5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.5. MINE PLANT GENERAL OPERATIONS

5.2.5.2. COMPRESSED AIR FACILITIES

The total daily cost for a compressed air plant is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on mine air requirements (X), in cubic meters per minute. The curves are valid for operations between 20 and 2,000 m^3, operating two shifts per day. The costs consist primarily of charges for the maintenance and repair of compressors as well as the electric power to run them. All labor costs are restricted to repair and maintenance labor, and supplies are restricted to infrequent pipe section or pipe joint replacement.

If actual compressed air requirements are known or can be estimated the evaluator may determine the operating cost by consulting the curve directly. If compressed air requirements are not known they may be estimated from the following information:

Mining Method	Air requirement m^3/min) per metric ton per shift
Shrinkage, cut and fill, mechanized cut and fill, square-set stoping methods:	
Range	0.027-0.265
Average	0.200
Blasthole mining:	
Range	0.073-0.094
Average	0.083
Longhole drilling, sublevel, block caving methods:	
Range	0.050-0.093
Average	0.070
Open stoping:	
Range	0.170-0.260
Average	0.200

BASE CURVE

(L) Labor Operating Costs $(Y_L) = 0.006(X)^{1.213}$

The operating labor costs are distributed as follows:

Direct labor	0%
Maintenance labor	100%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Maintenance and repair labor	100%	$17.66

Average wage for maintenance labor is $17.66 per worker-hour (including burden and average shift differential)

(S) Supply Operating Costs $(Y_S) = 0.743(X)^{1.214}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.013(X)^{1.213}$
The equipment operating cost consists of 60% for repair and maintenance parts and 40% for lubrication.

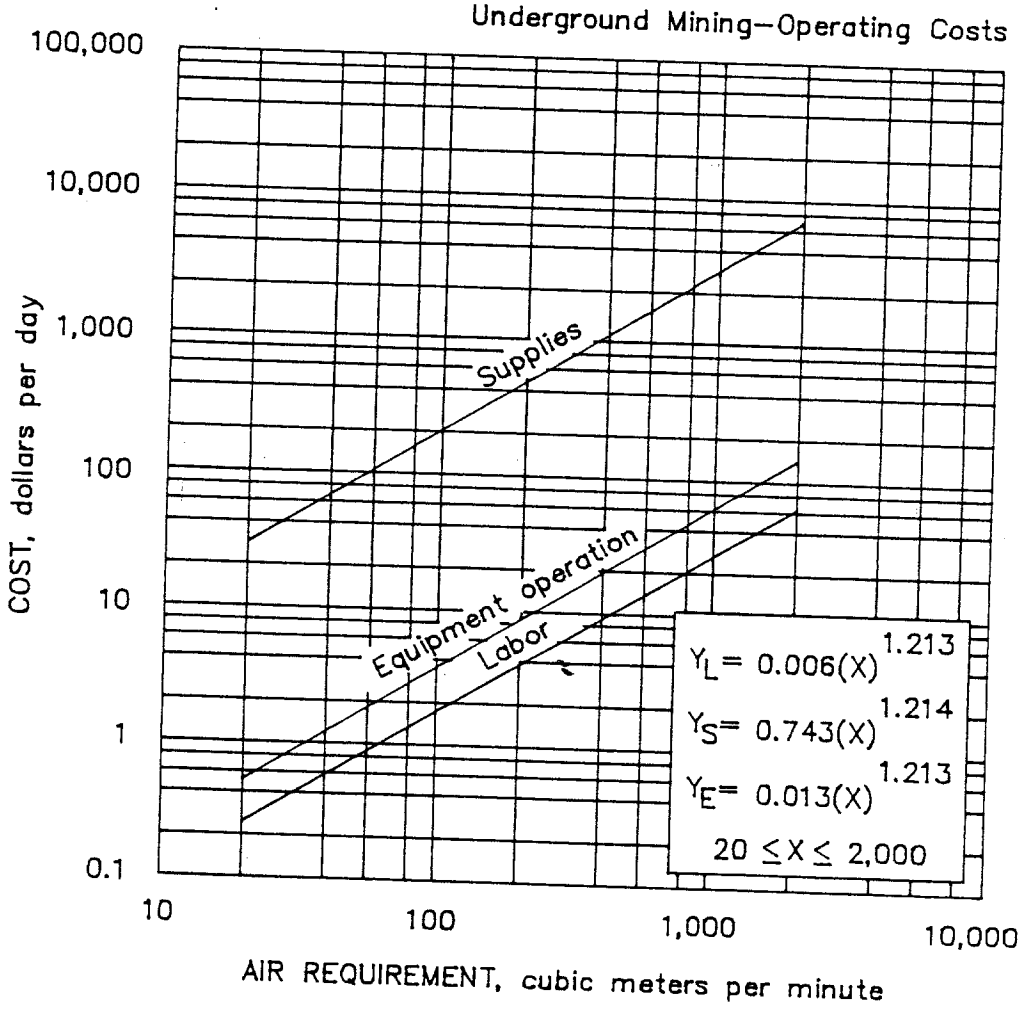
ADJUSTMENT FACTOR

Elevation Factor If elevation of the compressor plant varies from 1,600 m, a correction for altitude must be applied to the air requirements. To adjust air volume requirements, multiply the costs obtained from the compressed air curves by the following factor if the plant is not at 1,600 m elevation:

Elevation,			Elevation,		
ft	m	Factor	ft	m	Factor
0	0	0.85	6,000	1,831	1.03
1,000	305	0.87	7,000	2,136	1.07
2,000	610	0.90	8,000	2,441	1.11
3,000	915	0.93	9,000	2,746	1.15
4,000	1,220	0.96	10,000	3,050	1.19
5,000	1,526	0.99	12,500	3,813	1.31
5,249	1,600	1.00			

The factors can be generated from the following equation:

Elevation factor $(F_E) = 0.823+0.0001(G)$
where G = elevation, in meters.



5.2.5.2. Compressed air facilities

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.5. MINE PLANT GENERAL OPERATIONS

5.2.5.5. GENERAL ITEMS--COMMUNICATIONS, SANITATION, HOUSEKEEPING, FIRE PROTECTION AND ELECTRICAL

This set of curves covers the cost of general yard work, carpentry repair, janitorial services, plumbing, road grading, ditch cleaning, general mechanical repairs, handling incoming supplies and materials, electrical maintenance and repair, and general housekeeping. The tonnage mined is based on two shifts per day.

Total cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a production rate (X), in metric tons of ore and waste mined per day. The curves are valid for operations between 100 and 50,000 mt, operating two shifts per day. The curves include daily operating and maintenance costs associated with utility trucks, mobile cranes, motor patrols, various cleaning materials, and electrical-plumbing supplies.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 25.640(X)^{0.577}$
The operating labor costs are distributed as follows:

Direct labor	90%
Maintenance labor	10%

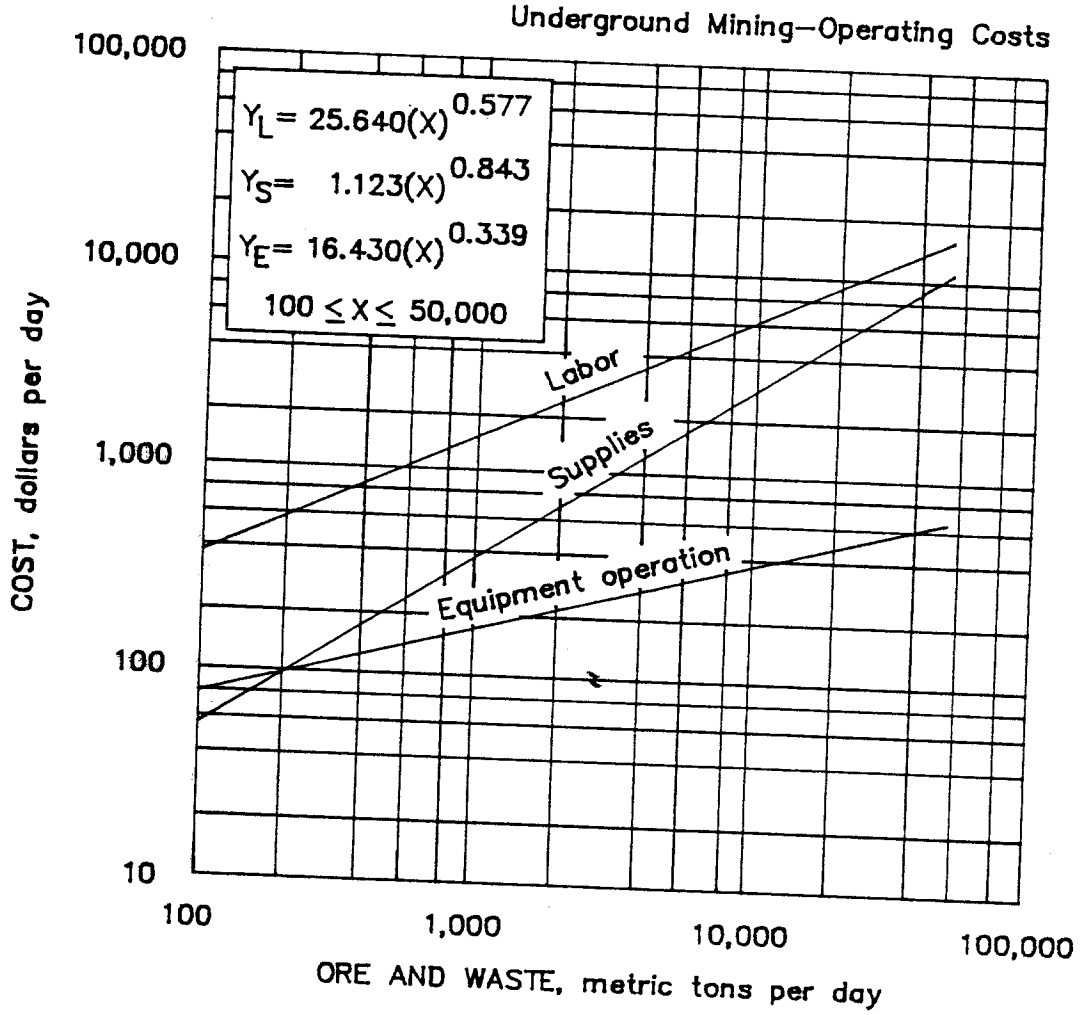
The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

	Small (100 to 1,000 mtpd)	Large (1,000 to 50,000 mtpd)	Av salary per hour (base rate)
Utility person	47%	20%	$15.43
Skiptender	-	11%	15.77
Equipment operator	14%	16%	18.18
General laborer	-	14%	14.11
Security janitor	33%	15%	14.25
Welder, first class	6%	15%	16.92
Electrician	-	9%	25.54

Average wage for labor for the small mine is $15.52 per worker-hour and for the large mine is $16.68 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.123(X)^{0.843}$.
The supply cost consists of 100% miscellaneous supplies.

(E) Equipment Operating Cost $(Y_E) = 16.430(X)^{0.339}$.
The equipment cost consists of 37% for parts, 54% for fuel and lubrication, and 9% for tires. The equipment operating curve includes the daily overhaul and maintenance costs for parts, and daily fuel, lubrication, and tire costs.



5.2.5.5. General items
COMMUNICATIONS, SANITATIONS, HOUSEKEEPING, FIRE PROTECTION, AND ELECTRICAL

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.5. MINE PLANT GENERAL OPERATIONS

5.2.5.7. PORTABLE POWER GENERATION

This section is to be used in conjunction with section 4.2.5.7. when electric power is unavailable through a commercial power utility company or when it would be uneconomical to run power distribution facilities to the user. The total cost per kilowatt hour (kW·h) replaces the commercial Denver, CO, power rate used in other sections of this manual.

These curves cover the cost of power production from a single portable power unit (see adjustment factor for multiple units) ranging from a small diesel generator with less than 100 kW output to a large gas turbine producing more than 20,000 kW of power.

Total cost is expressed in terms of cents per kilowatt hour for a specific power output. The curves cover the cost of labor for overhauls and normal repairs, parts for overhauls and normal repairs, and fuel and lubrication costs. The curves have been divided into three parts: the first part covering horizontal diesel generators from 18- to 400-kW output, the second part covering horizontal diesel generators from 400- to 2,900-kW output, and the last part covering gas turbine generators from 2,900- to 23,600-kW output.

Total cost is the sum of two separate cost curves (labor and equipment operation) based on a specific power output rating (X), in kilowatts. The curves are valid for generators between 18 to 23,600 kW. The curves include all daily operating and maintenance costs associated with power production per generator unit.

BASE CURVE

To convert from kilovolt ampere (kV·A) demand to kilowatt power output estimate the power factor (PF). This may vary from 0.80 for electric motor circuits to 1.00 for electric light circuits. The kilowatt output is then determined by kV·A x PF = kW. [Power Output Determination - for surface mine power output (kW), see section 2.2.4.2. For underground mine and mineral processing plant power demand (kV·A), see sections 4.2.5.3. and 6.1.8.4.(IC 9143)].

(L) Labor Operating Cost $(Y_{L\ 18\text{-}400\ kW}) = 0.169(X)^{-0.466}$
$(Y_{L\ 400\text{-}2,900\ kW}) = 0.409(X)^{-0.480}$
$(Y_{L\ 2,900\text{-}23,600\ kW}) = 0.008(X)^{-0.445}$

The operating labor costs are distributed as follows:

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

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

		Av salary per hour (base rate)
Mechanics.....	100%	$18.11

The average wage for maintenance labor is $18.11 per worker-hour (including burden and average shift differential).

The labor curves do not contain any operating labor costs since all units operate unattended in an automatic mode (some smaller units may not have automatic starting systems and would require a manual start). The only labor necessary is that which is required for maintenance and scheduled overhauls by mechanics.

(E) Equipment Operation Costs $(Y_E \text{ 18-400 kW}) = 0.145(X)^{-0.075}$
$(Y_E \text{ 400-2,900 kW}) = 0.158(X)^{-0.070}$
$(Y_E \text{ 2,900-23,600 kW}) = 0.131(X)^{-0.122}$

The general equipment operating cost component distribution is as follows:

Discription	Repair parts	Fuel and lube	Tires
Horizontal diesel:			
18 to 400 kW.....	18.0%	73%	9%
400 to 2,900 kW.....	12.0%	79%	9%
Gas turbine: 2,900 to 23,600 kW.....	11%	75%	14%

The parts category includes normal maintenance parts such as belts and pumps, and major overhaul items such as valves, injectors, brushes, and commutators. The fueling cost is based on $1.00/gal diesel fuel (at 7.093 lb/gal) or $3.20/1,000 ft^3 of natural gas with a Btu rating of 1,050 Btu's per cubic foot.

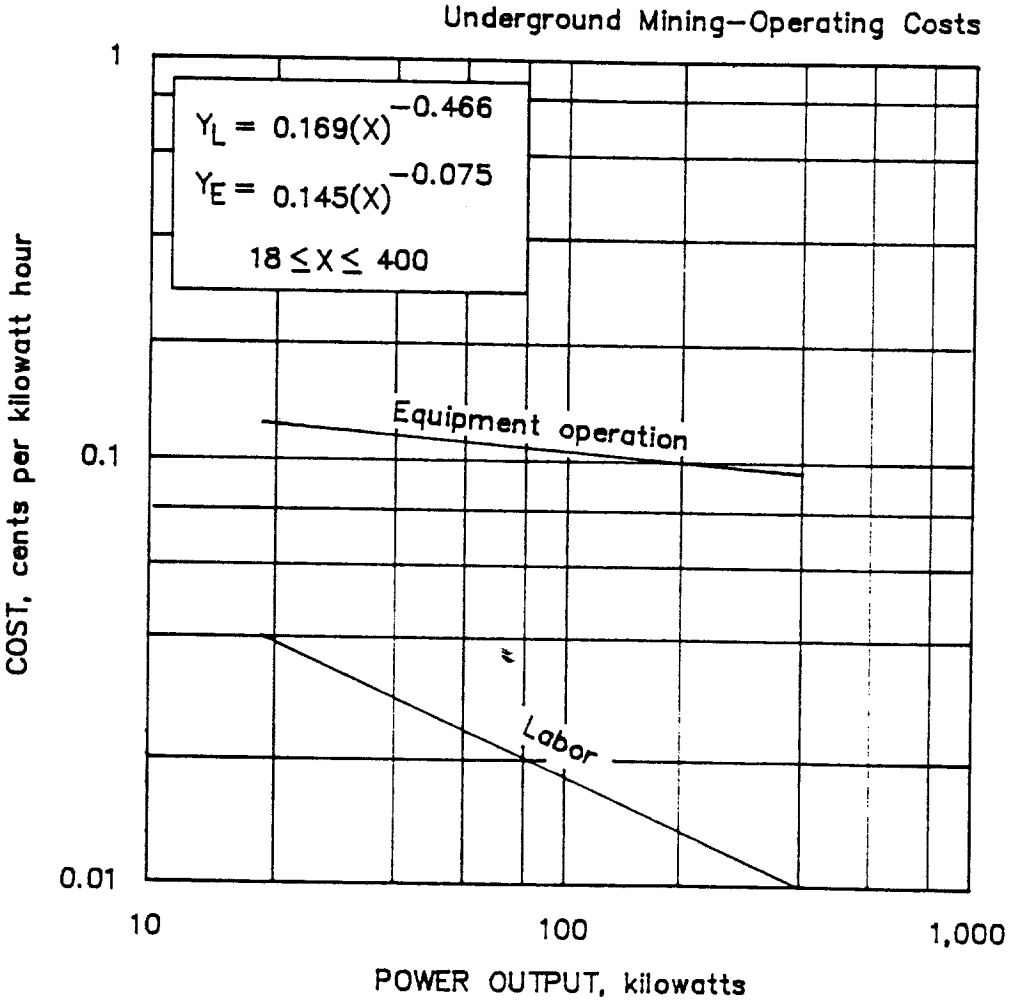
ADJUSTMENT FACTORS

Sulfur Fuels Factor If high sulfur fuels are used, multiply the labor and parts costs by the following factor:

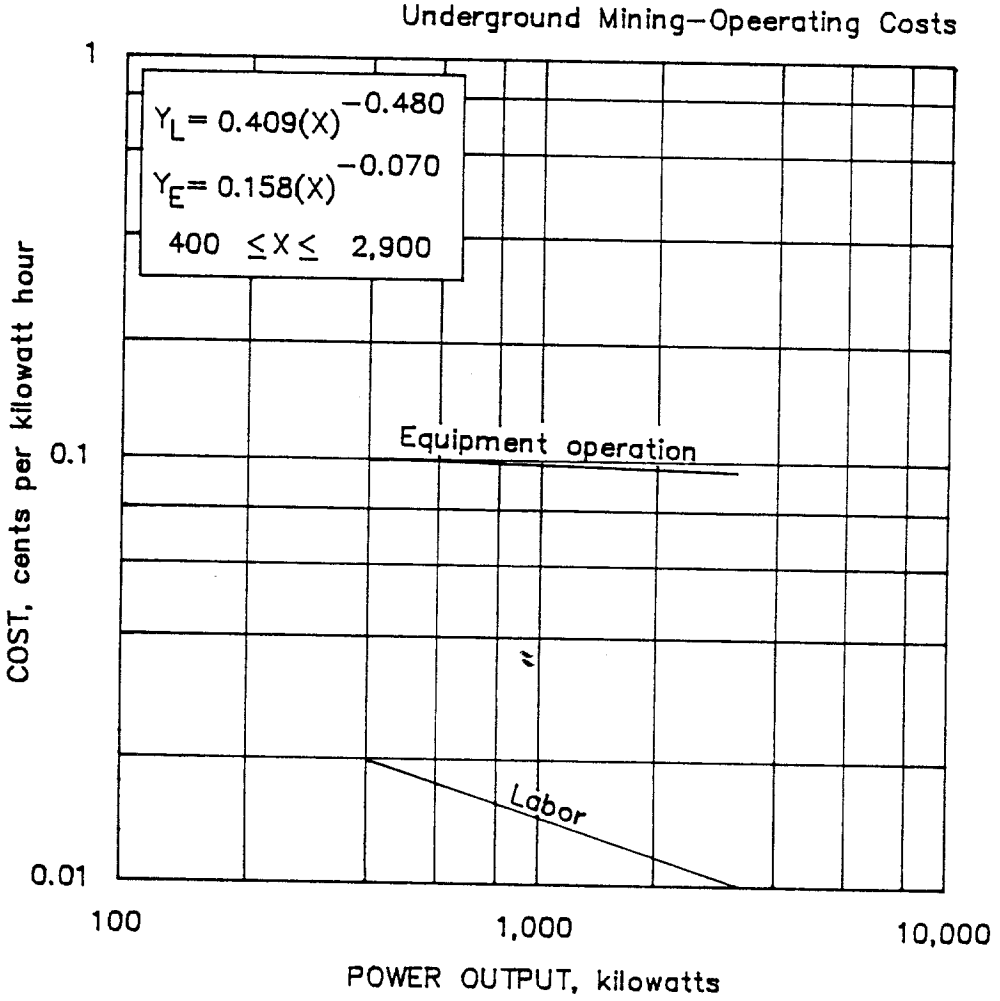
Sulfur fuels factor $(F_L) = 1.333$

Power Rate If power is to be supplied by more than one unit, then the total power output should be divided by the number of required units to obtain the power output per unit (X) needed for entering the curves.

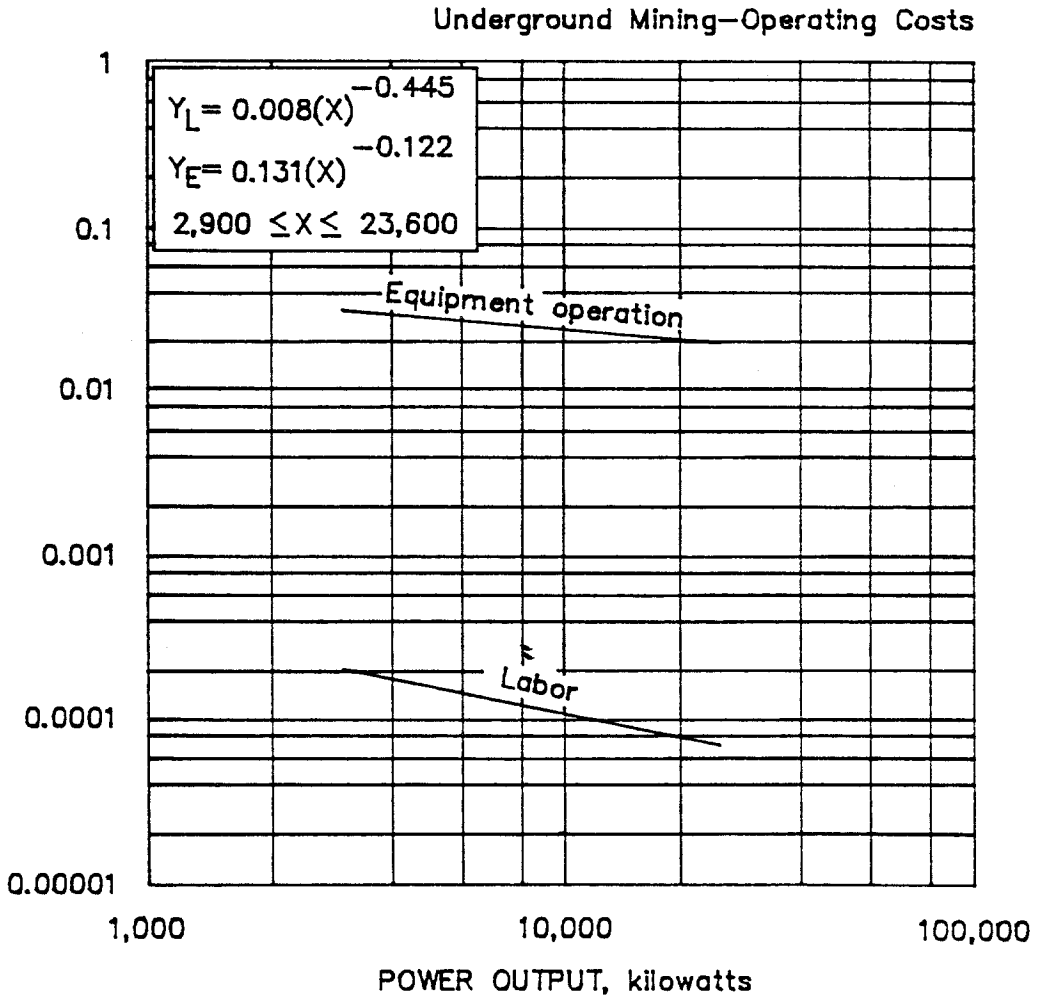
Power Source For those cases where power is supplied to the mine and mineral processing plant from different sources as a result of geographic or economic constraints, separate cost estimates, using this section, must be made to reflect the independent power outputs. This will result in different power costs for mines and mineral processing plants and must be accounted for separately in the mining and mineral processing sections of this manual.



5.2.5.7.a Portable power generation



5.2.5.7.b Portable power generation



5.2.5.7.c Portable power generation

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.5. MINE PLANT GENERAL OPERATIONS

5.2.5.9. STOCKPILE STORAGE FACILITIES

Stockpile operating costs, as determined in this section, are based on metric tons of stockpiled material reclaimed during a two-shift-per-day operation. The costs represented are only applicable for stockpiles formed and reclaimed by conveyors. The daily reclaim rate is typically about 67% of the stockpile's live storage capacity. Total stockpile capacity is normally about 600% of the daily reclaim rate. For example, a coarse ore stockpile for a mill operating at 10,000 mt of ore per day has a live storage capacity of about 15,000 mt and a total stockpile capacity of 60,000 mt.

Total operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the production rate (X), in metric tons material reclaimed from the stockpile per day. The curves are valid for operations between 2,000 to 200,000 mt, operating two shifts per day.

BASE CURVES

(L) Labor Operating Costs $(Y_L) = 7.229(X)^{0.503}$
The operating labor costs are distributed as follows:

Direct labor.....	33%
Maintenance labor.....	67%

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

	≈	Av salary per hour (base rate)
Mechanic.....	72.0%	$17.99
Conveyor operator.....	14.8%	14.89
Laborer.....	13.2%	13.26

Average wage for labor is $16.91 per worker-hour (including burden and average shift differential).

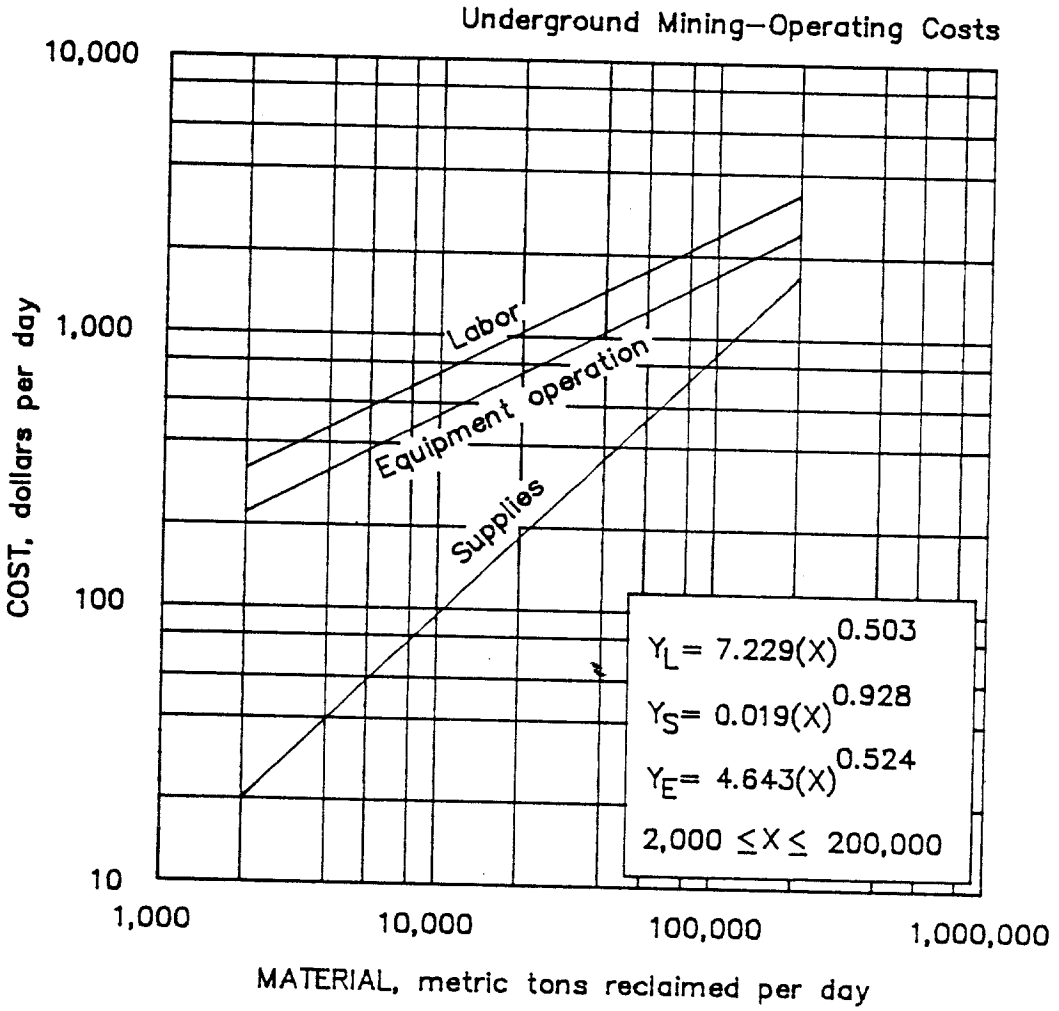
(S) Supply Operating Costs $(Y_S) = 0.019(X)^{0.928}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Costs $(Y_E) = 4.643(X)^{0.524}$
The equipment operation curve consists of 94% for repair and maintenance parts and 6% for lubrication.

ADJUSTMENT FACTOR

Shift-Reclaim Rate If a stockpile facility is operated one shift per day, multiply the daily reclaim rate by two; calculate the operating costs from the base curves using the adjusted reclaim rate; then decrease the calculated cost by 50% to arrive at the adjusted cost. If the facility is operated three shifts per

day, multiply the daily reclaim rate by 0.67; calculate the operating costs from the base curves using the adjusted reclaim rate; then increase the calculated cost by 50% to arrive at the adjusted cost.



5.2.5.9. Stockpile storage facilities

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.5. MINE PLANT GENERAL OPERATIONS

5.2.5.11. VENTILATION SYSTEM

Total cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having an air capacity (X), in cubic meters per minute. The curves are valid for operations between 1,000 and 60,000 m^3, operating three shifts per day. Main ventilation system cost consists of charges for repair and maintenance of fans as well as the electric power to run them. Operating costs for auxiliary ventilation equipment is accounted for in each mining method section. For a brief explanation of factors affecting mine ventilation systems, consult section 4.2.5.11.

If mine air quantity and mine pressure head (measured in pascals), are known, consult the base curves directly. If mine air quantity and mine head are not known, requirements may be estimated using the information below.

Mining Method	Air Quantity (m^3/min) per metric ton	Mine head (Pa)
Room and pillar:		
Range	0.539-5.208	1,245-2,191
Average	1.917	1,609
Sublevel caving, panel caving, sublevel blasthole, VCR, longhole:		
Range	1.158-7.881	872-3,586
Average	3.394	2,111
Block caving.		
Range	0.607-1.784	1,718-5,727
Average	1.163	2,117
Cut and fill, shrinkage, square set:		
Range	2.172-5.073	1,992-6,723
Average	3.789	4,171

(Pressure head conversions 1 psi = 27.7 in H_2O = 6.8948 kPa)

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 0.003(X)^{0.870}$

The operating labor costs are distributed as follows:

Direct labor	0%
Maintenance labor	100%

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Maintenance and repair labor..	100%	$17.66

Average wage for maintenance labor is $17.66 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.001(X)^{0.870} + [(H)(Q)(C)/1,997]$
The first part of the equation accounts for miscellaneous system costs and the second part of the equation accounts for electric power cost

where H = mine head in pascals
Q = quantity of air in cubic meters per minute.
and C = power cost in dollars per kilowatt hour (use $0.050/kW·h if unknown).

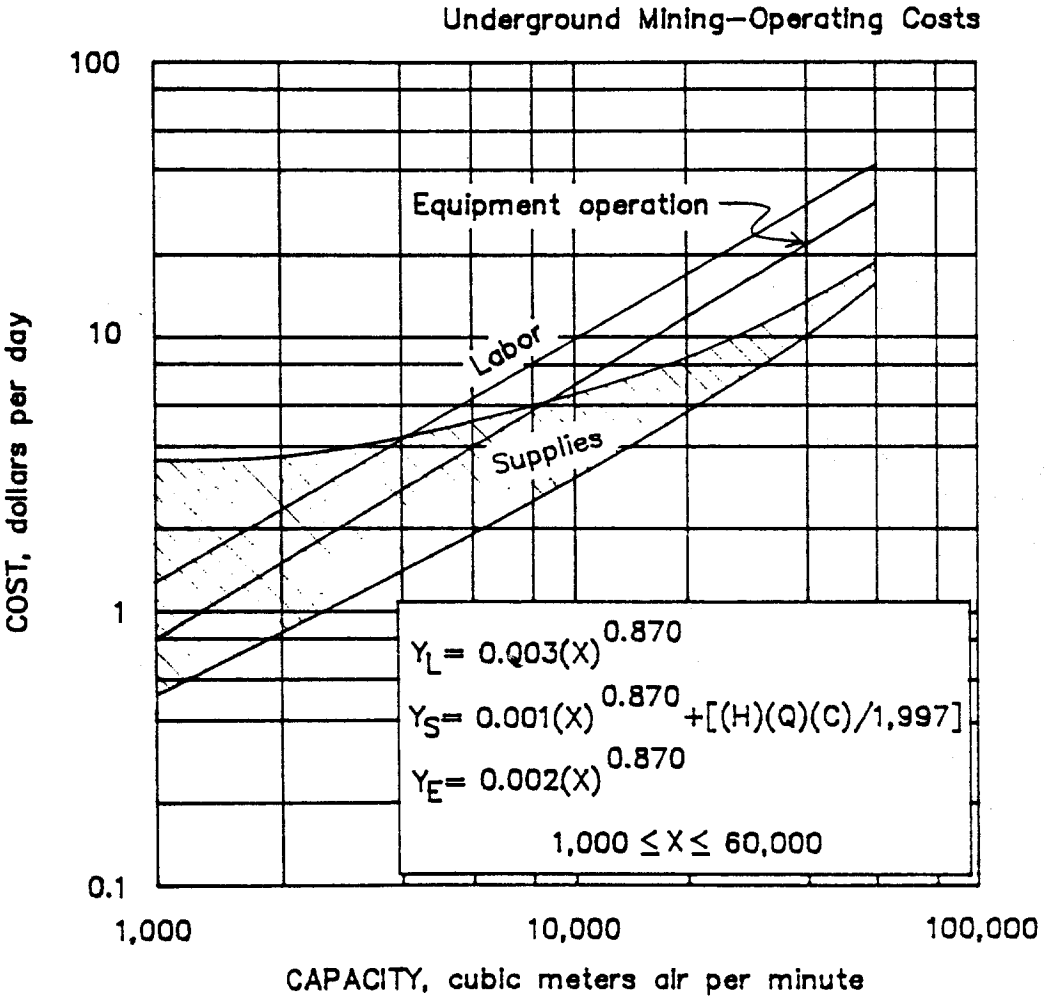
(E) Equipment Operating Cost $(Y_E) = 0.002(X)^{0.870}$
The equipment operating cost consists of 94% for fan repair and maintenance parts and 6% for lubrication.

ADJUSTMENT FACTORS

Air-Warming Factor Heat-plant operating costs correlate to the number of days per year the ventilation intake air must be heated above 0° C (see section 4.2.5.11). The number of heating days per year range from 92 for a climate similar to the Denver, CO, area to 169 for a cold climate. Apply operating costs throughout the entire year. Heat-plant equipment operating costs (E) range from $56/day per 2,830 m^3/min of ventilation for a climate similar to Denver to $490/day per 2,830 m^3/min of ventilation for a cold climate. Increase labor operating costs between $6.25/day per 2,830 m^3/min of ventilation for a climate similar to Denver to $11.50/day per 2,830 m^3/min for a cold climate.

Air-Cooling Factor If an air-cooling plant is required (see section 4.2.5.11.), multiply the costs obtained from the ventilation system curves by the following factor:

Air-cooling factor $(F_{C\ COOLING}) = 1.75$



5.2.5.11. Ventilation system

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.5. MINE PLANT GENERAL OPERATIONS

5.2.5.12.1. WATER AND DRAINAGE SYSTEM DRAINAGE AND DISPOSAL SYSTEM

The costs derived from these curves apply to underground mines where water is collected into a central drainage system and transported to sumps for initial settling and treatment. The water is then pumped, via a series of vertically emplaced stations, to either the mill or a tailings pond. A standard height of 610 m is used. As each case addressed will invariably require adjustment for depth, appropriate factors are provided in the ADJUSTMENT FACTORS section. Note that height in this discussion is identified as vertical pumping distance. Allowances have already been made for the discrepancies between pumping head and height pumped.

The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on the amount of water pumped (X), in cubic meters of water per day. The curves are valid for operations between 600 and 20,000 m^3, operating 24 h/d.

BASE CURVES

(L) Labor Operating Costs $(Y_L) = 0.304(X)^{0.757}$

The operating labor costs are distributed as follows:

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

Labor costs are distributed 48% for pump maintenance and repair and 52% for pipeline maintenance.

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Maintenance and repair labor.....	100%	$17.98

Average wage for maintenance labor is $17.98 per worker-hour (including burden and average shift differential).

(S) Supply Operating Costs $(Y_S) = 0.131(X)^{0.992}$

The supply cost consists of 100% electric power.

(E) Equipment Operating Costs $(Y_E) = 0.167(X)^{0.766}$

The equipment operating cost consists of 93% for repair and maintenance parts and 7% for lubrication.

ADJUSTMENT FACTOR

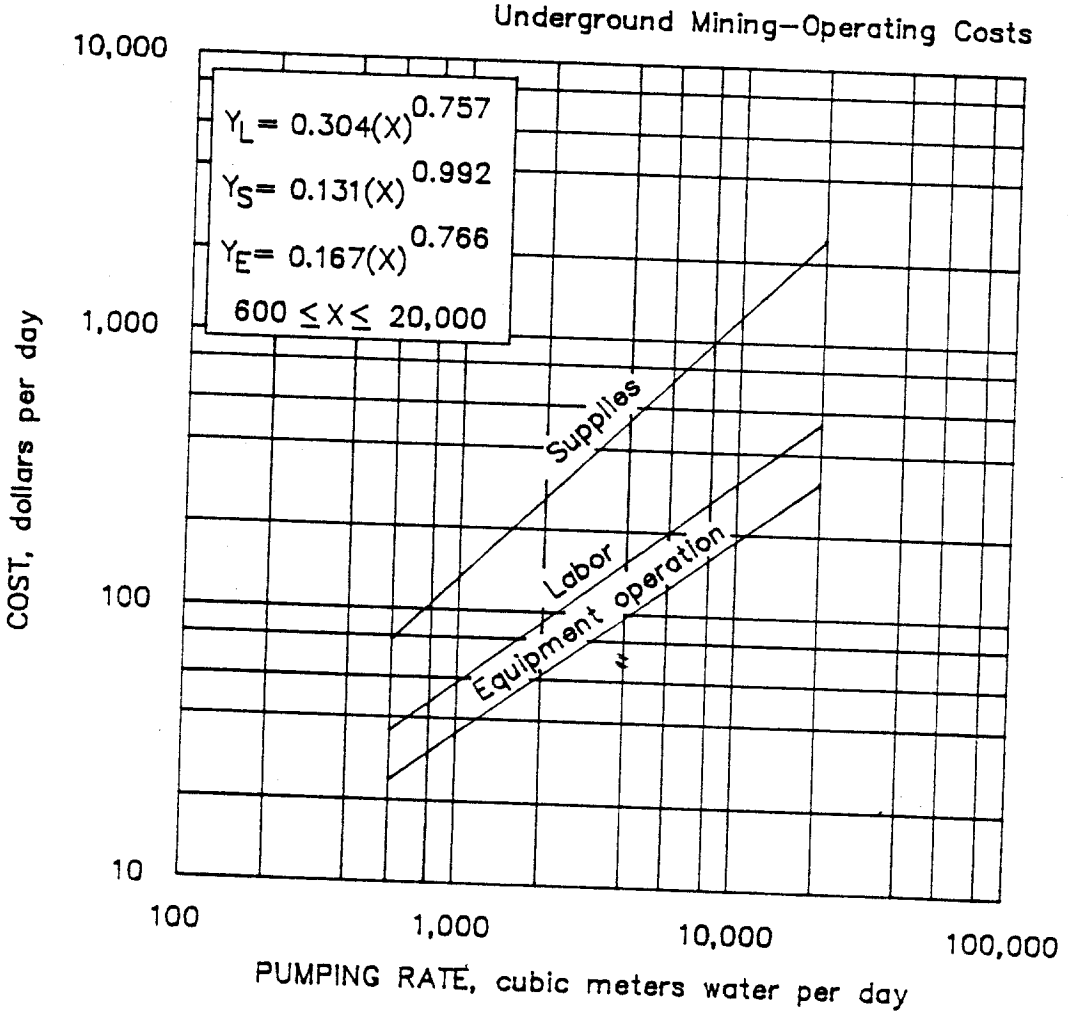
Total Pumping Height If pumping height is other than the 610 m used to determine the base curves, multiply the costs obtained from the drainage and disposal curves by the following factors:

Labor factor $(H_L) = 0.731e^{[0.0005(H)]}$

Supply factor $(H_S) = 0.0019(H)^{0.977}$

Equipment factor $(H_E) = 0.572e^{[0.001(H)]}$

where H = actual pumping height, in meters.



5.2.5.12.1. Water and drainage system
DRAINAGE AND DISPOSAL SYSTEM

5.2. UNDERGROUND MINING--OPERATING COSTS

5.2.5. MINE PLANT GENERAL OPERATIONS

5.2.5.12.2. WATER AND DRAINAGE SYSTEM
WATER SUPPLY SYSTEM (MAKEUP WATER)

Operating costs for water systems supplying up to 125 m^3/h, typical of an underground mine or a small mine and mill complex, are calculated from this section. Operating costs for larger joint-use mine-mill systems are calculated in section 7.1.8.14 (IC 9143).

If water quantity requirements are known and are less than 125 m^3/h, consult the base curves directly. If water quantity is not known, mine requirements (Y), cubic meters water per hour, may be estimated using the equations below. Mill requirements can be estimated from section 7.1.8.14.2 (IC 9143). Water volume required for an underground mine is dependent on the principle type of drilling equipment used, the major water user in underground mines.

Air-leg drills:
Water requirement[1] $Y_{(W\ AIR\text{-}LEG\ DRILL)} = 0.049(X_1)^{0.889}$

Jumbo and DTH drills:
Water requirement[1] $Y_{(W\ JUMBO/DTH\ DRILL)} = 0.025(X_1)^{0.749}$

where X_1 = ore mined, in metric tons per day.

[1] Daily water quantity = m^3/h x 16 operating h/d.

Operating costs for an isolated mine (i.e., no adjacent mill) are derived directly from the base curves. For a joint-use system, combine mine and mill water requirements and derive the total operating costs from the appropriate curve.

BASE CURVES

Total cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having mine water requirements (X), in cubic meters per day. The curves are valid for operations between 40 and 2,000 m^3, operating two shifts per day. These costs consist of charges for the maintenance and repair of pumps as well as the electric power to run them and infrequent pipeline repair.

(L) Labor Operating Cost $(Y_L) = 2.058(X)^{0.444}$
The operating labor costs are distributed as follows:

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

Labor operating curve component costs are distributed 32% for pump repair and maintenance and 68% for pipeline repair and maintenance.

The operating labor costs are based on straight days pay and consist of the following typical range of personnel:

		Av salary per hour (base rate)
Maintenance and repair labor.....	100%	$17.98

Average wage for maintenance labor is $17.98 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.680(X)^{0.627}$
The supply cost consists of 51% pipeline repair parts and 49% electric power.

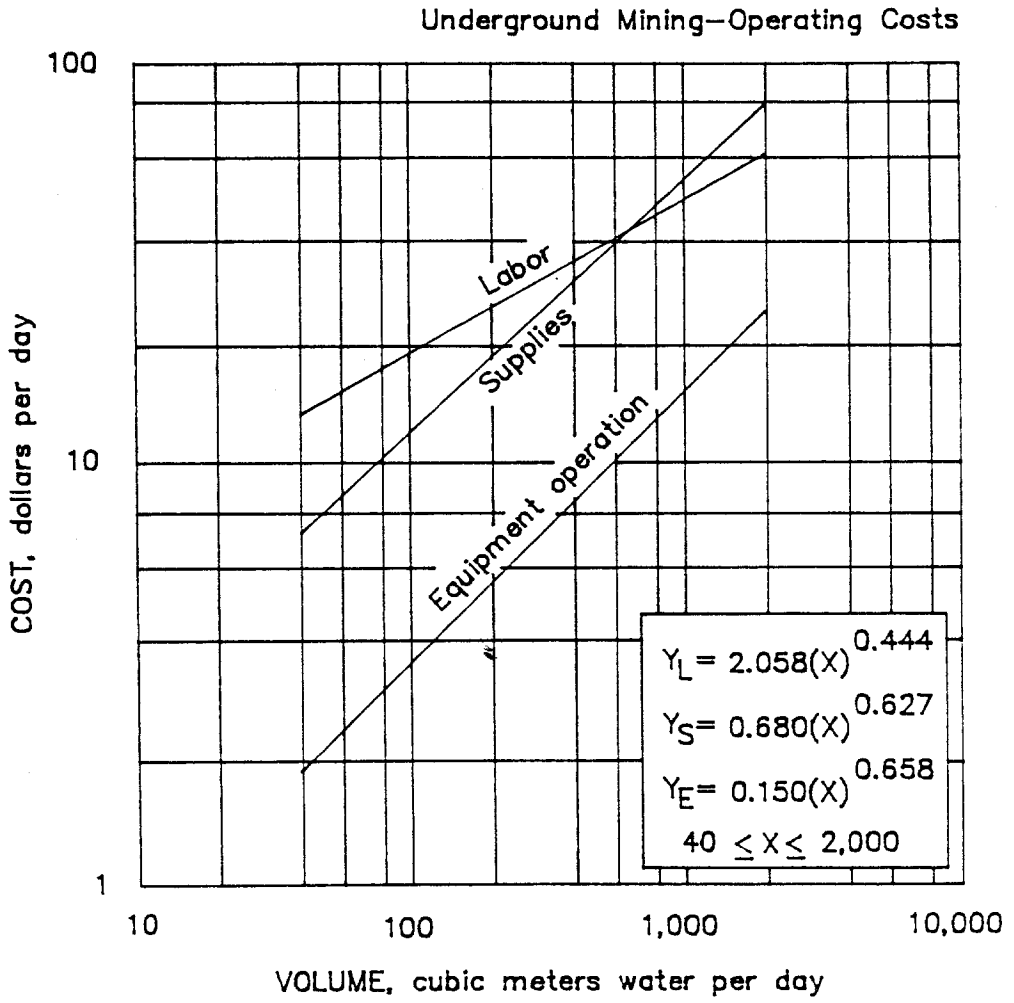
(E) Equipment Operating Cost $(Y_E) = 0.150(X)^{0.658}$
The equipment operating cost consist of 95% for pump repair and maintenance parts and 5% for lubrication.

ADJUSTMENT FACTORS

Joint-Use After deriving the joint-use water system operating cost from the appropriate curve using the combined mine and mill water quantity requirements, allocate mine operating cost versus mill operating cost based on the percentage of water quantity demand (i.e., if the mine requires 10% of the total quantity, operating cost is split 10% mine and 90% mill).

Purchased Water Factor On occasion, purchase of water from a nearby municipal water system is a viable alternative for a mine. If this is either the present case or is being evaluated as a possible water source, the water purveyor charges would be the sole operating cost. The evaluator should contact the local supplier to determine what the actual charges would be.

Shift Factor Curve costs should be reduced 50% for a one-shift-per-day operation and increased 50% for a mine operating three shifts per day.



5.2.5.12.2. Water and drainage system
WATER SUPPLY SYSTEM (MAKEUP WATER)