

**PROCESSING OF NORTH WAZIRISTAN
COPPER-SULFIDE ORE AND PROSPECTS
FOR THE ESTABLISHMENT OF A
CONCENTRATE PLANT**

BY

**M. Mansoor khan, khan Gul Jadoon
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M. Mansoor Khan¹ Khan Gul Jadoon¹ Ehteshamullah Khan¹ Mazhar Rafiq¹

ABSTRACT

With the land surface area of approximately 809,9043 km², Pakistan is endowed with non-ferrous metals including gold, copper, lead, zinc, chromium etc. While various important occurrences of copper have been identified throughout the Provinces of Balochistan and North West Frontier Province. The western mountains of Pakistan comprise the mountain ranges west of Hindukush and include the mountains of Swat and Chitral, the Koh-i-Safaid, the Waziristan hills, the Sulaiman Mountain range and Kirthar Hills. Investigations in the southern region have revealed the presence of promising copper mineralization at various places in North-Waziristan Agency. (FATA DC 1985). The chemical analysis of ore samples and estimated consumption of copper is presented here. The process technology and design study for a 2000 tons per day concentrator developed by the Department of Mining Engineering are summarized. A comparative analysis of candidate sites for locating such a concentrate plant is presented. The role of various government departments and private investment in the establishment of copper concentrator is identified and probable sources of international assistance are highlighted.

INTRODUCTION

The occurrences of copper were first reported in the area of North Waziristan early 70's. Since then, almost two decades ago, generally satisfactorily advances have been recorded with respect to exploration of the ore. The detail exploration work was recently carried out in collaboration with a Chinese consultant.(Wang Zhitian 1996) The local production of copper in Pakistan is hitherto almost nil. Finished copper sheets are imported from different countries to produce value added products for domestic consumption and exports like brass work etc. The Saindek copper-gold metal project which has already been established would start producing blister copper concentrate in the near future and will be a milestone in the base metal industry of Pakistan.

CHEMICAL ANALYSIS

The chemical and mineralogical analysis of the run-of-mine, of copper ore plays an important role in the selection of the smelting technology and concentrate. The chemical analysis of samples from different parts of North-Waziristan is presented below. Chemical analysis of copper ores from N-W area is given in table 1

¹ Faculty members, Department of Mining Engineering, NWFP, University of Engineering and Technology, Peshawar, Pakistan.

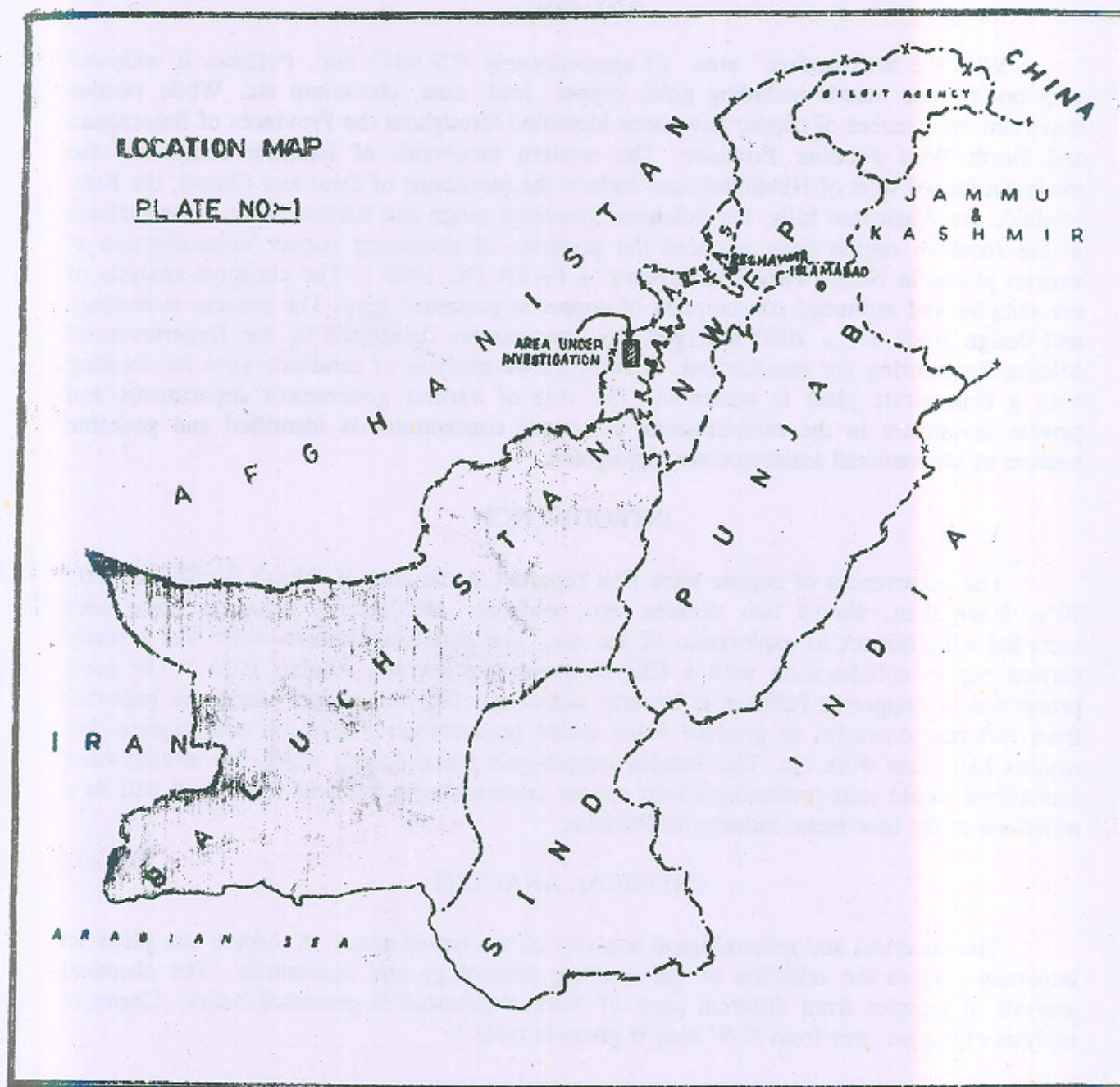
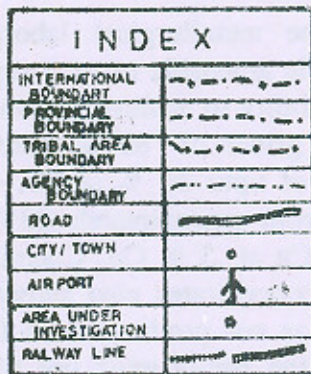


PLATE NO. III



SCALE:- 1" = 31.56 MILES

DRAWN BY: RIAZ AHMAD DURRANI

Table 1 . Elemental analysis of North Waziristan Copper Ore

Element	% age
Copper	.386 (cut-off) to 2
Zinc	.0134
Lead	.0126
Cobalt	.0110
Nickel	.0067
Silver	1.74
Gold	.22

The analysis of the samples was carried out by Mineral Testing Laboratory (SDA) and Mining Engineering Laboratories, NWFP University of Engineering and Technology, Peshawar.

PRODUCTION

The level of mineral production is a critical factor in the choice of concentrator and process technology. There are no accurate figures for the consumption of copper in Pakistan, as proper documents have not been kept. The open pit mine being worked by Saindek would produce about 15500 tons of Blister Copper yearly.

PROCESS TECHNOLOGY

The metallurgical laboratory test showed that the primary sulfide copper was particularly amenable to recovery by flotation (Mansoor 1989). The most important feature was the ability to achieve reasonable flotation recoveries at head grades down to as low as .3 % Cu at grinds of 80 % minus 75 μm (British sieve standard), and high flotation pulp densities of upto 30 % solids. Concentrate grade was strongly correlated with head grade varying from approximately 28% Cu at head grades of the ore of .9 % Cu and above, down to 22 % Cu at .3 % Cu. Chemical analysis by X-Ray Fluorescence technique (X.R.F) of ore and concentrates also showed some other precious metals in small quantities but their recovery as co- products need further investigations. The ore is subjected to flotation after reducing the run-of-mine ore to 80 % passing 75 μm size. The type of machinery to be employed and the method, size or capacity of the ore-dressing plant depends on a no of factors, including ore reserves, transportation distances, sources of energy, water availability, working conditions and related matters. A generalized flowsheet of copper prepared by the Department of Mining Engineering after pilot scale studies is presented in Figure 1.

PROPOSED FLOWSHEET FOR A 2000 TONS PER DAY COPPER CONCENTRATOR

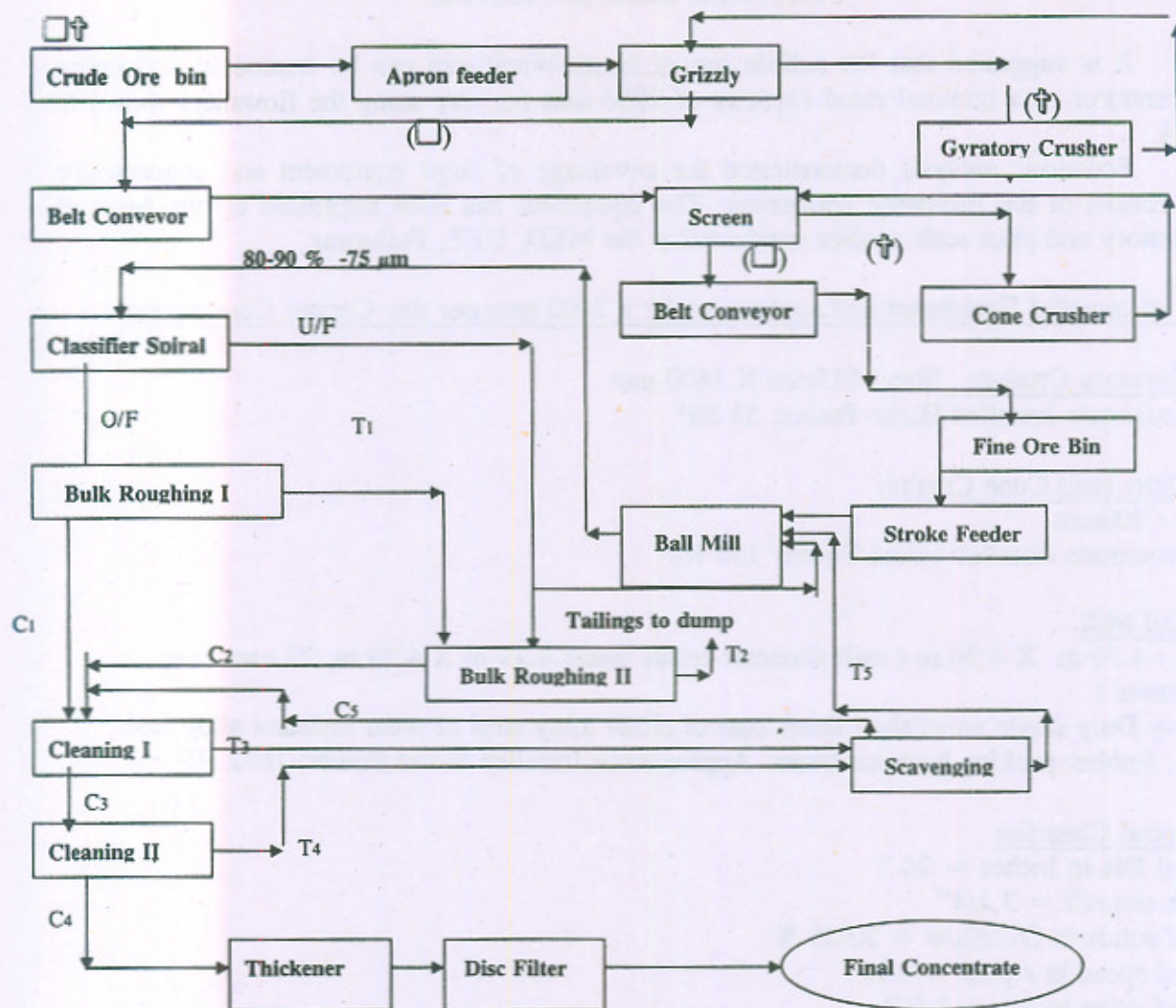


Figure.1

Key : O/F = Overflow, U/F = Underflow, C₁ = Bulk Concentrate I, C₂ = Bulk Concentrate II, C₃ = Cleaned Concentrate I, C₄ = Cleaned Concentrate II, C₅ = Scavenging Concentrate,

T₁ = Bulk Tailings I, T₂ = Bulk Tailings II, T₃ = Cleaning Tailings I, T₄ = Cleaning Tailings II, T₅ = Scavenging Tailings.

PROPOSED CONCENTRATOR

It is suggested that the sulfide ore of North-Waziristan can be treated in a flotation concentrator of a nominal rated capacity of 2000 tons per day using the flowsheet shown in Fig.1.

Economic analysis demonstrated the advantage of large equipment and concentrator can consist of the following equipment. The equipment has been suggested on the basis of laboratory and pilot scale studies conducted at the MED, UET, Peshawar.

List of essential Equipment and accessories for a 2000 tons per day Copper Concentrator

1. Gyratory Crusher : Size : 915mm X 1400 mm
Approximate Installed Horse Power: 55 HP

2. Short head Cone Crusher
Size : 900mm
Approximate Installed Horse Power: 110 HP

3. Ball Mill
Size : 4.36 m X 4.36 m (mill diameter inside liners 4.29 m X 4.29 m, 75 mm liner thickness)
Heavy Duty single wave shell liners cost of either alloy steel or wear resistant alloy cast Iron. Rubber packing between liners. Approximate Installed Horse Power: 1672 HP

4. Spiral Classifier
Spiral Dia in Inches = 24 "
Tank slope/ft = 3 1/4"
% of solids in Overflow = 30-35 %
Spiral speed in r.p.m = 4-16
HP of drive motor = 3 HP
Capacity = 112 to 213

5. Thickener
Size : 60' (Dia) X 12' (Length). Area = 2830 square feet. Volume = 33900 ft³. Installed motor Horse Power = 3 HP

6. Conditioners
Size : 18' X 18'. Installed Horse/Power 20 HP

7. Vertical Centrifugal Pump
Size : 12.5 ". Head = 40 ft. Installed Horse Power 6 HP

8. Apron Feeder
Size : 4' X 12' . Installed Horse Power 5 HP

9. Belt Feeder

Size : 30" X 10'. Installed Horse Power 7.5 HP

10. Conveyor Belts

Belt Width = 18 ". Installed Horse Power 3 HP. Length = 50m. Suggested Trough Idle spacing 4'6". Return Idler spacing 10'.

11. Rougher Flotation Cell (Free Flow Type)

No of Cells = 15, Volume per cell = 100 ft³

Installed Horse Power = 7 HP per cell

Size (L X W) = 5.2' X 5.2'

12. Rougher Flotation Cell (Free Flow Type)

No of Cells = 22, Volume per cell = 100 ft³

Installed Horse Power = 7 HP per cell

Size (L X W) = 5.2' X 5.2'

13. Cleaner Flotation Cell (Cell to Cell)

No of cells = 5 , Volume per cell = 50 ft³. 4.7 HP per cell. Size

(L X W) = 4' X 4'

14. Cleaner Flotation Cell (Cell to Cell Type)

No of cells = 4 , Volume per cell = 50 ft³. 4.7 HP per cell. Size

(L X W) = 4' X 4'

15. Scavengers

No of cells = 2 , Volume per cell = 50 ft³. 4.7 HP per cell. Size

(L X W) = 4' X 4'

16. Disc filter

No. Of discs = 5, Filter .75 HP, Filter Size = 4'

17. Fine Ore Bin or Stock Piles

Volume = 700 m³

18. Concentrate Bin

Size = 12' X 12' X 10'

19. Vibratory screens

Size 4' X 7', 1.5 HP

20. Ancillary Equipment , Wet Sample Splitter (Standard size), Centrifugal Pumps; Diaphragm, pumps etc and motors of different sizes and capacities, Dust Collectors (Various Sizes), Weightometers, Metal Detectors, Lime Slakers, Lime Pumps, Pulp Density Scales, Sieves, Heavy Liquids etc.

Table 2. Typical Flotation Conditions and Reagent Consumption

Time Minutes				Reagents (gms/ton)						
	G.t	C.t	F.t	NaPX	NaAmX	NaOH	NaCN	Na ₂ S	Na ₂ SiO ₃	Pine Oil
Rougher ₁	20	10	12-15	200	—	2200	—	50	—	46
Rougher ₂	—	8	12	60	—	1100	25	—	—	46
Cleaner ₁	—	5	12	—	20	800	—	—	150	35
Cleaner ₂	—	5	10	—	20	500	—	—	—	35
Scavenging	—	5	8	—	50	240	—	—	—	35

G.t= Grinding time, C.t= Conditioning time, F.t= Flotation time, NaPX= Sodium Propyl Xanthate, NaAmX= Sodium Amyl Xanthate

Table 3. Typical Flotation Conditions and Results for various stages of flotation

	P.d (%)	pH	Cu (%)	Rec. (%)
Bulk Roughing ₁	30	11.58	20-21	70-71
Bulk Roughing ₂	25	10	13-13.5	59
Cleaning ₁	15	10	22-23	91-93
Cleaning ₂	15	10-11	26-28	94-97
Scavenging	22-25	10-11	13-12	43-44
Overall			25-28	80-83

P.d = Pulp density, Cu = Copper, Rec. = Recovery

Table 4 . Relation between size of grinding and Cu % grade of concentrate

Size (-200 mesh)	Rougher concentrate grade (%)
50	13
60-70	16
80-90	20-22

The Federally Administered Tribal Area Development Corporation (FATA DC) has prepared a project-document in collaboration with a Chinese consultant, with a view to attracting the foreign investment for establishment of copper concentrate plant. The minimum capacity of the concentrator as suggested by Department of Mining Engineering should not be less than 2000 tpd (.6 million tons / year) with the provision for further expansion as required.

CONCENTRATOR

The normal practice of primary Cu-mineral production from ore involves the following steps:

Crushing:

The crushing section with two-stage reduction is suitable for smaller tonnage, depending upon the ore characteristics. The fines are removed by a grizzly or screen ahead of each reduction stage for higher efficiency and for reduced wear on crushing surfaces. An electromagnet for removal of tramp iron is placed over the feed conveyor to secondary crushing. A magnetic head pulley is also suitable. (Will, B.A. 1985); (Kelly, G.Errol 1982) (White Lane 1980) ; (Mullar aand Bhappu 1980) ; (McQuinston Frank W. Jr. And Shoemaker S. Robert); (Newton Joseph 1978).

Grinding:

Feed control is essential for efficient grinding and helps reduce surges and fluctuations throughout the entire plant. The Ball Mill in closed circuit with a spiral classifier discharges the pulp at about 60-70 % minus 200 mesh. The Ball Mill is equipped with a spiral screen on the discharge for removal of any tramp oversize, worn grinding balls, and wood chips form the circuit. Closed circuit wet grinding is always preferred in case of base metal concentrators because of it's efficiency and economics. Ball mills are used where fine grinding is the target. In some plants two stage grinding, a rod mill in conjunction with a ball

mill and classification unit has been successfully used . In such plants the rod mill acts a coarse crusher and effectively takes place of a secondary crusher. A ball or rod mill is designed on the basis of work Index (kwhr/ton) of ore and tonnage to be treated per day. The choice of a liner and grinding media depends upon the nature of ore. The product of grinding is supplied to the flotation or leaching unit after classification in a classifier. The product from the classifier is usually 60 to 70 % passing the required liberation size.(In case of N-W ore). (Will, B.A. 1985); (Kelly, G.Errol 1982) (White Lane 1980); (Mullar and Bhappu 1980) ; (McQuinston Frank W. Jr. And Shoemaker S. Robert); (Newton Joseph 1978).

Reagents:

Lime or caustic soda is usually added to the ball mill feed by reagent feeder. The frother and promoter are added in the classifier or conditioner prior to flotation to realize the full effect of the reagent. Reagents can also be stage added to the cells in the flotation circuit. It has really now become a universal practice to add the reagents like pH modifiers, depressants and sulfidizers during the grinding stage, while xanthates and frother in the conditioners prior to flotation. (Somasundaran. P and Moudgil. M. Brij. 1988); (Wills, B.A).

Flotation:

Sub-aerated flotation machines are used for both the rougher and cleaner circuits, where their cell to cell principle gives both high recovery and a good grade of concentrate. The rougher concentration is accomplished in 6 or 8 cell flotation machines with the concentrate from each going to a separate bank for cleaning and recleaning. Tails from the rougher circuit are discarded into the tailing pond. While tails for the cleaning cells can be scavenged. In another bank of cells the concentrate from the scavenger cell is returned to the head of the rougher cells. (Will, B.A. 1985); (Kelly, G.Errol 1982); (Mullar and Bhappu 1980); (Fuerstenau 1962).

Thickening and Filtering:

The concentrate collected from flotation is dewatered in a thickener and filter before being shipped to the smelter. The final cleaned flotation concentrate flows or is pumped to a thickener. The thickeners are often used to store concentrates for filtration at fixed intervals. The units should have heavy duty construction throughout, overload indicators and positive rake lifting features. From the thickener the concentrate flows to the disc filter, which almost removes 80 % water from it.

The hydrometallurgical treatment techniques are also gaining popularity, with the growing concern about the degradation of environment as a large no of perilous chemicals are used in flotation concentration. The hydrometallurgical technique involves the use of leaching agents such as Sulfuric acid, Ammonium Sulfate etc.. Leaching can be carried out

in-situ or in processing tanks. The leached solution is electrolyzed to obtain Blister Copper. (Will, B.A. 1985); (Kelly, G. Errol 1982); (Mullar aand Bhappu 1980).

DESIGN STUDY FOR A 2000 TPD COPPER CONCENTRATOR

Factors of simplicity, initial low capital cost, together with flowsheet flexibility for maximum results on a difficult ore are basic considerations in the design of this 2000 tpd concentrator.

The given design is expected to accomplish the desired metallurgical results, with low capital expenditure and operating costs.

Flowsheet

Following numerous laboratory tests, a flowsheet is developed that gives flexibility to handle the several types of copper ores. Two stage close circuit crushing, with average ore ground to 75 μm , gives optimum results regarding grade and recovery. An apron feeder controls the feed from crude ore bin to gyratory crusher while a wedge grizzly ahead of the gyratory crusher removes fines from the crusher feed. Screen removes the fines ahead of secondary crushing. An adjustable stroke feeder controls feed to the steel head ball mill, and the spiral classifier discharge is pumped direct to the flotation section.

Mill Site

The mill site should be selected within 4-10 miles from the mine and following main factors should be considered before mill site selection.

1. Availability of ample water and power.
2. Topography of mill site should provide gravity flow-minimum use of pumps, and minimum of excavation, retaining and foundation walls. The important part in any mill site is to be sure that the maximum use of cut and fill is utilized. Concrete is expensive and should be primarily considered for adequate foundation instead of expensive retaining walls and fills.
3. Adequate tailing disposal-with minimum maintenance.
4. Accessibility for operating labor and supplies and trucking etc.
5. Use of minimum labor in erection.
6. Availability of natural timber. (Chaterjee Kaulir Kisar 1991); (Kelly, G. Errol 1982); (Will, B.A. 1985); (Mullar aand Bhappu 1980)

Mill design

The machinery should be located for accessibility, ease of operation, minimum loss of floor space, resulting in reduced size of mill. The crude ore bin should be constructed of

steel or natural timber on the site, on a steep slope, reducing expenses of excavation and construction.

A grizzly should prevent oversize going into bin. The flotation machines should be mounted on steel supports, at minimum elevation with space platforms for drainage of machines and pipelines.

The building for crushing section and mill should be of light steel construction with corrugated sheet metal on walls and roof. The framework and trusses should be light weight for building support only and be provided with insulation, because of mild climatic conditions.

Roof ventilators and steel sash windows should be provided, and conveyor ways should have angle wall and roof supports covered with corrugated sheet metal.

Launders on cleaning stages should be made so that flow can be changed to regulate no of cells required, depending on the type of ore being treated. Wood or steel platforms and walkways should be installed in flotation sections, while piping between machines should be carried below floor.

All electric lighting and power wiring should be in rigid conduits. Connections to the motors should be flexible. Motor controls should be mounted on wall panels with stop and start push buttons located within sight or near each motor. Fluorescent lighting should be provided over flotation sections, as it would give operators better visual control of the flotation operation.

This design can result in comparatively low initial plant and give efficient operating results. Proper planning can prove worth while and result in operating costs and increased operating profits.

COMPARATIVE ANALYSIS AND CHOICE OF LOCATION OF CONCENTRATE PLANT

The most likely location for the establishment of copper concentrate plant in North-Waziristan area is Shinkai or Degan area. They are recommended because of the availability of mine facilities. The choice is also there that the concentrate be exported to Saindek copper gold project. This will definitely enhance the feasibility of setting up a copper refinery at Karachi. As the refinery, if established will have sufficient concentrate for treatment to produce Blister Copper.

ROLE OF GOVERNMENT DEPARTMENTS AND THE COMMUNITY

The various tiers of government have different roles to play to make a concentrate plant at North Waziristan a success. The Federally Administered Tribal Area development Corporation and Communication & Works departments can assist in the construction of all-weather roads to ameliorate accessibility. Similarly the FATA DC can carry out the construction or rehabilitation of state roads; water and rural electricity. Albeit the electricity is there in the areas but still, it is advantageous to initiate consultations with water and Power

Development Authority, to ensure the installation of power stations, transformers and related distribution facilities. The Federally Administered Tribal Areas Development Corporation and the local community could assist in the acquisition of land for Mining installations and residential areas.

All these effort towards improving the existing facilities and further expanding them will engender good results by the availability of genuine investors and industrialists who are ready for investment.

INTERNATIONAL ASSISTANCE

Although Pakistan has vast mineral resources and in particular Baluchistan and N-W.F.P, the country has hitherto attracted a negligible global capital investment in mining. But now the political atmosphere in the country is stable; the business is booming and the investment in all sections of the economy have shown positive trends.

It is beyond doubt that industrial development of a country is only achieved through progress in technology, expertise and finance. The level of technology and expertise in this regard has been markedly improved. The problem of finance can be solved by requesting World Bank, Multinational mining companies and donor agencies.. the demand for metallic and non-metallic mineral is continuously on the rise in Asia due to sky-rocketing industrial growth of the ASEAN (Association for South East Asian Nations) countries and China. Hence the chances of success for the project are very bright.

SUMMARY AND CONCLUSIONS

The efforts to upgrade the quality of North Waziristan Copper through the establishment of a concentrate , will result in increased exploitation of the local resources, and improvement in socio-economic condition of the local populace . It shall also definitely open new vistas for the exploitation of metallic minerals like chromite etc in the area.

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