# NML

## Annual Report

1978-79

National
Metallurgical
Laboratory

Jamshedpur, India

# ANNUAL REPORT

## 1978-79

**NATIONAL METALLURGICAL LABORATORY**
COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH
JAMSHEDPUR, INDIA

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# INTRODUCTION

The R & D efforts of National Metallurgical Laboratory provide a selective thrust on projects which have reached final stage of industrial evaluation/ transfer of technology/adaptive technologies with accent on import substitution. Promotional efforts are directed towards industrial establishment of NML processes & products.

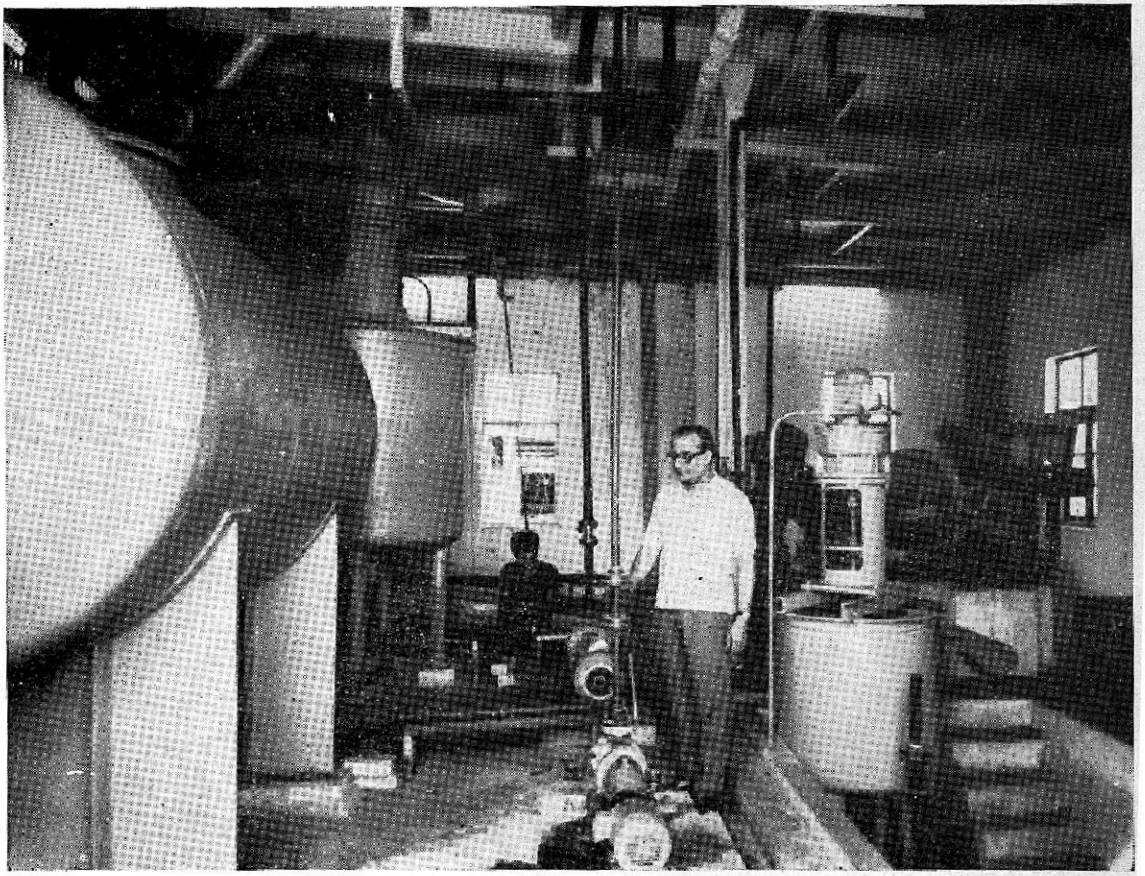
During this year, the Laboratory has successfully transfered the technology on production of electrolytic manganese dioxide to Central Research Organization, Government of Burma, Rangoon; under the Technical Assistance Programme of Govt. of India to Govt. of Burma through CSIR and NRDC. NML Scientists have assisted Central Research Organization, Rangoon; in setting up a pilot plant for production of electrolytic manganese dioxide suitable for use in dry cell based on NML developed technology.

In the field of development, testing and evaluation of high temperature creep resistant steels, phase I of the programme on creep stress rupture and stress relaxation properties at elevated temperatures of steels for Bharat Heavy Electricals Ltd., have been successfully completed. The Laboratory has again been called upon for its service and expertise in this field for their phase II programme. The schedules have been mutually discussed and the work is under initiation.

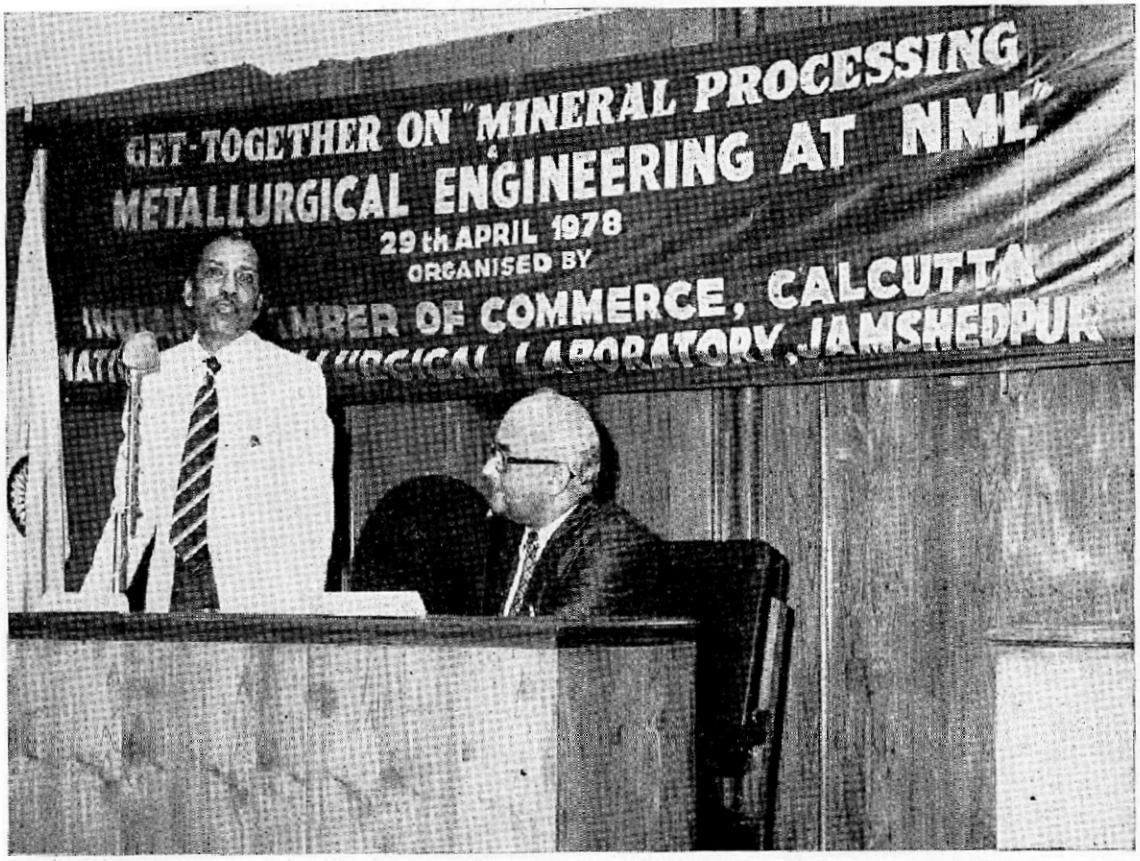
A large number of sponsored bench and pilot plant projects on mineral beneficiation have been conducted and completed on behalf of public and private sector organizations like Vishakapatnam Steel Plant; Pyrites Phosphate & Chemicals Ltd. ; Hindustan copper Ltd; Hindustan Zinc Ltd; SAIL, Rourkela; Dempo Mining Corporation; Central Coal Fields Ltd; Indian Iron & Steel Co. Ltd.; etc.

Plans are now underway for further industrial scale trials of the know-how on production of heat resistant cast iron alloy, 'NML Pyroloy 1000' at the works of M/s. Tata Iron & Steel Co. Ltd. About six hundred blades will now be put into trial for full fledged industrial evaluation at Tisco who are satisfied with the performance of the blades in their earlier trials. The NML developed know-how for reactive filter for aluminium industry has undergone successful field trials at Hindustan Aluminium Corporation, Renukoot; & Ordnance Factory, Ambajahari. Processes like dental amalgam alloy, copper-clad aluminium sheet, electrical resistance alloy for heating element, nickel-magnesium alloy, thermostatic bimetals, vanadium pentoxide from alumina sludge etc. were released to a number of new firms.

An International Collaborative Project on 'Atmospheric corrosion of metals and Alloys' was negotiated with National Research Institute for Metals, Tokyo, Japan. The Project is to run initially for a period of three years; comprising exposure tests with different metals and protective coatings so as to study various aspects of atmospheric corrosion, both in India and Japan, under similar climatic conditions. Another international collaborative project is under negotiation with SINTEFF—Norway on "Use of non-coking coal for generation of high potential reducing gases in molten metal reactions."



*View of the Electrolytic Manganese Dioxide Pilot Plant, 50 Kg/day installed at Central Research Organization, Rangoon; Govt. of Burma, with NML developed technology. The plant has been installed and commissioned with NML assistance*




*Prof. A. Ramachandran the then Director-General, CSIR, addressing the Get-together on "Mineral Processing & Metallurgical Engineering at NML"; along with him is Prof. V.A. Altekar, Director, NML. The Get-together was crganised by Indian Chamber of Commerce, Calcutta & NML*

Consultancy services and assistance have been provided to M/s. Rare Metals & Chemicals Ltd., Ranchi; for setting up a plant for production of vanadium pentoxide from alumina sludge based on NML know-how. Consultancy has also been provided to M/s. Dentifils, Jamshedpur; for setting up a unit for manufacture of dental amalgam alloy based on NML know-how.

Industrial problems have also been referred to by various CSIR Polytechnology Transfer Centres which were attended to.

The various Field Stations of the Laboratory continued to render services to the regional industries and undertake sponsored investigations.

A Seminar on 'Recent development on mineral preparation and extraction metallurgy of sulphide ore' was held in collaboration with Inst. of Engineers (India), Jamshedpur, Sub-Centre; Indian Institute of Metals, Jamshedpur Chapter & Indian Institute of Mineral Engineers. The Laboratory participated in a number of industrial and trade exhibitions and in 'Get-together' with industrialists, business entrepreneurs.

A special brochure and a special folder depicting NML's achievements, activities, services etc. were prepared and are under publication.

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

# RESEARCH, INVESTIGATION & DEVELOPMENT PROJECTS

## A. ORE DRESSING & MINERAL BENEFICIATION

### 1.0 Laboratory Scale Beneficiation Studies on a Low Grade Iron Ore from Syria. *Sponsored by M/s. MECON.*

A sample of low grade iron ore from Zabadani area in Syria was obtained through MECON for carrying out exploratory beneficiation studies for the purpose of participation in an iron and steel complex proposed to be set up by Government of Syria.

The sample a oolitic iron ore, assayed 26.39% Fe; 22.36% $SiO_2$ and 8.39% $Al_2O_3$. Reduction roast followed by low intensity magnetic separation produced a concentrate assaying 50.32% Fe; 11.4% $SiO_2$ and 4.5% $Al_2O_3$ with recovery of 81.1% Fe in the product.

### 1.1 Beneficiation of Powdery Iron Ore from Dempo Mining Corporation. *Sponsored by M/s. Dempo Mining Corporation, Goa.*

The Dempo Mining Corporation sent a rich iron ore fine termed 'Powder ore' for beneficiation studies in order to produce a super concentrate to be used as the pellet feed or other uses. The sample as received was—10 mm in size and assayed 65.0% Fe, 1.3% $SiO_2$, 3.8% $Al_2O_3$ and 2.7% loss on ignition.

Washing of the ore, followed by hydrocycloning of the washed sand after grinding yielded 50.6% by weight as a concentrate, assaying 67.4% Fe, 0.6% $SiO_2$ and 0.9% $Al_2O_3$. A second stage cycloning of the 1st overflow combined with the original slime produced second concentrate. The two concentrates combined together would weigh 85.2% and assay 66.6% Fe.

### 1.2 Beneficiation Studies on Lumpy Iron Ore for M/s. Dempo Mining Corporation. *Sponsored by M/s. Dempo Mining Corporation.*

Beneficiation studies were carried out on a lumpy iron ore for the purpose of upgrading it for high grade sinter or pelletizing feed. The ore, as received, assayed 61.0% Fe, 2.95% $SiO_2$ and 3.25% $Al_2O_3$. Tabling of the washed lump after crushing produced a concentrate assaying 65.8% Fe, 1.9% $SiO_2$ and 1.4% $Al_2O_3$ with a recovery of 34.5% Fe in the product. Cycloning of table tails after grinding as well as cycloning of washing and tabling slimes produced a combined concentrate assaying 60.92% Fe with a recovery of 34.3% Fe. This concentrate, mixed-up with the table concentrate, would produce a combined concentrate assaying 63.3% Fe with a recovery of 68.8% Fe, which would be an ideal material for use as the pelletization feed.

### 1.3 Beneficiation studies on Gua Run of Mine Iron Ore, Pt I Lump Ore. *Sponsored by M/s. Indian Iron & Steel Co. Ltd.*

About 100 tonnes of Gua iron ore of size ranging —75 mm to fines, was received for beneficiation and sintering studies. The sample as received assayed 61.8% Fe; 2.6% $SiO_2$; 3.7% $Al_2O_3$ and 5.0% LOI.

From the various test results it could be stated that −50+10 mm washed lumps can be very well directly employed for blast furnace while −10 mm fines may be utilized for sintering with advantage.

**1.4 Pilot Plant Beneficiation Studies on Gandhamardan Iron Ore.** *Sponsored by MECON.*

The ROM ore analysed 64% Fe, 1.9% $SiO_2$, 3.52% $Al_2O_3$ and 3.1% LOI. The ore was crushed to three sizes. The lump −50+10 mm analysed 65.52% Fe (Yield 48.3%), −30+10 mm analysed 64.73% Fe (Yield 53.0%), −20+6 mm analysed 64.4% Fe for an yield of 59.1% by weight. The fines analysed 62.72% Fe, 63.50% Fe and 64.0% Fe respectively. The tests on compressive strength, tumbling indices, thermal degradation, sieve analyses of ROM ore with chemical analyses, bulk density etc. were completed. Studies on reducibility, decripitation, washing, beneficiation, sintering and pelletisation are in progress.

**1.5 Beneficiation of Cr-Ni bearing Magnetite Sample from Phukpur area, Nagaland.** *Sponsored by Geological Survey of India.*

Nickel-chromium bearing magnetite from Nagaland was received for conducting bench scale tests in order to find out its amenability to beneficiation. The sample as received assayed 49.84% Fe ; 17.56% FeO ; 0.48% Ni ; 1.45% Cr ; 8.96% $SiO_2$ ; 8.59% $Al_2O_3$ ; 0.15% P ; 0.74% S ; 0.34% $TiO_2$. Preliminary magnetic separation tests carried out at low intensity yielded a magnetic fraction assaying 50.68% Fe ; 0.46% Ni and 2.65% Cr with respective recoveries of 91.5%, 88% and 87.8% in it. Further tests at different sizes and at varying intensities are in progress.

**2.0 Beneficiation Studies on Cu-Pb-Zn Complex Sulphide Ore from Deri, Rajasthan.** *Sponsored by M/s Rajasthan State Industrial Mineral Development Corporation.*

Bench scale beneficiation studies were carried on a sample of Cu-Pb-Zn complex sulphide ore from Deri mines, Rajasthan. The sample as received assayed 1.027% Cu ; 6.108% Pb and 8.097% Zn.

A large number of froth flotation tests were conducted to achieve sharp selectivity amongst the major valuable mineral phases. Due to the complex mineralogical and textural nature, beneficiation of the sample required lengthy processing schedules, which had to be operated in open circuit in bench scale tests. The zinc concentrate obtained assayed 53.61% Zn ; 0.85% Cu and 0.05% Pb with 70.8 ; 8.8 and 0.1% distributions respectively. The lead fraction assayed 44.79% Pb ; 4.10% Cu and 7.00% Zn with 63.4, 31.8 and 7.0% distributions respectively. Another Pb concentrate obtained assayed 53.47% Pb ; 0.9% Cu and 2.5% Zn with 32.6, 2.8 and 1.2% distributions respectively. A copper concentrate assayed 29.52% Cu ; 1.11% Pb and 2.20% Zn, with 37.7, 0.3 and 0.4% distributions respectively.

**3.0 Bench Scale Beneficiation Studies on a Complex Pb-Zn Ore from Chakula, Bhutan.** *Sponsored by Geological Survey of India, Bhutan Circle.*

Bench scale beneficiation studies were conducted on an oxidized complex Pb-Zn ore from Chakula, Bhutan. The sample assayed 4.7% Pb; 22.1% Zn; 23.8% Fe and 0.49% S.

The investigations conducted indicated that the oxidized Pb-Zn ore may not be amenable to beneficiation by physical ore-dressing methods with reasonable yield or recovery of mineral values.

**3.1 Bench Scale Beneficiation Studies on a Complex Pb-Zn Sample from Romegangri—Genekha Area.** *Sponsored by Geological Survey of India, Bhutan Circle.*

The ore, which was partially oxidized assayed 4.77% Pb; 6.2% Zn & 29.95% Ba. Preliminary gravity concentration tests as well as few flotation tests for the recovery of the economic minerals were completed and the assay results are awaited.

**4.0 Beneficiation of Manganese Ore from M/s. MOIL.** *Sponsored by M/s. Manganese Ore of India Ltd.*

Nineteen samples of manganese ores, from Balaghat mines, underground and flat section of Ukwa mines and a dioxide ore of battery grade sample, were received. Chemical analyses of ROM ores from Balaghat, flat and underground section of Ukwa were as follows:

| | Mn % | Fe % | $SiO_2$ % |
|---|---|---|---|
| Balaghat | 38.7 | 3.8 | 26.8 |
| Ukwa (U. G. Section) | 38.4 | 6.2 | 22.0 |
| Ukwa (F. Section) | 42.4 | 6.7 | 18.0 |

The ROM from Balaghat yielded a concentrate 57.9% by wt; assaying 50.8% Mn; 4.8% Fe and 7.7% $SiO_2$. The Ukwa flat and underground ROM sample yielded 63.1% and 59.8% by wt; and assayed 51.1% Mn, 5.7% Fe and 6.3% $SiO_2$ and 50.3% Mn, 6.8% Fe and 6.6% $SiO_2$ respectively. Large scale tests on the ROM samples are in progress for optimisation of the flow-sheet.

**4.1 Bench Scale Beneficiation Studies of Low Grade Siliceous Manganese Ore.** *Sponsored by M/s. Aryan Mining & Trading Corporation.*

The sample as received assayed 33.82% Mn, 53.50% $MnO_2$; 2.24% Fe; 35.36% $SiO_2$; 2.17% $Al_2O_3$; 2.73% BaO and 7.20% loss on ignition. Bench scale studies carried out with the sample yielded either an overall concentrate weighing 47.4% and analysing 79.35% $MnO_2$ and 2.27% Fe with 69.6% $MnO_2$ recovery in it, or a slightly inferior grade concentrate weighing 53.1% and assaying 77.82% $MnO_2$ and 2.50% Fe with higher $MnO_2$ recovery of 76.6%.

**4.2 Sintering Studies on Manganese Ore Fines.** *Sponsored by M/s. Ferro Alloy Corporation.*

M/s. Ferro Alloy Corporation Ltd., A.P., are interested to set up a sinter plant with a capacity of 50 tons/day sinter for its direct use in the production of high carbon ferro-manganese, thereby completely utilizing the in-plant generation of manganese ore fines. With this view bench scale investigations for determining the sintering characteristics was undertaken.

From the various tests results, the optimum feed rate for making suitable sinter was observed to be 6.5% water, 8% coke breeze, 35% return fines & 50.5% Mn ore fines. The average sintering rate, yield, % return fines & shatter stability & —6.4 mm fines generated during shatter tests were 5.8 cm/min. 65.3, 32.7, 87.6 & 7.4% respectively.

### 4.3 Beneficiation of a Manganese Ore Sample from M/s. Union Carbide Ltd. *Sponsored by M/s. Union Carbide Ltd.*

A low grade manganese ore sample from M/s. Union Carbide Ltd., Calcutta was received for carrying out bench scale beneficiation studies (physical tests only) so as to upgrade the $MnO_2$ content to about 85%. The sample as received assayed 74.32% $MnO_2$; 6.08% Fe; 3.46% $SiO_2$; 10.28% LOI etc.

Preliminary tabling tests followed by magnetic separation yielded a concentrate assaying 84.0% $MnO_2$. Further tests to improve the grade and recovery are in progress.

### 4.4 Petrological Studies of Manganese Ore Samples of Siljora-Kalimati Area. *Sponsored by M/s. Rungta Mines (P) Ltd.*

Six medium grade ferruginous manganese ore samples from the Siljora-Kalimati area of Keonjhar District, Orissa, were received for petrological studies on the basis of which a blended composite sample will be prepared for production of electrolytic manganese dioxide. The studies revealed that Mn varied from 34.71% to 41.8% and Fe from 11.2% to 18.76% in the samples and that both cryptomelane and psilomelane were present. Pyrolusite, manganite and wad constituted the other manganese minerals present in varying amounts in the samples. Goethite, hematite, laterite, kaolin and quartz constituted the ferruginous and other gangue associates. Silica was uniformly low in all the samples.

### 5.0 Beneficiation of Chrome Ore Samples from Boula Mines. *Sponsored by M/s. Ferro Alloy Corporation Ltd.*

Two samples of chromite from Boula Mines designated as (*i*) Ganga pit sample and (*ii*) Mixed run of mine ore were received for reducing their iron content to tolerable limits, so that the resulting product could be used for the production of ferro chrome. The samples as received assayed between 38 to 41% $Cr_2O_3$ with 14-15% Fe.

Preliminary gravity concentration tests like tabling at various sizes, straight magnetic separation etc., did not indicate encouraging results. Reduction roast followed by wet magnetic separation tests with both the samples were completed and the assay results are awaited.

## 6.0 Bench Scale Beneficiation Studies on a Low-grade wolframite Sample from Agargaon Area, Maharashtra. *Sponsored by M/s. Maharashtra State Mining Corporation & M. N. Dastur & Co.*

Bench scale investigations were undertaken on a low grade Wolframite sample from Agargaon, assaying 0.07% $WO_3$, with a view to exploring the possibilities of upgrading the ore by ore dressing methods so as to yield high grade concentrate consistent with high recovery.

Preliminary pre-concentration tests employing spiral, shaking tables etc., at coarse sizes did not indicate satisfactory results. Tabling at −48 mesh followed by several cleanings, produced a table concentrate assaying 29.01% $WO_3$ but with a low $WO_3$ recovery of 18.5% in it. This table concentrate, when subjected to magnetic separation yielded a magnetic fraction assaying 60.37% $WO_3$ with only 13.8% $WO_3$ recovery. Attempts to separate wolframite from tourmaline and the associated gangue were not successful.

## 7.0 Beneficiation of Low-grade Apatite from Pathargora Area, Singhbhum District, Bihar. *Sponsored by M/s. Indian Iron & Steel Co. Ltd.*

Two samples marked I & II of low-grade apatite were received for beneficiation studies with a view to upgrade them above 30% $P_2O_5$ so to make them sutiable for production of phosphatic fertilizer.

The sample I analysed as 10.03% $P_2O_5$ and 11.34% Fe while the sample II analysed 15.45% $P_2O_5$ and 9.06% Fe. A concentrate assaying 36.6% $P_2O_5$ with 85% recovery was obtained from sample I while sample II gave a concentrate assaying 38% $P_2O_5$ with 87.90% $P_2O_5$ recovery.

## 7.1 Mineralogical Study on Six Type Samples of Phosphate Rock from Purulia District, West Bengal. *Sponsored by West Bengal Mineral Development & Trading Corporation.*

Six apatite bearing rock samples marked $S_1$ to $S_6$ were received for mineralogical study. The sample $S_1$ was the highest apatite bearing one with less Fe and $SiO_2$ ($P_2O_5$ 40.50%, Fe 1.20%; $SiO_2$ 0.60%) while in others $P_2O_5$ ranged from 38.15%, Fe 26.4% and $SiO_2$ 0.1-44%. The physical manifestation of the siliceous gangue was chert followed by chalcedonic and silty material with quartz. From the mineral assemblage and textural study the samples $S_1$ to $S_6$ can be mixed with for making a composite sample for further beneficiation studies. $S_1$ is of high grade and need not be included in the composite as it needs no beneficiation.

## 7.2 Beneficiation Studies on a Composite Sample of Apatite from Beldih Mines, Purulia Dist. *Sponsored by M/s. West Bengal Mineral Development and Trading Corporation.*

Based on the detailed mineralogical studies carried on six samples of apatite; a composite sample prepared by the sponsor was received for beneficiation studies. The sample assayed about 30% $P_2O_5$. Preliminary studies are in progress.

**8.0 Pilot Plant Beneficiation Studies on Pyrite Sample from Amjhore, Bihar.** *Sponsored by M/s. Pyrites, Phosphates & Chemicals Ltd.*

A comprehensive investigation on beneficiation of ROM pyrite samples from Amjhore, Bihar; employing simple gravity treatment flowsheet was undertaken to collect necessary data for the proposed 2000 tpd plant to be set up by M/s. PPCL for supply of concentrates to Fertilizer Corporation of India Ltd., Sindri. Altogether five samples of the low-grade pyrite as mined were received and tested for collection of different technological and operating parameters in continuous closed circuit run in the pilot plant. A flowsheet for treatment of the pyrite ore was developed.

Continuous jigging followed by spiralling of −20 mesh fraction produced a combined concentrate assaying 38.5% S with a total S recovery of 74.1%. This was equivalent to a recovery of more than 90% of the pyrite sulphur associated with the pyrite band and was therefore considered quite satisfactory. Studies on pH built-up, water recirculation and results obtained on treating of freshly mined material, were also conducted. About 68.2% of the total water used for the beneficiation could be reclaimed during the pilot plant operation.

**9.0 Bench Scale Beneficiation Studies of Low-Grade Graphite Sample from Banswara District, Rajasthan.** *Sponsored by M/s. Rajasthan State Industrial & Mineral Development Corporation.*

The low-grade graphite sample received assayed 9.7% F.C. only. Flotation studies followed by a number of cleaning steps produced a graphite concentrate of 88.0% F.C. and 8.2% ash with a recovery of 70.5% F.C.

**9.1 Bench Scale Beneficiation Studies on a Low-Grade Graphite Sample from Taliha Mines, Arunachal Pradesh.** *Sponsored by Geological Survey of India, North-Eastern Region, Shillong.*

The sample as received assayed 10.87% F.C. and 80.76% ash. Flotation tests carried out under optimum conditions produced a graphite concentrate assaying 90.35% F.C. and 5.18% ash, with a fixed carbon recovery of of 83.94%.

**10.0 Reduction of Ash Content from the Coal Fines of Gidi Washery.** *Sponsored by M/s. Coal India Ltd.*

Coal fines sample were received from Gidi Washery with a view to bring down the ash content to below 17%. The sample composed of 10 mesh fines ranging down to 200 mesh and analysed 48.3% F.C.; 22.02% V.M. and 27.39% ash.

Flotation tests conducted on "as received" sample yielded a concentrate assaying 10.79% ash with 37% yield. Flotation after grinding yielded concentrates assaying 11.9% ash and 11.3% ash with 66.2% yield and 62.3% yield respectively. Five cleanings of the rougher concentrate further reduced the ash content to around 8-9%.

*Beneficiation of coal fines for reduction of ash content*

**10.1 Reduction of Ash Content in −0.5 mm Coal Slurry Sample from Patherdih Coal Washery.** *Sponsored by M/s. Central Coal Washery Organization Ltd.*

The sample of coal as received assayed 62.2% fixed carbon, 16.4% ash and 20.8% V.M. Flotation tests conducted with the sample indicated ash content in the concentrate could be lowered to 9.8% with an yield of 76.2% by wt. of the feed. After five cleanings, the ash content could be reduced to 7.8% for an yield of 61.9% by weight.

**10.2 Pilot Plant Investigation on the Reduction of Ash Content of the Coal Fines from Gidi Washery.** *Sponsored by M/s. Central Coal Fields Ltd.*

About 120 tonnes of coal fines from Gidi Washery were received for the reduction of its ash content by froth flotation technique. The size of the coal fines varied from 20 mm to fines. The average ash content was 28.0%.

Scrubbing and wet screening of the sample over a 20 mesh screen produced −20 mesh fraction which was floated directly for a low ash concentrate. The +20 mesh fraction was ground and floated to obtain a concentrate of acceptable grade. The combined concentrate assayed 16.4% ash.

**11.0 Beneficiation of Calc-Silicate-Graphite Sample from Rajpura—Dariba Area, Rajasthan; for Recovery of Barite.** *Sponsored by M/s. Hindustan Zinc Ltd.*

The sample investigated assayed 0.25% Cu; 1.2% Pb; 8.63% Zn; 4.03% Ba; 8.68% Fe; 13.75% S; 46.8% $SiO_2$ and 2.18% CaO+MgO. The economic minerals were galena, sphalerite, chalcopyrite and barite and the major gangue was quartzite. The object of the investigation was to produce a high grade barite concentrate.

Flotation studies were conducted with feeds of different fineness after taking out initially a graphite float and a sulphide float containing the Cu-Pb-Zn minerals. Afterwards, Barite was floated under optimum condition. A barite concentrate assaying 48% Ba with a recovery of 26.6% was obtained.

**11.1 Recovery of Barite from Calc-Silicate Sample containing Cu-Pb-Zn Complex Sulphides from Dariba—Rajpura, Rajasthan.** *Sponsored by M/s. Hindustan Zinc Ltd.*

The ore analysed 6.78% Zn ; 0.69% Pb ; 0.33% Cu ; 7.8% Fe ; 17.8% $BaSO_4$ ; 40.6% $SiO_2$ ; 12.44% S ; 0.51% $Al_2O_3$ ; 1.47% CaO and 0.9% MgO. The ore contained metallic minerals like pyrite, sphalerite, with minor amounts of galena, pyrrhotite and chalcopyrite. The non-metallic gangue contained valuable barite and undersirable quartz in appreciable quantitied. Good amount of pyrite and sphalerite was found locked with gangue.

Most of the sulphides were collected by a bulk sulphide float. The sulphide flotation tail was subjected to flotation to get barite rougher float which was reground and re-floated to yield a concentrate, assaying 52.1% Ba (90.6% $BaSO_4$).

**12.0 Beneficiation of a Low-Grade Composite Kyanite Sample from Maharashtra.** *Sponsored by M/s. Maharashtra State Mining Corporation Ltd.*

Four samples of kyanite from four different mines, varying in $Al_2O_3$ content from 36.42% to 48.99% were received. The detailed programme was drawn up by M/s. Development Consultant, Calcutta and finalised after discussion between NML, Development Consultant & Maharashtra State Mining Corporation Limited. Investigations were carried out on a composite sample by blending the four samples in the proportions given by M/s. Development Consultant. The composite assayed 40.78% $Al_2O_3$ and 44.48% $SiO_2$.

A concentrate having 60.7% $Al_2O_3$ with a recovery of 53.2% $Al_2O_3$ by straight flotation followed by cleanings of rougher float was obtained.

**13.0 Beneficiation Studies of Magnesium Dross Sample.** *Sponsored by M/s. Industrial Alloys.*

Beneficiation studies were carried out on a 10 tonnes magnesium dross sample assaying 63.5% Mg (total) ; 56.4% Mg (metallic) ; 9.78% $SiO_2$ and 6.03% $Al_2O_3$. The object of the investigation was to reject the oxidized fines from the sample. An overall yield of 90.4% by weight of metallic magnesium was obtained.

**14.0 Pilot Plant Studies on Reduction of Silica Content of a Magnesite Sample from Salem, Tamil Nadu.** *Sponsored by Department of Geology, Government of Tamil Nadu.*

The sample as received assayed 42.2% MgO, 7.0% $SiO_2$. and 1.0% CaO. Bench scale beneficiation studies using froth flotation method reduced the silica content to 2.26% with an yield of 52.4%. The pilot plant investigation

on this sample was primarily aimed to confirm the bench scale results. Results from the pilot plant investigation showed that an yield of 48% with a silica assay of 2.3% could be obtained when the middling was not recirculated. The close circuit operation increased the yield by about 5%.

**15.0 Determination of Crushing Strength of Limestone.** *Sponsored by M/s. MacNally Bharat Engineering Co.*

Crushing strength on seven limestone samples (Lumps) were conducted. These data were needed by the party for designing of crushing equipments for one of their limestone projects.

All the lumps ranging from 75 mm to 100 mm in size were dense with noted conchoidal and uneven fracture on the surfaces. This had resulted in their very uneven behaviour during the determination of crushing strength in each case. The crushing strength of the samples varied very widely from about 528 Kg/sq. cm. to as low as 112 Kg/sq. cm.

**15.1 Determination of Crushing Strength of Limestone Sample received from Bokaro Steel Plant.** *Sponsored by Bokaro Steel Plant Steel Authority of India Ltd.*

A few limestone lumps were received for testing for crushing strength. The crushing strength was determined which ranged from 855 Kg/Sq. cm. to 1750 Kg/Sq. cm.

**16.0 Comparative Studies on Collecting Properties of Xanthate Samples.** *Sponsored by M/s. Aceto Chemicals (P) Ltd.*

Two samples of sodium isopropyl xanthate, marked "Regular quality" and "Superior quality" were received for studies on their comparative performance as collectors for froth flotation. A series of tests were performed with these reagents as collectors and imported pine oil as frother on a typical Indian Sulphide Cu-ore, assaying 0.8% Cu.

The performance of the "Superior quality" xanthate was found to be more consistent than the "Regular quality" within the range of quantitative collector addition tested. The tailing loss with "Superior quality" xanthate was found to be lower. However given sufficient time of flotation and sufficient dose of addition, the "Regular" variety also performed well.

## B. REFRACTORY TECHNOLOGY

**17.0 Development of High Alumina Refractories using Kyanite and Technical Alumina.**

During the period under review, 80-85% $Al_2O_3$ refractory samples were prepared on bench scale. Cylindrical buttons of 2" dia and quarter size bricks of $4\frac{1}{2}" \times 2"$ were made and fired. Various properties such as apparent porosity, bulk density, C.C.S. P.L.C.R, thermal shock resistance, R.U.L. etc. were determined. Their chemical analyses were also done. Samples with a minimum of 18-19% apparent porosity were obtained.

## 18.0 Development of Synthetic Carbonaceous Product as a Substitute for Petroleum Coke and Anthracite.

This project aims at developing a suitable substitute of gas calcined anthractite used in cathode of aluminium reduction cell. The substiture should also replace calcined petroleum coke which is expected to be of short supply in near future. Experiments are being made with the raw materials like a blended coke from CFRI, a coal from Bhowrah Colliery, a coal from Assam and a foundry coke. Several compositions have been formed of which the properties in the green state were determined. Calcination studies of composition is in progress after which the testing and evaluation will be taken up.

## 19.0 Development of Carbon Bricks for Chemical Industry.

As assessed by the Carbon Panel, the future requirement of carbon bricks for the chemical industry is of the order of 700 tons per annum. These are required for the manufacture of phosphoric acid, caustic soda, detergents, fertilisers and other chemicals. At present these bricks are being imported. This project was initiated with a view to substituting the imported product.

One ton of green dense carbon bricks were made in the carbon plant. These bricks were fired in the electrical tunnel kiln at an appropriate temperature. Physical properties of such dense carbon bricks were studied and then crushed to various fractions $-5+20$, $-20+72$ and $-72$ BSS (ball mill fines). Out of these fractions, two maximum packing density mix based upon three fractions and two fraction system were selected. These two mixes were mixed with various proportions of binder (pitch) at a suitable temperature and pressed into bricks under hydraulic press. These bricks were fired in tunnel kiln at appropriate temperature. Physical properties i.e., apparent porosity, bulk density, cold crushing strength and modulus of rigidity of the bricks were studied.

From these observations it was derived that three fraction system exhibited better results as far as apparent porosity, bulk density and C.C.S. are concerned as compared to bricks made with two fraction system. Based on this three fraction system carbon bricks were made under hydraulic press using various percentages of binder. These bricks were heat treated in electrical tunnel kiln and are being examined for physical properties.

## 20.0 Studies on High Temperature Castables suitable for 1400°C-1700°C.

Castables for a continuous service temperature ranging from 1400°C to 1700°C can be made by using indigenous high alumina aggregates and high alumina cement. The most significant advantage of these castable is that it can be rammed at situ and is ready within one or two days for its direct exposure to flames. These possess high mechanical strength, refractoriness, abrasion resistance and great resistance to the attack of the gases.

Studies were conducted on NML made high alumina cement for standardisation purpose and various properties were determined. At present corundum has been selected as aggregate used for this type of castable. In the later

stage fused or sintered alumina will be tried. Physical properties of corundum i.e. physical appearance, bulk density, apparent porosity, apparent sp. gravity and chemical analysis were studied.

## 21.0 Development of Insulating Materials and Insulating Castables.

Alumina insulating blocks, free from iron oxide on a laboratory scale were made and their properties were evaluated. Further work is in progress.

## 22.0 Development of Graphite-Silicon Carbide Crucible.

Some suitable compositions of clay bonded and carbon bonded crucibles were developed. Bench scale experiments on these are in progress. Arrangements are also being made for fabricating larger sized crucibles. Some experiments are also being conducted to manufacture large sized crucibles by agreement with an industrial concern based on compositions developed at NML

## 23.0 Welding Flux.

Some of the previous flux compositions were modified with the aim to get the weld metal of the desired composition. Five such compositions were made and are being processed. Bead on plate tests would be performed to asses their suitability.

## 24.0 Testing of Binders and Raw Materials.

The objective of this project is to find the suitability of the available indigenous binders for the production of carbon refractories.

Two varieties of pitch from Rourkela, one variety from Bhilai and two varieties of tar from Shalimar Tar Product were investigated. All the properties e.g. proximate analysis, solvent extraction etc. have been determined. One more sample from Bhilai has been received and is under experimentation. After the determination of the properties all these binders will be used with a specific base material (dense carbon aggregate) to make bricks. The bricks will be tested and from the properties of the bricks thus obtained the binders used will be evaluated.

## 25.0 Development of Clay bonded Graphite Stopper Heads from Indigenous Raw Materials. *Sponsored by M/s Patna State Graphite Mining.*

Raw materials were procured from the licencee viz. M/s. Patna State Graphite Mining & Co., to make few numbers of these stopper heads for further in plant trials. After crushing and grinding the raw materials, the batch was made and fifteen stopper heads were fabricated Commercial production of these stopper heads by the firm will commence soon.

## 26.0 Testing and Evaluation work on Fireclays. *Sponsored by M/s. V. S. Krishna Ceramics & Potteries Ltd.*

Two fireclays from Konda Guntur and Bommur were received for evaluating their suitability for different end uses e.g. fireclay bricks, castables, ramming masses and mortars. The work is under progress.

**27.0 Sea Water Magnesia (Inter laboratory Project)—NML & Central Salt & Marine Chemicals Research Institute.**

CSMCRI is producing magnesium hydroxide from sea water in a pilot plant scale of 500 Kg. per day and are interested to know the suitability of this product for refractory purposes. This has resulted in formulating this inter-laboratory collaboration programme.

A sample of about 50 kg. of sea water magnesia was received from CSMCRI, Bhavnagar. The chemical analysis of the sample was determined. 2" dia buttons were made with the addition of iron oxide and without any addition from the above materials for sintering. The buttons were fired in the gas fired furnace at a temperature of 1600°C with 2 hr. soaking and their physical properties such as porosity and bulk density etc. were determined. Further work is in progress.

**28.0 Test on Reactivity of Lime.** *Sponsored by Steel Authority of India Ltd.*

A sample of limestone was obtained from SAIL, Ranchi, to conduct reactivity test of limestone after calcination. The reactivity of the calcined limestone was determined by:

(*i*) ASTM Method for slaking rate of quick lime.
(*ii*) Coarse grain titration method, Loss on ignition of all the calcined samples were determined at 1000°C after crushing the calcined lime to a fine powder.

It was inferred from the test results that for this limestone, a calcination temperature of 1000°C with 2 hours soaking in an electrically heated muffle kiln will produce a very good high reactive lime.

**29.0 Refractory Tests Conducted on behalf of Industries.**

| | *Nature of work* | *Sponsor* | *Test Conducted* |
|---|---|---|---|
| (*i*) | Testing of thermal conductivity of refractory bricks at elevated temp. | Dalmia Ceramics Ind. Ltd. | Thermal conductivity of Sup-60, Sup-70, HA-55, HA-60, HA-70, FCI & LMH. |
| (*ii*) | Testing of high alumina bricks | Ishwar Industries | Chemical analysis and physical properties of the bricks. |
| (*iii*) | Testing of air setting mortar | Vulcan Engg. Pvt. Ltd., | Setting time, sintering at 600 and 1000°C, CCS and seive analysis. |

| | | | |
|---|---|---|---|
| (*iv*) | Testing of thermal conductivity of bricks at a hot face temp. of 300°C. | Dalmia Ceramics Ind., Ltd. | Thermal conductivity of silicon and Alite bricks. |
| (*v*) | Testing of insulating bricks | The Dharmasi Morarji Chemical Co. Ltd. | App. porosity, B.D.; CCS & Reheat shrinkage. |

## C. EXTRACTION & CHEMICAL METALLURGY

### 30.0 Extraction and Recovery of Copper and Nickel from bulk Copper-Nickel Sulphide Concentrates of M/s. Uranium Corporation of India Ltd.

Bench scale experimental work on roasting with sodium chloride and solvent extraction of leach liquor from the sodium chloride roasting were completed.

Electric smelting of concentrate to produce high grade matte containing copper & nickel is in progress. Experiments are also in progress to develop process for recovery of nickel from the matte by leaching.

### 31.0 Extraction of Lead from Lead Concentrates.

Large scale continuous trials of lead smelting by NML-ALNAMA smelting process were conducted in the oil fired rotary furnace. About 10 tonnes of lead concentrate were successfully smelted. A detailed feasibility report for lead extraction plant based on NML-ALNAMA process was prepared.

### 32.0 Recovery of Metallic Values by Bacterial Leaching.

Laboratory scale studies on Malanjkhand & Mosabani low grade copper ores were completed. A project proposal under inter-laboratory programme for field trials for under-ground and heap leaching of low-grade copper ores at Mosabani is under consideration.

### 33.0 Purification of Low-grade Molybdenite Concentrates

Three different processes for purification of low-grade molybdenite concentrate, received from M/s. UCIL, were developed. The experimental work was completed.

### 34.0 Recovery of Vanadium Pentoxide from Vanadium containing Slag of M/s. Visvesvaraya Iron & Steel Ltd.

Semi-large scale trials for the production of $V_2O_5$ from slag are almost completed. Based on the earlier work carried out on the bench-scale, a report has been prepared.

### 35.0 Recovery of Vanadium from Sodium based Vanadium Sludge of Aluminium Industry.

Demonstration of the process was given to M/s. Rare Metals & Chemicals, Ranchi. Advisory and Consultancy Services were offered for design & commissioning for treatment of 2T/day sludge plant. The plant is expected to go in production soon. A technical report-cum-technology mannual was prepared and given to the firm.

### 36.0 Electric Smelting of Dolomite for Extraction of Magnesium.

Erection & lining of shell and roof was completed. The auxiliary units like magnesium remelting furnace has been fabricated.

### 37.0 Extraction and Recovery of Copper, Lead & Zinc from Complex Sulphide Ore/Concentrate from Ambamata, Gujarat.

Preliminary studies on roasting and leaching of sulphide concentrate were completed with 98% and 95% recoveries of copper and zinc in solution respectively.

### 37.1 Extraction and Recovery of Copper, Lead & Zinc from Complex Sulphide Ore/Concentrates from Deri, Rajasthan.

Preliminary studies on roasting and leaching of sulphide ore concentrates were completed with recoveries of 95% copper and 95% zinc in the solution.

### 38.0 Recovery of Pigment Grade Iron Oxide & Sulphur Values from Ferrous Sulphate Hepta Hydrate.

Preliminary static bed roasting studies were completed. The 6" dia Dorrco-fluo-solid roaster was renovated for fluidized bed roasting trials of mono-hydrate.

### 38.1 Production of Pigment Grade Ferric Oxide and Recovery of Sulphuric Acid from Ferrous Sulphate, Obtained as Bye-product in Pickling Plants.

The various parameters for production of pigment grade ferric oxide and recovery of sulphuric acid from ferrous sulphate crystals, obtained as a bye-product from the pickling plant of Bokaro Steel Limited, are under study. The optimum decomposition temperature and the time of calcination were determined. Conditions of grinding and washing the ferric oxide product are being standardized. Arrangement are being made to get the sample of ferric oxide produced at NML evaluated by consumer industries for its properties as a pigment.

### 39.0 Extraction and Recovery of Zinc and Lead from Mixed Oxide and Silicate Ore from Chakula, Bhutan. *Sponsored by G.S.I. Bhutan Circle.*

Bench scale leaching studies for recovery of zinc and lead have been nearly completed with good recovereis. Interim report on these studies has been submitted.

## 40.0 Chemical Beneficiation of Low-grade Bauxite from Goa.

Systematic studies were carried out on laboratory scale for selective removal of iron from a sample of low-grade ferruginous bauxite. Investigation report has been prepared.

## 41.0 Production of Metal Powder.

M/s. Nalco Metal Production, Madurai, another licencee are installing their plant for production of metal powder by NML developed process.

## 42.0 Production of Distilled Zinc Dust.

Development work on the alternate resistor furnace distillation unit is underway. A plant is being installed by the licenced firm.

## 43.0 Recovery of Copper, Lead, Zinc, Nickel and Elemental Sulphur from Sulphide Mineral Concentrates.

*(i) Complex Copper-Nickel Concentrate*

Separation and recovery of copper and nickel from the leached solution obtained by leaching copper-nickel concentrates in ferric chloride solution were studied by electrolysis in a double compartmental cell with insoluble anodes. It was found that removal of copper can be effected to over 70% without significant co-deposition of nickel in the deposit but current efficiency decreases with time. Separation of the remaining copper and recovery of the nickel from the spent electrolyte are under progress.

*(ii) Lead Concentrates*

Studies on the leaching of lead concentrates in ferric chloride-sodium chloride solution and separation of lead as lead chloride on cooling the hot filtered leach solution were carried out. Recovery of lead from lead chloride by electrolysis in an aqueous bath of sodium chloride-lead chloride is being examined. Preliminary experiments on electrolysis of the lead chloride-sodium chloride solution yielded a current efficiency of 99%. Influence of variables such as temperature current density etc. on the current efficiency and nature of the deposit is being studied.

## 44.0 Studies on Processing of Sulphide Concentrates—Recovery of Metal Values as Chemicals Directly from Copper Concentrates.

After preliminary bench scale tests, laboratory scale studies and cyclic operation were completed. The chemical treatment was carried out at 700 gm/batch and more than 98% Pb and 96% Zn with about 10% Fe could be removed from the concentrate. Copper loss was around 1%. Purification of leach liquor and crystallisation yielded a product conforming to chemical grade copper sulphate of ISI specificiation.

Necessary specifications for the equipment for treatment of 1-5 Kg per batch, based on the process flow sheet examined, have been drawn.

## 45.0 Preparation of Fluorine Chemicals.

One tonne of cryolite, prepared at NML, was evaluated in the aluminium reduction cells at the Hirakud Plant of Indian Aluminium Company over a period of one month. Indalco has reported that the preliminary indications are favourable for the use of NML cryolite in aluminium reduction cells. However, this should be confirmed by extended field trials for which 25 tonnes of cryolite will be required. In this connection, the feasibility of converting the cryolite recovery plant of Indalco at Belgam to cryolite production unit by NML technology is being examined.

## 46.0 Hydro-Electro-Metallurgical Project.

Further attempts were made to expedite construction of the Process Bays. The security lodge, water supply, power supply works continued and are expected to be ready very shortly.

## D. IRON & STEEL TECHNOLOGY

## 47.0 Production of Sponge Iron in Vertical Retort Furnace.

After the installation of the vertical retort furnace for the production of sponge iron, capacity 1.2 to 1.5 tonnes/day was completed, initial trials were conducted. Three successful campaigns were completed using Bailadila iron ore and non-coking coal from Banke Colliery. During the campaigns, the studies on the effect of size of iron ore and coal particles, ratio of iron ore and coal, retention time of the raw materials in constant temperature zone were studied. During these experiments, sponge iron of metallisation varying from 75-94% was produced. Attempts were made to keep the heat transfer and the constant temperature zone as uniform as possible. Under optimum conditions, metallisation of more than 90% was obtained. Attempts are under way to determine the optimum capacity of the retort under fully stabilised conditions and the life of retorts. These two parameters are important for economic evaluation and exploitation of the technical know-how in the industry.

## 47.1 Use of Sponge Iron as Steel Scrap in Steel Manufacture

The mechanical properties of the wires drawn from the two high carbon industrial heats made, using 40% sponge iron in the charge, were studied. It was noted that though no breakage was experienced during wire drawing operation, one heat showed 80% rejection of the product and no failure in the other case.

The cause of this observation was investigated and the entire history of the processing of both the heats was studied. The cause was atributed to the processing of the liquid steel in the refining stages. The report is under preparation.

## 48.0 Physico-Chemical Testing of Iron Ores.

The following samples were tested for their reducibility, thermal degradation, Linder degradation and swelling index:

(1) *Reducibility*

| *Sample* | *Sponsorer* |
|---|---|
| (*i*) Gandhamardan iron ore | MECON |
| (*ii*) Gandhamardan iron ore sinters | MECON |
| (*iii*) Gandhamardan iron ore pellets | MECON |

(2) *Thermal Degradation (Under Oxidising Atmosphere)*

| | |
|---|---|
| (*i*) Daitary iron ore | M/s. TISCO |
| (*ii*) Sakradih iron ore | M/s. Torsteel, Calcutta |
| (*iii*) Gandhamardan iron ore | MECON |
| (*iv*) Gandhamardan sinter | MECON |

(3) *Linder Degradation*

| | |
|---|---|
| (*i*) Gandhamardan lump ore | MECON |
| (*ii*) Gandhamardan sinter | MECON |

(4) *Swelling Index*

| | |
|---|---|
| (*i*) Gandhamardan pellets | MECON |

**49.0 Development of High Strength Low Alloy Steel.**

In continuation of previous work on vanadium-nitrogen steels, endeavours were made to establish the mechanism of strengthening of these steels. Calculations of solubility products of $V_4C_3$ and VN from chemical composition of the steels were made and compared with the available data on solubility products of these compounds at 900°C, 950°C and 1000°C. It was observed that solubility products of $V_4C_3$ at the above three temperatures obtained from available data were always greater than those obtained from chemical compositions, whereas solubility product of VN at 900°C, 950°C and 1000°C were lower than those obtained from chemical compositions. These indicate that all $V_4C_3$ goes in solution in austenite whereas some VN always remain out of solution under normalizing condition. It has, therefore, been assumed that $V_4C_3$ is the more potent sources of strengthening than VN in these steels.

**50.0 Development of Reduced Nickel Austenitic Stainless Steels.**

Eighteen 2 Kg. experimental heats of Cr-Ni-Cu-Mn stainless steels were made within wide compositional range to study the effect of composition on the corrosion resistance. Six 10 Kg. and four 2 Kg. ingots were forged into slabs. Further work is in progress.

**51.0 Special Steel Making by Basic Oxygen Process.**

All the jobs pertaining to erection and installation of the unit along with its equipment were completed. The commissioning and trial will commence.

## 52.0 External Desulphurization of Ferrous Melts.

*(i) Development of Briquetting Mix for Desulphurization of Hot Metal and Steel*

Laboratory scale experiments establishing the process to be capable of bringing down sulphur in both hot metal and steel to extra low levels (less than 0.01%), was completed. In-plant trial demonstrations of the process is being carried out in a reputed Foundry with encouraging results. The process is also suitable for large scale applications in integrated steel plants which is being explored.

*(ii) Desulphurization of Hot Metal in the Ladle by Synthetic Compounds*

Work is in progress to develop desulphurizing agents which are added in the form of powder mixture into the ladle to which hot metal when poured resulted in desulphurization efficiency to the extent of 40 to 70%. The reagents employed are cheap and the technique is easy to adopt without having to depend on fancy dispensing units or other infrastructural facilities.

## 53.0 Alloying by Direct Reduction of Oxide Concentrates into the Molten Bath.

Exploratory work carried out so far has established that it is possible to have a recovery of 93-98% Mo and 85-95% V, by adding exothermic briquettes of the respective oxide concentrates direct into the molten steel in the ladle or in the furnace. This will entail a considerable saving in the cost of alloying, since an intermediate step namely that of ferro-alloy making, is done away with. Laboratory experiments to establish the process parameters for the efficient recovery of Mo & V from their oxides were completed and large scale trial is awaited.

## 54.0 Production of Martensitic Steel Electrode Ingots for Firth (India) & HAL, Koraput. *Sponsored by M/s. Firth (India) Steel Co. Ltd.*

This project was taken up for the production of martensitic stainless steel electrodes, measuring 2.5 m length × 175 mm dia. and weighing 500 Kg. each. The electrode is to be used subsequently for ESR treatment by M/s. FISCO. The material being developed is of strategic importance, as it is required for the engine components in MIG aircrafts. There are ten elements to be simultaneously controlled within specified limits in making this alloy. One heat was made in the laboratory 0.8 T electric furnace and an electrode successfully cast. The composition of the casting, except for a 0.05% overshot of V over the maxm. specified limit, was within the specified limit. Two more heats are planned for future work.

## E. DEVELOPMENT & STUDY ON ALLOYS.

## 55.0 Development of Aluminium Cables & Conductors—Electric Grade Aluminium Alloy NML-PM2.

*Industrial Production of NML-PM2*

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

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

*Product Development*

The NML-PM2 multi-layer paper covered strips of different sizes for one phase winding of 20/16 MVA, 132/33/11 KV power transformer were supplied to Bharat Heavy Electricals Ltd., Bhopal. The winding of the transformer using NML-PM2 strips for one phase winding is in progress.

Based on the satisfactory experience with the use of Weasel and Rabbit ACSR conductor using NML-PM2 in the coastal regions, Gujarat Electricity Board have installed the commercial length of 300 km. of overhead conductor using 4 strands of NML-PM2 and 3 strands of EC aluminium.

Research Designs & Standards Organization, Lucknow; through their different railway workshops have continued their co-operation for use of NML-PM2 enamelled wires in the windings of signalling equipments as a substitute of copper. The different fine size bare wires were processed at M/s. Indian Cable Co. Ltd., and the enamelling of these wires is under process in collaboration with Dr. Beck & Co. (India) Ltd. Poona; for supply to railway workshops. Enamelling trials have given encouraging results and the electrical and mechanical properties are superior to the specified properties as per relevant Indian Standards.

*Specifications*

Based on the encouraging performance of NML-PM2 welding cables and flexibles experienced by railway workshops, RDSO has drawn the specifications for NML-PM2 giving reference to revised Indian Standards.

Indian Standards have revised the following specifications to include the requirements of NML-PM2 aluminium alloy for cable and conductor applications:

| | | |
|---|---|---|
| (*i*) | IS 4026-1978 | EC grade aluminium ingots |
| (*ii*) | IS 5484-1978 | EC grade aluminium rods produced by continuous casting and rolling. |
| (*iii*) | IS 1841-1978 | EC grade aluminium rods produced by hot rolling. |

The NML-PM2 aluminium alloy has been included as additional grade of EC aluminium designated as grade 3. The requirements of cables and conductors can now be met from NML-PM2 with ISI Certification Mark giving reference to grade 3 aluminium of above specifications.

## 55.1 High Strength Aluminium Alloy Conductor.

An aluminium alloy, designated NML-PM215 under development has (*i*) tensile strength up to 30 kg/mm$^2$ (*ii*) % elongation 10-15% (*iii*) electrical conductivity 50% IACS, in heat treated condition. The alloy possesses properties for potential use as grooved contact wire in railway electrification. Industrial trials for (*i*) casting the billet by semi-continuous D.C. method, (*ii*) production of 19 mm dia. rod by extrusion and (*iii*) making grooved contact wire were conducted in leading cable manufacturing industries. The samples of grooved contact wire were sent to RDSO for evaluation.

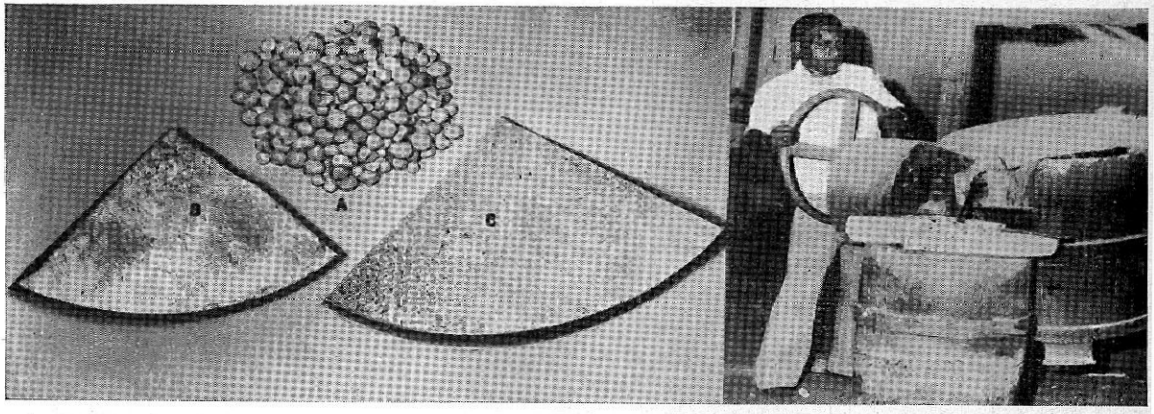
## 56.0 Development of Aluminium base Bearing Alloys.

Castings were made after modification of the conditions of solidification and the properties were evaluated. A second batch of casting of floating bushes have been made for further field trials at RDSO. Lucknow.

## 57.0 Methods to Improve Mechanical and Physical Properties in Aluminium and its Alloys.

(*a*) *Filtration of Liquid Metals*

During the year under review, a number of commercial scale trials were carried out. At Ordnance Factory, Ambajhari (OFAJ) in continuation of the encouraging results on HE 15 alloy, further filtration was done on C-21/51 alloy (Al-Zn-Mg alloy). The filter medium was independently used by OFAJ and they observed marked increase in productivity. Trials were also carried out at batch productions at Aluminium Manufacturing Company, Calcutta on LM 9 alloy and semi continuous system at Electrical Manufacturing Company, Calcutta; on 6061, 6063 and 5086 alloys. In all cases the samples were collected and these trials revealed that the filter unit has the following advantages:




*Reactive filter developed at NML for filtration of aluminium & its alloys for improving the cleanliness of melt. (A) NML reactive filter (B) Cast without NML filter (C) Cast with NML filter*

(*i*) can be easily incorporated in batch, semi-continuous or continuous casting system at any convenient location
(*ii*) the filter medium remains stable and about 20 tons of molten metal can be filtered
(*iii*) effects grain refinement and a uniform distribution of polyhedral grains across the transverse section in contrast to large feathery grains in unfiltered alloy
(*iv*) effects reduction of oxide/inclusions/sodium levels in filtered alloys
(*v*) reduces tendency to hot tearing
(*vi*) increases productivity in the casting and extrusion shops.

(*b*) *Special Melting Technique for Removal of Volatile Impurities*

Based upon earlier work, 100-110 Kg. of Al-Mg alloys were prepared. The material was used in the preparation of LM10 alloy at Aluminium Manufacturing Company, Calcutta. Good surface finish and fluidity were observed. Further quantities of 100 Kg. have been made.

**58.0 Development of High Strength Aluminium Alloy for Aircraft Applications.** *Sponsored by M/s. Hindustan Aircraft Ltd., Koraput.*

HAL, Koraput has sponsored the project on the development of AK4 alloy (Al-Cu-Ni-Mg-Fe-alloy), as a part of their import substitution programme. Experimental heats of 5 Kg. were made, the cast billets were homogenised and their extrusion parameters were determined. A suitable heat-treatment was given to the extruded rods to achieve the required properties of about 36 Kg/mm$^2$ UTS and 8% elongation. Based on this study large scale billets weighing about 150 Kg. were made and these are to be extruded at Ordnance factory, Ambajhari.

**59.0 Studies on High Strength Weldable Al-Zn-Mg Alloys.**

For studying the effect of alloying additions and heat treatment in the weldable Al-Zn-Mg alloy on stress corrosion susceptibility, a large number of heats with varying compositions were made. Studies on the effect of billet homogenisation temperature and extrusion parameters are in progress.

**60.0 Thermo-Mechanical Treatment of Aluminium Alloy.**

Thermo-mechanical treatments of NML-PM215 aluminium alloy and its effect on the mechanical and electrical properties were studied. The alloy was taken in form of extruded rod of 19 mm and 12 mm dia. The amount of deformation and heat treatment schedule were optimised for improvement in mechanical properties. This TMT will be useful for incorporating in production of grooved contact wire from NML-PM215 aluminium alloys.

**61.0 Development of Aluminium base Welding Electrode Wire.**

About 22 Kg. of NML-PM6 welding filler wires of 14 and 16 SWG were made and supplied to HAL Bangalore, to meet their requirements and also for product evaluation. Filler wires—aiming to obtain higher tensile strength (30-32 kg/mm$^2$) in the weld area were developed. The wire samples (16 SWG) were sent to Ordnance Factory, Ambajhari for its evaluation and suitability as the substitution for the imported welding filler wires.

Larger heats were made of NML-PM7 welding filler wire. The cast billets after heat-treatments were extruded and drawn to required sizes of wires. The work is in progress.

## 62.0 Development of Thermostatic Bimetals.

Production technology for batch production of the following groups of bimetals has been developed.

(*i*) *All-Ferrous Thermostatic Bimetal*

This incorporates ferrous alloys only as high and low expansion alloys. Different types have been developed in this group suitable for use over different temperature ranges. Production technology is ready for commercial exploitation and has been released to some entrepreneurs.

(*ii*) *Thermo-bimetals Incorporating Copper-base Alloys as High Expansion Component*

In this group brass-invar and silicon-bronze-invar type has been developed. The former is used where high thermal or electrical conductivity is desireable, the latter is suitable in corrosive environment. Both cast-bonding as well as explosive-welding techniques have been developed for this group.

The samples sent to various users have received satisfactory performance report.

(*iii*) *Thermo-bimetal Involving Mn-base Alloy as High Expansion Component*

This group of bimetal has the highest sensitivity. The samples sent to various users has given satisfactory service and the technology is ready for commercial exploitation.

## 63.0 Development of Clad Metals.

Various clad metals have been developed for strategic application, cost reduction, conservation of scarce material as well as to improve performance and efficiency.

(*i*) *Stainless Clad Mild Steel*

This clad metal is a cheaper substitute of stainless steel. In it a comparatively thin layer of costly stainless steel provides corrosion resistance and cheaper mild steel base bear the strength. Laboratory scale production technology has been developed which is now scaled up.

(*ii*) *Duplex Shear Blade*

This composite clad consists of a tool steel layer bonded to a mild steel or low alloy steel base. This composite is not only a cheaper substitute for shear blade and some other cutting tool applications, but it has also some special application where widely different hardness is demanded in opposite faces of

the shear blade. Optimum conditions for bonding various thickness and alloy combinations, as well as heat-treatment schedule are under development.

### *(iii) Copper Clad Aluminium Sheet*

This consists of a thin layer of copper cladded to thicker aluminium base. For many applications this clad product could be a cheaper substitute for copper, but at present this is mainly being used as transition joint in electrical traction and electrical equipment between an aluminium and a copper conductor. The technology has been developed and leased out for commercial exploitation.

### *(iv) Stainless Clad Aluminium Sheet*

A thin foil of stainless steel bonded to aluminium would be a cheaper substitute for stainless steel for many applications. For frying pan and cooking utensils where uniform heating is desirable, its performance would be much superior to that of stainless steel because of excellent thermal conductivity of aluminium. Work is in progress for developing a viable technology for bonding stainless steel to aluminium so as to produce adequately ductile clad sheet.

## 64.0 Electrical Resistance Alloys.

Suggestion and technical assistance were given to the licencees of the process to solve the production problems. The problem on the formation of localised oxidation blisters on the surface of the wire after certain hours of run was referred by M/s. Cable Works, Faridabad. The cause of these defects was identified and the suggestions were provided to the firm to overcome this problem. The physical and mechanical properties of the alloys produced by the firm were also evaluated and have been found satisfactory as per specification.

## 64.1 Development of Iron-Chromium-Nickel Alloys.

In order to develop an iron-base alloy suitable for use as heating element at about 1000°C, number of heats were made. Appreciable amount of Cr and smaller percentage of nickel were added as alloying elements. The ingots were forged, rod-rolled and drawn to the wires. The physical and mechanical properties of the alloys were evaluated. On the basis of these properties, appropriate composition has been developed to suit the intended application of the alloy.

## 64.2 Development of High Temperature Alloy.

Development of this alloy was centred around Fe-Cr-Al system. Small additions of other alloying elements were also added to improve the life and quality of the alloy. Several heats were made, forged, rod-rolled and then drawn to wires. The physical and mechanical properties of the wires were evaluated. An appropriate composition has been worked out to suit the intended application of the alloy.

## 65.0 Dental Amalgam Alloy.

The process for the production of Dental Amalgam Alloy was released to M/s. Dentfils India Ltd. The firm is now actively engaged in the production of the alloy.

Further work on the davelopment of a low-silver amalgam with 50% silver is being carried out. The physical properties of the alloys were evaluated and the results are being compared with the conventional alloys.

### 66.0 Production Technology of Contact Materials.

For the development of different types of contact materials the first phase of exploratory work was centred round on the silver-cadmium alloys. The alloy of silver and cadmium was melted and cast in a pencil mould several small pieces were cut from the ingot and each piece was subjected to different heat-treatment schedules in order to convert the cadmium of the alloy to cadmium oxide. The physical and mechanical properties were determined and the values were found to be comparable with the imported alloy.

## F. DEVELOPMENT OF MAGNETIC MATERIALS

### 67.0 Development of High Permeability Nickel-Iron Alloys. *Sponsored by M/s. Guest, Keen & Williams Ltd., Howrah.*

In the second phase, the work on the development of three alloys similar to Rho metal, Radio metal and H.C.R. alloys was taken up and completed. Work on cold rolled HCR alloys to develop rectangular hysteresis loop and maximum permeability by cold rolling and annealing and magnetic annealing is in progress. Another alloy similar to Mu metal having 4.5% Mo has been developed.

### 68.0 Development of Permanent Magnets based on High Crystal Anisotropy and Exchange Anisotropy.

The reduction-diffusion trials using samarium oxide, cobalt and calcium granules for the preparation of Sm-Co magnets were continued. It was found difficult to produce $SmCo_5$ magnets by this technique. To carry out this reduction-diffusion technique it has been found necessary to design a reactor. The design has been made and the fabrication work is being persued.

### 68.1 Low Carbon Soft Magnetic Iron.

2650 Kg of soft iron of different sections 65 mm sq. and rounds of 45 mm, 25 mm & 16 mm hot rolled from the commercial heat prepared and processed in the industry has been supplied to the following organisations against their requirement for use in electro magnetic relay components.

(*i*) M/s. North Eastern Railway, Gorakhpur,
(*ii*) M/s. South Central Railway, Secunderabad,
(*iii*) M/s. Hindustan Aeronautics Limited, Lucknow,
(*iv*) M/s. Bharat Electronics Limited, Bangalore.

Work is in hand to undertake the cold drawing of these hot rolled soft iron rods in an industrial plant.

## G. TESTING OF MATERIALS

### 69.0 Central Creep Testing Facility.

During the period, work on the following projects was conducted.

(*i*) *Development and Testing of Creep Resistance Steels. Sponsored by M/s. Bharat Heavy Electricals Ltd.*

The following grades of steels were tested for evaluation of their long-term high temperature properties:

| *Steel* | *Manufacturer* | *End Use* |
|---|---|---|
| 1¼ CrIMo¾ V TiB | MUSCO | Steam turbine bolting up to 565°C. |
| 1¼ Cr½ Mo (En-20B grade) | MUSCO | Steam turbine bolting up to 480°C. |
| 1 Cr½ Mo | VISL | Forgings & seamless superheater tubes of high pressure boilers up to 510°C. |
| 2¼ Cr-1 Mo | MUSCO & ASP | Seamless superheater tubes of high pressure boilers up to 565°C. |
| 1¼ Cr½ Mo (0.5FO grade) | CFFP | Steam turbine castings up to 510°C. |
| 1 Cr1 Mo½V (FOV grade) | CFFP | Steam turbine castings up to 565°C. |
| 1¼Cr1 Mo¼V (1.4 FOV grade) | CFFP | Steam turbine forgings up to 565°C. |

The results obtained on various grades of indigenously manufactured conventional creep resistant steels given above, in general, are in good agreement with the international/collaborators test data on corresponding grades of steels. Based on the data collected so far the first four grades of the above steels have been accepted as import substitutes for thermal power plant applications.

(*ii*) *Accelerated Stress-rupture Testing of 12Cr Steel. Sponsored by M/s. Bharat Heavy Electricass Ltd.*

Stress-rupture tests are being conducted on steel samples supplied by BHEL R & D Division at three temperatures 600°, 625° and 700°C and at two stress levels 6 and 8 kg/mm² at each temperature.

(*iii*) *Creep-rupture Testing of AISI 316 Grade Stainless Steel. Sponsored by Reactor Research Centre, Kalpakkam.*

Long-term creep-repture tests are in progress on imported AISI 316 grade austenitic stainless steel plates required in building the core components of the sodium cooled fast breeder test reactor at the Reactor Research Centre, Kalpakkam. In the absence of base line design data on the imported steel, RRC desired NML to generate the same.

Creep-rupture tests for durations over 27,000 hours have been completed on samples from three plates and an interim test report has been submitted. Against one of their R & D investigations, RRC also desired NML to conduct creep-rupture tests at 650° and 700°C to give rupture lives in the range 1,000-10,000 hours on samples from one of the above casts but under different heat treatment conditions. The tests for durations up to 5,000 hours have been completed and others are in progress.

(*iv*) *Creep-rupture Testing of 2¼Cr1Mo Steel Forgings for Superheater Tubes. Sponsored by Research & Development Centre for Iron & Steel, Steel Authority of India Ltd., Ranchi.*

R & D Centre, SAIL, sponsored an investigation on 2¼Cr1Mo steel to study the following:

(*a*) Evaluation of strain rate sensitivity and creep-rupture properties, taking the specimens from different casts concering the specified range of chemical composition.

(*b*) Creep crack growth both in weldments and in virgin metal.

One cast of the steel has so far been supplied. Hot tensile tests under varying strain rates in the temperature range 400°-600°C were completed. Creep tests at 550°C and at different stress levels in the range 7-19 kg/mm² are in progress. Test durations up to 3,000 hours have been completed.

(*v*) *Estimation of Residual Creep Life of Superheater Tubes. Sponsored by M/s. Bharat Heavy Electricals Ltd.*

In view of the repeated premature convection superheater tube failures in a reasonably young thermal power station. BHEL desired to carry out an investigation to estimate the residual creep life of the tubes to enable them in taking decisions with regard to (*a*) Whether the steel corresponds to the specified grade with regard to its long-term stress-rupture properties and to determine if an useful life left over. (*b*) Whether to go for repairs or for total replacement of tubing. (*c*) To plan the outages, if necessary, as per the convenience/power demand.

Residual creep life can be roughly estimated on the basis of the concept of life fractions at various actual service conditions being cumulative. In the absence of reliable history, method of predicting the residual life through accelerated stress-rupture tests was adopted. Uni-axial stress-rupture tests were carried at a constant stress 6.09 kg/mm² corresponding to the design stress and at temperature 620°, 600°, 580° and 565°C, all above the designed temperature of 480°C. The findings more readily accounted the premature failures for the material defeciencies rather than for operational abuses. A final report on this project has been submitted.

Subsequently BHEL sent some more samples for accelerated stress-rupture testing of tube samples for the estimation of residual creep life. The tests on these samples are now in progress.

(*vi*) *Development of Nickel Free Creep Resistant Austenitic Steels*

Keeping in view that conventional creep resistant austenitic steels containing nickel for which India lacks in raw materials resources, two different types of steels (*i*) Cr-Mn-N and (*ii*) Cr-Mn were developed. These were found to possess elevated temperature properties comparable to those of AISI 316 & Esshite 1250 Steels.

Cr-Mn-N steel is under evaluation for its suitability for exhaust valves of the automotive engines. The report on Cr-Mn austenitic type of austenitic steel which was sent to M/s. Flight Refuelling Ltd., Dorset, U.K. at their request in order to evaluate its suitability for heat exchangers in the primary circuit of a high temperature reactor, is awaited.

(*vii*) *Development of High Temperature Bolting Steels*

High temperature bolting steels of Cr-Mo-V type with high vanadium content used in steam power plant spossess high creep strength but are prone to failure due to notch-embrittlement on prolonged service. Based on the short-term improved properties observed with the Cr-Mo-V steels containing TiB additions, it has been subsequently used in a number of modern power plants. Recent reports on TiB containing steels, however, show that the benefits realised from short-term testing are not retained on long-term service and suffers from low notch-ductility. The present work is aimed to improve the long-term notch-rupture ductility of this steel without sacrificing the creep strength through minor alloying additions and suitable heat-treatment. The results available so far are very encouraging and a few steel compositions have been finalised for long-term testing.

(*viii*) *Design and Development of a Load Cell Suitable for Wire and Rod Drawing Dies*

In wire and rod drawing industries, it has been observed that the dies fail prematurely mainly due to the excessive pressure being exerted on the dies. The project aims at the development of load cell to measure the pressure being exerted on these dies during operation. This enables to control the pressure on the dies which, in turn, helps in (*i*) increasing the life of the dies, and (*ii*) in controlling the quality of the product drawn.

A high sensitivity variable-inductance type instrument transducer has been developed. Using this instrument transducer a prototype load cell to measure upto a maximum load of 225 kg was designed and fabricated. The performance of the load cell has been tested on the wire drawing machine available at the NML using the audio-oscillator. The results were found to be very satisfactory. Since the audio-oscillator forms an intergral part of the load cell, arrangements are being made to procure the same as per the designed specifications.

(*ix*) *Short-term Test Programmes*

Materials were received for limited testing as given below to determine their specified properties.

| *Material* | *Nature of Investigation* | *Sponsoring Organisation* |
|---|---|---|
| 1. Carbon steel boiler tubes | As per IRB 1950 | Indian Oil Corporation, Barauni. |
| 2. Carbon steel boiler tubes | As per IBR 1950 | Nagaland Pulp & Papers Co. Ltd. |
| 3. Carbon and low alloy steel boiler tubes | Hot tensile tests | ACC - Vickers - Babcock Ltd., Durgapur. |
| 4. HK40 (25Cr20Ni) steel castings for use in petro-chemical/Fertilizer Plants | Creep-rupture tests for Lloyds Stamping | Shivananda Steels Ltd., Madras. |
| 5. Aluminium alloys under different mechanically worked/heat treatment conditions | Creep-rupture tests against a project leading to Ph.D. | Dept. of Metallurgy, BHU. |
| 6. 12CrMoV ESR melted steel | Acceptance tests as per BHEL's Technical Delivery Conditions | BHEL R & D. |
| 7. Seamless & ERW carbon steel boiler tubes (swaged) | Metallurgical evaluation | Nagaland Pulp & Paper Co. Ltd. |
| *Material* | *Nature of Investigation* | *Sponsoring Organisation* |
| 8. P. C. Wires | Stress-relaxation and other tests as per IS : 1785 & IS : 6003 under ISI Certification Marks Scheme | ISI on behalf of various steel wire manufacturers. |
| 9. Weld metal deposits of austenitic & low alloy ferritic steel welding electrodes | Creep, stress-rupture and hot tensile tests | D & H Secheron Electrodes Ltd., Advani-Oerlikon Ltd., and Philips India Ltd. |
| 10. 15Mo3 steel boiler tubes | Short-term accelerated stress-rupture tests for the estimation of residual creep life | BHEL R & D. |
| 11. 12CrMoV steel forgings for high temperature applications other than steam turbine blading | Short-term accelerated stress-rupture tests | BHEL R & D. |

## H. METALLURGICAL INVESTIGATION STUDIES ON METALS & ALLOYS

**70.0 Failure of Winding Ropes.** *Sponsored by M/s. Eastern Coal Fields Ltd.*

Winding ropes at Bansra & Mahabir collieries were reported to have failed prematurely in service. Metallurgical investigations carried out showed that although the winding ropes conformed to chemical composition and mechanical properties, surface imperfections on the surface had contributed to fatigue failure.

**70.1 Pig Casting Mould Material for Developing Indigenous Substitute.** *Sponsored by M/s. Indian Aluminium Co. Ltd., Mysore.*

Metallurgical tests were carried out on imported pig casting mould material with a view to develop indigenous substitute.

**70.2 Metallurgical Examination of Armour Plate of Ball Mill.** *Sponsored by Patratu Thermal Power Station, Hazaribagh.*

Armour plate material of the ball mill for crushing coal on metallurgical studies revealed the inadequacy of heat treatment imparted to get optimum service performance.

**70.3 Metallurgical Examination of Pump Impeller, Liner and Elevator Links.** *Sponsored by M/s. Central Coal Fields Ltd., Giridih Washery, Hazaribagh.*

Metallurgical evaluation of the components was carried out to develop steels for their manufacture from indigenous resources.

**70.4 Metallurgical Evaluation of Hangers for 132 KV/DC Transmission Line.** *Sponsored by Bihar State Electricity Board.*

Metallurgical evaluation of the hangers for D/C transmission line revealed that ample scope exists for better welding technique and post weld heat treatment in order to obtain satisfactory service performance.

**70.5 Mechanical Strength of Mild Steel Tube at −60°C.** *Sponsored by M/s. Engineers India Ltd.*

Mechanical properties of MS tube at −60°C was carried out to ascertain the notch ductility at different strain rages.

**70.6 Metallurgical Evaluation of POP-2 WH Boiler Tube.** *Sponsored by M/s. Indian Explosive Ltd., Gomia.*

Results of metallurgical tests showed that the boiler tube material conformed to the specification.

**70.7 Metallurgical Examination of Steel Crusher Hammer.** *Sponsored by M/s. Kalyanpur Lime & Cement Works Ltd., Rohtas.*

Metallurgical examination showed that the austenitic manganese steel was improperly heat treated and resulted in premature failure.

**70.8 Failure of Drill Pipes.** *Sponsored by Oil & Natural Gas Commission, Ramsahar Project.*

Metallurgical examination of the premature failure of the 5" OD imported drill pipes showed that the failure had taken place on account of hydrogen embrittlement arising out of hydrogen sulphide environment in the oil well. It was suggested to use conventional inhibitors and sulphide scavangers in the drilling mud and also the use of advanced handling technology of the drill pipe.

**70.9 Failure of Boiler Tube.** *Sponsored by Madhya Pradesh Electricity Board.*

The cause of premature failure of the boiler tube was due to local overheating probably on account of blocking or general water starvation on faulty circulation.

**70.10 Metallurgical Evaluation of Extruded Lead Alloy Cable Sheath.** *Sponsored by M/s. Indian Cable Co., Jamshedpur.*

Metallurgical tests were carried out on samples of extruded lead cable sheath containing ridge and plain surfaces in respect of mechanical strength and microstructure. The ridge formation was attributed to non-metallic impurities and oxides of lead trapped during extrusion. The problem could be alleviated by control of oxygen content in the alloy.

**70.11 Failure of 'Silo' and other Stainless Steel Equipment.** *Sponsored by Mother Dairy, Calcutta.*

Metallurgical investigation on buckling and corrosion of 'Silo' and other equipment revealed that although the material was specified for the purpose, absence of post-weld heat treatment resulted in stress corrosion cracking on account of water used for storage containing chloride irons.

**70.12 Failure of Weld Joint in Platen Superheater Header.** *Sponsored by Chandrapura Thermal Power Station, DVC.*

Metallurgical studies revealed that the weld cracking had taken place as a result of the use of plain carbon steel welding electrodes in place of $2\frac{1}{2}$ Cr IMo or of $ICr\frac{1}{2}$ Mo steel electrodes and due to the segregation of inclusions at the grain boundaries. The header was subsequently rewelded, as per the 'advice' with matching low alloy steel electrodes and put into service.

**70.13 Failure of Economiser Tubes.** *Sponsored by Chandrapura Thermal Power Station, DVC.*

Metallurgical examination of the failed and a new tube showed that the new tube itself sustains microscopic damage viz. cracks and voids at inclusions and grain boundaries and corrosion fissures at the surface. Further the tubes

were found that they do not strictly correspond to the Specification with regard to the hot finishing and final heat-treatment.

**70.14 Failure of Water Wall Tube.** *Sponsored by Durgapur Thermal Power Station, DVC.*

It was observed that the failure had taken place on account of hydrogen embrittlement and creep cracking.

**70.15 Failure of Water Wall Tube.** *Sponsored by Patratu Thermal Power Station, Bihar State Electricity Board.*

Results of metallurgical examination showed that the failure was due to overheating. It was also observed that the quality of welding of the fins to the tube in failed region was not proper.

**70.16 Metallurgical Study of the Steam Chest of CIES Valve.** *Sponsored by Chandrapura Thermal Power Station, DVC.*

Chemical analyses showed that the casting was of specified quality. Metallographic examination revealed the presence of remanent cast structure which, in turn, showed that the casting was not properly heat-treated.

**70.17 Failure and Weld Repair of Hydro-turbine blades of Panchet Hydel Power Station and Weld Repairing of a Crack in IP Cylinder of 200 MW Steam Turbine of Unit IV of Durgapur Thermal Power Station.** *Sponsored by DVC.*

Consultancy services were rendered to M/s. Damoder Valley Corporation on the above problems which has led to early restoration of plants for powe rgeneration and quality control of the components.

## I. FOUNDRY TECHNOLOGY

### 71.0 Heat Resistant Cast Iron.

An agreement was signed with Tata Iron & Steel Co. Ltd., for industrial scale production of the heat resistant cast iron and ultimate take over of the process. One large heat was made for casting of carrier blades for reheating furnace.

Evaluation of element pins for electric furnace was carried out under load and satisfactory results were obtained. Arrangements are being made for industrial evaluation of the product in collaboration with M/s. G.E.C., Calcutta.

Fingers for pipe annealing furnace were cast and their service evaluation will be taken up at IISCO Stanton Pipe & Foundry Co. Ltd., Ujjain.

### 72.0 Development of Self-setting and Fluid Sand Process.

Fluidizing experiments with ferrochrome slag as hardner were completed. Further experiments with ester hardners were taken up.

### 73.0 Wear and Abrasion Resistant Cast Iron.

Wooden pattern for the hammer rings was fabricated and a few rings were cast for industrial evauation in coal crushing plant.

A few castings of coal crushing hammers weighing about 27 Kg were cast with NML-alloy and are awaiting evaluation in a coal mill. A few plates were also cast with NML-alloy and contacts were made for their evaluation in ash handling tank at a thermal power station. The casting of the flanged pipe in 'NML-Wear Not' showed hair line cracks. Efforts are being made to get these pipes and other components cast in industrial foundry for purposes of evaluation study in the transportation of slurry and handling of abrasive materials.

## J. CORROSION STUDIES ON METALS & ALLOYS

### 74.0 Studies on Stress Corrosion Cracking of Metals.

Studies on stress corrosion cracking of mild steel in hot solution of ammonium nitrate were carried out. Parameters such as effect of stress, concentration of solution, $P_H$, cold working etc. were studied. Panel arrangements were made to study the stress corrosion phenomena of stainless steels in chloride, with particular emphasis on concentration of chloride and some metallurgical factors like cold working, heat treatment etc.

### 75.0 Development of Aluminium Anode (Superal) for Cathodic Protection.

During the period under review, a large scale melting trial of the alloy was successfully conducted in an aluminium industry in the light of consumer's acceptability test. A part of the alloy made was utilised to cathodically protect the hull surface of R.E. Gaveshani, an ocean going research vessel belonging to the National Institute of Oceanography, Goa.

### 76.0 Evaluation of Inhibitors for Corrosion Control in Re-circulating Cooling Water and Steam Condensate System.

Experimental set up for dynamic tests (rig test) as suggested in under progress.

### 77.0 Development of High Temperature Oxidation Resistant Chromium Steels.

During the period under review, several heats of various compositional ranges were prepared. Mechanical working of these steels were completed. Oxidation/hot corrosion tests with the test samples are in progress. In situ tests under industrial conditions are simultaneously planned.

### 78.0 Studies on Hydrogen Embrittlement of Steel in Aqueous System.

Hydrogen embrittlement of cold rolled mild steel in 1 $NH_2SO_4$ under static load at room temperature was studied. Cathodic charging of the steel wire with hydrogen at different current densitites is being studied. The results showed that with increase in current densitites the time to failure decreases at a constant load.

## K. SURFACE COATING ON METALS

### 79.0 Nickel-Iron Alloy Plating (70% Ni, 30% Fe) as a Substitute for Nickel Plating for Commercial Plating Purposes.

Ni-Fe alloy plating was successfully carried out and some samples were sent to parties for evaluation.

### 80.0 Plating of Cobalt-Tin Alloy as Substitute for Chromium Plating.

The optimum conditions of deposition were obtained which can be applied on larger scale.

### 81.0 Electroless Nickel Plating.

Experiments were conducted to study the effects of various complexing agents over the rate of plating.

### 82.0 Plating on ABS Plastics.

Project was taken up on loaboratory scale and successfully carried out using electroless nickel plating.

### 83.0 Development of Alkali Silicate—Zinc Dust Coating.

Silicate solutions were successfully prepared from commercially available sodium silicate solutions by ion-exchange treatment. A number of zinc rich primer compositions based on the above vehicle and zinc powder of about 98% metallic zinc content were made with minute additions of wetting and stabilising agents. Various factors such as pot stability of zinc silicate primer, its brushability and the galvanic protection offered by the primer on mild steel samples were studied. The effect of curing conditions on the protective properties of the primers were studied.

### 84.0 Chromizing and Calorizing of Low Alloy Steel for High Temperature Surface.

Samples from ICr-$\frac{1}{2}$ Mo castings supplied by BHEL were calorized in hermitically sealed retorts under optimum conditions. The Al concentration was analysed by electron micro probe and it was found to be 65% upto a depth of 100 microns and decreasing upto 28% near the metal-coating boundary. Cyclic oxidation tests were carried on calorised mild steel and low alloy steel specimens and compared with the data on respective blanks with a view

to finding out the spalling resistance of the coating and oxidation resistance of the coated samples under the above conditions. The mild steel samples were heated to 700°C and kept for 5 hours at that temperature and cooled to room temperature under standard conditions. The cycle was repeated six times. Similarly calorized alloy steel and blank specimens were subjected to 8 cycles. In both the cases, the oxidation resistance of calorized samples was increased to at least 30 times. Continuous oxidation tests on calorized mild steel and low alloy steel specimens were carried at 700° and 800°C using thermal balance and the results are being analysed.

### 85.0 Electro-galvanising of Steel Wires from the Fluo-borate Bath.

Experiments are under way on laboratory scale to optimise the conditions for large scale-up. A few firms have shown interest in the project.

## L. STANDARD REFERENCE MATERIALS & ANALYTICAL WORK

### 86.0 Preparation of Chemical Standareds.

So far 33 different types of standard sample have been prepared and being sold to industries, educational and research organizations.

The following materials were taken up for preparation of standard samples :

(*i*) Low alloy steel
(*ii*) Alloy cast iron
(*iii*) High carbon steel.

During the period, work was completed on (*i*) alloy cast iron and (*ii*) high carbon steel and samples were released for sale with certificate. 109.8 Kg. of different types of reference samples worth Rs. 1.3 lakhs were sold during the period.

### 87.0 Preparation of Spectrographic Standards.

Preparation of low alloy steel standard was completed and made ready for sale. Samples worth mark Rs. 6 thousand were sold during the period.

### 88.0 Analytical Work.

(*i*) *Chemical and Instrumental Analysis*

5357 samples for 13657 radicals were analysis.

(*ii*) *Analysis of Gases in Metals*

167 samples for 218 radicals were analysis.

(*iii*) *Spectrographic Analysis*

(*a*) X-ray Fluorscence Analysis-1520 samples for 2421 radicals.
(*b*) Spectrography—246 sample for 512 radicals.

*(iv) Petrological & D.T.A. Studies on Ores & Minerals*

Detailed petrological & differential thermal analysis studies were conducted on 41 samples of ores and minerals received for beneficiation and other studies in the Laboratory.

## M. APPLIED BASIC PROJECTS

### 89.0 Studies on Two Phase Solidification in Aluminium Alloy.

A special arrangement (Fig. 1) was fabricated to vigorously agitate mechanically the semi-solid state of Al alloys containing 12% silicon and other elements like Fe, Cu etc. and one Y alloy composition. A uniform dis-

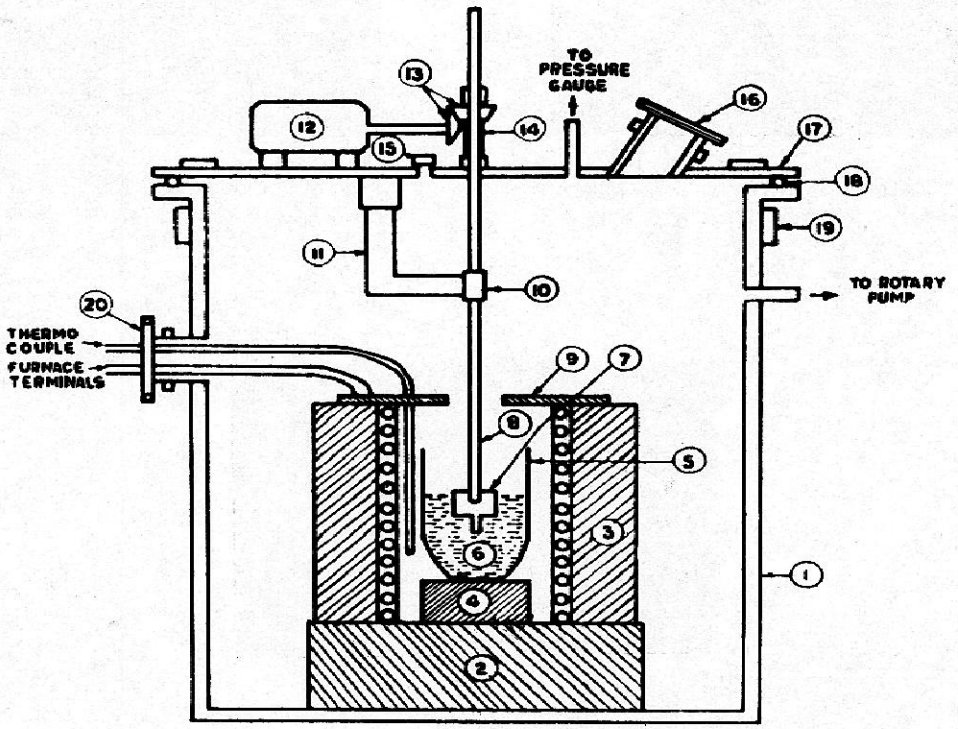



FIG: SETUP FOR VACUUM STIRRING OF MOLTEN METAL

1 VACUUM CHAMBER
2 FURNACE SUPPORT
3 RESISTANCE FURNACE
4 CRUCIBLE SUPPORT
5 CRUCIBLE
6 MOLTEN METAL
7 GRAPHITE NOZZLE
8 S.S. ROD
9 ASBESTOS SHIELD
10 BUSH
11 SUPPORTING BRACKET
12 MOTOR
13 BEVEL GEARS
14 SUPPORT
15 VACUUM RELEASE VALVE
16 VIEWING WINDOW
17 LID
18 O RING
19 COOLING CHANNELS
20 WINDOW FOR ELECTRICAL CONNECTIONS

persion of immiscible phases like lead, graphite etc. was aimed in this arrangements. About 6% Pb was added to the vigorously agitating semi-solid metal composition and immediately cast. Similarly a uniform dispersion of appropriate size graphite-particle was achieved by this process. Typical microstructures of dispersion of lead in Al-12%, Si alloy. Y alloy and graphite dispersion in commercial aluminium are shown in the figures 2, 3 and 4.

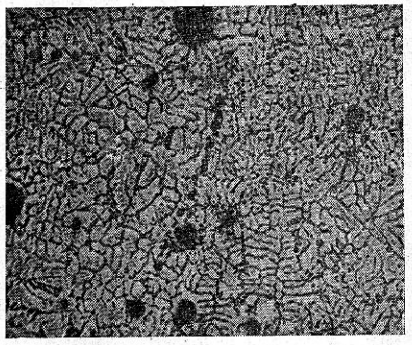


*Fig. 2 Microstructure of Rheocast Y alloy containing 6% Pb × 100*

*Fig. 3 Microstructure of Rheocast Al-12% Si alloy containing 6% Pb ×100*

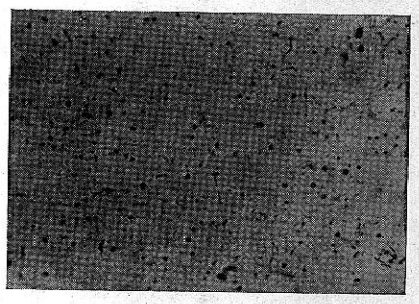


*Fig. 4 Shows the distribution of graphite particles in Al-matrix×200*

## 90.0 Study of the Physical and Mechanical Properties of Splat Cooled Aluminium Alloys.

Complex Al-Si alloys and high strength Al-Zn-Mg alloys were processed for Al-Si & Al-Ni alloys and the properties were evaluated. Tables 1*a* & *b* shows the properties achieved by rapid solidification process.

**Table 1a**

Tensile Properties of Al-Si Alloys

| Alloy | UTS Kg/mm² | % Elong. | % RA | BHN | Reference |
|---|---|---|---|---|---|
| Al-20 Si | (*i*) 28.6 | 5 | 4 | 102 | Present work |
| | (*ii*) 27.2 | 4 | 4 | 96 | |
| LM-28 | (*i*) 20.2 | 0.5 | — | 120 | |

(*i*) Solution treated and artificially aged condition.
(*ii*) As extruded condition.

**Table 1b**

Tensile Properties of Al-Zn-Mg alloys

| Alloy | UTS Kg/mm² | % Elong. | % RA | Remarks | Reference |
|---|---|---|---|---|---|
| Al-Zn-Mg I $T_6$ | 58.5 | — | — | Failed by mechanical slippage | Present work |
| Al-Zn-Mg II $T_6$ | 59.70 | — | — | Do | Do |
| Al-Zn-Mg III $T_6$ | 56.75 | 18 | 27 | Normal Fracture | Do |
| 7075 $T_6$ | 58.35 | 11 | — | — | Standard Alloys |
| 7079 $T_6$ | 54.8 | 14 | — | — | Do |
| 7039 $T_{51}$ | 42.2 | 13 | — | — | Do |

## 91.0 Fundamental Studies on Factors affecting Bentonite Properties.

Electron diffraction photographs of all bentonite samples were completed. Activation studies on gas treated and as-received samples were taken up.

# LARGE SCALE FACILITIES

## 92.0 Mineral Beneficiation.

Large scale investigations conducted on different types of low grade ores and minerals have been reported in the Chapter 'Research, Investigation & Development Projects' under Section 'A' 'Ore Dressing & Mineral Beneficiation'.

## 93.0 Dense Carbon Aggregate and Soderbarg Paste.

Thirty tonnes of soderberg paste made in the carbon plant were supplied to M/s. Ferro Alloys Corporation, Shreeramnagar for its industrial evaluation. This paste has been tried in two electrodes of the closed type furnace for making Ferro manganese. Actual performance report is still awaited. Soderberg paste project is over and is ready for transfer of technology.

## 94.0 Electrolytic Manganese and Electrolytic Manganese Dioxide.

An electrolytic manganese dioxide pilot plant with a capacity of 50 Kg per day based on the technology developed at NML was set up and commissioned at Central Research Organisation, Rangoon, Burma; under the Indian Technical and Economic Co-operation Programme. The ore from Burma was evaluated at NML for its amenability for production of EMD. A scientist was deputed to Burma to help in the commissioning of the pilot plant and training of Burmese staff in the operation of the plant.

A joint sector company, Electro-Chem. (Orissa) Ltd., has been formed between Industrial Promotion and Investment Corporation of Orissa Ltd., and M/s. Rungta and Sons (Pvt.) Ltd., for production of 3000 tonnes of electrolytic manganese dioxide at Joda-Barbil area. The manganese ore from Silijora-Kalimati mines was evaluated for production of EMD in this plant. M/s. T. K. Chemicals Ltd., the first licencee to produce EMD in the country based on NML technology, are progressing in production in their plant at Trivandrum.

# NML UNIT IN CSIR COMPLEX, MADRAS

The Unit, during the period under review, has made steady progress in its scientific and technical activities in several disciplines. A number of organisations both in the public and private sector have utilised the services and expertise available at the NML Unit. New items of equipment have been added. A semi quantitative metal spectroscope has been set up for metal analysis as also gas evolution apparatus for testing aluminium dross. The Unit has been successful in developing a semi-automatic carbon analyser for rapid and efficient analysis of carbon. The Unit has taken up and completed several projects in the fields of industrial metallurgy, heat-treatment, foundry, mineral dressing, chemical metallurgy etc. the notable project being the studies on iron ore samples from Bellary-Hospet Region, referred to by MECON, Ranchi. The Laboratory has also undertaken inter-laboratory projects in collaboration with other Units of the CSIR Campus such as development of dry scrubbing unit for reclamation of foundry sands. A Technological Bay is under construction to augment ore-testing facilities, to house heat-treatment and melting furnaces as also equipment for chemical metallurgy work. A brief resume of the progress of various projects and other activities during the period is furnished below:

(*i*) **Purification of a Silica Sand Sample from Kerala.** *Sponsored by Department of State Geology & Mining, Kerala.*

A sample of silica sand from Shertalai analysing 93.7% silica, 2.34% alumina, 1.3% $Fe_2O_3$ and 1.43% $TiO_2$ was subjected to intensive beneficiation studies with a view to removing the heavys as far as possible to obtain an enriched silica fraction suitable for glass manufacture. Screening, wet classification and tabling methods were investigated and a sand fraction analysing 98.1% silica was obtained. Treatment of this sand fraction to high intensity, dry magnetic separation produced a non-magnetic fraction analysing as high as 99.7% silica with satisfactory yields. This sand because of its high sintering range, high silica content, four sieve distribution and good physical property when bonded with yellow dextrin and bentobite is suitable for heavy medium and alloy steel castings with suitable washes as necessary.

(*ii*) **Beneficiation and Pelletisation Studies on a Sample of Low-grade Limestone.** *Sponsored by M/s. Industrial Chemicals, Sankarnagar.*

A sample of low-grade limestone analysing 43.74% CaO and 20.2% silica was subjected to intensive laboratory beneficiation studies to obtain a calcite concentrate analysing as low as 0.5% silica so that this product after suitable agglomeration methods could be used for calcium carbide manufacture. A concentrate analysing 54.8% CaO with 0.4% $SiO_2$ was obtained. The yield of the concentrate was also quite good. Pelletisation studies were subsequently conducted on the calcite concentrate using molasses and dextrin as binders. The pellets produced had satisfactory green and dry strength and could be used in the electric furnace after calcination in a rotary kiln for calcium carbide production.

(*iii*) **Studies on Iron Ore Samples from Bellary-Hospet Region.** *Sponsored by M/s. MECON, Ranchi.*

Detailed investigations were conducted on ten iron ore samples with a view to determining physical, chemical and crushability of the samples so that the lumps produced after crushing and screening could be used for blast furnace iron production and the fines after suitable beneficiation and grinding could be used for production of good quality pellets suitable for export purposes.

The chemical analysis of the 10 ROM type samples showed that the samples had 63-68% Fe, 0.4-2.7% $Al_2O_3$, 0.5-3.5% $SiO_2$. Two group samples composites 1 and 2 were prepared after mixing in suitable proportions. Crushability studies conducted on these revealed that a set of 30 mm jaw setting is the optimum. Wet classification studies conducted on the screened −10 mm materials yielded classifier sands suitable for pellet making after grinding.

Batch pelletisation studies were conducted on a composite classifier sand sample. The fluxed pellets satisfied the grade, crushing strength, swelling index and had good reducibility as well.

Sintering trials conducted on the dry screened fines of group samples 1 and 2 indicated that moderately good quality oxide as well as basic sinters could be produced with satisfactory strength, shatter index and reducibility values.

(*iv*) **Beneficiation of Molybdenite from Tamil Nadu.** *Sponsored by GSI, Tamil Nadu Circle.*

A sample of baryte quartzite schist carrying 0.03% Mo is being investigated to obtain a molybdenum concentrate suitable for Fe-Mo manufacture. The rock carries trace amounts of bismuth and silver and efforts are being made to recover the above metallic values as well. Initial floatation trials have been made to float off the sulphide minerals using conventional collectors and frothers.

(*v*) **Beneficiation of Magnesite—Field Tests.** *Sponsored by M/s. Burn & Co. Salem.*

Preliminary arrangements for pilot tests on heavy-media treatment for magnesite, at the mine site of Burn & Co., were completed. The trials are planned to treat 150-200 T of ore, with a view to establishing the feasibility of heavy media separation treatment to magnesite.

(*vi*) **Reducibility Studies on Iron Ores.** *Sponsored by M/s. MECON, Ranchi.*

Experimental set up for reducibility studies on iron ores, pellets and sinters based on Gakushin and Linder tests was completed. Nearly 60 Gakushin reducibility experiments were carried out on iron ores, sinters and pellets and about 15 Linder experiments on pellets. Thermal degradation tests were also carried out on the iron ore samples and the swelling indices of the pellets were measured with the mercury hydrometer fabricated by the Unit. The results of the studies have been incorporated in the report on 'Studies on iron ore samples from Bellary-Hospet Region'.

(*vii*) **Reducibility studies on Iron Ores.** *Sponsored by M/s. Mineral & Metal Trading Corporation.*

Two samples of Goa iron ores were tested for Gakushin reducbility, thermal degradation and tumbling and abrasion indices.

(*viii*) **Reclamation of Sand from Core Scrap of M/s. Ennore Foundries, Madras.**

Different samples of leg core, bench core, jacket core, new system sand and old system sands were investigated. The studies on new system sand and old system sand were mainly concentrated on lowering the $R_2O_3$ and LOI and improving the $SiO_2$ content. The reclaimed sands from all these scrap were equivalent to the original sands from which these cores were made both in chemical composition and size grading. Only in the jacket core scrap the reclaimed sand could not be improved to the desired level of about 93% $SiO_2$ stipulated by the party. Reclaimed samples of 5 Kg each prepared from the scraps were sent to the party for shop testing.

(*ix*) **Development of Fluid Bed Reactor for the Calcination of Limestone and other Minerals.**

Literature survey was completed. Designing of the reactor is under progress. It is proposed to have a perspex model of the reactor. A 2 stainless steel reactor that is available has been used in the thermal reclamation of foundry sands.

(*x*) **Modernisation of Small Scale Industries.**

At the instance of Small Scale Industries Service Institute, Madras, NML Unit was retained as Consultant for the preparation of a scheme for modernisation of small scale industries in Tamil Nadu. Six foundries were selected in the above scheme, three from Madras and one each from Coimbatore, Erode and Villupuram. The concerned foundries were visited by scientist of the Unit for collection of data and accordingly a scheme of modernisation was prepared for 3 foundries. The scheme for the other foundries is in progress.

(*xi*) **Design and Fabrication.**

The following design assignments were completed:

(*a*) Layout and assembly of pot-grate furnace unit
(*b*) Linder test unit
(*c*) P.C.E. equipment—specimen rotation system.

(*xii*) Besides the above investigations and work, the Unit conducted physical and mechanical testing of foundry sand samples, metals and alloys; heat-treatment of various industrial products; metallographic studies on metallurgical failure cases; chemical analysis of 348 samples for 1150 radicals; refractory tests e.g. spalling, thermal conductivity etc., on refractory materials from industries etc. The unit has also developed a modified type of conventional carbon apparatus (Strohlein type).

# NML FIELD STATIONS

## NML FIELD STATION, HOWRAH

The NML Field Station, Howrah is rendering technical services to a large number of foundry and engineering industries in and around Calcutta by providing both physical tests and chemical analysis of various metals and minerals. Besides testing jobs, the Field Station took keen interest in making contact with small scale metallurgical industries and foundries to offer technical guidance and have attended many technical enquiries related to specification, import substitution, product development, improvement of the quality product etc. The Field Station has also helped a number of firms in finding solution to their testing products by direct involvement with the industries.

This Field Station is keeping an upward trend since 1977 in various activities. The increase in the activities is reflected in the revenues being earned which exceeded Rs. 50,000.00. This Field Station has been provided with a magnetic crack detector as a part of non-destructive testing and an effort has been made to utilise this facility for inspection of the metallography testing facility has been almost completed and work has already been undertaken from various industries. The Laboratory will be shortly equipped with the heat treatment facility and instrumental analysis to enable to undertake more chemical analysis work and to take up investigational jobs in order to meet the rising demands from the various industries. The following will give a general account of the work carried out during the period.

| | | |
|---|---|---|
| (*i*) | Chemical analysis—No. of radicals analysed | 2324 |
| (*ii*) | Mechanical testing—No. of tests carried out | 260 |
| (*iii*) | Other tests (Sand, Asbestos etc.) | 6 |
| (*iv*) | Details of Metallographic investigations: | |

(*a*) Ferrous sample received from M/s. Superior Castings Pvt. Ltd.
(*b*) Cast Iron sample received from M/s. Superior Castings Pvt. Ltd.
(*c*) Cast Iron sample received from M/s. Precision Casting Pvt. Ltd.
(*d*) Ferrouns sample received from M/s. Precision Casting Pvt. Ltd.
(*e*) Cast Iron sample received from M/s. Mukherjee Engg. Works Pvt. Ltd.
(*f*) Ferrou sample received from M/s. Mahinder Spicer Ltd.

| | | |
|---|---|---|
| (*v*) | No. of Firms taken help with regard to analysis and testing | 108 |
| (*vi*) | No. of Firms taken help with regard to technical enquiries/investigations | 35 |

## NML FIELD STATION, BATALA

The NML Field Station, Batala ; continued to assist the small scale foundries of Northern Region particularly the foundries of Batala in the production of

high duty graded C.I. machine tool castings by way of periodic visits and by attending to their day to day problems in moulding, core making, cupola operation etc., and suggesting remedial measures for the elimination of casting defects. This station is also guiding the local foundries in the selection and application of proper raw materials for their day to day use by providing them analytical facilities.

During the period, the NML Field Station, Batala has provided the following testing facilities and consultancy jobs to the foundry industry:

| | | |
|---|---|---|
| (*i*) | Total No. of foundry visits to guide them on the spot | 86 |
| (*ii*) | Total No. of technical enquiries attended through personal discussion and correspondence | 87 |
| (*iii*) | Total No. of samples tested/chemically analysed | 114 |
| (*iv*) | Total No. of samples tested for hardness | 13 |
| (*v*) | Total No. of Cupola designs released | 5 |

## NML FIELD STATION, AHMEDABAD

The field station did the following work during the period :

(*i*) Analysis—1090 samples for 3367 radicals
(*ii*) Sand & bentonite testing—10 samples
(*iii*) Mechanical testing—1.

# ENGINEERING ACTIVITIES

## DESIGN ENGINEERING

The following major design work was undertaken during the period:

(*i*) Design of rotary feeder for operation under vacuum and for use with the single electrode furnace.

(*ii*) Design of apparatus for testing the permeability of refractory samples

(*iii*) Design of tilting arrangement for Tocco induction melting furnace.

### Mechanical Engineering

The workshop is providing the following services:

(*i*) Preparation of standard test specimens from materials developed by scientists as well as from failure samples received from outside parties

(*ii*) Maintenance of laboratory equipment

(*iii*) Checking, assembly and installation of equipment received in the laboratory as and when required

(*iv*) Fabrication/machining of special purpose components, equipment, etc. required for experimental work.

### Electronics Engineering

A. DEVELOPMENT PROJECTS

*Design, Development and Fabrication of Thyristor Control System for Rolling Mill Motors.*

Literature study and preliminary design is under progress.

B. INSTRUMENTATION WORK

(*i*) *Mineral Processing*

Potentiometric Recorders, Flow meters and $P_H$ meters were overhauled, repaired and calibrated.

(*ii*) *Hydro-electrometallurgy Project*

Spekol spectrophotometers, AIMIL gas chromatograph and Nucon gas chromatographs were repaired and tested.

(*iii*) *Instrumental Analysis*

Several faults in Philips XRF spectrometer and Pye Unicam Atomic Absorption Spectrophotometer were identified and rectified.

(*iv*) *Corrosion*

Philips D.C. microvelt meter was repaired and calibrated.

C. MAJOR MAINTENANCE, INSTALLATION AND CALIBRATION JOBS COMPLETED

(*i*) X-Y Recorder
(*ii*) DTA Apparatus
(*iii*) X-Ray diffractometer
(*iv*) Rolling Mill controls
(*v*) Temperature controllers (25 Nos.)
(*vi*) Vibrograph
(*vii*) Geiger counting system
(*viii*) Contamination monitor

**Electrical Engineering**

A. DEVELOPMENT WORK

(*i*) *Electrothermal Smelting of Lead Concentrate*

A series of smelting campaigns were conducted in a 140 KVA electric furnace; electroslag smelting technique, based on Joule's heating, was adopted. Resistivities of slag of two different compositions of lead concentrate with various compositions of mixture were determined. Refractory materials for the bottom of the furnace and lead well had been proven for satisfactory performance, the side walls need further improvement.

(*ii*) *Extraction of Magnesium in a Single Electrode Electric Furnace.*

Lay out for the equipment was finished and the installation of various equipment was in progress.

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

The furnace was commissioned for service test. The furnace has already given a life of 9580 hours continuously at 850°C.

B. CONSULTANCY FOR GRAPHITE BENEFICIATION PLANT AT UDAIPUR.

Specifications of various motor control centres were prepared and detailed. Quotations were studied and finalised.

C. ESTABLISHMENT OF SPECIAL FACILITY FOR R & D PROJECTS.

Establishment of special facility for smelting non-ferrous metals such as lead, zinc etc., and melting of special steels and alloys, was taken up. In this connection, one 350 KW, graphite rod resistance furnace for indirect resistance heating was procured and its installation was carried out.

D. DESIGN OF POWER DISTRIBUTION SYSTEM, PREPARATION OF LAY OUT, SCHEDULE OF QUANTITIES AND SPECIFICATIONS; AND MANAGEMENT FOR INSTALLATION.

Design of power distribution system, preparation of lay outs, schedule of quantities and specifications; and management for installations, in connection with following were carried out;

(*i*) Vertical retort sponge iron furnace
(*ii*) Graphite rod resistance furnace
(*iii*) 50 KW, high frequency furnace
(*iv*) Pneumatic hammer and electric furnaces
(*v*) Flood lights on newly built watch towers
(*vi*) Renovation of wirings of administrative blocks and analytical laboratory.

E. BREAKDOWN REPAIR AND PREVENTIVE MAINTENANCE.

Breakdown repair and preventive maintenance were carried out for electrical equipments of the laboratory, its pilot plants and residential areas comprising of high tension substations, electric arc furnaces, high frequency furnaces, resistance furnaces, rectifiers, motors and their control centres, temperature and humidity control equipment etc.

**Civil Engineering.**

A. WORK COMPLETED.

1. Construction of shed for pneumatic hammer at the backside of Technological Block.
2. Development of the M.S. Type II Flats area at Agrico.
3. De-silting of cooling tank at FPTD.
4. Providing and fixing M.S. grill to windows & doors, backside of old 'H' type Qrts. at Tuiladungri.
5. General maintenance buildings, roofs at Marine Corrosion Research Station, Digha.
6. Internal security ventilation system for 'G' type quarters.
7. Modification in 'F' type quarter within the NML premises.
8. Providing store room at site office at Agrico.
9. Modification of Corrosion room at 2nd floor (East wing) at NML.
10. Installation of graphite rod resistance furnace at NML.
11. Shifting the gas line, water seal platform etc. at back side of Technological Block.

12. Painting and polishing of doors, parition wall etc. of eastern & western wing at NML.
13. Providing louvers for vertical reduction furnace & gas producing plant shed at MBPP.
14. White washing, colour washing, distempering & wood painting etc. at MBPP.
15. Repairing of damaged roof in NML Office.
16. Water proofing treatment to some portion of NML Building.
17. Making small cabin in the workshop & electrical maintenance shop at MBPP.
18. Modification of water logging, soaking pit in M.S. Flat Agrico.
19. Painting of furnace Equipments at FPTD.

B. WORK IN PROGRESS

1. Renovation of Analytical Section of Chem. Division, NML.

# PLANNING OF RESEARCH & DEVELOPMENT PROJECTS

Project-wise planning and programming of Research and Development work was continued on the new Five Year Plan proposals. The Annual Plan for 1979-80 comprising revised estimates for 1978-79 and budget estimate for 1979-80 was prepared on the basis of the requirements under on going and new research projects, international collaborative projects, pilot plant studies, infrastructural facilities and institutional programmes etc.

## Proposals for the Rolling Plan 1979-84.

A Rolling Plan document was prepared covering the period 1979-84 and the document was mainly based on the 'Indicative Plan Proposals for the Sixth Plan.'

Efforts of the planning wing were directed towards the proposals relating to large scale facilities viz. "Creation of Modern Mineral Development Facilities" through FRG assistance, Augmentation of extractive metallurgy facilities (HEMP) through UNDP assistance and Augmentation of the creep testing facilities.

A meeting of the Scientific Advisory Committee of NML was held on Nov. 2nd & 3rd 1978 under the Chairmanship of Dr. V. S. Arunachalam, Director, Defence Metallurgical Research Laboratory. Scientists and Technologists drawn from R & D organizations and industrial units of the country attended the meeting wherein the ongoing Scientific Programmes and New Proposals of the laboratory were discussed at length. After a thorough review of the project portfolios, decisions were taken with respect to various inputs.

In an effort to keep pace with growing sophistication in R and D hardware, a second generation Transmission Electron Microscope (EM-400) was procured which was separately financed by the CSIR from the modernization fund. This sophisticated facility when fully commissioned would function as a nucleus for the fundamental/applied research activity in the eastern region in the field of metallurgy. Its services will be available to scientists from other organizations.

An international collaborative project was negotiated between NML and NRIM Tokyo, Japan on "Studies on atmospheric corrosion of metals and alloys." The objective of the R & D programme is to expose various types of steel samples produced in both the countries at different locations in India and Japan for their corrosion behaviour.

An international collaborative project was negotiated between NML and SINTEF—Norway on the R and D programme "Use of non-coking coal for generation of high potential reducing gases in molten metal reactions."

# PUBLICATIONS

During the period under review, the following publications were prepared anb edited.

### NML Technical Journal

The issues of NML Technical Journal Vol. 20, 1978 were edited and published.

### Annual Report

The Annual Report of the Laboratory for the year 1976-77 was prepared, edited and published.

### Documented Survey on Metallurgical Development

The issues of this publication were brought out.

### Monograph on Indian Ores & Minerals

The Monograph on "Beneficiation and Agglomeration Techniques for Industrial and Economic Exploitation of Ores and Minerals in India" comprising of five parts and annexure is now under printing. Manuscript of each part runs over hundred pages. Printing is nearly completion of Pt. I and II of the monograph.

### Special Brochure

A special brochure entitled "R & D Achievements" covering major achievements and activities during the period 1970-79, has been prepared and is under publication.

### Special Folder

A special folder entitled "Technology, Expertise, Consultancy and Services" has been prepared and is under publication.

### Special Report

A number of special reports such as achievements and activities of the Laboratory during the recent years; report for inclusion in CSIR Annual report; reports needed for plan proposals etc. were prepared.

### Publicity of Processes & Products

Some of the NML developed products and processes which are ready for commercialization were published through newspapers and other media.

A number of hand outs on NML developed products and processes were prepared.

## NML News Letter

The monthly issues of the News Letter were published.

## Papers Published and Presented

Details furnished in Appendix I.

## Research and Investigation Reports Prepared

Details furnished in Appendix II.

# LIBRARY & DOCUMENTATION SERVICE

The Library added 415 items in the form of monographs, standards, patent specifications etc. during the period.

Several major extensive bibliographies on specific subjects requested by the scientists of the Laboratory as well as external research workers were supplied on request according to their research needs. More than 50 institutions having their R and D wings showed their keen interests to avail resources of this Library.

Many institutions within the country and abroad availed the benefit of reprographic services from the comprehensive collection of this Library.

The documentation service was strengthened by distribution of copies of well-scanned daily Current Awareness Service to the research scientists of the Laboratory. It was further improved by an introduction of regular feed-back system through the comments from the users. The News clipping service was continued.

### Get-together on 'Recent Developments in Mineral Processing & Metallurgical Engineering at NML'

The Laboratory jointly with Indian Chamber of Commerce, organised a get-together on 'Recent developments in mineral processing and metallurgical engineering at NML' at India Exchange Place, Calcutta on 29th April, 1978. Dr. A Ramachandran, Secretary, Deptt. of Science and Technology and Director-General, Scientific & Industrial Research, inaugurated the get-together; Sri J. M. Jatia, President, Indian Chamber of Commerce, presided over the function. Large number of delegates representing industries under large and small scale, technical experts and entrepreneurs attended the function, which was followed by discussions on the know-how developed at NML. The discussions were conducted in groups, covering specified disciplines, such as mineral processing, refractories, fluxes, extractive metallurgy, utilisation of waste, non-ferrous metallurgy; iron and steel technology; metal working; metal finishing and service facilities available at NML for the industries.

In the concluding session, Prof. V. A. Altekar, Director invited the entrepreneurs to make the best use of the know-hows developed by the NML and the facilities available for testing of raw materials, mineral processing, chemical analysis etc.

### State Level R & D Committee for Bihar

The 10th Meeting of the State Level R D & D (Research, Design and Development) Committee for Bihar was held at Barauni on the 30th and 31st August, 1978 in which NML participated as Chairman of Meeting.

A Get-together of the small scale industrialists/entrepreneurs, officials of the Bihar Govt. representatives from various institutions and agencies was arranged along with the Meeting.

### Exhibitions

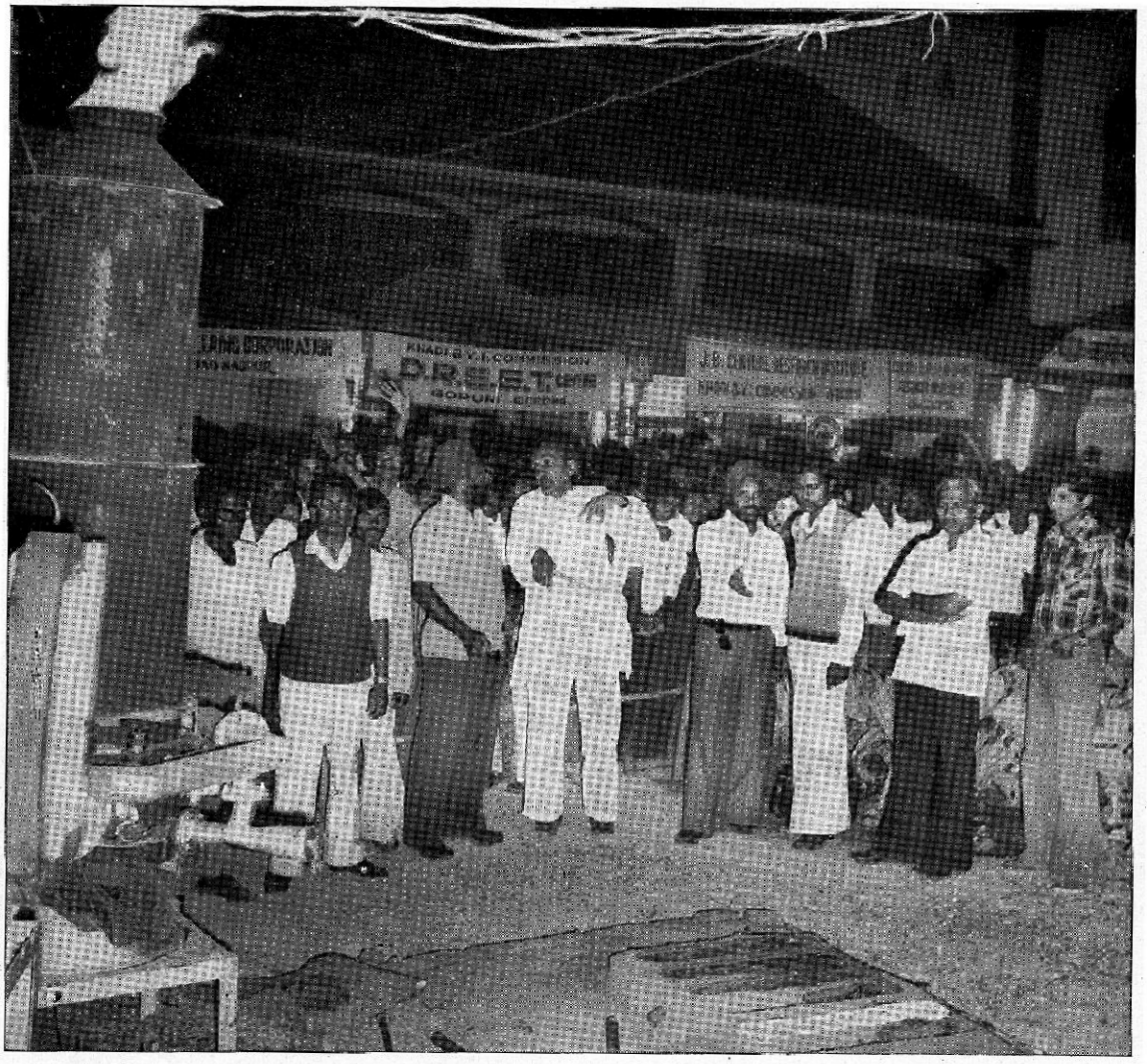
NML has got an expert exhibition team to prepare exhibits on different NML expertise. The artistic design and display layout of NML exhibits and stalls in different exhibition had been very much appreciated by the visitors. During the year 1978-79 NML participated in the following exhibitions:

(*a*) Exhibition at the time of get-together on 'Recent development in mineral processing and metallurgical engineering at NML' held at Calcutta on 29th April, 1978.

(*b*) Indian National Exhibition in Moscow, August, 1978.

(*c*) Exhibition on 'Science for villages' organised at Wardha.

(*d*) Exhibition on 'Advance in Chemical Metallurgy' organised at BARC, Bombay from 3rd to 6th January, 1979.



*Demonstration of 'Mini-Cupola' designed at NML at the exhibition on "Science for Villages" held at Wardha*

*View of the NML Stall at the exhibition on "Advances in Chemical Metallurgy" organised by Bhabha Atomic Research Centre, Bombay*

NML participated in the 40th Anniversary Function of Magan Sangrahalaya organised by the Centre of Science for Villages, held at Wardha, which was inaugurated by the Prime Minister on 30th December, 1978. The exhibits on rural technology comprised demonstration of a mini-cupola as designed and developed at NML for melting and casting of pig iron and similar alloys.

Samples of hard clad shear blades for multiple applications in leather and wood industries and also for use in agricultural implements and hot-dip aluminised samples for use as fencing wires, in burners of gobar gas plants etc were exhibited. The participation was well appreciated and the demonstration of mini-cupola operation had given rise for its further field trials for small rural workshops.

**NML—MECON Agreement**

The following is the review of the progress of the agreement on the projects and development work.

(*i*) *Process Technology for Production of Electrolytic Manganese Dioxide/ Manganese metal*

M/s. Orissa Mining Corpn. Ltd., entrusted NML with the testing of Nishikhal manganese ore deposit sample to find out its suitability for the production of electrolytic manganese dioxide and MECON with the preparation of a feasibility report for setting up a plant of 5 to 10 tonnes per day capacity based on test results.

Discussions were held at NML amongst MOC, NML and MECON and the test schedules were finalised. OMC has however indicated that at present they are not interested to proceed ahead with this project.

(*ii*) *Benefiaiation of Indian Magnesite*

NML had conducted bench scale and pilot plant studies on magnesite samples from Salem and the test results were found to be encouraging were furnished to the Sponsor—M/s. Burn and Company. The firm had desired to have further trials and necessary action is under way for running the Heavy media separation plant at Salem. MECON is in touch with M/s. Tamil Nadu Industrial Development Corpn. (TIDCO) and M/s. Burn and Co. for their interest in setting up of a Magnesite Plant at Salem.

(*iii*) *Beneficiation/Agglomeration/Upgradation of Manganese ore*

M/s. Manganese Ore (India) Limited, (MOIL), have sponsored investigation on manganese ores from their mines for beneficiation, agglomeration and utilization of the same. The work on the ore sample is currently under progress. M/s. MECON has submitted their quotation for preparation of project report(s) on beneficiation/agglomeration/upgradation plant(s) based on the test results of the NML and assistance to MOIL in the construction and commissioning of the Plant(s), after discussions with NML. The subject matter is under consideration of MOIL.

(*iv*) *Testing of Iron ore from Gandhamardan Deposit*

OMC has entrusted MECON with preparation of a Feasibility Report and development of Gandhamardan iron ore mine and setting up a pelletization plant. The testing of iron ore sample required for the preparation of the above report has been entrusted to NML. The tests are under progress at NML.

(*v*) *Froth Flotation of Coal Middling*

NML has approached MECON for techno-economic assessment of the pilot plant investigations carried out at NML on froth flotation of coal middlings, rejects and fines obtained from a few coal washeries. Subsequently, the NML has indicated the broad scope of work to be undertaken by MECON.

**Consultancy Services**

The following institutional consultancy services are in progress on under negotiation:

| | *Title* | *Party* | *Terms* |
|---|---|---|---|
| (*i*) | Advisory-cum-technical consultancy | Rajasthan Graphite Pvt. Ltd. Calcutta | Technical advice and assistance in setting up of a graphite beneficiation plant for treatment of 24 tonnes of graphite ore/day (based on sponsored work carried out at NML). |
| (*ii*) | Advisory-cum-technical consultancy | Rare Metals & Chemicals, Ranchi | Technical advice and assistance to set up a plant for vanadium pentoxide from alumina sludge (2 tonnes of sludge/day) (based on the know-how released through NRDC). |
| (*iii*) | ,, | Atlanta Engg. Calcutta | Advisory/technical consultancy services for appraisal of the report for scrutiny of the scheme submitted for establishment of a factory for manufacturing bearings. |
| (*iv*) | Advisory-cum-technical consultancy | Dentifils Jamshedpur | Advisory consultancy for setting up the production unit for manufacture of dental amalgam alloy of a capacity of 2 Kg/day (Based on NML know-how released through NRDC. |

| | | | |
|---|---|---|---|
| (*v*) | " | Durgapur Thermal Power Station (DVC) Durgapur | Advisory/technical consultance service on (*i*) welding of IP cylinder of 200 MW steam turbined and (*ii*) hydroturbine Hydel Power Station & subsequent repairs by welding. |

**Industrial Problems Referred to by Various CSIR Polytechnology Transfer Centres.**

The following industrial and technical problems were referred to NML by various CSIR Polytechnology Transfer Centres at Patna, Bangalore, Bhopal and Hyderabad.

(*i*) Problems of M/s. Bihar Aluminium Utensils Manufacturers Association, referred by PTC Patna. The problem related to blistering and cracking during the processing of utensils leading to rejection of 20-25% of the finished products. The NML has undertaken the Institutional Consultancy Services on sponsorship basis for the preparation of a report for melting of aluminium scrap for the casting of billets used by the aforesaid association for the production of utensils with a view to reduce/eliminate problems concerning the formation of blisters and cracks in the finished products. The work is in progress.

(*ii*) Problems of M/s. Thermit Alloys Pvt. Ltd., Shimoga Karnataka referred by CSIR PTC, Bangalore :- The firm is interested in the utilisation of high alumina slag for refractory purposes. The above sponsored work has been accepted by NML and is in progress.

(*iii*) Problems of M/s. Onkar Chand Steel Strips, Raipur, referred by CSIR PTC, Bhopal : The firm was interested in getting a technical feasibility report for the cold rolling, hardening and tempering of high carbon steel strips. The institutional consultancy services had been completed and the reports had been submitted to the party.

(*iv*) Production of refractories sponsored by M/s. Bihar Industrial Technical Consultancy Organisation Ltd., referred by CSIR PTC, Patna : Advisory consultancy service for technical appraisal of report of a firm for their proposed diversification for production of high alumina bricks, monolithic refractories etc. was undertaken and completed.

**Training**

Training facilities were provided to candidates deputed from various organisations such as technical institutions, universities, state and central Govt. departments in the fields of ore dressing and minerals beneficiation, refractories, extraction metallurgy, atomic absorption, spectro-photometry, analytical chemistry and large scale facilities in the respective fields. Eleven persons were trained during the period.

# PATENTS AND PROCESSES

## Patents Filed

| *Title* | *Inventors* |
|---|---|
| 1. An improved process for desulphurisation of ferrous melts | V. A. Altekar, D. J. Chakraborty & R. N. Guin |

## Patents Sealed

| | |
|---|---|
| 1. An improved process for the production of zinc dust (I.P. 141657) | V. A. Altekar & B. V. S. Yedavalli |
| 2. A process for the production of hot reducing gases for production of sponge iron and the like (I.P. 142032) | Prof. V. A. Altekar |
| 3. Improvements in or relating to recovery of selemium from copper refinery slimes (I.P. 142483) | Narinder Singh & S. B. Mathur |
| 4. Improvements in or relating to the plant for production of cellur metal (I.P. 1425721) | S. K. Sinha & G. N. Rao |
| 5. Improvements in or relating to recovery of tellurium from copper refinery slime (I.P. 142775) | Narinder Singh & S. B. Mathur |
| 6. An improved method and apparatus for making spherical aluminium particles (I.P. 142872) | D. D. Akerkar & A. K. Nayak |
| 7. Improvements in or relating to preparation of manganese sulphate from manganese ores (Joint patent with M/s. M. M. Suri & Associates Pvt. Ltd. New Delhi (I.P. 142965) | V. A. Altekar H. K. Chakraborty N. Dhananjayan P. Sen Gupta (N. M. L.) S. K. Groker & P. C. Bhatna (MMSA) |
| 8. An improved method for electro-thermal distillation of metals and alloys (I.P. 143216) | V. A. Altekar |
| 9. Improvement in or relating to the production of moulds and cores for the manufacture of castings (I.P. 143320) | G. N. Rao & S. K. Sinha |
| 10. Extraction of Ni and Co values from lateritic and limonitic nickeliferous ores by coal reduction and ammonical leaching in presence of catalyst. (I.P. 143334) | B. N. Singh M. Mahanty, D. D. Akerkar & V. A. Altekar |

## Transfer of Technology to Industrial Firms

A. The following processes were released through NRDC

| *Process* | *Party* |
|---|---|
| 1. Dental amalgam alloy | M/s. Dentifils India, Jamshedpur. |
| 2. Copper Clad Aluminium Sheet | M/s. Adarsh Engineers, Jamshedpur. |
| 3. Electrical resistance alloys for heating elements | 1. M/s. S. K. Mitra, Calcutta<br>2. M/s. Beni Ltd., Calcutta. |
| 4. Nickel-magnesium alloy | M/s. Industrial Minerals & Metals, Delhi. |
| 5. Thermostatic bimetals | M/s. Thermo Bi-metal India Enterprise, Daltonganj. |
| 6. Vanadium pentoxide from alumina sludge | M/s. Wire Cond. Delhi P. Ltd. New Delhi. |

B. The following technology has been transferred abroad

| *Title* | *Party* | *Remarks* |
|---|---|---|
| Setting up of a pilot plant for production of electrolytic manganese dioxide (50 Kg per day) | Central Res. Orgn. Govt. of Burma, Rangoon | Technical aid under the Indian techno & economic cooperation programme (ILEC by Govt. of Burma through CSIR/NRDC under the co-ordination of NRDC. M/s. M. M. Suri & Associates Pvt. Ltd. New Delhi are the consultants for procurement, despatch, erection of the plant. NML is assisting by deputing a scientist for commissioning of the plant and training of Burmese personnel. |

C. The following process was commercialised during the year

| *Process* | *Party* | *Remarks* |
|---|---|---|
| Production of dental amalgam alloy | M/s. Dentifils (India) Ltd., Jamshedpur | Trial production |

# PHOTOGRAPHIC, REPROGRAPHIC & PRINTING SERVICES

## Photographic & Reprographic Services

Technical photographic and reprographic services as an aid to R & D work was rendered as per details below :

(*i*) Technical photography—services rendered in various research projects include assistance to scientists for photographic documentation of the various stages of the research projects up to the final illustrations of the project reports.

(*ii*) Reprographic services—The overall need for the scientists for documentation work viz. photocopy, reflex prints etc. of technical papers as well as slide making for lectures etc. have been attended to.

(*iii*) General photography—In addition to the technical assistance to research projects, the general photographic need of the laboratory viz. coverage of visits, seminars etc. have also been attended to.

## Printing & Binding Services

Printing of NML News letter, folders, brochures, relating to R & D activities of the laboratory; office stationary; publicity display material for exhibition; jobs pertaining to seminar/get-together and exhibition; printing of covers of investigation reports etc. and their bindings were conducted.

# GENERAL

## Receipient of Honours, Awards etc.

Prof. V. A. Altekar, Director, has received the distinguished Achievement Medal of the Colorado School of Mines, U.S.A. for 1979 in recognition of his contribution in the general field of mineral engineering. He is the first Indian to receive this Honour.

Dr. R. Kumar, Scientist F, was accorded promotion as Scientist with Director's grade under the 'Distinguished Scheme of CSIR' in recognition of his contribution in metallurgical and creep testing fields.

## Foreign Deputation/Training in India and Abroad

| | |
|---|---|
| Prof. V. A. Altekar<br>Director | Deputed to Turkey as a Member of the Govt. of India Delegation under the 'Technology Transfer Programme'. |
| Dr. R. Kumar<br>Scientist | Deputed to Peurto Madryn, Chubat, Argentina as an Observer of UNIDO and attended the International Conference on 'Aluminium Transformation Technology and Development'. |
| Shri S. C. Moulik<br>Scientist | Attended the 16th UNIDO in-plant group training programme for iron and steel engineers held at Zaporozhye, Ukraine, U.S.S.R. |
| Shri K. K. Singh<br>Scientist | Deputed to U.K. under bilateral exchange programme scheme of CSIR & British Council. |
| Shri K. N. Gupta<br>Scientist | Deputed to 'SINTEF', Norway for preparing the feasibility report on the project, 'Use of non-coking coal for generation of high reduction potential gases for sponge iron'. |
| Dr. L. P. Pandey<br>Scientist | Deputed to Czechoslovakia under the exchange of scientist programme. |
| Shri P. K. Sengupta<br>Scientist | Deputed to Burma for commissioning of the electrolytic manganese dioxide pilot plant set up at Central Research Station, Burma; under the Indian Technical & Economic Co-operation Programme. |
| Shri M. K. Banerjee<br>S.S.A. | Deputed to Japan for participation in the collaborative research work at National Research Institute for Metals in the field of 'Atmospheric Corrosion of Metals'. |
| Dr. S. K. Narang<br>Scientist | Attended a course on 'Electro-forming' at Bombay organised by M/s. International Nickel Services. |

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

| | | |
|---|---|---|
| Prof. V. A. Altekar<br>Director | Member | Board of Governors of National Institute of Foundry & Forge Technology, Ranchi. |
| | Member | Board of Governors of Regional Engineering College, Rourkela. |
| | Vice-Chairman | Structural & Metals Division Council (SMDC) of Indian Standards Institutions. |
| | Vice-Chairman | Standing Working Committee on Metallurgical Engineering (SMDC) of Indian Standards Institution. |
| | Member | Working Group Industries Constituted by Bihar State Planning Board. |
| | Member | Task Force for Large & Heavy Industries of Bihar State Planning Board. |
| | Member | Task force for Intermediate Industries of Bihar State Planning Board. |
| Dr. R. Kumar<br>Scientist | Member | Refractory & Corrosion Committee of CSIR for 1978-81. |
| | Fellow | Institution of Engineers (India). |
| | Convenor | Aluminium Conductor Panel of ISI-SMDC 10 (Light metals and other alloys). |
| Dr. M. R. K. Rao<br>Scientist | Member | Working Group on Industrial (Non-metallic) minerals constituted by Planning Commission. |
| Dr. P. Prabhakaran<br>Scientist | Fellow | Electro Chemical Society of India and Society for Advancement of Electrochemical Science & Technology. |
| Shri S. Rao Addanki<br>Scientist | Fellow | Electrochemical Society of India. |
| Dr. S. K. Narang<br>Scientist | Member | Governing Council of Electrochemical Society of India. |

| | | |
|---|---|---|
| Shri M. J. Shahani Scientist | Council Member | Powder Metallurgy Association of India. |
| | Member | ISI Committee EDC 38 (Automotive Vehicles). |
| | Member | ISI Committee SMDC 28 (Hot—dip Coating). |
| | Member | ISI Committee SMDC 30 (Powder Metallurgy). |
| Shri G. N. Rao Scientist | Member | Foundry Sectional Committee SMDC 17. |
| | Member | Managing Committee, Ind. Inst., of Foundrymen, Jamshedpur Chapter. |
| Dr. L. P. Pandey Scientist | Member | Council of Institution of Chemists (India). |
| | Member | Expert Committee for Central Revenue Laboratories, Ministry of Finance, Govt. of India. |
| Dr. V. N. Choudhury | Member | Indian Ceramic Society. |

**Lectures**

A number of lectures were delivered by eminent Indian & Foreign scientists, technologists, management personnel etc. during the period. Lectures were also delivered by NML Scientists in professional bodies, technical institutions etc.

**Activities of Societies, Club and Canteen**

NML Staff Co-operative Credit Society continued its transaction and circulated nearly a million rupees. The Credit Society also operates Savings Bank Account for members and dividends to share holders are given. NML canteen catered to the staff members snacks, lunch, tea, coffee etc. at reasonable rate.

The NML club maintained its sporting, cultural and social activities. The club organised various indoor tournaments including cards, chess, table tennis, badminton etc. Facilities were also provided by the club for playing these games. A football tournament between the various sections and divisions of the laboratory & pilot plants were organised. Cricket practice was arranged. The club also subscribes to various magazines and newspaper for the members. Periodic film shows were also held.

The kindergarten schools at Agrico and Tuliadungri colonies were managed efficiently. There is a regular rise of students in these two schools. Music, art and dance classes were held regularly.

### Purchase & Stores

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

### Administration & Accounts

Administration & Accounts Section handled the administrative and budgetory affairs of the Laboratory.

### Safety First & First Aid Sections

Safety measures are enforced for operating the various plant equipments of the Laboratory, gas pipe line etc. and inspection of safety measures was carried out periodically. There was no major casualty.

The dispensaries and first aid sections were strengthened. The dispensaries in the residential colonies of the NML Staff rendered service to the Staff members and their families. The first aid sections at NML main building & pilot plants attended the minor injuries. Medicines were given to the ailing staff members.

### Budget Figures

| *Recurring (Non-Plan)* | | *Figures in Lakhs of rupees (1 Lakh=$10^6$)* |
|---|---|---|
| P-1 | Pay of Officers | 23.70 |
| P-2 | Pay of Establishment | 29.88 |
| P-3 | Allowances & Honorarium etc. | 36.59 |
| P-4 | Contingencies | 15.50 |
| P-6 | Maintenance | 1.57 |
| P-7 | Chemicals | 13.26 |
| Large Scale Facilities | | |
| PP-1 (*i*) | Equipment | 9.80 |
| PP-1 (*ii*) | Building & Services | |
| PP-2 | Provision for staff | |
| PP-3 | Purchase of raw materials | |
| PP-4 | Miscellaneous & Contingencies | |
| | Total | 130.30 |

*Capital (Non-Plan)*

*Figures in Lakhs of rupees (1 Lakh=$10^6$)*

| | | |
|---|---|---|
| P-5 (3) | Equipment & Machinery (replacement) | 5.00 |
| P-5 (4) | Library books & journals | 2.35 |
| | Total | 7.35 |

*Recurring (Plan)*

| | | |
|---|---|---|
| P-1 | Pay of Officers | 18.00 |
| P-2 | Pay of Establishment | |
| P-3 | Allowances & Honorarium etc. | |
| | Total | 18.00 |

*Capital (Plan)*

| | | |
|---|---|---|
| P-5 (1) | Works | 3.50 |
| P-5 (2) | Services | 1.50 |
| P-5 (3) | Equipment (Addition) | 35.00 |
| P-5 (4) | Furniture (Addition) | 00.45 |
| | Total | 40.45 |
| | **Grand Total** | **196.10** |

# APPENDIX I

1. Inhibition of sea water corrosion by chromate addition—D. K. Khan, D. K. Basu, & K. P. Mukherjee; NML Technical Journal Vol. 20 (1 & 2), 1978.

2. Application of solution technique using synthetic standards in spectrochemical analysis—M. K. Ghosh; NML Technical Journal, Vol. 20, (1 & 2), 1978.

3. Estimation of metallic, ferrous & ferric iron—K. K. Padhi, A. C. Biswas & L. P. Pandey; NML Technical Journal, Vol. 20, (1 & 2), 1978.

4. Thermodynamic properties of liquid lead-tin system—C. S. Sivaramakrishnan; NML Technical Journal Vol. 20 (1 & 2), 1978.

5. The effect of humidity and temperature on the hardening characteristics of sodium silicate bonded self setting sand mixes—G. N. Rao, S. K. Sinha & T. A. Beek; NML Technical Journal, Vol. 20 (1 & 2), 1978.

6. Stability of liquid lead base alloys; some simple considerations—C. S. Sivaramakrishnan; NML Technical Journal Vol. 20 (3 & 4), 1978.

7. Decrepitation behaviour of Lohara iron ore from Maharashtra—J. S. Padan, Onkar Singh & K. N. Gupta; NML Technical Journal, Vol. 20 (3 & 4), 1978.

8. Spectrophotometric determination of copper and minor constituents in low grade copper ores—S. B. Mandal; NML Technical Journal, Vol. 20 (3 & 4), 1978.

9. X-ray fluorescence analysis of silica and alumina in some ores—M. K. Ghosh, Rajeev & S. V. Gopalkrishna; NML Technical Journal, Vol. 20 (3 & 4), 1978.

10. Microstructural studies on intergranular corrosion on Al-Mg-Si alloys with and without chromium addition—Kishori Lal & R. Kumar; presented at the All India Symposium on "Corrosion: Science, Technology & Prevention" organised by Institution of Engineers, Bombay, April 1978.

11. Corrosion of steam heater in a boiler plant—A case study—P. S. Nag & K. P. Mukherjee; same as Sl. No. 10.

12. Available hydrogen and its relation to dissolution rate of steel—M. K. Banerjee & Inder Singh, same as Sl. No. 10.

13. Effect of cold drawing of steel on acid corrosion and its inhibition—M. K. Banerjee, Inder Singh, P. K. Dey & T. R. Soni; same as Sl. No. 10.

14. Some observations on material selection and corrosion problem encountered in oil refinery and petrochemical industries—G. G. Nair, B. N. Halder & R. Kumar; Chemical Engineering, World, Bombay, Vol. XIV, No. 2. February, 1979.

15. Importance of aluminium and its alloys in chemical industries—A. N. Mukherjee & Inder Singh; communicated to 'Corrosion & Maintenance' Bombay.

16. Metallurgical research in iron & steel industry—G. S. Minhas, V. Muthukrishnan & K. N. Srivastava; 'Motif' special supplement on 70 years of Steel Making in India—29-5-78.

17. Stainless steel as a material for surgical implants—B. N. Halder, G. G. Nair, R.. Kumar & R. N. Singh; communicated to 'Science Reporter' New Delhi.

18. Beneficiation studies on complex Pb-Zn-Cu sulphide ore samples from Sargipalli mines, Orissa—D. M. Chakrabarty, S. K. Sengupta & S. K. Banerjee; presented at the All India Seminar on "Recent Developments in Mineral Preparation & Extraction Metallurgy of Sulphide Ores" organised by NML, Inst. of Engineers (India) Jamshedpur Sub-Centre, Indian Inst. of Metals (Jamshedpur Chapter) & Indian Inst. of Mineral Engineers; June 1978.

19. Beneficiation of manganese ores from Maharashtra—P. D. Prasad Rao, N. Chakravarty & G. P. Mathur; same as Sl. No. 18.

20. Beneficiation of complex Pb-Zn-ores from Genekha area Bhutan—S. N. Prasad, M. V. Ranganathan & N. Chakravarty; same as Sl. No. 18.

21. Indian kyanite and sillimanite and their beneficiation studies at NML—S. Rafiuddin, H. Patnaik, N. Chakravarty, & S. K. Banerjee; same as Sl. No. 18.

22. Advances in sintering-operator's view point—H. Patnaik, N. P. Srivastava & G. P. Mathur; same as Sl. No. 18.

23. Recovery of copper and nickel by solvent extraction from leach liquor obtained by salt roasting of copper-nickel sulfide concentrates—(Mrs.) Malavika Mukherjee & D. D. Akerkar; same as Sl. No. 18.

24. Single cell extraction of Zn & $MnO_2$ from zinc sulphide and manganese ores—A. M. Pande, K. N. Gupta & V. A. Altekar; same as Sl. No. 18.

25. Ferric chloride leaching of sulphide concentrates of copper and copper-nickel—G. Basu, P. K. Sinha; S. C. Aush, N. Dhananjayan & V. A. Altekar; same as Sl. No. 18.

26. Direct leaching of lead concentrates in ferric chloride or ferric sulphate solution—P. K. Sinha, G. Basu, S. C. Aush, N. Dhananjayan & V. A. Altekar; same as Sl. No. 18.

27. Smelting of low grade lead concentrate—Narinder Singh, S. B. Mathur & V. A. Altekar; same as Sl. No. 18.

28. Electro-smelting of lead concentrate—Narinder Singh, S. B. Mathur & V. A. Altekar; same as Sl. No. 18.

29. Some aspects of processing of copper and nickel sulphide concentrates for the recovery of copper and nickel—Z. H. Khan, D. S. R. Murthy & D. D. Akerkar; same as Sl. No. 18.

30. Studies on the purification of molybdenite concentrate—A. N. Saha, S. R. Srinivasan, D. D. Akerkar & V. A. Altekar; same as Sl. No. 18.

31. Electrothermal smelting of copper sulphide concentrates—B. V. S. Yadavelli; same as Sl. No. 18.

32. Determination of power demand of electric resistance furnace—H. Singh; communicated to Journal of Inst. of Engineers (India) Calcutta.

33. Some observations on distribution of carbides in cast high speed steel cutting tools—R. K. Dubey & S. P. Chakraborty; Indian Journal of Engineers, July-Sept. 1978.

34. Refractories for reheating and heat treatment furnaces and recent trends—P. C. Sen; communicated to Seminar on "Role of Refractories on Re-heating & Heat treatment Furnaces" organised by Ind. Inst. of Metals, (Calcutta Chapter) August, 1978.

35. A simultaneous chelatometric determination of calcium and magnesium in magnesite—V. N. Chowdhury, B. C. Mukherjee, B. C. Bose & L. P. Pandey; communicated to Indian Journal of Technology, CSIR, New Delhi.

36. Spectrophotometric determination of vanadium in bauxite by potassium ferricyanide—K. K. Padhi, (Mrs.) S. Ghoshal, N. Ghosh, A. C. Biswas & L. P. Pandey; communicated to Journal of Institution of Chemists, Calcutta.

37. Oxygen enriched hot air blast cupola iron melting—R. Santokh Singh & P. S. Virdi; communicated to Indian Foundry Journal, Calcutta.

38. X-ray fluoresance spectrometry in metals and minerals analysis—S. C. Srivastava; communicated to Journal of Mines, Metals & Fuel, Calcutta.

39. Utilization of electric arc furnace in the production of low carbon soft iron—R. D. Gupta & V. A. Altekar; communicated for presentation at the Seminar on "Electric Furnace Steel Making & its Future in India" organised by Ind. Inst. of Metals (Bombay Chapter), Sept. 1978.

40. Projects at National Metallurgical Laboratory for small and tiny sectors—B. M. Dutta & K. N. Srivastava; communicated to Adityapur Industrial Development Authority; Jamshedpur.

41. Influence of melting technology on the ageing behaviour of Al-Mg Alloys—R. K. Mahanti & R. Kumar; presented at the Seminar on "Aluminium" organised by Indian Institute of Metals (Delhi Chapter), October, 1978.

42. Adventures in the aluminium alloy melting technology—R. Kumar & C. S. Sivaramakrishnan; same as Sl. No. 41 & Light Metal Age Vol. 36 (No. 11 & 12), 1978, P. 5.

43. Influence of metallurgical and processing factors on the stress corrosion susceptibility of welded Al-Zn-Mg alloy—B. K. Saxena, Kishorilal & R. Kumar; same as Sl. No. 41.

44. Grain refinement of Al—1.25% Mn alloy—V. V. Rao, A. N. Sinha & R. Kumar; same as Sl. No. 41.

45. Research and development in the field of aluminium technology—R. Kumar; same as Sl. No. 41.

46. Recovery of vanadium pentoxide from vanadiferous sludge of alumina plants—Narinder Singh, S. B. Mathur, D. D. Akerkar & V. A. Altekar; same as Sl. No. 41.

47. Liquidus and phase relationship in some high alumina blast furnace slag composition—R. V. Hargave & M. R. K. Rao; presented at the 32nd Annual Technical Meeting of Ind. Inst. of Metals, November, 1978.

48. Studies in the thermal decomposition of manganese carbonate for the production of manganese dioxide—M. G. Bodas, D. D. Akerkar & V. A. Altekar; same as Sl. No. 47.

49. The simultaneous complexometric determination of iron and calcium in phosphate rock—B. C. Bose, V. N. Choudhury & L. P. Pandey; presented at the Golden Jubilee Symposium in "Recent Development in Applied Analytical Chemistry" organised by Inst. of Chemists, November, 1978.

50. Arsenozol III as metallochromic indicator for complexometric titrations of molybdenum in ferro-molybdenum—B. C. Mukherjee, V. N. Choudhury & L. P. Pandey; same as Sl. No. 49.

51. Rapid complexometric determination of manganese in manganese ores—V. N. Choudhury, S. K. Bera & L. P. Pandey; same as Sl. No. 49.

52. Rapid determination of copper and zinc in complex Cu-Pb-Zn ores—R. K. Parashar, D. N. Choudhury, V. N. Choudhury & L. P. Pandey; same as Sl. No. 49.

53. Vanadium high strength low alloy steels for low temperature use—S. S. Bhatnagar, B. K. Guha & R. K. Sinha; communicated to Journal of Material Science (U.S.A.).

54. R & D in Metallurgy—V. A. Altekar; Commerce Annual Number, 1978.

55. R & D work on Mineral Processing at NML—V. A. Altekar; communicated to Mineral Processing Journal (Holland).

56. Review of the Proceedings of XIth International Mineral Processing Congress—V. A. Altekar; Proceedings of XIth Mineral Processing Congress, held at Caligiri, Italy, 1977.

57. The importance of liquid limit test in the evaluation of bentonite for foundry use—R. R. Dash & G. N. Rao; presented at the 28th Annual Convention of Indian Institute of Foundrymen, Bangalore, February, 1979.

58. Advancement in the production of S. G. iron—R. K. Dubey & S. P. Chakraborty; communicated to Indian Journal of Engineers, Calcutta.

59. Engineering system of the creep testing laboratory—H. Singh; communicated to Journal of Industrial Development & General Engineering of Inst. of Engineers, Calcutta.

60. Techniques of foam insulation—A. K. Bose & M. R. K. Rao; communicated to Seminar on 'Special Ceramics & 43rd Annual Session' of Indian Ceramic Society, March, 1979.

61. Special ceramic filter for aluminium alloy—C. S. Sivaramakrishnan, R. K. Mehanti & R. Kumar; same as Sl. No. 60.

62. Rosin cored solder wire for electronic industry—P. Basak & R. K. Dubey; communicated to Indian Journal of Engineers, Calcutta.

63. Development of variable inductance type instrument transducer—Gurudev Jaura; communicated to Journal of Institution of Engineers (Cal.), Engineering Division.

64. Relation between the theoretical hydrogen and observed hydrogen in the presence of inhibitors—V. A. Altekar, Inder Singh, M. K. Banerjee & M. K. Singh; communicated for presentation at the Symposium on 'Corrosion Inhibitors & Protective Surface Coatings' organised by Defence Materials & Stores Research Development, Kanpur, February, 1979.

65. A note on the occurrence and requirement of kyanite in India and preliminary investigations on the refractory properties and processing of beneficiated kyanite concentrate—M. R. K. Rao, N. B. Sirkar, P. C. Sen & R. V. Hargane; communicated for presentation at the 43rd Annual Session of Indian Ceramic Society, Banaras, March, 1979.

66. A note on the effect of grinding on the properties of high alumina refractory cement—M. C. Kundra & S. K. Malaviya; same as Sl. No. 65.

67. Role of froth flotation and coal beneficiation—N. Chakravarty & G. P. Mathur; presented at the Annual Technical Session of Indian Inst. of Mineral Engineers held at Ranchi, August 1978.

68. Beneficiation of low grade graphites of Palamau district, Bihar—M. V. Rangathan, D. M. Chakraborty & N. Chakravarty; same as Sl. No. 67.

69. Beneficiation of Purulia rock phosphate—P. D. Prasad Rao, S. K. Banerjee & G. P. Mathur; same as Sl. No. 67.

70. Beneficiation of limestone at NML—A. Peruvadhanulu & G. P. Mathur; same as Sl. No. 67.

71. Plasma and its application in metallurgical processes—Premchand & H. P. Krug; presented at the International Conference on 'Advances in Chemical Metallurgy' organised by Bhabha Atomic Research Centre, Bombay, January, 1979.

72. Thermodynamic and phase equilibria involved during smelting of vanadium bearing titaniferous magnetite ore and making vanadium rich slag—N. Subhramanyam, A. K. Nayak & D. D. Akerkar; same as Sl. No. 71.

73. Extraction of nickel and cobalt from nickeliferous oxide ores of India—B. N. Singh, M. S. Mahanty, D. D. Akerkar & V. A. Altekar; same as Sl. No. 71.

74. Development of metallothermic process for smelting of lead concentrate—Narinder Singh, S. B. Mathur & V. A. Altekar; same as Sl. No. 71.

75. Tungsten & its recovery from scrap—Premchand & V. A. Altekar; presented at the 2nd International Conference on 'New Horizons in Materials—Tungsten & Molybdenum' held at Hyderabad, March, 1979.

76. Extraction of vanadium pentoxide from alumina sludge—Narinder Singh, S. B. Mathur, D. D. Akerkar & V. A. Altekar; presented at the 31st Annual Session of Indian Institute of Chemical Engineers, Cochin, December, 1978.

77. Development of aluminium/alloy aluminium conductor for electrical industries—R. Kumar, Manjit Singh & Kishori Lal; communicated to the Seminar on 'Aluminium' held at Bangalore.

78. Ausrolling of spring steels for automatic applications—S. P. Chakraborty, S. K. Chaudhary & R. K. Dubey; Transaction of Indian Inst. of Metals, December, 1979.

79. Production technology of dental amalgam alloy—V. A. Altekar, R. K. Dubey & P. Bysack; Journal of Indian Dental Association, Vol. 49, No. 3, pp. 93-99, 1977.

80. Melting trials with cast iron boring briquettes in cupola and arc furnace—V. A. Altekar, R. Santokh Singh G. N. Rao, V. S. Virdi & R. R. Dash—Trans. Ind. Inst. of Metals, Vol. 31, No. 3, June, 1978.

81. Effect of additive on the high and room temperature strength properties of sodium silicate bonded sands—S. K. Sinhababu, T. A. Back & G. N. Rao; communicated to Indian Journal of Engineers, Calcutta.

82. How to upgrade lean bentonite for foundry use—R. R. Dash, S. K. Sinhababu & G. N. Rao; communicated for publication in Foundry Special Issue from IIT, Khargpur.

83. Rapidly solidified magnetic alloys—V. V. Rao, A. N. Sinha & R. Kumar; presented at the Annual Meeting of Magnetic Society of India, Calcutta.

84. Powder metallurgical processing of rapidly solidified Al-Si and Al-Zn-Mg alloys—S. P. Mukherjee, V. V. Rao & R. Kumar; presented at the Annual Technical Conference of Powder Metallurgy Association of India, Calcutta.

85. Use of dense carbon aggregate as base material for soderberg electrode—Proceeding of the All India Seminar on 'Carbon Technology' held at Korba, organised by IIM.

86. Refractories for induction furnaces for melting non-ferrous metals—N. N. Mathur & M. R. K. Rao; presented at the Seminar on "Refractories for Non-ferrous Industries" organised by Indian Refractory Makers' Association, Calcutta, January, 1979.

87. Liboration analysis and release analysis—C. Satyanarayana & P. R. Khangaonkar; presented at the 32nd Annual Technical Meeting of Ind. Inst. of Metals. November, 1978.

88. Design engineering in India—P. R. Khangaonkar; presented at the Conference on National Design Engineeing held at IIT, Madras, December, 1978.

89. Spectrometric determination of chromium in low alloy steels by atomic absorption spectrometry—L. P. Pandey, A. Ghosh, P. Dasgupta & A. S. Rao; Talanta (25), 482, 1978.

90. Standard samples—preparation, standardisation and their utilisation—V. A. Altekar & L. P. Pandey; ISI Bulletion (30) 213, 1978.

91. Preparation of standard reference materials—role of NML—P. Sanyal & L. P. Pandey; communicated to Journal of National Academy of Science.

92. Standard reference materials of low alloy steel—P. Sanyal, K. K. Gupta & L. P. Pandey; communicated to Research & Industry.

93. Amorphous soft magnetic alloys—R. Kumar & V. V. Rao; presented at the Annual Meeting of Magnetic Society of India, Calcutta.

94. Corrosion of metal—studies at NML—K. P. Mukherjee & V. A. Altekar; Corrosion Engineering and Maintenance, Vol. 1 April, 1978.

95. Immersion plating of tin and its alloys without external currents—S. K. Narang; Galvanatechnik, Vol. 70, No. 5, 404-411, 1979.

96. Steel supported annealed NML-PM2 conductor—A new concept for distribution lines—R. Kumar; Journal of Institution of Engineers (India) July, 1978.

97. Iron and steel making research in India—K. N. Gupta, presented at ILAFA-19 Congress, held at Rio-de-Janeiro, Brazil, November, 1978.

98. Control of inclusion morphology and cleanliness of steel by rare earth addition—D. J. Chakrabarti, R. N. Guin & V. A. Altekar; presented at 5th ASPA Seminar in Madras and published in Tool & Alloy Steel, March, 1978.

# APPENDIX II

## Research & Investigations Completed and Reports Prepared

1. Reduction of ash content from the coal fines of Gidi washery received from M/s. Coal India Ltd.,—K. K. Bhattacharyya, P. D. Prasada Rao, N. Chakravarty & G. P. Mathur, (IR 970/78).

2. Use of cast iron boring briquesttes in cupola melting—R. Santokh Singh, P. S. Virdhi, G. P. Mathur & V. A. Altekar. (IR 971/78).

3. Investigation on the amenability of the manganese ore sample from Munsar mines supplied by M/s. Development Corporation of Vidarbha Ltd., for production of electrolytic manganese dioxide.—P. L. Sengupta & N. Dhananjan (IR 972/78).

4. Grinding characteristics of a sample of vanadium bearing slag received from Extractive Met. Divn. NML,—S. K. Sengupta, D. M. Chakrabarty & S. K. Banerjee, (IR 973/78).

5. Beneficiation of low grade composite kyanite sample from Maharashtra State Mining Corporation Ltd.,—T. C. De, K. K. Bhattacharya, S. K. Sengupta, N. Chakravarty & G. P. Mathur, (IR 974/78).

6. Pilot plant studies on beneficiation and sintering of a composite iron ore from Bailadila Deposits 4 & 5 for the Vishakhapatnam Steel Project—Tirath Singh, R. K. Kunwar, P. K. Sinha, J. S. Padan, B. L. Sengupta, N. Chakraborty, S. K. Banerjee & G. P. Mathur, (IR 975/78).

7. Pilot plant studies on reduction of silica content of a magnesite sample from Salem, Tamil Nadu—S. C. Maulik, S. K. Sil, B. L. Sengupta, N. Chakraborty & G. P. Mathur, (IR 976/78).

8. Bench scale beneficiation studies of low grade siliceous manganese ore received from M/s. Aryan Mining & Trading Corporation Pvt. Ltd., Jamshedpur—M. C. Das, S. K. Sil, N. P. Srivastava, N. Chakraborty & G. P. Mathur, (IR 977/78).

9. Pilot plant beneficiation studies of pyrite samples from Amjhore, Bihar—P. K. Sinha, V. S. Chatterjee, S. K. Biswas, S. R. Joti, B. L. Sengupta, N. Chakraborty, S. K. Banerjee & G. P. Mathur, (IR 978/78).

10. Pilot plant studies on sintering of Barsua iron ore fines and filter cake from Rourkela Steel Plant—R. K. Kunwar, Tirath Singh, A. K. Srivastava, J. S. Padan, B. L. Sengupta, N. Chakraborty, S. K. Banerjee & G. P. Mathur, (979/78).

11. Bench scale beneficiation studies on a complex Pb-Zn ore (oxidized) from Chakula, Bhutan—M. V. Rangnathan, S. N. Prasad, N. Chakraborty, S. K. Banerjee & G. P. Mathur, (980/78).

12. Pilot plant studies on beneficiation of low grade iron ore from Bicholias Mines of M/s. Dempo Mining Corporation, Goa—P. K. Sinha, V. S. Chatterjee, S. Biswas, S. R. Ghosh, N. Chakraborty, S. K. Banerjee & G. P. Mathur, (IR 981/78).

13. Effect of carbide distribution on the HK-40 heat resistant steel—C. Satyanarayana, V. Mohan & P. R. Khangaonkar, (IR 982/78).

14. Failure of (construction water) cast iron pipe. Its causes & methods of prevention—R. Jha, K. P. Mukherjee, (IR 983/78).

15. Beneficiation studies of magnesium dross sample for M/s. Industrial Alloys, Calcutta—S. R. Ghosh, P. R. Sinha, B. L. Sengupta, N. Chakraborty, S. K. Banerjee & G. P. Mathur, (IR 984/78).

16. Beneficiation of a low grade apatite sample from Pathargora Mines of M/s. IISCO—K. K. Bhattacharya, T. C. De, N. Chakraborty & G. P. Mathur, (IR 985/78).

17. DTA & TG study on sulphides of zinc concentrate—R. D. Gupta (IR 986/78).

18. DTA & TG study on sulphides of copper nickel concentrate—R. D. Gupta, (IR 987/78).

19. Determination of crushing strength or limestone samples received from M/s. MC Nally Bharat Engineering Co.—A. Peravadhanulu, B. Banerjee & S. K. Banerjee, (IR 988/78).

20. Mineralogical study on six type samples of phosphate rock from Purulia Dist. West Bengal Mineral Development & Trading Corpn. Ltd., Calcutta —A. Peravadhanulu, B. Banerjee & S. K. Banerjee, (IR 989/78).

21. Chemical analysis & Petrological studies of six manganese ore sample of the Siljora kalimati area received from M/s. Rungta Mines (P) Ltd.— Bhaskar Banerjee, A. Peravadhanulu & S. K. Banerjee, (IR 990/78).

22. Bench scale beneficiation studies on low grade graphite samples from Banswara Dist. Rajasthan for M/s. R. S. I. M. D. C. Ltd.—N. Chakravorty, L. Sahoo & G. P. Mathur, (IR 991/78).

23. Bench scale tests data on the 1 : 1 blended manganese ore sample, from Kanan pit and Banda pit of Silijora kalimati mines, supplied by Electrochem. (Orissa) Ltd.,—P. L. Sengupta & Dr. N. Dhananjan, (IR 992/78).

24. Determination of crushing strength of limestone sample received from Bokaro Steel Plant (SAIL)—A. Peravadhanulu & S. K. Banerjee, (IR 993/78).

25. Incidence of high temperature oxidation of thermocouple metallic sheath used for the measurement of blast furnace stove dome temperature—R. Jha & K. P. Mukherjee, (IR 994/78).

26. Recovery of barite from calc-silicate sample containing Cu-Pb-Zn complex sulphides from Dariba-Rajpura, Rajasthan, H. Z. Ltd.,—S. Rafiuddin, P. N. Pathak, N. Chakraborty & G. P. Mathur, (IR 996/78).

27. Beneficiation and pelletization studies on a low grade limestone (arenaceous) sample from M/s. Ind. Chem. Ltd., Samkarnagar, Tamil Nadu—K. Vijayaraghan, V. Mohan, P. V. Ramman & P. R. Khangaonkar, (IR 996/78).

28. Comparative studies on collecting properties of Xanthate samples received from M/s. Aceto Chemicals Pvt. Ltd., Calcutta—S. K. Sengupta, D. M. Chakraborty & S. K. Banerjee, (IR 997/78).

29. Bench scale beneficiation studies on a low grade graphite sample from Taliha mines, Subansiri Dist. of Arunachal Pradesh, received from Dy. Director General, GSI North Eastern Region, Shillong—S. Prasad, M. V. Ranganathan, N. Chakravorty & G. P. Mathur, (IR 998/78).

30. Purification of silica sand from Kerala and testing of its suitability—V. Mohan, K. Vijayaraghan, K. S. Vijayanarayan, P. V. Raman, P. R. Khangaonkar, (IR 999/78).

31. Studies on iron ore samples from Bellary Hospet Region, (IR 1000/78).

32. Reduction of ash content in a —0.5 mm slurry sample of coal from Patherdih coal washery for M/s. Central Coal Washeries Organisation Ltd., by forth flotation—S. K. Sil, M. V. Ranganathan, N. Chakraborty & G. P. Mathur, (IR 1001/78).

33. Beneficiation studies of low grade apatite from Pathargora area, Dist. Singhbhum, Bihar received from Indian Iron & Steel Co. Ltd.,—T. C. De, N. Chakraborty, G. P. Mathur, (IR 1002/78).

34. Laboratory scale beneficiation studies on a low grade iron ore from Syria—S. K. Biswas, K. K. Bhattacharjee, B. Banerjee, A. Peravadhanulu, B. L. Sengupta, N. Chakraborty, S. K. Banerjee & G. P. Mathur, (IR 1003/78).

35. Beneficiation of powdey iron ore from Dempo Mining Corporation, Goa—U. S. Chatterjee, S. K. Biswas, P. K. Sinha, S. R. Ghosh, B. L. Sengupta, N. Chakraverty & G. P. Mathur, (IR 1004/78).

36. Investigation on a lumpy iron ore from M/s. Dempo Mining Corporation, Goa—U. S. Chatterjee, S. K. Biswas, P. K. Singh, S. R. Ghosh, B. L. Sengupta, N. Chakravorty & G. P. Mathur, (IR 1005/78).

37. Pilot plant investigation on the reduction of ash content from the coal fines of Gidi washery—B. L. Sengupta, S. C. Maulik, K. K. Bhattacharya, P. D. Prasad Rao, A. K. Mallik, N. Chakerverty, S. K. Banerjee & G. P. Mather, (IR 1006/78).

38. Sintering studies on manganese ore fines from M/s. Ferro Alloy Corporation, Ltd., Andhra Pradesh—R. K. Kunwar, Tirath Singh, J. S. Padan, N. Chakraverty, S. K. Banerjee & G. P. Mathur, (IR 1007/78).

39. Report on industrial evaluation of NML reactive filter at ordnance factory, Ambajhari—Dr. R. Kumar, C. S. Shivaramakrishnan, R. K. Mahanti & B. K. Saxena, (IR 1008/79).

40. Beneficiation studies on Cu-Pb-Zn complex sulphide ore sample from Deri, Rajasthan—S. K. Sengupta, D. M. Chakraborty, S. K. Banerjee & G. P. Mathur, (IR 1009/79).

41. Beneficiation studies on Gua rom iron ore from M/s. Indian Iron & Steel Co.—Tirath Singh, A. K. P. Srivastava, J. S. Padan, B. L. Sengupta, N. Chakraberty, S. K. Banerjee & G. P. Mathur, (IR 1010/79).

42. A chloridizing roast leach process for the extraction of copper and nickel from bulk copper-nickel sulphide concentrates of UCIL—Z. H. Khan, D. S. R. Murthy & D. D. Akarkar, (IR 1011/79).

43. Metallurgical examination of the imported extruded aluminium alloy—AK 4—(IR 1012/79).

44. Moulding characteristics of Bhalwahi sand from Directorate of Geology & Mining, Lucknow, U. P.—R. C. Arora & R. N. P. Gupta, (IR 1013/79).

45. Moulding characteristics of Naribari sand from Directorate of Geology & Minging, Lucknow, U. P.—R. C. Arora & R. N. P. Gupta, (IR 1014/79).

46. Moulding characteristics of sand samples No. J-4 from Directorate of Geology & Mining, Lucknow, U.P.—H. P. Singh & R. N. P. Gupta, (IR 1015/79).

47. Test report on Burmese manganese ore for production of electrolytic manganese dioxide—N. Dhananjan & P. L. Sengupta, (IR 1016/79).

48. Utilization of electric arc furnace in the production of low carbon soft iron—R. D. Gupta & V. A. Altekar, (RR 384/78).

49. Production of vanadium rich slag by electric smelting of vanadium bearing titaniferous ores of Masanikere, Karnataka and Oxygen blowing of vanadium iron at V.I.S. Ltd., Bhadravati—P. V. Vishwanathan, B. V. S. Yadavalli, N. Subramanayam, D. D. Akerkar, P. R. Khangaonkar & V. A. Altekar, (RR 385/79).