6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.1. COMMINUTION

6.1.1.1. CRUSHING

The capital cost for crushing includes the acquisition and installation of equipment to crush run-of-mine ore to a size suitable for grinding or other beneficiation operations. The crushing circuit includes primary, secondary, and, if necessary, tertiary crusher, screens, and the attendant materials handling equipment (feeders, belt conveyors, etc.). The curve is valid for secondary and tertiary crushing when the mobile crushing section (6.1.1.2.) is used. The total capital cost is based on a single cost curve having a feed rate (X), in metric tons of ore per day. The curve is valid for operations between 500 and 100,000 mtpd, operating three shifts per day.

BASE CURVE

The base curve was developed for the reduction of a medium hard ore (work index of 14.3 kW·h/mt) from run of mine size to 80% passing 1.27 cm (0.5 in.). The process commences with the introduction of the ore into the primary crusher and terminates with the final crusher discharge conveyor.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	14%
Construction supply cost.....	13%
Purchased equipment cost.....	71%
Transportation cost..........	2%

The total capital cost is $(Y_C) = 2,392.492(X)^{0.775}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 334.949(X)^{0.775}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 311.024(X)^{0.775}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 1,746.519(X)^{0.775}$

ADJUSTMENT FACTORS

<u>Ore Hardness Factor</u> The base curves are premised on an ore hardness (work index) of 14.3 kW·h/mt. To adjust for a different work index, multiply the cost obtained from the curve by the following factor:

Ore hardness factor $(F_H) = 0.995(14.3/I)^{-0.744}$
where I = new work index, in kilowatt hours per metric ton.

<u>Product Size Factor</u> The particle size of the crushed product is ultimately dependent on the discharge opening setting of the final crusher(s) in the series. To adjust for a crusher discharge setting other than 1.27 cm, multiply the cost obtained from the curve by the following factor:

Product size factor $(F_S) = 1.122(S)^{-0.714}$
where S = new crusher discharge setting, in centimeters.

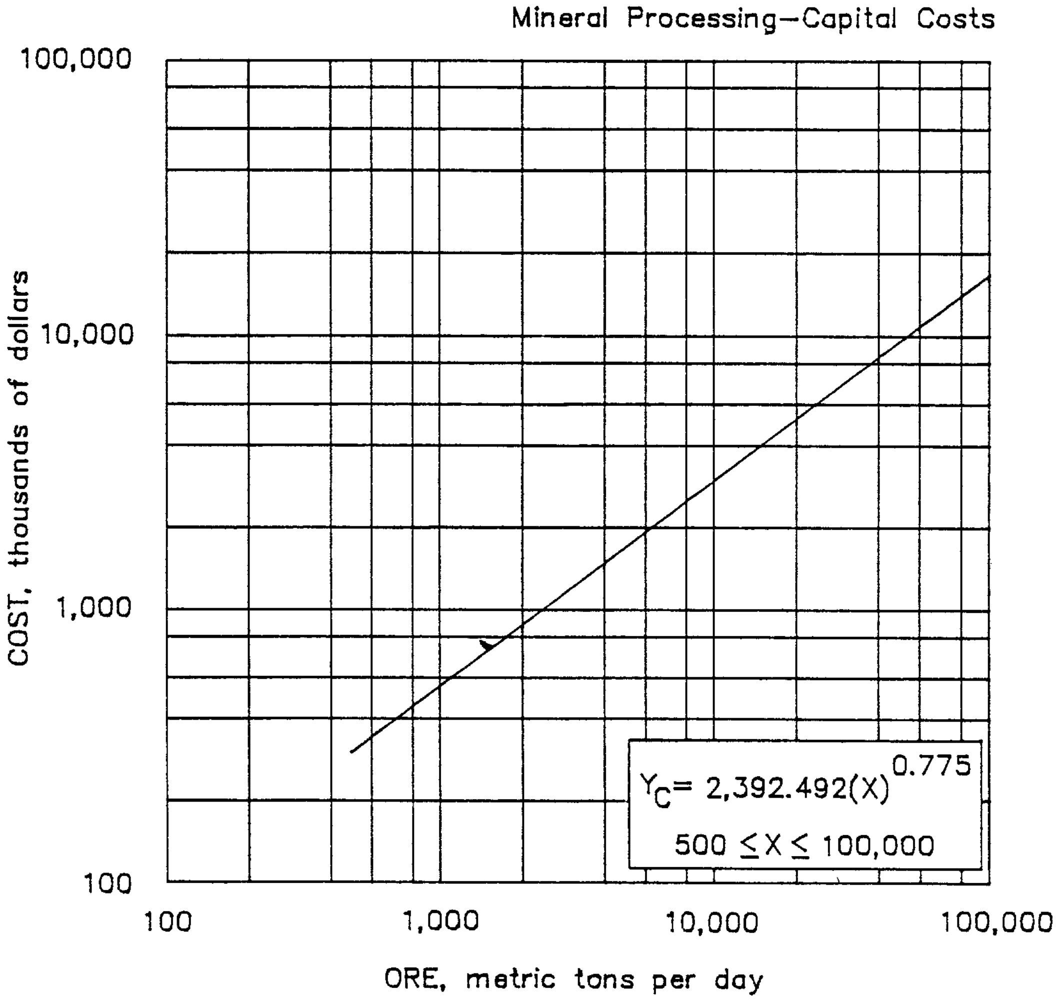
Mobile Crushing Factor In the event that mobile crushers are to be used as the primary crushers, multiply the costs obtained from the curves by the following factors to determine the costs of secondary and tertiary crushing:

Mobile crushing factor $(F_M) = 0.676$

Long Distance Conveyors The base curves are predicated on the assumption that the primary crusher(s) are reasonably proximate to the fine crushing facility. If the distance between primary and secondary crushing facilities exceeds 150 m, a long distance conveyor should be included in the cost estimate (see section 6.1.7.5.).

Coarse Ore Storage Factor The base curve contains no allowance for coarse ore storage. The capital cost for coarse ore storage facilities can be calculated from the following equation and added to the total cost:

Coarse ore storage factor $(F_C) = 224.000(C)^{0.957}$
where C = capacity of coarse ore storage, in metric tons.



6.1.1.1. Crushing

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.1. COMMINUTION

6.1.1.2. MOBILE CRUSHING

The capital cost for mobile crushing is the for acquisition and installation of equipment needed to perform primary crushing on an ore. The mobile crusher includes feed arrangement, crusher, rock breaker and discharge conveyor. The total capital cost is based on a single cost curve having an adjusted feed rate (X), in metric tons of ore per day. The curve is valid for operations between 17,600 and 79,000 mtpd, operating three shifts per day.

BASE CURVE

The base curve is predicated on the primary crushing of an ore at an open side setting of 7 in (17.78 cm) utilizing a mobile crusher. The ore has a work index of 14.3 kW·/mt of ore. The process commences with the direct dumping of the ore into the crusher and terminates at the crusher discharge conveyor.

The cost curves includes all the costs associated with the acquisition and installation of the mobile crusher.

The capital cost derived from the curve is a combination of the following costs:

	Small (17,600 to 35,000 mtpd)	Large (35,000 to 79,000 mtpd)
Installation labor cost........	3.2%	5.9%
Installation materials cost....	0.2%	34.5%
Purchased equipment cost.......	83.8%	58.2%
Transportation cost............	12.8%	1.4%

The total mobile crushing capital cost is $(Y_C) = 2{,}532.149(X)^{0.697}$ and is distributed as follows:

(L) Installation Labor Cost $(Y_{L\ SMALL}) = 81.029(X)^{0.697}$
$(Y_{L\ LARGE}) = 149.397(X)^{0.697}$

(S) Installation Materials Cost $(Y_{S\ SMALL}) = 5.064(X)^{0.697}$
$(Y_{S\ LARGE}) = 873.591(X)^{0.697}$

(E) Purchased Equipment Cost $(Y_{E\ SMALL}) = 2{,}446.056(X)^{0.697}$
$(Y_{E\ LARGE}) = 1{,}509.161(X)^{0.697}$

At production rates less than 35,000 mtpd, the mobile crusher consists of preassembled units which are, for the most part, factory built and require only minimal on-site erection.

ADJUSTMENT FACTORS

Ore Hardness Factor The base curve is based on an ore hardness of 14.3 kW·h/mt. To adjust for a different work index, multiply the cost obtained from the curve by the following factor:

Ore hardness factor $(F_H) = 0.1545/(I)^{-0.702}$
where I = new work index, in kilowatt hours per metric ton.

Crusher Setting Factor The base curve is premised on an open side crushing setting of 17.78 cm (7 in). To adjust for a new crusher setting, multiply the cost obtained from the curve by the following factor:

Crusher setting factor $(F_S) = 0.120(S)^{0.734}$
where S = new crusher setting, in centimeters.

Feeding the Crusher with a Fixed Angle Apron Feeder from Bench Above Factor The base case assumed direct dumping of the ore into the primary crusher. If the option of utilizing a fixed angle apron from the bench above the crusher is adopted, multiply the cost obtained from the curve by the following factor:

Fixed angle bench above factor $(F_{A\ SMALL}) = 1.22$
$(F_{A\ LARGE}) = 1.52$

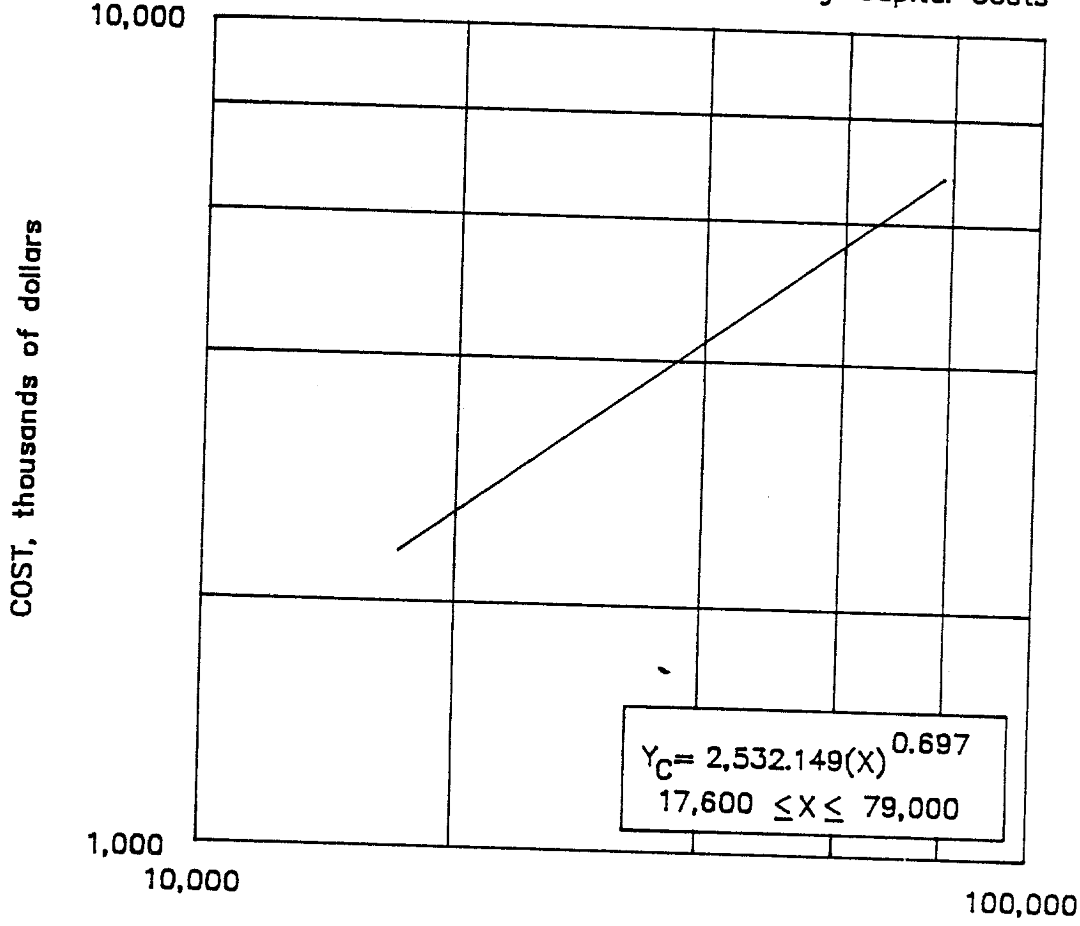
Feeding the Crusher with a Fixed Angle Apron Feeder from the Same Bench Factor The crusher can also be fed from the same bench utilizing a fixed angle apron feeder. In this case, multiply the cost obtained from the curve by the following factor:

Fixed angle same bench factor $(F_F) = 0.217(X)^{0.188}$
where X = ore feed, in metric tons per day.

Feeding the Crusher with a Variable Angle Apron Feeder from Same Bench Factor The most operating flexibility is obtained by feeding the crusher with an apron feeder that is capable of adjusting to different ground elevations. For this scenario, multiply the cost obtained from the curve by the following factor:

Variable angle same bench factor $(F_V) = 0.109(X)^{0.266}$
where X = ore feed, in metric tons per day.

Mineral Processing—Capital Costs



6.1.1.2. Mobile crushing

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.1. COMMINUTION

6.1.1.3. IMPACT CRUSHING

Impact crushers have a limited application in the mining industry but are effective on relatively nonabrasive ores such as soft iron ores, phosphate, trona, gypsum, and some limestones. This type of crusher is used to reduce ores that tend to be plastic and/or tend to pack when crushing forces are applied slowly, as in the case of jaw or gyratory crushers. Impact crushers depend on high hammer velocities for crushing and should not be used on ores containing over 15% equivalent silica because of high wear. Impact crushers should be considered when a high size reduction ratio and a large percentage of fines are desired.

BASE CURVE

Impact crushing capital cost includes all costs associated with acquisition and installation of primary and secondary impact crushers, surge bins, feeders, screens, conveyors, and foundations. Impact crushing facility capital cost is based on a single cost curve having a feed rate (X), in metric tons of mine run ore per day, that is reduced to minus 0.95 cm (3/8 in.). The curve is valid for operations between 1,200 and 20,000 mtpd, operating two shifts per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	10%
Construction supply cost.....	9%
Purchased equipment cost.....	79%
Transportation cost..........	2%

A typical breakdown of the major cost components is

Primary impact crushers......	20%
Secondary impact crushers....	30%
Screens......................	12%
Feeders......................	11%
Surge bins...................	20%
Conveyors....................	7%

The total capital cost is $(Y_C) = 6{,}743.170(X)^{0.609}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 674.317(X)^{0.609}$

(S) Construction Supply Cost $(Y_S) = 606.885(X)^{0.609}$

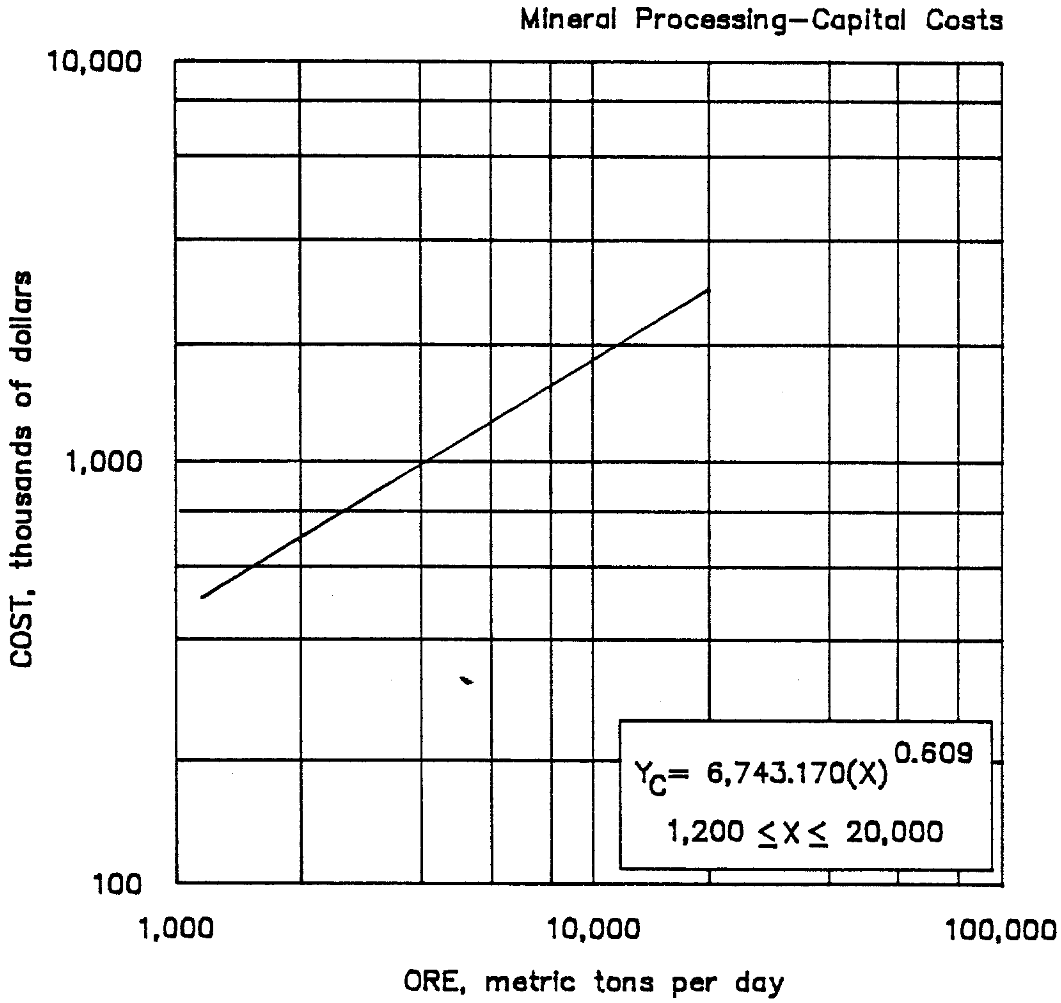
(E) Purchased Equipment Cost $(Y_E) = 5{,}461.968(X)^{0.609}$

ADJUSTMENT FACTORS

Alternative Application If mine run ore is minus 20 cm (8 in) because of mining technique (continuous miner, conveyor feeder breaker, etc.) then primary impact crushers are not required. Use the following cost equation in place of $Y(_C)$, based on a daily feed rate (X) and a two-shift-per-day schedule, only if primary impact crushers are not required:

Alternative application $(Y_{C\ ALTERNATIVE}) = 729.000(X)^{0.782}$
where X = ore feed, in metric tons per day.

Shift-Feed Rate Factor Due to high maintenance requirements, impact crushers are limited to not more than two shifts per day. If the crushing facility operates one shift per day, multiply the daily feed rate (metric tons per day) by two, then enter the adjusted daily feed rate into the cost equation.



6.1.1.3. Impact crushing

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.2. COMMINUTION

6.1.2.1. GRINDING

The capital cost for grinding includes the acquisition and installation of equipment to grind run-of-mine ore to a size suitable for further beneficiation operations. The major equipment associated with the grinding circuit includes rod mills, ball mills, feeders, conveyors, pumps, and classifiers. The total capital cost is based on a single cost curve having a feed rate (X), in metric tons of ore per day. The curve is valid for operations between 380 and 100,000 mtpd, operating three shifts per day.

BASE CURVE

The base curves were developed for the grinding of a medium hard ore (work index of 14.3 kW·h/mt) from 80% passing 1.27 cm to 80% passing 65 mesh. The process commences at the mill feed conveyors and terminates with the cyclone classifier overflow.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	19%
Construction supply cost.....	10%
Purchased equipment cost.....	69%
Transportation cost..........	2%

The total capital cost is $(Y_C) = 4{,}457.437(X)^{0.806}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 846.913(X)^{0.806}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 445.744(X)^{0.806}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 3{,}164.780(X)^{0.806}$

ADJUSTMENT FACTORS

<u>Ore Hardness Factor</u> The base curves are premised on an ore hardness of 14.3 kW·h/mt. To adjust for a different work index, multiply the cost obtained from the curve by the following factor:

Ore hardness factor $(F_H) = 0.117/(I)^{-0.806}$
where I = new work index, in kilowatt hours per metric ton.

<u>Size Factor</u> The base curve is predicated on grinding crushed ore of 80% passing 1.27 cm to a final particle size of 80% passing 65 mesh. To allow for variation in either the particle size of the feed to the grinding circuit or of the ground ore, multiply the cost obtained from the curve by the following factor:

Product size factor $(F_S) = (S/0.055)^{0.806}$
where $S = [(1/(P)^{0.5})-(1/(F)^{0.5})]$,
F = particle size, in microns passing 80% of the feed to the grinding circuit,
and P = particle size, in microns passing 80% of the final product.

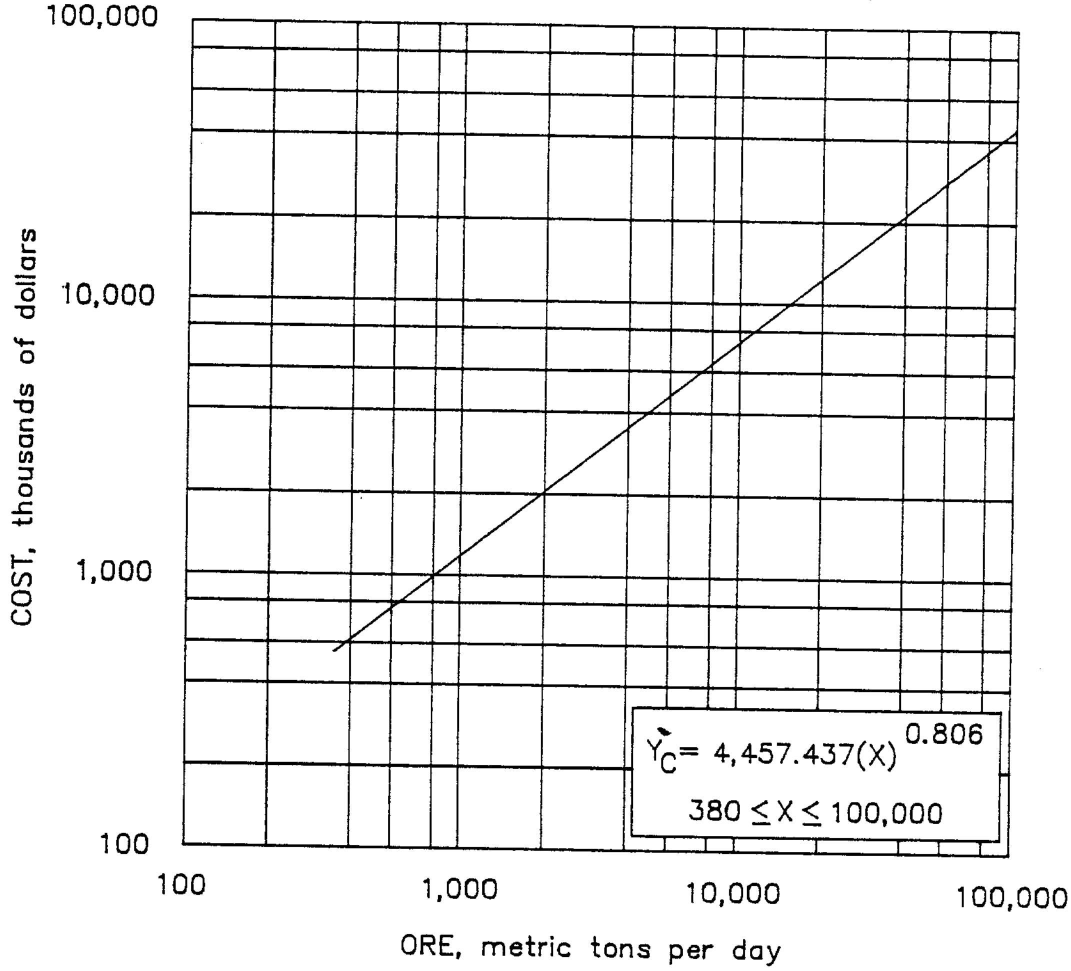
The following tabulation gives mesh sizes versus microns.

Mesh sizes versus microns

mesh[1]	microns[2]	mesh[1]	microns[2]	mesh[1]	microns[2]
2.....	11,058.183	45.....	371.368	200.....	73.061
5.....	4,073.138	50.....	331.077	230.....	62.737
10.....	1,913.403	60.....	271.407	270.....	52.677
15.....	1,229.892	70.....	229.430	300.....	46.961
20.....	898.843	80.....	198.353	325.....	43.038
25.....	704.777	100.....	155.527	400.....	34.321
30.....	577.756	120.....	127.497	600.....	22.061
35.....	488.396	140.....	107.777		
40.....	422.242	170.....	87.220		

[1]2.354 X (mesh number)$^{-1.090}$ = centimeters
[2]Centimeters X 10,000 = microns

Mineral Processing—Capital Costs



6.1.2.1. Grinding

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.2. COMMINUTION

6.1.2.2. SEMIAUTOGENOUS GRINDING

The capital cost for semiautogenous grinding (SAG) is for the acquisition and installation of equipment needed to process an ore at a given particular size. The semiautogenous circuit includes feed conveyors, grinding mills, screens, sumps, and pumps (as needed).

BASE CURVE

The base curve is predicated on processing a sulfide ore from minus 6 to 9 in (15.2-22.9 cm) into a slurry for subsequent ball or pebble milling. The product of the primary SAG mill is a nominal minus 3/8 in (0.95 cm). The power required is 10.4 kW·h/mt based upon the installed mill horsepower being completely pulled.

The total capital cost is based on a single cost curve having an adjusted feed rate (X), in metric tons of ore per day. The curves are valid for operations between 330 and 11,600 mt (a single mill of varying size) and between 11,600 and 111,800 mtpd, operating one shift per day.

The cost curves include all the costs associated with the acquisition and installation of the necessary conveyors, mills, screens and pumps.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	16.4%
Construction supply cost.....	3.6%
Purchased equipment cost.....	77.3%
Transportation cost..........	2.7%

The capital cost for a small semiautogenous mill (330 to 11,600 mtpd) is $(Y_{C\ SMALL}) = 47{,}647.047(X)^{0.468}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_{L\ SMALL}) = 7{,}814.116(X)^{0.468}$

(S) <u>Construction Supply Cost</u> $(Y_{S\ SMALL}) = 1{,}715.294(X)^{0.468}$

(E) <u>Purchased Equipment Cost</u> $(Y_{E\ SMALL}) = 38{,}117.637(X)^{0.468}$

The capital cost for a large semiautogenous mill (11,600 to 111,800 mtpd) is $(Y_{C\ LARGE}) = 563.836(X)^{0.972}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_{L\ LARGE}) = 95.852(X)^{0.972}$

(S) <u>Construction Supply Cost</u> $(Y_{S\ LARGE}) = 28.192(X)^{0.972}$

(E) <u>Purchased Equipment Cost</u> $(Y_{E\ LARGE}) = 439.792(X)^{0.972}$

ADJUSTMENT FACTORS

Single-Stage (SAG) Grinding Factor If the SAG mill is to be used for single stage grinding, i.e., the SAG mill operates in closed circuit with cyclones to produce the grinding circuit final product, multiply the cost obtained from the curve by the following factor:

Single stage grinding factor $(F_S) = 1.299(X)^{-0.014}$
where X = milling rate, in metric tons per day.

The above assumes a required power input of 10.4 kW·h/mt. It must be cautioned that the use of a SAG mill as the only stage of grinding must be predicated upon extensive testing.

Hardness Factor The required energy input for the base SAG mill cases is 10.4 kW·h/mt (assuming full power draw on the mill motors). The only means of determining the required power input is to perform large-scale batch tests or pilot testing. To adjust for different required power inputs, multiply the cost obtained from the curve by the following factor:

Hardness factor $(F_H) = 0.1058(N)^{0.959}$
where N = new power requirements, in kilowatt hours per metric ton

Uranium Factor The processing of uranium ores represents a special case for SAG milling. SAG mills can operate as single stage grinding circuits processing uranium ores at relatively low power input (3 kW·h/mt). If uranium ores are being processed, multiply the cost obtained from the curve by the following factor:

Uranium factor $(F_U) = 0.354(X)^{0.072}$
where X = feed rate, in metric tons ore per day.

Autogenous Grinding (Sulfide) Factor The base curve for SAG mills in a two stage circuit can be adjusted to reflect autogenous grinding in a two stage circuit, assuming the same power requirements for grinding (10.4 kW·h/mt). Multiply the cost obtained from the curve by the following factor:

Autogenous grinding (sulfide) factor $(F_A) = 0.995$

The use of autogenous grinding normally require more power input per metric ton than SAG and the necessary power requirements must be determined by testing.

Iron Ore (SAG) Factor To adjust for the grinding of taconite in a two-stage circuit with the primary mill being a SAG mill, multiply the cost obtained from the curve by the following factor:

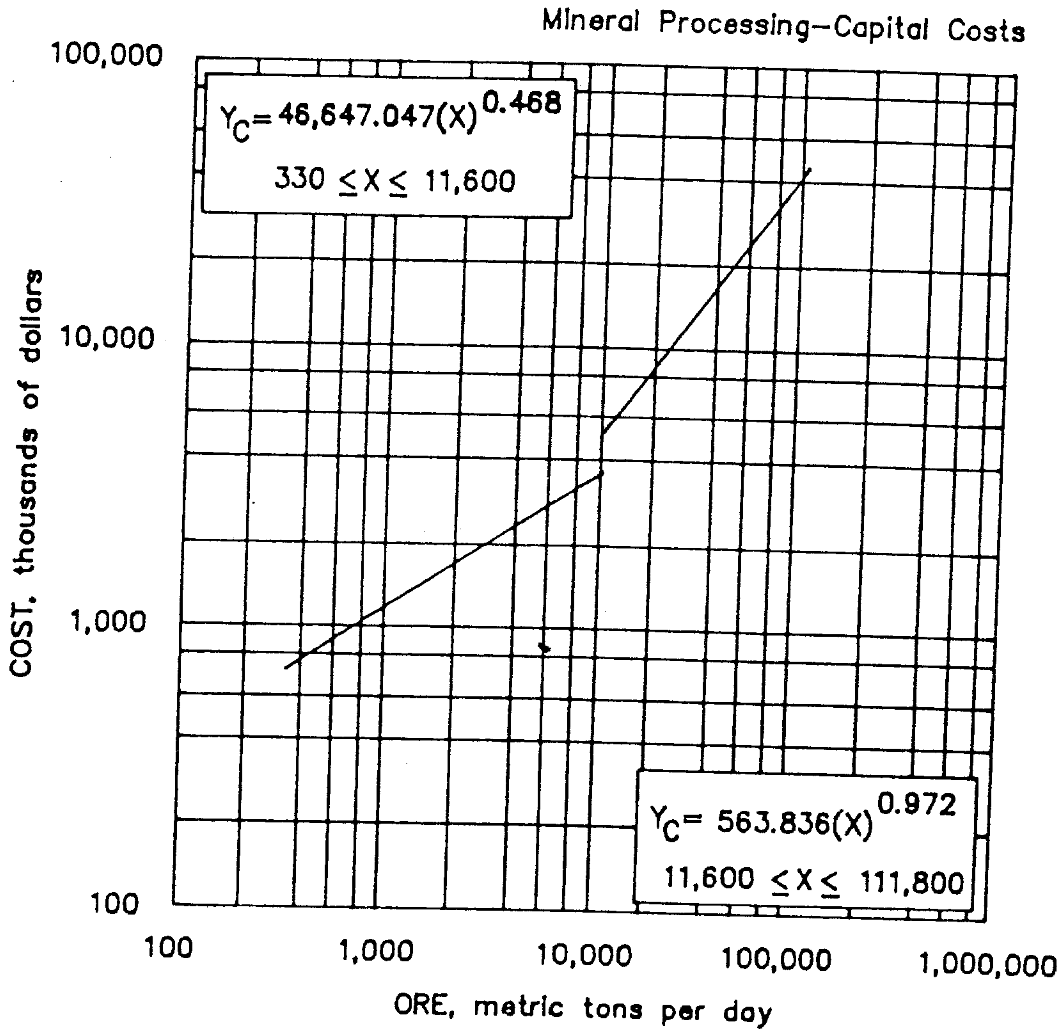
Iron ore (SAG) factor $(F_I) = 1.24$

The power requirements for SAG milling the taconite ore was taken as 16 kW·h/mt. The SAG mill product is 40% minus 325 mesh.

Iron Ore (Autogenous) Factor To adjust for the grinding of taconite in a two-stage circuit with the primary mill being an autogenous mill, multiply the cost obtained from the curve by the following factor:

Iron ore (autogenous) factor $(F_O) = 1.95$

The power requirement was set at 20.9 kW·h/mt and the autogenous mill product at 100% minus 16 mesh.



6.1.2.2. Semiautogenous grinding

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.2. COMMINUTION

6.1.2.3. RAYMOND MILL GRINDING

The capital cost for Raymond mill grinding is for the acquisition and installation of equipment needed to process barite. The Raymond mill circuit includes feed storage, a complete packaged Raymond mill unit, and product conveying. Included in the Raymond mill package is a Raymond roller mill, whizzer separator, fan, cyclone, cyclone valve, and vent baghouse. The circuit can process barite with a maximum lump size of 3/4 in (1.9 cm) and a product ranging from 70% to 99% minus 325 mesh.

BASE CURVE

The total capital cost is based on a single cost curve having an adjusted feed rate (X), in metric tons of ore per day. The curve is valid for operations between 115 and 1,290 mtpd, operating two shifts per day. The curve includes all costs associated with the acquisition of the necessary bins, mills, cyclones, fans, and conveyors. The base curve is for grinding dry barite to a final product size of 90% minus 325 mesh. The mill requirement is based on 12.2 hp·h/mt.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	13.0%
Construction supply cost.....	3.0%
Purchased equipment cost.....	82.9%
Transportation cost..........	1.1%

The total capital cost is $(Y_C) = 5{,}509.259(X)^{0.792}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 716.204(X)^{0.792}$

(S) Construction Supply Cost $(Y_S) = 165.278(X)^{0.792}$

(E) Purchased Equipment Cost $(Y_E) = 4{,}672.777(X)^{0.792}$

ADJUSTMENT FACTORS

Grind Factor The capacity of the mill is very dependent on the required final product size distribution. To adjust for a final product other than 90% minus 325 mesh, multiply the cost obtained from the curve by the following factor:

Grind factor $(F_G) = 0.024(G)^{-1.16}$
where G = new grind percentage, expressed as cumulative percent passing 325 mesh.

Hardness Factor Barite ores vary widely in the amount of power required to process a unit weight to a particular size. No means of estimating the required power is available, short of having the vendor treat a given sample. Given the required mill power per metric ton, multiply the cost obtained from the curve by the following factor:

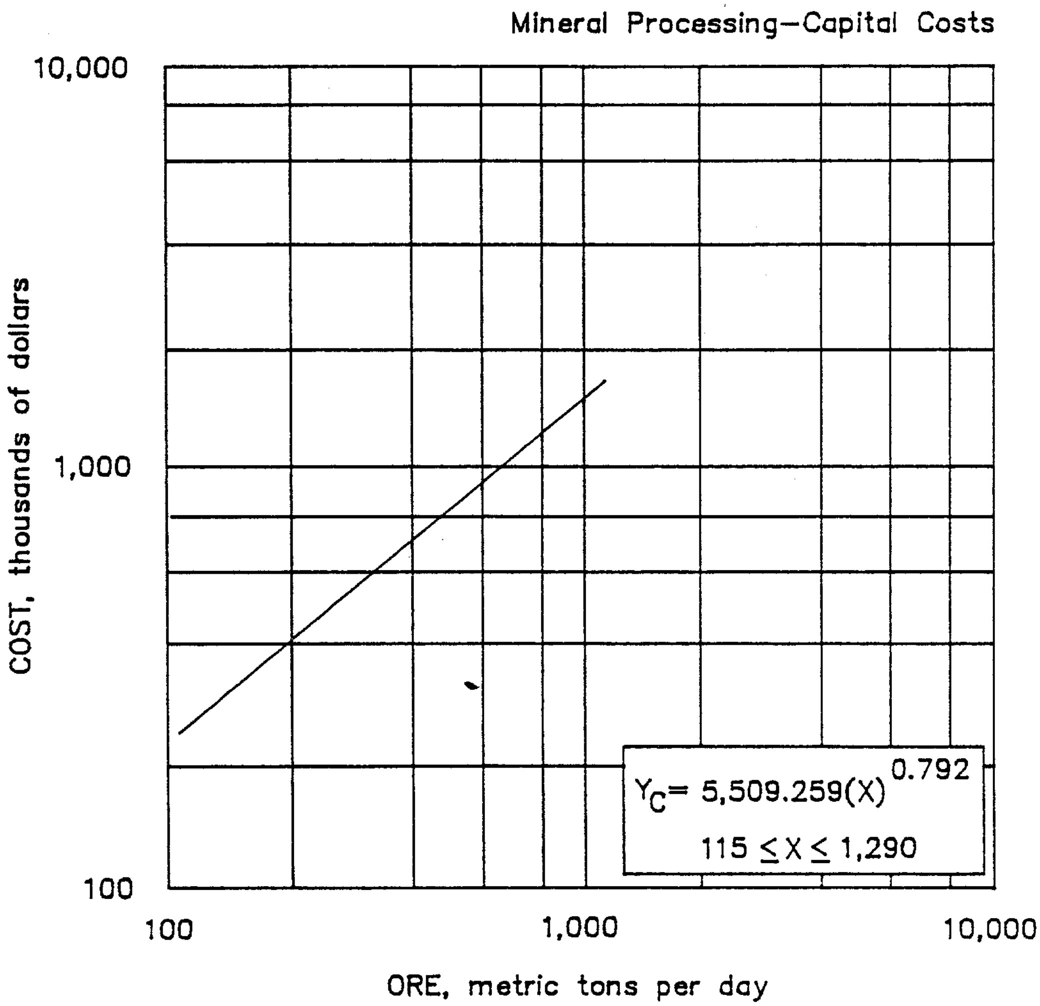
Hardness factor $(F_H) = (12.200/H)^{-0.794}$
where H = new estimated power required, in horsepower hours per metric ton.

Flash Drying Factor The base curve assumes grinding without drying in the mill. Should flash drying be incorporated in the mill design, multiply the cost obtained from the curve by the following factor:

Flash drying factor $(F_F) = 1.2$

Potash Factor The costs can be adjusted for grinding potash (langbeinite) by multiplying the cost obtained from the curve by the following factor:

Potash factor $(F_P) = 1.204$



6.1.2.3. Raymond mill grinding