7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.1. AMALGAMATION

The operating cost curves for amalgamation are given on a cost per day basis. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) at the feed rate (X), in metric tons of feed material to the amalgamation circuit per day. The curves are valid for operations between 0.40 and 65.0 mtpd. At low feed rates, the amalgamation circuit is normally operated on a one batch per day cycle, while at high feed rates, the operation is continuous.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 20.230(X)^{0.251}$
The operating labor costs consist of the following typical range of personnel:

	Small (0.4 to 1 mtpd)	Large (1 to 65 mtpd)
Direct labor................	100%	82%
Maintenance labor...........	0%	18%

The average base salary including burden for labor is as follows:

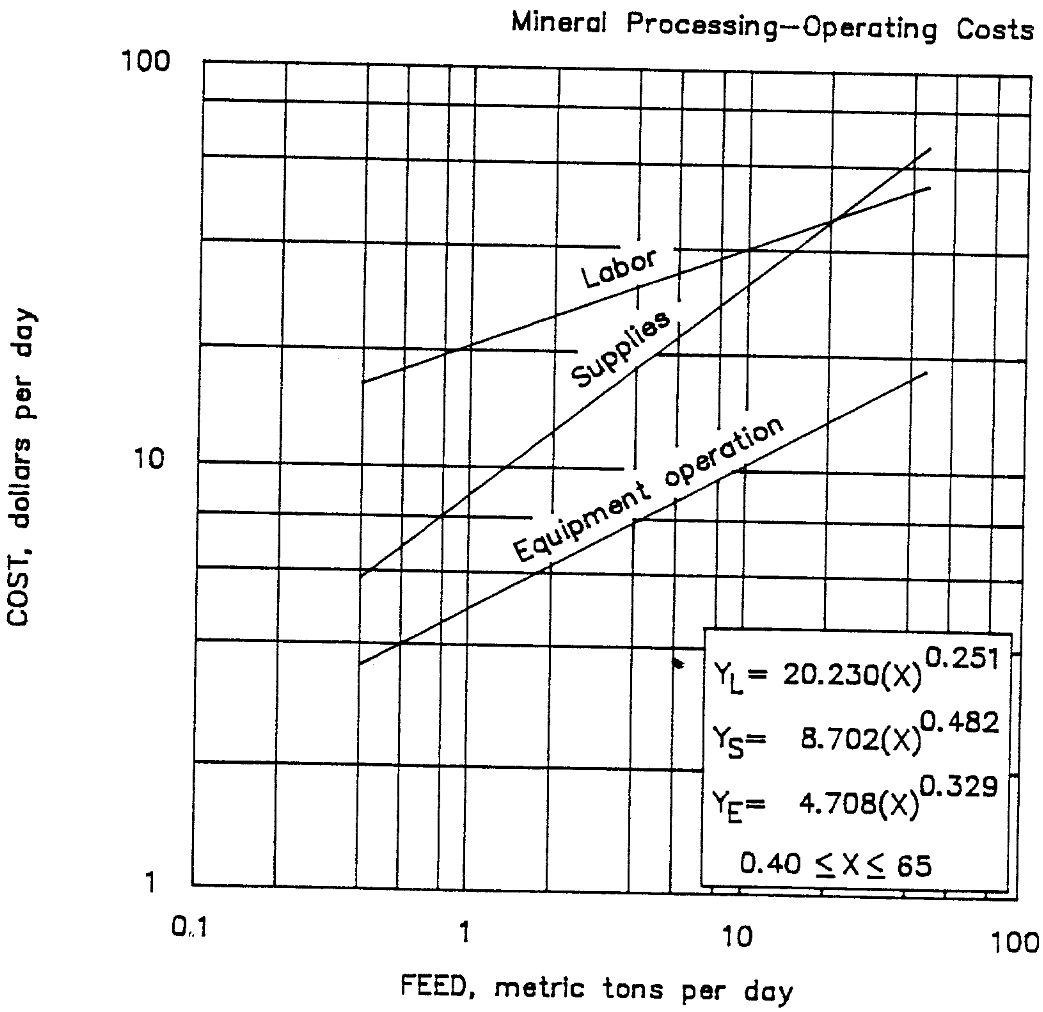
	Small (0.4 to 1 mtpd)	Av salary per hour (base rate)	Large (1 to 65 mtpd)	Av salary per hour (base rate)
Mill operator...........	100%	$16.78	100%	$17.11

The average wage for labor is $16.92 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 8.702(X)^{0.482}$
The supply cost consists of the following:

	Small (0.4 to 1 mtpd)	Large (1 to 65 mtpd)
Electric power.........	23%	81%
Mercury................	77%	19%

(E) Equipment Operating Cost $(Y_E) = 4.708(X)^{0.329}$
The equipment operation curve consists of 100% for repair parts and materials.



7.1.6.1. Amalgamation

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.2.1. BRINE RECOVERY
LITHIUM (WELLS)

The operating cost curves include the operation and maintenance of the brine recovery system, including solar evaporation ponds where applicable. The total daily operating cost for lithium from wells is the sum of three separate cost curves (labor, supplies, and equipment operation) having a feed rate (X), in liters of brine solution per minute pumped from the well field to the solar evaporation ponds. The curves are valid for operations between 1,300 and 9,700 L of brine solution, operating three shifts per day.

BASE CURVE

The operating cost curves for a lithium brine recovery includes the wells and solar evaporation ponds.

(L) Labor Operating Cost $(Y_L) = 5.985(X)^{0.635}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	80%
Maintenance labor...........	20%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Pond operator..............	38%	$16.78
Dragline operator...........	5%	16.78
Loader operator............	9%	16.78
Truck driver...............	15%	16.78
Laborer....................	33%	11.68

The average wage for labor is $15.02 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.147(X)^{0.958}$
The supply operating cost consists of 99.5% electric power and 0.5% lime.

(E) Equipment Operating Cost $(Y_E) = 5.550(X)^{0.493}$
The equipment operating curve includes an allowance for the replacement of items such as motors, pump parts, piping, and the operation of mobile equipment associated with the lithium brine recovery system.

Diesel fuel....................	34.0%
Gasoline.......................	18.1%
Mobile equipment repair parts...	17.1%
Pumping system repair parts.....	12.5%
Tires..........................	11.3%
Lubrication....................	7.0%

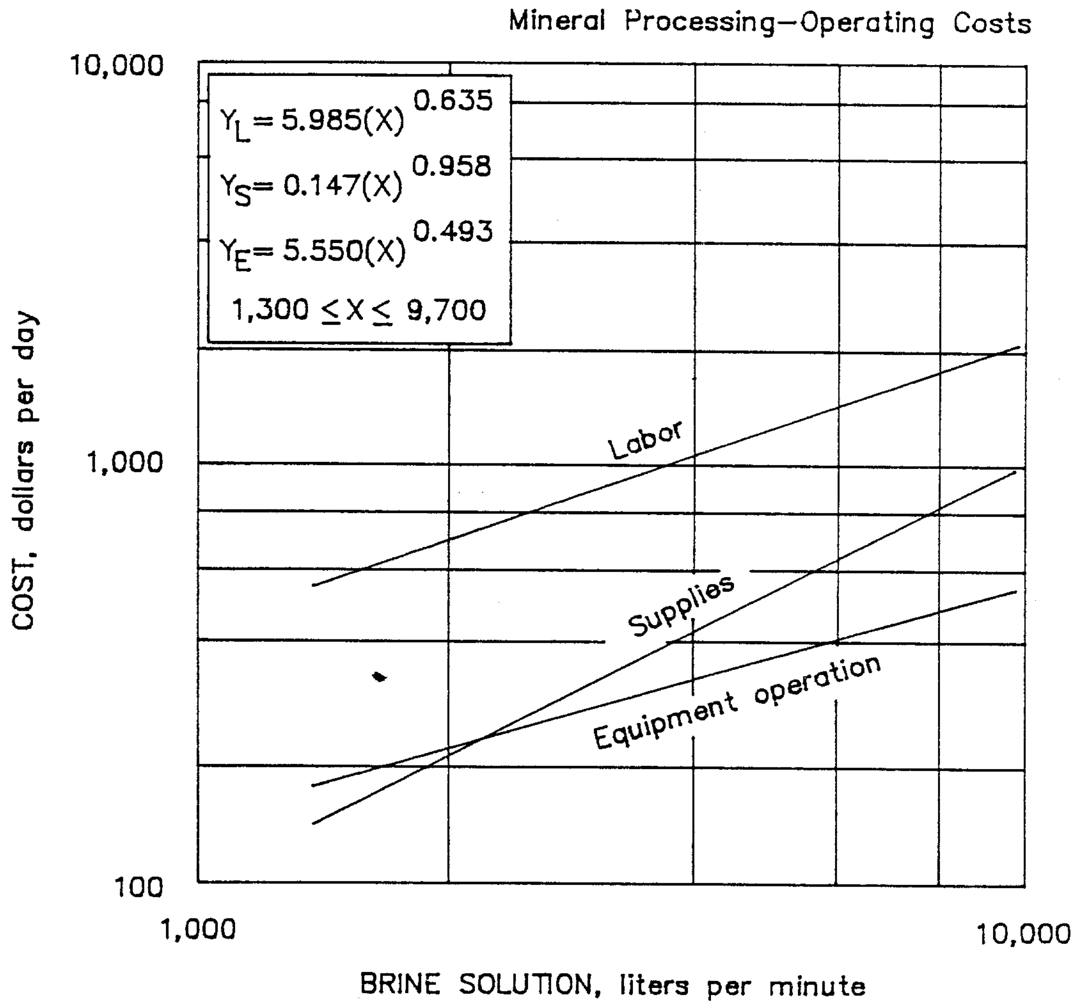
ADJUSTMENT FACTORS

<u>Well Depth Factor</u> The curves are based on an average well depth of 150 m. To adjust for a different well depth, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.078(D)^{0.508}$

Equipment operation factor $(F_E) = 0.921(D)^{0.016}$

where D = well depth, in meters.



7.1.6.2.1. Brine recovery
LITHIUM (WELLS)

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.2.2. BRINE RECOVERY
MAGNESIUM (SEAWATER)

The operating cost curves for a brine recovery system from seawater for the extraction of magnesium consists of the seawater pumping system located on a pier. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a feed rate (X), in liters of seawater per minute pumped to the extraction plant. The curves are valid for operations between 3,500 and 91,400 L/min of brine solution, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 0.082(X)^{0.615}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	93%
Maintenance labor...........	7%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Control room operator.......	11%	$17.23
Pump operator...............	89%	16.78

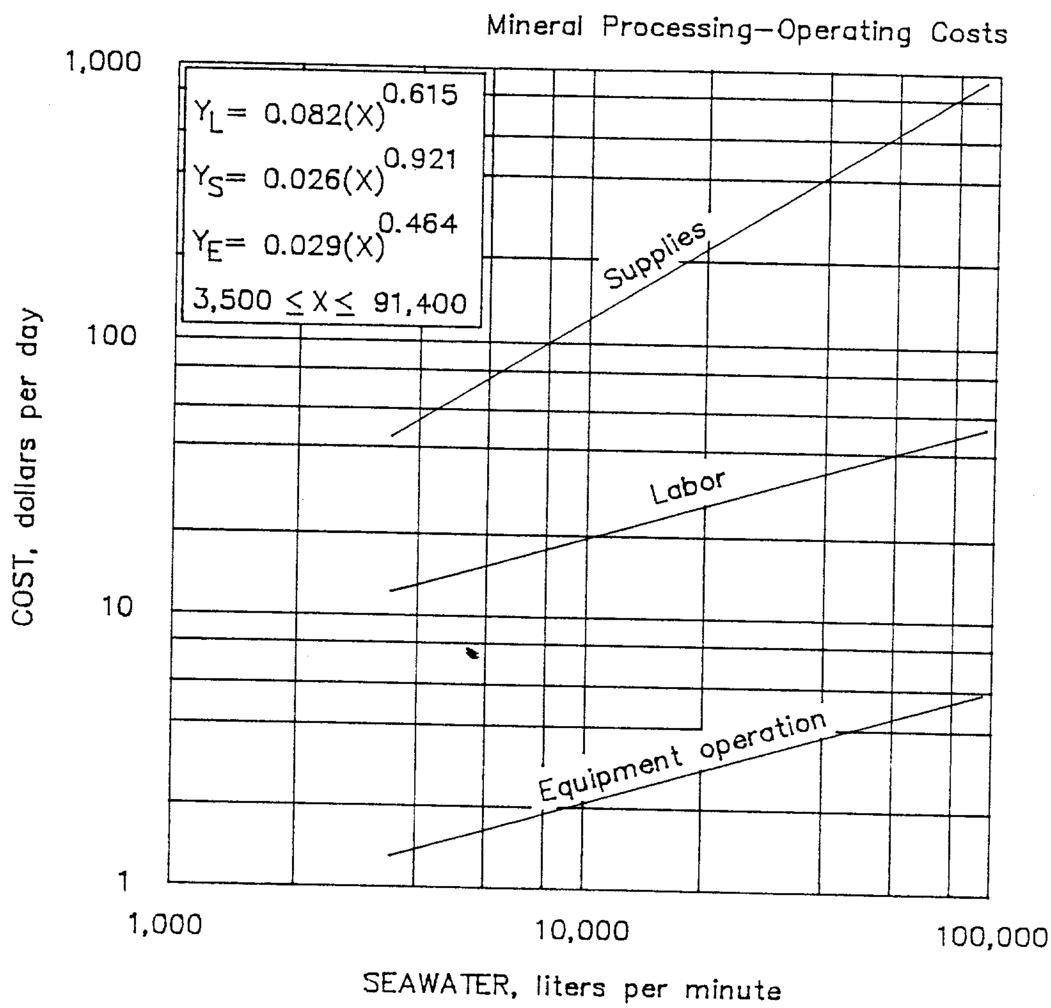
Direct labor costs average $16.83 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.026(X)^{0.921}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.029(X)^{0.464}$
The equipment operation curve consists of 100% for repair parts and materials for the seawater pumps.

ADJUSTMENT FACTOR

Shift Factor The base curves are based on a three-shift-per-day operation. It is desirable to operate the seawater pumping system on a continuous basis to maintain a steady feed to the subsequent processing circuits. No adjustment factor for a one- or two-shift-per-day operation is recommended.



7.1.6.2.2. Brine recovery
MAGNESIUM (SEAWATER)

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.2.3. BRINE RECOVERY MAGNESIUM (WELLS)

The operating cost curves for a brine recovery system from wells for the extraction of magnesium consists of the well field pumping system and storage facility at the chemical plant. The total daily operating cost for magnesium from wells is the sum of three separate cost curves (labor, supplies, and equipment operation) having a feed rate (X), in liters of brine solution per minute pumped from the well field to the chemical processing plant. The curves are valid for operations between 770 and 7,000 L/min of brine solution, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 0.316(X)^{0.986}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	36%
Maintenance labor...........	64%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Pumpman-oiler...............	100%	$16.78

Direct labor costs average $16.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.729(X)^{0.979}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.223(X)^{0.969}$
The equipment operation curve consists of

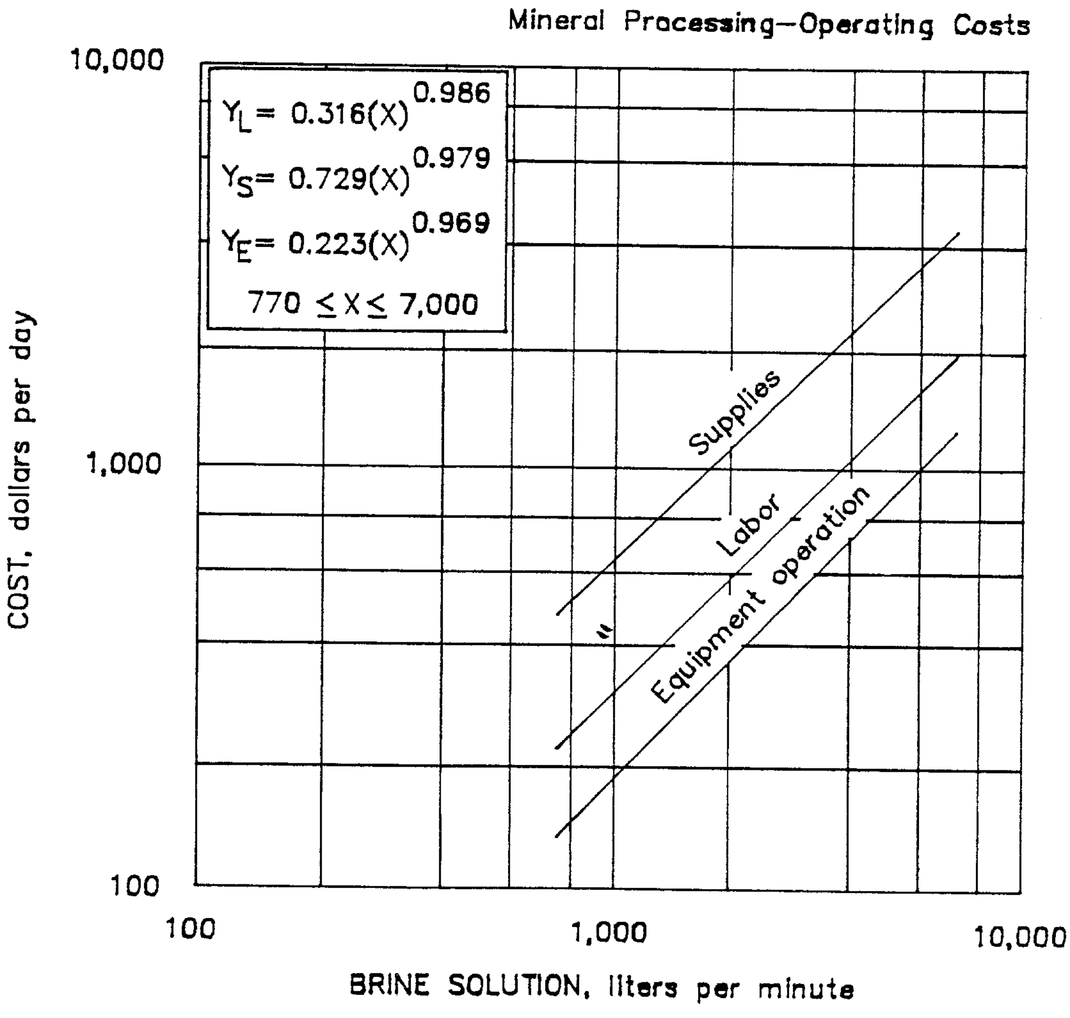
Pumping system repair parts......	85.7%
Gasoline.........................	6.9%
Diesel fuel......................	4.1%
Lubrication......................	1.6%
Tires............................	0.9%
Mobile equipment repair parts....	0.8%

ADJUSTMENT FACTOR

Well Depth Factor The curves are based on an average well depth of 1,400 m. To adjust for a different well depth, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.043(D)^{0.434}$

Equipment operation factor $(F_E) = 0.442(D)^{0.113}$
where D = well depth, in meters.



7.1.6.2.3. Brine recovery
MAGNESIUM (WELLS)

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.2.4. BRINE RECOVERY MAGNESIUM-POTASH (LAKES)

The operating cost curves for a brine recovery system from lakes for the extraction of magnesium and potash consist of a brine pumping system, solar evaporation ponds, mobile and harvesting equipment. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a feed rate (X), in billion liters of brine solution per year pumped from the lake to the to the solar evaporation ponds. The curves are valid for operations between 50 and 105 billion L/yr of brine solution, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 49.455(X)^{0.886}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	83%
Maintenance labor...........	17%

The average base salary including burden for labor is as follows:

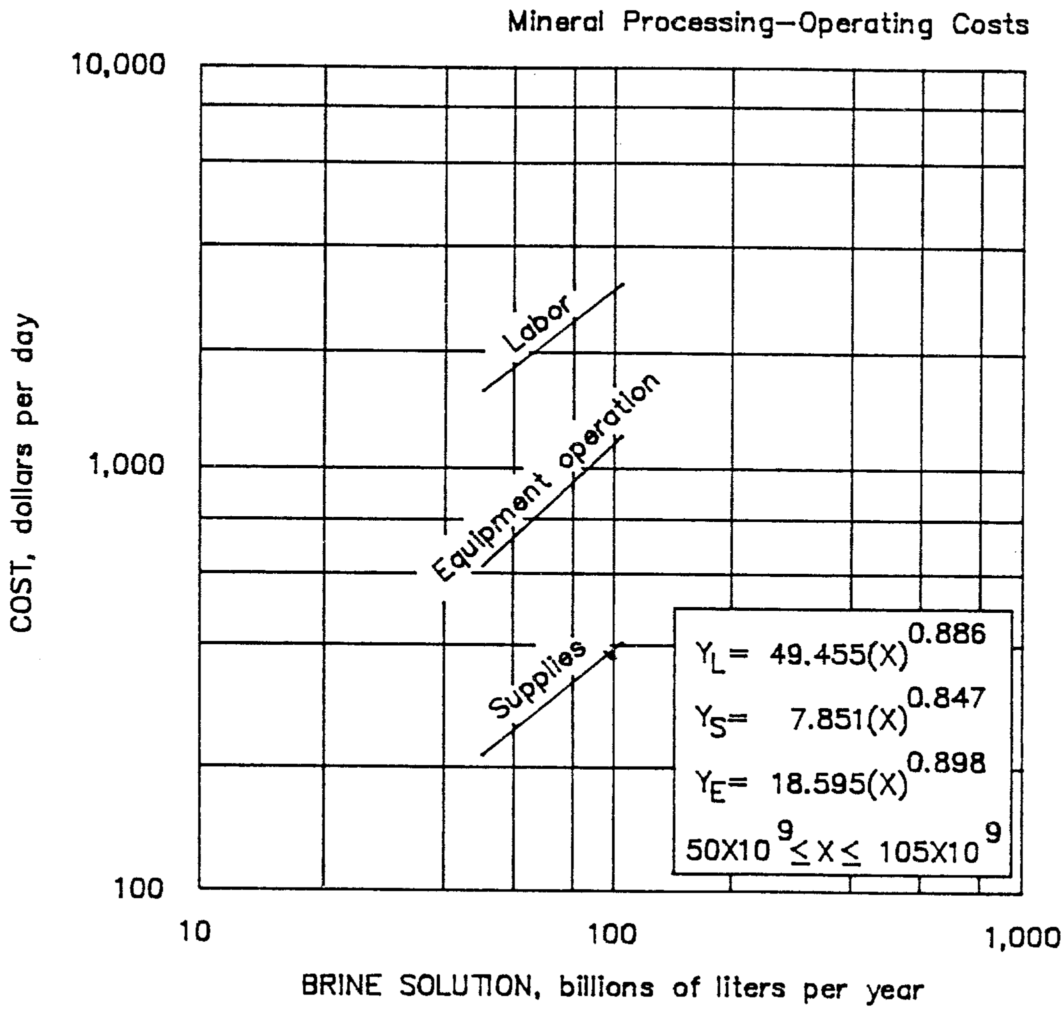
		Av salary per hour (base rate)
Pumpman....................	6%	$16.78
Equipment operator..........	63%	16.78
Scraper operator............	23%	16.78
Harvest control operator....	8%	16.78

Direct labor costs average $16.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 7.851(X)^{0.847}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 18.595(X)^{0.898}$
The equipment operation curve consists of

Diesel fuel......................	35.1%
Mobile equipment repair parts....	34.5%
Pumping system repair parts......	12.2%
Tires............................	7.8%
Gasoline.........................	7.1%
Lubrication......................	3.3%



7.1.6.2.4. Brine recovery
MAGNESIUM/POTASH (LAKES)

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.2.5. BRINE RECOVERY
POTASH (FLOODED MINE)

The operating cost curves for a brine recovery system from a flooded mine for the extraction of potash consists of the brine pumping system, solar evaporation ponds, and mobile and harvesting equipment. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a feed rate (X), in liters of brine solution per minute pumped from the flooded mine to the solar evaporation ponds. The curves are valid for operations between 3,200 and 13,000 L/min, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 4.349(X)^{0.638}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	84%
Maintenance labor...........	16%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Pond operator...............	37%	$16.78
Scraper operator............	26%	16.78
Laborer.....................	37%	11.68

Direct labor costs average $15.20 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.134(X)^{0.948}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $Y_E = 0.569(X)^{0.711}$
The equipment operation curve consists of

Gasoline........................	28.8%
Diesel fuel.....................	21.8%
Mobile equipment repair parts....	17.3%
Tires...........................	16.8%
Pumping system repair parts......	10.6%
Lubrication.....................	4.7%

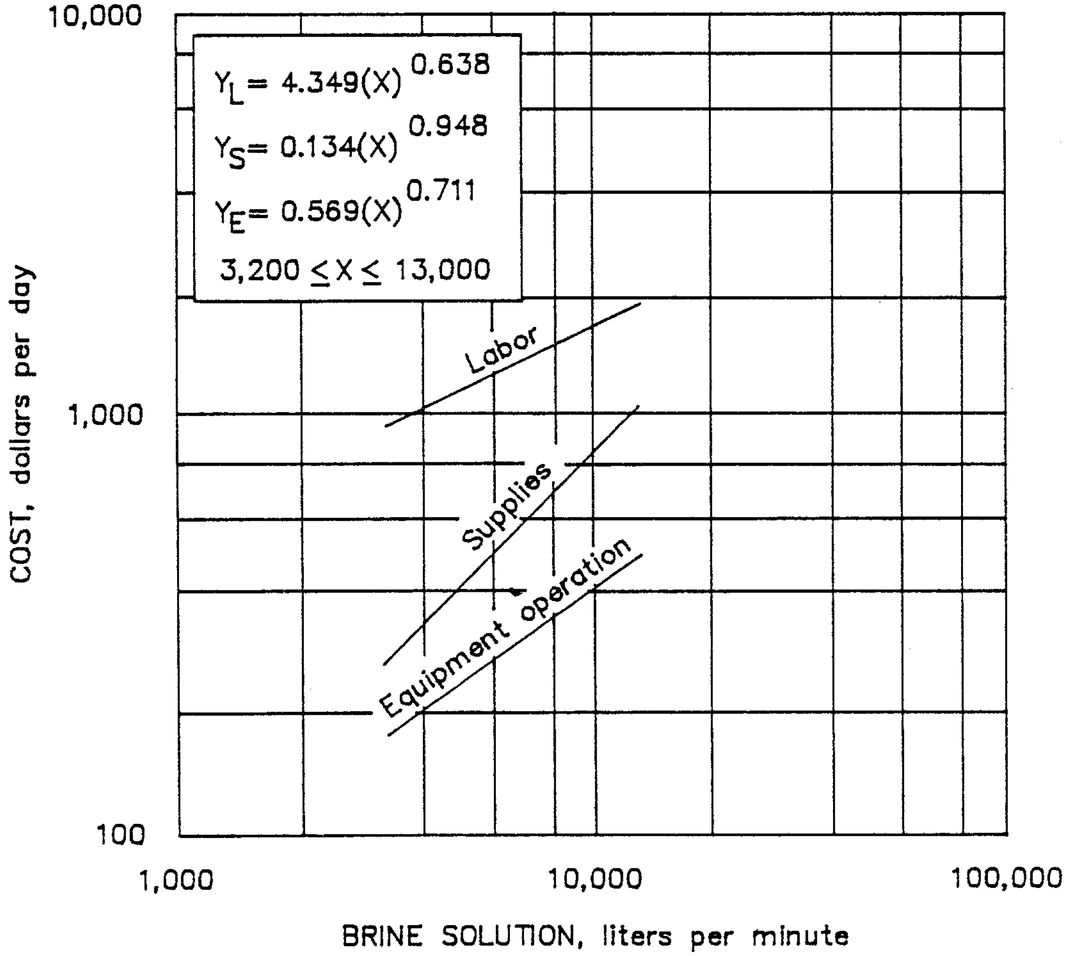
ADJUSTMENT FACTOR

Pumping Head Factor The curves are based on an average pumping head of 244 m. To adjust for a different pumping head, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.106(H)^{0.408}$

Equipment operation factor $(F_E) = 0.832(H)^{0.034}$
where H = pumping head, in meters.

Mineral Processing—Operating Costs



7.1.6.2.5. Brine recovery
POTASH (FLOODED MINE)

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.3. CALCINATION (ROTARY KILN)

This section covers the cost of calcining (or applying high heat to) limestone or other ores or materials, using appropriate adjustment factors. Common to all these applications is the use of a refractory-lined rotary kiln, with the heat flowing counter current to the flow of the product. No utilization of waste heat is considered although the rotary-kiln treatment of certain materials is accompanied by waste-heat boilers or other energy-conserving equipment.

The great majority of plants in the United States calcining limestone ($CaCO_3$) to lime (CaO) use coal, a major change from a decade ago, when natural gas or fuel oil were the predominant fuels. This section includes delivery of the material to the kiln and conveyance of the product from the kiln. Coal handling from railway cars through the coal mill is included, as well as dust collection from the kilns.

Major equipment, in addition to the kiln, consists of conveyor belts, fans, dust-collecting equipment, coal-handling equipment, and controls. This section includes a subsection allowing the user to cost the storage and load-out of the product.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the calcined product output (X), in metric tons of material per day. The curves are valid for operations between 100 and 6,000 mtpd, operating three shifts per day. The curves do not include crushing; the ratio of maximum-to-minimum size of the feed particles should not exceed 3:1 for mini-
mally acceptable kiln operation and 2:1 for optimum kiln operation. For limestone, about 62% of feed to the kiln is recovered as product (lime), the balance being lost as dust or CO_2.

A tabulation is provided that lists characteristics of materials which are commonly processed in a rotary kiln. Using the tabulation, adjustments can be made for materials other than limestone.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 48.580(X)^{0.567}$
The operating labor costs consist of the following typical range of personnel:

	Small (100 to 750 mtpd)	Large (750 to 6,000 mtpd)
Direct labor	46%	19%
Maintenance labor	54%	81%

The average base salary including burden for labor is as follows:

	Small (100 to 750 mtpd)	Large (750 to 6,000 mtpd)	Av salary per hour (base rate)
Kiln operator..............	74%	62%	$15.89
Utility....................	17%	19%	14.56
Coal handling	9%	19%	14.56

The average wage for labor is $15.66 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 16.038(X)^{0.991}$
Supplies costs consist of 84% bituminous coal and 16% electric power.

(E) Equipment Operating Cost $(Y_E) = 12.318(X)^{0.722}$
Equipment operation consists of 93% for repair parts and 7% lubricants for kilns, coal mills, fans, conveyors, elevators, and other equipment.

ADJUSTMENT FACTORS

The cost of fuel (coal) is dependent on the price of the coal, freight rates, heat content, and heat rate required to calcine a particular ore or material. Heating values used in this section are 11,300 Btu heat content per pound of coal and 7.44 million Btu heat requirement per metric ton of lime produced. Note that the heat requirement for calcining other ores or materials may vary considerably from this figure (see tabulation).

Fuel Oil Adjustment Factor If fuel oil is used instead of coal, multiply the labor cost obtained from the curve by the following factor:

Labor factor $(F_{L\ OIL}) = 0.92$

multiply the fuel portion of the supply cost by the following factor:

Supply factor (fuel) $(F_{S\ OIL}) = 4.6$

and multiply the electric power portion of the supply cost by the following factor:

Supply factor (electric power) $(F_{S\ OIL}) = 0.71$

and multiply the equipment operation cost obtained from the curve by the following factor:

Equipment operation factor $(F_{E\ OIL}) = 0.97$

Natural Gas Adjustment Factor If natural gas is used instead of coal multiply the labor cost obtained from the curve by the following factor:

Labor factor $(F_{L\ GAS}) = 0.85$

multiply the fuel portion of the supply cost by the following factor:

Supply factor (fuel) $(F_{S\ GAS}) = 2.2$

and multiply the electric power portion of the supply cost by the following factor:

Supply factor (electric power) $(F_{S\ GAS}) = 0.7$

and multiply the equipment operation cost obtained from the curve by the following factor:

Equipment operation factor $(F_{E\ GAS}) = 0.95$

<u>Heat Rate Factor</u> When the heat rate for calcining a material is different than that for limestone (7.44 MMBtu/mt), multiply the fuel portion of the supply curve by the appropriate value from the fuel rate column of product, of the tabulation that follows.

<u>Length-to-Diameter Ratio Factor</u> For length-to-diameter (L/D) ratios different than 32, multiply the electric power portion of the supply curve by the following factor (see the length-diameter ratio), column of the following tabulation for ratios for various commodities):

Supply factor (electric power) $(F_{S\ L/D}) = 0.710(R)^{0.098}$
where R = length-to-diameter multiplier from the table.

<u>Specific Gravity Factor</u> For specific gravities different than 1.18, multiply the electric power portion of the supply curve by the following factor (see the specific gravity column of the tabulation for SG values for various commodities).

Supply factor (electric power) $(F_{S\ SG}) = 0.990(S)^{0.059}$
where S = specific gravity multiplier from the table.

Actual costs, unit prices, wages, and other values, if known, may be substituted for values given in the above descriptions.

STORAGE AND LOADOUT OF PRODUCT

Should it be desired to store the product from the kiln and load it into either trucks or railroad cars, this section will supply costs for this operation. Included are conveyors, bucket elevators, vibrating-screen, crusher, and steel storage bins. The total daily operating cost is the sum of three separate cost equations (labor, supplies, and equipment operation) based on the product storage, load-out rate (X), in metric tons material per day. The curves are valid for operations between 100 and 6,000 mtpd, operating three shifts per day.

(L) Labor Operating Cost $(Y_L) = 29.610(X)^{0.470}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	32%
Maintenance labor...........	68%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Conveyor operator...........	100%	$14.56

The average wage for labor is $14.81 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.450(X)^{0.685}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 37.450(X)^{0.400}$
The equipment operation curve consist of 93% for repair parts and 7% for lubricants for conveyors, elevators, screens, and the crusher.

Rotary kiln calcination - Feed and product characteristics and cost factors

Product and feed or reaction	Normal moisture in feed, %	Fuel rate[1] Btu/mt product	Fuel cost multi-plier[2]	Length diameter ratio[3] (L/D)	Specific gravity[4]
Lime (CaO): Limestone	0- 3	7.44	1.00	32	1.18
Lime, magnesia: Dolomite	0- 3	7.55	1.01	35	1.18
Alumina: Aluminum hydroxide	15	5.40	0.73	30	1.04
Light weight aggregate: Clay, shale	3- 7	2.54	0.34	18	0.56
Petroleum coke: Burn off volatiles	6-14	1.65	0.22	20	0.69
Clay: Evaporate H_2O and densifier	0-24	5.62	0.76	24	0.85
Periclase: Brucite, magnesiz	50	12.68	1.70	30	1.93
Phosphate:					
Nodulize	15-30	3.31	0.44	22	1.28
Calcine $CaCO_3$	0- 1	4.32	0.58	36	1.28
Burn off carbonaceous material	10-15	2.04	0.27	20	1.28
Diatomaceous earth: Burn off carbonaceous material	0- 5	4.8	0.63	15	0.52
Manganese oxide: Manganese carbonate	3-10	4.5	0.60	28	1.90

[1]Lime value is from kiln manufacturer; others are averages from Engineering and Mining Journal, June 1980, page 139.

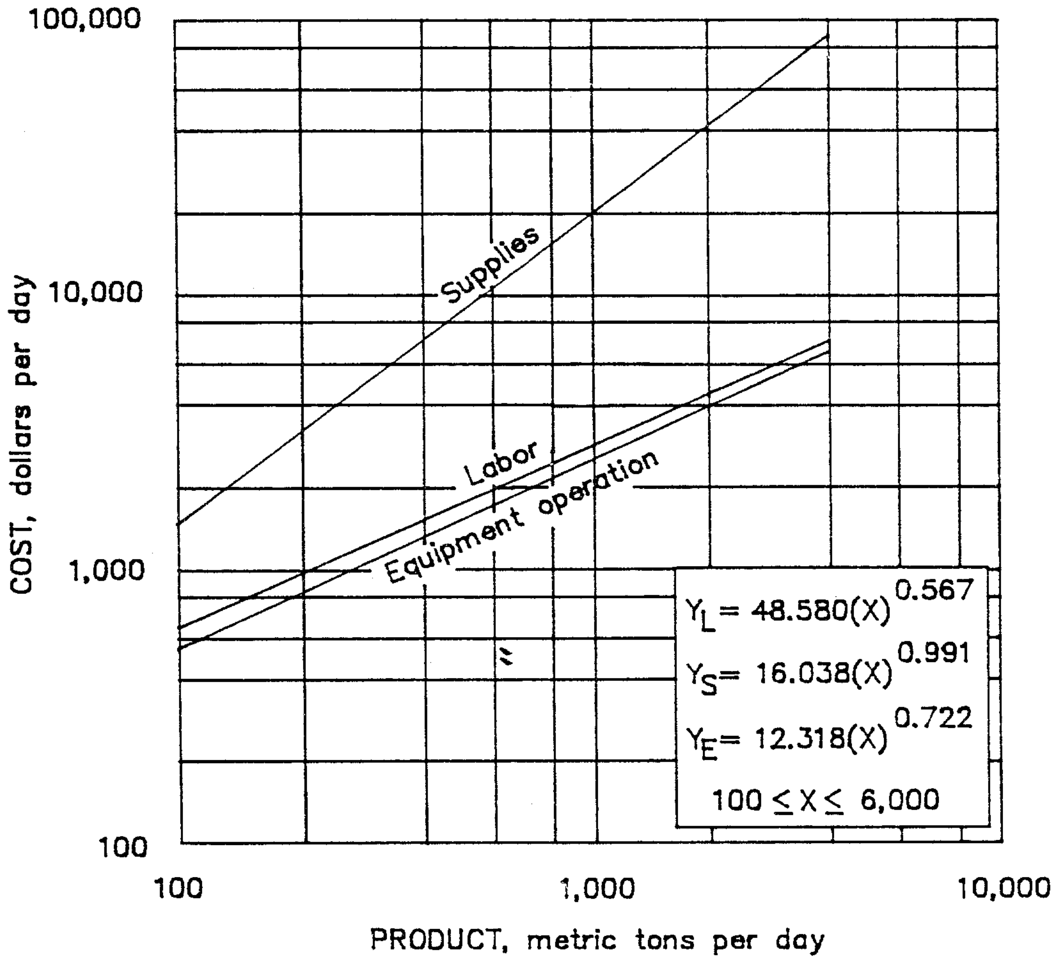
[2]To determine cost of coal burned to calcine a particular material, multiply the fuel portion of the supplies curve by the appropriate multiplier.

[3]Averages for kiln: from Engineering and Mining Journal, June 1980, page 139.

[4]Approximate average values (bulk form, i.e., including voids) of materials during processing in the kiln; values from various sources: KVS Handbook, Perry's Engineering Manual, CRC Handbook.

NOTE.—No sulfides are considered because: 1) sulfides are not usually roasted in a rotary kiln (multiple-hearth vertical furnaces are frequently used), 2) the varying amounts of sulfur (oxidation of which is exothermic) would make fuel adjustment factors cumbersome, and 3) a flue gas scrubber (with lime addition) is probably necessary to meet environmental requirements (unless the SO_2 is used for acid manufacturing, which is not infrequently the case).

Mineral Processing—Capital Costs



7.1.6.3. Calcination (rotary kiln)

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.4. CALCINING (DEADBURNED MAGNESIUM)

The operating cost curves for calcining are given on a metric tons of feed per day basis. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) at the capacity rate (X), in metric tons of feed material to the kiln per day, The curves are valid for capacities between 60 and 910 mtpd, operating on a continuous basis.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 64.611(X)^{0.517}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	69%
Maintenance labor...........	31%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Control room operator.......	51%	$17.56
Kiln helper.................	49%	13.99

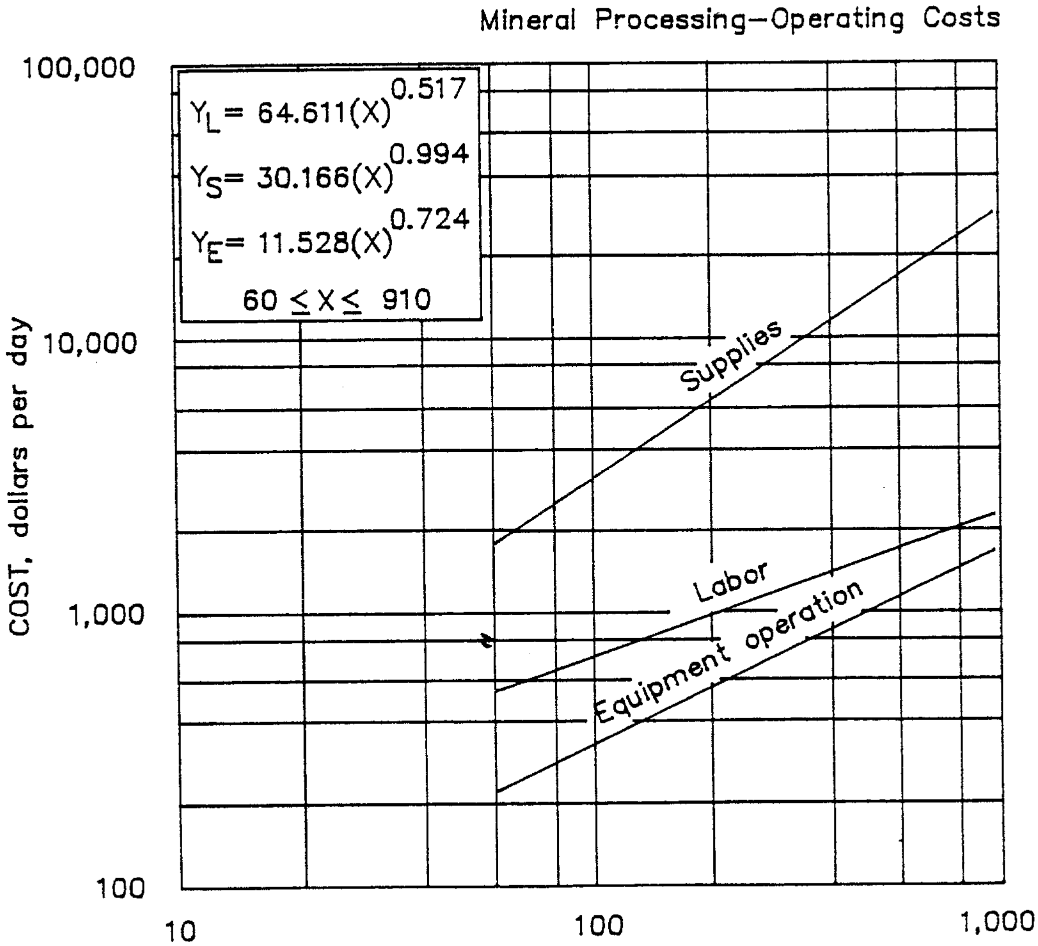
The average wage for labor is $16.19 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 30.166(X)^{0.994}$
The supply costs consist of 96.5% natural gas and 3.5% electric power.

(E) Equipment Operating Cost $(Y_E) = 11.528(X)^{0.724}$
The equipment operation curve consists of 100% for repair parts and materials.

ADJUSTMENT FACTOR

Shift Factor The base curve is premised on a three-shift-per-day operation. Based on industry practice, it is desirable to operate a calcining operation for deadburned magnesium on a continuous basis. Therefore, no adjustment factor for the number of operating shifts is recommended.



7.1.6.4. Calcining (deadburn magnesium)

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.5. COMPACTION

The operating costs for compaction are given on a metric ton per day of final product basis for the compaction of potash. The costs include the operation of compactors, impactors, screens, screw conveyors, belt conveyors, and bucket elevators. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the compaction rate (X), in metric tons of final compacted product per day. The curves are valid for operations between 220 and 3,150 mtpd, operating three shifts per day.

BASE CURVE

The base curve is for the compaction of potash. The base curves assume that 50% of the compactor feed will report as final product.

(L) Labor Operating Cost $(Y_L) = 3.831(X)^{0.715}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	76%
Maintenance labor...........	24%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Compaction operator	100%	$16.78

The average wage for labor is $16.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.977(X)^{0.990}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 3.489(X)^{0.783}$
The equipment operation curve consists of 100% for repair parts and materials.

ADJUSTMENT FACTORS

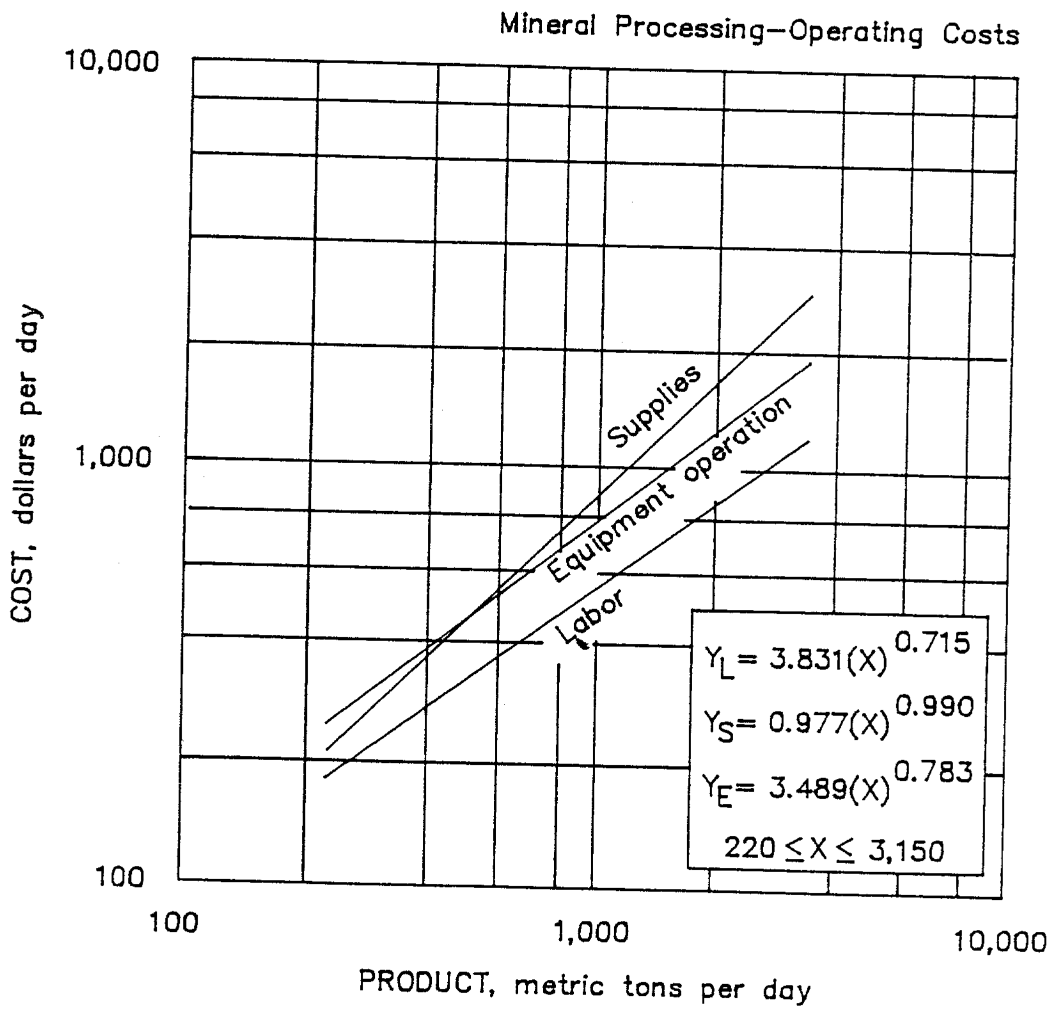
Compactor Feed Product Factor The dominant factor in compaction is the percent of compactor feed reports as final product. The base curve that is predicated on 50% of the compactor feed reporting as final product. The normal range of this variable is 25% to 75% of the feed reporting as product. To adjust for varying quantities of product in the compactor feed, multiply the costs obtained from the curves by the following factors:

Labor factor $(Y_L) = 1.020[(50/P)]^{0.721}$

Supply factor $(Y_S) = 50/P$

Equipment operating factor $(Y_E) = 0.992[(50/P)]^{0.798}$
where P = percent of feed reporting as product.

Shift Factor The curve is based on a three-shift-per-day operation. Typically, compaction circuits must be run continuously. For a one- or two-shift operation, decrease the operating costs proportionately.



7.1.6.5. Compaction

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.6. CRYSTALLIZATION

The operating cost curves for a potash crystallization circuit include its operation and maintenance of the crystallization circuit. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the production rate (X), in metric tons of crystallized product per day. The curves are valid for operations between 50 and 4,350 mtpd, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 21.076(X)^{0.549}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	52%
Maintenance labor...........	48%

The average base wages including burden for labor are as follows:

		Av salary per hour (base rate)
Control room operator.......	33%	$17.56
Crystallizer operator.......	60%	16.78
Laborer....................	7%	13.86

The average wage for labor is $16.95 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 5.317(X)^{0.990}$
The supply cost consists of 80.1% natural gas, 19.3% electric power, and 0.6% flocculant.

(E) Equipment Operation Cost $(Y_E) = 4.492(X)^{0.678}$
The equipment operation curve consists of 100% for repair parts and materials. The curve includes an allowance for the replacement of items such as motors, pumps parts, bearings, piping, and parts associated with the crystallization circuit.

ADJUSTMENT FACTORS

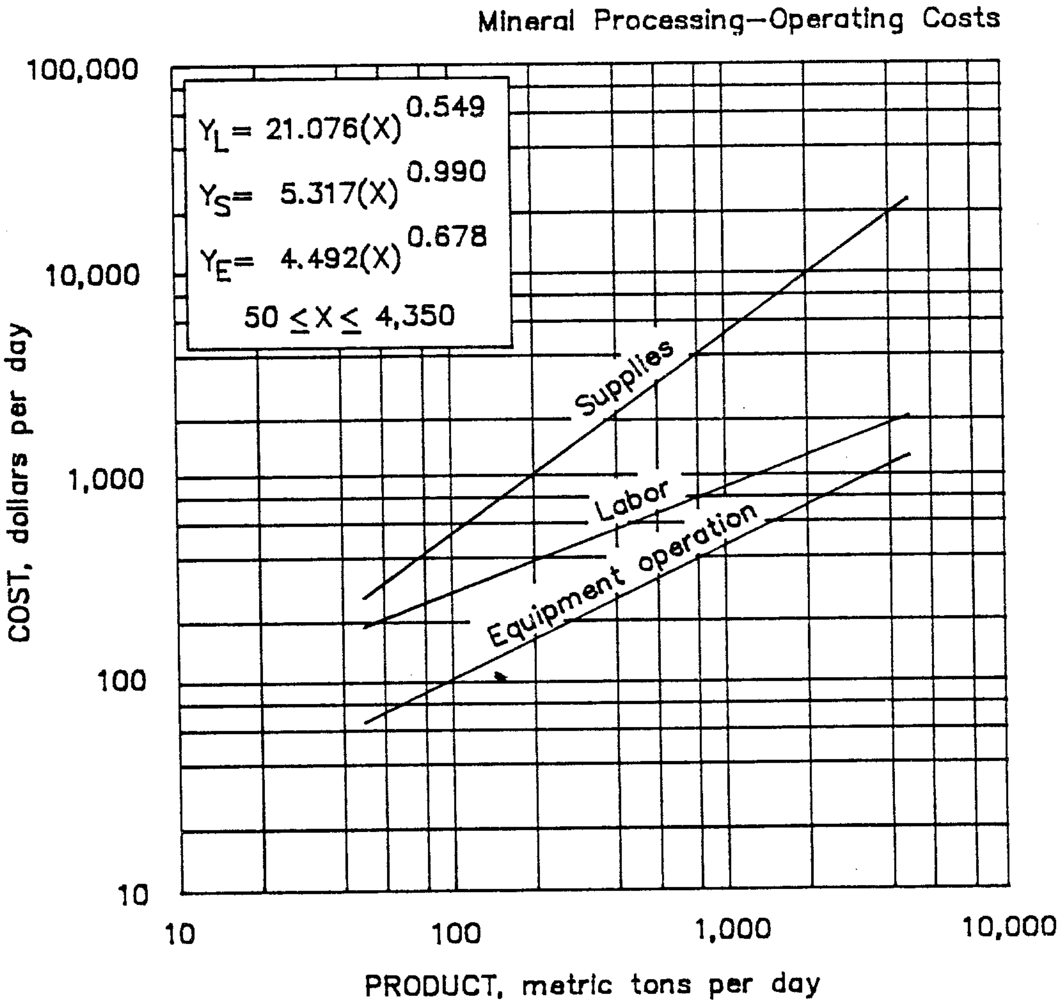
Shift Factor The base curves are based on a three-shift-per-day operation. It is desirable to operate a crystallization circuit on a continuous basis. Therefore, no adjustment factor for the number of shifts is recommended for crystallization.

Leaching Factor The base curves are premised on feed sources from effluents, baghouses, and dust collectors to the crystallization circuit for the recovery of crystallized potash. To adjust for the leaching of tailings or ore (no dissolving tanks), multiply the costs obtained from the curves by the following factors:

Labor factor (F_L) = 1.24

Supply factor (F_S) = 2.02

Equipment operation factor (F_E) = 1.25



7.1.6.6. Crystallization

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.7. FRASCH PROCESS

The operating cost curves for Frasch process include the production of moltén sulfur from underground deposits through the loading facility for transpor- tation in railcars or trucks to the consumer. Major equipment items operated include the sulfur wells, hot water process softeners, air compressors, mine water heaters, reagent handling system, sulfur relay stations, sulfur loading facilities, and pumps. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on an adjusted feed rate (X), in metric tons of sulfur per day. The curves are valid for operations between 1,150 and 7,900 mtpd, operating three shifts per day.

BASE CURVES

(L) <u>Labor Operating Cost</u> $(Y_L) = 175.888(X)^{0.585}$

The operating labor costs consist of the following typical range of personnel:

Direct labor.................	71%
Maintenance labor...........	29%

The operating labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Control room operator.......	11%	$17.23
Operator A..................	4%	16.78
Operator B..................	10%	13.66
Equipment operator..........	6%	16.78
Truck driver................	11%	16.78
Driller.....................	10%	16.78
Driller B...................	17%	13.66
Utility operator............	24%	14.56
Technician..................	7%	15.44

The average mine labor cost per worker-hour is $15.78 (including burden and average shift differential).

(S) <u>Supply Operating Cost</u> $(Y_S) = 31.934(X)^{0.991}$

The supply cost consists of 85.4% natural gas, 7.4% electric power, 4.3% water, 2.4% fuel, and 0.5% reagents.

(E) <u>Equipment Operating Cost</u> $(Y_E) = 4.918(X)^{0.997}$

The equipment operation curve consists of 80.8% for the replacement of production wells and 19.2% for repair parts and materials.

ADJUSTMENT FACTORS

Water-Sulfur Ratio Factor The base curve is based on a water-sulfur ratio of 3,000 gal of water per metric ton of sulfur produced. To adjust the base curve for other ratios, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor (F_S) = 0.0003(R)+0.030

Equipment operating factor (F_E) = 0.00002(R)+0.932
where R = water/sulfur ratio, in gallons of water per metric ton of sulfur produced.

Water Quality Factor The base curves are based on a raw water quality as total hardness of 100 mg of $CaCO_3$ per milliliter. To adjust the base curves for other water qualities, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor (F_S) = 0.00007(W)+0.994

Equipment operating factor (F_E) = 0.00001(W)+0.999
where W = water quality as total hardness of $CaCO_3$ per milliliter.

Bleeder Well Factor The base curves did not consider the use of bleeder wells. To adjust for the utilization of bleeder wells, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor (F_S) = 0.58

Equipment operating factor (F_E) = 1.35

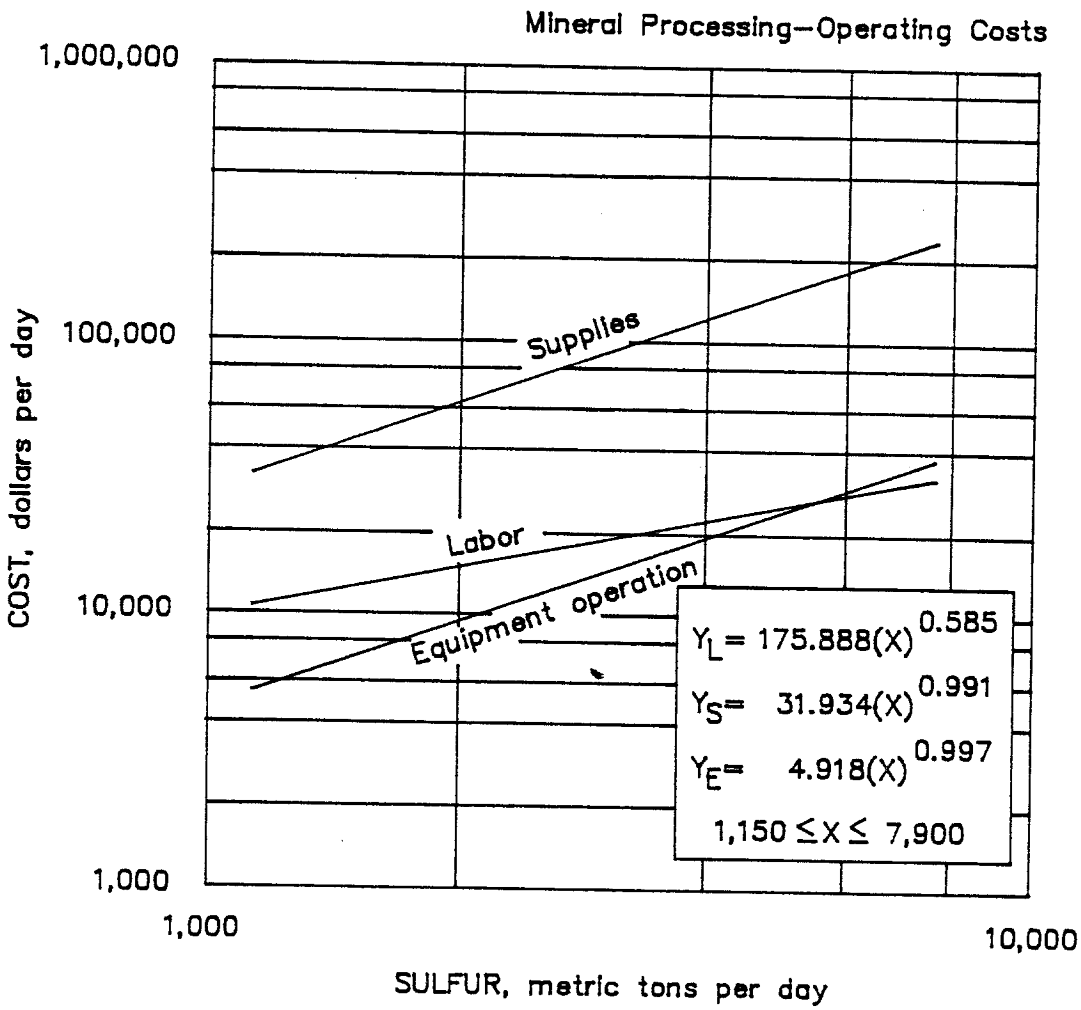
The operating supplies curve for the bleeder well adjustment factor consists of 71.3% for natural gas, 14.2% for electric power, 4.1% for fuel, 2.2% for water, and 8.2% for reagents. The equipment operation curve for the bleeder well adjustment factor consists of 22.8% for repair parts and materials, 59.6% for the replacement of production wells, and 17.6% for the replacement of bleeder wells.

Seawater Factor The base curves did not consider the use of seawater instead of raw water. To adjust for the utilization of seawater, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor (F_S) = 0.8

Equipment operating factor (F_E) = 1.1

The operating supplies curve for the seawater adjustment factor consists of 80.8% or natural gas, 9.3% for electric power, 2.9% for fuel, and 7.0% for reagents. The equipment operation curve for the seawater adjustment factor consists of 26.4% for repair parts and materials and 73.6% for replacement of production wells.



7.1.6.7. Frash process

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.8. HANDSORTING

This section provides costs for the removal from run-of-mine ore of selected grades of material by hand. The substances removed may be valueless gangue, waste rock not worth processing, or unusually rich ore. Any costs associated with moving the material to the sorting surface are not included in this section. Ore may be coming from another process section or from the mining operation. It is assumed that the ore will be delivered on a belt conveyor; if a different method is used, costs should be adjusted. Costs in this section include moving the material past the pickers and sorting the material into bins or piles by hand. Costs obtained from this section should not be applied to gemstones.

The total daily operating cost is the sum of three separate cost curves (labor, supply, and equipment operation) based on the feed rate to the picking belt (X), in metric tons of material per day. The curves are valid for operations between 40 and 2,000 mtpd, operating one shift per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 9.249(X)^{0.983}$
Using local labor rates and a range of 0.049 to 4.5 mt of selected material picked per hour, a daily labor rate can be determined. The labor curve is based on an average of 1 mt of selected material picked per hour, selected material equalling 10% of total feed.

The operating labor costs consist of the following typical range of personnel:

Direct labor................	99%
Maintenance labor...........	1%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Hand pickers................	100%	$13.66

The average wage for labor is $13.66 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.002(X)^{1.268}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.093(X)^{0.916}$
Equipment operating costs are dependent on the type of sorting surface used. Surfaces used could include sorting floors, tables, fixed chutes and grizzlies, belt conveyors, pan conveyors, revolving tables or shaking surfaces. Equipment operating costs would range from insignificant for a sorting floor to $77.97 per day for a 42-in by 110-ft (106.7-cm by 33.5-m) belt conveyor operating 8 h/d.

The equipment operation curve covers the daily operation cost for belt conveyors and consists of 94% for repair parts and 6% for lubricants.

Costs for water needed to wash the material before sorting is included in the water supply section.

ADJUSTMENT FACTOR

Labor Factor To calculate the labor cost for different conditions, use the following formula:

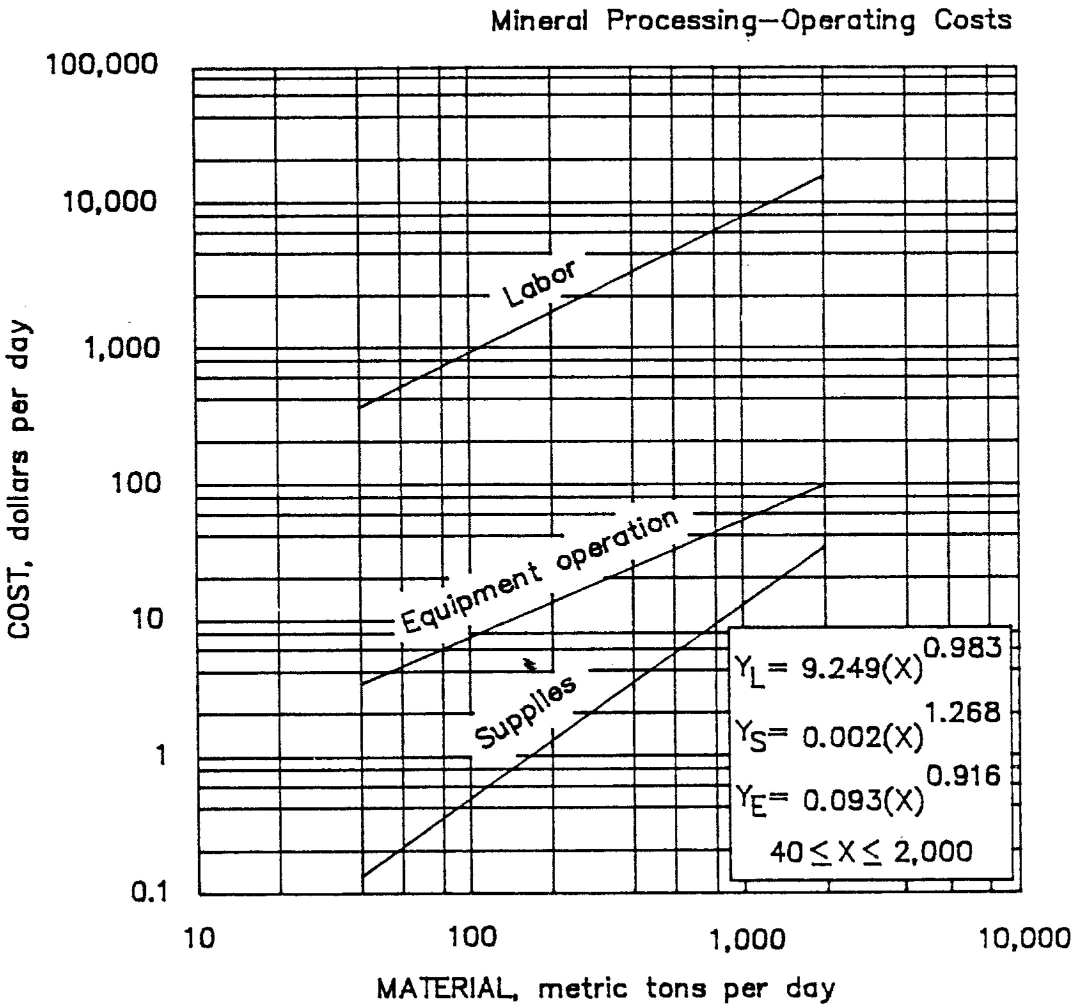
Labor cost per day = [(W)(X)(G)]/R

where W = local labor rate, in dollars per hour,
X = total feed to the picking belt, in metric tons per day,
G = percent picked, expressed as a decimal,
and R = amount of selected material picked per laborer, in metric tons per hour.

The following Table gives three typical rates of handsorting for gold-silver operations:

Typical handsorting rates for gold-silver operations

Metric tons picked per laborer hour (R)	Total feed picked (G)
1.4	15%
0.15-0.23	10%
0.68	1.75%-2.25%



7.1.6.8. Handsorting

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.9. LIME SLAKING

The operating cost curves for lime slaking are given on a per shift basis rather than a cost per day basis. The costs include the operation of the lime loop pumps. The total daily operating cost is the sum of three separate cost curves (labor, supply, and equipment operation) based on the feed rate (X), in metric tons of lime per shift. The curves are valid for operations between 20 and 125 mt/sh, operating one shift per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 11.474(X)^{0.416}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	97%
Maintenance labor...........	3%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Mill suboperator...........	100%	$14.56

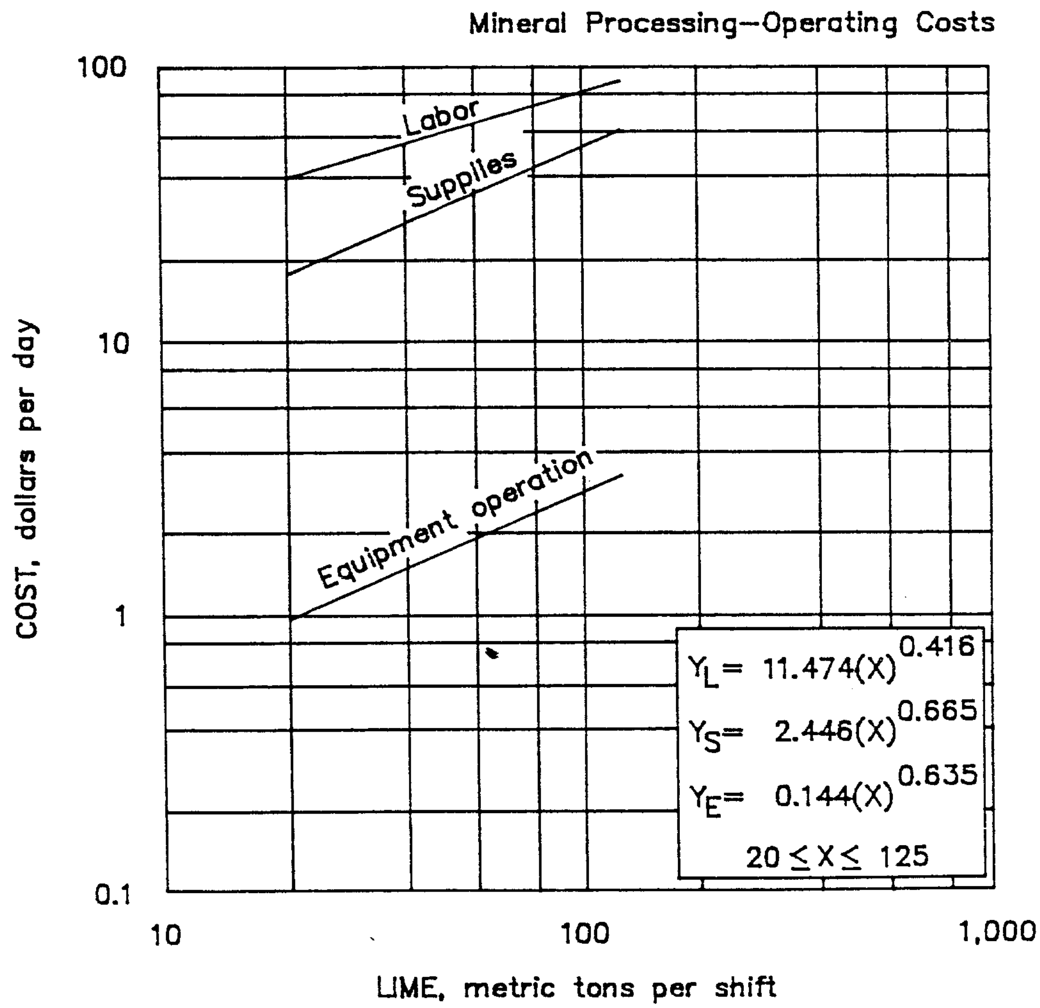
The average wage for labor is $14.63 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 2.446(X)^{0.665}$
The supply cost consists of 100% electric power. Grinding media consumption in the slaking mill is negligible and is not included in the supply operating cost.

(E) Equipment Operation Cost $(Y_E) = 0.144(X)^{0.635}$
The equipment operation curve consists of 100% for repair parts and materials. The curve includes an allowance for the replacement of pump parts.

ADJUSTMENT FACTOR

Shift Factor The curve is based on a one-shift-per-day operation. Typically, lime slaking circuits are operated primarily on day shift only. For a two- or three-shift operation, increase the operating costs proportionately.



7.1.6.9. Lime slaking

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.10.1. MERCURY APPLICATIONS
MERCURY CONDENSERS

The operating cost curves for mercury condensers are given on a per day basis. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a capacity rate (X), in metric tons of feed material to the furnace per day. The curves are valid for operations between 0.15 and 115 mtpd. The mercury condenser is normally operated on a one-batch-per-day cycle for small operations. For large operations, it is assumed to be on a continuous basis.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 15.585(X)^{0.350}$
The operating labor costs consist of the following typical range of personnel:

	Small (0.15 to 7 mtpd)	Large (7 to 115 mtpd)
Direct labor................	100%	46%
Maintenance labor...........	0%	54%

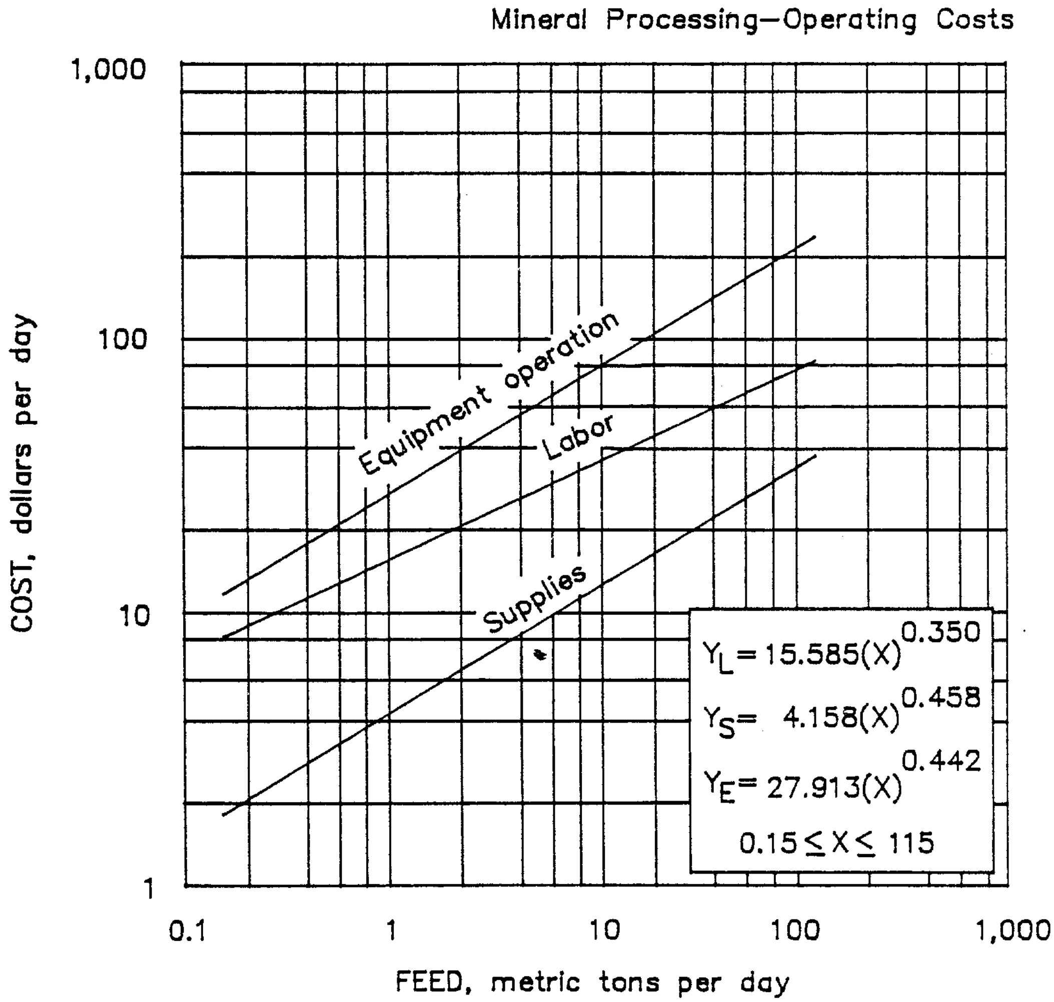
The average base salary including burden for labor is as follows:

	Small (0.15 to 7 mtpd)	Av salary per hour (base rate)	Large (7 to 115 mtpd)	Av salary per hour (base rate)
Mill operator..........	100%	$16.78	100%	$17.11

The average wage for labor is $16.95 per worker-hour (including burden and average shift differential).

(S) Supply Operation Cost $(Y_S) = 4.158(X)^{0.458}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 27.913(X)^{0.442}$
The equipment operation curve consists of 100% for repair parts and materials. For the large operations 88% of the repair parts and materials costs are for the replacement of condenser tubes, return hoppers, and bends and 12% for miscellaneous items.



7.1.6.10.1 Mercury applications
MERCURY CONDENSERS

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.10.2. MERCURY APPLICATIONS
MERCURY RETORTS

The operating cost curves for mercury retorts are given on a per day basis. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the feed rate (X), in kilograms feed per day. The curves are valid for operations between 40 and 1,100 kg/d, operating on a one-batch-per-day cycle.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 0.713(X)^{0.630}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	100%
Maintenance labor...........	0%

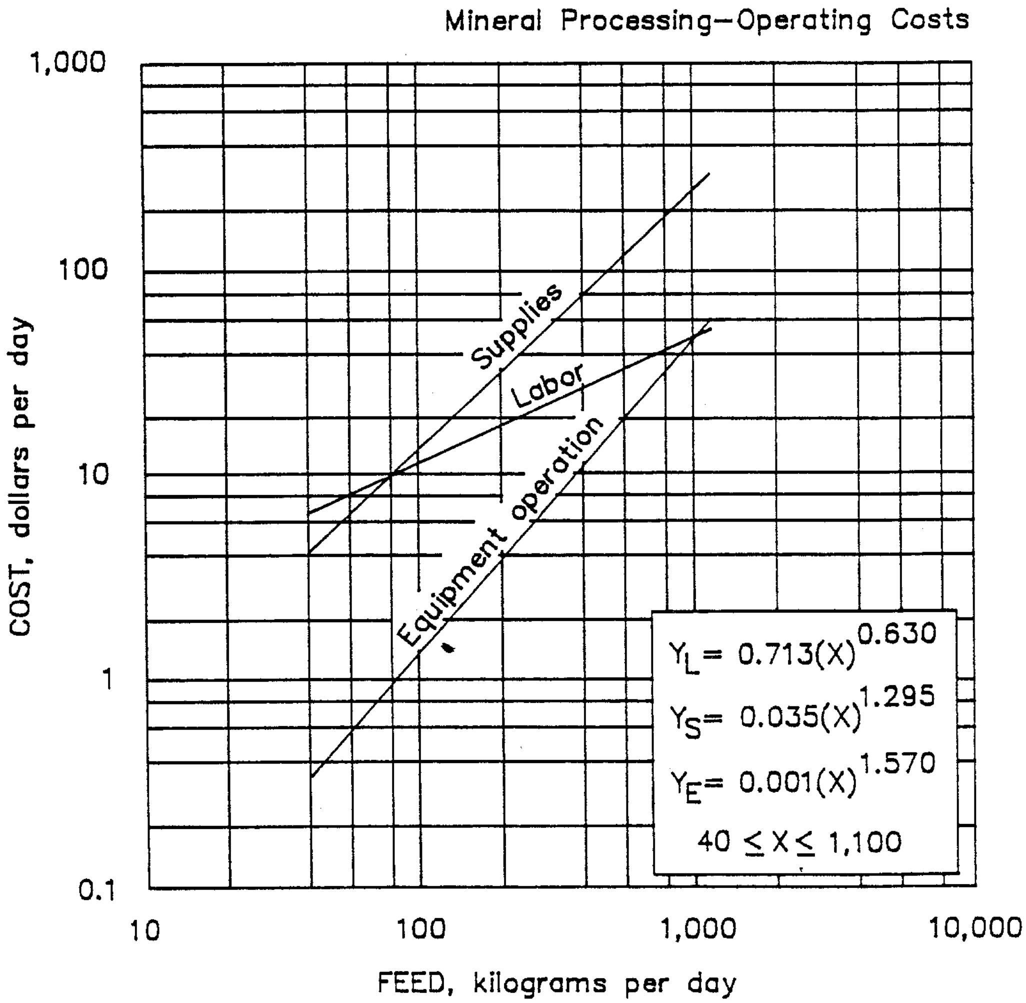
The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Mill operator...............	100%	$16.78

The average wage for labor is $16.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.035(X)^{1.295}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.001(X)^{1.570}$
The equipment operation curve consists of 100% for repair parts and materials.



7.1.6.10.2. Mercury applications
MERCURY RETORTS

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.11. PELLETIZING

The operating cost curves for pelletizing are given on a metric ton per day basis. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the capacity rate (X), in metric tons of pellet production per day. The curves are valid for operations between 6,400 and 28,000 mtpd, operating three shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 9.133(X)^{0.719}$
The operating labor costs consist of the following typical range of personnel:

Direct labor...........	47%
Maintenance labor......	53%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Control room operator.......	4%	$17.56
Pelletizing operator........	15%	17.11
Pelletizing suboperator.....	9%	14.56
Pelletizing helper..........	7%	11.68
Laborer.....................	12%	11.68
Mechanic....................	53%	16.78

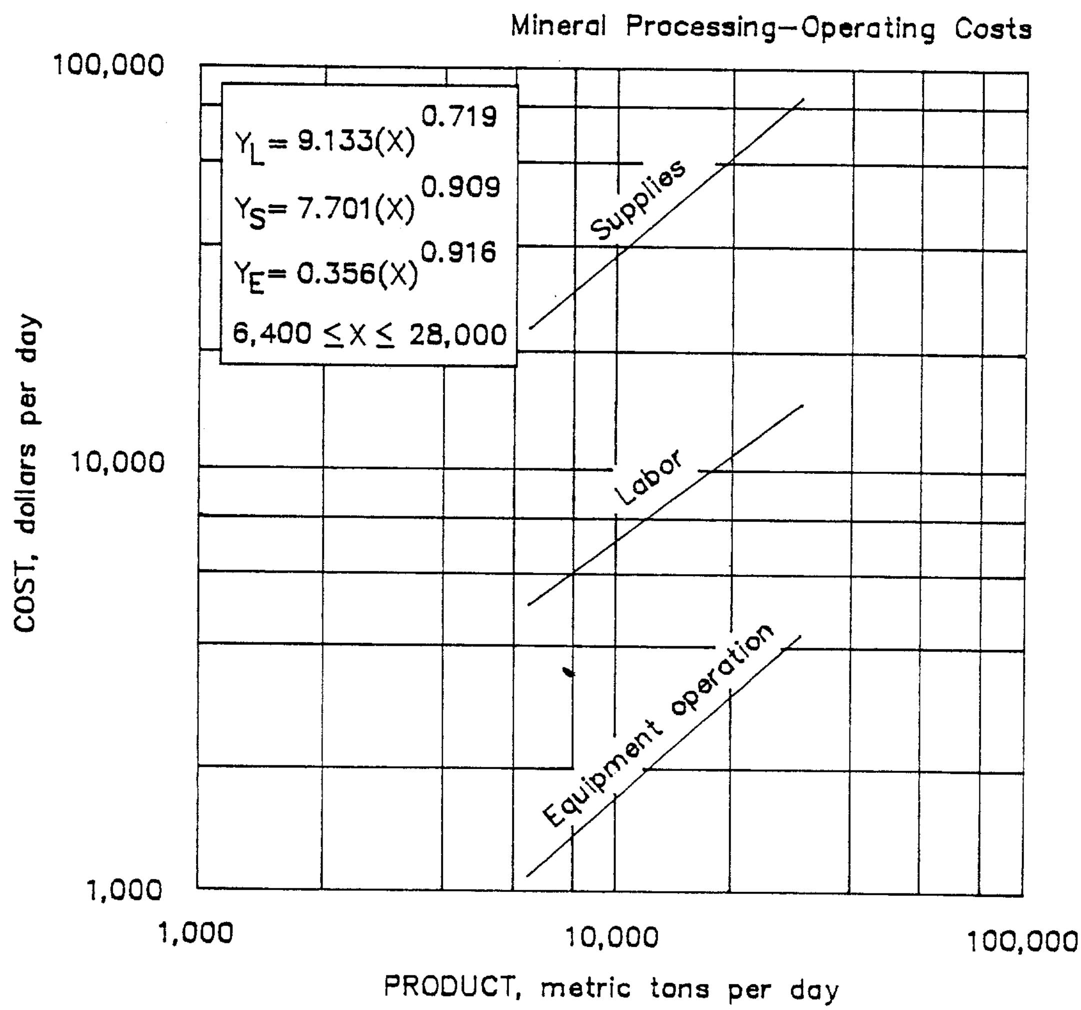
The average wage for labor is $15.69 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 7.701(X)^{0.909}$
The supply costs consist of 58.6% natural gas, 29.9% electric power, and 11.5% bentonite.

(E) Equipment Operating Cost $(Y_E) = 0.356(X)^{0.916}$
The equipment operation curve consists of 100% for repair parts and materials.

ADJUSTMENT FACTOR

Shift Factor The base curves are based on a three-shift-per-day operation. The pelletizing plant must be operated on a continuous basis to maintain a steady rate of feed to the indurating furnace. No adjustment factor for a one- or two-shift operation is recommended for pelletizing.



7.1.6.11. Pelletizing

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.12.1. WASHING AND SCREENING

This operation covers the cost of washing and screening loosely consolidated ores such as barite. Costs include the use of trommel screens, log washers, vibrating screens, water guns, and pumps. Washing separates the gangue from the ore, and screening separates the ore into two or more sizes. The sized ore is then usually processed further by various means. Washing is usually the first step as the ore enters the processing plant. Screening may be combined with crushing and grinding in various combinations, depending on plant design, or may be a completely independent operation.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operations) based on the feed rate (X), in metric tons material per day. The curves are valid for operations between 100 and 30,000 mtpd, operating two shifts per day. The curves include all daily operating and maintenance costs associated with washing and screening.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 130.175(X)^{0.150}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	71%
Maintenance labor...........	29%

The average base salary including burden for labor is as follows:

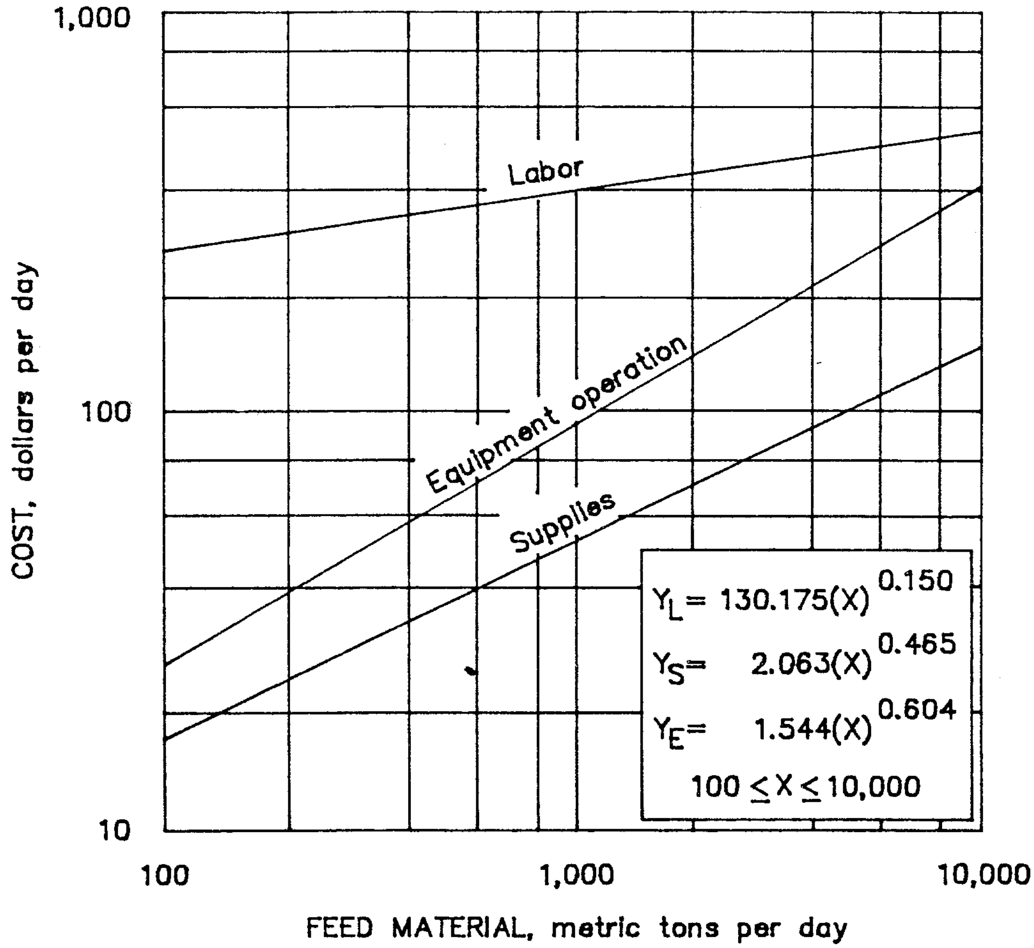
	Small (100 to 2,000 mtpd)	Large (2,000 to 30,000 mtpd)	Av salary per hour (base rate)
Water-gun operator..........	93%	-	$13.66
Floor walker................	7%	100%	15.89

The average wage for labor is $15.48 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 2.063(X)^{0.465}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 1.544(X)^{0.604}$
The equipment operating costs consist of 93% for repair parts and 7% for lubricants. The equipment operation curve covers the daily operating cost for all trommel screens, log washers, vibrating screens, water guns, and pumps, and includes allowances for replacement and maintenance of log caps, wear plates, and trommel linings.

Mineral Processing—Operating Costs



7.1.6.12.1. Washing and screening

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.12.2. WASHING AND SCREENING PHOSPHATE

This operation covers the cost of washing and screening (including ore feed preparation for flotation) of loosely consolidated phosphate ores. Costs include the use of trommel screens, hammermills, log washers, flume and vibrating screens, classifiers, and cyclones. Washing and screening separates the minus 1.91-cm (0.75-in), plus 14- or 16-mesh phosphate material (called pebble concentrate) from the finer material. The finer material containing phosphate is then processed in the feed preparation circuit where the clay fraction is removed from the plus 150-mesh material consisting of phosphate and silica sands. This plus 150-mesh material goes to the flotation circuit.

The total daily cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a feed rate (X), in metric tons material per day. The curves are valid for operations between 5,000 and 70,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated with washing and screening (including feed preparation for flotation).

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 0.0547(X)+1,570.000$

The operating labor costs consist of the following typical range of personnel:

	Small (5,000 to 22,000 mtpd)	Large (22,000 to 70,000 mtpd)
Direct labor................	56%	45%
Maintenance labor...........	44%	55%

The average base salary including burden for labor is as follows:

	Small (5,000 to 22,000 mtpd)	Large (22,000 to 70,000 mtpd)	Av salary per hour (base rate)
Washer/feed prep operator...	61%	37%	$15.89
Laborer.....................	39%	63%	14.12

The average wage for labor is $15.20 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.00189(X)^{1.487}$

The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 1,304.820e^{0.0000284(X)}$

The equipment operation curve consists of 94% for repair parts and 6% for lubricants. The curve covers the daily operating cost for all screens, cyclones, and pumps, and for pipe replacement.

ADJUSTMENT FACTOR

Polyurethane Liner Factor If polyurethane liners for screens, pumps, cyclones, and other equipment within the washing and screening circuit are utilized to reduce excessive abrasion by the ore, multiply the cost obtained from the maintenance portion of the labor curve by the following factor:

Labor factor $(F_L) = 0.75$

The equipment operations curve is not affected because the increased cost of polyurethane liners offsets the cost saved by increased wear life.