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MINERAL BENEFICIATION IN PAKISTAN WITH PARTICULAR REFERENCE TO THE UNIDO ASSISTED PROJECT FOR ESTABLISHMENT OF A MINERAL BENEFICIATION PILOT PLANT*

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INTRODUCTION

Pakistan is endowed with a great potential of mineral resources. Although industrial minerals have been mined and utilized in the local industries, the metallic minerals have been explored and are also being developed. Local industry is familiar with the mining of chromite since long and the deposits of copper at Saindak, iron ores at Kalabagh and Nokundi, Lead-Zinc in NWFP and Baluchistan etc. are well established deposits and may play significant role in the economic development of the country. The important mineral resources occur in the four provinces of the country; both proven and probable reserves are listed in Table-1. The industrial minerals deposits are generally extensive and of high grade and need little or no upgradation. The metallic minerals deposits, on the other hand, are smaller in size and require concentration before subjecting to industrial use.

In the first decade after the independence of the country, little effort was made towards exploration and development of the mineral resources. In the second and third decades, however, attempts were made towards discovering new minerals deposits. As a result of these efforts deposits of high grade industrial minerals were picked up for exploitation. Table-2 indicates the annual production and value per tonne of industrial minerals.

The metallic minerals, however, being low in quality and associated with wide variations of the gangue minerals, could not be marketed as such and also because of the lack of mineral processing infrastructure. As the mineral activities progressed, the exploration agencies started referring their

problems to the foreign countries. Tonnes of ores were sent abroad for bench and pilot plant scale beneficiation tests. A few examples of involvement of the foreign agencies in mineral evaluation are given in Table-3.

In order to get the above minerals evaluated and to have the technical and economic feasibility reports prepared, the country has incurred millions of rupees in foreign exchange. A substantial part of such studies could have been undertaken by the existing R&D organizaitons in the country. This approach could have lent strength to the R&D organizations in order to take up studies related to mineral utilization.

Presently the mineral activity in Pakistan is characterized by:

a) Survey and Mapping

b) Exploration

c) Mining and

d) Exploitation

Various agencies involved in the above activities in the public sector are listed in Table-4.

These agencies are either Federally or Provincially controlled. During the course of their exploration and exploitation work, the agencies have been taking help of Pakistan Council of Scientific and Indistrial Research for mineralogical, chemical, beneficiation, development of mineral-based products and extraction studies. It is felt that the R&D organization could have been more effectively utilized had there been closer liaison with the mineral agencies.

ORGANIZATIONS ENGAGED ON R&D WORK ON MINERAL

Research and development work in the country is undertaken by the following organizations.

Name of Centre	Role
- PCSIR, Peshawar	Mineral identification and evaluation.
- PCSIR, Lahore	R&D work on mineral beneficiation & mineral utilization (Production of mineral based chemicals, extraction of metals and production of alloys).
- PCSIR, Quetta	Mineral identification, evaluation and processing (under development)
- Atomic Energy Mineral Centre	Beneficiaiton of nuclear and heavy minerals

Most of the work is done by the PCSIR although some analytical and assaying is also referred to the universities. The Atomic Energy Mineral Centre confines itself to the classified work.

R&D WORK ON MINERALS AT PCSIR LAHORE

Realizing the need for a centralized facility to undertake R&D work on different minerals belonging to various parts of the country, the Minerals and Metallurgy Division was established in 1956 at PCSIR Laboratories, Lahore, to carry out chemical and mineralogical examination including bench scale beneficiation studies on minerals. It was also well within the competence of the Division to extract metals from minerals and concentrates using hydro-, pyro-, electro- metallurgical methods. Process flow sheets were made for the production of mineral-based chemicals based on technically and economically viable processes developed on the bench scale work.

Accordingly, the Division chalked out an R&D programme first to familiarise itself with problems encountered by the mineral and metal industry during utilization and then to suggest suitable methods to overcome them.

Resource-deficient as the Division was in the beginning, the research activities remained dormant. Subsequently, however, with the allocation of adequate fund by the Government of Pakistan and the growing interest of the mineral exploring agencies both in public and private sectors, the R&D activities of the Divisions expanded considerably. Some of the more

significant studies on minerals completed for various organizations are shown in Table-5. In view of the growing volume of work and the need to effectively serve the mineral sector, the Division enlarged its scope of work by undertaking mineral processing and hydro-metallurgical jobs on pilot scale. Accordingly, a proposal was prepared in 1984 to establish a multipurpose ore beneficiation pilot plant (M.O.B.), which could handle all types of work on metallic and non-metallic minerals found anywhere in the country.

MULTIPURPOSE ORE BENEFICIATION PILOT PLANT

The basic idea to establish a multi-purpose pilot plant was to create a central R&D facility on the pattern of Australian Mineral Development Laboratory, AMDEL, (Australia); Federal Mineral Processing Division, (Canada); Warren Spring Laboratory, (U.K.); Mineral Processing plant, Indian Bureau of Mines; Pilot Plants of the US Bureau of Mines, BRGM (France); EMEI Institute for Ores, Sichuon (China); and MTA, (Turkey). These research and development centres have pilot plant facilities and are manned by technical staff belonging to various scientific and engineering disciplines such as chemical, mechanical, electrical, metallurgical, applied chemistry, organic chemistry, foundry and workshop. Scientists and facilities belonging to these disciplines are always needed to efficiently run such pilot plants.

The other important aspect of an R&D centre is the technical manpower available for the centre within the organization; and around the Mineral and Metallurgy Division when their is enough foreign and local trained manpower (a total of 38 scientists, technologists and engineers, including 9 Ph.Ds.) to run a pilot plant. Keeping in view all the above mentioned aspects, a proposal to establish a multi-purpose ore beneficiation pilot plant was submitted to the Government of Pakistan with the following objectives:-

- Making available technical information in respect of mineral beneficiation projects of national importance.
- Development and application of mineral processing technology within the country. This will phase out dependence on foreign agencies.
- Promotion of import substitution in respect of minerals and mineral based products.
- Saving of foreign exchange spent on mineral examination.

- Establishment of a nucleus for beneficiation of indigenous minerals. This will initiate interest in producing value-added products based on local ores and minerals.
- Generation of self-reliance regarding designing fabrication and installation of mineral processing equipment.
- Building up skilled and trained manpower.

In April, 1984 the Multipurpose Ore Beneficiation project was approved by the Government of Pakistan at a cost of 19.71 million rupees. The break up cost is given in Table-6. Immediately after approval, the fabrication of the equipment was started in the workshop of the Lahore Laboratories and installation of the locally fabricated equipment available and listed in the Table-8 & 9 were properly housed. In July, 1986 the plant was inaugurated by Dr. M. A. Kazi, Advisor to the Prime Minister for Science and Technology. On this occasion a folder highlighting usefulness of the first integrated unit capable of handling almost all types of ores at a rated capacity of nearly 2 - 3 Tonnes/day was published. Lists of pilot plant and laboratory equipment available are given in Tables 7 & 8, respectively.

Layout of the plant is shown in Fig. 1 and comprises the following:

- Comminution
- Dry Concentration
- Wet Concentration
- Hydrometallurgy
- Filtration & drying
- Flotation
- Mineral based chemicals

The Laboratory and pilot plant equipment listed in Table-9 & 10 is essentially required for mineral identification and fill in some of the missing unit-operations.

Since 1986, the Wet Concentration, Filtration, Drying, Flotation and Mineral Based Chemical Sections have extensively been used and contributed in the completion of the following projects:-

i) Pilot Scale beneficiation of Azad Kashmir graphite and the preparation of pre-investment feasibility report for AKMIDC.

ii) Pilot Scale Processing of Muslimbagh and Malakand Chromites.

iii) Pilot Scale Production of lead and zinc concentrates from Besham lead-zinc ore.

iv) Pilot Scale Production of chrome chemicals from chromites (The process has been leased out to M/s. Locus Enterprises, Islamabad for Rs. 5 million).

v) Pilot Plant Production of mould powder additive for Pakistan Steel Mills, from nephylene syenite.

vi) Pilot Scale Studies to optimize parameters for technology development for commercialization of lead, zinc, chromium and barium based chemicals from

a) Lead-zinc ore (Bisham, Kohistan),
b) Chromite (Malakand and Muslimbagh),
c) baryte (Khuzdar, Hazara).

The last mentioned study was sponsored by the Ministry of Petroleum and Natural Resoureces for Rs. one million. The study, the three parts, highlighted the technical and economic aspects of utilization including the possibilities of designing, fabrication of unit/operations, on the basis of the experience and confidence gained through the establishment and operation of Multipurpose Ore Beneficiation within the country.

The projects which are either being studied or included in our future plan of study on the pilot plan are as follows:

i) Benficiation of Khuzdar lead-zinc ore

ii) Hydrometallurgical processing of rare earths and precious metals

iii) Upgradation of fluorite of Dir and Khuzdar

iv) Beneficiation of Chilghazi iron ore

v) Beneficiation of bauxite and laterite of Khushab

vi) Processing of Kalabagh iron ores

vii) Heavy minerals recovery from beach sands of Sind and Baluchistan

Equally important is the set-up for hydrometallurgical laboratory for the extraction of precious and rare metals earths from occurances which have been reported by the S.D.A., AKMIDC, PMDC, B.D.A., G.S.P. The proposed facilities, which will cost around 60 million rupees including 50 million rupees in Foreign Exchange, will process and extract precious metals such as gold, silver, platinum, palladium, iridium, osmium, as well as rare earth elements. Besides R&D work on zirconium, niobium, tantalum, nickel, cobalt, etc. is also being planned. With these studies it is essential that the following work may be undertaken:

- Characterization of the precious, heavy and rare earth metals bearing ores of Pakistan
- Preparation of Concentrates on Laboratory and pilot plant scales
- Extraction of metals from ores by hydro-pro-electro-metallurgical methods

The facilities added to the existing laboratories and pilot plant in the Division would mean the creation of a centre of excellence where R&D on industrial and metallic minerals including precious metals and high-tech minerals (rare elements) would be carried out. The anticipated benefits to be accured by strengthening the Division are summarized as follows:

ANTICIPATED OUTPUTS

- Manpower build-up
- Development of indigenous mineral technologies
- Enhancement of designing and fabricating capabilities
- A step towards self-reliance
- Facilitate technology transfer
- Saving in foreign exchange on units which can be had from local market
- Opening up of avenues for technical and financial collaboration with other countries
- Promotion of inputs by private and public sectors
- Generation of employment opportunities

ASSISTANCE OF UNDP/UNIDO FOR ESTABLISHMENT OF ORE BENEFICIATION PILOT PLANT

The UNDP, after the approval of its project document in December, 1985, committed the following financial inputs:

Experts	US$	138,775
Training		59,000
Equipment		195,000
Miscellanceous		4,325
	Total US$	398,000

The UNDP was expected to provide its share of inputs over a period of two years (1986, 1987). The latest position of the expenditure, however, is as follows:

	Total No. comitted	Received/ Utilized	Balance
Experts	20 m/m	12 m/m	8 m/m
Equipment	7 Nos.	5 Nos.	2 Nos.
Training	12 m/m	7.5 m/m	4.5 m/m

Two experts, specialized in mineral processing, have already spent a year and checked the plant layout and helped in installation of UNIDO supplied equipment. Two more experts, one in mineral beneficiation and other in hydrometallurgy are expected to join the project to give final touches to the operation of the plant and provide the necessary advice in establishing a hydrometallurgical section.

Four PCSIR scientists, associated with the project, have already completed two months training in mineral processing institutes of U.K. and the USA. Such a training has helped in the execution of the project in the light of modern developments in mineral beneficiation. Two more scientists will be leaving for study visits for a period of two months each, to study pilot plant operations in Australia and the USA.

The important component of foreign equipment was needed as was not available locally. The following list of equipment was required for procurement by UNIDO as these were not manufactured in Pakistan:

1. Jaw Crusher
2. Hydrocane Crusher
3. Disc Filter Station
4. Hydro-sizer
5. Crossbelt Separator
6. Ball Mill Accessories
7. Impellers for flotation Cells

The first four items have been received and installed, whereas the other three items are being arranged by UNIDO. With the installation of these equipment the pilot plant will be operational on continuous basis.

CONCLUSIONS

1. Establishment of the Multipurpose Ore Beneficiation Pilot Plant, when fully operational, would create a facility which could help in research and development of mineral resources available in Pakistan. The facility as has already been shown will asist public and private sectors in beneficiation as well as in commercialization of the processes so developed.

2. The assistance of UNDP/UNIDO to the project is not only timely and useful but has heldped in its conceptual approval and implementation stages. Surely without the association of the UNDP it would have taken longer in getting approved through the normai channels in Pakistan.

3. Although the UNIDO component is only 25% of the total, cost yet the equipment worth 200,000 dollars comprising latest version of mineral processing units gives the project a modern touch.

4. The foreign experts, in most of the cases, reviewed the design of the processes and the layout of the plant and thus gave the necessary guidance and suggestion which in turn induced confidence in the young scientists and engineers working on this project. Similarly the foreign training to the Pakistani scientists has been rewarding in more than one ways in giving them exposure to latest pilot plant facilities and this updated their knowledge. Besides the useful discussions they had with scientists of the mineral processing institutes resulted in cross fertilization of many ideas.

5. The utility of this plant is already discernible in that the beneficiation and production of chemicals from:

a) Chromite

b) Lead Zinc Ores

c) Barite

has been highlighted. Already quite a few enterpreneurs have shown their interest in these processes and are ready to enter into agreement with PCSIR for the first time in setting commercial plants on turn key basis.

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9. Sheikh N., K. Hussain and A.A. Qureshi, Bench and Pilot Scale Studies on Chromites of Malakand and Zhob Valley (1986).

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TABLE-1: MINERAL POTENTIAL IN PAKISTAN

BALUCHISTAN	QUANTITY MT	QUALITY/GRADE
Chromite	6	30-50% Cr_2O_3
Copper	412	0.43% Cu
Iron Ore	40	30-45% Fe_3O_4
Gypsum	400	Good quality
Barite	2	" "
Magnesite	0.03	" "
Manganese	0.05	30-40% MnO_2
Limestone, Dolomite Antimony, Zinc, Lead, Molybdenum, Garnet, Vesuvianite, Lithium, talc	extensive	Low grade but economical
NWFP		
Lead-Zinc	-	Economical grade
Rock Phosphate	30	27% P_2O_5
Chromite	6	30-40% Cr_2O_3
Limestone, Dolomite	extensive	Good Grade
Magnesite	5	Medium Grade
Graphite	5	10-12% Graphite
China Clay	2.5	Medium Grade
Antimony	0.03	High Grade
Gold, Silver	-	Under investigation
Copper	-	"
Soapstone	3	Good Quality
Feldspar	-	" "
Ne-Syenite	400	Medium Grade
Magnetite	5	" "
Fuller's earth	-	" "
Baryte	0.1	Medium to good grade
Gemstone, Beryl	-	" " " "

SIND	QUANTITY MT	QUALITY/GRADE
Coal	400	Low to Medium grade
China Clay	Large	Good to Medium grade
Clay Minerals	Large	" " " "
Gypsum	Extensive	Good Grade
Limestone	Extensive	" "
Dolomite	Extensive	" "
Fuller's earth	-	" "
Heay minerals	-	Low Grade
PUNJAB		
Rock salt	5000	Good Grade
Silica sand	Extensive	Medium to Good Grade
Iron Ore	400	Low Grade
Limestone	Extensive	Medium to Good Grade
Dolomite	"	" " " "
Gypsum	Large	Good Grade
Coal	100	Low to Medium Grade
Celestite	Promising	80-90%
Fuller's earth	Large	Medium to Good Grade
Bentonite	40	" " " "
Bauxite, Laterite	Extensive	Low Grade
Fire clay	1000	Medium to Good Grade

TABLE-2 INVESTMENT & PRODUCTION COST OF SELECTED INDUSTRIAL MINERALS*

Mineral	Value of Fixed Assets (x000)	Production Cost (x000)	Gross Value of Production (x000)	Annual Production (tonnes)	Value Per tonne (Rs.)	Sale price/ Tonne (Rs.)
Barytes	5676	3329	18687	21000	890	200
China Clay	6530	429	13069	40022	327	500
Chromite	452	495	5429	1108	4900	1000
Fire Clay	387	87	5151	60000	86	150
Lime-stone	322905	34194	107565	3401000	32	40
Rock salt	22387	3779	51811	514000	101	500
Dolomite (N.W.F.P.)	190	76	579	24224	24	100

*Census of Mining Industries 1980-81. Federal bureau of Statistics.

TABLE-3

INVOLVEMENT OF FOREIGN AGENCIES ON PAKISTANI MINERALS

Iron Ores 1965-82	-	Department of Mineral Processing Energy, Mines and Resources, Ottawa, Canada
	-	Minnesota Mineral Resource Research Centre, Minnepollis, USA
	-	Romania Research Centre
	-	Aramco, USA
	-	Salzqitter, Germany
	-	U.S.S.R.
	-	IRSID/AIRBO, France
Saindak Copper Ore 1978-82	-	Seltrust Engineering Co., London
	-	MSME, Tucson, Arizona, USA
Phosphate Rock 1976-80	-	Warren Spring Labs.
	-	Stevenage, Herts, U.K.
Chromite 1952-73	-	Denver Equipment Co., Colorado, U.S.A.
	-	USGS, USA
	-	Schmitz, West Germany

TABLE-4 ORGANIZATIONS CONCERNED WITH EXPLORATION AND DEVELOPMENT OF MINERALS

	Name of Organizations	Role
i)	Baluchistan Development Authority (BDA)	Exploration & Development
ii)	Sarhad Development Authority (SDA) Mineral Wing	Exploration & Development
iii)	Punjab Mineral Development Corporation (PUNJMIN)	Exploration, Development and Utilization
iv)	Azad Kashmir Mineral and Industrial Development Corporation (AKMIDC - Mineral Wing)	Exploration & Development
v)	Pakistan Mineral Development Corporation (PMDC)	Exploration & Development and Utilization
vi)	Federally Administered Trible Agency (FATA-Mineral Wing)	Exploration
vii)	Geological Survey of Pakistan (GSP)	Survey 7 Exploration
viii)	Gemstone Corporation	Exploration & Development of Gem Stones
ix)	Resources Development Corporation (RDC)	Copper Development
x)	Pakistan Industrial Development Corporation	Exploration, Development and Utilization

TABLE-5 IMPORTANT STUDIES COMPLETED ON PILOT SCALE

1. Iron Ores:
    1. Kalabagh, Mianwali, Punjab
    2. Dammen Nasar N.W.F.P. (Magnetite)
    3. Chilghazi, Baluchistan (Magnetite)
    4. Pachinkoh, Baluchistan (Magnetitie)

2. Chromite of:
    1. Muslimbagh, Baluchistan
    2. Malakan, N.W.F.P.

3. Graphite of:
    1. Kel, Azad Kashmir
    2. Mooriwali, Azad Kashmir
    3. Malakand, N.W.F.P.

4. Copper of:
    1. Saindak, Baluchistan
    2. North Waziristan, N.W.F.P.

5. Lead-Zinc of:
    1. Besham, Kohistan, N.W.F.P.
    2. Gonga, Baluchistan (on bench scale)

6. Nepheline Synite of:
    1. Koga, N.W.F.P.

7. Baryte of:
    1. Khuzdar, Baluchistan
    2. Hazara, N.W.F.P.

8. Bauxite of:
    1. Khushab, Punjab

TABLE-6

FINANCIAL INPUTS FOR M.O.B. PROJECT

Total Project Costr: Rs.19,710,000/-

	Local (Rs.)	Foreign (US$)
GOP Contribution	9,310,600	366,000
UNDP Contribution	-	389,000
Total:	9,319,600	764,000

Details of GOP Contribution

Civil Work	4,300,000	-
Equipment	2,000,000	366,000
Lab. Fixture, Vehicles, Manpower, Utilities etc.	3,019,600	-
Total:	9,319,600	366,000

Detail of UNDP Contribution

Equipment	US$	195,000
Training		50,000
Experts		138,775
Miscellaneous		4,325
Total:	US$	398,000

TABLE-7 PILOT PLANT EQUIPMENT AVAILABLE

I. Crushing and Grinding		
1.	Jaw Crusher (local)	1 No.
2.	Roll Crusher (Denver)	2 Nos.
3.	Ball Mill (local)	1 Nos.
4.	Denver Rod Mill	2 Nos.
II. Magnetic and Electrostate Separators		
1.	Stearns Dry Magnetic Separator	1 No.
2.	Dings wet Magnetic Separator	1 No.
3.	Eriez High Intensity Wet Magnetic Separator	1 No.
4.	Devies High Intensity Dry Magnetic Separator	1 No.
III. Flotation		
1.	Flotation machine, local 400 liters	3 Nos.
2.	Flotation machine Denver 220 liters	6 Nos.
IV. Screening		
1.	Wilfley's shaking Tables, (local)	3 Nos.
2.	Humphrey's spirals, (local)	3 Nos.
3.	Centrifuge, (local)	1 No.
VI. Briquetting, Drying, Filtration, Mixing, Storage and Transportation		
1.	Dunbar Briquetting Press	1 No.
2.	Tray Dryer, (local)	1 No.
3.	Bucket Elevator, (local)	1 No.
4.	Conditioning Tanks, (local)	2 Nos.
5.	Storage Bin, (local)	1 No.
VII. Hydrometallurgy		
1.	Tanks with stirrers, (local)	2 Nos.
2.	Hydrolyser tank, (local)	1 No.
3.	Digestion vessels, (local)	4 Nos.
4.	Steam jacketed vessels, (local)	4 Nos.
5.	Steam jacketed lead lined vessels, (local)	2 Nos.
6.	Crystalliser tanks, (local)	2 Nos.

TABLE-8 LABORATORY EQUIPMENT AVAILABLE

I. Crushing & Grinding

1.	Bico Braun Bond Index Mill	1 No.
2.	Denver Ball Mills	2 Nos.
3.	Denver Rod Mills	3 Nos.
4.	Sample Grinding Disc Mill	1 No.
5.	Ball Mill	(1 No. Local 20 Kg)
6.	Pulverizer, Mine & Smelter Co.	1 No.
7.	Hammer Mill	1 No.

II. Magnetic & Electrostatic Separators

1.	Isodynamic Magnetic Separator	1 No.
2.	Davis tube tester	1 No.
3.	Davies non-entraining magnetic separator	1 No.

III. Flotation

1.	Wemco flotation machine	1 No.
2.	Denver D-12 flotation cell	1 No.
3.	Denver Sub-aeration flotation cell	1 No.

IV. Screening

1.	Sieve shaker, Retsch	1 No.
2.	Sieve Shaker, Internatinal Combustion	1 No.
3.	Test Sieves	2 Nos.

V. Gravity Separation

1.	Wilfley shaking table	1 No.
2.	Humphrey's spiral	1 No.
3.	Mineral Jig	1 No.
4.	Cone classifier	1 No.
5.	Bowl classifier	1 No.
6.	Cyclone classifier	1 No.
7.	Centrifuge	1 No.

TABLE-9 LABORATORY EQUIPMENT REQUIRED

			US $
I.	Mineral Identification		
1.	Polarization and Incident light Microscope Research microscope with accessories such as universal stage, microphotometry attachement and reflectance measurement, with heating stage.	1 No.	30,000
2.	X-ray diffractometer with recording goniometer, camera and copper, chromium, tungsten and iron tubes and other accessories.	1 No.	90,000
3.	DTA/TGA and DIG measurement apparatus upto 1400^{o}C with recording and other accessories.		
	- Research type with provision of isothermal measurements	1 No.	25,000
4.	Microhardness tester	1 No.	10,000
5.	Grinding and polishing equipment for coarse, medium and fine grinding and pilishing accessories; grinding clothe and polishing compounds, (Complete Unit	1 No.)	9,000
II.	Quantitative Elemetal Analysis		
1.	X-ray Fluorescence Spectrometer	1 No.	1,00,000
III.	Mineral Processing		
1.	Laboratory Jaw Crusher 50 Kg/hr	1 No.	2,000
2.	Cyclosizer (Warman)		15,000
3.	Gausseme		2,000

TABLE-10 PILOT PLANT EQUIPMENT REQUIRED

			US $
I.	**Crushing and Grinding Equipment**		
1.	Ball Mill 4' x 5' (Dry) (1.0-5t/hr)	1 No.	30,000
2.	Jaw Crusher 10-15 t/hr	1 No.	9,000
II.	**Flotation**		
1.	Denver Flotation machine No. 12 Bank of six cells	1 No.	12,000
III.	**Filtration**		
1.	Disc Filter Station 2 Discs 120 cm dia	1 No.	44,500
IV.	**Gravity Separation**		
1.	Heavy media separator t/hr	1 No.	10,000
V.	**Miscellaneous Pilot Plant Equipment**		
1.	Apron feeder (40cm widthx300cm length)	1 No.	3,000
2.	Fluid bed Roaster 4" dia, with cyclone	1 No.	5,000
3.	Computer (Foxboro or IBM)	1 No.	1,00,000
4.	Photocopying machine	1 No.	6,000
5.	Slide projector	1 No.	500
VI.	**Pyrometallurgy**		
1.	Reduceability of iron ores and pellets apparatus	1 No.	50,000
2.	Sintering and Induration Machine for pellets	1 No.	6,000
	Total (Laboratory and Pilot Plant)		559,000
	(US $ [Rs.13.60) Say		Rs.7,602,400

VII. Sample Preparation & Mineralogy

1.	Apex Grinding & Polishing Machine	1 No.
2.	Buehler Vibromet Polisher	1 No.
3.	Microscope (Reiehert)	1 No.
4.	Microscope (Erma)	1 No.
5.	Mieroscope (Leitz)	1 No.
6.	Abbe' Refrastometer	1 No.

VIII. Assay

1.	Atomic Absorption Spectrophotometer, Hungry	1 No.
2.	Flame Photometer	1 No.
3.	Spectrophotometer, Bosch and Lomb	1 No.
4.	Spectrophotometer, Hitachi	1 No.
5.	Box Furnace, Thermolyne, 1000^{o}C	1 No.
6.	Box Furnace, Gallenkamp, 1000^{o}C	1 No.
7.	Box Furnace, Gallenkamp, 1000^{o}C	1 No.
8.	Tube Furnace Gallenkamp, 1000^{o}C	1 No.
9.	Tube Furnace, Dietert, 1400^{o}C	1 No.
10.	Gas Crucible Furnace	1 No.
11.	Hot Plate 18" x 10"	1 No.
12.	Hot plate with stirrer	1 No.
13.	Hot plate (sybron/thermolyne)	2 Nos.
14.	Drying oven, Griffin, 300^{o}C	1 No.
15.	Drying oven, memert, 300^{o}C	1 No.
16.	Drying oven, BtL, 400^{o}C	1 No.
17.	Electric Balance, Single Pan, Sartorius	1 No.
18.	Electric Balance,, Single Pna, Stanton	1 No.
19.	Double Pna Balance, Chine	2 Nos.
20.	Distillation Still, All Glass	1 No.
21.	Distillation Still, China	1 No.
22.	Water Bath, Gallenkamp	1 No.
23.	Water Bath, Memert	1 No.
24.	PH meter, digital	1 No.
25.	PH meter, analong	1 No.
26.	Temperature control unit, Cambridge	1 No.
27.	Temperature control Unit, Wheelen	1 No.
28.	Gas Analysis apparatus	1 No.
29.	UV Lamp	1 No.

30.	Cmbridge Pen Polarograph	1 No.

IX. Briquetting, Drying, Filtration, Mixing, Storage and Transportation

1.	Vacuum pump	2 Nos.
2.	Filter press, plate type	1 No.
3.	Denver Filter drum	2 Nos.
4.	Superagitator	
5.	Press 20 tonnes	1 No.
6.	Disc pelletizer	1 No.
7.	Pellet feed mixer	1 No.
8.	Vacuum oven	1 No.
9.	Slurry pumps	2 Nos.
10.	Sludge pump	1 No.
11.	IR Lamp	1 No.

X. Miscellaneous Laboratory

1.	D.C. current Generator	1 No.
2.	Izod Testing machine	1 No.
3.	Induction Furnace, Wild & Barfield	2 Nos.
4.	Heat treatment furnace, Heraeus, 15^{o}C	1 No.
5.	Reagent feeder	3 Nos.
6.	Rockwell Hardness Testing Machine	1 No.
7.	Central panel (Electrical)	1 No.

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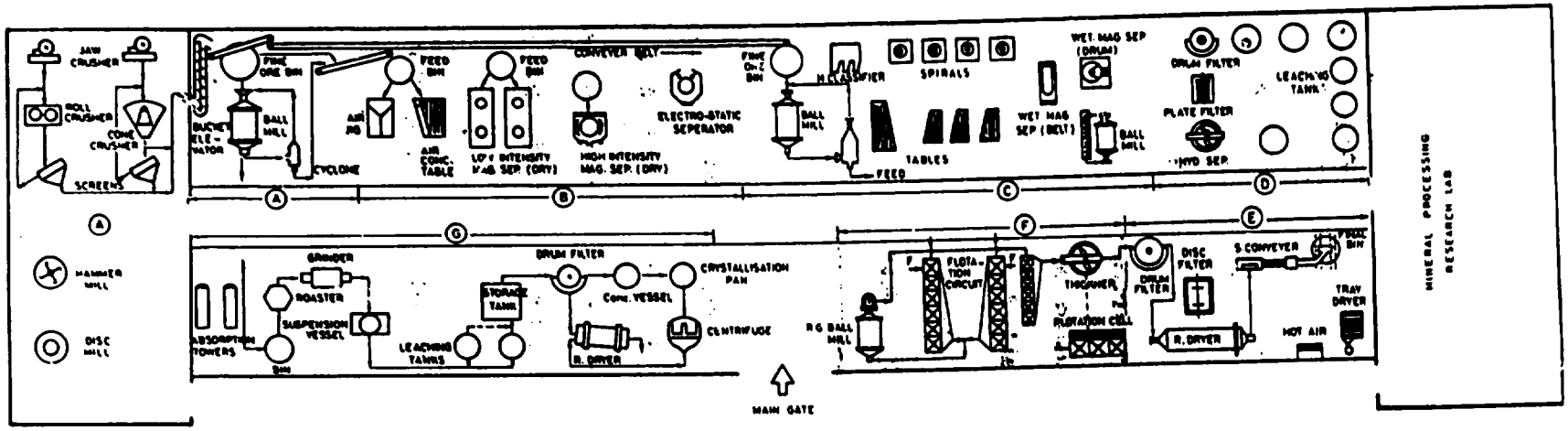
FIG. 1

GENERAL LAYOUT OF MULTIPURPOSE ORE BENEFICIATION PILOT PLANT



OPERATIONS

(A) COMMINUTION SECTION

- Primary and secondary crushing
- Grinding
- Classification

(B) DRY CONCENTRATION SECTION

- Density based separation
- Magnetic separation (low & high intensity)
- Electrostatic separation

(C) WET CONCENTRATION SECTION

- Density based separation
- Magnetic separation (low & high intensity)

(D) HYDROMETALLURGY SECTION

- Leaching (acid, alkali, cyanide etc)
- Solvent extraction
- Ion exchange
- Cementation

(E) FILTRATION AND DRYING SECTION

- Drum plate and disc filtration
- Tunnel and tray drying
- Packing and disposal of concentrates

(F) FLOTATION SECTION

- Roughing
- Regrinding
- Cleaning
- Recleaning

(G) MINERAL BASED CHEMICAL SECTION

- Roasting
- Leaching
- Filtration
- Evaporation
- Crystallization
- Carbonation
- Centrifugation