact springs.

Laboratory scale production technology for the production of Ni-Ag alloy contact springs has been studied in detail. The know how developed can be utilised by small-scale industries. This will reduce the total imports of alloy strips and foils required for various specialised industries. The casting technology, cold and hot workability, the mechanical properties and electrical conductivity as required under service conditions were standardised.

1.2.26 Brazing alloy clad Aluminium.

In continuation of the work previously reported, the furnace brazing experiments conducted, using standard fluxes gave encouraging results, where as fluxless brazing of aluminium could not be achieved Dip-salt bath brazing with sodium and potasium chloride as salt mixture gave erratic results. Work is in progress on the preparation of necessary brazing fluxes for aluminium and their use in furnace-brazing and dip-flux brazing of the alloy clad aluminium.

1.2.27 Development of Electrode materials for resistance welding.

1.2.27 2 *Cu-Ag Alloy* : Optimum conditions of copper rich copper-silver alloy with respect to mechanical and physical properties, percentage of cold reduction for required hardness and the softening temperature under cold reduction conditions have been established.

1.2.2.72 *Cu-Cr alloy* : Development work on copper-chromium alloys containing 0.5 to 1% chromium as welding electrodes has been carried out. These alloys are in demand due to a combination of properties. The alloy respond well to heat treatment both in as cast and in wrought conditions and have specified hardness and electrical properties. Investigations with a view to prepare a master alloy containing 8-10% Cr by the direct addition of Cr in molten copper and to increase the amount of Cr in the master alloys are in progress.

1.2.28. Aluminium-Magnesium wrough alloys.

1.2.28.1 *Al-Mg(7-10%)-Misch metal wrought alloys* : Trial hot rolling of six industrial sized ingots of Al -7% Mg -3% Misch metal alloy was carried out at the India Govt. Mint, Bombay. Due to non-availability of proper furnace, the existing facilities were used to hot roll the slabs prepared in the mint to approximately 6 mm thickness. Exact rolling conditions and perfection of rolling technique could not be achieved in the absence of a tilt pouring device. It was observed that the ingots prepared in the Laboratory could not be hot-rolled with the equipment available at the Mint.

1.2.28.2 *Al-Mg -Misch metal -Cr-wrought alloys* : Ignots of Al-(7 to 8.5%) Mg—(0.5 to 2.5%) Misch metal —(0.15 to 0.30%) —Cr alloys produced in laboratory experiments were quite sound and free from pin hole porosity. The grain size could not be further lowered with conventional nucleants for such alloys. Presence of Cr in these alloys accounted for the higher grain-size obtained. Microstructure of these alloys showed non-metallic inclusions. Filtering the liquid alloy through glass wool did not yield encouraging results. Other techniques are under consideration.

1.2.29 Development of Aluminium base bearing alloy.

Technical know-how on the production of aluminium base bearing slloys has been developed, after a comprehensive study on the effect of pouring temperature, laddle holding period, deoxidation and designing of proper mould. The alloys so developed can substitute imported items. Some of the compositions developed showed superior properties to the Cu-base bearing alloys currently in use in the railways.

1.2.30 Magnetic materials

1.2.30.1 *Alnico-V alloys* : Columner crystals could be grown upto 40 —44 mm in length by small additions of alloying elememts to the silicon killed melt, by controlling pouring temperature, temperature of the mould, thickness of the chill plates and use of exothermic mixtures. Thermo-magnetic treatments were given to these specimens and magnetic properties were determined ballistically. The results obtained are :

Coercive force	He	~	600-7C0 oersteds
Remanence	Br	~	13500—14500 gauss
Energy product	(BH) max.	~	6.0—7.50 m.g.o.

1.2.30.2 *Isotropic mixed ferrites* : The effect of addition of various oxides was investigated on lead barium ferrites. The sintered specimens were tested for magnetic properties. The ferrites studied gave energy products below 1.20 and 1.40 m.g.o.

1.2-31 Low alloy High strength Structural steel.

The optimun range of alloying additions essential to maintain the required specfication and properties in the vanadium bearing low carbon steel having a Mn/C ratio between 10 to 15 have been continued. No significant improvement in yield point was observed when Mn/C ratio in 0.7% C steel was increased to 24, The lowest impact transition temperature was obtained when the Mn/C ratio was 15 and carbon was 0.1%. It was observed that to obtain the toughest lower temperature transformed product (massive martensite), the carbon content should be $\leqslant$ 0.3%. In a special heat prepared for the purpose the carbon and silicon contents were found slightly on the higher side. The steel had fairly good hot workabilty and could accomodate heavy deformations without developing cracks. The scales formed during preheating flaked off quite easily during working. Tensile strength was 105.5 kg/sq mm (67 ton/sq. in) and elongation 19%. Further work to determine transformation temperature at various cooling rates and to improve the toughness of steel is in progress.

1.2.32 High Strength alloys.

In continuation of the results reported last year, investigations were extended to two more Fe-Al-Si compositions, which were aged between 300° and 500°C for periods extending up to 1000 hours.These samples were also studied for their micro-structure and hardness. Tensile tests were carried out after different ageing treatments. The alloys offer promise as a substitute for weathering steels and bigger heats of these alloys are being made for further developmental work.

1.2.33 High Temperature alloys.

Some more heats were prepared varying the grain refining elements to the Fe-Cr-Al alloy system, maintaining both Cr and Al content in the higher range. Hardness of cast ingots were within the range of 230-260 BHN. Hot workability of the ingots on slow heating and after proper soaking at 1250°C showed good forgeability, from 50 mm square bar to 12.7 mm square bar. The ingots containing higher percentage of grain refining elements behaved in brittle fashion. Cold wire drawing and determination of mechanical properties of different heats were being carried out. High temperature oxidation of three heats when conducted at 1300°C for 100 hours indicated resistance to scaling. Grain growth was found to be more in those heats containing grain-refining elements than without the same. Work is under progress to standardise the cold working schedule under different heat treatment conditions.

1.2.34 Stainless Steel Projects.

1.2.34.1 *Nickel free Stainless steel* : Few more heats of Cr-Mn-N stainless steel were made in 20 KW high frequency furnace and were homogenized at 1050°C for various times and then hot rolled directly.

Specimens prepared from 3 different Cr-Mn-N stainless steel were given ageing treatment at different temperatures for various duration of time after solution treatment. Hardness of the aged specimens were also determined. Further work is under progress.

1.2.34.2 *High Chromium High manganese iron* : High chromium cast iron with addition of suitable alloying elements were produced with ferritic, martensitic or austenitic matrix. As there was no phase change in the austenitic irons, these were found suitable for applications where cyclic heating and cooling take place. Such austenitic irons in use generally contains 15-17% Ni. Apart from Ni, Mn is also known to be a strong austenite stabilizer and trials conducted with this material was successfully completed.

In the several heats prepared, as reported earlier, it was found that the iron become austenitic by addition of Mn but suffered from high amount of scaling at high temperature compared to iron containing Ni. The scaling could not be suppressed to any satisfactory level even by adding Al, a strong scale resistant constituents, to the extent of 2%, in some heats. Further work is under progress.

1.2.34.3 *Austenitic Creep resisting steets* : To study the effect of Mo addition to the basic Cr-Mn-N-C steel several heats each of 10 kg had been prepared and hot forged in the temperature range of 900 to 1200°C, to a size of 35 mm square. Solution treatment was carried for 4 hours at 1250°C and then air cooled. Creep tests on these specimen are in progress at different stress levels in the temperature range of 700-750°C.

It was observed on plain Cr-Mn-N-C steel having different C/N that stress induced precipitation and creep rupture took place at the matrix-precipitate module interface. In order to minimise this effect prior ageing treatment at 750°C for 17 hours were found desirable. The steels having low and high C/N ratio, the ductility and the rupture time increases considerably when the samples were given prior ageing treatment, though minimum creep rate was practically same in both the cases. The work being continued under differenr test conditions.

1.2.34.4 *Stainless Steel for safety razor blades* : In order to determine the metallurgical characteristics and know-how of steel strip suitable for the manufacture of stainless steel safety razor blades, a number of stainless steel blades available in the market were investigated. The steel composition ranged from 12 to 15% chromium and 0.6 to 0.8% carbon which could be readily manufactured in the country with indigenous materials by installing proper cold rolling mills for strips of 0.1 mm thickness. This has considerable export potential target which is around Rs 1 crore annually. Development of the technology will reduce the import of stainless steel strips.

1.2.35 Cr-Mn-Ti Martensitic white iron.

Effects of addition of Cr, Mn and Ti together with small additions of Mo & V on the structural and mechanical properties of white iron was studied and observed that with 5-7% Cr, 1.25—3% Mn, 1% Ti, 1% Cu and 0.5% V and Mo each resulting in high hardness (690-800 VPN) and a martensitic matrix structure.

1.2.36 Development of Die and Tool Steel.

1.2.36.1 *Die Steel* : In continuation of the work reported last year, high temperature corrosion characteristics of the die steel (PM 501), were studied by standard technique. The results indicated better corrosion resistant properties than the conventional variety of die steel. Eight number die blanks with 15 to 20 mm external dia were prepared and sent to Aluminium Industries for extrusion trials. Twenty more die of bore sizes varying between 0.91 mm (0.036″) to 1.52 mm (0.060″)

were heat treated for optimum properties and sent to cable manufacturers for industrial trials in wire drawing purpose. The results indicated that the die steel developed have very good performance. Further industrial trials at the cable manufacturing firms are in progress.

1.2.36.2 *High Speed tool steel*: The optimum austenizing temperature of 18-4-1 type high speed tool steel bars was found between 11°0°C and 1200°C and soaking time varied between 8-10 minutes. Grain growth due to long period of soaking was restricted by small addition of titanium. Quenched samples were tempered thrice and hardness in each case was more than 800 VPN. Specimens are under preparation for cuttlng tools.

1.2.37 Submerged arc Welding flux.

During the period the development work for basic fluxes with low silica and silica free agglomerated fluxes was continued. The raw materials used for low silica fluxes were ferro-manganese slag, corrundum, alumina, limestone, calcined magnesia, wollastonite and ferro-alloys in different combinations. Weld deposition characteristics of these fluxes were studied by depositing weld beads on 12 mm thick steel plates. The basic fluxes had CaO/MgO as base. Some of these fluxes gave encouraging results while others needed improvements. Wollastonite based basic fluxes are under development.

Fe-Mn slag was successfully substituted for mangauese ore in preparing the high manganese fused flux compositions. The sulphur content of these fluxes was higher than normaily obtained in fluxes prepared from manganese ore.

1.2.38 Effects of Alternating currents on corrosion of metals.

The explantion for the variation of corrosion rate on mild steel with change of A. C. frequency has been established and reported last year, in accordance with the cell capacitance and reactance in the circuit. Similar studies on aluminium have also been carried out. Due to experimental difficulties results are insufficient for any clear conclusion and the work is being continued.

1.2.39 Testing of various Inorganic coatings on steel exposed to industrial atmospere at Jamshedpur.

In order to evolve suitable protective scheme for structural materials, atmospheric corrosion data are under collection. Painted and unpainted steels and other material pannels which includes Al-clad, anodised, galvanised, aluminised, mild steel, Aluminium (alcoran treated) have been exposed at Jamshedpur and Digha. Tests on the pannels to periodical observations are being continued.

1.2.40 Evalution of the Corrosion resistance properties of Plastic coatings by Electro-chemical methods.

Ionic permeability, water absorption and electrical neutrality are considered most important factors on which the performance of all the polymer coatings depend. A. C. bridge to measure resistance of the plastic coatings developed and water absorption properties were used to assess best possible formulation in shortest time. Out of five compositions developed, two top coat and primer formulations gave promising results. The work is under progress.

1.2.41 Intergal colour anodizing of Al and Al alloys.

Studies made on the effects of concentration of the solution and temperature of bath on the nature and depth of the colour obtained integrally during anodizing. The effect of pretreatment given to the sample before anodizing and the freshness of the anodizing solution on the integral colour developed on the anodizing samples was also studied. Some samples of aluminised steel were also studied for possible anodizing. Cupping test and salt spray corrosion resistance behaviour and workability of the anodized samples were also performed.

1.2.42 Preparation of Standard samples.

Preparation of bulk samples from selected size of turnings, sieving, sampling and analyses have been continued and certificates from outside testing centres were completed for plain carbon steel of 0.2 and 0.4%C and low alloy steel containing manganese, chromium, nickel, copper and molybdenum. Nearly 30 kg of standards were sold to outside parties.

Preparation and analysis of following standard samples are under progress :

(i) Brass (ii) 0.8%C steel (iii) Cast iron (iv) Fluorspar.

1.2.43 Electro-chemical probe.

Work on development of electro-chemical probe for rapid determination of disolved oxygen in liquid steel has been initiated.

1.2.44 Analysis of Metals, Alloys, Minerals etc.

1.2.44.1 *Chemical Analysis* : During the period 4050 samples with 10,583 radicals were chemically analysed for different investigations persued in the different divisions/sections of the laboratory, including the investigations sponsored by outside organisations.

1.2.44.2 *Spectrographic Analysis*: : Two hundred eighteen samples were qualitatively analysed for all major and trace elements and forty two samples were analysed for 82 radicals quantitatively during the period including twenty two samples from outside parties.

1.2.44.3 *Petrological, Microscopic and X-ray Fluoresence analysis* : Comprehensive petrological and microscopic studies were conducted on twenty seven low grade ores and minerals in supporting the ore dressing investigations. X-ray fluoresence analysis of 1400 samples with 3600 radicals/ elements were also performed on diverse nature of different test products like concentrates, middlings, tailings, head samples etc during the processing operation. Sixteen specialised samples with 36 radicals were also analysed for sponsored investigations.

1.2.44.4 *Differenttal Thermal analysis* : Six samples were analysed for confirmation of mineral phases in ores and other non-metallic samples.

1.2.45 Gases in metals.

150 samples, from different research projects in the laboratory, other laboratories and institutes comprising of ferrous metals and alloys were analysed for gases by vacuum fushion method. Besides 100 samples were analysed for CO, CO_2, O_2, N_2, H_2 and CH_4.

1.3 Applied Basic Projects

1.3.1 Study of the reaction of Carbon dioxide with hydro carbons and reaction products for reduction of metallic oxides.

Reaction of carbon dioxide with hydrocarbons (naphtha) formed an integral step in the production of sponge iron from iron ores with naphtha. Systematic study has been undertaken to react mixtures of various amounts of carbon dioxide and naptha with iron ores and to ascertain the composition of end products for determining the efficiency. Gaseous samples were tested at various stages of reaction and it was possible to produce a suitable mixture of carbon monoxide and hydrogen, which has maximum reduction potential. The results have been used for sponge iron production in a continuous reactor.

1.3.2 Thermal conductivity of Iron ores.

In continuation of work already reported, studies are underway to determine the thermal conductivity of various iron ores between 350—800°C in a specially designed and fabricated apparatus for the purpose. For comparison of results iron ore cubes of known thermal conductivities have been used in place of silver cubes as done in previous experiments.

1.3.3 Electrical resistivity of Iron ore pellets reduced to various degree.

The primary electrical properties of pre-reduced iron ore pellets to various degrees and at various temperatures were determined as required for electric smelting. The electrical resistivity varied from 1.5 megohm to 8 ohm for different degrees of reduction (10-100%) at temperatures between 30 to 1000°C.

1.3.4 Electrical Conductivity of Ferro-Alloy burden material.

The behaviour of the burden materials at the higher smelting temperatures has been ascertained and improved burden compositions developed to reduce processing costs. The relative resistivities of packed sieve fractions of various commonly used burden materials are under progress.

1.3.5 Fluidized moulding Sand mixture

Experiments were conducted in small scale to develop fluidized moulding sand mixture based on sodium silicate and dicalcium silicate, where the drawbacks namely, absence of cleam lift up of pattern leaving a ragged surface of the mould or core and unduly long time to settle have been successfully overcome by adding certain low cost, widely available compounds. One of the compounds acts as a defoamer and addition of seperate defoaming agent has been eliminated. Large scale trials are under progress.

1.3.6 Knockout properties of CO_2 process Core mixtures.

The knock-out properties of CO_2/ sodium silicate bonded core mixtures have been assesed by means of small test castings. Although satisfactory knock out properties have been obtained with a proprietary additive containing ammonium chloride granules coated with shellac, it has serious drawbacks in the surface finish of the castings. The investigations have shown that the knock-out properties improved substantially by use of either carbonaceous or refractory type clay. In CO_2 process the difflculty of removing the core mixture has been attributed due to the high permanent expansion occured with silica sands. The work is under progress.

1.3.7 High Silicon Cast iron.

High silicon iron casting being hard as well as corrosion resistant are employed in construction of various corrosion resistant chemical plants' equipment. Several heats have been made in indirect are furnace and studies are under progress.

1.3.8 Effect of Silicon Carbide formation on Ferro-alloy production.

The formation of silicon carbide during smelting in submerged are furnances is deleterious to the electrical characteristics generated (power consumption, furnace stability etc.). The samples colletced during ferro-silicon campaign are under study.

1.3.9 Electro-slag remelting.

Work on electo-slag remelting to establish a proper unit to produce cast ingots upto 12.7 to 15.2 cm diameter has been initiated. Refining of different grades of alloy steels by the process is also under progress to obtain optimum mechanical and physical properties.

1.3.10 Carburising of Grain refined Steel at higher temperature.

In continuation to the previous work, the effect of Ti addition on the high temperature carburising characteristics of low carbon Nb-treated grain refined steels were studied.

The grain size was determined by linear intercept (ASTM) method on furnane cooled specimens. The tensile tests were carried out in Hounsfield Tensometer. Impact toughness of the core was determined on standard charpy specimens at room temperature.

From mechanical properties and grain size of the samples before and after carburising indicate that the temperature above 930°C has definite advantage to achieve same case depth in shorter time mainly due to gradual change in carbon concentration in the case and case-core interface.

1.3.11 Kinetics and morphology of Graphite precipitation during Malleabilization.

The malleabilization characteristics of white iron depend on the presence of certain elements. The effect of aluminium and boron on the kinetics of graphitization and morphology of graphite nodules were studied in details with *iron-carbon-silicon* alloys. The aluminium was held constant in the composition of the alloy while boron was varied from 0.001 to 0.004 in steps of 0.001%. Further, aluminium content was also increased in steps of 0.05% from 0.10%. Isothermal expansion of the specimen during graphitisation reaction was determined by a dial gauge dilatometer immersed in a salt bath held at a temperature of 950°C. The morphology of the graphite nodules were studied by determining the rate of growth with time. It was found that variation of boron at a definite level of alumina did not materially alter the kinetics of malleabilization while increase in aluminium promoted the graphitising reaction.

1.3.12 Structure of Liquid metals.

1.3.12.1 *Al-Si system* : The hypo and eutectic Al-Si alloys behave differently from hyper eutectic alloys. Silicon segregates preferentially away from the centrifuging axis in hypo-eutectic alloys and oppositely in the case of hyper-eutectic alloys. It was concluded that the clusters were mainly Si-Si hyper alloys where as Al-Si clusters formed in hypo-alloys. Such contradictory behaviour of the hypo and hyper Al-Si alloys is responsible for the divergence in the modification mechanism of the alloys.

1.3.13 Liquid metal and Solidification

1.3.13.1 *Thin films* : The experiments at rapid solidification of Al-Si alloys, containing 5.8, 9.9, 12.56 and 18.39 atomic percentage silicon, were carried out to obtain thin fiims. The cast films were metallographically examiaed. The sequence of structural changes were studied by micro hardness and lattice parametar measurements after annealing the film in vacuum between 110°-400°C for 30 minutes. The results indicated that increase of solid solubility is effected in rapid solidification.

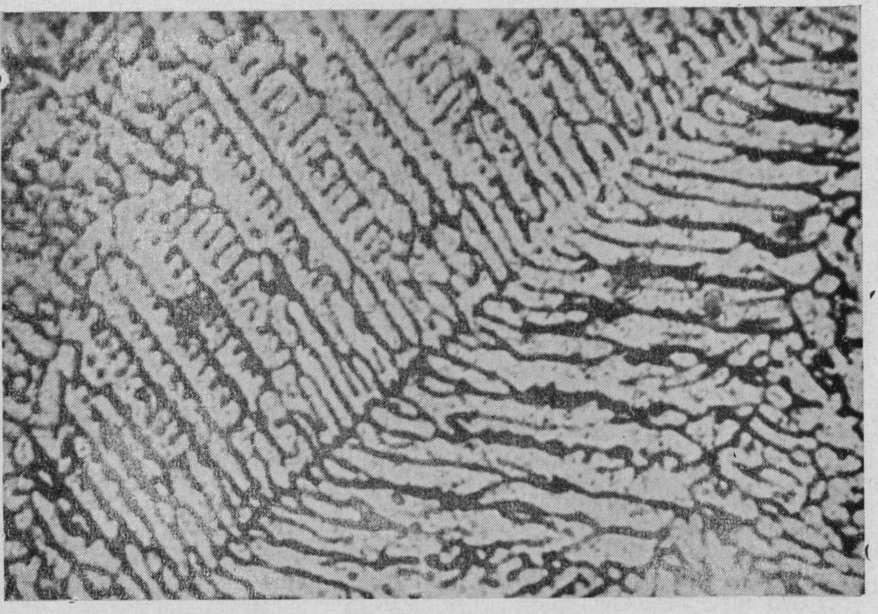
1.3.13.2 *Unidirectional solidification* : Experiments were carried out with eutectic composition of Al-Cu and Al-Ni to obtain unidirectional solidification but no significant alignment of the lamellae could be produced due to traces of impurities present in the element hence further experiments were suspended.

1.3.14. Effect of Inhomogeneity on the mechanical properties of Al and its alloys.

In Al-alloys, the impurities introduced during melting operation greatly impairs the mechanical properties and demands careful and controlled melting and solidification to improve the quality of casting. Al-Mg alloys in particular, were studied due to considerable melting loss and the presence of certain elements give rise to 'cawliflower' structure. A specially developed technique was employed usiug Al-alloys containing 1-10%Mg. It was observed that minimum 'cawliflower' structure was produced in the ingots by the technique as compared to melting under fluxes.

1.3.15 Thermodynamic properties of Liquid metals and alloys.

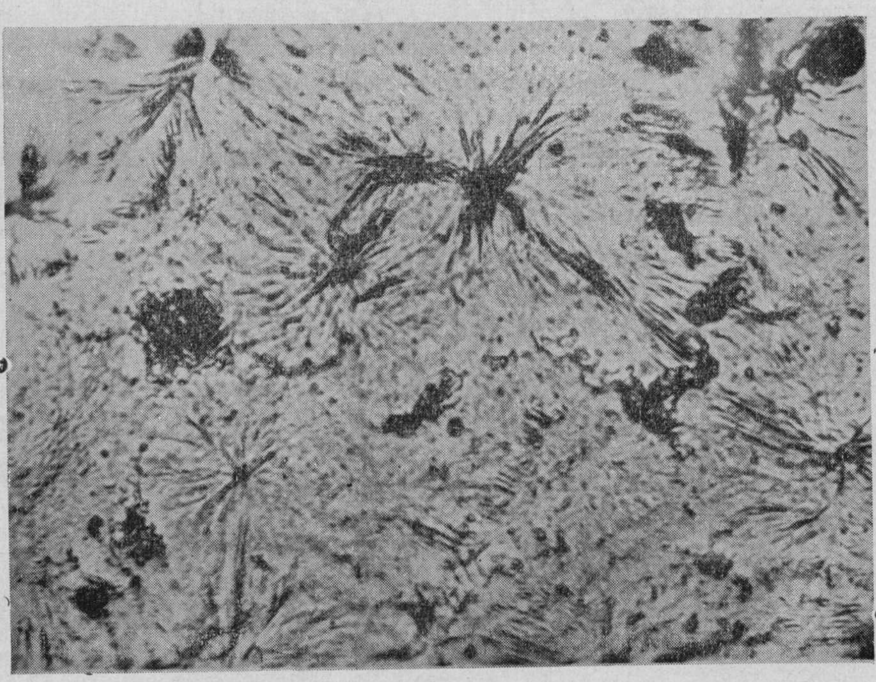
1.3.15.1. *Pb-Sb system* : By using e.m.f. cell the thermodynamic parameters like activity, partial and integral molar quantities were derived



Cast structures of rapidly solidified Al-Si alloys.

(top) Al—5.8 at % Si) (× 350)

(bottom) Al—12·56 at % Si) (× 350)



through conventional equation for the pure compenents, whilst for the alloys, graphical integration methods were employed. It was observed that the activities of Pb and Sb obtained at 400° and 500°C showed a positive deviation from Raoult's Law at these temperatures of the system. The degree of deviation decreased with the increase of temperature and indicated incipient immiscibility. The inflection in activity over certain composition range confirmed the existence of immiscibility by centrifuging technique.

1.3.15.2 *Second order transformation in liquid metals aud alloys-DTA Study.*

The results of DTA studies have confirmed some of the deductions of thermodynamic observations made on lead-antimony system by emf technique. The lead alloy containing 20% antimony did not show any pronounced lambda transformations in the DTA curve which was in confirmity with the activity values of this alloy at 400 and 500°C, where the two curves intersected and crossed over.

1.3.16 Metallographic study of the solidification of Al-Cu alloys.

Anodic oxidation technique was employed for studying Al-Cu alloys prepared from super pure metals. It was observed that the cell size varied as a function of (i) pouring temperature and (ii) the degree of supercooling in a complex manner. The cell size was observed to be maximum when cast from 840°C at less than 50°C under cooling but it decreased with increasing pouring temperature at higher degrees of undercooling. The cell size was found to be independent at low pouring temperatures and justified the low pouring temperature normally practiced, to obtain sound castings with uniform structure. Addition of copper refined the cell size.

1.3.17 Prefered Orientation in extruded rods.

The x-ray diffraction of the extruded rods at a pitch of 0·996 mm (5% of the original diameter of the extruded rod) indicated the following results :

1.3.17.1 *Duralmin extruded rods* : (a) Central zone (thickness-2.01 mm)— The results showed random orientation of the grains without any indication of a texture. Orientation in this zone remained unchanged.

(b) Intermediate zone (thickness-5.489 mm)—Double texture of 50% (111) and 50% (100) superimposed and 4 random orientation of the grains, was showed in this zone. The percentage and scatter of the texture remained constant. (c) Surface zone (thickness 1.98 mm)—Double texture of (100) and (111) was found in the structure superimposed upon a random orientation of the grains. However (100) texture increased gradually from 50% to 80%, and (111) texture decreased gradually from 50% to 20% throughout this zone.

1.3.17.2 *Commercially pure aluminium :* (a) Surface zone (thickness 5.486 mm) showed texture with its increasing scatter towards the centre. (b) central zone (thickness 3.99 mm) consisted of only random orientation.

1.3.18 Grain Size control of Non-ferrous metals and alloys.

A brochure based on the inoculant PM-120 has been published after completing the projected work.

1.3.19 Co-efficient of Thermal expansion of metals and alloys.

1.3.19.1 *Cu-Mn System :* After completing the work with Al-Mn alloys, the work was extended to the entire composition of Cu-Mn alloys in γ phase range between room temperature and 400°C. The initial increase of the co-efficient of expansion with addition of Mn to Cu has been attributed to super paramagnetism and the peak observed at 70 atomic percentage of Mn was due to the loss of antiferromagnetism. As such the alloy can be suitably used for temperature controllers, precision instruments. Further development work is under progress with bigger heats.

1.3.19.2 *Other system* : The work on low melting alloys was extended to cover Bi-Sn, Bi-Pb, Bi-Cd, Cd-Sn and Bi-Sb systems. The variation of the co-efficient of thermal expansion in Bi-Sb system was proportional to atomic percentage of the constitutent phase and due to complete solid solubility while in the other four eutectic system the coefficient of thermal expansion was proportional to volume percentage of the constituent phase.

1.3.20 Curie temperature of Cobalt alloys.

The experimental set up for measuring curie temperature of cobalt alloys in inert atomospheres has been completed. The difficulties of maintaining proper vacuum has also been rectified. Cleaner melts of cobalt has been prepared and support rods of cobalt are under preparation.

1.3.21 Cryogenic steel.

In continuation of the work reported last year, further heats were made ranging the composition of C, Si, Ti, Nb and Al to improve the tensile strength and hardness, which finally varied between 90 to 92 t.s.i. and Brinell hardness number between 394 to 404 respectively with a load of 187.5 kg using 2.5 mm dia ball. The micro-structure of as forged, quenched, tempered at 500°C were also examined.

1.3.22 High Temperature bolting materials.

Exploratory work to study the creep and creep embrittlement behaviour of Cr-Mo-V steel containing high vanadium viz 1% Cr, 1 to $\frac{3}{4}$% V and under various heat treatment conditions has been taken up. Six melts of this type of alloy steel with different additions of Ti and B were made. Mechanical working and heat treatment of these steels are under progress.

1.3.23 Electro-deposition of Composite materials :

The electro-deposition of nickel-alumina composite have been studied. The physical and mechanical properties with respect to hardness, tensile strength and high temperature oxidation resistance of the composite material are found superior to those of pure nickel deposits. The composite is brittle initially due to high hydrogen content which could be removed by annealing at 650°C and finds application in wear, abrassion, impact and oxidation resistance purposes.

1.3.34 Study of Quench sensitivity of weldable Al-Zn-Mg alloys.

The work was initiated in order to develop the weldable Al-Zn-Mg alloys of reduced quench sensitivity by adjusting the composition of zinc and magnesium and by suitable alloying additions and heat treatment process. Al-Zn-Mg alloys having Zn/Mg ratio of 2, 3, 4 with total Zn and Mg less than 7 wt % were cast. Nucleant was used as grain refiner. Homogenization treatment was carried out at 470°C for 48 hours and hot rolled to 9.5 mm thickness, and further homogenized. Ageing after solution treatment was done by hardness measurement. Quenching rate was varied. Micro structure of the hot rolled specimens are under test and the work is being continued.

1.3.25 Development of Selflubricating bearing material.

The conventional powder metallurgy method incorporating solid lubricant such as graphite, PTFE, metal sulphide etc in metallic matrix has not found suitable due to decomposition at the sintering temperature or inhibit sintering or may form compound with metel powder. The exploratory work consists of impregnating a highly porous metallic skeleton by solid lubricant leading to a dense product with encouraging results. The detailed study is under progress to establish optimum conditions.

1,3.26 Studies on Metallurgical Slags :

1.3.26.1 *Phase studies* : In continuation of the work reported earlier, the liquidus of the slags found to be varied between 1385° and 1535°C. Primary and secondary phases present in the slag were identified. Usually melilite occured as primary phase but with high Mg0, spinel occured as primary phase with high liquidus temperature and melilite as secondary phase. Further work is under progress with 28% alumina slags.

1.3.26.2. *High Alumina Slag* : The work with radio-active tracers for determination of sulphur in the slag is under progress.

Contact angle measurements of a number of slag samples were made from photographs taken in the hot stage microscope in order to determine the surface tension indirectly. Work is under progress.

1.3.26 3 *Sulphur Capacity of slag* : In view of progressive increase in the alumina content in the Indian blast furnace slags, the comprehensive study on the partition of sulphur and the rate of reduction of silica to silicon in the metal have been continued. At the definite alumina level of 24% in a synthetic slag the Mg0 content was varied from 3% to 9% in steps of 2% for studying the effect of Mg0 on the sulphur partition. A pig iron containing 1% sulphur was prepared and equilibrated with the synthetic slag in a high frequency furnace and the transfer of sulphur was determined by radio-active technique.

1.3.27 Evaluation of Inhibitor efficiency and Hydrogen pick up by steel during pickling.

Embrittlement of high carbon steel (0.86%C) in N H_2SO_4, containing different concentrations of inhibitors such as thiourea, phenylthiourea, sym-di-o-tolylthiourea, thiosemicarbazide, MN' di-isopropyl thiourea, allylthiourea, quinoline, acriflavine and asenic (As_2O_3) was studied at 40°C and the cracking time as a measure of susceptibility. The results indicated that corrosion cracking susceptibility of high carboh steel was being influenced markedly by the concentration of the inhibitors and working of the steel. Cold rolled wire cracked more quickly than normalised wire. Further, inhibition efficiency decreased with the increase in pickling time and the hydrogen pickup varied with $t^{\frac{1}{2}}$. In the case of lower member of thiourea derivatives hydrogen pick up was more compared to the heterocyclic compounds, aniline and its derivatives.

1.3.28 Studies on Stress corrosion characteristics.

1.3.28.1. *Al-Mg Alloy:* Three specimen have been tested in the Distington stress-corrosion testing machine of 50% of the proof stress of the specimen.

1.3.28.3 *Copper base alloys:* Experiments involving direct loading of the Cu-Zn and Cu-Al wires to different stress levels, 5-25 kg/mm², in ammonia atmosphere at temperatures varying between 30-60²C have been studied. Anodic and cathodic polarisation on stress corrosion cracking were also measured.

1.3.29, Corrosion and oxidation resisant Diffusion coating on steel.

Chromising on mild steel of 0. 2 and 0. 07% C in a pack process with various activating agents were carried out at 1000-1100°C when a coating thickness of 80-120 microns were obtained. Micro-hardness varied from 140-90 VPN. Simultaneous diffusion coating of Cr, Si and Al in combination did not yield satisfactory results in a pack process. 30% chromium steel as container of the pack and argon atmosphere were found adequate. Diffusion coating of steel at room temperature by slurry process is under progress.

1.3.30. Determination of the weight of Aluminium coating.

Two different methods were adopted to find the weight of aluminium coating in aluminium coated steel sheet and wire. The processes after standardisation indicated thatNaOH-HCl method was more reliable than HCl-$SbCl_3$-$SnCI_2$ method for the determination of weight of aluminium coatings on steel articles.

1.3.31. Modified Analytical procedures:

1.3.31.1 *Rapid Spectrophotometric method for determination of Alumiua in Iron ore* : Spectrophotometric method has been applied to determine alumina contents in iron ore upto 5% gave encouraging results. Work is under progress with higher alumina content.

1.3.31.2 *Simultaneous Polarographic determination of Ni-Co and Ni-Mn :* In the presence of high nickel, polarographic estimation of Co was not possible. Quite a number of solutions for Ni & Co in presence of Mn are currently under investigation. A method has been developed by which nickel content about twice that of cobalt was satisfactorily obtained. Work is under progress having higher ratio of Ni and Co.

1.3.31.3 A satisfactory electrolyte and maxima suppressor has been used to derermine Ni content for ratio of Ni : Mn upto 2 : 1. The accuracy of the results checked with spectrophotometrically compared favourably.

1.3.31 4 *Spectographic analysis of residual elements in Fello-alloys* : To develop a suitable spectrographic method for analyses of trace elements such as Mn, Ni, V, Cu, Mo, Co, Al and Ti upto a limit of 0.1%, usually present in Ferro-chrome, has been initiated. A set of 5 synthetic standard solutions were prepared and measured photometrically by non-recording microphotometer. The reproducibility and accuracy of the method is under standardisation.

1.3.31.5 *Determination of Niobium in Steel* : In order to determine low amount of noibium in mild steel and stainless steel, a secondary standards in the form of solid discs were attempted after ascertaining the Nb content through chemical analysis. The counter electrode for mild steel was spec-pure copper rod and specpure carbon rod was used for stainless steel at 80° cone. Encouraging results were obtained and now under standardisation with respect to reproducibility and accuracy.

2.0 PILOT PLANT ACTIVITIES

2.1 Ore Beneficiation Pilot Plant.

Pilot Plant benefication and agglomeration studies of seven different iron ores and lime stone, manganese ores, copper ores, wolframite minerals and beach sands have been already reported under sponsored projects.

2.2 Manganese Pilot Plant.

Successful campaigns were organised to study the feasibility of electrolytic production of manganese and manganese dioxide utilising various Indian ores and materials based on the process developed on bench scale. During these runs 1,2 tonnes of Mn metal was collected of which 500 kg of the metal was despatched to various organisations.

The durability and economy of PVC lining as alternate to lead lining for reactor vessels are being carried out. Speed of agitators in the reactor vessels were also studied to establish the settling of solids and vortex formation.

The suitability of Mn ore and Ferro-Mn slag for production of electrolytic Manganese metal have been cited under sponsored work.

2.3 Preparation of Synthetic cryolite.

Arrangements of trials at 50 kg of cryolite per batch has been initiated to collect data for design of equipment and expertise the process know-how. Most of the equipment was installed and almost ready for operation.

2.4 Dense Carbon & Soderberg Paste.

The half-tonne capacity Dense Carbon Aggregate Pilot Plant has been commissioned to prepare and to ascertain the quality of the materials as a substitute for calcined anthracite coke also to collect data for scaling up to industrial production.

Regular production of raw briquettes had started and reached the targetted capacity towards the end of the year after considerable teething trouble with the indigenously procured equipments especially the hydraulic press and grinding units. The treatment of raw briquettes was conducted in a downdraft due to delay in procuring the heating elements for electric tunnel kiln. Crushing of the heat treated briquettes were under progress. to the desired particle size. Trials have yielded dense carbon aggregate having slightly superior properties than produced on laboratory-scale.

2.5 Hot-Dip Aluminising of Steel.

Silicon carbide lining to cast iron pots were tested for Aluminising plant. The pot was subjected to repeated heating and cooling with molten aluminium showed cracks similar to the pot used for extended period with molten aluminium. Experiments were also conducted to improve the finish of hot dip aluminised steel panels. Preliminary experiments with baffle plates (Cr 24%, Ni-16%) showed increasing oxidation resistant characteristics in the galvanizing furnaee.

Demonstration and training to the representative of Bharat Aluminising, Ahmedabad was given when nearly 50 sheets of mild steel of 0·9m x 20·3Cm x 16 gauge size were aluminised.

3.0 SPECIAL PROJECT

3.1 Sponge Iron.

Campaigns were continued for production of sponge iron by rotary kiln and vertical shaft furnace using non coking coals, charcoals, gases and naphtha.

3.1.1 Rotary kiln.

Sponsored work is being continued with raw materials supplied by different organisations.

3.1.2 Vertical shaft furnaces.

Extensive investigations were conducted in a specially designed and fabricated vertical shaft furnace for making sponge iron with different iron ores and non coking coals and to study their characteristics with variation of retention time. It was observed that even with a reasonably low retention time the degree of metallization was satisfactory.

The operational characteristics of sponge iron production in a vertical shaft furnace in camparison with a rotary kiln has also been ascertained.

3.1.3 By Naptha injection.

Production of sponge iron or iron powder was developed by using naphtha, a petroleum product. At elevated temperature naphtha cracked down to 85% carbon and 15% hydrogen. By insitu reforming of naphtha vapour, iron ores were directly reduced in a reactor to obtain sponge iron of 90—98% metallization. After successful bench scale operation, a continuous static bed reactor has been designed and installed, on the basis of requisite parameters, having a capacity of 3 kg/hour. Efficient reduction of ores were obtained in a large number of trials which indicate economic feasibility of the process commercially in localities where naphtha is in abundance.

3.2 Culcium-metal production.

Successful bench-scale extraction of calcium has been completed using thermal method. Trials were based on vacuum retorts of 25 kg limestone to yield upto 6 kg of calcium metal. The effect of briquetting size and pressure of formation, temperature, vacuum etc. have been studied. Semi pilot scale studies has been initiated.

3.3 Bacterial leaching

Preliminary studies were initiated to ascertain thc possibilities of recovering metals such as copper, zinc etc. from waste ore dumps, N.C.L., Poona will serve as a source for the thio-bacillus, thio oxidam from their bacillus breading and handling facilities. An inter laboratory group, comprising CMRS, NCL, RRL, Bhubaneswar and NML scientists, is being considered to tackle various aspects of the project.

3.4 Setting up of Central Creep Testing Facilities NML

The Ministry of Industrial Development and Steel and Heavy Engineering and concerned industries have collaborated with CSIR for the establishment of creep testing facility at NML.

A creep panel formed, which hold meeting in November 1971 and January 1972 to formulate and lay down the acceptance procedure for creep resistance steels for elevated temperature applications during the interim period as creep and stress rupture test data on Indian Steels which are not yet readily available. A new panel was also constituted to consider the difficulties of the steel makers with respect to the development of creep resistant steels. A sub-committee of the panel on turbine materials recommended the acceptance criteria for the creep resistant steel for steam turbines. The committee further suggested the commonly acceptable grade of steels for different application within the limitation of acceptance as per design codes of their respectives collaborators.

The foundation stone of the building for the Central Creep Testing Facility was laid on 22nd April, 1971 by Dr. Atma Ram, the then Director-General, Scientific and Industrial Research, New Delhi. The design features of the building with special isolated foundation were finalised along with uninterrupted power supply and proper ambient temperature control. The revised estimates after scrutiny by Building Advisory Committee have been accepted and construction tender invited.

UNIDO has floated global enquiries for purchasing the agreed equipments The offers received are under scrutiny.

3.5 Nimonic Alloys.

Preparation for trial heats have been initiated by air melting and vacuum melting of some Ni base high temperature alloys, currently imported to study their easting, working and heat treatment characteristics for use in the development of creep testing machines.

3.6 Preparation of Standard Samples (PL-480 Projects)

The project has been sponsored by the National Bureau of Standards, Washington for preparation of standard reference materials of three ferro-alloys. viz. High carbon Ferro-manganess, Low carbon Ferr-manganess and Ferro-titanium conforming to the ASTM specifications, for use in ferrous and non-ferrous industries for checking the methods of analysis.

3.6.1 High Carbon Ferro-manganese.

The proper grade materials after collection were crushed and sieve analyses of different fraction were carried out from which it was ascertained that $-60+100$ mesh fractions only would be ideal for preparation of standard samples. Homogenising of the material were carried in a cubical mixer and the samples were analysed in the Laboratory. Concurrent results were obtained from 5 other industrial Laboratories. Nearly 135 kg. samples were prepared.

3.6.2 Low Carbon Ferro-manganese.

117 Kg. of samples, $-60+100$ mesh fractions, of proper grade materials were collected having concurrent results from other laboratories.

3.6.3 Ferro-Titanium.

Difficulties were experienced in collecting proper grade of ferro-titanium with 20—27% Ti and 6% Max Al. It was possible only to procure a small quantity (500 kg) of material which met the specifications. Crusning, grinding and homogenizing the samples were caried out in different batches. The final sample after homogenizing weighed 173 Kg, with a particle size of $-60+100$ mesh B.S.S.

4.0 ENGINEERING ACTIVITIES AND FACILITIES

4.1 Design and Mechanical Engineering.

4.1.1 Research and Development.

Preparation of feasibiliյy reports has been continued to bring out the industrial viability of NML developed processess.

4.1.1.1 *Multipurpose Hydro-cum-Electrometallurgical facilily* : Work has been carried out to prepare plant layouts and equipment specifications. Plans for shifting of relevant equipments to the site were initiated including the shifting of 500 KVA submerged are furnace.

4.1.1.2 *Ferro-molybdenum production proto-types* : The design and development of proto type unit for ferro-molybdenum by alumino-thermic process has been continued with maximum stress on mechanization. The feasibility rəport is being prepared.

4.1.1.3 *Metal Powder production prototype* : Active design on a production oriented proto type has been underway to produce a range of non-ferrous metal powders with critical accent on automation-cum-mechanisation from the quality point of view. The design work has been supported by actual trials in semi-pilot-scale unit.

4.1.1.4. *Tin-free Steel processing Unit :* Feasibility report on the application of the tin-free steel process developed at NML is under preparation. Two approaches have been studied. One relates to the conversion of cut sheet hot dip tinning lines to tin free sheet lines and the other is concerned with the continuous tin free steel process for steel strips.

4.1.2 The feasiblity reports of the following NML processes are under preparation :

(1) Production unit capable oi manufacturing an aggregate of 2000 tonnes per annum of clay boneded and carbon bonded graphite crucibles.

(2) Submerged Arc furnace plants for various ferroalloys.

(3) Electrolytic manganese metal and manganese dioxide production plants.

(4) Basic side blown converter plants.

(5) Metal powders manufacturing units.

(6) Zinc distillaation of dross units.

4.1.3 Miscellaneous facilities.

The mechanical workshop completed fabrication of large number of test specimens, spare parts for replacements and equipments for various projects. Tracing and reprographic sections prepared over 500 tracings followed by over 13,000 prints for various research/development projects.

4.2 Electrical.

4.2.1 Development.

4.2.1.2 *Furnace for Creep testing.* Atter completing the design of the furnace for constant temperature of ± 1°C, for 150 mm zone and determining the by-pass resistors and power requirement to hold the furnace in the range of 300-1000°C, one proto type furnance was fabricated and commissioned for operational test.

4.2.1.2 *Electro-Slag refining* : The constant current controller was developed and its sensitivity ascertained. Feasibility of utilizing the submerged arc furnace for electro-slag refining was critically examined and observed that voltage and current controls were not suitable for the purpose. The various parameters of one 140 KVA transformer was tested at various loads in relation to its suitability for electro-slag refining.

4.2.1.3 *Automatic power-imput Controller for high temperature resistace furnances,* A solid state device for automatically controlling the power imput of high temperature furnance, by keeping the current constant and varying the voltage as the winding resistance increases is under development.

4.2.1.4 *Extra-high vovtage transformer* : One 2.5 KVA transformer 230/100,000 volts for 'X-ray' duty has been designed.

4.2.2 Design and fabrication.

4.2.2.1 *Power, temperature and humidity control system for Central Creep Testing Facility* : To supply special requirement of uninterrupted electrical power to creep facility, a suitable power supply net work and 6600 volts feeder to sub-station was designed. Automatic mains failure starting type stand-by diesel-alternators has been incorporated with voltage stabilizers to minimise the voltage fluctuations. Automatic temperature and humidity control was also incorporated. These data was supplied to the consultants.

4.2.2.2 Three high temperature resistance furnaces for the temperature range of 1550° to 1700°C have been designed where Platinum-Rhodium heating elements are to be used. The fabrication and testing of two such units were completed. Beside high temperature furnaces, twenty two pot and tube furnace using nichrone or kanthal heating elements were designed and fabricated. In addition special furnaccs viz. vertical reduction kiln, split furnace and non-inductive tube furnaces were designed and fabricated.

4.2.3 Instalation and commissioning of several equipments, machinaries and power distribution systems were planned and executed.

4.2.4 Repairs and Preventive maintenance.

A number of breakdown repairs of various electrical equipments, control system and low distribution network were carried out. Preventive maintenance of electrical equipments viz. power transformers, circuit breakers, rectifiers, drives, lifts and cranes and control devices were periodically checked according to the duty of the individual equipments and their performance during the last year.

4.3 Electronics Engineering and Instrumentation.

4.3.1 Development.

4.3.1.1 *High current electronic Potentiostat* : Several direct coupled d.c. amplification, design and fabrication were tested. Differential solid state amplifier was found suitable.

4.3.1.2 *Precision temperature Controller (solid state)* : It is proposed to use suitable SCR (silicon-controlled rectifier) for control purpose and under necessary design.

4.3.1.3 *Solid state automatic Thermogravimetric balance* : LDR (light dependent resistor) has been decided upon for use in which differental d.c. amplifire (transistorised) has been under design.

4.3.1.4 *Displacement actuated electronic Trigger for high temperature Creep testing* : An electronic trigger is being developed for closing the armature circuit of a continuously excited d.c. shunt motor, which reduces the applied load by means of gearing to the hand wheel of the creep machine. The electrical contract is broken as soon as the original value of strain is obtained. The design of a Schemidt tigger circuit has been completed and is under fabrication.

4.3.1.5 The necessary specification for both pneumatic and electronic instruments have been prepared for centralised instrumentation system for a sponge iron plant.

4.3.2 Maintenance, Installation etc.

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

(i) Repair of Electron beam melting furnace.

(ii) Modification of Electron microscope, EM 6.

(iii) Repair of Phillips X-ray diffractometer, Autrometer and Delta-therm.

(iv) Repair and modification of Carl Zeiss spectrophotometer.

(v) Repair of Magna potentiostat.

(vi) Installation of Ultrasonic flaw detector, oscilloscopes, potentiostat, audio system, industrial X-ray equipment and nucleonic instruments.

(vii) Maintenance of electronic and process control instruments of FPTD, MBPP, Carbon Plant, Magnesium Plant, Creep Laboratory and NML Field Stations.

4.4 Civil Engineering.

Various civil engineering jobs relating to enclosure of Heavy Media Seperation plant, raw material shed and bins at MBPP, R.C.C. roofing for Extractive Metallurgy room over the crushing section, (Tech. Block). extension of Library; office, control rooms and surface drainage at Dense Carbon Aggregate Pilot Plant and foundation for machines, partition walls etc. were carried out. In addition to proper maintenance of water, gas and compressed air supply to the laboratory and pilot plants, permanent filtered and unfiltered water line connections to Dense Carbon Plant were also completed.

4.5 Glass Blowing Facilities :

Thirty two specialised glass and silica equipments and parts required in connection with the research activities were fabricated during the year. In addition 797 other glass blowing jobs were also carried out.

5.0 NML FIELD STATIONS

5.1 Foundry Stations :

The technical services and guidance were rendered by the field stations to the industries located in their respective regions on diverse aspects of foundry technology. The selection of proper raw materials includes facility for analyses for ferrous and non-ferrous metals and their alloys, testing of sands, bentonite and other foundry raw materials, and application of modern techniques of production, scientific methods of metal melting and casting. Quality control and improving the productivity by eliminating casting and moulding defects and production techniques to meet export requirements by on spot assistance to number of foundries were provided. Extensive work has also been carried out by the field stations in exploiting and investigating the regional resources with regard to foundry raw materials of the respective regions in collaboration with the Geological Survey of India and State Geology and Mining departments. 36 investigations on indigenous Foundry sand and bentonites were conducted under own programme of work.

5.2 Marine Corrosion Station, Digha.

5.2.1 Atmospheric corrosion of metals and alloys under marine atmosphere at Digha (NML and Corrosion Advisory Bureau, Metals Research Committee, CSIR).

5.2.1.1 In order to select right type of materials by corrosion engineers and designers for various installations in a coastal area the work on long term basis have been initiated jointly by the N.M.L. & Corrosion Advisory Bureau. Alumnium 2 S, Aluminium 3 S, Aluminium 57 S, Brass, Copper, Nickel, Monel, Zinc etc. materials are under exposure for last 8 years. The corrosion rates have been determined after 6 years of exposure which indicated that the corrosion rates of Al, Nickel and Monel were low compared to others. Tiscor and mild steel panels exposed for 6 months both at sea beach and at the laboratory premises indicated that TISCOR has better atmospheric corrosion rates. Exposure will continue for next 2 years.

5.2.1.2 Expriments on the effect of mass and heating of mild steel specimen varying the heating and exposure period indicated that the effect of corrosion on mild steel depends with or without heating and varied with exposure period. Effect of mass of the specimen on atmospheric corrosion has been continued.

5.2.1.3 High conductivity Al wires developed at NML are under exposure at Digha along with INDAL & HINDAL aluminium wires for past 1½ years. Electrical resistivity of the wires did not show any marked change in their values after different period of exposure between 3 months to 1 year.

5.2.1.4 Metereological data at Digha have also been collocted.

5.2.2 Seawater Corrosion of different metals and alloys.

5.2.2.1 Effect of chromate inhibitor in seawater on corrosion of mild steel coupled to Zn, Cu, Al in different area ratios were studied which indicated that corrosion rates of all the couples decrease with increase in chromate concentration and that the 'catchment area principle' is not strictly followed in all the cases. Further test under progress.

5.2.2.2 Effect of chloride ions on corrosion of mild steel in solutions containing benzoate inhibitor have been initiated.

5.2.2.3 Effect of alternate immersion of mild steel, Cu & Zn samples in sea water on their corrosion rates have been studied. Results are encouraging enough to warrent further studies.

5.2.3 Effect of Annealing on Atmospheric and Seawater corrosion of metals and alloys.

Cold rolled mild steel samples were annealed at different temperature between 200 to 800°C and tested for their atmospheric corrosion and corrosion in seawater and acids of 3 different concentration. Cold working has no effect on atmospheric and on acid corrosion. However, in sea water, a small decrease in corrosion rate of samples annealed at 200°C was noticed, but polarisation studies did not reveal any notable change. Further work is under progress.

6.0 PUBLICATION AND INFORMATIONS

6.1 Publication.

6.1.1 NML Technical Journal

The Journal has continued its publication containing research and technological development projects at NML in various metallurgical deciplines and is highly commended at home and abroad. Exchange agreements with 60 Indian and 70 Foreign publications were established and presently subscribed by 154 institutions and individuals.

6.1.2 Documentation Cell

Twelve issues of the monthly publication 'Documented Survey on Metallurgical Developments' an abstracting service from current periodicals were issued during the period. The service has been highly appreciated by user scientists and metallurgists and has already more than 50 paying subscribers, in addition to its circulation to the scientists of the Laboratory. It has been converted into a priced publication from January 1972.

6.1.3 In addition to the publication of Annual Report of the Laboratory, 1969-70 and 1970-71, a number of special reports prepared in connection with meeting, get togethers and augumenting defence requirements, Iron and Steel industries, mineral processing, small scale industries, interaction of laboratory and public sector enterprises covering various industrial investigations of interest and expertise and facilities available at the Laboratory.

6.1.4 The following brochures were also published :

(i) Dense Carbon Aggregate Pilot Plant.

(ii) Central Creep Testing Facility.

(iii) Grain Size Control in Aluminium and Aluminium Alloy Castings.

(iv) Superal

(v) Achievement of NML in Research and Development.

6.2 Information.

The Library has added 1360 new books and 1500 bounded journals. Over 300 journals were subscribed to and in addition 130 journals were received in exchange for the NML Technical Journal. The central documentation system viz. abstract cards for metallurgical informations were prepared on different disciplines of research and made available to the scientific staff of the laboratory and outside organisations. The weekly 'Index of Current Titles' from periodicals received has been continued and has been found immensely useful in the scanning and selection of materials by the scientific staff. The Library has a collection of nearly 4000 Indian Patent Specifications on different metallurgical subjects.

6.3 Reprographic Service

Preparation of photostate 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.

7.0 PUBLIC RELATION AND INDUSTRIAL LIAISON

7.1 The programme of personal discussions, joint technical meetings and organising Get-together with representatives of metallurgical industries and interested entrepreneurs to acquaint them with the type of expertise and facilities in research and development in the industrial field available at NML has been vigorously continued. As a result of these concentrated and concrete effort a much greater degree of confidence has been created making fuller utilization of the facilities available at NML. A number of major public and private sector industries including small scale industries have continuously called at NML with specific metallurgical problems in their own development field, culminating in the shape of longs/hort range sponsored research investigations/development works.

7.2 One hundred six foreign collaboration applications from various Indian firms were screened critically vis-a-vis products/process with respect to know-how envisaged against the expertise already available at NML.

7.3 A few hundreds of technical personnel belonging to various organisations/institutes visited the laboratory to get acquainted with research and development activities and type of facilities available at the Laboratory. Some of these products which figured during discussions related to coarse as well as finer fractions of different metal powders, plating compositions, ferro-alloys, bimetals, sponge iron, alnico magnets etc.

7.4 Technical Aid and Services:

The technical enquiries from 65 Goverment and semi-Government organisations and 167 from private sector industrial organisations and 55 enquiries pertaining to details of processes/patents of the laboratory and to provide latest technical informations/data were attended to. In addition 39 new sponsored projects were undertaken during the year and 33 of the total sponsored projects were completed. Technical service, consultancy and assistance were rendered to 41 industrial units, Government institutions and large scale industries.

7.5 Training facilities provided at NML.

Training facilities at the laboratory have been extended to thirty staff members of different organisations/institutes in the field of mineral beneficiation and agglomeration, metallography, foundry, heat-treatment, metal working, chemical and spectroscopic analysis, X-ray diffraction and electron microscopy, various techniques of metal extraction, corrosion problems etc.

7.6 Training of NML staff.

A number of NML scientists/technologists have been deputed for inplant training in various metallurgical organisations and establishments within the country, related to their own research activities in iron and steel making, thermal-treatment, powder metallurgy, instrumentation, foundry technology, corrosion etc.

7.7 Extension Services.

Expertise available at NML for the development of small ancillary industries and the products developed at NML were exhibited during the seminar on 'Prospects of Small Scale Metallurgical Industries' at Bangalore during the celebration of the 9th Metallurgist's day.

7.8 Visitors:

Shri S. Mohan Kumaramangalam, Union Minister for Steel and Mines, was shown round the NML and its various pilot plants on 19th January 1972. He envinced keen interest in the production of pig iron from pellets made from beneficiated Asswan Iron ore as well as steel from pre-reduced Asswan ore. He was also shown the work being carried out in the laboratory on substitute materials developed at the NML, such as nickel free heating elements, tin free steel, nickel free stainless steel, aluminising in place of galvanizing, etc. Shri N. A. Palkhiwala, Vice Chairman, Tata Iron & Steel Co. Ltd,, also visited the labaratory on this occation.

Shri C. Subramaniam, Union Minister for Planning, Science and Technology, visited the NML and its Pilot plants on 11th February 1972. He showed keen interest in the various process and products developed by the laboratory. The Minister also addressed the Staff of the laboratory underlining the role of self reliance in the field of seience and technology. He hopped that the country would have a scientific and technological revolution (similar to 'Green revolution' in the field of agriculture) and thus achieve the goal of self reliance.

During the period nearly 2000 students, professors, experts, industrilists and entrepreneurs visited the Laboratory and its pilot plants.

Some of the imporhant visitors were :

1. Hon'ble Shri D. K. Barooah, Governor of Bihar.
2. Dr. C. V. S. Ratnam, Mg. Director, National Research Development Corpn. New Delhi.
3. Dr. Atma Ram, Director-General, Scientific and Industrial Research, New Delhi.
4. Shri J. H. Lascelles, Sr. Industrial Field Adviser, UNDP, New Delhi.
5. Sir. J. J. Ghandy, Director, Tata Industries Ltd., Jamshedpur.
6. Shri H. C. Sarin, Secretary, Dept. of Steel, Ministry of Steel and Mines, New Delhi.
7. Shri S. Moolgaokar, Vice Chairman, Tata Iron & Steel Co. Ltd., Bombay.
8. Shri J. J. Mandelson, Australia.
9. Shri S. P. Khaithan, President and Council Members, All India Non-Ferrous Manufacturing Association.
10. Shri S. C. Dey, Tech. Adviser (Boiler) & Secretary, Central Boiler Board, Ministry of Industrial Development, New Delhi.
11. Shri N. Subrahmanyan, Secretary, Deptt. of Mines & Metals, New Delhi.
12. Shri K. Matsubara Japanese Technical Delegation.
13. Dr. M. Ulda. ,, ,, ,,

14. A team of members of the Parliamentary Consultative Committee for the Ministry of Steel & Mines.

15. Dr. L. C. Correa de Silva, Chief, Metallurgical Industries Section, UNIDO, Vienna.

16. Dr. B. R. Nijhawan, Sr. Industrial Adviser, UNIDO, Vienna.

17. Shri J. H. Giedroyc, M. S. Atkins & Partners, U.K.

18. Shri Tamekazy Tabata, Nippon Steel Corpn., Japan.

19. Shri H. I. Martin, Sr. Vice President, Swindell-Dresslor Co., Pittsburg, U.S.A.

20. Shri Carlos Otto Sanio, Chief, Testing of Material Laboratory, Buenos Aires, Argentina.

21. Shri Baluit Balkay, Chief, Section of Alutero (Design Inst. of Al. Industry), Budapest, Hungary.

22. Dr. M. N. Dastur, Mg. Director, M. N. Dastur & Co., Calcutta.

23. Shri Servet Buyuran, Guvenevler, Ankara, Turkey.

24. Shri Mohmoud Kamel Hussein, National Research Centre, Dokki, Cairo U. A. R.

25. Shri R. D. Lalkaka, Dasturco, Dusseldorf, W. Germany.

26. Shri Mohammed Dia El-Din Mohamoud Fahmy, Project Manager, Egyptian Iron & Steel Co., Cairo, UAR.

27. Shri Moacelio Mendes, Representative of USIMINAS, Rio de Janeiro, Brazil.

28. Shri W. R. K. Davies, Power Gas Corpn, U. K.

29. Shri R. M. Nadkarni, Arthur D. Little Inc., U. S. A.

30. Shri L. Takats, Hungary.

31. Dr. Ing. Horst Koning, Director, Demag Aktiengesellschaft, Duisburg, W. Germany.

32. Prof. Golovanenko Russian Experts. I.I.T, Kharagpur.

33. Prof. Shiriaev „ „

34. Prof. Kozlov „ „

35. Shri Akinwunmi Adecboye, Project Manager, Nigerian Steel Development Authority, Lagos, Nigeria.

36. Dr. B. D. Nag Chowdhury, Scientific Adviser, Ministry of Defence, New Delhi.

37. Dr. Hari Narayan, Director, National Geophysical Research Institute. Hyderabad.

38. Prof. M. G. Fontana, Chairman, Metallurgical Engg. Dept. & Director of Corrosion Centre, Chio State University, Chio. U. S. A.

39. Shri C. N. Horton, Science Officer, British Council, U. K.

40. Dr. M. S. Levis, Representative, British Council, U. K.

41. Shri L. Nagy, Scientist, Hungary.

8. GENERAL

8.1 Colloquia :

Thirteen papers presented by NML Staff members were discussed at the Colloquia and 17 important lectures were delivered by men of distinction covering various metallurgical aspects. The following special lectures were delivered :

LECTURERS

1. Dr. V. P. Gupta, Asst. Professor, I.I,T., Kharagpur	Direct observations of dislocation behaviour during creep. 26.4.71 & 27.4.71
2. Dr. G. S. Upadhyaya, Associate Professor, University of Roorkee	Stable electronic configuration model & its role in matallurgy. 18.5.71 & 19.5.71
3. Prof. P. K. Jena, Professor Metallurgy, Benaras Hindu University Varanasi.	(i) Extraction of Refractory Metals. 4.6.71 and (ii) The role of kinetics in extractive Metallurgy. 5.6.71
4. Dr. Mahabir Ram, Asst. Professor, R.I.T., Jamshedpur	Chemistry of electroslag remelting. 10.6.71
5. Prof. K. P. Abraham, Associate Professor, Indian Institute of Science, Bangalore	(i) Thermodynamic properties of metal oxide system using the solid electrolytic galvanic cell technique. 24.6.71 and (ii) Kinetic aspects of gas-solid reaction. 25.6.71
6. Mr. R. J. Miller, UNIDO, Vienna	Trends in iron making. 29.6.71

7, Dr. B. R. Nijhawan, UNIDO, Vienna	UNIDO & R & D programmes. 29.6.71
8. Dr. P. P. Das, Associate Professor, B. E. College, Calcutta	Tempering characteristics of certain alloy S. G. Iron. 9.8.71
9. Prof. A. K. Seal, Professor of Metallurgy, B. E. College, Calcutta	Development of Maraging Steels with indigenous raw materials. 29.10.71 & 30.10.71
10. Dr. Amit Chatterjee, W. Germany	A fundamental study of the process metallurgy in L-D Steelmaking. 3.11.71
11. Dr. H. Koning, W. Germany	Direct Reduction of iron ore. 14.2.72
12. Prof. M. G. Fontana, U.S.A.	Corrosion problems. (23.2.1972)
13. Mr. Lajos Nagy, Hungary	Noise reduction in pre-fabricated building industry. 14.3.72

8.2 Specialised equipments.

Some of the important additions to the equiment procured and ordered are as below :

(1) Double yoke Mangetic Tester

(2) D. S. M. Screen

(3) High frequentcy induction melting furnace

(4) Fast rise Time potentiostat with accessories

(5) Ultrasonic flaw cum thickness detection unit with accessories

(6) Sigmatest crack detector

(7) X-Y_1-Y_2 Recorder

(8) Double beam Oscilloscope

(9) Voltage Stabilizer

(10) Sieving and Straining machine

(11) Potentiometric millvolt recorder

(12) Kirloskar air compressors & spares

(13) Ball Mill

(14) Universal D. T. A. Unit

8.3 Safety first and First Aid Sections.

Vigorous drive was maintained for accident free records at different pilot plants, workshop and other places, resulting no major casualty during the year. Periodic inspection at various hazardous points were also carried out. Adequate safety materials and protecting garments were provided with according to the nature and zone of work place.

8.4 Activity of Societies and Club.

NML Staff Co-operative Credit Society, and the N.M.L. Co-operative Consumers Store continued their activities.

The NML Club continmed its various sporting and other activities and participated in the local sports. A number of social functions were also organised.

8.5 Staff News :

8.5.1 Honours and Awards :

(1) Dr. M. R. K. Rao, Scientist—9th National Metallurgist's Day Award for his outstanding contributions in Metallurgical Refractories, November, 1971.

(2) Sri S. K. Ray, Scientist—Certificate of merit by the Invention Promotion Board for the 1972 Republic day award.

(3) Dr. N. Dhananjayan, Scientist—Binani Gold Medal, as author of the best paper in non-ferrous metallurgy, published in the Transaction of Indian Institute of Metals during 1970, at Silver Jubilee Function of I.I.M., February 1972.

8.5.2 Membership on outside bodies.

1. Prof. V. A. Altekar Director	Chairman,	(i) Group-9, Pilot Plant activities and Group-10, ferro-alloys, NCST Panel-7, Mining, Steel & Metallurgical Industries.
		(ii) Task force on Iron & Steel (Ministry of Steel & Mines).
	Director	(i) Board of Directors, Hindusthan Copper Ltd.
		(ii) Board of Directors, Hindusthan Steel Ltd.,
		(iii) Board of Directors Uranium Corpn. of India Ltd.
	Member	(i) Board of Governors, National Institute of Foundry & Forge Technology, Ranchi.
		(ii) Advisory Panel, National Chemical Laboratory, Poona.
		(iii) Panel of the Advisory Council of Non-ferrous metals (Ministry of Steel & Mines).
		(iv) Technical Committee for the establishment of Aluminium Research Institute in India.
		(v) Editorial Board 'The Research & Industry'.
2. Dr. A. B. Chatterjea Dy. Director	Chairman,	Group-3, Iron & Steel Sub Panel, Refractories for Metallurgical Plants, NCST Panel-7
	Member	Academic Council and Board of Research & Engineering Studies, Burdwan University.

3.	Dr. R. Kumar Scientist	Member	(i) NCST Committee on assesment of R & D capabilities at important metallurgical centres. (ii) Academic Council, National Institute of Foundry & Forge Technology, Ranchi.
4.	Shri R. M. Krishnan Scientist	Member	Board of Governors, National Institute of Foundry & Forge Technology, Ranchi. (Representing the Institute of Indian Foundrymen).
5.	Shri P. K. Gupta Scientist	Chairman	Group-5, Thermal treatment equipment, NCST Panel-6, Heavy Engineering Machinery.
6,	Shri M. J. Shahani Scientist	Member	Group-7, Powder Metallurgy, NCST Panel-7, and Group-5. Thermal equipment, NCST Panel-6.
7.	Shri G. P, Mathur Scientist	Director Member	Board of Directors, Pyrite, Phosphate & Chemicals Ltd., Group-1, Ore & Minerals and Group-2, Iron & Steel, NCST Panel-7.
8.	Dr. A. K. Lahiri Scientist	Member	International Standing Committee for the Study of Corrosion and Protection of underground Pipe line of the International water supply Association, London.
9.	Shri V. S. Sampath Scientist	Member	Group-4, Common Nonferrous metals, NCST Panel-7.

10. Forty eight Scientists of the Laboratory are serving the various Committees of Indian Standard Organisations.

8.5.3 Special Lectures Delivered

1. *Advanced Ferrous Metallography & Liquid Metals*—Dr. R. Kumar, Benaras Hindu University, Varanasi, June/July, 1971.

2. *Recent Trends in Iron making*—Prof. V. A. Altekar—Indian Institute of Technology, Kharagpur, July, 1971.

3. *Rhythm in phase transformation in steel*—Dr. R. Kumar—Indian Institute of Technology, Kharagpur, July, 1971.

4. *Prevention of Corrosion process*—Dr. A. K. Lahiri—Indian Institute of Technology, Kharagpur, July, 1971.

5. *Thermal expansion of Pb-Sn & Pb-Cd alloys*—Shri L. J. Balasundaram—The Dept. of Metallurgy, Ind. Inst. of Science, Bangalore, August, 1971.

6. *Crystal structure of metals*—L. J. Balasundaram—Vivekananda College, Madras, August 1971.

7. *Hume-Rothery and his contribution to metallurgy*—L. J. Balasundaram —St. Joseph College, Madras, August, 1971.

8. *Heat Treatments*—Dr. R. Kumar—National Institute of Foundry & Forge Technology, Ranchi, October, 1971.

9. *Iron and Steel making practice*—A. B. Chatterjea—Regional Institute of Technoloy, Jamshedpur, December, 1971.

10. *Iron making by various techniques including low shatf furnace*—Dr. A. B. Chatterjea—To the graduate students of Indian Insitute of Technology, Madras, at Jamshedpur, December, 1971.

11. *Modern Physico-chemical methods for metallurgical analysis*—Dr. H. P. Bhattacharya—To the graduate students of Indian Institute of Technology, Madras, at Jamshedpur, December, 1971.

12. *Ore dressing technology for Indian ores*—Shri H. Patnaik—To the graduate students of Indian Institute of Technolog, Madras, at Jamshedpur, December, 1971.

8.5.4 NML scientists recognised as research guides and examiners for post graduate studies, by different Universities/Institutes of Technology.

1. Dr. A. B. Chatterjea — Universities of Calcutta, Burdwan, B.H.U. & Ranchi ; I.I.T., Kharagpur and Bombay; and Indian Institute of Science, Bagalore.

2. Dr. R. Kumar — Universities of Patna, Ranchi, Rajasthan, Panjab and B.H.U.

3. Dr. A. K. Lahiri — Universities of Gujarat, Sambalpur, Ranchi & Sagaur.

4. Dr. J. K. Mukherji — University of Patna.

8.5.5 Foreign Deputation/Training in India & Abroad

1. Prof. V. A. Altekar Director.

   To attend the 38th International Foundry Congress, W. Germany.

   To attend the meeting of International Commission under the auspices of the International Committee of Foundry Technical Associations.

   To visit M/s. Lurgi Gesellschaft, Frankfurt/W. Germany for studying their plant and examining its suitability for NML's Project.

   To attend International Conference on Maximising the yield of non-ferrous metals processes, Liege, Belgium.

   For detailed discussion with UNIDO at Vienna, Austria regarding the work under progress for the 'Asswan Iron Ore' sponsored by the UNIDO.

   (2-10-71 to 19-10-71)

2. Dr. A. B. Chatterjea Deputy Director	To attend Symposium on 'Blast Furnace Injection' at Woolongong, organised by The Australian Inst. of Mining and Metallurgy, Australia, and To visit and study the commercial Rotary kiln plant for sponge iron production at Auckland (New Zealand) (11-2-72 to 28-2-72)
3. Shri P. K. Bagchi Scientist	Training in Nuclear Electronic Instruments at Electronics Corp. of India Ltd., Hydeerabad and to visit Electronics Division, Bhabha Atomic Research Centre, Trombay, Bombay. (14.4.71 to 8.6.71)
4. Shri R. M. D. Nayar J. T. A.	To participate in short term course in Micro and semi micro chemistry at the Summer Institute, University of Madras. (26.5.71 to 15.6.71)
5. Sri R. Choubey Scientiest	To study the Creep Testing and research development work on high temperature creep resistant alloys at different important research centres at U.K., Belgium and West Germany under United Nations Development (Special Fund) Programme. (29.5.71 to 3.8.71)
6. Shri T. R. Soni S.S.A.	For training in Ultrasonic Testing at the Research, Design & Sandards Organisation, Lucknow. (5.6.71 to 30.6.71)
7. Shri B. K. Saxena Scientiest and 8. Shri C. S. Sivaramakrishnan, Scientist	To attend Summer School in Advanced Metallography, Benaaras Hindu University, Varanasi. (19.6.71 to 19.7.71)

9. Shri P. S. Nag S.L.A.	To participate in the Refresher Course on Corrosion and its Prevention, at the Central Electrochemical Research Institute, Karaikudi. (3.7.71 to 14.8.71)
10. Shri N. V. Naidu Field Officer	To participate in the short term course in Foundry Technology, at the Indian Institute of Technology, Kharagpur. (12.7.71 to 2.10.71)
11. Shri Somnath Kar J.T.A.	Air Conditining Maintenance.
12. Shri V. Srinivasan S.S.A.	Fabrication and shop maintenance.
13. Shri S. R. Paul S.T.A.	Workshop maintenance. Under Maintenance Engg. Course at Jamshedpur Productivity Council, Jamshedpur. (11.8.71 to 27.8.71)
14. Shri N. Chakravorty Scientist	Study in the field of latest trends and developments in the agglomeration techniques in association with the Institution of Advanced Research and Training Centers in Mineral Engineering, Canada. (Under the Colombo Plan). (21.8.71 to 13.3.72)
15. Shri K. N. Srivastava Liaison Offlcer	Short term course in Areas of business, Finance, Maketing, Production Management, Industrial Relation, General Management Organisational behaviour at Xavier Labour Relation Institute, Jamshedpur. (24.8.71 to 30.11.71)

16. Shri K. N. Gupta Scientist and 17. Dr. T. V. Prasad Scientist and 18. Shri S. K. Banerjee Scientist	To participate Special Coure on 'Value Engineering' at Jamshedpur Productivity Council, Jamshedpur. (14.9.71 to 24. 9.71)
19. Dr. A. K. Lahiri Scientist	In the field of Fertilizer Management and Technology with special emphasis on Corrosion/Water treatment. (Under USAID Programme.) (27.10.71 to 28.1.72)
20. Shri G. G. Nair Scientist	Training in Magnesium Melting at Hindusthan Aeronautics Ltd., Bangalore and in Hindusthan Machine Tools, Bangalore. (29.10.71 to 13.12.71)
21. Shri M. N. P. Verma Field Officer	To participate in the advanced course in Foundry Practice, at the Indian Institute of Technology, Kharagpur. (12.11.71 to 18.12.71)
22. Shri M. R. Kulkarni S.S.A.	Training in heat treatment shops & in Central Metallurrgical Laboratory of Telco. (10.1.72 to 5.2.72)
23. Shri B. K. Paul Scientist and 24. Shri A. C. Biswas Scintist	Short term training in the Fuel Testing Technology at CFRI, Jealgora. (18.2.72 to 25.2.72)
25. Shri J. Goswami Scientist	Training in Fuel Analysis and Testing at CFRI, Jealgora. (15.3.72 to 22.3.72)

26. Shri S. M. Arora Scientist	To participate in the Refresher Course on 'Hot-dip Galvanizing' at the Indian Hot-dip Galvanizers' Association, New Delhi. (17.3.72 to 25.3.72)

8.5.6 Laboratory welcomed the following new staff members in its fold during the period.

1.	Shri G. K. Bandyopadhyay	Scientist 'B'	17-5-71
2.	,, Syed Rafiuddin	Chem. Engineer	8-11-71
3.	Mrs. Aruna Bahadur	S.S.A.	31-12-71
4.	Shri Amarendra Kumar Das	J.T.A.	6-1-72
5.	,, Amaresh Kumar Sinha	J.S.A.	14-1-72
6.	,, Baljender Singh	J.S.A.	21-2-72
7.	,, Manas Ranjan Das	J.S.A.	28-1-72
8.	,, R. K. Prashar	J.T.A.	14-2-72

8.5.7 The following staff members were promoted during the period.

1.	Dr. R. Kumar	Promoted as	Scientist 'F'
2.	Dr. Y. N. Trehan	,,	Scientist 'E'
3.	Shri M. K. Ghosh	,,	Scientist 'C'
4.	,, M. C. Kundra	,,	,,
5.	Dr. P. Prabhakaran	,,	,,
6.	Shri S. K. Banerjee	,,	,,
7.	Shri B. K. Guha	,,	,,
8.	,, P. K. Som	,,	,,
9.	,, Narinder Singh	,,	,,
10.	,, K. P. Mukherjee	,,	,,
11.	,, V. Muthukrishnan	,,	,,
12.	,, Gurdial Singh	,,	,,

13.	Dr. A. K. Nayak	Promoted as	Scientist 'C'
14.	Dr. Manjit Singh	,,	,,
15.	Shri P. V. Raman	,,	,,
16.	,, B. L. Sen Gupta	,,	,,
17.	,, A. M. Pande	,,	S.S.A.
18.	,, P. S. Nag	,,	J.S.A.
19.	,, S. K. Sinha	,,	J.S.A.
20.	,, S. P. Chakraborty	,,	J.S.A.
21.	,, R. R. Dash	,,	J.S.A.
22.	Mrs. Sunanda Ghosal	,,	J.S.A.
23.	Shri A. K. Sinha Mahapatra	,,	J.S.A.
24.	,, N. B. Sarkar	,,	J.S.A.
25.	,, D. N. Choudhury	,,	J.T.A.
26.	,, S. C. Dev	,,	J.T.A.
27.	,, Bhaskar Banerjee	,,	J.T.A.

8.5.8 The following staff members were transfered on new assignment.

1.	Shri K. K. Gupta S.S.A.	...	Appointed as Shift-in-Charge in the Magnesium Project of the NML (30-7-71)
2.	Shri J. E. Manner Scientist, C	...	Appointed as Sr. Translating & Abstracting Officer in NSF Project, INSDOC, New Delhi. (on lien) (8-10-1971.)
3.	Shri Ranjit Sinha S.S.A.	...	Appointed as Translating Officer in the NSF Project, INSDOC, New Delhi (on lien) (1-11-71.)
4.	Shri M. R. Pramanik S.L.A.	...	Appointed as J. T. A. in the Magnesium Project of NML (14-12-71.)

5.	Shri A. K. Kanjilal S.L.A.	... Appointed as J. S. A. in National Physical Lab., New Delhi (7-1-72.)
6.	Shri R. M. Krishnad Scientist, E	... Appointed as Industrial Adviser, Iron & Steel Control, Dept. of Steel, Ministry of Iron & Steel, Calcutta. (on lien) (25-12-71.)

8.5.9 The following staff members have resigned from the service.

1.	Shri P. K. Gupta	S.S.A.	31.5.71
2.	Dr. J. K. Mukherjee,	Scientist C	18.8.71
3.	Shri G. Radhakrishnan	S.S.A.	28.8.71
4.	Shri P. B. Chatterjee	S.L.A.	3.9.71
5.	Shri Sri Ram Chaurasia	J.T.A.	12.11.71
6.	Shri G. K. Bandyopadhyay	Scientist B	18.1.72
7.	Shri S. C. Taluja	J.S.A.	14.2.72

8.5.10 The following staff members have retired during the period.

Name/Designation	*Date of Joining*	*Date of Retirement*
1. Shri S. P. Mandal Garden Supervisor	1.7.1950	10.4.1971
2. Shri P. C. Lahiri Assistant	20.9.1948	1.11.1971
3. Dr. C. R. Guha, M.B.B.S. Assistant Surgeon	10.4,1961	31.1.1972

8.5.11 Staff position as on 31.3.1972.

Scientific	Gazetted	...	117
	Non Gazetted	...	74
Technical	Gazetted	...	13
	Non Gazetted	...	355
Administration	Gazetted	...	4
	Non Gazetted	...	120
Class IV	Technical	...	150
	Non Technical	...	115
	TOTAL	...	948

OTHERS

Pool Officers		...	2
Research Fellows	Senior	...	5
	Junior	...	9
Other type of Traines	Graduate Apprentices		24
	TOTAL	...	40

9.0 SYMPOSIA AND SEMINARS

9.1 Seminar on Monolithic Refractories.

A Seminar on 'Monolithic Refractories' was organised jointly by Indian Refractory Makers Association, The Indian Ceramic Society—Jamshedpur Section and National Metallurgical Laboratory, Jamshedpur at the latter place on 22nd to 24th April, 1971. Dr. Atma Ram, Director-General, Scientific & Industrial Research inaugurated the seminar and Sir Jehangir J. Ghandy presided.

Dr. S. S. Ghose, Chairman of the Organising Committee focussed special attention on monolithic refractories over conventional shaped refractories, their advantages and world and Indian trend towards its greater use.

In all 21 technical papers were presented including 4 from NML during the seminar, which covered developments, usage, practical shop floor practice and performance of different monolithic refractories, advantages, costs etc. with lively discussions. A special lecture was delivered by Sri S. Viswanathan, General Superintendent, Tata Iron & Steel Co. Ltd., on 'Scope of monolithic Refractories for Iron & Steel Industries'. An exhibition on 'Monolithic Refractories' products' was also inaugurated during the seminar.

9.2 Creation and Transfer of Metallurgical Know how : UNIDO workshop.

An international workshop on 'Creation and Transfer of Matallurgical Know how' organised by United Nations Industrial Development Organisations (UNIDO) in co-operation with National Metallurgical Laboratory, Jamshedpur was held at NML from 7 to 11 December, 1971. The workshop was inaugurated by Shri S. K. Nanavati, Managing Director, Tata Iron & Steel Co. Ltd., Jamshedpur.

The participants at the workshop included nine experts from various countries, besides twenty five metallurgists from developing countries and experts from private and public sector industries in India, acted as fellows and observers. Representatives from UNIDO at the Workshopincluded Dr. L. C. Correagapde Silva, Chief, Metallurgical Industries Section and Dr. B. R. Nijhawan, Senior Inter-Regional Adviser, who was also the Officer-in-Charge of the Workshop. Prof. V. A. Altekar acted as Rapporteur. Mr. L. Takats of Hungary and Mr. M. K. Hussein of Arab Republic of Egypt were declared elected as Chairman and Vice-Chairman for the workshop.

The workshop discussed problems concerning the difficulties, modus operandi and objectives for the creation of specialised metallurgical expertise and technical know-how and pre-requisites for establishment of metallurgical industries in developing countries. The workshop has recorded ten principal recommendations which includes :

Increasing technical self sufficiency for the developing countries for which UNIDO should act as antenna in ensuring that the transfer of metallurgical know-how leads to the development of technical consultancy. Repetitive import of know-how be avoided and where technology is imported, it should be improved upon and modified to indigenous conditions to develop local talent. Local talents must be developed and harnessed to become technically self-sufficient. UNIDO should also assist in the formulation of development programmes in metallurgical industries and techno-economic evaluation of new metallurgical projects and sponsor the preparation of detailed project reports and should catalyze the establishment of metallurgical technology centres and in expansion of such centres in specialized fields where these already exist, also assist in training programmes to creat trained metallurgical cadres for effective implementation of the know-how transfered. UNIDO should also provide necessary technical experts and technical consultancy services for the growth and development of metallurgical industries in developing countries.

9.3 Convention of Indian Institute of Mineral Engineers.

The fourth Annual Technical Convention of the Indian Institute of Mineral Engineers (IIME) jointly organised by IIME and National Metallurgical Laboratory (NML) Jamshedpur, was held on 19 to 20 February 1972 at N.M.L.

The Convention was inaugurated by Dr. B. D. Nag Chowdhury, Scientific Adviser to the Union Minister for Defence & Director General, Defence Researeh & Development Organisation.

The Convention focussed particular attention on the importance of beneficiation and agglomeration of ores for the development of mineral based industries.

Eighteen technical papers including six from NML were presented during the convention and discussed. There was five special lectures delivered by experts in different aspects. Over hundred delegates from various research organisations, Government departments and industries attended the Seminar.

9.4 Standardization in Foundries : Foundry Convention and Seminar.

The twenty-second Annual Foundry Convention and a Seminar on Standardization in Foundries, organised jointly by the Institute of Indian Foundrymen (I.I.F), the National Metallurgical Laboratory, Jamshedpur (N.M.L) and the Indian Standard Institution (ISI) were held at NML, Jamshedpur, from 26th to 28th February, 1972.

Shri S. Mohan Kumarmangalam, Union Minister for Steel & Mines, inaugurated the Convension. Mr. F. A. A. Jasdanwalla, President, I. I. F., presided.

The subject of the Convention and the Seminar was to provide a forum for the foundry technologists, metallurgists and scientists to discuss the present status of the foundry technology in India and the benefits derived by the foundry by the introduction of standardisation and utilization of the results of recent researches aimed at import substitution and export promotion.

Three papers on standardisation in foundries and fourteen papers including three from NML on topics of interest to the foundry industry were presented and discussed at the technical session of the convension. About 200 delegates from Foundries, Government Departments, Scientific Organisations and Research Institutions have attended the annual convention and seminar. Sri S. Bhoothalingam, Director-General, National Council of Applied Economic Research, has delivered a special lecture.

9.5 Special events.

9.5.1 The foundation stone of the Central Creep Testing Facility (being set up at the NML, Jamshedpur with UNDP assistance as a Special

Fund Project) was laid by Dr. Atma Ram, Director-General, Scientific & Industrial Research on 22nd April, 1971.

9.5.2 A pilot plant for the production of 500 kg/day low ash content dense carbon aggregates based on a process developed at NML, was inaugurated by Dr. Atma Ram, Director-General, Scientifie & Industrial Research, on 22nd April, 1971.

9.5.3 The 20-30 tonne/hr Heavy Media Separation Plant, (a gift from House of Tatas, as a token of appreciation of the services rendered by the NML on beneficiation studies of raw materials of Tata Iron & Steel Co Ltd.), was inaugurated by Shri H. C. Sarin, Secretary, Department of Steel, Ministry of Steel & Mines, Government of India on 5th May, 1971.

APPENDIX I

Papers Published, Presented and Communicated

Papers published in *NML Technical Journal* Vol. 13, February 1971.

1. *Impact of Melting Procedures on Foundry Technology of Aluminium*— C. S. Sivaramakrishnan, K. M. Chowdary & Rajendra Kumar.

2. *Studies on Mould Wall Movement of Nodular Iron Castings in Green Sand Mould*—R. R. Dash, R. K. Dubey & P. K. Gupte.

3. *Effect of Titanium, Aluminium & Other Additions on the Solidification & Structure of Steel Ingots*—K. N. Gupta.

4. *Inoculation of Cast Iron*—G. N. Rao & P. K. Gupte.

5. *Corrosion of Mild Steel in the Marine Atmosphere at Digha*—S. Rao Addankai & A. K. Dey.

Papers published in *NML Technical Journal*, Vol. 13 May 1971.

6. *Central Creep Testing Faciliiy at the National Metallurgica Laboratory.*

7. *Fluidized Bed Roasting of Zinc Sulphide Concentrates-Some Equiii-brium Considerations*—S. R. Srinivasan & P. P. Bhatnagar.

8. *Increase in Casting Yield by Use of Exothermic Riser*—G. N. Rao & P. R. Prasad.

9. *Some Observations on Ausforming of High-Carbon High-Chromium Die Steel*—S. P. Chakravorty, R. K. Dubey & P. K. Gupte.

10. *Preparation of Aluminium Fluoride*—M. L. Dey & Gurdial Singh.

Paper published in *NML Technical Journal*, Vol. 13 August 1971.

11. *Studies on the Mechanical Properties of Ni-Mn Maraging Steels*— J. K. Mukherjee.

12. *Development of Magnectic Materials at the National Metallurgical Laboratory*—Ved Prakash.

13. *Form of Hydrogen in Steel*—J. Konar & N. G. Banerji.

14. *Some Observetions on Isothermal Ageing Behaviour of Wrought Al-Mg-Si Alloys*—C. Sharma & S. Pramanik.

15. *Some Experiences in Melting with Electron Beam Melting Furnace*—N. K. Das & L. J. Balasundaram.

16. *Sponge iron process may help raise India's steel industry*—V. A. Altekar & C. Sharma, *Annual number, Eastern Metals Review*, April, 1971.

17. *Micro structure and properties of chrome-magnesite refractories from indigenous raw materials*—N. N. Mathur, M. R. K. Rao & P. C. Sen, *Trans. of Indian Cerm. Soc.* XXIX No 6 1970, 151-165.

18. *Structure of some 17% Cr-Mn-N stainless steel*—P. L. Ahuja, B. N. Halder & S. S. Bhatnagar, *Jr. of Material Science*, June 1971, 439.

19. *The Development of shellac as a binding materials in foundry*—T. A. Beck, R. K. Dubey & P. K. Gupte, *Indian Fdy. Jr.*, April, 1971.

20. *Pressure dependence of oxidation rate of Cu-40 Mn alloys at 800°C*—P. K. Panda, A. K. Lahiri & T. Banerjee, *Scripta Metallurgia*, 5, 1971, 677.

21. *Plastic and protective coatings in chemical industry*—A Review—P. Prabhakaran & V, A. Altekar, *Trans. of SAEST*, 6, Oct-Dec. 1971.

22. *Corrosion Problem in chemical industries—Some case studies*—S. R. Addanki, K. P. Mukherjee & A. K. Lahiri, *Trans. of SAEST*, 6, Oct-Dec. 1971.

23. *A study of grain size control in aluminium and aluminium alloy ingots and castings*—Rajendra Kumar, *The British Foundrymen*, 65, Feb. 1972.

24. *Kinnetics of selective chlorination of ilmenite using hydrogen chloride in fluidized bed*—A. S. Athavale & V. A. Altekar, *I & E C Process Des. & Dev. American Chem. Soc.* Vol. 10, 4, 1971.

25. *Prospect of the development of Minerals and metals industries in Bihar, Spl. Supplement 'Statesman'*, January 22, 1972.

26. *Mechanical properties of explosively cladded plates*—S. K. Banerjee & B. Crossland, *Metal Const. & Br. Weld. Jr.*, July, '71.

27. *Some metallurgical problems in welding*—B. N. Das, *Ind. Welding Jr.* Sept. 1971.

28. *Technological development in explosive welding of metals*—S. K. Banerjee, *Ind. Welding Jr.*, Sept. 1971.

29. *Some aspects of stainless steel corrosion*—K. P. Mukherjee, A. K. Lahiri & V. A. Altekar, *Chemical Age of India,* 22 (11) 1971.

30. *Grain refinement by short austenitising treatments*—P. Chakravarty, R. Chattopadhya, B. K. Guha & S. S. Bhatnagar, *Trans. Indian Inst. of Metals*, 24, Dec. '70.

31. *Recrystallisation of rapidly solidified aluminium-copper alloys—a metallographic study*—S. K. Bose & Rajendra Kumar, *Trans. Indian Inst. of Metals*. 23, Dec. 1970.

32. *Metallurgical research in India*—V. A. Altekar, *112th Anniversary number, The Indian & Eastern Engineer,* 1971.

33. *Influence of liquidus on the stability of liquid eutectic systems*—Rajendra Kumar & C. S. Sivaramakrishnar, *Trans. Ind. Inst. of Metals,* 23, Dec. 1970.

34. *Electro-aluminising of mild steel*—N. L. Nichani, V. A. Altekar & A. S. Athavale, *Trans. of Ind. Inst. of Metals,* 24, March 1971.

35. *Structure and properties of copper-chromium maraging steel with niobinm and molybdenum*—R. Chattopadhyay, B. K. Guha & S. S. Bhatnagar, *Trans. Indian Inst. of Metal,* 24, June 1971.

36. *Thermodynamic analysis of Mg-Sn alloys*—A. K. Nayak & W. Oelsen, *Trans. Ind. Inst. of Metals* 24, June 1971.

37. *Determination of the heats of formation of the solid and liquid Mg-Sn alloys at 20° and 800°C respectively and the heat content of the alloys at 800°C*—A. K. Nayak & W. Oelsen, *Trans. Ind. Inst. of Metals,* 24, June 1971.

38. *The effect of iron additions on the magnetic propreties of Co-15% Al alloy*—C. R. Tiwari & Ved Prakash, *Trans. Ind. Inst. of Metals,* 24, Sept. 1971.

39. *An equation for (equilibrium) vapour pressures of metals from kinetic theory of gases*—L. J. Balasundaram, *Trans. Ind. Inst. of Metals,* 24, Dec. 1971.

40. *Vinyl coatings in progress*—P. Prabhakaram & V. A. Altekar, *Trans. Ind. of Metals*, 24, Dec. 1971.

41. *Studies on suitability of Rampur sand for steel foundry use*—A. Das, A. Dutta, G. N. Rao & P. K. Gupte, *Foundry News*, 3, March 1972.

42. *Fe-Ti alloys : New high hardness materials*--S. P. Mukherjee & Rajendra Kumar, *Proc. of Seminar on Newer Materials for industrial application*, 1971.

43. *An appraisal of metal casting science*—C. S. Sivaramakrishnan & C. C. Ojha, *Foundry News*, 2, Nov. 1971.

44. *Co-efficient of thermal expansion of Pb-Sn and Pb-Cd-alloys*—L. J. Balasundaram & A. N. Sinha, *Jr. Appl. Phys*, 42, 1971, 5207.

45. *Importance of research & development*—V. A. Altekar, *Economics Times*, February 26, 1972.

Papers communicated for publication :

46. *Impact of research on foundry industry*—V. A. Altekar & R. M. Krishnan, *Ind. Jr. of Engineers, Calcutta*, Fdy. No.

47. *How to raduce scrap castings*—G. N. Rao & P. K. Gupte, *Indian Jr. of Engineers, Calcutta, Fdy. No.*

48. *Effect of manganese on the magnetic properties of Co-14% Al alloys*—Ved Prakash & C. R. Tiwari, *Trans. Ind. Inst. of Metals.*

49. *Material selection, design and inspection against corrosion in chemical industry*—A. K. Lahiri, *Dye-Chem. Sphere.*

50. *Sintered maraging alloys*—J. K. Mukherjee, *Scripta Metallurgia, U.S.A.*

51. *Studies on nickel-manganese maraging steels*—J. K. Mukherjee, *Jr. of Iron & Steel Inst., London.*

52. *Hydrogen absorption by cold rolled steel in inhibited sulphuric acid*—Inder Singh, A. K. Lahiri & T. Banerjee, *Ind. Jr. of Technology, New Delhi.*

53. *Immiscibility in binery alloys of Group 1B metals (copper, silver, gold)—A semi emperical approach*—R. Kumar, *Jr. of Material Science, U.K.*

54. *Immiscibility in binary alloys of Group 1A metals (lithium, sodium, potassium)*—R. Kumar, *Jr. of Met. Science, U.K.*

55. *A study of solidification of Al and Al-Cu alloys by anodic oxidation technique*—Mrs. A. Bahadur & R. Kumar, *Intn. Jr. of Metallography.*

56. *Metallographic studies of raptdly salidified Al-Cu alloys*—R. Kumar & S. K. Bose. *Jr. Intn. Metallo. Soc., U.S.A.*

57. *Thermal expansian of copper-manganese alloys*—A. N. Sinha & L. J. Balasundaram, *Trans. Ind. Inst. of Metals.*

58. *Sodium silicate bonded sands*—A. Dutt, G. N. Rao & P. K. Gupte, *Jr. of Inst. of Ind. Foundrymen.*

59. *Electro-deposited nickel-alumina composites*—P. K. Sinha, N. Dhananjayan & H. K. Chakravarti, *Plating Jr. of American Chem. Soc. U.S.A.*

60. *Powder metallurgy*—S. K. Singh, *Vigyan Pragati, CSIR, New Delhi.*

61. *Recovery of mercury from effluents*—S. B. Mathur, N. Singh, M. J. Shahani & V. A. Altekar, *Chem. Age. of India., Bombay.*

62. *Tin free steel*—A. K. Sinha Mahapatra, N. Dhananjayan & V. A. Altekar, *Eastern Metals Review, Annual number* 1972.

Papers presented at the Seminar on 'Monolithic Refractories' Jamshedpur, April 1971.

63. *Composition and phase relationships in high alumina cement and castables*—M. R. K. Rao.

64. *Properties of some Indian refractory plastics and castables*—A. K. Bose & T. V. Prasad.

65. *Design, production and use of some high alumina castables*—M. C. Kundra & H. P. S. Murthy.

66. *Some experiments on phosphate bonded high alumina mixes*, M. C. Kundra & H. P. S. Murthy.

Presented at the Symposia on 'The Problems of raw materials for metallurgical and chemical industries', Ranchi, May 1971.

67. *Development of Industrial raw materials at the NML*—G. P. Mathur & V. A. Altekar.

Papers presented at the Symposium on 'Corrosion in Chemical Industries', Madras, June 1971.

68. *Corrosion problem in chemical industies—Some case studies*—S. Rao Addakani, K. P. Mukherjee & A. K. Lahiri.

69. *Methods for inspection of proeess equipments against corrosion damage*—A. K. Lahiri.

Presented at the Seminar on 'Modern Technologies', Calcutta, June 1971.

70. *Scope of Mini-Steel plants based on sponge iron,*—A. B. Chatterjea & V. A. Altekar.

Papers presented at the Seminar on 'Newer Materials for Industrial application', Bangalore, Sept. 1971.

71. *Fe-Ti alloys—New high hardness materials*—S. P. Mukherjee & R. Kumar.

72. *Clad metals and their industrial applieations*—B. N. Das.

Presented in the Symposia 'On Corrosion resistance of copper and its alloys', Bombay, October 1971.

73. *Corrosion testing methods and interpretation of data*—A. K. Lahiri.

Papers presented at the Symposia on 'Application of Stainless Steel in Design & Fabrication for Chemical and Process Industries', Durgapur, October, 1971.

74. *Some aspects of stainless steel corrosion*—K. P. Mukherjee, A. K. Lahiri & V. A. Altekar.

75. *Application of stainless steel in design and fabrication for chemical and process industries*—K. P. Mukherjee.

Presented at the Technical Session on 'Role of Additional Agents in Metal Deposition and Corrosion inhibition', Madras, Tamilnadu, Nov. 1971.

76. *Acid inhibition of miid steel in presence of Thioureae*—Inder Singh & A. K. Lahiri.

Presented on the 9th Metallurgist day Celebration, Bangalore, November 1971.

77. *Prospects of small scale metullurgical industries—Role of NML in their development*—K. N. Srivastava & S. N. Pandey.

Presented in the Seminar 'Workshop on Creation and Transfer of Metallurgical Know-how', Jamshedpur. Dec. 1971.

78. *The role of research and development work and pilot plants in the creation and transfer of metallurgical know-how in developing countries and regions*—V. A. Altekar.

Papers presented at the 25th Annual Technical Meeting and Silver Jubilee Celebration of Indian Institute of Metals, New Delhi, February 1972.

79. *Grain refinenement in steels,*—R. Chattopadhya, B. K. Guha & S. S. Bhatnagar.

80. *Embrittlement of high carbon steel in inhibited acid*—Inder Singh, A. K. Lahiri & V. A. Altekar.

81. *Nature of high temperature scale formed during oil ash corrosion*—H. R. Thilakan & A. K. Lahiri.

82. *Production of molten pig iron from fine grained iron ore, fuel and limestone*—R. Santok Singh, P.S. Virdhi & A. B. Chatterjea.

83. *Co-efficient of thermal expansion of copper—manganess alloys*—L. J. Balasundaram & A. N. Sinha.

84. *Studies on chlorination, Magnesite*—S. K. Roychowdhury, S. C. Aush & P. K. Som.

85. *Recent trends in ilmenite benefication*—C. Sankaran, P. P. Bhatnagar & V. A. Altekar.

86. *Recent trends in nickel extraction technology*—Prem chand, V. S. Sampath, P. P. Bhatnagar & V. A. Altekar.

87. *17% Cr-Mn-N stainless steels*—S. S. Bhatnagar & B. R. Nijhawan.

88. *Some observations on the production of iron powder by atomisation*—J. Goswami, S. B. Ghosh, A. B. Chatterjea, & V. A. Altakar.

89. *Some experience on direct reduction with non coking coals in rotary kiln*—V. A. Alterkar, A. B. Chatterjea, K. N. Gupta, G. P. Mathur & A. N. Kapoor.

Papers presented at the Symposia on 'Nuclear Physics and Solid State Physics', Hyderabad, February, 1972.

90. *Thermal expansion of Bismuth-Tin and Bismuth-Lead alloys*—L. J. Balasundaram & A. N. Sinha.

91. *Saturation magnetization of Cobalt-Aluminium-Manganese alloys*—Ved Prakash & C. R. Tiwari.

Papers presented at the 4th Annual Technical Convention, Indian Institute of Mineral Engineers, Jamshedpur. Feb. 1972.

92. *Beneficiation of a complex Cu-Pb-Zn ore from Dariba—Rajpura, Rajasthan*—P. V. Raman, S. K. Sengupta & G. P. Mathur.

93. *Heavy media hydrocyclones in mineral beneficiation*—D. M. Chakravarti.

94. *Pelletization as a process of agglomeration for Indian iron ore fines with particular reference to Donamalai & Bailadila ores*—B. L. Sengupta & G. P. Mathur.

95. *Benefication studies with pyrite-pyrrhotite samples from Saladipura, Rajasthan*—P. D. Prasada Rao, C. Satyanarayana, K. Vilayaraghvan & G. P. Mathnr.

96. *Beneficiation studies of low grade molybdenite samples from Tamilnadu*—C. Satyanarayana, S. K. Banerjee & G. P. Mathur.

97. *An infra red study of the adsorbed species of lead minerals with xanthate-dixanthogens*—M. S. Prasad.

Papers presented at the 22nd Annual Convention of the Institute of Indian Foundrymen, Jamshedpur, Feb. 1972.

98. *Impact of modern metallurgical concepts in metal castings*—R. K. Mahanty, C. S. Sivaramakrishnan, Manjit Singh & Rajendra Kumar.

99. *Some Observations on Cr-Mn-Ti martensitic white cast iron*—R. R. Dash, G. G. Nair, R. K. Dubey and P. K. Gupte.

100. *Sodium silicate-bonded sand*—Ashimesh Dutta, G. N. Rao & P. K. Gupte.

Papers communicated for presentation at the 2nd South American Symposium on 'Corrosion', Brazil, Nov. 1971.

101. *Role of Heterocyclic group of inhibitors on metal dissolution and hydrogen pick up by steel during pickling and cathodic charges*—Inder Singh, A. K. Lahiri and V. A. Altekar.

102. *Some observations on properties of rust formed on plain carbon and low alloy steel*—A. K. Lahiri, K. P. Mukherjee and S. Rao Addanki.

103. *Stress corrosion cracking of homogenous copper alloys*—A. K. Lahiri and U. K. Chatterjee.

Communicated for presentation on the Silver Jubilee of Indian Standard Institution, New Delhi, April 1972.

104. *Importance of Indian standards and role of NML in their development*—K. N. Srivastava.

Papers communicated for presentation at the 5th International Congress on 'Metallic Corrosion', Tokyo, Japan, May 1972.

105. *Inhibition of acid corrosion and hydrogen absorption in presence of some mercaptans*—V. A. Altekar, Inder Singh & A. K. Lahiri.

106. *Oxydation of copper-manganese alloys at 700-900°C*—A. K. Lahiri, P. K. Panda and T. Banerjee.

Papers communicated for presentation in the Symposium on 'Industrial Metallurgy', Silver Jubilee Celebration, Indian Institute of Science, Bangalore, May 1972.

107 *Structure and modification of Al-Si alloys*—Manjit Singh and Rajendra Kumar.

108. *Recovery of stacking fault nodes in Cu-8.36 wt. % Al alloy during annealing*—S. K. Bose, M.M.F. Denonot & J. Caisso.

109. *Selenium in Xerography*—Narinder Singh & W. Stronczak.

110. *High strength Fe-Al-Si & alloys*—N. K. Das and L. J. Balasundaram.

111. *Problems of research utilisation,*—K. N. Srivastava and S. N. Pandey, For presentation on Panel discussion on Metallurgical Education and Research during Silver Jubilee celebration.

APPENDIX II

Scientific Investigations & Reports

1. Reclamation of corroded dynamo stampings—A. K. Lahiri (I.R 616/71)

2. Recovery of metallics from the furnace dross samples of M/s. Kamani Metals & Alloys Ltd., Bombay—V. R. K. Sharma, S. K. Banerjee & G. P, Mathur (I. R 617/71)

3. Moulding characteristics of sand sample No. UPSS 4, received from Director of Geology & Mining, Lucknow.—R. C. Arora, M. N. P. Verma, G. N. Rao & P. K. Gupte (I. R 618/71)

4, Moulding characteristics of sand sample No. UPSS 5, received from Director of G. & M., Lucknow—R. C, Arora, M.N.P. Verma, G. N. Rao & P. K. Gupte (I.R. 619/71)

5. Moulding characteristics of sand sample No. UPSS 6, received from Director of G. & M., Lucknow—R. C. Arora, N. M. P. Verma, G. N. Rao & P. K. Gupte (I. R 620/71)

6. Moulding characteristics of sand sample No. UPSS 7, received from Director of G. & M., Lueknow—R. C. Arora, M. N. P. Verma, G. N. Rao & P. K. Gupte (I.R 621/71)

7. Moulding characteristics of sand sample No. UPSS 8, received from Director of G. & M., Lucknow—R. C. Arora, M. N. P. Verma, G. N. Rao & P. K. Gupte (I.R 622/71)

8. Moulding characteristics of sand sample No. UPSS 9, received from Director of G. & M., Lucknow—R. C. Arora, N. M. P. Verma, G. N. Rao & P. K. Gupte (I.R· 623/71)

9. Moulding characteristics of sand sample No. GSS 1, collected by NML Foundry Station, Batala—R. C. Arora, M. N. P. Verma, G. N. Rao & P. K. Gupte (I.R 624/71)

10. Moulding characteristics of sand sample No. G. S. I. (ix)—K. S. Vijayanarayanan, N. V. Naidu, G. N. Rao & P. K, Gupte (I.R 625/71)

11. Moulding characteristics of sand sample No. G. S. I. (x)—K. S. Vijayanarayanan, N. V. Naidu, G. N. Rao & P. K. Gupte (I.R 626/71)

12. Moulding characteristics of sand sample No. G. S. I. (xii)—K. S. Vijayanarayanan, N. V. Naidu, G. N. Rao & P. K. Gupte (I.R. 627/71)

13. Beneficiation of low grade phosphate rock (Sample No. 5) from Jamar Kotra area, Udaipur Dt., Rajasthan—S. Prasad, S. K. Banerjee & G. P. Mathur (I.R 628/71)

14. Study of grinding characteristics of Diamondiferrous tuff sample from M/s. Diamond Minlng Project, Panna (M.P)—V. R. K. Sharma, S. C. Maulik & G. P. Mathur (I.R 629/71)

15. Utilisation of Joda ferro manganese salg for production of electrolytic manganese metal—A. M. Pande, P. L. Sengupta & N. Dhananjayan (I.R 630/71)

16. Discolouration of copper tapes used for coaxial cables—A. N. Mukherjee & A. K. Lahiri (I.R 631/71)

17. Pilot plant studies on beneficiation and pelletization of iron ore samples from deposit No. 14 of Bailadila mines of NMDC Ltd. —P. K. Sinha, R. K. Kanwar, Joga Singh, N. Chakravarty & G. P. Mathur (I. R 632/71)

18. Beneficiation of low grade molybdenite sample (L2) from Karadikuttam, Madurai Dist., Tamil Nadu—C. Satyanarayanan, S. K. Banerjee & G. P. Mathur (I. R 633/71)

19. Beneficiation studies on Bolani ore fines received from Bolani Ores Ltd., Orissa—B. L. Sengupta & G. P. Mathur (I. R 634/71)

20. Determination of micro-hardness of case-carburising steel samples received from M/s. Tisco Ltd., Jamshedpur Part I.—P. D. Prasada Rao, A. Peravadhanulu & G. P. Mathur (I. R 635/71)

21. Beneficiation studies on a low grade molybdenite sample (L—3) from Palnitaluk, Madurai Dist., Tamil Nadu—M. V. Ranganathan, S. K. Banerjee & G. P. Mathur (I. R. 636/71)

22. Beneficiation of a Beach sand sample from Gujarat—N. Chakravory & G. P. Mathur (I. R. 637/71)

23. Investigation report on the utilisation of high manganese slag from the ferro-manganese plant of M/s Khandelwal Ferro Alloys Ltd. for production of electroytic manganese metal.—A. M. Pande, P. L. Sengupta & N. Dhananjayan (I. R. 638/71)

24. Investigation report on the utilisation of Zinc ash, formed as a by product in the galvanising plant of M/s Khandelwal Tubes, Kanhan—S. C. Aush, P. K. Sinha & N. Dhananjayan (I. R 639/71)

25. Investigation report on studies on physical characteristics of $-40+10$ mm size lumpy iron ores from Kiriburu and Barajamda for Bokaro Steel Plant—Joga Singh, P. K. Sinha & G. P. Mathur (I. R 640/71)

26. Petrological studies on the high grade kyanite-sillimanite samples of Dahagaon mines, Bhandara Dt., Maharashtra & Calcined kyanite sample from Japan received from M/s. Maharashtra Minerals Corpn. Ltd., -A. Peravadhanulu, B. Banerjee & G. P. Mathur (I. R 641/71)

27. Beneficiation studies on a kyanite-sillimanite sample from Maharashtra Minerals Corpn. Ltd.,—K. Vijayaraghavan, P. V. Raman & G. P. Mathur (I. R 642/71)

28. Beneficiation of low grade molybdenite sample (L—1) from Karadikuttam, Madurai Dist., Tamil Nadu—C. Satyanarayanan, S. K. Banerjee & G. P. Mathur (I. R 643/71)

29. Investigation report on studies on the suitability of manganese ore supplied by Mysore State Industrial Development Corpn. for production of electrolytic manganese metal—A. M. Pande, P. L. Sengupta & N. Dhananjayan (I. R 644/71)

30. Investigation on experimental rolling of niobium steeel—B. N. Das, G. D. Sani & K. S. Rajan (I. R 645/71)

31. Investigation on impact properties of three types of steel—B. N. Das, T. R. Soni & K. S. Rajan (I. R 646/71)

32. Beneficiation studies on a low grade rock phosphate sample from Karbaria block, Udaipur Dist., Rajasthan—S. K. Sengupta, S. K. Banerjee & G. P. Mathur (I. R 647/71)

33. Moulding characteristics of Beldhaura sand, Dist. Burdwan, West Bengal—Amitava Das, Ashimesh Dutt, G. N. Rao & P. K. Gupte (I. R. 648/72)

34. Moulding characteristics of Narandhaura sand, Dist. Burdwan, W. Bengal—Amitava Das, Ashimesh Dutt, G. N. Rao & P. K. Gnpte (I. R. 649/72)

35. Moulding characteristics of Nonia Nala sand, Dist. Burdwan, W. Bengal—Amitava Das, Ashimesh Dutt, G. N. Rao & P. N. Gupte (I. R. 650/72)

36. Moulding characteristics of Domodar sand (Pt. II) Dist. Burdwan, W. Bengal—Amitava Das, Ashimesh Dutt, G. N. Rao & P. K. Gupte (I. R. 651/72)

37. Moulding characteristics of Damodar sand (Pt. I) Dist. Burdwan, W. Bengal—Amitava Das, Ashimesh Dutt, G. N. Rao & P. K. Gupte (I. R. 652/72)

38. Moulding characteristics of Purusattampur sand, Dist. Burdwan, W. Bengal—Amitava Das, Ashimesh Dutt, G N. Rao & P. K. Gupte (I. R. 653/72)

39. Moulding characteristics of Dehika sand, Dist. Burdwan, W. Bengal —Amitava Das, Ashimesh Dutta, G. N. Rao & P. K. Gupte (I. R. 654/72)

40. Moulding characteristics of Damodarpur sand (Pt. I) Dist. Burdwan, W. Bengal—Amitava Das, Ashimesh Dutta, G. N. Rao & P. K. Gupte (I. R. 655/72)

41. Moulding characteristics of Ajoy river sand (Pt. I) Dist. Burdwan, W. Bengal—Amitava Das, Ashimesh Dutt, G. N. Rao & P. K. Gupte (I. R. 656/72)

42. Moulding characteristics of Ajoy river sand (Pt. II) Dist. Burdwan, W. Bengal—Amitava Das, Ashimesh Dutt, G. N. Rao & P. K. Gupte (I. R. 657/72)

43. Moulding characteristics of Ajoy river sand (Pt. III) Dist. Burdwan, W. Bengal—Amitava Das, Ashimesh Dutt, G. N. Rao & P. K. Gupte (I. R. 658/72)

44. Moulding characteristics of Phuljhari sand (Pt. I) Dist. Burdwan, W. Bengal—Amitava Das, Ashimesh Dutta, G. N. Rao & P. K. Gupte (I. R. 659/72)

45. Moulding characteristics of sand sample No. ASS 1 collected by NML Field Station, Batala—R. C. Arora, M. N. P. Verma, G. N. Rao & P. K. Gupte (I. R. 660/72)

46. Moulding characteristics of Surajdeval sand—P. R. Shastry, R. Prasad, G. N. Rao & P. K. Gupte (I. R. 661/72)

47. Petrological investigation on phosphorite sample from Durmala, Massoorie area, U. P., received from IIT, Kanpur—Bhaskar Banerjee, A. Peravadhanulu & G. P. Mathur (I. R. 662/72)

48. Studies on suitability of Rampur sand for steel foundry use—Amitava Das, Ashimesh Dutta, G. N. Rao & P. K. Gupte (I. R. 663/72)

49. Determination of work indices on three iron ore concentrate samples from Kudremukh, NMDC—K. Vijayaraghavan, P. V. Raman & S. K. Banerjee (I. R. 664/72)

50. Determination of bond's work index and rates of settling on (i) an iron ore concentrate and (ii) tailing from Kudremukh—K. Vijayaraghavan, M. L. Viswakarma & G. P. Mathur (I. R. 665/72),

51. Testing of xanthate samples received from M/s. Polychem Industries, Ranchi—M. V. Ranganathan, P. V. Ramau & S. K. Banerjee (I.R, 666/72).

52. Recovery of scheelite from Walker's dump, Kolar Gold Fields, Mysore—R. K. Kanwar, P. V. Raman & G. P. Mathur (I.R. 667/72).

53. Beneficiation of low grade wolframite from Degana, Rajasthan —D. M. Chakravarty, R. K. Kunwar & G. P. Mathur (I.R 668/72)

54. Studies on ammonical pressure leaching of bulk Ni-Cu-Mo sulphide concentrate—A. K. Saha, M. S. Mahanty, D. S. Tandon & P. P. Bhatnagar (I.R 669/72)

55. Determination of microhardness of carburized steel specimens received from M/s. Tata Iron & Steel Co. Ltd., Jamshedpur (Pt. II) —P. D. Prasada Rao, A. Peravadhanulu & S. K. Banerjee (I.R 670/72)

56. Metallographic studies of rapidly solidified Al-Cu alloys—Rajendra Kumar & S. K. Bose (R.R 289/71)

57. Second order traasformation in liquid metals and alloys —DTA Study —Rajeadra Kumar & G. Misra (R.R 290/71)

58. Thermal expansion coefficients of some low melting point alloys—L. J. Balasundaram & A. N. Sinha (R.R 291/71)

59. A study of grain size coatrol in aluminium and aluminium alloy ingots and castings—Rajendra Kumar (R.R 292/71)

60. Some experiments on phosphate bonded high alumina mixes—M. C. Kundra & H. P. S. Murthy (R.R 293/71)

61. Design, preparation and use of some high alumina castables—M. C. Kundra & H. P. S. Murthy (R.R 294/71)

62. Preparation of Aluminium fluoride—M. L. Dey & Gurdial Singh (R.R 295/71)

63. Extraction of selenium from slimes of copper electrolysis by sulphuric acid roasting—Narinder Singh & S. B. Mathur (R.R 296/71)

64. Extraction of Tellurium from anode slimes obtained from copper electro-refining—Narinder Singh & S. B. Mathur (R.R 297/71)

65 Properties of some Indian refractory plastics and castables—A. K. Bose & T. V. Prasad (R.R. 298/71)

66. Sintered maraging alleys—J. K. Mukherjee (R.R 299/71)

67. Studies on nickel-manganese maraging steel—J. K. Mukherjee (R.R 300/71)

68. Investigation report on the iron melting in a cupola with arrangement for preheating the air blast by effluent gas—R. Santok Singh & A. B. Chatterjea (R.R 301/71)

69. The oxidation characteristics of pre-reduced iron ore pellets at room temperature—S. R. Ghosh, K. C. Ghosh & A. N. Kapoor (R.R 302/71)

70. A study of solidification of Al & Al-Cu alloys by anodic oxidation technique—Mrs Aruna Bahadur & R. Kumar (R.R 303/72)

71. High temperature thermo-mechanical treatment (hot-cold working) of some low alloy steels—J. K. Mukherjee (R.R. 304/72)

72. Studies on the mechanical properties of Ni-Mn maraging steels—J. K. Mukherjee (R.R 305/72)

73. Immiscibility in binary alloys of group 1A metals (lithium, sodium and potassium)—Rajendra Kumar (R.R 306/72)

74. Immiscibility in binary alloys of group IB Metals (copper, silver, aad gold)—A semi empirical approach—Rajendra Kumar (R.R. 307/72)

75. An appraisal of the beneficiation and sintering characteristics of some of the low grade maaganese ores with special refereace to the ores of Bihar and Orissa—B. L. Sengupta & G. P. Mathur (S.R. 183/72)

76. How to reduce scrap castings—G. N. Rao & P. K. Gupte (S. R. 184/72)

77. Pelletisation as a process of agglomeration for Indian/Iron ore fines with refcrence to Donimalai and Bailadila ores—B. L. Sengupta & G. P. Mathur (S. R. 185/72)

78. Structure of liquid metals and alloys—Rajendra Kumar (L.R. 88/72)

APPENDIX III

Patents & Process

(a) Patents field :

1. Indian Patent No. 131021	A method for treatment of the oxidised zinc dust or zinc blowings to preferentially remove the oxide coating—Shri G. Basak, Shri V. S. Sampath & Shri P. P. Bhatnagar.
2. Indian Patent No. 131607	A process for selective reduction of iron oxides in complex ores —Prof. V. A. Altekar.
3. Indian Patent No. 131637	A process for production of sponge iron—Prof. V. A. Altekar.
4. Indian Patent No. 131685	An improved method relating to the extraction of Nickel and cobalt values from oxidised (lateritic) ores—Shri C. Sankaran, Shri M. S. Mahanty & Prof. V. A. Altekar.
5. Indian Patent No. 131823	A simple heat-exchanger for preheating the air in cupola—Dr. A. B. Chatterjea & Shri R. Santokh Singh.
6. Indian Patent No. 133700	Fe-Ti alloys—New high hardness materials—Dr. R. Kumar & Shri S. P. Mukherjee.

7. Indian Patent No. 134377 — Improvement in or relating to the preparation of pellets containing carbonate ores and carbonaceous materials—Shri P. K. Som, Shri S. K. Roy Chowdhury & Shri S. C. Aush.

8. Indian Patent No. 135030 — Improvements in or relating to prevention of tarnishing of copper and copper-base alloys —Shri A. N. Mukherji, Shri S. R. Addanki & Dr. A. K. Lahiri.

(b) **Patents accepted** :

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

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

APPENDIX IV

Sponsored Investigation Completed

1. Laboratory and Pilot Plant scale studies on the Asswan Iron ore from the Arab Republic of Egypt.	United Natious Industrial Development Organisation.
2. Pilot plant studies on beneficiation aud pelletisation of iron ore samples from Deposit No. 14 of Bailadila mines.	National Mineral Development Corpn. New Delhi.
3. Bond's work Index and rates of settling of iron ore concentrate and tailings samples.	-do-
4. Grindability tests on iron ore samples.	Kudremukh Iron Ore Projects.
5. Beneficiation of low grade copper ore.	Indian Copper Complex Ghatsila.
6. Ramming mix for induction furnace.	-do-
7. Recovery of metallics from the furnace dross samples.	M/s. Kamani Metals & Alloys Ltd., Bombay.
8. Calcination and beneficiation of kyanite-sillimanite samples.	Maharashtra Minerals Corpn. Ltd., Bombay.
9. Suitability of Mn ore for production of Electrolytic Mn Metal.	Mysore State Industrial Dev. Corpn., Bangalore.
10. Stress-rupture and ageing behaviour of steel casting.	Bharat Heavy Electricals Ltd., Hyderabad.
11. Reclamation of corroded dynamo-stampigs.	-do-

12.	Tests on Kiriburu Iron 'ore, lumpy samples and sintering of iron ore fines.	Bokaro Steel Ltd., Bokaro.
13.	Beneficiation of Bolani ore fines.	Bolani Ores Ltd., Bolani.
14.	Feasibility report for setting up an eleetrolytic Mn metal plant.	Manganese Ores (I) Ltd., Nagpur.
15.	Beneficiation & recovery of Scheelite (Walker's Dump)	Kolar Gold Fields, Mysore.
16.	Beneficiation of low grade phosphate samples.	Director, Mines & Geology, Udaipur.
17.	Beneficiation of low grade wolframe ores.	Director, Mines & Geology, Rajasthan.
18.	Beneficiation of low grade molybdenite (3 samples).	Geological Survey of India, Tamilnadu Circle, Tamilnadu.
19.	Beneficiation of beach sand.	Geological Survey of India, Gujarat.
20.	Metallurgical studies for evaluation of hammer bits.	Hindusthan Steel Ltd., Ranchi.
21.	Nitriding of Fe-Cr.	Alloy Steel Plant, H. S. L. Durgapur.
22.	Experimental rolling of Niobium steel.	Central Research & Development, H. S. L. Durgapur.
23.	Failure of crude storage tank.	Cochin Refinaries Ltd., Cochin.
24.	Failure of turbo-centrifugal compressors.	M/s. Tata Chemicals Ltd., Mithapur.
25.	Development of Technology and preparation of impeller plates.	M/s. Tata Engg. & Locomotive Co. Ltd. Jamshedpur.
26.	Metallurgical testing of C.I. pipes.	Garrison Engr. Bhandara.
27.	Discolourrtion of copper tapes co-axial cables.	Hindusthan Cables Ltd. Rupnarayanpur.
28.	Utilisation of Joda ferro-manganess slag for production of electrolytic Mn metals.	M/s. Tata Iron & Steel Co. Ltd., Jamshedpur.

29. Cracking of brass tubes used in sugar evaporators.	M/s. Multi-melals Ltd., Kota.
30. Laboratory scale studies on Nickel ore from Sukhinda	M/s. Chemical & Metallurgical Design Co. (P) Ltd., New Delhi.
31. Failure of shoes for conveyance Kg-783 for folax grate cooler.	M/s. Orissa Cement Ltd., Orissa.
32. Physical characteristics of six lumpy iron ores.	Industrial Development Corpn. of Orissa Ltd.
33. Physical characteristics of six lumpy iron ores from Kiriburu & Barajamda.	Bokaro Steel Ltd., Bokaro.
34. Appraisal of raw materials for iron making.	Bokaro Steel & IDCOL.
35. Utilization of waste zinc ash.	M/s.Cominco Binani Zinc Ltd., Alwaye.
36. Corrosion of economiser tuber.	Indian Drugs & Pharmaceutical Ltd., Rishikesh.

APPENDIX V

Executive Council Members

1. Shri K. T. Chandy,
   (*Chairman*),
   Kerala State Industrial
   Development Corpn. Ltd.,
   Post Box No. 105,
   Trivandrum-1, Kerala

2. Sir J. J. Ghandy,
   Director,
   Tata Iron & Steel Co. Ltd.,
   Jamshedpur

3. Dr. D. P. Antia,
   Dy. Managing Director,
   Managing Director,
   Union Carbide (India) Ltd.,
   1, Middleton Street,
   Calcutta-16

4. Dr. R. V. Tamhankar,
   Director, Defence Metallurgical
   Research Laboratory,
   Phisalbanda,
   Hyderabad-23

5. Dr Brahm Prakash,
   Director, Metallurgy Group,
   Bhabha Atomic Research
   Centre,
   C. S. M. Marg,
   Bombay-1

6. Dr. P. Dayal,
   Sr. Industrial Adviser (Metals),
   Dept. of Mines & Metals,
   Ministry of Steel & Mines,
   Government of India,
   Shastri Bhavan, New Delhi-1.

7. Prof. T. R. Anantharaman,
   Prof & Head of the Dept.
   of Metallurgy,
   Benaras Hindu University,
   Varanasi-5.

8. Shri F. A, A. Jasdanwalla,
   Technical Director,
   Indian Standard Metal Co, Ltd.,
   ISM Estate, Chinchpokli
   Cross Lane,
   Bombay-27.

9. Shri R.L. Khanna,
   Works Manager,
   Indian Copper Complex
   P,O. Ghatsila,
   Singhbhum.

10. Shri Rup Rai,
    General Superintendent,
    Rourkela Steel Plant, H.S.L.,
    Rourkela, Orissa.

11. Prof V. A. Altekar,
Director,
National Metallurgical
Laboratory,
Jamshedpur-7·

12. Director-General,
Seientific & Industrial Research,
Rafi Marg, New Delhi-1.
(*Ex-officio member*)

13. Finance Adviser,
Council of Scientific & Industrial
Research Rafi Marg,
New Delhi.
(*Ex-officio member*)

14. Dr. A. B. Chatterjea,
Dy. Director,
National Metallurgical
Laboratory, Jamshedpur-7.
(*Non-member secretary*)

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