OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

Distr.
LIMITED

ID/WG.146/82
14 June 1973

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Third Interregional Symposium
on the Iron and Steel Industry

Brasilia, Brazil, 14 - 21 October 1973

Agenda item 8

THE NATIONAL METALLURGICAL LABORATORY OF INDIA
A CASE STUDY OF THE DEVELOPMENT OF
A RESEARCH AND DEVELOPMENT INSTITUTE[1/]

by

V.A. Altekar
National Metallurgical Laboratory
India

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

id.73-4368

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

S U M M A R Y

Conceived during the World War II years, the National Metallurgical Laboratory (NML) at Jamshedpur, India, came into being in November 1950, to take care of the R&D requirements of an infant but growing metallurgical industry. Equipped with sophisticated equipment and pilot plants covering a wide spectrum of disciplines from mineral beneficiation and processing, and refractories on one hand to development of special alloys, heat-treatments, surface finishes, and corrosion prevention on the other, the NML has done yeoman service to the fast-growing industry. Its contributions in the field of raw-materials evaluation for the existing six steel plants and the three newly proposed ones have been greatly appreciated by local and foreign consultants. Its contributions to establishment of a 500-tonnes-per-day fluorspar-flotation plant, entirely based on indigenous technology and engineering, its pioneering work on non-ferrous ores of copper, lead, zinc, nickel, pyrites, phosphate rock, iron-ore washing and agglomeration, and many others have born fruits and has resulted in commercial operations. In the field of extractive metallurgy, its decade of work with a 7 M^3 low-shaft furnace on Indian raw-materials, its development of processes for electrolytic manganese and dioxide, ferro-alloys, basic side-blown-converter technology, recovery of secondary metals, etc., are finding industrial usage. Its programme of substitute-alloys development included nickel-free austenitic steels, nickel-free heating elements and high-temperature alloys, aluminium conductors, sacrificial anodes, coinage alloys, which have found industrial applications and acceptance.

Now, over a thousand strong, the NML is poised for further growth to bear the additional burden arising out of the next Five Year Plan. A UNIDO-aided million-dollar creep-testing and high-temperature materials facility, a multi-purpose hydro-electro-metallurgy pilot plant; demonstration plants for direct-reduction technologies developed by NML are some of the current growth programmes to take care of demands being made by the fast developing economy. NML has also undertaken assignments from other developing countries.

I. INTRODUCTION

INDIA has had a long tradition of basic research in such sciences as mathematics, astronomy, and a rule of thumb practice of such technologies as chemistry, medicine, and metallurgy. The country is littered with old slag dumps, mostly near the remote mine sites, which stand witness to the skill of ancient and medieval smelters of such metals as gold, copper, silver, lead, iron, and zinc. The last two deserve a special mention. Steel from India was a coveted item in civilisations flourishing in ancient times. The world-renowned Damascus steel was being originally made in this country, and the famous Iron Pillar at Delhi was built over 1500 years ago. The technology of production of zinc migrated to the West in the medieval times. Inspite of this tradition, India had not been able to keep pace with the growth of research and expansion of industries in the West.

Growth of modern industry in India is not an organic extension of the above-mentioned tradition. It is the growth from an implant of ideas and import of technologies from the West and thus constitutes a break from its historical antecedents. Some of the early organised efforts were directed to the utilisation of natural wealth of the land by creation of such institutions as Survey of India (1757), Geological Survey of India (1851), and Forest Research Institute (1906). However, these and like institutions were neither intended to, nor did they infact, serve any purpose of industrial growth and economic development of the country in those years.

A radical change in the pattern of scientific and technological research in India was brought about by the out-break of the second World War. The most significant event was the establishment of the Council of Scientific & Industrial Research (CSIR) in 1942. The decade 1940-50 in India is marked by initiations of a large number of R&D laboratories in various disciplines of science and technologies. This remarkable change is attributable to the enlightened political and scientific leadership which came to the forefront, and their implicit and oft-repeated faith that political independence could only be sustained by economic independence and that R&D is a forerunner and a basic component of industrial development. This breadth of vision, depth of understanding, and planned programme of investment in R&D has been inherited by all those who subsequently came to the helm of affairs, and has even been enshrined as an article of faith in the form of Scientific Policy Resolution moved in the Parliament in 1958.

Origin

The origin of the National Metallurgical Laboratory (NML) dates back to 1940, when the Board of Scientific Research set up a Metals Committee which in its very first meeting closely examined the future development of the country's metallurgical industry and came to the considered decision that, to ensure its progress and expansion, it was essential to establish a Central Organisation in the nature of a National Metallurgical Laboratory. The CSIR, soon after its formation in 1942, took up the matter and set up a Planning Group for the NML. The original plan for the Laboratory was considerably pruned to suit the availability of funds and a plan to start the NML on a 4 hectare plot of land adjacent to the premier Tata Iron & Steel Company at Jamshedpur was taken up for execution in 1946. The Laboratory was inaugurated in 1950, by the then Prime Minister.

Status of Industry - 1946

Laying the Foundation Stone of the NML in 1946, the then Governor-General had briefly touched upon the status of the then metallurgical industry of the country which, it will be interesting and relevant here to draw upon.

"During the years of War, India's steel production reached two million tons per year. The production of copper by the only smelter exceeded 7,000 tons per year, and the infant aluminium industry was striving to reach the 10,000 tons mark. Other metallurgical enterprises such as alloy steels, ferro-alloys, a lead smelter were also started, but the position was not one for complacency. Although we had a sizable iron and steel industry, the country was backward in many other fields. It was entirely dependent on imports for high-speed tool-steels, alloy steels, copper, aluminium, magnesium, various ferrous and non-ferrous alloys. In consequence the engineering industries, the manufacturers of I.C. engines, electrical industry, ship-building, air-craft, and chemical industries which depended on metallurgy for the supply of the necessary constructional material had not grown up in the country. If India was to embark on industrialisation and achieve success in a reasonable measure, high priority must be given to the establishment of metallurgical industry. All the valuable minerals must be worked up for the growing needs of the country and not just exported as hither to. .....

..... It was estimated that the various hydro-electric projects would produce over 4 million kW of power, a major part of which would be available near the mineral resources of the country. Electro-metallurgical industries, based on this low-cost power, could play a great role in the industrial life of the country. The country's immediate needs of 20,000 tons of aluminium, 5,000 tons of magnesium, 15,000 tons of copper, 60,000 tons of electric furnace steel per year, and large quantities of other electro-thermal products like alloy steels, ferro-chrome, ferro-silicon, graphite, and carborundum could be based on this cheap power. .....

..... For the organisation and progress of industries, scientific research of a high order is an essential pre-requisite. It helps the industries earn a handsome dividends. However, without prosperity the industry cannot afford research and without research the industry cannot prosper. The responsibility of breaking this vicious circle then falls on the Government, which must help scientific research in the cause of national progress. .....

..... While carrying out such tasks as devolve on it in connection with metallurgical research, it was hoped that NML would endeavour to promote research by the industry itself, so that it can soon come to rely upon its own strength and initiative."

The above few paragraphs have been condensed for reproduction since they are indicative of not only the stage set in India for starting on a National Metallurgical Laboratory, but also indicative of the hopes and aspirations from NML so vividly expressed by the leaders.

Scope

The original planning group had visualised a very broad spectrum of scope and activities for the NML. All aspects of metallurgical research, both fundamental and applied, as also researches on preparation of ores, minerals, and refractories were included in the scope of work at NML. Provision was made for pilot-plant work in preparation and smelting of ferrous and non-ferrous ores, melting and casting techniques, shaping and forming of metals and alloys and their heat-treatment, the electro-chemistry of metals, and studies in corrosion and its prevention. Metals for which the country had cheap and abundant raw-materials such as aluminium, titanium, manganese, and beryllium were specially mentioned. Development of substitute non-ferrous alloys which were scarce in the country were particularly emphasised. Of particular mention was the plan for "application of research results to commercial operating conditions, and for the study of such conditions as they affect the quality of the products and the efficiency and economy of commercial production". Dilating on the relative importance of fundamental and applied research at the time of foundation-stone laying ceremony in 1946, it was stipulated that equal importance will be given to both. However, in the "initial stages, the special and urgent needs of the industry in the country will focus more attention on applied aspects. But this circumstance would vanish as soon as the industry has been set on all its fours."

It is obvious from the perusal of early records that the planners had correctly realised the importance of atomic energy in 1946, and had also realised the advantageous position India was in, for harnessing nuclear power. They had therefore included impressive list of proposals for work on the atomic minerals, their processing, extraction, refining, and shaping. However, with the setting up of a separate Department of Atomic Energy (DAE) in 1954, much of the early work done by the NML was diverted to and taken over by the DAE. Similarly, the Defence Research and Development Organisation came into being in 1958, and, with the creation of a Defence Metallurgical Research Laboratory, pressures on NML further eased, allowing the NML to pay greater attention to the needs of the fast-growing Metallurgical industry.

With the advent of the University Grants Commission in 1953, emphasis shifted in the National Laboratories from basic to applied research. The NML has all along correctly balanced the two in view of the national needs and priorities for applied work on one hand and the creative urge of talented scientists for basic research on the other hand.

Starting with a scheme of 64,000 sq.ft. built-in-area on a 4 hectare plot, the plan called for an expenditure of funds equivalent to US $ 1 million in 1946 for buildings and equipment. An additional sum equivalent to US $ 200,000 was estimated for a housing colony for 90% of the estimated 153 staff.

Although India was embarking into an era of organised research & development for the first time in its history, the document "Revised Scheme for the establishment of the National Metallurgical Laboratory" prepared by the CSIR in 1946 was an admirably wholesome document, which with slight modifications to suit local conditions can be still used as a base-line model for a similar project in another developing area.

<u>Location of NML</u>

The decision to locate the NML at Jamshedpur was taken after considering several factors into account. "It was the heart of metallurgical industry and gave excellent opportunities for study of practical operating problems at the numerous metallurgical industries such as the Tata Iron & Steel Company, The Tin Plate Company, the Indian Steel & Wire Products Company, the Indian Cable Company and a number of foundries and machine shops. The only Copper Smelter was hardly 20 miles away. Future growth of the iron and steel industry would take place around the country's iron-ore-coal belt for which Jamshedpur would be central. All important engineering units were coming up in Calcutta region about 150 miles to the east of Jamshedpur. Such a location would ensure the close contact between the research workers and the industry, which was so essential for successful application of research to the industry."

Over two decades have passed since this decision was taken and implemented. A remarkable growth of metallurgical industry has since taken place in the country. Four new steel plants have since come up. Heavy engineering units for heavy castings and forgings have come up. Aluminium smelting capacity has gone up to 150,000 tons per year. A lead smelter sprang up. Uranium mill came into being. But Jamshedpur and the National Metallurgical Laboratory have continued to occupy the central place, in the ever-growing industrial map of the country.

II. ORGANISATION

The National Metallurgical Laboratory (NML) is one in a chain of over 40 National Laboratories and Institutes established by the Council of Scientific and Industrial Research (CSIR), in various disciplines and technologies in various parts of the country.

The CSIR is a Society registered under the Societies' Registration Act XXI of 1860 and came into being on 12th March, 1942. The main authority of the Society is its Governing Body which administers, directs, and controls the affairs of the Society subject to its rules and regulations and bye-laws. The Prime Minister of India is ex-officio its President and the Minister for Science & Technology its Vice-President. The Director-General, Scientific & Industrial Research, is the principal executive officer of the Society and is responsible for the proper administration of its affairs under the direction and guidance of the Governing Body. The funds of the Society mainly consist of grants made by the Government of India, besides contributions and receipts from other sources, and income from investments.

The working of the National Metallurgical Laboratory (NML) is administered by an Executive Council appointed by the Governing Body of the Society. The

Executive Council is responsible for the control and general direction of the Laboratory within the frame-work of rules and regulations and directives issued from time to time by the Governing Body.

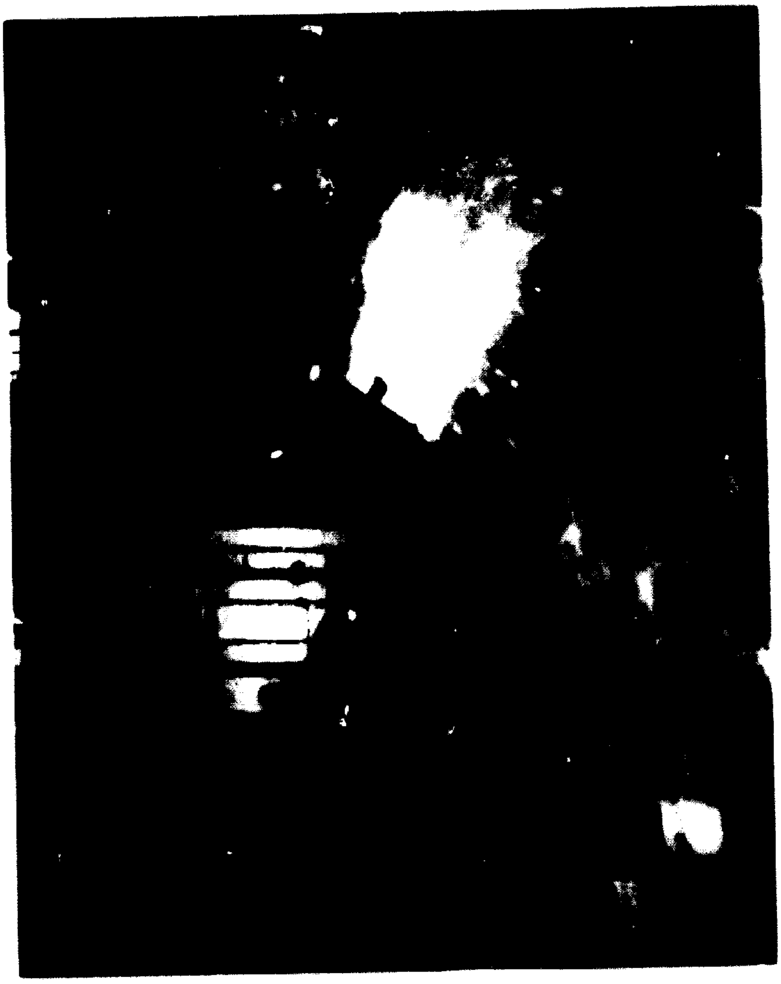
Membership of the Executive Council includes Chairmen of public-sector plants, executives from ferrous and non-ferrous industries, senior officers from Ministries of Industry, Steel & Mines, professors from Institutes of Technology, etc. The Executive Council is assisted by various Sub-committees, such as Scientific Sub-committee, Building & Finance Sub-Committee and other bodies with such functions as may be assigned to them to assist the Council in its work. The main functions of the Executive Council are (i) to consider and approve the scientific programme as recommended by the Scientific Sub-Committee, (ii) to frame the annual budget of the Laboratory on the recommendations of the Building & Finance Sub-committee and to regulate expenditure, and (iii) to determine the strength of staff, etc. The Director is the principal executive officer of the Laboratory and is responsible for its proper administration. He exercises general supervision over all scientific and industrial researches and other activities of the Laboratory.

<u>Divisions</u>

The Laboratory has the following major disciplines:

i) Mineral Beneficiation
ii) Extraction Metallurgy
iii) Iron & Steel Production
iv) Refractories
v) Material Science & Alloys Development
vi) Corrosion
vii) Foundry Field Stations
viii) Engineering Services
ix) Analytical Services

The Mineral Beneficiation Wing has a bay well equipped with standard bench-scale equipment. It also operates a pilot plant which has been described later. Iron and Steel Production Wing looks after raw-materials evaluation, operates a low-shaft furnace, develops process for production of steel from pig iron and pig iron from iron ores. It has hot-blast cupolas, a basic-lined side-blown converter, and equipment for standard tests for assessment of raw-materials. Extraction Metallurgy deals with chemical, electrolytic, and pyro-metallurgical extraction of metals from the raw-materials. It has numerous equipment for conducting the above processes. It has facilities for electro-thermal smelting, electrolytic recovery, vacuo-thermal reduction, distillation, etc. Refractories Division



Basic-Lined Side-Blown Converter

have standard equipment for testing of raw-materials and finished products and have medium-size equipment, such as presses, extruders, firing furnaces, tunnel kilns, bogey kilns, etc.

Material Science Wing looks after operation involving, melting, casting, metal working, shaping, testing, joining, alloys development and testing, etc. It is well equipped with cupolas, direct and indirect arc furnaces, induction and vacuum furnaces, electro-slag refining unit, foundry bay, forging presses, rolling mill, 500-ton extrusion press, various mechanical testing and heat-treatment equipment, welding equipment, hot-stage metallographs, electron-microscope, X-ray diffractometer, scanning electron-microscope, electron-beam melting furnace and many other standard equipments. It also administers four Field Stations of NML which are giving service to the Foundry Industry.

Corrosion Section has numerous standard equipments for studies in corrosion and its prevention. There is a Marine Corrosion Research Station on the sea coast of the bay of Bengal. This section also runs a Corrosion Advisory Bureau to help the industry. Engineering Services Group comprises all other disciplines, such as electrical workshop, machine-shop, electronics section, design and drafting and engineering section.

In addition to the above, there is a group of scientists engaged in Research Coordination, Planning & Development, Information and Publication, Industrial Liaison activities. There is a well equipped Library with 55,000 titles, and subscription to over 600 periodicals.

The administrative details are looked after by an Administrative Officer assisted by Section Officers, Purchase Officer, Stores Officer, Accounts Officer, Security Officer, and others.

The present strength exceeds 1000. Scientists are drawn from all parts of the country. Housing has been provided for about 25 per cent of them in 4 colonies. A NML Staff Club looks after the social activities. Medical facilities have been well provided in numerous dispensaries in the town, as also in the well equipped Main Hospital of the Steel Company.

Staff

No study of an Institution will be complete without a mention of its staff.

While formulating the plan for the Laboratory, the CSIR had formulated a Planning Committee comprising of the best available talent in the country. Chief executives from steel plants, metallurgical smelter, and industries, and educational institutes had contributed to the deliberations which resulted in the final plan of the NML.

NML's first Director was a renowned French Professor; its second, a renowned metallurgist from U.K. These first five years were sufficient time for an Indian metallurgist to take over the reins of the Laboratory. The laboratory made significant advances, and scientific contributions and developed itself well with a number of pilot plants in the regime of its first Indian director. Indianisation of this critical post was thus fully justified.

The success and achievement of the NML are due to its staff. The real credit for this supply of qualified metallurgical engineers goes to a Pandit who, as founder and Vice-Chancellor of Banaras Hindu University established a Department of Mining & Metallurgy fifty years ago ! By 1950 there were three centres turning out about 100 metallurgical graduates every year. By 1965 the rate of production of metallurgical engineers had reached 700 per year, and had to be temporarily reduced a little, after the intake of the newly established steel plants had stabilised. The under-graduate and post-graduate educational facilities in the field of metallurgy in India today are comparable to those of the West with the emergence of four new Institutes of Technologies at Kanpur, Kharagpur, Madras and Bombay. Those at Banaras and Bangalore have also received tremendous inputs. India had been self-sufficient in civil, electrical, and mechanical engineers. By 1960 several institutes had started courses in chemical engineering and electronic engineering as well. The NML has drawn copiously from all these sources. Some of the staff are, in addition, educated in well known schools abroad.

NML had suffered a set-back in its recruitment in the middle Fifties when its expansion period coincided with the establishment of three new steel plants which swept away all the available metallurgical engineers. In recent years the imbalance has been sufficiently corrected. Engineers from other disciplines have also been inducted on its roll.

Fighting intellectual obsolescence is a perpetual task in a R&D Institute. NML has deputed over 75 of its staff for training abroad; about 100, in addition, have been sent on deputations for specialised training in the country. Every year about forty are deputed to participate in technical seminars, symposia, and meetings at other places. About 3-4 scientists are deputed every year abroad for international conferences, visits, and discussions. Another 3-4 are deputed for training from 3-9 months. Last year over forty experts and special invitees came to NML and gave lectures in the field of their respective specialisation of relevance to NML. At least a dozen are deputed every year to attend special courses in India, not only in technical subjects but also in subjects like material management, research management etc.

Some relevant statistics concerning staff position are included here:

Progressive increase of staff strength
in N.M.L. since 1954

Year		Total staff strength	Year		Total staff strength
1954	...	281	1964	...	1055
1955	...	301	1965	...	1032
1956	...	296	1966	...	1035
1957	...	345	1967	...	1074
1958	...	462	1968	...	1072
1959	...	555	1969	...	1070
1960	...	631	1970	...	1077
1961	...	695	1971	...	1036
1962	...	904	1972	...	1068
1963	...	922	1973	...	1096

Present scientific and technical staff engaged on R&D (excluding pilot plant staff)

Post-graduate in science

		Ph.D.	M.Sc.	Total
Physics	..	1	8	9
Chemistry	..	6	9	15
Geology	..	1	4	5
Others	..	-	2	2
				31

Degree holders in engineering & technologies

Discipline	Ph.D.	M.Sc.	B.Sc.	Total
Metallurgical Engg.	8	10	19	37
Chemical Engg.	-	5	3	8
Foundry & allied	-	5	-	5
Mining Engg.	-	-	2	2
Mineral Technology	-	5	-	5
Electrical	-	-	1	1
Mechanical	-	2	1	3
Others	-	5	-	5
	8	32	26	66

Diploma holders in Engineering	28
Diploma in Medicine	2
Graduates in Science	155
Trained Technicians	23
Skilled and semi-skilled workers	205
Others	60
	473

Grand total 570

III. SOME ACHIEVEMENTS

Two decades of purposeful existence is bound to result in a long list of credits. An attempt has been made to bring out briefly only a few of the salient achievements of NML which have made a significant mark on industrial growth.

MINERAL PROCESSING

It is but natural that in a developing country, which is engaged in the initial efforts at industrialisation, establishment of basic metallurgical smelting industries would be its primary task. The Fifties and the Sixties were characteristic period when the NML was called upon to shoulder the full responsibilities of thorough and full assessment of raw-materials required for the establishment of such basic industries. Four new steel plants were initiated, and two of the existing ones were expanded. Several large, organised mines were opened up to step up foreign trade to earn the much needed foreign exchange for development. Pre-processing of iron ores, iron-ore fines, and their agglomeration, beneficiation of copper ores, lead-zinc ores, pyrites, phosphate rocks, graphite, fluorspar, chrome ores, manganese ores, refractory minerals, atomic minerals etc. were the crying need of the period. The NML fully responded to this demand.

In the field of iron ores, NML has fully assessed a large number of iron-ore samples for all the steel plants in the country. The assignments have included very comprehensive and thorough evaluation and treatment. Investigations in washing of iron ores and ore fines have been utilised for the establishment of several commercial iron-ore washing and fines agglomeration plants such as at Goa (500,000 tonnes per year), Barsua (1 million tonnes per year), and Noamundy (1 million tonnes per year). Several others are in the offing based on data provided by NML. Similar work done for the Bokaro Steel Plant was greatly appreciated by the Russian Consultants. Work done for the Tata Iron & Steel Company was publicly appreciated by the Chairman of the company in one of his annual speeches. Said he in 1960 ".... I wish to record our appreciation of the assistance we have received from the NML at Jamshedpur, whose investigations, taken at our request, have formed, to some extent, the basis of our ore-beneficiation programme".

A complete assessment of the iron ores call for determination of their reducibilities under various conditions specified by the customer; it also calls for the determination of their micro- and macro-porosities, and their high-temperature behaviour under load and reducing conditions. Scores of iron ores have been thus investigated by the NML for the sponsoring steel plants which have shaped their procurement policies and blast-furnace operations in light of the reports submitted by the NML. Extensive studies have been sponsored at NML for the three proposed steel plants at Vizag, Vijayanagar, and Salem.

Direct Reduction

More recently, taking into consideration the fast depleting reserves of coking coals and their complete non-availability in most parts of the country, NML started a concerted programme of development of technologies for direct reduction of iron ores. Efforts have been intensified on process based on use of unreformed naphtha, which was first developed on a 100 g batch scale and then scaled up to a continuous 100 kg per day scale. It is now in the process of further scale-up to 5-tons per day. A rotary kiln, originally intended for magnetising reduction roast, was modified and pressed into service for development of sponge iron with non-coking coals. The kiln has so far produced hundreds of tons of sponge iron, which in turn is undergoing in-plant melting trials. Besides developing the know-how, the kiln is now being used for assessment of various coals and iron ores for their suitability for sponge-iron production in hundred-ton lots. This pioneering effort to develop the rotary kiln technology for production of sponge iron in the country was greatly appreciated by the Government, who have allocated about US $ 1 million for establishment of a 100 M^3 kiln for scale-up, design, and demonstration needs.

Yet another method for production of sponge iron, using non-coking coals, is the externally heated vertical retort process, which has some relevance in a developing country like India. A retort capable of producing about 200 kg of sponge per day has been in operation and evaluation.

Non-ferrous Minerals

Although iron and steel industry represents the bulk of metallurgical industry and consequently demands a major share of NML efforts, other metallic minerals are by no means treated less important at NML.

There is a long-standing arrangement between the NML and the Geological Survey of India (GSI) under which samples of ores discovered by the latter are sent over to NML for routine beneficiation tests on bench scale.

A large number of private and public sector undertakings have been sending a variety of ores and minerals to NML for beneficiation tests. In most of the cases the sponsor initially requires bench-scale data. In an ever-increasing number these are followed up by requests for pilot-plant scale investigations as well.

An existing copper mill, for their expansion programme, wanted to review economics and efficiencies of their existing pneumatic flotation systems with mechanical flotation systems. Over 100-tons of their ores were treated in the NML pilot plant, which has a number of modern cells for comparison. A new copper concentrator with its treatment capacity for 8,000 tons of ore per day was based on the beneficiation tests conducted at NML. New copper mills coming up at Rakha (2,000 tonnes per day), Surda (2,000 tonnes per day), and Malanjkhand (4,000 tonnes per day) are based on the technology developed in the pilot plant of NML.

Recently, the existing Pb-Zn mill in Rajasthan was expanded to 2,000 tonnes per day on the basis of data provided by the NML. Pilot-plant testing of lead ores of Andhra Pradesh has been completed for a proposed 500-tonnes per day mill. Several multi-metal deposits have been proved to contain enough reserves to justify beneficiation plants of several thousand tons per day. The NML facilities have been booked in advance for testing these ores.

Pyrite reserves have been located in Bihar and Rajasthan. The commercial operations at both the places have been based upon the pilot-plant results provided by NML. The 20-tons per hour heavy-media separation plant of NML was pressed into service for this work.

Non-metallic Minerals

Non-metallics have received equal importance at NML. Perhaps the greatest achievement and involvement of NML was in developing the technology and providing the necessary expertise for the establishment of a 500-tons per day Fluorspar Beneficiation Plant in Gujarat. The plant is unique in that the process technology and the engineering was, for the first time, 100% Indian. Engineers from NML commissioned the project in June 1970.

A large number of phosphate rock reserves have been recently located in the West. The pilot plant was busy in 1969-70 period in establishment of the beneficiation technique for these samples. NML is involved as a process consultant on one of these projects.

A large number of graphite samples have been tested over the last two decades. NML have recently teamed up with the State Government of Andhra Pradesh for establishment of a 'custom mill' to meet the requirements of a large number of small operators in the graphite-bearing areas of that state. The mill has been so designed as to be able to treat a large number and types of ores producing several grades of graphite concentrates suitable for various industries.

Manganese ore has been the principal source of export earnings for India, which had ranked at or near the top of exporting countries. The occurances are widely scattered in the country. One of the first tasks of the ore-dressing division was to systematically study the manganese ores from all ore-producing centres. This study has been incorporated in a monograph entitled 'Manganese Ores of India'. The study has resulted in a classification of the ores from the point of view of beneficiation programmes. NML has also patented a process for thermal beneficiation of ferruginous manganese ores. Strikingly enough, most of this research activity remained unutilised. Except for the establishment of a Heavy Media Separation Plant near Nagpur, much of mineral production, even by large enterprises, went on almost without beneficiation. For every ton of exportable grade of ore produced at the mines, two to three tons of low-grade ores were discarded at the mine site. There was neither any legal compulsion nor a sense of national conservancy amongst the mine operators. More recently, the semi-nationalised MOIL have sponsored pilot-scale investigations on a number of manganese ore samples from their various mines and are actively considering collaboration with the NML for establishment of 1,000 tons per day mill for which NML have submitted a feasibility report.

Consultancy Services

NML has gone beyond the role of pilot-plant testing of ores. We are now offering collaboration terms which include all necessary testing work; design of most economical and efficient flow-sheet; drawing up equipment specifications, formulation of tender documents for procurement of plant and equipment; evaluation of bids received; selection of vendors, and contractors for supply, erection and commissioning of the plant; training and recruitment of supervisory staff; and commissioning of the process.

NML has by no means restricted their services to only Indian sponsors. Raw-materials from neighbouring countries have also been processed at NML. Most recently, under an UNIDO assignment, NML received and processed over 150 tonnes of low-grade iron ore from Arab Republic Egypt. The near 40% Fe-containing oolitic iron ore was upgraded to 53%, pelletised, and smelted in a 500 kVA submerged arc furnace to determine the flow-sheet and design parameters.

Nor are these facilities used for minerals alone. Recently, a large non-ferrous foundry in the North, encouraged by the results of investigations, have asked NML to put up a slag and dross treatment plant for the recovery of metallics.

R & D IN NON-FERROUS FIELD

Although the iron and steel industry loomed large while planning and locating the NML in 1946, and it still does so today, NML has given due attention to R&D activities in the field of non-ferrous metals.

Growth of Non-ferrous Metals Industry

The non-ferrous metals production was limited only to meagre amounts of copper, lead, and antimony a quarter of a century ago. Rapid strides have, however, been made during the past two decades. Copper production at the existing smelter near Jamshedpur has since doubled with the installation of a flash smelter and an electrolytic refinery. Yet another 8,000 tonnes per day concentrator has gone on stream for a new smelter coming up 100 miles west of Delhi. A couple of promising large deposits are under speedy exploitation. Two zinc refineries have sprung up - one based on indigenous production of concentrates, and the other based on imported concentrates. Yet another major zinc smelter is being planned at a coastal site to process imported concentrates. The existing lead smelter is under renovation and expansion, and another is being planned to take care of the concentrates from a 500-tons per day mill. Production of aluminium has multiplied ten times during this period and several new units came up based on the abundant reserves of good-grade bauxite. An extensive deposit of lateritic nickel ore was discovered and is under active exploitation.

In all these and similar developmental programmes, NML has played its important role. In case of nickel, for example, NML has been active on the problem of recovery of nickel values from the copper-belt ore. Extraction studies had been completed on nickel ores from different locations in India, including those from Sukinda which is now under exploitation. The response of two serpentinous ores and three lateritic ores to different approaches was studied. The lateritic ores responded well to reduction-roast, ammoniacal leaching followed by nickel precipitation. A firm of consulting engineers is now collaborating for pilot-plant investigations at the NML to confirm the results obtained earlier. The investigations will result in a project report for an industrial venture in the state sector.

A process for selective chlorination of nickel from the lateritic nickel ore is being developed. The process accomplishes over 90% of nickel recovery. Selective adsorbents for nickel from mixed solutions are also being developed. Trials for production of ferro-nickel from the ferruginous lateritic ore are also under way.

NML's contributions in the field of processing of low-grade non-ferrous metal ores is too wide-spread to be cited here. Over 250 such investigations have been completed at the instances of various agencies. Restrictions of reserves and availability of funds do not always permit projects to come up; but recently the tempo of industrial growth has resulted in rise of utilisation of the results. Several beneficiation plants have come up or are coming up based on the investigations at the NML.

The Laboratory has been engaged as consultants for several concentrator projects. NML was also involved as consultants for the improvement and expansion of the only lead smelter. Considerable work has been done on secondary metal recovery and alloy development - this is being described elsewhere.

Ferro-alloys

Of all the development work at the NML in the field of extraction metallurgy, the most comprehensively conceived, well executed, and fruitful has been its contribution in the field of ferro-alloys technology development. With abundance of certain raw-materials for ferro-alloys manufacture in the country, it was most logical to initiate development programmes for the best exploitation to establish a sound technology to help the budding industry. The work in NML can be grouped as (i) physical and chemical pre-processing of raw-materials, (ii) alumino-thermic production of carbon free ferro-alloys, and (iii) electro-thermal smelting techniques.

In the field of pre-processing, mention has already been made to the extensive beneficiation work on manganese ores, chromites, ilmenites, etc. Mention may also be made to development of a process for thermal beneficiation of ferruginous manganese ores. Another process was developed for selective chlorination of iron from ilmenite and chromite using hydro-chloric acid. For extraction of vanadium pentoxide from vanadiferous magnetite, a salt-roasting process was established on pilot-plant scale to treat one ton of the magnetite per day.

The work conducted in the 500 kVA submerged-arc furnace has been summarised elsewhere. A single-step process for production of low-carbon ferro-chrome was developed and passed on to the industry. It comprises of melting high-carbon ferro-chrome and ferro-silicon in certain proportion, which results in the elimination of carbon. Excess silicon is eliminated by additions of chromite or chromium-rich slag.

Perhaps the most remunerative amongst the transferred technologies from the NML pertain to the licences issued for the manufacture of carbon-free ferro-alloys. This know-how was so much in demand until recently that we had to finally close files to avoid unhealthy completion and uneconomic working.

Current programmes include items of such topical interest as ferro-nickel, calcium silicide etc.

Metallurgical Wastes

In a developing country considerable attention needs to be paid for metal recoveries from the wastes. Lack of such know-how and facilities have resulted in exports of very valuable material at dirt-cheap prices from the country.

NML has been active to develop workable know-how to promote waste re-processing units in the country. A special international symposium was organised at NML few years ago to focus attention of technologists and entrepreneurs on this important aspect of metal conservation.

An elaborate programme of development work was initiated on recovery of zinc values from zinc wastes. A process for recovery of zinc from zinc dross by atmospheric and vacuum distillation was perfected at the instance of the industry. Similarly, recovery of zinc from zinc ashes and skimmings were also developed. Chlorine removal from the ashes have enabled a zinc smelter to reclaim them and put them back into the circuit. Zinc hydroxide waste from the manufacture of sodium hydrosulphite has been processed for production of valuable, rubber-grade zinc-oxide and the process is under transfer to industry. Similarly, know-how has been developed for recovery of aluminium from its wastes and drosses.

A project for recovery of tin from the tin-plate scrap based on the technology developed at the NML is coming up in Jamshedpur in the small industries sector.

A major non-ferrous foundry in the North is establishing an elaborate programme of metal recovery from its foundry-slag with NML collaboration.

Development of Standard & Substitute Alloys

One of the stipulations at the time of formation of NML was that work on development of substitute alloys would be taken up at NML. Naturally this aspect of work has received major attention at NML. A look at the resources of the country and its import requirements had indicated that India would be self-sufficient in aluminium and manganese only and that it will have to depend on imports of such important metals as copper, zinc, lead and nickel. Accordingly, the following substitution programme was envisaged and followed.

Development of aluminium conductors, to replace copper conductors where-ever possible has been in operation at NML. The country has been one of the pioneers in switching over to aluminium conductors for power transmission. A specially conducting and ductile grade of aluminium conductor has been developed which will replace copper for communication cables in many applications. The know-how transfer is now under negotiation. Another major contribution of NML has been its development of aluminium-based coinage alloys.

To find substitute for nickel in major alloys has been a major activity. One successful effort was the development of a nickel-free heating element. Its resistivity characteristics, heating life, and maximum usable temperature are almost similar to those of Ni-Cr alloy. One plant based on this know-how has come up near Delhi; one more is in the project stage.

A substitute alloy which evoked considerable interest was the nickel-free austenitic stainless steel based on the Cr-Mn-N system. The development work included production of sheets, which were subsequently pressed into various shapes. Comprehensive work has been conducted on the corrosion resistance of this steel in comparison with standard nickel-containing steels of the 3-hundred series. The high-temperature creep and oxidation resistance properties of this alloy are superior.

Know-how for manufacture of standard alloys is also often required. NML has helped the industry by development of technology for such standard materials as nickel-silver, bi-metallics, spring materials, clad materials (such as stainless steel,mild steel, copper on aluminium etc.).

A special group has been working on the development of know-how for magnetic materials. Alnico-type permanent magnets with oriented columnar grains, hard and soft ferrites for various applications, and magnetically soft materials have been developed.

Abrasion-resistant irons have been developed in collaboration with a local foundry who needed the same for their sand-blasting impellor blades. Most of the Railways obtain their requirements of soft-magnetic irons from NML.

Surface Finishing & Corrosion Prevention

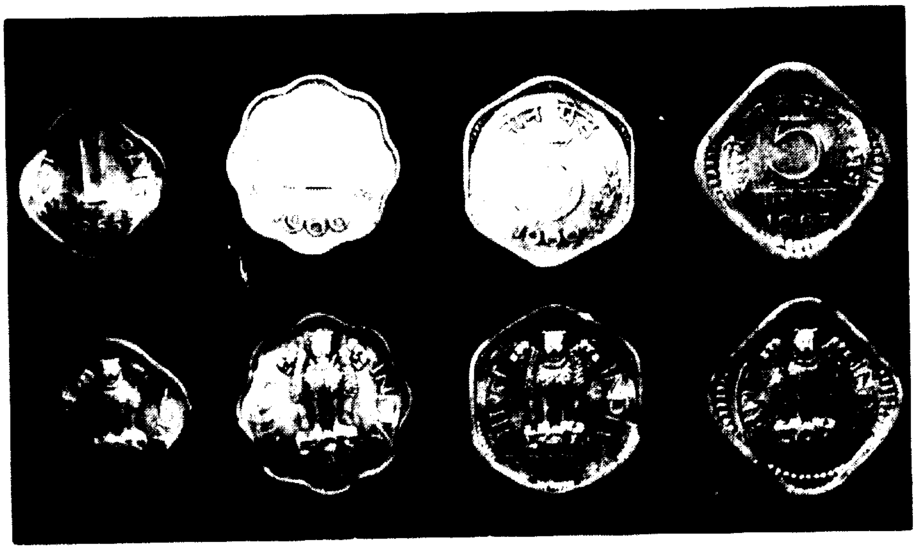
One of the important methods of metal conservancy is to increase its life by prevention of its corrosion. NML has an active cell which has devoted its energy in this direction.

Ways and means have been developed at NML for obtaining durable surface finishes and protective coatings. Some of the contributions in this field include electro-plating of bright nickel - a process which has been well appreciated and utilised by the industry. A self-regulating hard chromium-plating bath has also been transferred to the industry. Two successful electrolytic tin-free-steel processes have been developed at NML. The products have been tested and approved by the consumers.

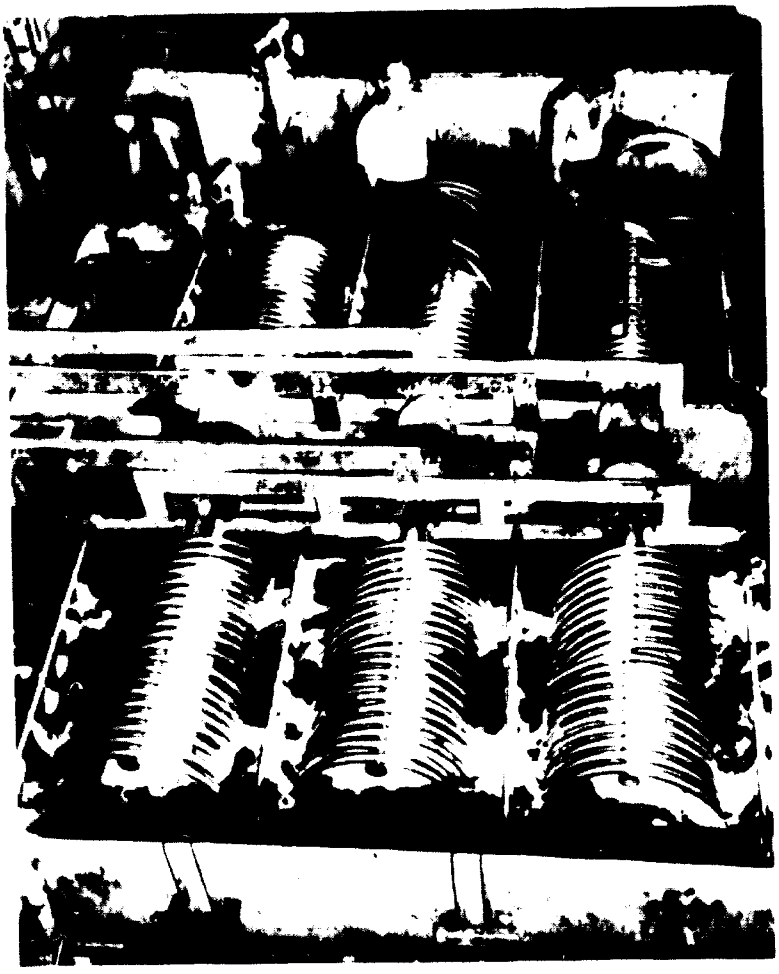
Aluminising as a substitute process for hot-dip galvanising has been developed and promoted. This know-how has been developed on pilot-plant scale. Already the process has been leased out to manufacturers of wires. A group has been actively working on plastic coating of steel. All these developments have to duly pass through our rigid tests at the Marine Corrosion Centre on the sea coast at Digha on the Bay of Bengal.

Corrosion and its prevention has been actively persued. Teams of scientists have been in contact with such groups of factories as fertiliser, petro-chemicals, power-plants etc. and have been actively advising them on corrosion problems and investigating corrosion failures. A Corrosion Advisory Bureau has been established at NML which undertakes programmes on national scale. A 'Corrosion Map of India' has been established and published. Similarly work on soil corrosion map is in progress.

Studies in stress-corrosion cracking of metals in general and light alloys in particular are in progress. Corrosion inhibitors have also received their due share of attention. An aluminium-based alloy has been developed as a sacrificial anode for cathodic protection of ships' hulls and has undergone successful trials. The corrosion group is also busy with routine corrosion-resistance testing of alloys under development by other groups at NML.



NML's Coinage Alloy



NML Ni-plating in Industrial Plant

IV. PILOT-PLANT & IN-PLANT R&D BY NML

A National Laboratory like NML cannot be considered as adequate or complete without the R&D facilities incorporating pilot plants. The original planners back in the forties had envisaged pilot-plant facilities in a number of disciplines. It was fully realised that "the value of the investigations to the industry is largely determined by their success on semi-process and pilot-plant scale". It is no wonder then that over the years the NML should have come by a large array of pilot plants. At NML a considerable proportion of efforts in men, matter and money are being spent in testing out the results of bench-scale operations. It is the success or failure in the pilot-plant investigations which ultimately determines whether a particular process will find eventual industrial application or will perish by the way-side on the difficult road between research and industrial production. Furthermore, these pilot-plants have served a dual purpose in a developing country like India. On one hand, they have allowed inter-disciplinary approach and team work for determining operating parameters and scale-up factors; on the other hand, they have considerably bridged the 'credibility gap' between the prospective entrepreneur and the laboratory scientists.

The term 'pilot-plants' does not always have the same connotation to persons belonging to different disciplines. But, in general, they can be built with either a specific process or a product in mind, or with the objective of flexible, multi-purpose large-scale proving or testing facilities. The former types are built around a single process, and once the development work on the process is completed and the same transferred to the industry, very little work or justification for it to continue in the Laboratory remains. On the other hand, multi-purpose pilot-plants have a flexible processing capacity and to accommodate any combination of routes or steps. A much larger number of processes can be tried out in such a plant with any particular set of raw-materials; or, the pilot-plant helps in establishment of production technologies for a greater variety of products from different raw-materials.

The NML have had a large number of both the types. In order to bring out the successes achieved through these facilities, it will be pertinent here to briefly describe them and the roles they have played in the transfer of technology from the NML to the industry.

PILOT-PLANT FOR PROCESSING OF LOW-GRADE ORES

Any developing country desirous of exploiting its mineral wealth can not do without a pilot-plant for ore beneficiation. The Mineral Beneficiation Pilot Plant (MBPP) at NML is one of the earliest multi-purpose semi-industrial testing unit. It deserves to be mentioned first because of the yeoman service it has done to the establishment of scores of new multi-million dollar industries all over the country. It ranks the highest in terms not only the number of investigations completed, but also in the number and variety of industries serviced, the total capital investment that it has helped to establish, and for the Laboratory the proportion of annual revenue that it has helped secure. The MBPP has been designed on the lines of a custom mill capable of treating any ore with the most efficient and economic technique. The raw ore of 6" to 8" size is received in hoppers, and dumped into a feeding bin discharging into a jaw-crusher which reduces it to 1" to 1½" size. Belt conveyors carry the crushed ore to a secondary crushing room, where gyratory and cone crushers with intermediate screening can give a product of 6-12 mm size. The crushing programme can be so adjusted as to deliver a closely sized material in any range. Dry or wet grinding of the crushed ore can be done in conical or cylindrical ball mills with ½ to 1-ton per hour capacities. Pneumatic or rake hydraulic classifiers ensure a desired fine size range. Aero-fall mill, as also vibro-energy mill and a fluid energy mill, are under procurement.

Separatory processes include gravity concentration in a 20 ton-per-hour capacity heavy-media-separation plant with 7' dia. cones, and a media-cleaning circuit. Jigs of various designs, shaking tables, spiral classifiers are also provided. Banks of sub-aeration machines can handle any flotation circuit. Flotation cells of several makes have been installed for comparative performance trials, under strict conditions. Wet and dry magnetic separators are also provided. High-tension electro-static separators capable of generating 60-80 kV D.C. are also provided.

Washing of ores and agglomeration of ore fines has been one of the prominent areas of contribution of the pilot-plant. Hydraulic washers, dewatering equipment, a continuous sinter strand, a pot-grate sinter furnace, a 6' dia. pelletising disc, and a heat-hardening furnace are some of the standard units in this section. Thickeners, disc and drum filters, rotary dryers are provided in the wet concentration of the minerals.

A 35' long, oil-fired rotary-kiln had been obtained for conducting magnetising roasting of iron and manganese ores. Recently the same has been considerably modified for developing the production techniques for sponge-iron with non-coking coals. Several hundred tons of raw-materials have been processed through this kiln for production of sponge-iron and developing techniques with them. Modifications include coal-throwing system; air injections through the shell length; retainer rings; and product cooling facilities.

A Wellman Galusha gas producer is an essential service facility for this pilot plant. Large number of receiving bins have been provided for incoming consignments. Following statistics may be relevent and interesting in this context:

A TYPICAL ACTIVITY DATA SHEET OF A NML PILOT-PLANT

Mineral Beneficiation Pilot Plant (MBPP)

1. Date of Inauguration ... ... February, 1962.
2. Number of investigations completed since February,1962 ... 65
3. Data for last 3 years

Investigations completed			Revenue obtained	
1970	...	3 Nos.	US $	4,800
1971	...	5 Nos.	US $	15,000
1972	...	8 Nos.	US $	50,400

4. Names of major sponsors along with the number of investigations sponsored so far

i) Hindustan Steel Limited* .. 12 Nos.
ii) National Mineral Development Corporation* .. 11 Nos.
iii) Tata Iron & Steel Co. Ltd. .. 4 Nos.
iv) Pyrites, Phosphates & Chemicals Limited* .. 3 Nos.
v) Manganese Ore India Ltd.* .. 3 Nos.
vi) Indian Copper Corporation* .. 3 Nos.
vii) Gujarat Mineral Development Corporation .. 2 Nos.
viii) M/s. Bolani Ores Limited .. 2 Nos.

ix) Hindustan Copper Limited* .. 2 Nos.
x) Hindustan Zinc Limited* .. 1 No.
xi) United Nations Industrial Development Organisation .. 1 No.

* Government of India Undertakings

5. Mineral-wise classification

Minerals	Projects completed	Minerals	Projects completed
Iron ore	31	Quartzite	2
Copper ore	6	Phosphate rock	2
Limestone	7	Chrome	2
Manganese ore	4	Pyrite	2
Fluorspar	2	Lead ore	1
Gypsum	1	Selenite	1
Beach sand	3	L.D.dust	1

6. Industrial plants based on NML Reports

Broadly based on the results obtained at MBPP, the following plants have been installed or are being planned for installation:

(i) 500 tonnes per day Fluorspar Beneficiation Plant at Kadipani, Gujarat:- The Laboratory was associated with the project right from testing of the samples to the commissioning of the plant. The plant costing US $ 3 M is now producing fluorspar concentrates of different grades valued at about US $ 6 M annually.

(ii) 1000 tonnes per day Concentrator at Rakha of Hindustan Copper Limited:- The plant is designed on the basis of flow-sheet developed in NML pilot plant and is expected to go into production at the end of this year.

(iii) Iron Ore Pelletising Plant at Pale Mines, Goa:- The plant is producing 0.5 million tonnes of heat hardened pellets for export purposes costing about US $ 4.6 M.

(iv) The following iron-ore washing plants have been established based on the flow-sheets developed in the NML pilot-plants:

(a) Iron-ore washing plant at Barsua (Rourkela Steel Plant). Capacity 14,000 tonnes per day of raw ore. There is a saving of nearly US $ 10 M per year in the cost of production due to the reduction of alumina content after washing.

(b) Iron-ore washing plant at Kiriburu (NMDC) (Bokaro Steel Plant). Capacity 14,000 tonnes per day. There is a saving of about US $ 4 M per year in pig-iron production due to reduction of insolubles and alumina content after washing.

(c) Iron-ore washing plant of TISCO. Capacity 14,000 tonnes per day installed at an estimated cost of about US $ 1 M per year in pig-iron production after washing.

(d) Iron-ore washing plant at Bailadila mines of NMDC to treat 14,000 tonnes per day of raw ore. There will be an expected saving of about US $ 1 M per year in pig-iron production due to decrease in alumina content in the washed ore.

(v) The following sinter plants have been established based on the pilot-plants tests conducted at the NML:

(a) Sinter plants at the Rourkela Steel Plant. Capacity 6,000 tonnes per day. The plant is in operation and the fines costing about US $ 600,000, which otherwise would have been wasted every year, are utilised.

(b) Iron-ore sinter plant at TISCO. Capacity 5,000 tonnes per day. There is a saving of about US $ 900,000 due to utilisation of the fines.

(c) Iron-ore sinter plant at Durgapur. Capacity 5,000 tonnes per day. Fines costing about US $ 900,000 are utilised.

(d) Iron-ore sinter plant at Bhilai. Capacity 6,000 tonnes per day. Saving of about US $ 900,000 per year due to utilisation of fines.

7. Pilot-plant investigations on the following important deposits are in progress and will result in the establishment of the following important concentrators:

(i) 50 tonnes per day graphite-beneficiation plant for Andhra Pradesh Industrial Development Corpn.

(ii) 1,000 tonnes per day manganese-beneficiation plant for Manganese Ores (India) Ltd. near Nagpur.

(iii) A slag-processing plant for a non-ferrous foundry in Jullundur.

8. Consultancy Services

The scientists and engineers in the Mineral Beneficiation Pilot Plant have a long experience of not only pilot-plant investigations but also of plant practices and plant design. The NML have offered consultancy services incorporating testing of ores and development of flow-sheets, commissioning of the commercial units, and training up of supervisors.

The NML has been acting as Consultants for the following projects:

(a) 500 tonnes per day Fluorspar Beneficiation Plant at Kadipani, Gujarat.

(b) 1,000 tonnes per day copper concentrator at Rakha.

Negotiations for the Consultancy Services for the following projects are underway:

(c) A custom mill for graphite concentration in Andhra Pradesh.

(d) 1,000 tonnes per day manganese-beneficiation plant for Manganese Ore India Limited.

(e) A processing plant for the recovery of metallics from furnace-slag.

9. Prospects of utilisation of NML expertise in the near future

(i) Beneficiation plant for Malanjkhand Copper ore, Madhya Pradesh.

(ii) 500 tonnes per day beneficiation plant for Cu-Pb ore at Bandalamottu, Andhra Pradesh.

(iii) 4,000 tonnes per day beneficiation plant for the concentration of pyrite-pyrrhotite in Saladipura, Rajasthan.

(iv) 1,000 tonnes per day manganese ore beneficiation plant.

LOW-SHAFT FURNACE PILOT-PLANT

Another unique feature of the NML is its pilot plant low-shaft furnace for assessment of the possibilities of utilisation of sub-standard ores and fuels for obtaining commercial grades of pig iron. The plant comprises of a 7.3 M^3 low-shaft furnace having a 1.3 M dia. hearth and 3.6 M effective height between the tuyere level and stock line. A single-stage turbo-blower with an intake capacity of 5,000 M^3 air delivers the same at a pressure of 1.3 atm. The blast is heated to 600°C by a metal-tube recuperator and fed into the furnace through four water-cooled copper-tuyeres of 90 MM diameter at a velocity of 90 M/sec. and a pressure of 3,000 MM water column.

Elaborate gas-cleaning system includes a down-comer, a dust-catcher, a water-spray cooler-cum-scrubber, a Thyssen disintegrator, followed by a final scrubber. The clean gas is burnt in the recuperator and the gas in excess is flared off. The plant is served by a two-line railway siding capable of handling five wagons per day. The raw-materials received are stock-piled in the receiving yards and screened.

An elaborate raw-materials preparation plant includes a hot briquetting unit for single-component charge comprising of iron-ore fines, flux fines and coal/coke fines hot-mixed and pressed with sulphite lye/tar binders. The briquetting press is of the Belgian rolls type. The facility was put-up at a cost of US $ 0.5 M in 1959 and over US $ 3 million were spent on investigations in subsequent years.

Over 45 long-term campaigns resulting in thousands of tons of pig-iron, were conducted over a period of ten years. Raw-materials from all parts of the country were tested for their assessment. Based on the results of these campaigns, a monograph in the form of an issue of the NML's Technical Journal was published in 1971. Of interest to the regular blast-furnace operators were the pioneering trials for injecting naphtha through the tuyeres. The technique was later taken up for commercial trials and practice at the neighbouring steel plant. Oil injection in blast-furnace operation in India is of great significance because of the very high ash content (24-26%) in the coke.

Besides assessment of the raw-materials and development of oil injection technology, the low-shaft furnace served an important purpose of training up of staff and workers in a round-the-clock, industrial type of project work. There is band of highly skilled workers knowledgeable in the art of operating a furnace.

More recently, the furnace has been used for developing know-how for ferro-alloy manufacture.

500 kVA SUBMERGED ARC FURNACE

A pilot-plant for development of electro-thermic smelting processes, particularly in view of the abundant reserves of ferro-alloy raw-materials, was installed in 1961. The 500 kVA Birlefco submerged electric arc furnace with 8' dia. shell can be rotated either way. The furnace has been designed as an open-top unit with very efficient dust and fume suction system. The versatile power supply system can deliver power at any of the several voltage tappings, through the 8" dia. electrodes.

Several campaigns have been carried out in this pilot-plant, for developing the production techniques for ferro-alloys from the local raw-materials. A single-step process for production of low-carbon ferro-chrome was also developed and passed on to industry. More recently the furnace was used for UNIDO-sponsored project for smelting of pre-reduced iron-ore pellets made from concentrates of Aswan Iron ore.

Currently the furnace is being used for development of know-how for calcium silicide and ferro-nickel.

Activity Data

Following data on the activity of this pilot-plant is relevant:

1. Date of establishment:- February 1962

2. No. of investigations completed

   33 campaigns of durations from 7 days to 40 days each.

3. Titles of some major investigations

   (a) Production of high-carbon ferro-chrome using Talcher low-temperature-carbonization-coke as the reductant - Sponsored by industry.

   (b) Production of high-carbon ferro-chrome and silico-chrome - Sponsored by industry.

   (c) Production of silico-chrome by single-stage process with the raw-materials supplied by sponsoring industry.

   (d) Production of high-carbon ferro-manganese using low-temperature carbonization-coke of Katkana Collieries of Madhya Pradesh - Sponsored.

   (e) Smelting of pre-reduced Aswan Iron-ore pellets - Sponsored by UNIDO.

4. Technologies developed & transferred

   (a) A process for the production of high-carbon ferro-chrome, silico-chrome from indigenous chromites.

(b) A process for utilisation of low-temperature carbonised-coke in the production of silico-manganese and ferro-manganese.

Talchar coke is now being used in the production of ferro-chrome at Jaipur-road Plant of Orissa Industrial Development Corporation with an established capacity of 10,000 metric tons of the alloy.

Based on data supplied by NML, both low-carbon and high-carbon ferro-chrome are being produced at M/s. Ferro-alloy Corporation, Garividi, with capacity of 10,000 tonnes per year.

Value of these products manufactured by the above two firms is approximately US $ 10,000,000.

ELECTROLYTIC MANGANESE AND MANGANESE DIOXIDE PILOT-PLANT

As an example of a 'single-purpose' pilot-plant installed at NML, the above-mentioned plant deserves special attention. As one of the principal producers of manganese ores, the abundant availability of the ore was sought to be utilised for production of more valuable products from the same. The metal (EM) and dioxide (EMD) are both attractive products and the electro-deposition of the two was perfected at NML on the basis of working a 50 kg per day pilot plant for each. The ground ore is reduced in a rotary kiln, digested in agitated vessels, purified, and electrolysed under controlled conditions for production of either EM or EMD. The metal has been supplied to many industrial units, and the dioxide has been tested and approved by user industries in India and abroad.

Recently the NML entered into an agreement with a firm of consulting engineers through whom the transfer of this know-how is being affected for two customers - one in Kerala, and the other, for a state-sector undertaking, in Orissa.

After the transfer of this technology at the above-mentioned places, it is proposed to close down this thirteen-year-old pilot-plant, and to utilise the serviceable equipment for the proposed multi-purpose electro-metallurgical pilot-plant, which can as well be put on the EMD production circuit.

Whereas the career of this pilot-plant is thus coming to a fruitful end, it does call for some introspection. Obviously, thirteen years is too long a period of wait for a pilot-plant to fructify into commercial unit. Private R&D establishments would have taken the hard and obvious decision to wind it up long ago. A number of reasons could be cited for this long gestation period.

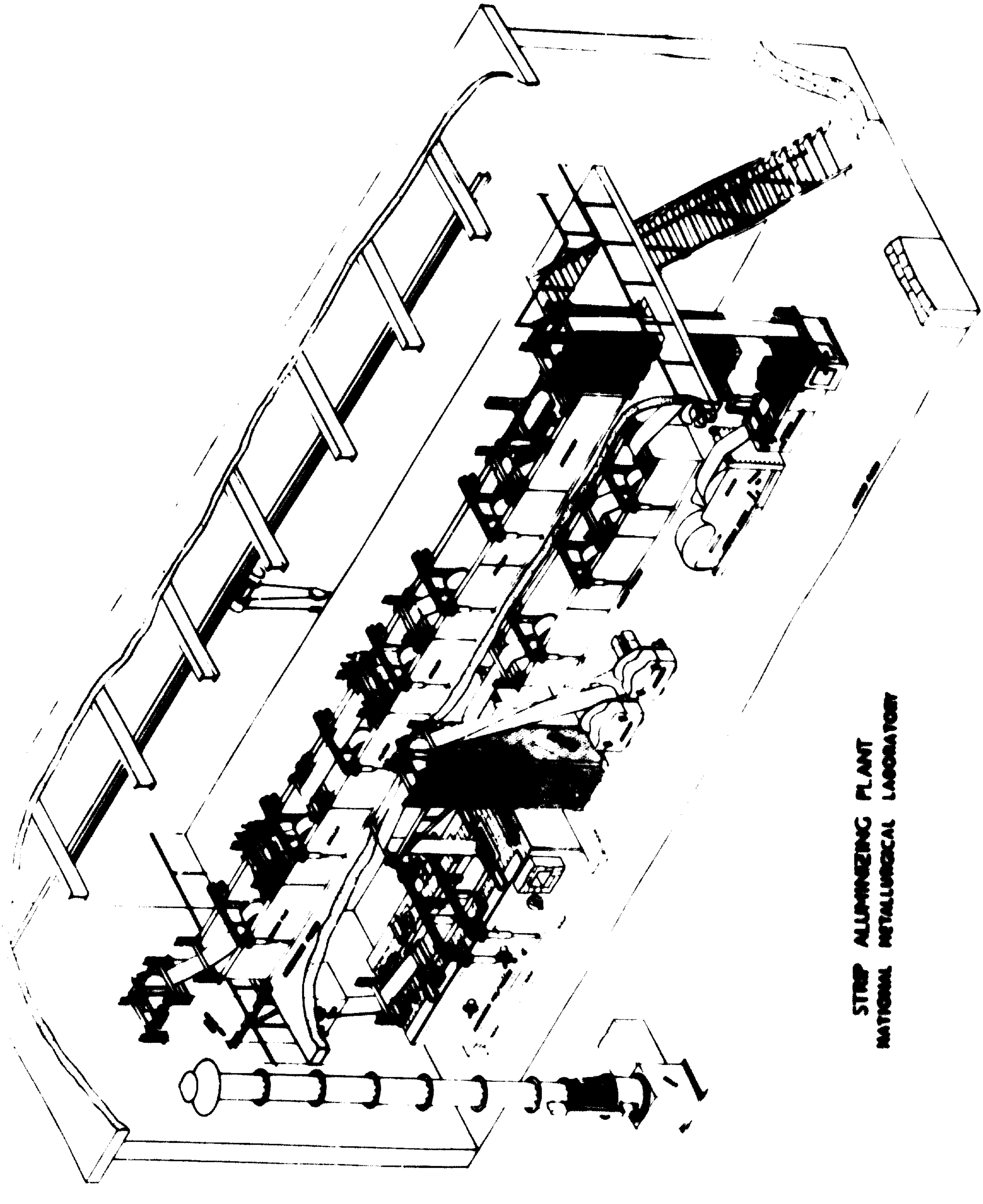
Perhaps the technology was developed much before its time, and the industry was not particular in exploiting the same. Now the time has changed. The demand for EMD is soaring up. This could be perhaps linked up with the 'green revolution' in the country-side, where bumper cash crops have generated untaxed cash in the hands of millions of farmers. The sale and demand of transistors as also torch-lights have sky-rocketed in the rural areas. Entrepreneurship has now come forward to lift off the NML know-how for the EMD.

OTHER PILOT-PLANTS

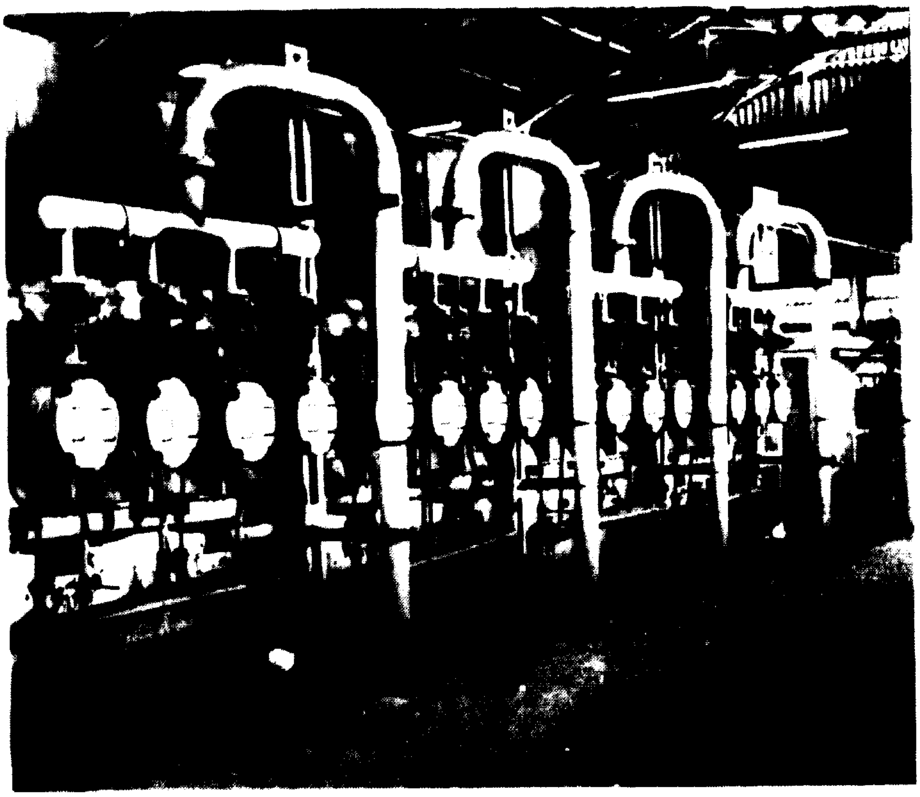
Vanadium:- Some more self-initiated pilot plants were put up at NML, but they could not survive the apathy of the entrepreneur-ship. One amongst them is worth mentioning here. Based on the successful experiments on the bench scale, a pilot plant was put up for extraction of vanadium pentoxide from the titaniferrous magnetites available in the vicinity of the Laboratory. The one-ton per day processing unit comprised of a salt-roasting rotary kiln, leaching and precipitation tanks and filters, dryers etc. After numerous confirmatory experiments and trials, feasibility report was prepared and submitted to several prospective entreprenuers including the State and Central Governments. For a long time no one seemed to be interested in putting up a vanadium plant. In the mean-time, a more attractive route was established and commissioned in another country. This route enabled production of iron and steel with recovery of vanadium almost as a bye-product. The equipment of this pilot-plant is now being cannibalised for a new multipurpose hydrometallurgy pilot-plant.

Direct Arc Furnace:- One of the most successfully utilised general facility with the NML has been our 500 kVA three-electrode, direct-arc melting furnace. This has not only been used for developing a number of special-purpose irons and steels, but has been also used for developing the know-how for melting sponge iron into steels. Along with the standardisation of the generally accepted practice of melting down steel scrap and sponge iron in proportion of 1:1, successful trials have been conducted for melting the sponge iron with pig iron as well. The technical expertise at the NML has been often utilised by the industry for obtaining their requirements of highly sophisticated but small quantities of alloys made to stringent specifications in this small direct arc furnace.

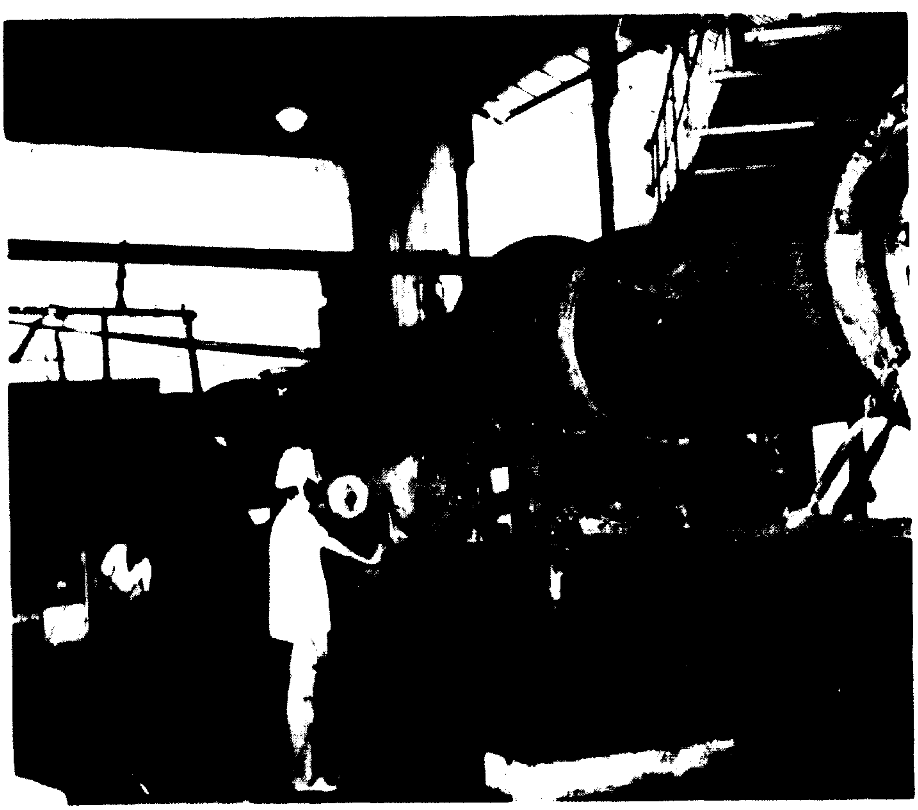
Strip Hot-dip Coating:- Continuous hot-dip coating of steel strips will be shortly conducted in a pilot plant for aluminising techniques developed at the NML. This is the logical evolution from smaller-scale development work which was carried out in the Laboratory. The plant will be used



STRIP ALUMINIZING PLANT
NATIONAL METALLURGICAL LABORATORY



Magnesium Plant



Rotary kiln for sponge-iron

for other metal coatings also. Aluminising has a special significance to India in the context of the dearth of zinc for galvanising and self-sufficiency in aluminium. Some units for aluminising have come up in the country, but the response was never as great as was expected due to restricted imports of zinc.

Dense Carbon Aggregates:- A pilot plant has been recently put up for the development and production of dense carbon aggregates as substitute for anthracite coal, which is not available in India. Processing low-ash-coals, run-of-the-still pitch, and other additives, an aggregate is made from which such products as the soderberg paste, and cathode lining of the aluminium reduction pots can be made. This 500 kgs per day unit is committed to supply trial lots to electric pig iron furnaces in a steel plant and cathode lining blocks for trials at an aluminium plant.

NML's MAGNESIUM PLANT

Often, it comes to the lot of a R&D unit like NML to go beyond the stage of putting up a pilot-plant. It is called upon to put up a semi-commercial/demonstration unit. Such was the case when the country faced an urgent need for magnesium metal in an emergency. A single-retort, silico-thermic unit had been earlier in operation at NML. It was required that a regular, 250 tons-per-year production unit be established based on the know-how developed at the NML. A plant was accordingly designed and commissioned under the project-managership of a senior scientist who had developed the know-how. The plant, which went on production trials in 1971, comprises of a dolomite calcination kiln, a grinding, batching, and briquetting unit, a battery of oil-fired furnace with 16 retorts, and a battery of four electrically heated retorts, and an induction furnace for melting down the crowns. Trials have also been conducted on production of calcium metal by metallothermy using the same equipment.

IN-PLANT R&D BY N.M.L.

Very often, it is not enough to have pilot plants and demonstration units. Some R&D work can be best done in established commercial units. While commenting on the decision to locate the NML at Jamshedpur at the time of inauguration of the NML in 1950, the chairman of the TISCO had said "Of all branches of technology and science, metallurgical research lends itself most to full scale tests in large industrial establishments. What better instrument for this purpose could be found than a large and integrated iron and steel plant.....". Some important development work such as improved L.D. lining, better stoppers, more persistent hot-tops made out of agricultural wastes, low-alloy high-strength steels are some of the examples of what can best be attempted in a commercial steel plant. A few typical cases will be illustrated here, wherein projects, whether sponsored by the customer, or self-initiated, were finally completed in commercial units.

Aluminium Conductors:- A group of scientists at NML while working on the solidification of certain aluminium alloys hit upon a composition which not only gave an electrical conductivity as good as that of pure aluminium, but also yielded a wire of exceptional ductility. After repeated trials in the Laboratory, it was finally decided that the best course for rapid development and transfer of this technology would be to conduct in-plant trials on tonnage quantity of the alloy and make it available for manufacture of kilometer lengths of sheathed cables for field trials by communication agencies. However, no single plant seemed to possess all the facilities required in this trial. Several tons of alloy ingots were cast in one place; the ingots were then transferred to another place several hundred kilometers away for 'wire drawing'. The drawn wire was then transferred another few hundred kilometers to a factory where strands were sheathed into cables, of kilometer lengths. The cables were then transported another several-hundred kilometers for field testing by the post and telegraph and railway authorities. The procedure adopted was so effective that the process has been transferred to an eager entrepreneur without any difficulty.

Refractory Materials:- NML scientists have been busy developing their own ideas, or those of the sponsors in the steel plants. One of them had difficulty procuring Forsterite bricks for the checker-work under the open hearths. Imports could not be readily arranged. NML was called upon to develop the same from indigenous sources. Based on locally available talc/serpentine sources, a technique was evolved to make the bricks of the required specifications. Several tons of the bricks were made and sent to the plant for comparative trials. The bricks were declared by them to be as good as the imported. In the mean-time the imports were allowed!

Alloy Steels:- It is beyond the means of even the best equipped laboratory to develop a low-alloy steel which is sensitive to rigid rolling schedules. Development of a niobium-treated steel in tonnage quantities could be done only in a steel plant. With the co-operation of one such unit, tonnage quantities of plates were manufactured which showed 75% improvement in yield strength with a transition temperature of -40°C.

FUTURE TRENDS IN PILOT-PLANTS

In recent years there has been considerable thought given to the role of pilot plants in an organisation like the NML. There is now a distinct trend towards early identification of the likely customers of the process and the need to involve one from the early stages of pilot plant work. It has also been felt that Consulting Engineering firms have a distinct contributive role to play in planning and operation of a pilot-plant project, in order to ensure an early transfer of technology. In some cases it has been felt that for the purpose of obtaining scale-up data or design parameters, it is unnecessary to have a complete pilot plant for that process. It may well be that only one or two process steps, which may be unique to the process, may need larger-scale testing. Yet another trend is to install multi-purpose pilot plants, which can accommodate a number of possible flow-sheets, thus enabling treatment of a variety of raw-materials.

Hydro-electro Metallurgy:- One such multi-purpose project at NML deserves a special mention. Hydro- and electro-metallurgical processes have a distinct role to play in extractive metallurgy. Most of the approaches can be classified into roasting, calcination, leaching, purification, precipitation, electro-deposition etc. In order to determine the optimum parameters for ores and concentrates, mostly of non-ferrous metals, for metal extraction therefrom, a comprehensive large-scale facility is being established at the NML. Ores of such metals as copper, aluminium, zinc, nickel, manganese etc. can be investigated in this facility. Besides the usual crushing, grinding, and sizing equipment, the facility will have (a) a roasting and calcination bay with rotary kiln, multiple hearth-furnace, fluidised bed unit etc; (b) a leaching bay, with atmospheric and high-pressure leaching in acid or alkaline systems; (c) thickening, filtration, washing, and similar unit operations; a bay for purification and storage of pregnant liquors; (d) a bay for chemical precipitation; (e) a bay for electro-deposition with a 200 kVA transformer-reactifier set; solvent extraction and ion-exchange facilities; analytical facilities etc. The ambitious scheme is being worked out in stages.

The above narrated brief account of the NML's pilot-plant activities will clearly bring out the importance of pilot-plants in a developing country. Judicious use of available funds can enable establish a flexible and comprehensive facility and help bridge the credibility gap, which is so often responsible for non-utilisation of the indigenous technology. More so, it can enable a knowledgeable group of engineers to obtain all the relevant design data for doing scale-up and project engineering work for industrial ventures.

V. SPECIAL SERVICES

In addition to the general usefulness of the NML to the industry, there are certain special services offered by the NML.

Advice to Foundries:- Indian foundry industry is characterised by only a few well organised foundries with well equipped control laboratories on one hand, and thousands of small operators concentrated in a few pockets in the country on the other. If the latter were to make a significant contribution to the development of the nation, it was essential that certain minimum technical services be offered to these ill-equipped operations. Accordingly, NML established extension centres - field stations at four places in the country where bulk of the small foundry industry was concentrated. These are Batala in the North, Howrah in the East, Madras in the South, and Ahmedabad in the West. These centres are equipped with instruments for complete foundry control from raw-materials to finished products. Chemical analysis, metallographic examinations, sand control, mechanical testing, and similar facilities are provided and are being constantly used by the small operators. Technical advice is freely given on foundry production problems. Recently a decision was taken to increase the scope of these stations to meet additional local requirements. The field stations have been actively investigating local foundry raw-materials and have published a monograph on 'Foundry Sands of India'.

Standard Samples:- Standard samples for chemical analyses are commonly required in metallurgical industry. NML started a cell for production of standard samples and has so far produced over a dozen most commonly wanted varieties. In a joint collaborative project with the National Bureau of Standards of U.S.A. three ferro-alloy samples were prepared as standards. A proposal for preparation of spectrographic standard samples has been approved recently and work has been initiated.

Failure-studies:- Service failures of metallic parts of machinery are a common phenomena. Such parts are often sent to NML for close examination and analysis of reasons for the failures. Similarly, many other types of samples are handled at NML at the instance of the industry.

Creep-testing:- With the industrialisation, the country has become power-hungry, and many thermal power stations have come up and many more have been planned. This has increased the tempo of production of high-temperature steels. NML has a 25-point creep-testing facility, which logged more than 100,000 hours of testing in 1971.

Creep Testing Machines at NML

UNIDO aided New Creep Laboratory at NML

Recently, with the aid of the UNDP this facility is being increased to 150 test points as a million dollar project. This facility will greatly help in the rapid development of high-temperature steels and manufacture of power (generation) equipment.

Liaison:- Liaison and Information Division is an active asset of NML and helps to bring the Laboratory closer to the people in general and users in particular. At least half a dozen customers, users or prospective entrepreneurs are daily attended upon at the NML. In addition, at least a dozen NML scientists are on tour every month attending meetings organised by numerous governmental agencies, companies, and institutions. Periodic 'get-togethers' arranged at various industrial and trading centres in the country with the help of local directorates of industry, or mines as also of chambers of commerce to bring together prospective entrepreneurs and inventors and scientists of the NML.

Information:- A large number of technical enquiries involving library reference work are attended to by the NML. Every month a documented survey of metallurgical development is compiled and mailed to subscribers all over the country.

Symposia & Seminars:- NML has served as a useful platform for national and international exchange of ideas and information. Over a dozen international symposia have been held so far on various specific topics. Currently, an international symposium on production of sponge iron has been arranged and promises a record response. Besides such international gatherings, smaller seminars are arranged more frequently. For the first time workers from different centres met at NML to plan a national strategy for R&D work on bacterial leaching of ores.

VI. FUTURE PLANS

Even as far back as 1942, when the CSIR first referred the formation of NML to the Metals Committee, one of the terms was to consider and advice if one or more such laboratories were required. The Metals Committee after due consideration to the state of industrialisation then existing in the country had advised the formation of one, to begin with.

The three intervening decades have brought a tremendous difference in the status of the country's metallurgical industry. Steel plants have increased from two to six and three more are under feasibility study and existing ones are doubling up. Aluminium production has increased fifteen-fold, and is planned to touch half-million ton mark by the end of the Fifth Plan period. There have been similar increases in production of copper, zinc, iron ore, manganese ore, ferro-alloy plants, thermal power stations, heavy and light engineering industries, and other user industries. Pressure of work has been steadily increasing and NML has been making an adequate response to this pressure from time to time. Its latest development plans, which include establishment of a creep research centre, a multi-purpose hydro-cum-electro-metallurgy facility and its development facility for sponge-iron, all coming up during the next three years, will triple the assets of the NML over its 1970 figure and increase its staff strength to ten times over its 1950 figure. There are physical constrains for further growth and expansion at NML.

In a fast-growing country, of a size equal to that of Europe, there is scope and need for more such institutes. In a single developed European country, one-fifteenth the size of India, there are four Ore Research Institutes and two high-temperature metal research institutes of the size of NML. A developing country like India can not afford to have inadequate R&D facilities as a constraint on its rate of development. Proposals for setting up of specialised Institutes are under active consideration. Much discussion has taken place on the proposal to establish an Aluminium Research Institute - possibly as a cooperative effort of the industry and the CSIR. The Steel Authority are actively organising their own R&D structures, with centres in every steel plant. There have been proposals for a Corrosion Research Institute, a Refractory Research Institute, and some others. NML has been actively associated with these deliberations and has made objective contributions to such proposals. We do not share the apprehensions that such institutes will supplant the role of NML. In a fast-growing country our roles will be complementary rather than competing.

Looking back over the two decades of its active existence, the National Metallurgical Laboratory at Jamshedpur justly feels proud of its contributions to the growth and development of metallurgical industry in the country. It looks forward with confidence to decades of continued dominant role as a premier R&D institute in metallurgy in India.

8. 4. 74