## 6.1. MINERAL PROCESSING--CAPITAL COSTS

### 6.1.5. HYDROMETALLURGY

#### 6.1.5.1.1. ACID LEACHING BERYLLIUM ORE

The capital cost includes the acquisition and installation of equipment items associated with the acid leaching circuit. The capital cost is based on a single curve having an adjusted feed rate (X), in metric tons of ore or concentrate leached per day. The curve is valid for operations between 85 and 560 mtpd, operating three shifts per day.

BASE CURVE

The total capital cost for beryllium ore is for the acquisition and installation of the purchased equipment items.

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

| | |
|---|---|
| Construction labor cost.... | 39.5% |
| Construction supply cost... | 19.3% |
| Purchased equipment cost... | 40.9% |
| Transportation cost........ | 0.3% |

The total capital cost is $(Y_C) = 44{,}887.857(X)^{0.367}$ and is distributed as follows:

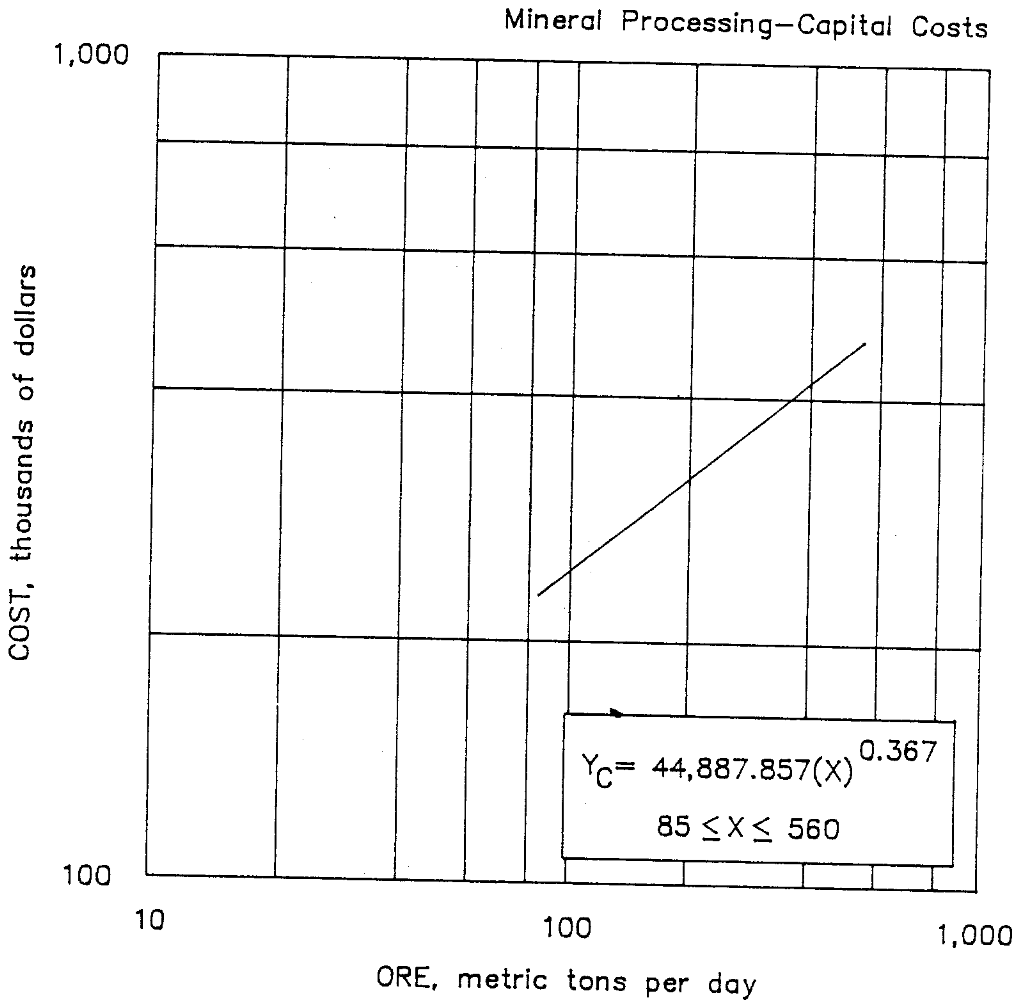
(L) Construction Labor Cost $(Y_L) = 17{,}730.704(X)^{0.367}$

(S) Construction Supply Cost $(Y_S) = 8{,}663.356(X)^{0.367}$

(E) Purchased Equipment Cost $(Y_E) = 18{,}493.797(X)^{0.367}$

ADJUSTMENT FACTOR

Shift Factor The curve is based on a three-shift-per-day operation. Beryllium leaching operations would probably operate on a continuous basis to maintain a steady flow rate to the subsequent countercurrent decantation (CCD) thickening circuit. No shift adjustment factor is recommended for acid leaching of beryllium ores.




6.1.5.1.1. Acid leaching
BERYLLIUM ORE

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.1.2. ACID LEACHING
CARBONATE

The capital cost includes the acquisition and installation of equipment items associated with the acid leaching circuit. The capital cost curve is based on a single cost curve having an adjusted feed rate (X), in metric tons of ore or concentrate leached per day. The curve is valid for operations between 4 and 1,700 mtpd, operating three shifts per day.

BASE CURVE

The total capital cost is based on a single curve at an adjusted feed rate (X) for the acquisition and installation of the purchased equipment items. For the base case, it has been assumed that the concentrate contains 5% carbonates as $CO_3$, and is leached for 4 h.

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

| | |
|---|---|
| Construction labor cost.... | 42.4% |
| Construction supply cost... | 16.3% |
| Purchased equipment cost... | 41.0% |
| Transportation cost........ | 0.3% |

The total capital cost is $(Y_C) = 7{,}337.140(X)^{0.541}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 3{,}110.947(X)^{0.541}$

(S) Construction Supply Cost $(Y_S) = 1{,}195.954(X)^{0.541}$

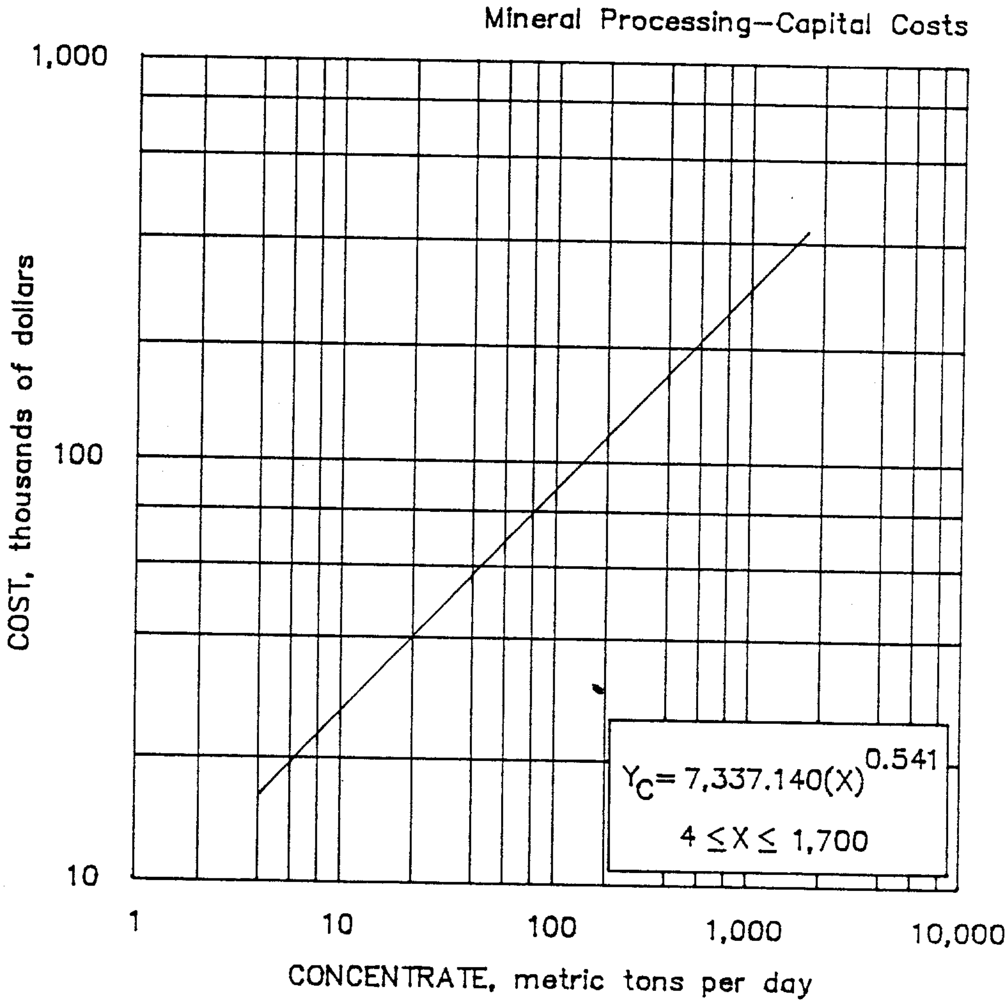
(E) Purchased Equipment Cost $(Y_E) = 3{,}030.239(X)^{0.541}$

ADJUSTMENT FACTORS

Leaching Time Factor To adjust the capital cost curve for leaching times other than 4 h, multiply the cost obtained from the curve by the following factor:

Leaching time factor $(F_H) = 0.339(H)^{0.775}$
where H = leach time, in hours.

Percent Carbonate Factor There is no adjustment factor for concentrates that con tain other than 5% carbonates.




6.1.5.1.2. Acid leaching
CARBONATE

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.1.3. ACID LEACHING
COPPER ORE

The capital cost includes the acquisition and installation of equipment items associated with the acid leaching circuit. The capital cost is based on a single curve having an adjusted feed rate (X), in metric tons of ore or concentrate leached per day. The curve is valid for operations between 3,000 and 10,500 mtpd, operating three shifts per day.

BASE CURVE

The total capital cost for copper ore is for the acquisition and installation of the purchased equipment items.

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

| | |
|---|---|
| Construction labor cost.... | 20.6% |
| Construction supply cost... | 54.7% |
| Purchased equipment cost... | 24.3% |
| Transportation cost........ | 0.4% |

The total capital cost is $(Y_C) = 1{,}665.555(X)^{0.792}$ and is distributed as follows:

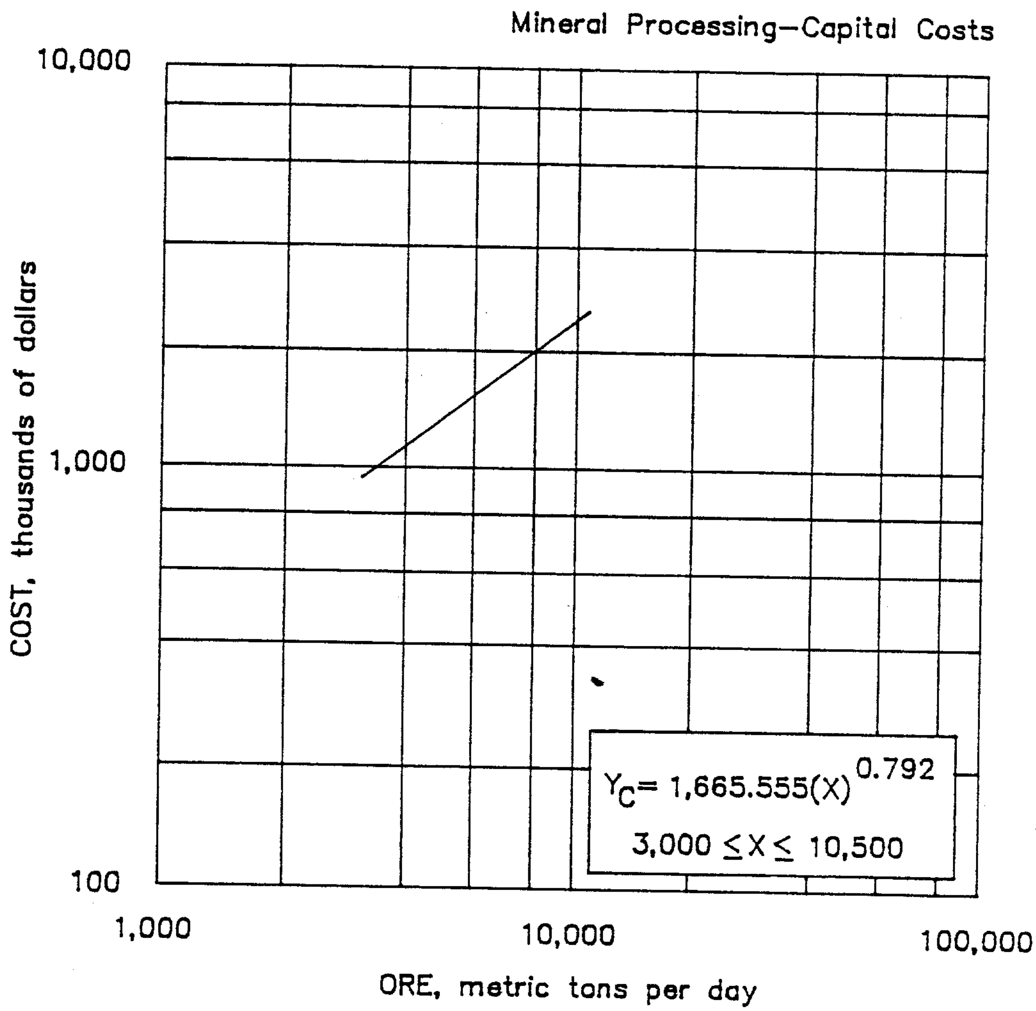
(L) Construction Labor Cost $(Y_L) = 343.104(X)^{0.792}$

(S) Construction Supply Cost $(Y_S) = 911.059(X)^{0.792}$

(E) Purchased Equipment Cost $(Y_E) = 411.392(X)^{0.792}$

ADJUSTMENT FACTOR

Shift Factor The curve is based on a three-shift-per-day operation. Copper leaching operations would probably operate on a continuous basis to maintain a steady flow rate to the subsequent CCD thickening circuit. No shift adjustment factor is recommended for acid leaching of copper ores.




6.1.5.1.3. Acid leaching
COPPER ORE

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.1.4. ACID LEACHING
PYROCHLORE

The capital cost includes the acquisition and installation of equipment items associated with the acid leaching circuit. The capital cost is based on a single curve having an adjusted feed rate (X), in metric tons of ore or concentrate leached per day. The curve is valid for operations between 4 and 170 mtpd, operating three shifts per day.

BASE CURVE

The total capital cost for pyrochlore concentrate is for the acquisition and installation of the purchased equipment items for a two-stage leach circuit.

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

| | |
|---|---|
| Construction labor cost.... | 24.8% |
| Construction supply cost... | 8.3% |
| Purchased equipment cost... | 66.5% |
| Transportation cost........ | 0.4% |

The total capital cost is $(Y_C) = 49{,}424.843(X)^{0.342}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 12{,}257.361(X)^{0.342}$

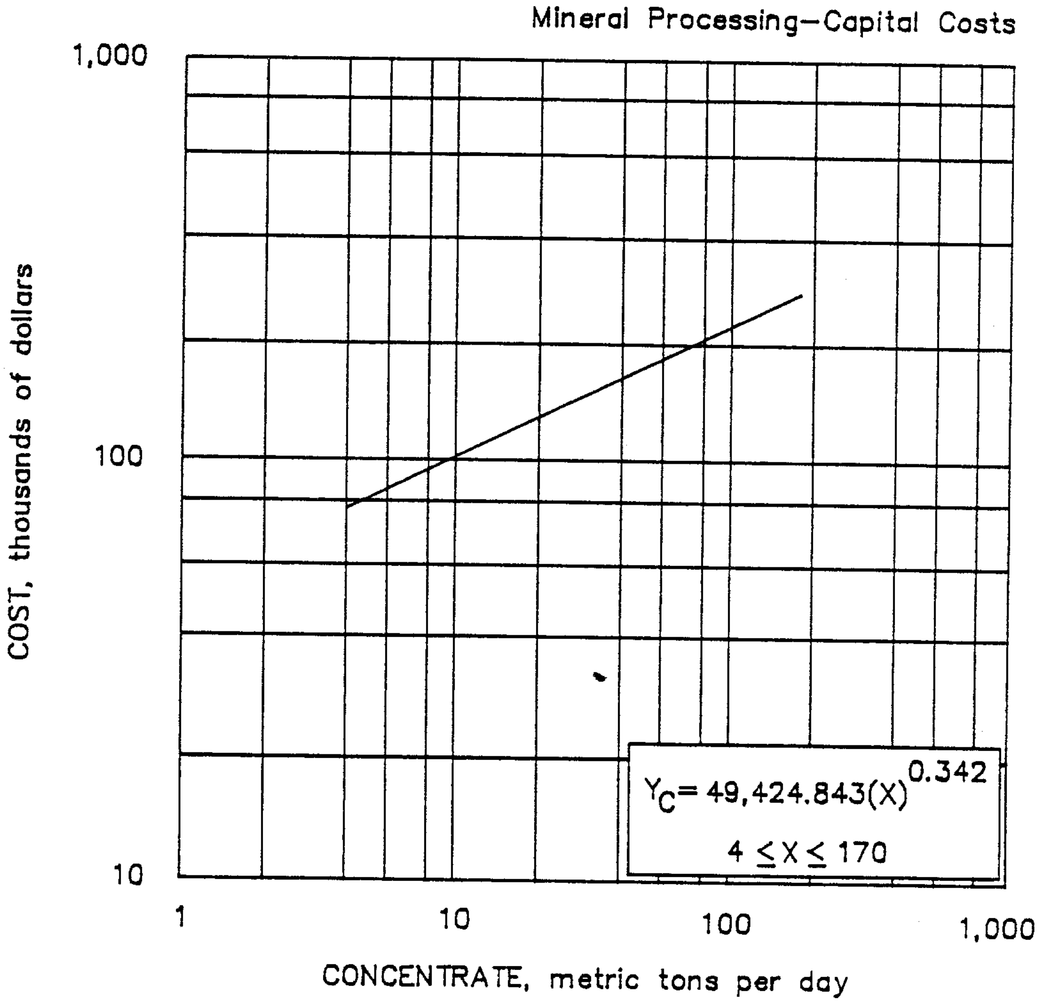
(S) Construction Supply Cost $(Y_S) = 4{,}102.262(X)^{0.342}$

(E) Purchased Equipment Cost $(Y_E) = 33{,}065.220(X)^{0.342}$

ADJUSTMENT FACTOR

One-Stage Leach Circuit Factor The base curve is based on a two-stage leach circuit operation. To adjust for a one-stage leach circuit, multiply the cost obtained from the curve by the following factor:

One-stage leach circuit factor $(F_1) = 0.22$




6.1.5.1.4. Acid leaching
PYROCHLORE

## 6.1. MINERAL PROCESSING--CAPITAL COSTS

### 6.1.5. HYDROMETALLURGY

#### 6.1.5.1.5. LEACHING CARBON-IN-PULP

The capital cost for the carbon-in-pulp (CIP) cyanide leaching process includes acquisition and installation of all equipment, including pumps, piping, wiring, carbon inventory, etc., necessary to provide thickening; leaching; wood-chip and trash removal screening; carbon adsorption, countercurrent transfer, screening, Zadra-type stripping, acid treatment, and reactivation by heating and quenching; electrowinning; scavenger recovery from bleed streams and tailing water; bullion refining and casting; and instrumentation, control-system, and computerization. Comminution and tailings disposal costs are not included.

The curve is not applicable to conventional cyanide agitation leaching with Merrill-Crowe precipitation; preagglomeration of ores; carbon-in-leach; preoxidation of carbonaceous or graphitic ores; carbon in column; autoclave or pressure leaching; amalgamation; high-intensity leaching circuitry; vat, heap, or dump leaching; or leaching with lixiviants other than cyanide, such as thiourea, thiosulfate, or aqueous chlorine.

BASE CURVE

The total cost is based on a single cost curve having an adjusted feed rate (X), in dry metric tons per day. The curve is valid for operations between 300 and 2,200 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition and installation of the equipment described above. No allowance is made for precious metal lockup in solution or on the carbon.

The cost curve is a combination of the following:

| | Small (300 to 1,100 mtpd) | Large (1,100 to 2,200 mtpd) |
|---|---|---|
| Construction labor cost........ | 35% | 14% |
| Construction supply cost....... | 30% | 23% |
| Purchased equipment cost....... | 35% | 54% |

The total capital cost is $(Y_C) = 85{,}471.000(X)^{0.617}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ SMALL}) = 29{,}914.850(X)^{0.617}$
(S) Construction Supply Cost $(Y_{S\ SMALL}) = 25{,}641.300(X)^{0.617}$
(E) Purchased Equipment Cost $(Y_{E\ SMALL}) = 29{,}914.850(X)^{0.617}$

(L) Construction Labor Cost $(Y_{L\ LARGE}) = 11{,}965.940(X)^{0.617}$
(S) Construction Supply Cost $(Y_{S\ LARGE}) = 27{,}350.720(X)^{0.617}$
(E) Purchased Equipment Cost $(Y_{E\ LARGE}) = 46{,}154.340(X)^{0.617}$

## ADJUSTMENT FACTORS

Carbon-in-Leach Plant Cost The cost of a similarily sized carbon-in-leach (CIL) plant may be calculated by the following equation:

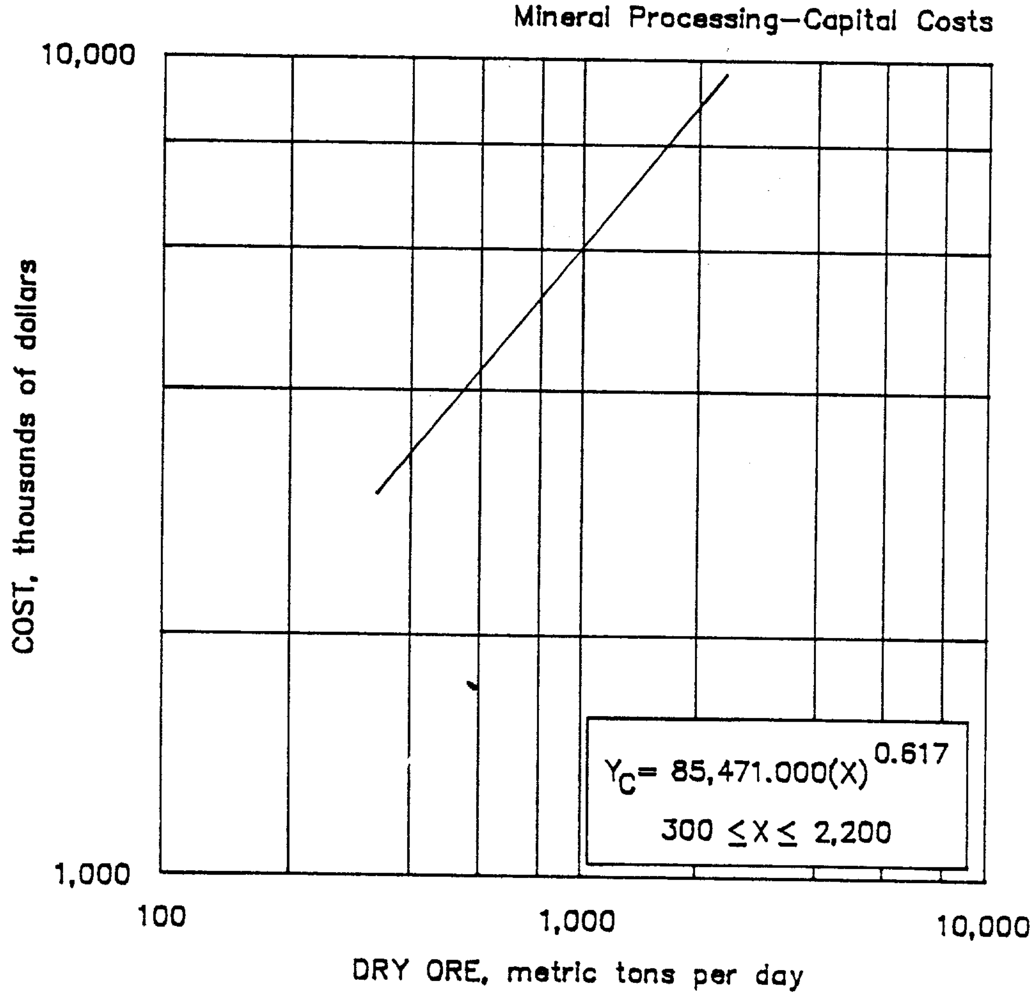
Carbon-in-leach plant cost $(Y_I) = 0.750(Y_C)$
where
$(Y_C)$ = capital cost determined from the base curve.

Heap Leach Cost The capital cost of the facilities needed for auxiliary heap leaching process can be estimated to plus or minus 25% in average 1984 dollars[1]. The basic equation applies to operations greater than 900 mtpd and includes pads, ponds, piping, pumps, and a Merrill-Crowe or carbon adsorption recovery plant. Excluded are the costs of exploration, infrastructure (roads, water, etc.), preproduction stripping costs (for open pit mines), mining equipment, crushing-agglomeration equipment, and reclamation.

The total capital cost of heap leaching facilities may be calculated by the following equation:

Heap leach cost $(Y_H)$ = (\$1200 to \$1400)(X)
where X = ore processed, in metric tons per day.

[1]Callicutt, W. W. Economic Aspects of Heap Leaching. Paper in Evaluation, Design, and Operation of Precious Metal Heap Leaching Projects, coordinated by D. J. A. Van Zyl (Soc. of Min. Eng. Fall Meeting and Exhibit, Albuquerque, NM, Oct. 13-15, 1985). Soc. of Min. Eng., 1985, pp. 39-66.




6.1.5.1.5. Leaching
CARBON—IN—PULP

# 6.1. MINERAL PROCESSING--CAPITAL COSTS

## 6.1.5. HYDROMETALLURGY

### 6.1.5.1.6. LEACHING
### COPPER DUMP

Capital costs for copper dump leaching by trickle-spray-leaching to enhance percolation assumes no clearing costs or auxiliary facilities for recovery of byproducts such as uranium or cobalt. A leach time of 6 months is assumed with 2 months following being allowed for dump "resting" with equipment left in place prior to resumption of leaching. The resulting pregnant solution is recovered and pumped approximately 3,000 m to a solvent extraction and electrowinning operation. Barren solution is returned to the leach dump barren-solution tank where pH is adjusted. Costs for solvent extraction and electrowinning are not included.

The dump leach curves are inapplicable to heap leaching, vat percolation leaching, in situ leaching, leaching of precious metals, leaching with basic reagents when large quantities of acid-consuming materials are present, pachuca tank leaching, slime leaching, leach-precipitation-flotation, or injection leaching. Total capital cost, however, closely approximates costs for ponding, i.e., flood leaching.

BASE CURVE

The capital cost is based on a single curve having a solution feed rate (X), in liters per minute. The curve is valid for operations between 3,000 and 12,000 L/min, operating three shifts per day. The curve includes costs of acquisition, transportation, and installation of equipment required for trickle dump leaching, collection of the resulting pregnant liquors after passage through the dump, transfer of the liquors to the solvent extraction pregnant liquor pond, and return of barren solution to the dumps.

The final cost including transportation, derived from the curve is a combination of the following costs:

| | |
|---|---|
| Construction labor cost...... | 19% |
| Purchased equipment cost..... | 81% |

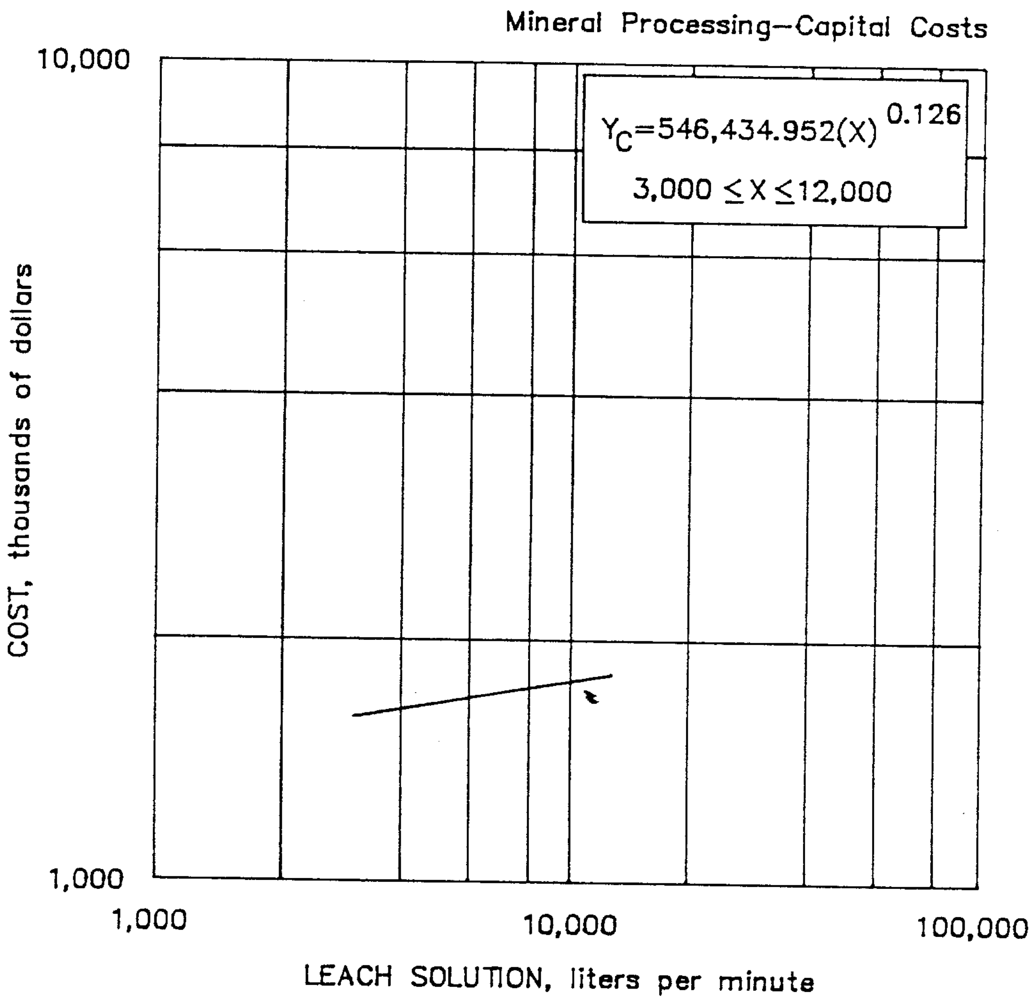
The capital cost consists of the following range of equipment costs:

| | Small (3,000 to 7,800 L/min) | Large (7,800 to 12,000 L/min) |
|---|---|---|
| Pumps................ | 5% | 8% |
| Pipe and couplings... | 54% | 55% |
| Pond................. | 1% | 1% |
| Tanks................ | 5% | 5% |
| Vehicles............. | 35% | 31% |

The total capital cost is $(Y_C) = 546,434.952(X)^{0.126}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 103,822.641(X)^{0.126}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 442,612.311(X)^{0.126}$




6.1.5.1.6. Leaching
COPPER DUMP

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.1.7. LEACHING
CONVENTIONAL CYANIDE LEACHING WITH MERRILL-CROWE PRECIPITATION

The capital cost for cyanide agitation leaching and recovery includes acquisition and installation of all equipment, including pumps, piping, instrumentation, wiring, etc., necessary for cyanide agitation leaching of 80% minus 200-mesh ore; countercurrent decantation; pregnant solution holding; pregnant solution final pressure clarification; deaeration including vacuum equipment; Merrill-Crowe zinc precipitation; precious metal pressure filtration; carbon column scavenger recovery from bleed streams and tailings return water; acid pretreatment of precipitates; and bullion refining and casting facilities. Comminution and tailings disposal costs are not included.

The curves cannot be applied to carbon-in-pulp (CIP) mills; preagglomeration of ores; carbon-in-leach; preoxidation of carbonaceous or graphitic ores; carbon-in-column; autoclave or pressure leaching; amalgamation; high-intensity leaching circuitry; vat, heap, or dump leaching; or leaching with lixiviants other than cyanide such as thiourea, thiosulfate, or aqueous chlorine. For lower throughputs, the curve is applicable to circuitry used for leaching of flotation and/or gravity concentrates.

Capital cost is not generally affected by variation in feed grade, as is the capital cost of similarly sized CIP mills, but is instead largely determined by the incoming feed flow rate.

BASE CURVE

The total cost is based on a single cost curve having an adjusted feed rate (X), in dry metric tons per day. The curve is valid for operations between 5 and 2,800 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition and installation of all equipment described above.

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

| | |
|---|---|
| Construction labor cost...... | 22% |
| Construction supply cost..... | 24% |
| Purchased equipment cost..... | 54% |

The total capital cost is $(Y) = 34{,}913.533(X)^{0.784}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 7{,}680.977(X)^{0.784}$

(S) Construction Supply Cost $(Y_S) = 8{,}379.248(X)^{0.784}$

(E) Purchased Equipment Cost $(Y_E) = 18{,}853.308(X)^{0.784}$

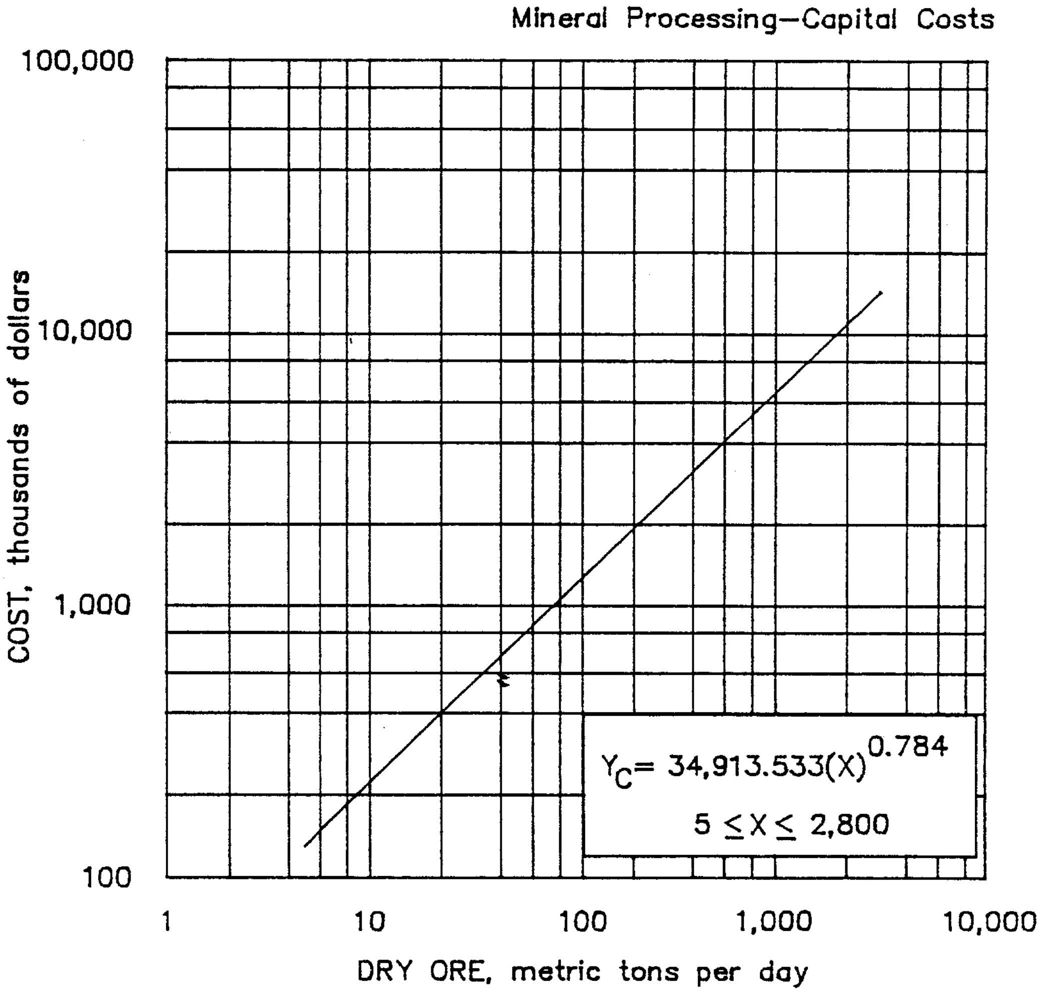
ADJUSTMENT FACTORS

Heap Leach Cost The capital cost of the facilities needed for auxiliary heap leaching process can be estimated to plus or minus 25% in average 1984 dollars[1]. The basic equation applies to operations greater than 900 mtpd and includes pads, ponds, piping, pumps, and a Merrill-Crowe or carbon adsorption recovery plant. Excluded are the costs of exploration, infrastructure (roads, water, etc.), preproduction stripping costs (for open pit mines), mining equipment, crushing-agglomeration equipment, and reclamation.

The total capital cost of heap leaching facilities may be calculated by the following equation:

Heap leach cost $(Y_H)$ = (\$1200 to \$1400)(X)
where X = ore processed, in metric tons per day.

[1]Callicutt, W. W. Economic Aspects of Heap Leaching. Paper in Evaluation, Design, and Operation of Precious Metal Heap Leaching Projects, coordinated by D. J. A. Van Zyl (Soc. of Min. Eng. Fall Meeting and Exhibit, Albuquerque, NM, Oct. 13-15, 1985). Soc. of Min. Eng., 1985, pp. 39-66.




6.1.5.1.7. Leaching
CONVENTIONAL CYANIDE LEACHING WITH
MERRILL-CROWE PRECIPITATION

# 6.1. MINERAL PROCESSING--CAPITAL COSTS

## 6.1.5. HYDROMETALLURGY

### 6.1.5.1.8. LEACHING URANIUM

The capital cost for uranium leaching includes the acquisition and installation of equipment items following fine grinding through the production of uranium concentrate as yellowcake. The cost curve consists of the leaching, countercurrent decantation, solvent extraction, precipitation, and drying.

BASE CURVE

The total cost is based on a single cost curve having a feed rate (X), in dry metric tons of ore per day. The curve is valid for operations between 770 and 6,300 mtpd, operating three shifts per day. The curve includes all costs associated with the acquisition and installation of the equipment items.

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

| | Small (770 to 2,000 mtpd) | Large (2,000 to 6,300 mtpd) |
|---|---|---|
| Construction labor cost..... | 17.6% | 21.6% |
| Construction supply cost.... | 27.7% | 38.8% |
| Purchased equipment cost.... | 54.0% | 38.9% |
| Transportation cost......... | 0.7% | 0.7% |

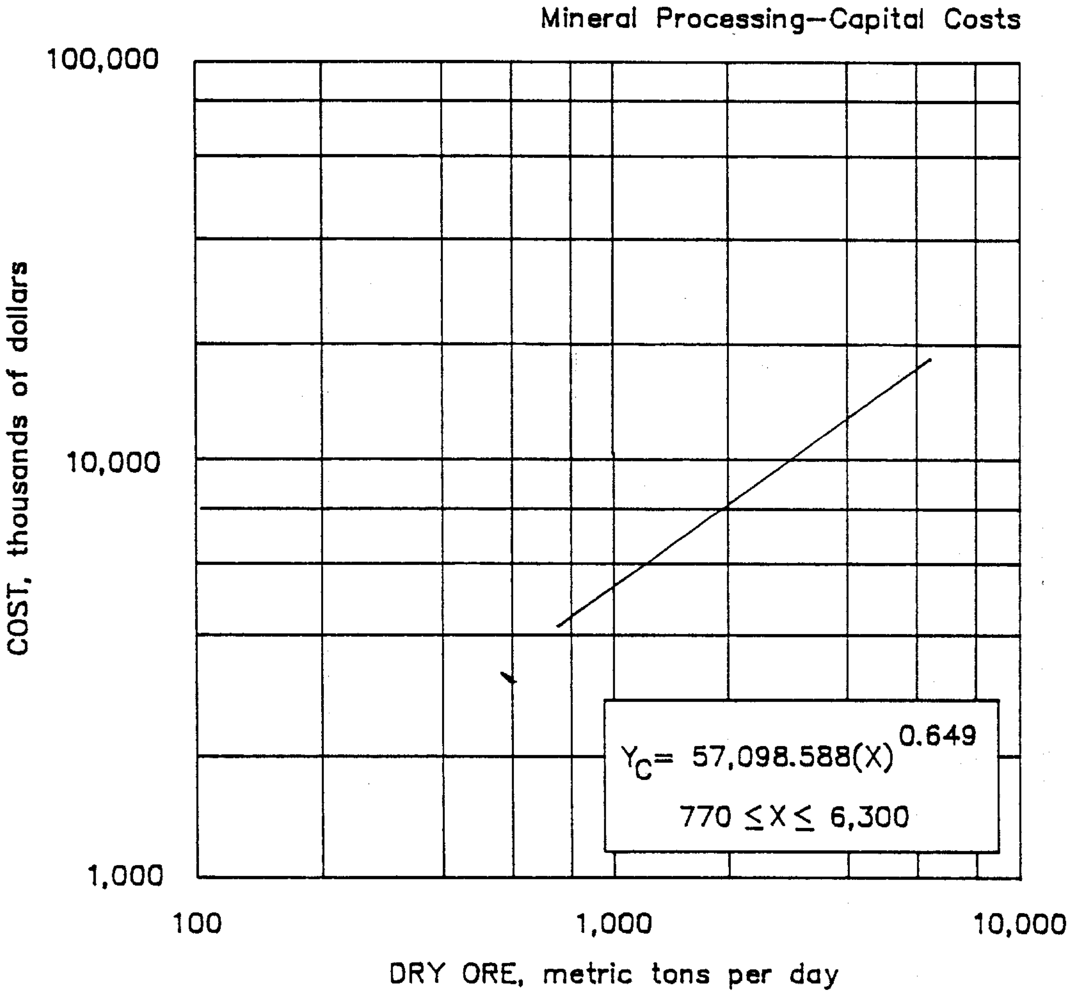
The total capital cost is $(Y_C) = 57{,}098.588(X)^{0.649}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ SMALL}) = 10{,}049.351(X)^{0.649}$
(S) Construction Supply Cost $(Y_{S\ SMALL}) = 15{,}816.309(X)^{0.649}$
(E) Purchased Equipment Cost $(Y_{E\ SMALL}) = 31{,}232.928(X)^{0.649}$

(L) Construction Labor Cost $(Y_{L\ LARGE}) = 12{,}333.295(X)^{0.649}$
(S) Construction Supply Cost $(Y_{S\ LARGE}) = 22{,}154.252(X)^{0.649}$
(E) Purchased Equipment Cost $(Y_{E\ LARGE}) = 22{,}611.041(X)^{0.649}$

ADJUSTMENT FACTORS

Shift Factor The curve is based on a three-shift-per-day operation. Typically, uranium milling operations are operations are operated on a continuous basis to maintain steady flow rates between the various circuits. No adjustment factor is recommended for uranium leaching.




6.1.5.1.8. Leaching
URANIUM

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.2.1. SOLVENT EXTRACTION
BERYLLIUM

The capital cost includes the acquisition and installation of equipment items associated with the solvent extraction circuit for beryllium. Major equipment items include storage tanks, pumps, mixer-settlers, and mixer mechanisms.

BASE CURVE

The total capital cost for the beryllium solvent extraction circuit is based on a single curve having an adjusted feed rate (X), in liters of clarified pregnant aqueous solution to the solvent extraction circuit per minute. The curve is valid for operations between 85 and 575 L/min, operating three shifts per day.

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

| | |
|---|---|
| Construction labor cost.... | 7.3% |
| Construction supply cost... | 9.2% |
| Purchased equipment cost... | 83.5% |

The total capital cost is $(Y_C) = 23{,}690.266(X)^{0.672}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 1{,}729.389(X)^{0.672}$

(S) Construction Supply Cost $(Y_S) = 2{,}179.504(X)^{0.672}$

(E) Purchased Equipment Cost $(Y_E) = 19{,}781.373(X)^{0.672}$

ADJUSTMENT FACTORS

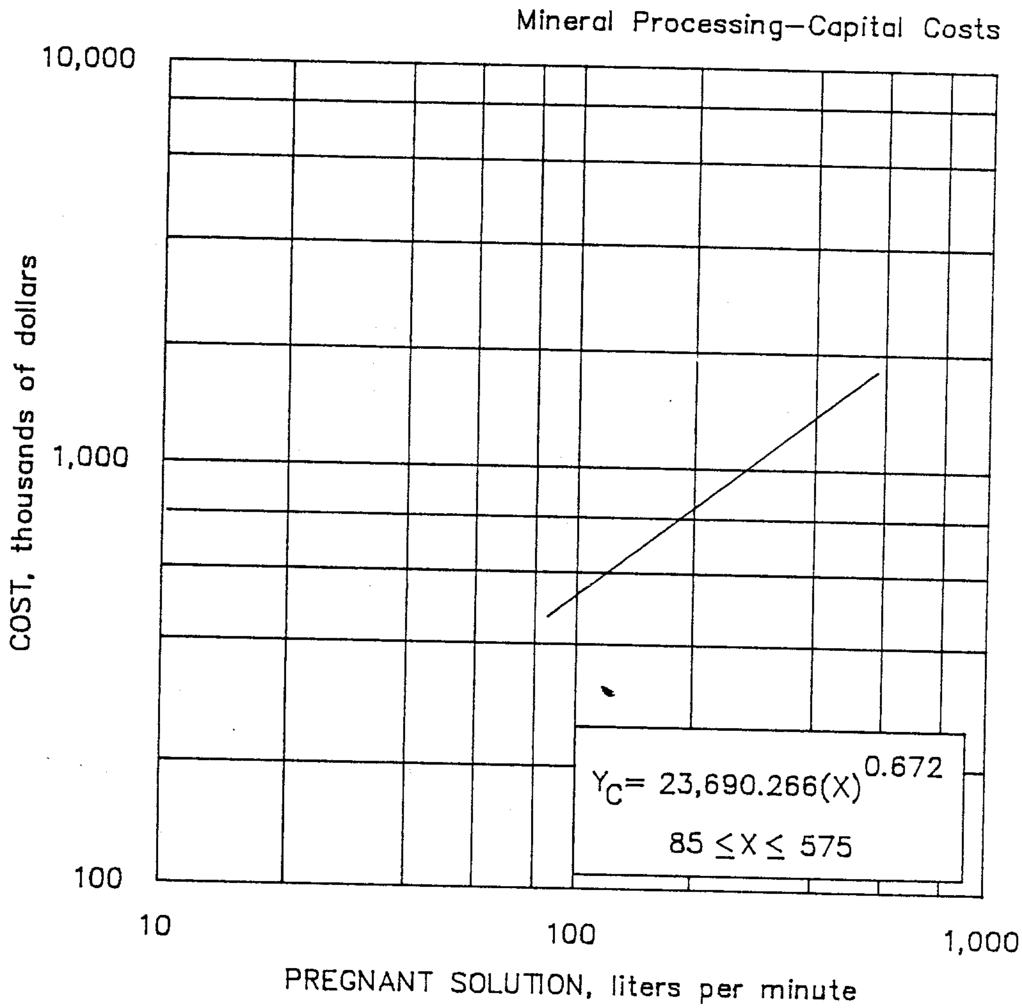
Shift Factor The capital cost curve is based on a three-shift-per-day operation. It is desirable to operate a beryllium solvent extraction circuit on a continuous basis to minimize the formation of crud and/or emulsion. The crud and/or emulsion from a beryllium solvent extraction circuit would probably contain radioactive materials that would require special disposal and/or processing at an additional cost. Therefore, no shift factor is recommended for beryllium solvent extraction circuits.

Number of Extraction Stages Factor The base curve is premised on the installation of seven extraction stages in the beryllium solvent extraction circuit. To adjust for a different number of extraction stages, multiply the cost obtained from the curve by the following factor:

Number of extraction stages factor $(F_E) = 0.326(E)^{0.576}$
where E = actual number of extraction stages.

<u>Number of Stripping Stages Factor</u> The base curve is premised on the installation of two stripping stages in the beryllium solvent extraction circuit. To adjust for a different number of stripping stages, multiply the cost obtained from the curve by the following factor:

Number of stripping stages factor $(F_S) = 0.883(S)^{0.180}$
where S = actual number of stripping stages.




6.1.5.2.1. Solvent extraction
BERYLLIUM

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.2.2. SOLVENT EXTRACTION
COPPER

The capital cost includes the acquisition and installation of equipment items associated with the solvent extraction circuit for copper. Major equipment items include storage tanks, pumps, mixer-settlers, and mixer mechanisms.

BASE CURVE

The capital cost curve is based on a single curve having an adjusted feed rate (X), in liters of clarified pregnant aqueous solution to the solvent extraction circuit per minute. The curve is valid for operations between 8,000 and 27,000 L/min, operating three shifts per day.

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

| | |
|---|---|
| Construction labor cost.... | 25.3% |
| Construction supply cost... | 51.4% |
| Purchased equipment cost... | 22.9% |
| Transportation cost........ | 0.4% |

The total capital cost is $(Y_C) = 382.979(X)^{0.955}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 96.894(X)^{0.955}$

(S) Construction Supply Cost $(Y_S) = 196.851(X)^{0.955}$

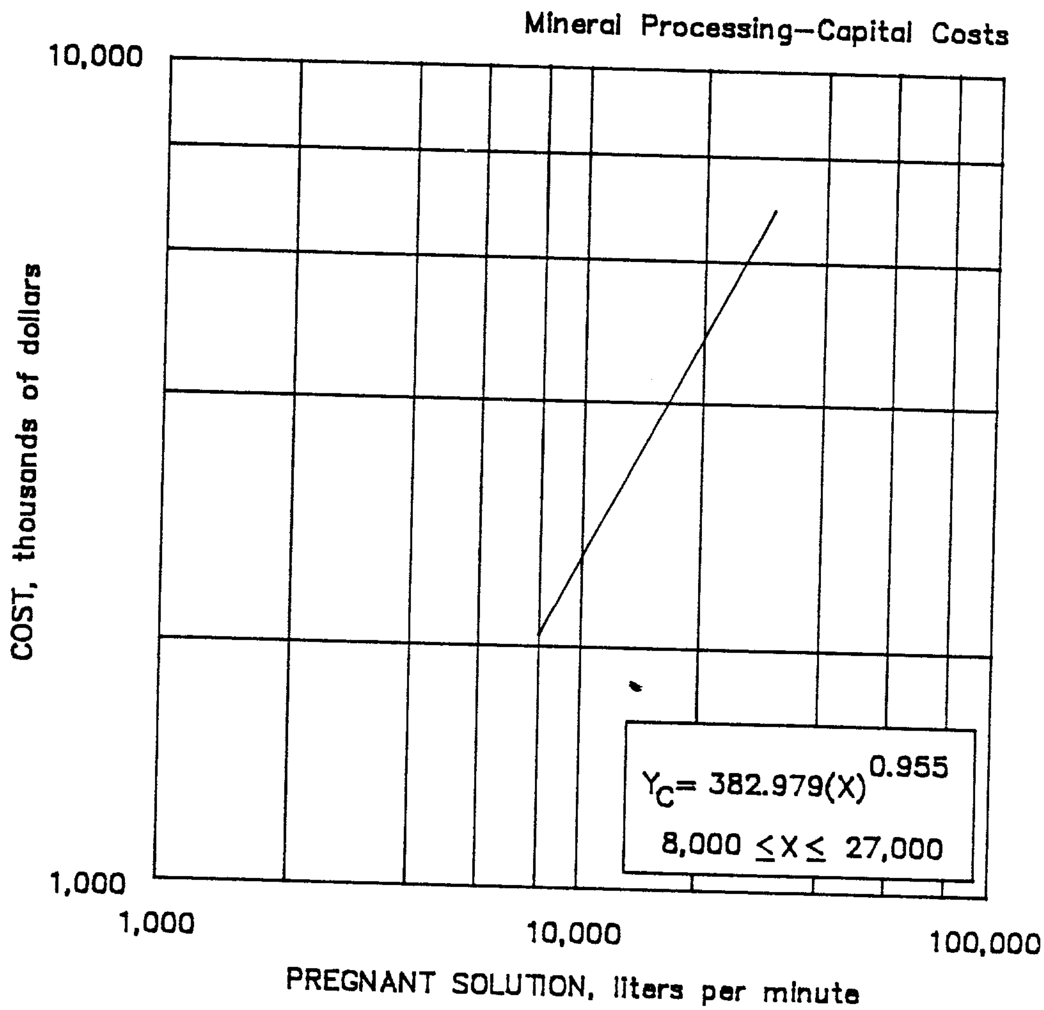
(E) Purchased Equipment Cost $(Y_E) = 89.234(X)^{0.955}$

ADJUSTMENT FACTORS

Shift Factor The capital cost curve is based on a three-shift-per-day operation. It is desirable to operate a copper solvent extraction circuit on a continuous basis to minimize the formation of crud and/or emulsion. The crud and/or emulsion from a copper solvent extraction circuit would probably contain radioactive materials that would require special disposal and/or processing at an additional cost. Therefore, no shift factor for copper solvent extraction circuits is recommended.

Number of Stages Factor The base curve is premised on a total of eight stages (four extraction and four stripping) in the solvent extraction circuit. To adjust for a different number of stages, multiply the cost obtained from the curve by the following factor:

Number of stages factor $(F_N) = 0.249(N)^{0.668}$
where N = total number of extraction and stripping stages.




6.1.5.2.2. Solvent extraction
COPPER