INTRODUCTION

MINERAL beneficiation, ore-dressing, ore concentration and upgrading are synonymous terms used for the techniques or processes for the separation of economic mineral or minerals to the desired limits from other associated worthless mineral constituents usually termed as "gangue" minerals in a low grade ore. Beneficiation of low grade ores plays a very important role and very vital in the conservation and economic utilisation of the mineral wealth of a country, and more so in a developing country like India where a good number of its important mineral resources are of very low grade and need beneficiation treatment for their use as raw materials in the various mineral-based industries either individually or mixed with some other materials.

Concentration or beneficiation process of a low grade ore can be achieved by virtue of the differences in the physical, chemical and physico-chemical properties of the constituent minerals present in it. Thus difference in specific gravity, magnetic succeptibility, electrical conductivity and surface properties like wettability of minerals are taken advantage for the effective separation of one mineral from the other. Chemical properties are utilized only to a limited extent in ore-dressing.

Ore-dressing Methods

Ore-dressing primarily consists of two important stages of operation namely (i) liberation of the valuable and economic minerals from the gangue minerals/material, and (ii) actual separation of the two groups of minerals. Whatever beneficiation method is adopted the preparation of the ore remains common in that the required mineral/minerals of economic value must be liberated from the associated gangue. This liberation is brought about by crushing and grinding of the ore to the required degree of fineness. This follows the separation of the minerals by various concentration processes suitable depending on the nature of the minerals in the ore.

Crushing and grinding are done by the use of different types of crushers (Jaw crushers, Gyratory crushers etc.) and different types of mills (Ball-mills, Rod mills, Pulverisers, Pebble mills etc.). Grinding operation can be done both in dry and wet conditions, whereas crushing is done invariably under dry condition.

Gravity methods of concentration are used where there is difference between the specific gravity of the economic mineral/minerals and that of the gangue. The method of separation utilises heavy media separation, Jigs, shaking tables with water medium, air tables (pneumatic tables) and Humphrey's spirals. Heavy media separation process employs a suitable liquid medium of aqueous suspension put in the separating density normally ranging from 1.2 to 3.4 and to treat material of size ranging from 6 mm to 150 mm. The medium materials used are very fine sand and magnetite (for coal separation), galena and ferro-silicon (for iron ores, manganese ores, pyrite, lead-zinc ores etc.).

The Jigs consist essentially of a box with a sieve in the bottom, through which pulsating currents of water pass separating the material fed on to the sieves into layers depending upon specific gravity. Jigs are used to treat materials of size ranges of 19 mm down to 48 mesh size (0.298 mm). Jigs are extensively used in concentration of coal, manganese ores, tin ores, wolfram ores etc.

Treatment of finer feeds of below −10 mesh (1.65 mm) for gravity separation is done by using

Humphrey's spirals and shaking tables in a water medium. Beach sands, iron ores, chrome ores etc. in association with lighter siliceous gangue minerals can be treated by them. Humphrey's spiral is best suited for sandy material with little fines, while shaking tables are most effective in separating fine heavy minerals from coarse light ones. Now-a-days pneumatic tables are used to some extent in place of shaking tables where compressed air is used as the separating medium in place of water.

The very common and most important method of concentration which has been undergoing rapid development in the realm of mineral concentration is flotation process, which is based on the surface properties of mineral grains that can be modified by temporary physico-chemical action by the addition of some chemical reagents to the ore pulp in very minute quantities. In flotation process the whole of the ore is reduced to a relatively fine state at which the different minerals are liberated from one another. Most of the very low grade sulphide ores which are not amenable to gravity concentration, as well as some non-sulphides and non-metallic minerals can be concentrated by flotation methods. Thus complex copper lead-zinc ores, limestone, fluorspar, etc. can be treated by flotation techniques.

Magnetic separation is being employed for the treatment and separation of magnetic minerals from the non-magnetic minerals. Electrostatic separation which makes use of the difference in electrical conductivities of minerals has become very common in the treatment of beach sands for the separation of zircon and rutile.

For the agglomeration of ore fines generated in huge tonnages in the mine sites using machanized mining of iron ores etc., and for the fine concentrates sintering and pelletising methods are adopted. Thus sintering is adopted when the material size is finer than 9 mm as in the case of iron ores, chromite, manganese ore etc. Pelletising is resorted when the material is finer than 150 microns as in the case of blue dust, fluorspar concentrates, limestone concentrates etc.

While laboratory scale testing of the process or processes of concentration on any ore will indicate their applicability to the ore in general, commercial scale utilization of the beneficiation flowsheet can only be determined on the basis of prior pilot plant trials, which include the investigation of the over-all economic and technical feasibility of a process not only under laboratory conditions but also under simulated, proto-type industrial scale trials. Whenever research results have established the economic viability and technical feasibility of upgrading tests on pilot plant scale, industrial scale flow-sheets will be worked out on the basis of which the full-fledged beneficiation plants are to be established in the country.

Beneficiation Studies at N.M.L.

Deposits of different ores and minerals in India, as earlier indicated, are mostly of low grade in nature and cannot be directly used as such unless they are beneficiated and upgraded and brought to the desired grade limit for their utilisation as raw materials in the various mineral-based industries in the country. The feasibility or degree of amenability of any low grade ore for beneficiation treatment depends on its basic mineralogical assemblage and their gangue minerals present, their association, texture and degree of interlocking.

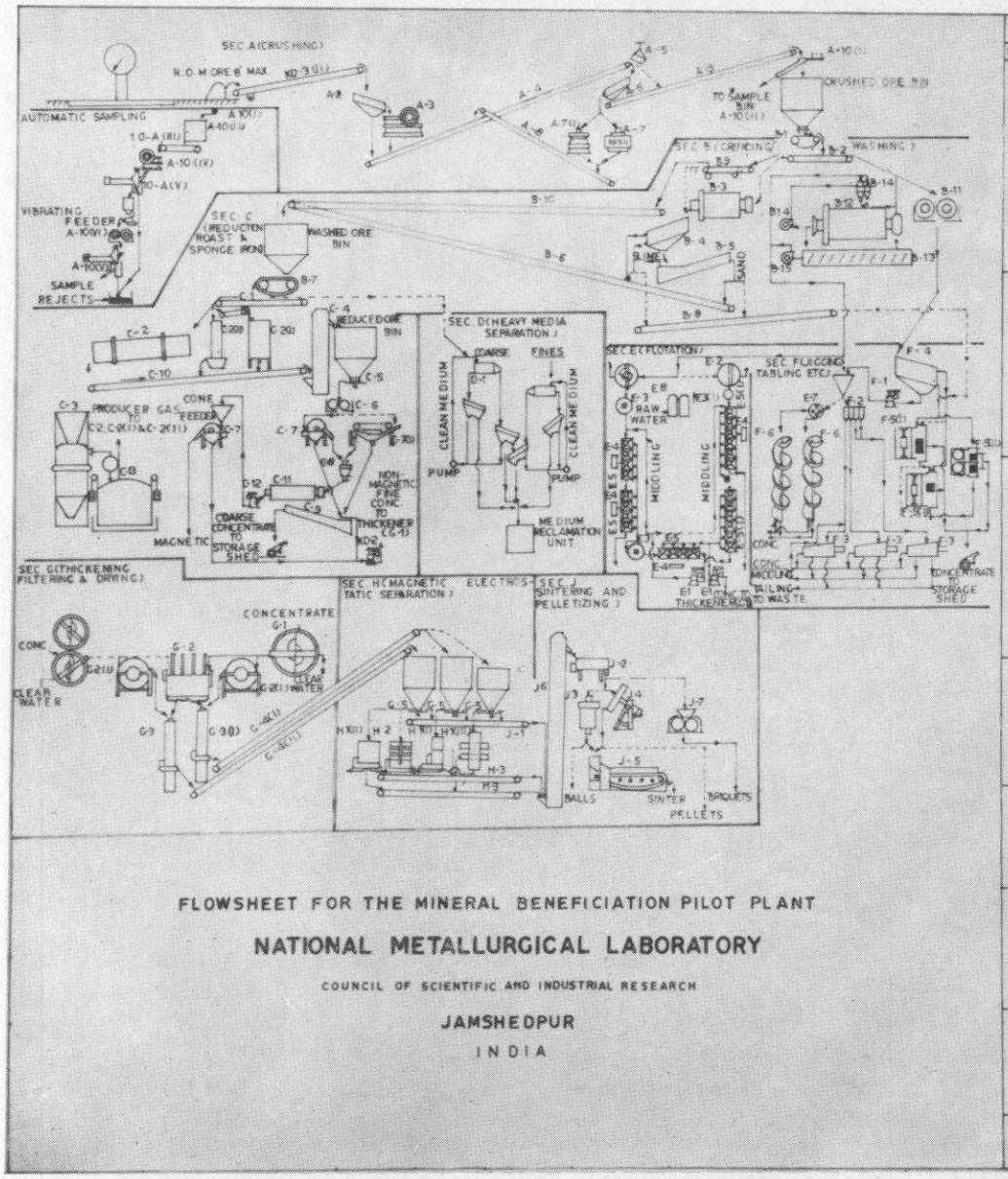
The National Metallurgical Laboratory is well equipped on modern lines to undertake planned research work on mineral beneficiation of all types of low grade ores and minerals, both on bench as well as on pilot plant scale. With the setting up of an integrated pilot plant with a capacity of ore treatment upto 5 tonnes/hour depending upon the flowsheet developed, the necessity of sending large tonnage of ore samples to overseas laboratories for continuous beneficiation trials has now been put to an end.

Exhaustive batch and pilot plant scale investigations have been undertaken at NML which cover almost all types of low grade ores emanating from the various parts of the country from existing as well as virgin mines during the last over 27 years. Since its inception, over 450 research investigations have been undertaken successfully and the results issued to the entrepreneurs who are both in the public sector and private sector organisations, individual mine owners etc. spread through out the country. Wherever investigation results have established the economic and technical feasibility of the upgrading procedures involved, industrial flow sheets have been worked out on the basis of which, some important beneficiation, sintering and pelletizing plants for iron ores, manganese ores, flourspar, copper ores, graphite etc. have

either been set up or being planned to be processed by the industries. The results thus obtained have provided invaluable data to organisations like P.P.C.L., H.C.L., H.S.L., N.M.D.C., T.I.S.Co., G.M.D.C., etc. in formulating their economic pattern of exploitation of ores and minerals.

The laboratory had completed exhaustive studies on beneficiation, sintering, pelletization for iron ores received from various captive mines of India which covered more than 100 samples. In the same way studies have been undertaken on manganese ores, chromite ores, copper, lead and zinc complex ores, tungsten and molybdenum ores, graphite, apatite, phosphate rock, pyrite, flourspar, limestones, magnesite, bauxite etc. Laboratory scale and pilot plant scale studies are given briefly in the following pages under Part II.

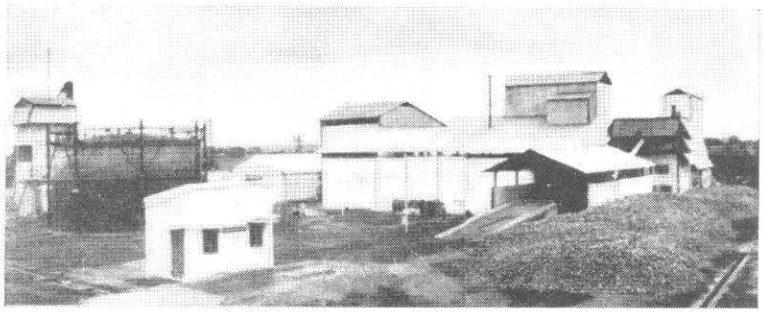
The physical characteristics and other additional data like crushing strength, grindability and work index etc., essential for designing of the process equipments are dealt with under Part III.



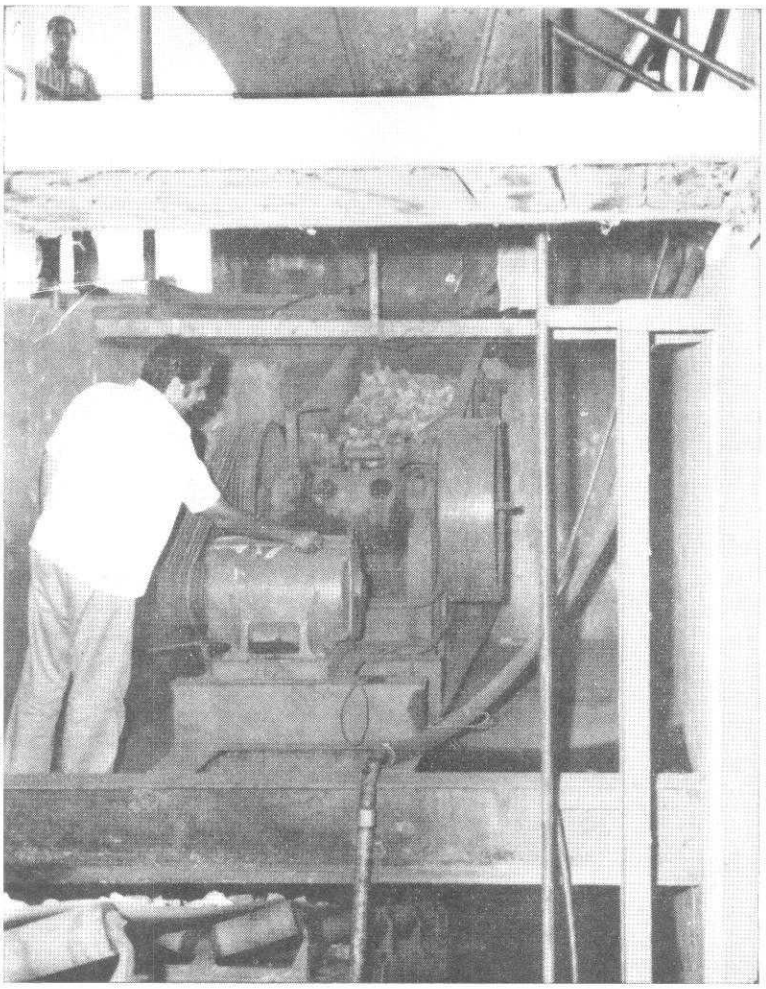
LIST OF EQUIPMENT

SEC	NO.	DESCRIPTION		QTY
A	1	WEIHING PLATFORM	2000	1
	2	VIBRATING GRIZZLY	2 X 5	1
	3	JAW CRUSHER	10 X 16	1
	4	BELT CONVEYOR	16 X 10	1
	5	GUARD MAGNET	24	1
	6	VIBRATING SCEEN	2 X 4	1
	7	SYMONS CONE CRUSHER	2	1
	7(a)	GYRATORY CRUSHER		1
	8	BELT CONVEYOR	16 X 50	1
	9	" "	16 X 75	1
	10(a)	SAMPLE CUTTER		1
	10(b)	SAMPLE BIN		1
	10(c)	ORE FEEDER		1
	10(d)	JAW CRUSHER	5 X 6	1
	10(e)	SAMPLE SPLITTER SYNDERO		2
	10(f)	ROLL CRUSHER	10 X 6	1
B	1	CONSTANT WEIGHT FEEDER		1
	2	BELT CONVEYOR	16 X 25	1
	3	BLADE MILL	3 X 4	1
	4	VIBRATING SCREEN	2 X 4	1
	5	SPIRAL CLASSIFIER	12 X 9-6	1
	6	BELT CONVEYOR	16 X 130	1
	7	APRON ORE FEEDER	18 X 6	1
	8	BELT CONVEYOR	12 X 32	1
	9	" "	16 X 18	1
	10	" "	16 X 120	1
	11	ROLL CRUSHER	16 Ø X 10	1
	12	BALL MILL	3 Ø X 6	1
	13	RAKE CLASSIFIER	18 X 14-8	1
	14	CYCLONE CLASSIFIER		1
	15	SAND PUMP	2	1
C	1	BELT CONVEYOR	16 X 25	1
	2	ROTARY KILN FOR SPONGE IRON	3 Ø X 30	1
	2(a)	MULTIPLE HEARTH		1
	2(b)	VERTICAL FURNACE		1
	3	GAS PRODUCER		1
	4	BUCKET ELEVATOR	35	1
	5	DISC FEEDER	2 Ø	1
	6	ROLL CRUSHER	12 Ø X 8	1
	7	ELECTROMAGNETIC SEPARATOR		2
	7(a)	" "		1
	8	DEMAGNETIZING COIL		1
	9	SPIRAL CLASSIFIER	9 X 5-8	1
	10	BELT CONVEYOR	16 X 65	1
	11	ROD MILL	16 X 4	1
	12	VERTICAL SAND PUMP	1½	1
	13	GAS HOLDER	20000 CU.FT.	1
E	1	VERTICAL SAND PUMP		2
	2	HYDRO CLASSIFIER	4 Ø	2
	3	CONDITIONER	3 Ø X 4	2
	3(a)	"	18 X 18 Ø	2
	4	WET REAGENT FEEDER		4
	5	FLOTATION (M) CELL UNIT		3
	5(a)	" " (R) " "		3
	6	AUTOMATIC PULP SAMPLER		2
	7	DRY REAGENT FEEDER		1
	8	WATER SOFTENING UNIT		1
F	1	VERTICAL SAND PUMP	1½	1
	2	HYDROSIZER	4 X 1' COM.	1
	3	SHAKING TABLE	1-6 X 2-6	3
	4	VIBRATING SCREEN	2 X 4	1
	5(a)	JIG-HARZ TYPE	18 X 32	2
	5(b)	MINERAL JIG DUPLEX	8 x 12	1
	6	SPIRAL CONCENTRATOR		2
	7	PULP DISTRIBUTOR 4 COMPT.		1
G	1	THICKENER	16 Ø X 8	1
	1(a)	" "	9 Ø X 6	1
	2	DISC FILTER	4 Ø X 4 DISKS	1
	2(a)	DRUM FILTER	4 Ø X 2-6	2
	3	ROTARY DRYER	16 Ø 10	2
	3(a)	"	16 Ø 16	1
	4(a)	BELT CONVEYOR	12 X 105	1
	4(b)	"	12 X 110	1
	5	DISC FEEDER	18 Ø	3
	6	HYDROCLASSIFIER	6 Ø	1
H	1(a)	MAGNETIC SEPARATOR		1
	1(b)	" "	(DUPLEX)	1
	1(c)	" "	(CROSS BELT)	1
	2	ELECTROSTATIC SEPARATOR		1
	3	BELT CONVEYOR	12 X 25	2
J	1	BELT CONVEYOR	12 X 25	1
	2	PADDLE MIXER	3 X 8	1
	3	BALLING DRUM	2 Ø X 4	1
	4	PELLETIZING DISC	5 Ø	1
	5	SINTER STRAND		1
	6	BUCKET ELEVATOR	38	1
	7	BRIQUETTING PRESS		1

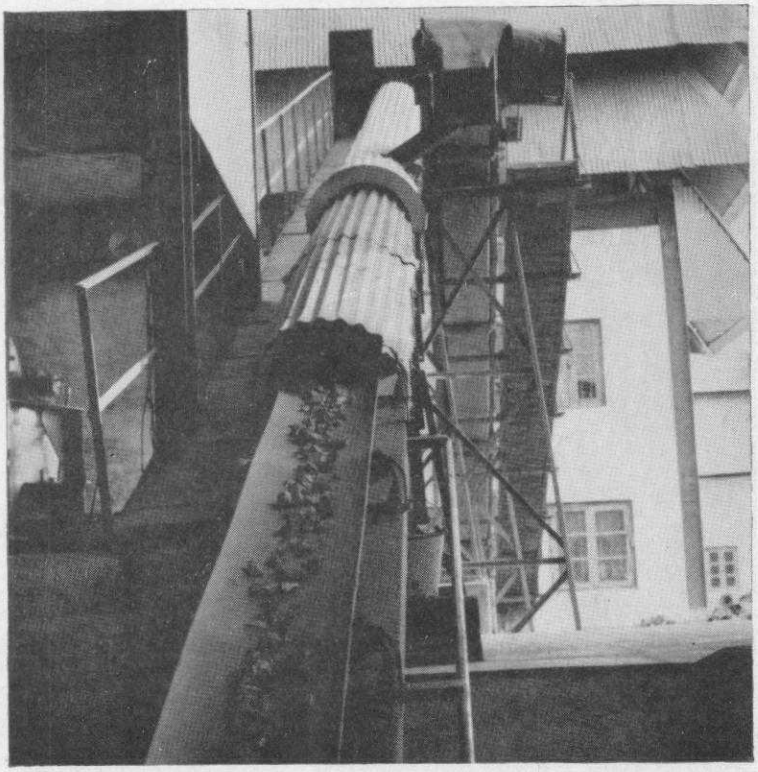
Flowsheet of Mineral Beneficiation Pilot Plant of NML.



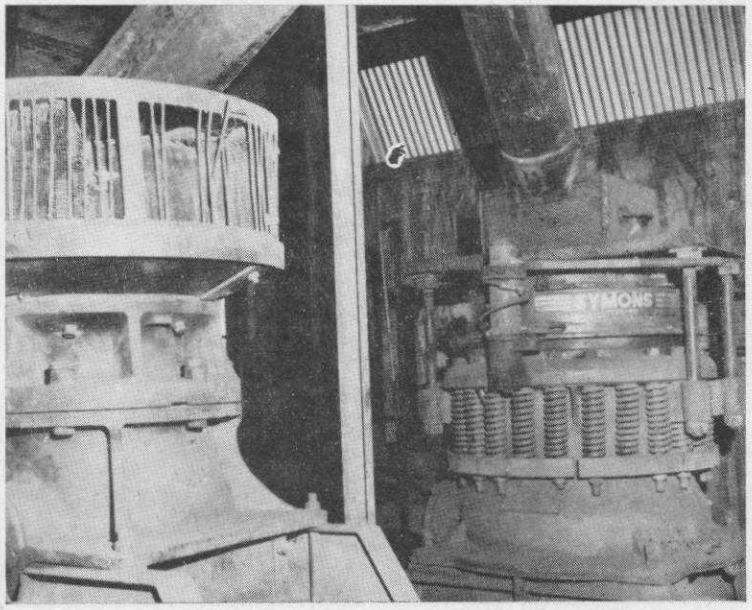
A General View of the Mineral Beneficiation Pilot Plant (MBPP) of NML.



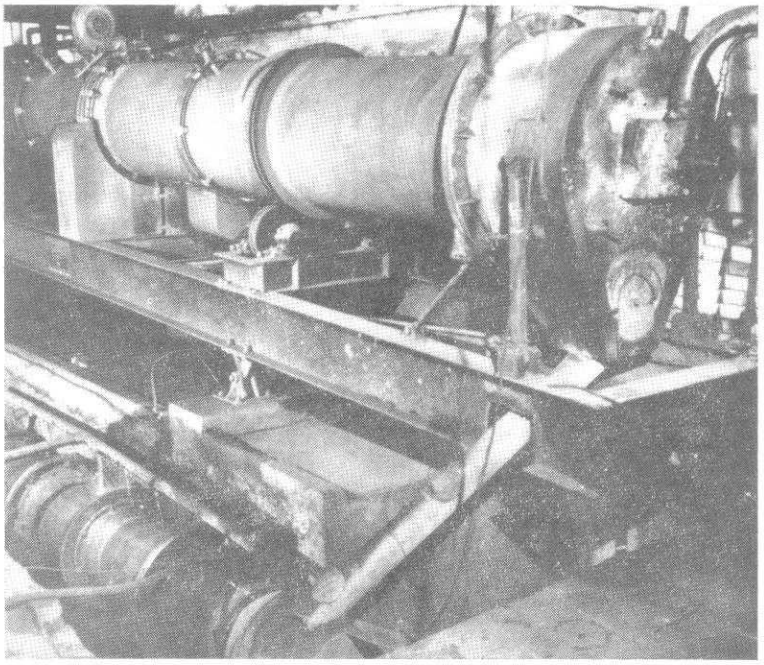
Hopper, Primary Crusher (Jaw Crusher) Grizzly and Belt Conveyor at the Mineral Beneficiation Pilot Plant.



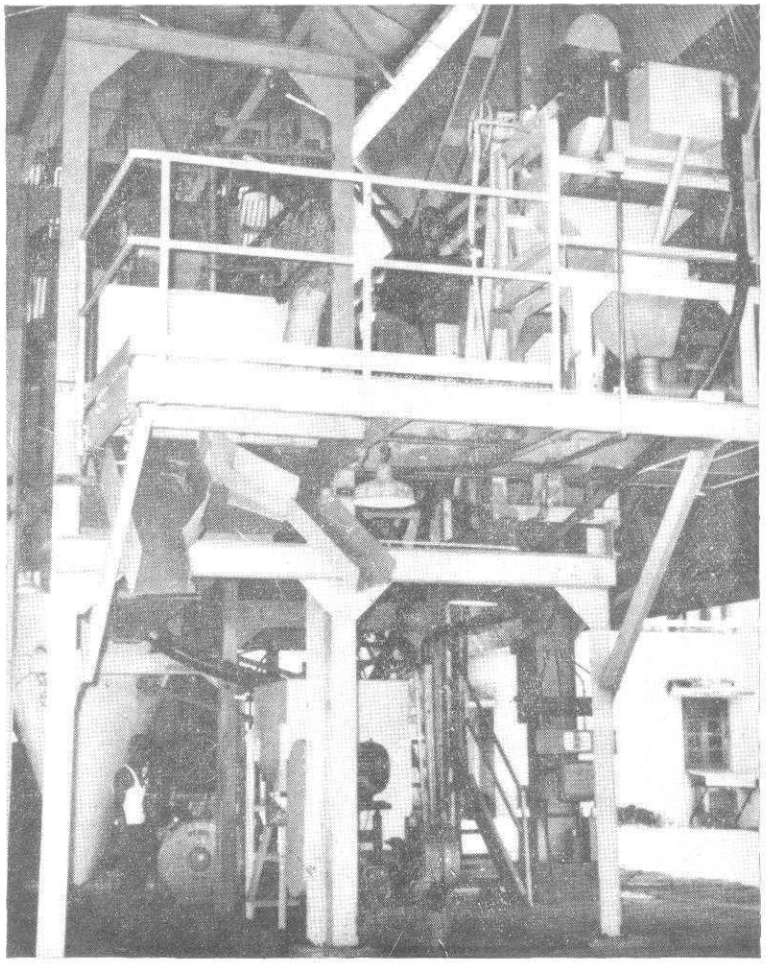
Belt Conveyor Feeding the Secondary Crushing section of the Mineral Beneficiation Pilot Plant (MBPP).



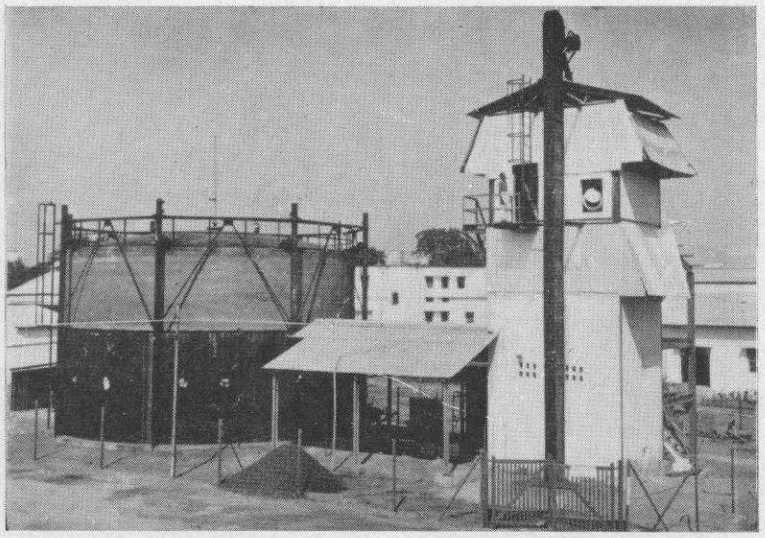
Secondary Crushers at the Mineral Beneficiation Pilot Plant.



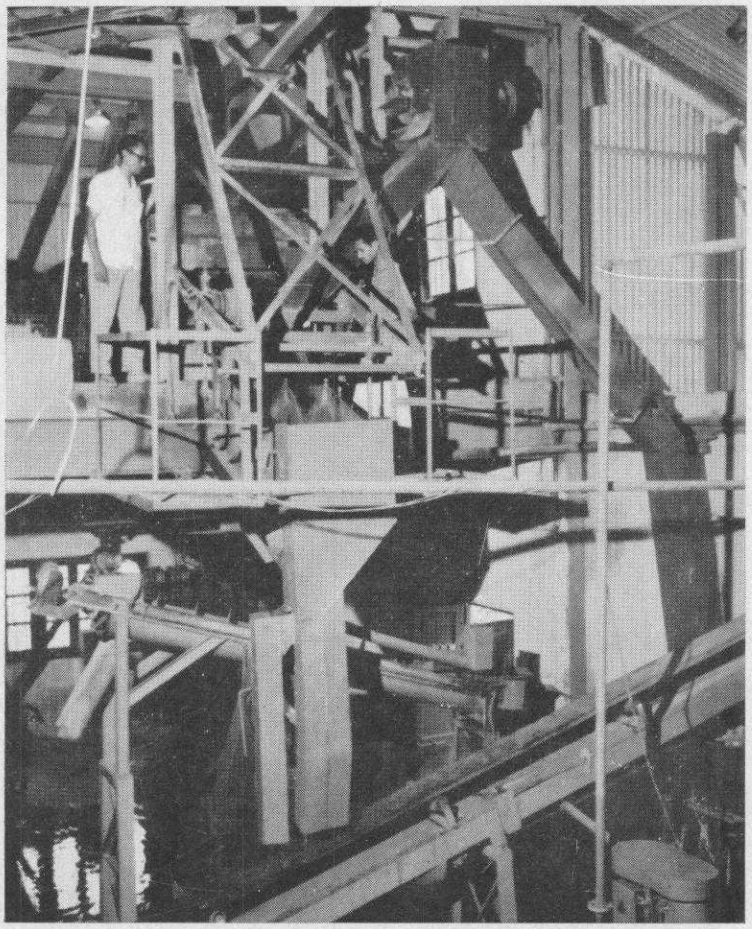
Rotary Kiln at the Mineral Beneficiation Pilot Plant.



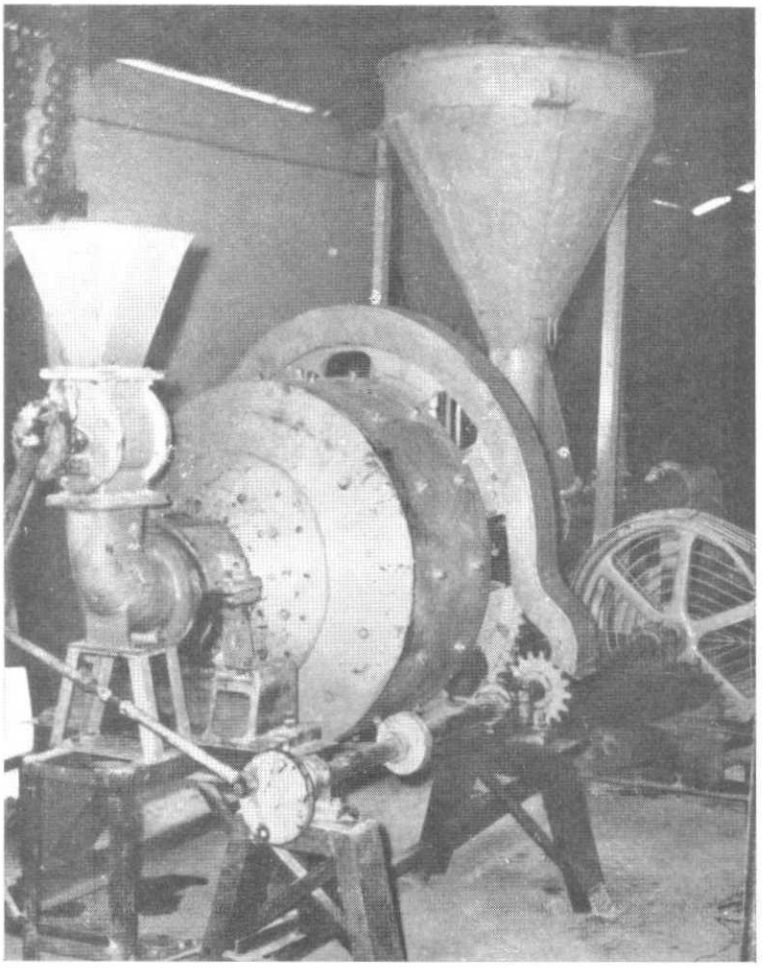
H.M.S. Plant at the Mineral Beneficiation Pilot Plant.



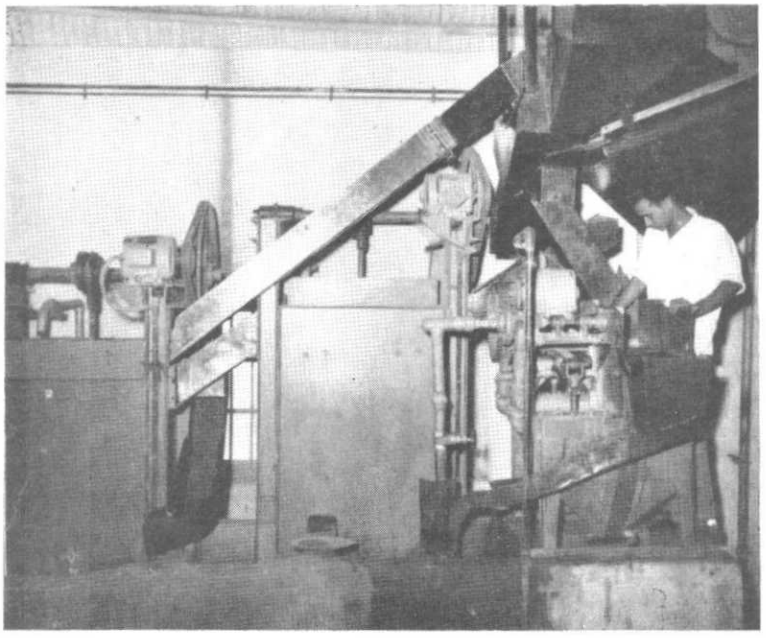
Gas Producer Plant and Holder at the Mineral Beneficiation Pilot Plant.



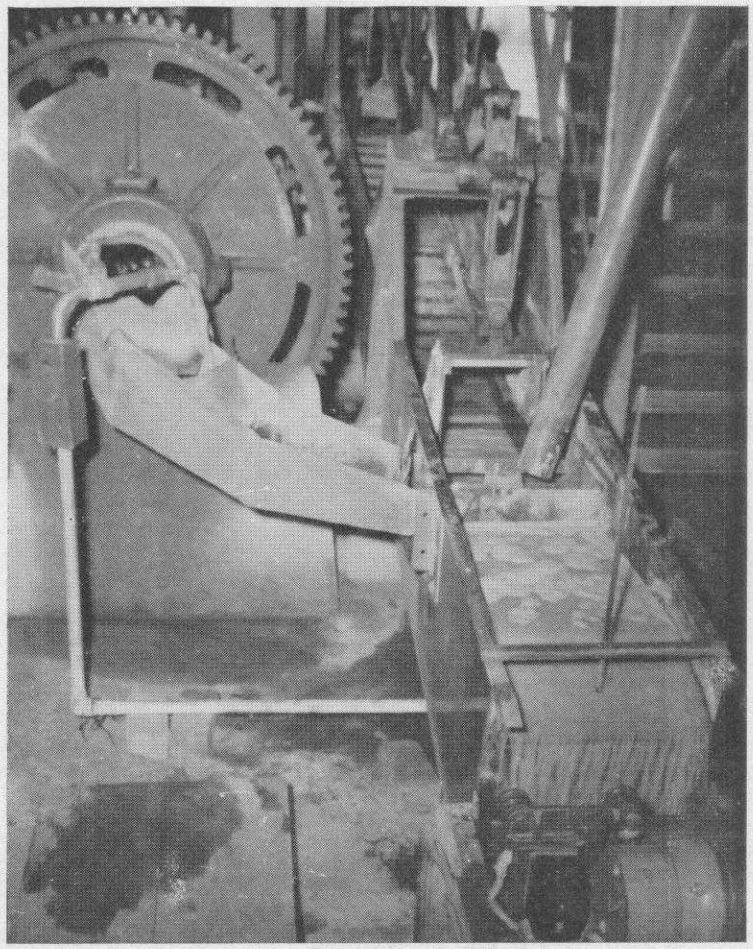
A view of the iron ore Washing Section showing log washer discharge end. Double deck vibrating screen and spiral classifiers of the Mineral Beneficiation Pilot Plant.



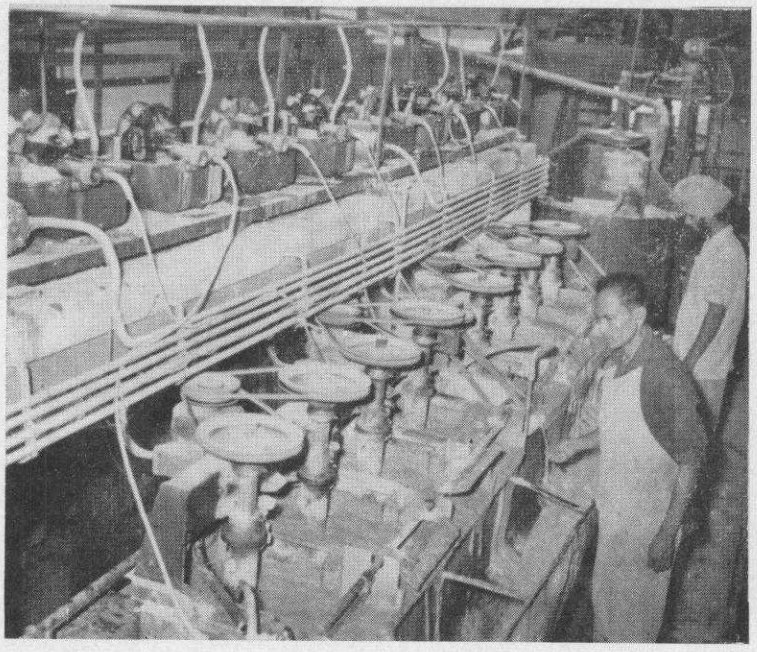
Dry grinding Unit at Mineral Beneficiation Pilot Plant.



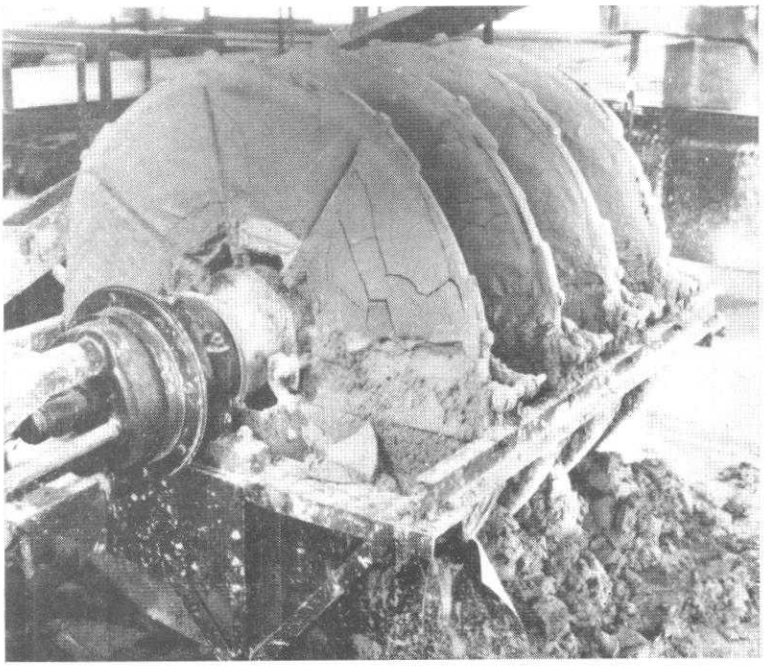
Harz and Mineral Jigs in operation at Mineral Beneficiation Pilot Plant.



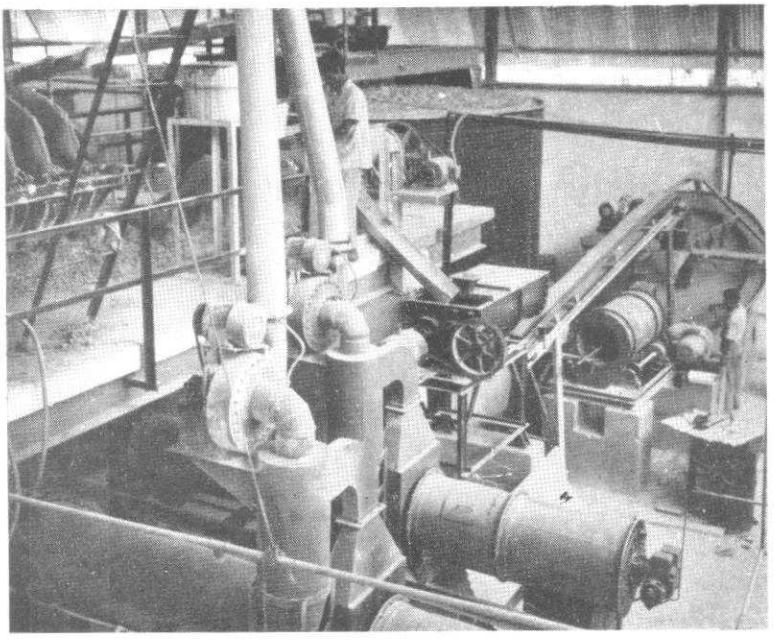
Ball Mill and Rake classifier at Mineral Beneficiation Pilot Plant.



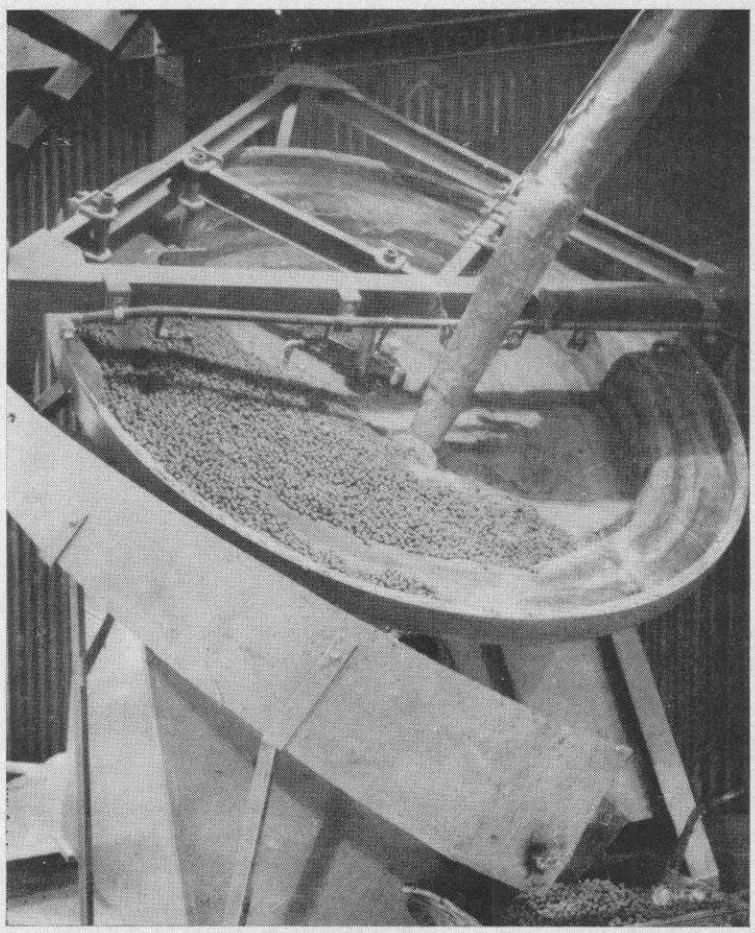
A view of flotation cells with reagent feeders and conditioner at Mineral Beneficiation Pilot Plant.



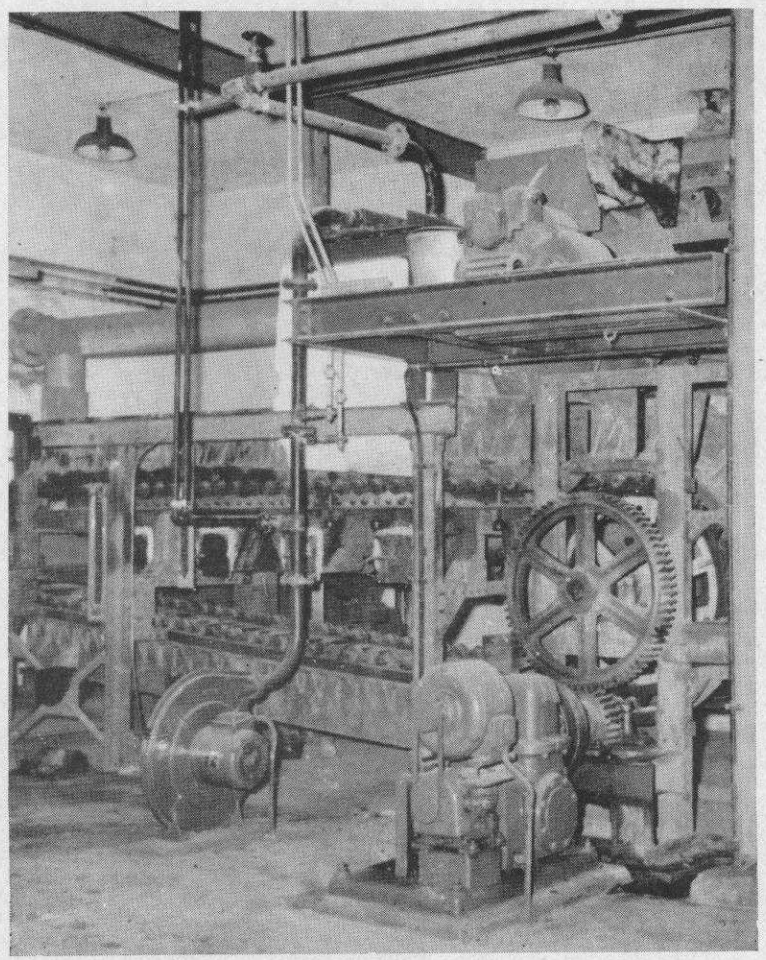
Vacuum Disc Filter with filter cake in the foreground at Mineral Beneficiation Pilot Plant.



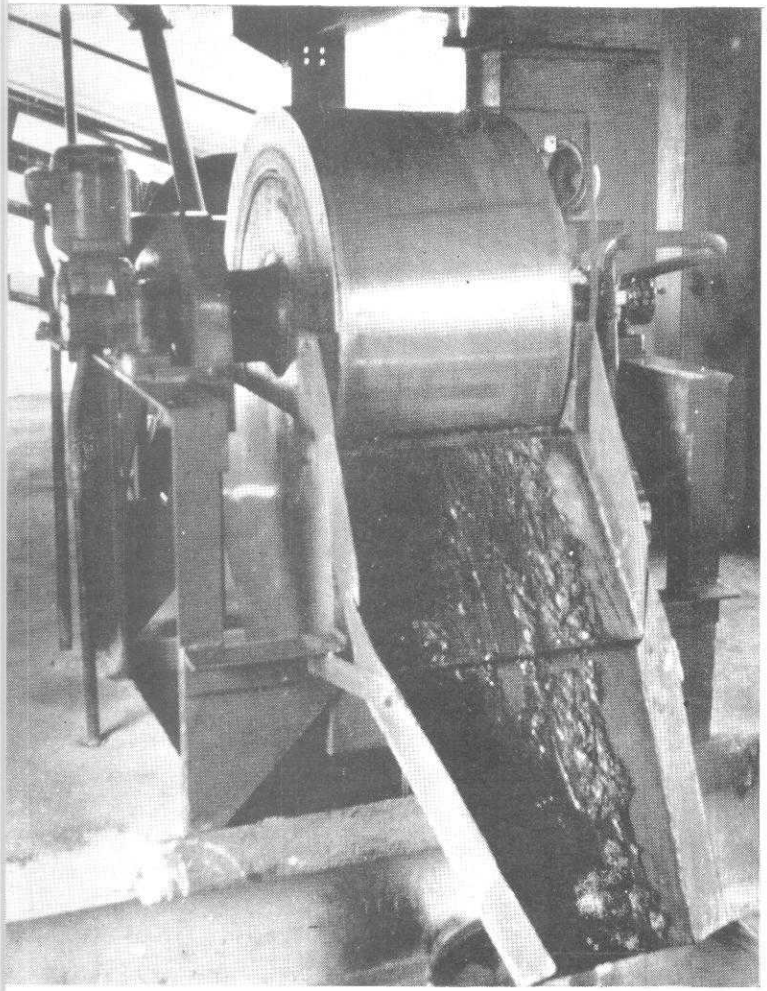
Rotary Driers with Thickener and Disc Filter in the back ground at Mineral Beneficiation Pilot Plant.



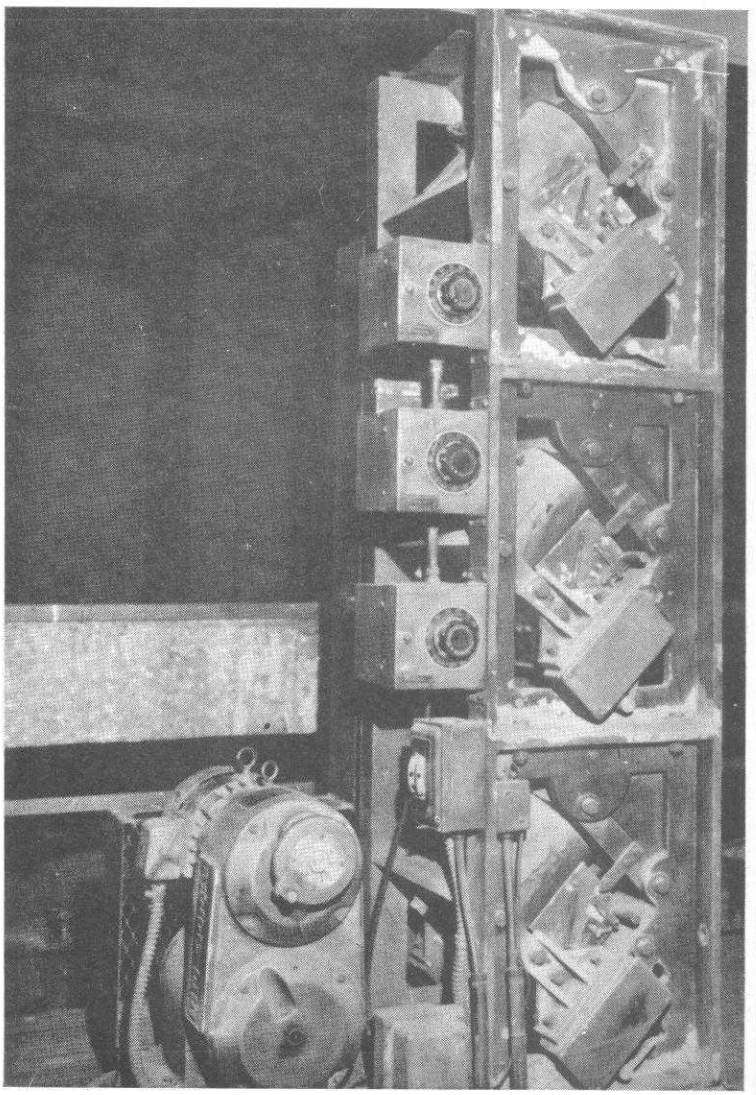
Disc Pelletizer (2 metres dia) in operation at Mineral Beneficiation Pilot Plant.



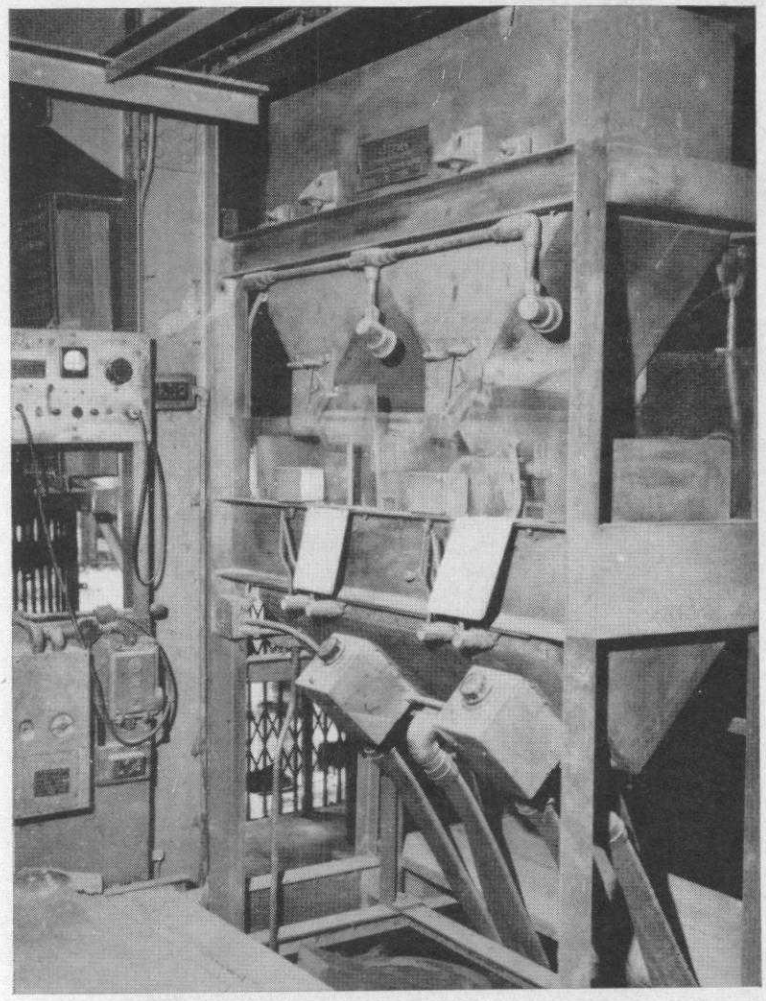
Continuous Sintering Unit at Mineral Beneficiation Pilot Plant.



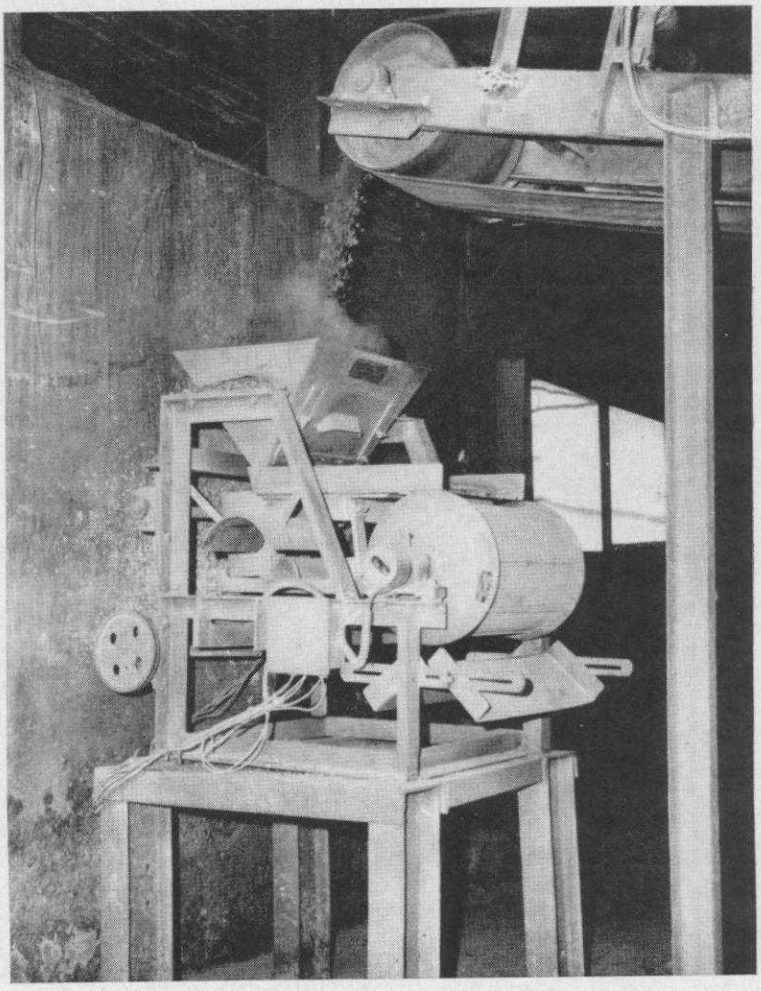
Continuous Drum Type Wet Electromagnetic Separator at Mineral Beneficiation Pilot Plant.



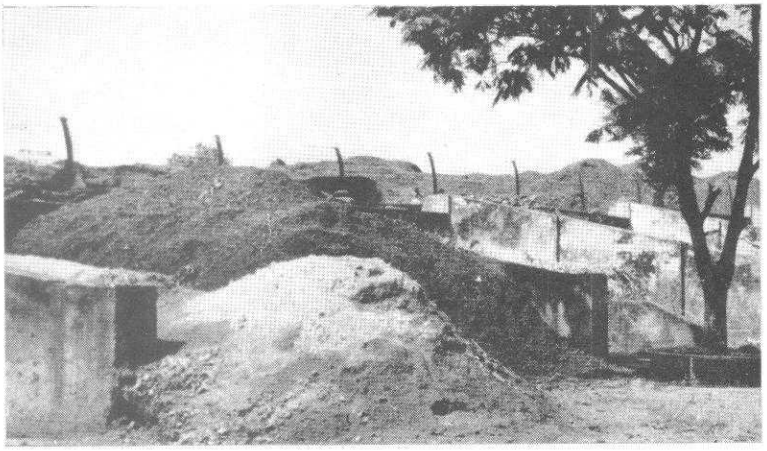
Induced Rolls at the Mineral Beneficiation Pilot Plant.



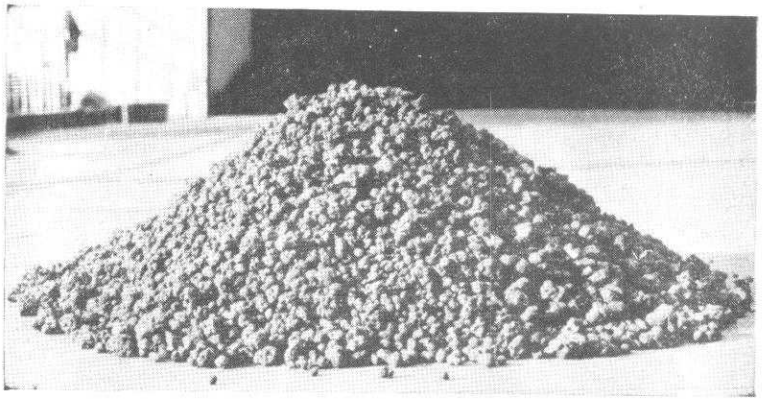
High Tension Separator
at the Mineral Beneficiation
Pilot Plant.



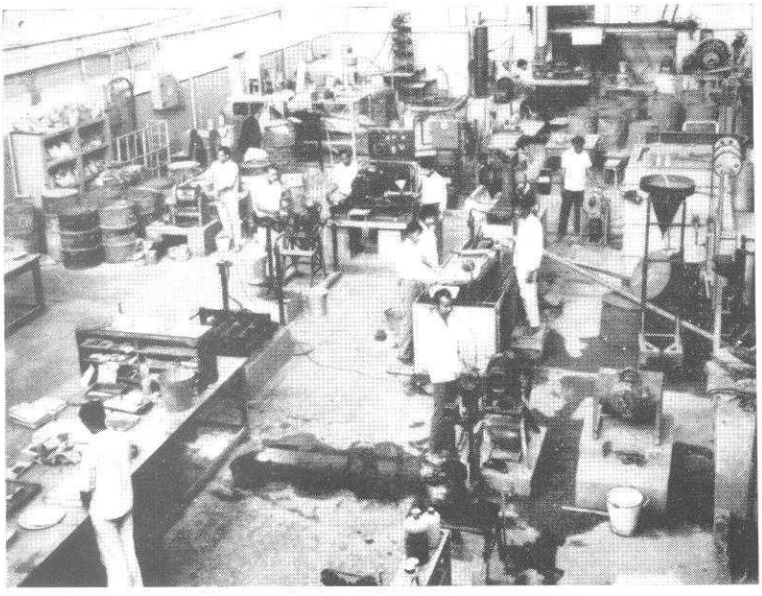
Dry Magnetic Separator
at the Mineral
Beneficiation Pilot Plant.



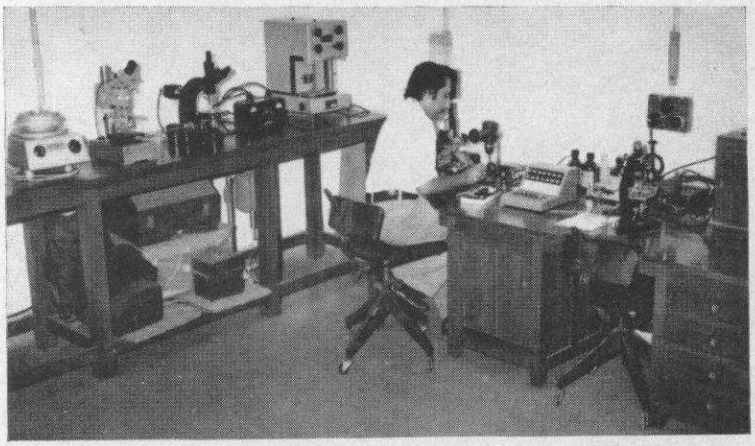
Ore cubicles at the Mineral Beneficiation Pilot Plant.



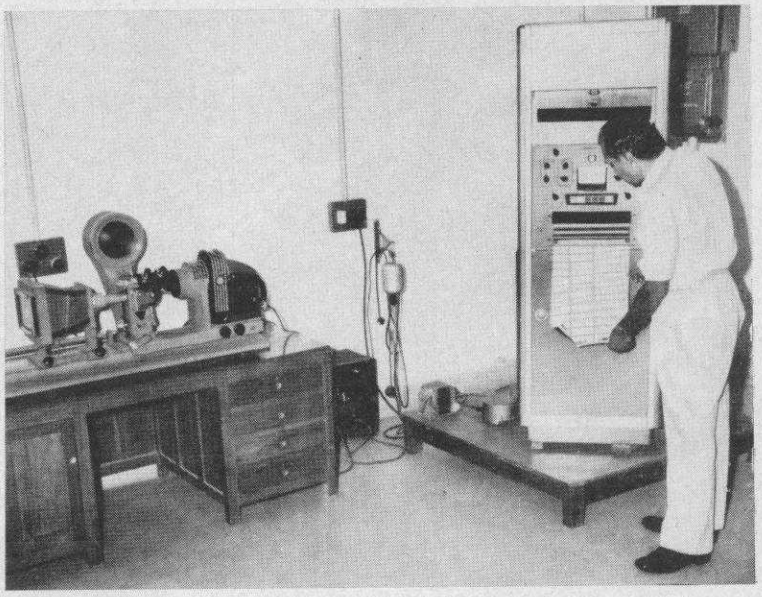
Sponge iron heap at the Mineral Beneficiation Pilot Plant.



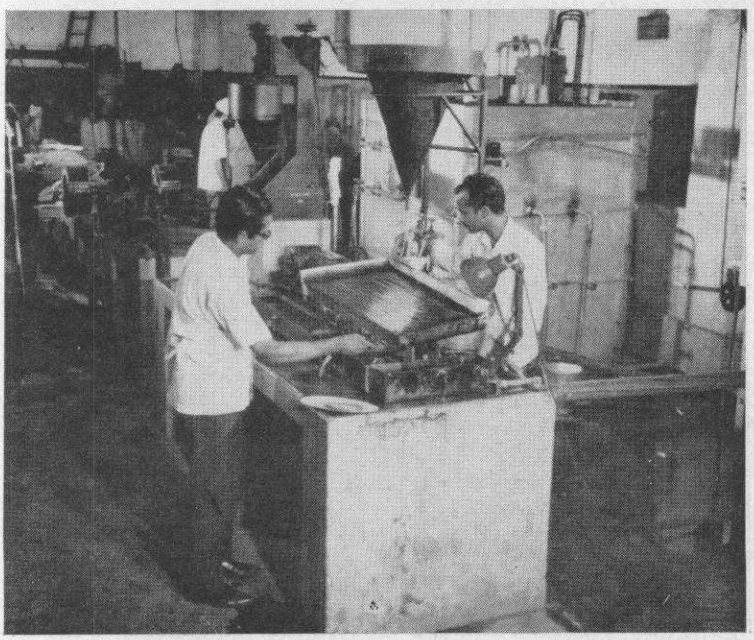
A general view of the Ore-dressing Batch Laboratory.



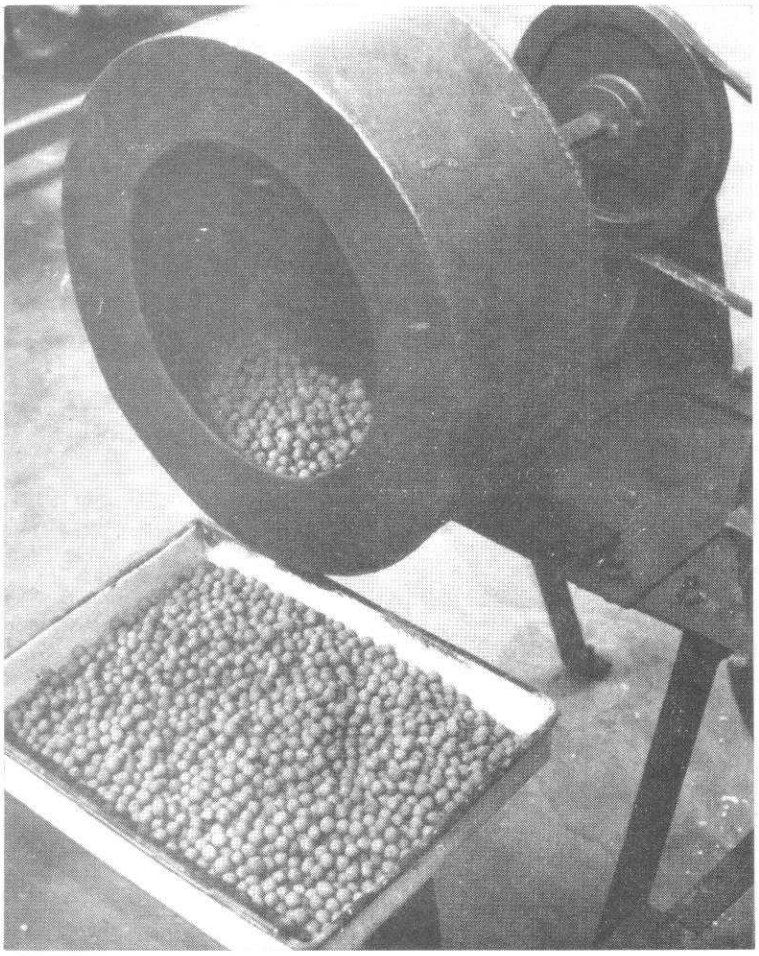
A view of Petrology Section showing Microscopes, Point Counter, Microhardness Tester etc.



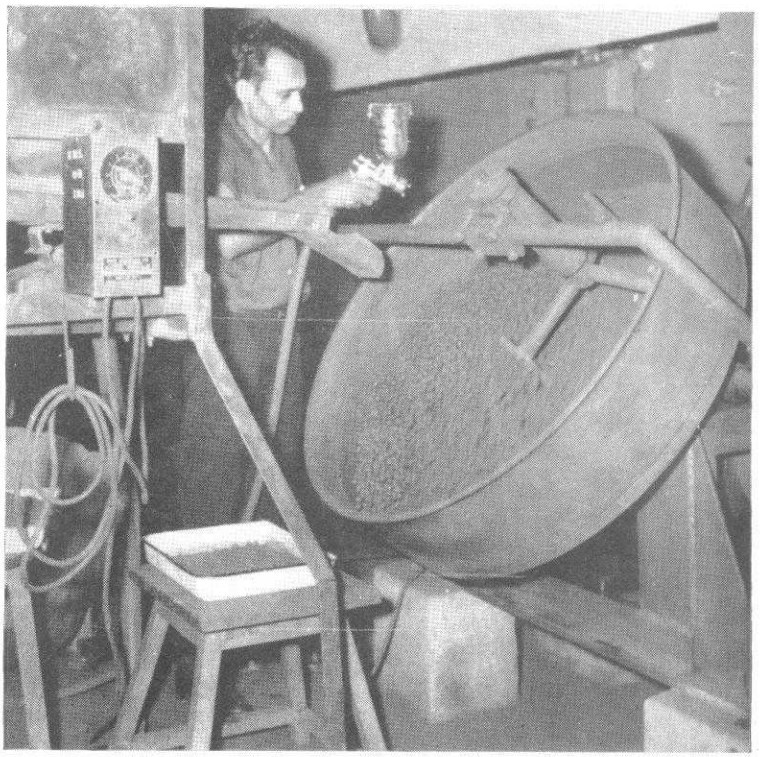
A view of Petrology Section showing Deltatherm, Micro-drill and Metallographic Microscope.



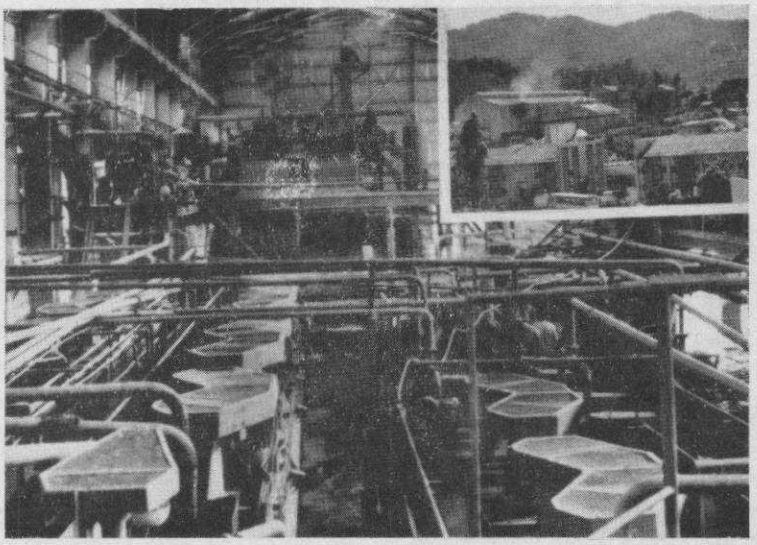
A Section of the Ore-dressing Batch Laboratory at NML showing gravity separation.



Batch Drum Pelletizer at Ore-dressing Laboratory of NML.



Batch Disc Pelletizer with Vibratory Feeder at Ore-dressing Laboratory of NML.



A view of Flotation Section of Fluorspar Beneficiation Plant of GMDC at Kadipani, Baroda Dist. A general view of the plant is given in the inset.