4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.2. COMPRESSED AIR FACILITIES

Capital costs for compressed air system, as presented here, are based on capacity of the facilities. This section will deal with compressors having an atmospheric pressure intake and a discharge pressure of 689 to 861 kPa (100 to 125 psi). Higher pressure compressor systems (1724 to 2413 kPa) are accounted for in the appropriate mining methods sections (vertical crater retreat and blasthole). A compressed air system includes primary air compressor(s) as well as backup or auxillary compressor(s), ancillary compressor equipment, piping to the mine portal or collar, and a compressor building. An air compressor system may include reciprocating, rotary, and/or centrifugal compressors. Reciprocating compressors are commonly used in all sizes of underground mines. Rotary compressors have the greatest application for supplying 689 kPa (100 psi) air to small- and medium-sized underground mines. Centrifugal compressors are commonly used in medium- and large-sized underground mines when large volumes of compressed air are required with minor demand fluctuations. The volume of compressed air required for underground mines (measured in cubic meters per minute) is dependent on the type of mining method used. If compressed air requirements for a mine are not known they can be estimated from the following information:

Mining Method	Air requirement per metric ton per shift, (m^3/min)
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

Total cost is based on a single cost curve having a total compressor capacity (X), in cubic meters installed capacity per minute, which includes line losses, leaks, and drilling diversity for a plant installed at 1,600 m (5,249 ft) elevation. The curve is valid for capacities between 20 and 2,000 m^3/min.

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

Construction labor cost.......	7%
Construction supply cost......	5%
Purchased equipment cost......	88%

The total compressed air facilities capital cost is $(Y_C) = 9{,}884.496(X)^{0.695}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 691.915(X)^{0.695}$

(S) Construction Supply Cost $(Y_S) = 494.225(X)^{0.695}$

(E) Purchased Equipment Cost $(Y_E) = 8{,}698.356(X)^{0.695}$

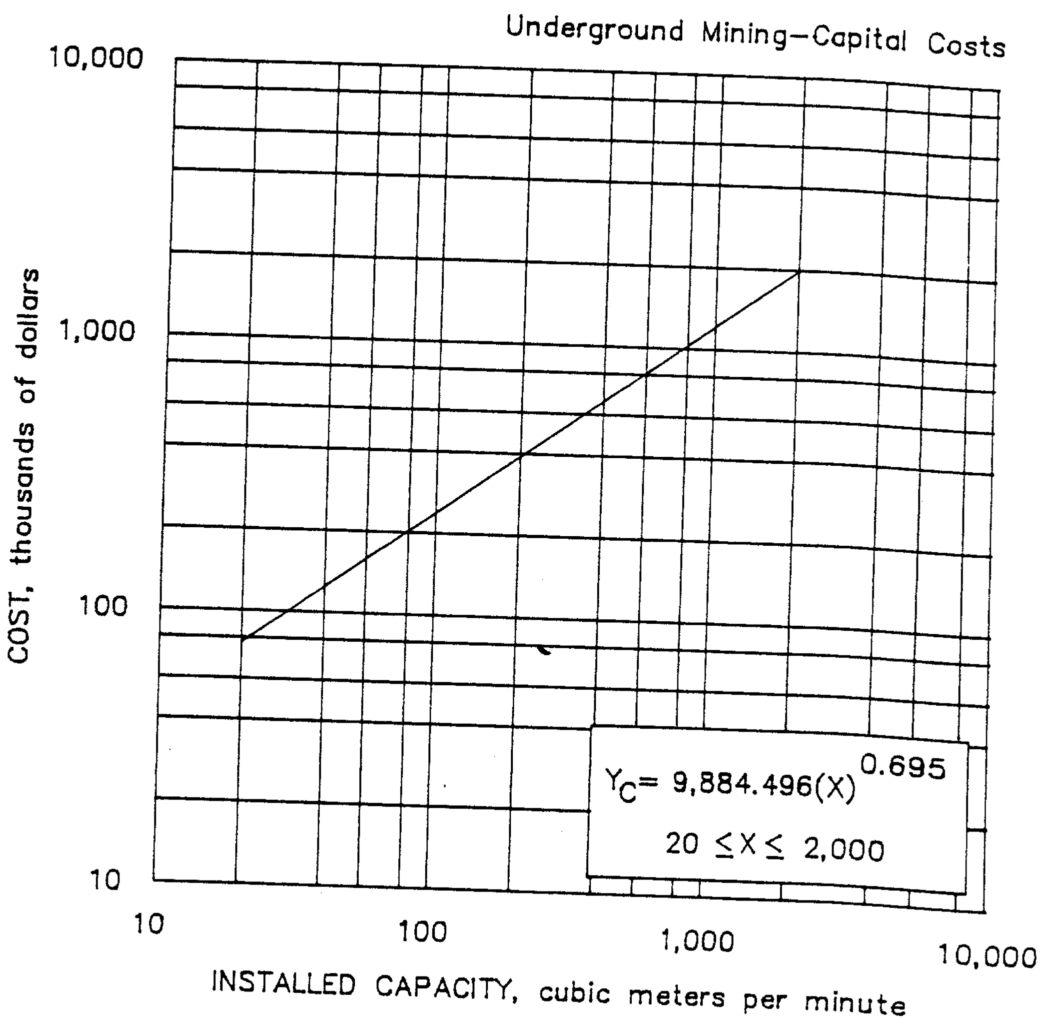
ADJUSTMENT FACTOR

Elevation Factor If elevation of the compressor plant varies from 1,600 m (5,249 ft) a correction for altitude must be applied to the air requirements. To adjust air volume requirements, multiply the cost obtained from the curve by the following factor:

Elevation,			Elevation,		
ft	mt	Factor	ft	mt	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.



4.2.5.2. Compressed air facilities

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.3. ELECTRICAL SYSTEM

Costs derived from this section include the purchase and installation of all electrical devices as well as lines and poles to service all surface and underground facilities. Power is carried to the servicing transformer at each building or load location. This includes all distribution lines on the surface, the major distribution lines down the shaft, and subfeeders to the load locations throughout the mine.

Two methods of cost determination are presented:

1) Determine standardized power requirements from the equations given below and using this value, determine the electrical system capital cost by referring to the base curve or the related equation.

Tonnage/electrical consumption equations:

Total kW = $46.61(T)^{0.640}$
where: T = ore and waste mined, in metric tons per day.

2) Determine the electrical consumption rate for the mine under study through review of the motor and lighting requirements, and use this total value rather than standardized power requirements for cost determination using the base curve.

BASE CURVE

The total cost is based on a single curve having power requirements (X), in total kilowatts. The curve is valid for operations between 1,000 and 40,000 kW, operating two shifts per day.

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

Construction labor cost.......	67%
Construction supply cost......	12%
Purchased equipment cost......	21%

The total electrical system capital cost is $(Y_C) = 934.503(X)^{0.720}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 626.117(X)^{0.720}$

(S) Construction Supply Cost $(Y_S) = 112.140(X)^{0.720}$

(E) Purchased Equipment Cost $(Y_E) = 196.246(X)^{0.720}$

ADJUSTMENT FACTORS

Substation Factor In many cases, power companies are able to supply power directly and a substation is not required; or, if it is required, the power company is willing to absorb the cost of its installation. This is especially true for the smaller tonnage facilities whose power usage does not exceed 10,000 kV·A. To adjust the electrical system capital costs for these instances, multiply the costs obtained from the curves by the following factors:

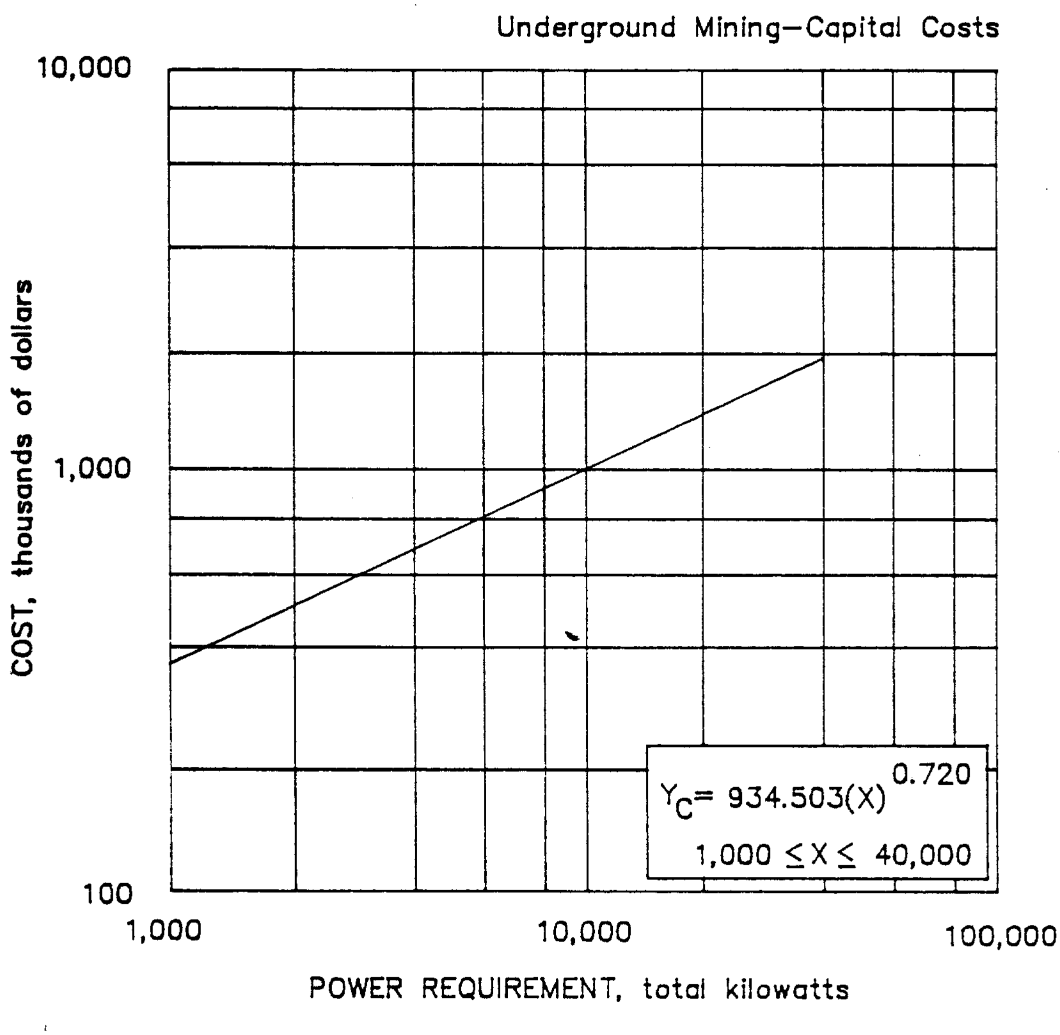
Labor factor (F_L) = 0.93

Supply factor (F_S) = 0.98

Purchased equipment factor (F_E) = 0.53

Adit Entry Factor In the event an adit entry is the primary means of access for the mine under investigation it is necessary to reduce the total kilowatt demand by the power requirements for hoisting and drainage. As both of these activities will not be required in that instance, reduce the total power appropriately before determining the capital cost using the cost equation contained in this section. If the evaluator has estimated or knows the power requirements for these activities, the adjustment can be made directly. If the power requirements are being estimated using the metric tons mined to kilowatt demand equation on the previous page, multiply the costs obtained from the curves by the following factor:

Adit entry factor (F_A) = 0.47



4.2.5.3. Electrical system

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.4. FUELING SYSTEM

The capital cost of fueling systems is based on estimated daily mine production, and accounts for all supplies and equipment needed for fuel storage and distribution, as well as installation labor. Costs are based on shaft entry mines serviced primarily by diesel equipment. Factors are provided for nondiesel operations, and mines accessed by adits. Mines generally have large surface fuel storage facilities that are connected by feeder lines to small underground distribution tanks. Small operations may rely on a single small fuel truck or rail fuel car that can be transported between levels.

The total capital cost is based on a single curve having a production rate (X), in metric tons ore and waste mined per day. The curve is valid for operations between 20 and 50,000 mtpd, operating two shifts per day.

BASE CURVE

Total cost accounts for purchase and installation of all surface and under- ground fuel storage tanks, tank fittings, foundations, individual tank piping, connecting pipes, pipe hangers, pumps, valves, and filters.

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

Construction labor cost.......	21%
Construction supply cost......	77%
Purchased equipment cost......	2%

The total small fueling system, 20 to 375 mtpd, capital cost is $(Y_{C\ SMALL}) = 11{,}547.394(X)^{0.000}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_{L\ SMALL}) = 2{,}424.953(X)^{0.000}$

(S) <u>Construction Supply Cost</u> $(Y_{S\ SMALL}) = 8{,}891.493(X)^{0.000}$

(E) <u>Purchased Equipment Cost</u> $(Y_{E\ SMALL}) = 230.948(X)^{0.000}$

The total large fueling system, 375 to 50,000 mtpd, capital cost is $(Y_{C\ LARGE}) = 10{,}362.394+3.161(X)$ is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_{L\ LARGE}) = 2{,}176.103+0.664(X)$

(S) <u>Construction Supply Cost</u> $(Y_{S\ LARGE}) = 7{,}979.043+2.434(X)$

(E) <u>Purchased Equipment Cost</u> $(Y_{E\ LARGE}) = 207.248+0.063(X)$

ADJUSTMENT FACTORS

<u>Nondiesel Mine Factor</u> In mines where the majority of the equipment is powered by sources other than diesel fuel, only a small surface storage facility is needed.

To account for this reduction in equipment, multiply the cost obtained from the curve by the following factor:

Nondiesel mine factor $(F_N) = 0.148$

Adit Entry Factor Mines that use an adit as their main access often depend on fuel trucks for diesel distribution rather than an underground fuel tank and pumping station. To account for the elimination of the underground fueling station, and the addition of a fuel truck, multiply the cost obtained from the curve by the following factor:

Adit entry factor $(F_A) = 0.854$

CAUTION Some States prohibit the storage of diesel fuel underground. This information can be obtained from the agency in charge of mining regulation for the State in question. If the deposit is in a State that prohibits underground fuel storage, the adit entry factor must be applied. This will eliminate the underground fueling station and account for an alternative distribution system.

The total office capital cost is $(Y_{C\ SQUARE\ METERS}) = 812.061(X)^{0.965}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ OFFICES-SQ\ M}) = 316.704(X)^{0.965}$

(S) Construction Supply Cost $(Y_{S\ OFFICES-SQ\ M}) = 406.031(X)^{0.965}$

(E) Purchased Equipment Cost $(Y_{E\ OFFICES-SQ\ M}) = 89.327(X)^{0.965}$

The total office capital cost is $(Y_{C\ MTPD}) = 2{,}961.959(T)^{0.595}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ OFFICES-MTPD}) = 1{,}155.164(T)^{0.595}$

(S) Construction Supply Cost $(Y_{S\ OFFICES-MTPD}) = 1{,}480.980(T)^{0.595}$

(E) Purchased Equipment Cost $(Y_{E\ OFFICES-MTPD}) = 325.815(T)^{0.595}$

LABORATORIES

The total capital cost is based on a single cost curve having an area (X), in square meters of office space or on a single cost curve having a production rate (T), in metric tons ore and waste mined per day (a typical waste tonnage of 10% is assumed; if this percentage is substantially exceeded, the total tonnage should be used for T). The curve is valid for areas of 28 to 700 m^2, or 850 to 18,000 mtpd, operating two mining shifts per day. The capital cost curve for assay laboratories includes construction of sample preparation, analytical, and metallurgical laboratory space as well as crushing, assaying, and metallurgical laboratory equipment. The capital cost is based on steel building construction and is for a laboratory used only by the mine. If laboratory space requirements are not known they can be estimated from the following equation:

Square meters of laboratory space $= 0.687(T)^{0.628}$
where: T = ore and waste mined, in metric tons per day.

Use the larger of 28 m^2 or the computed value for actual cost determination through the base curve below if laboratory facilities are to be built on-site.

The final assay laboratory cost derived from the curve is a combination of the following costs:

Construction labor cost.......	20%
Construction supply cost......	22%
Purchased equipment cost......	58%

The total laboratory capital cost is $(Y_{C\ SQUARE\ METERS}) = 2{,}645.438(X)^{0.901}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ LABS-SQ\ M}) = 529.088(X)^{0.901}$

(S) Construction Supply Cost $(Y_{S\ LABS-SQ\ M}) = 581.996(X)^{0.901}$

(E) Purchased Equipment Cost $(Y_{E\ LABS-SQ\ M}) = 1534.354(X)^{0.901}$

The total laboratory capital cost is ($Y_{C\ MTPD}$) = $1{,}874.219(T)^{0.565}$ and is distributed as follows:

(L) Construction Labor Cost ($Y_{L\ LABS\text{-}MTPD}$) = $374.844(T)^{0.565}$

(S) Construction Supply Cost ($Y_{S\ LABS\text{-}MTPD}$) = $412.328(T)^{0.565}$

(E) Purchased Equipment Cost ($Y_{E\ LABS\text{-}MTPD}$) = $1{,}087.047(T)^{0.565}$

ADJUSTMENT FACTORS

Joint Facility Factor When laboratory facilities are jointly used, which is often the case, multiply the laboratory area requirements for the mine by 1.5, determine the appropriate capital cost, and then split the cost 50% for the mine and mill capital cost categories. Combined mine and mill laboratory area should not exceed 700 m^2. If the number of samples assayed by the mine and mill are known, laboratory cost should be divided on this basis.

Shift Factor It is important to note that if a smaller laboratory is built with the intent of operating three shifts per day rather than two, as assumed for the base case, capital costs will be substantially reduced. Likewise, space requirements for a laboratory operated one shift per day will be considerably greater. To adjust from the two shift basis it is necessary to multiply the shift ratio (base/actual) times the mine capacity before determining the space requirements through the tonnage/square meter relationship and then use the adjusted value for actual cost determination. For offices this is not generally considered to be a suitable adjustment as these facilities are invariably used only one shift per day.

Weather Factor For office facilities and laboratory facilities located in climates that vary from the Denver, CO, area, multiply the costs obtained from the curves by the following factors:

Mild areas:

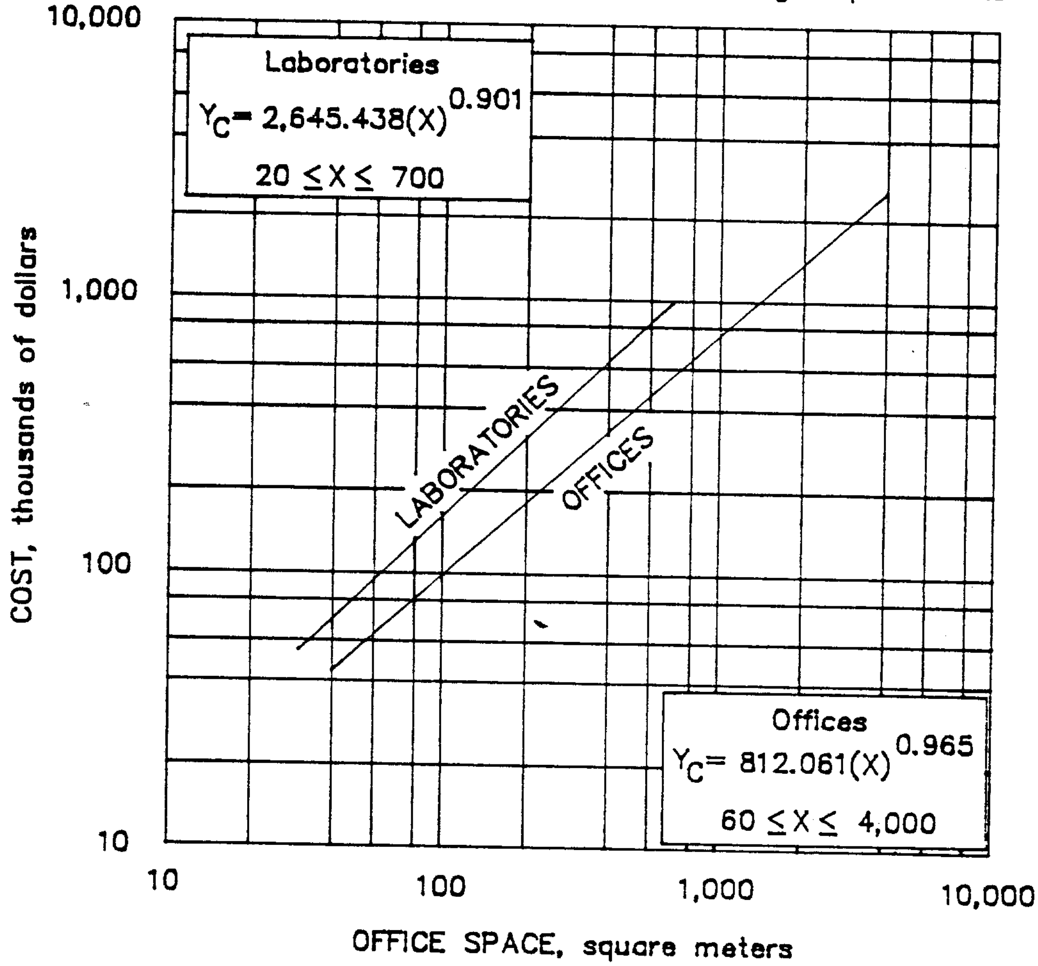
Weather factor ($F_{L\ OFFICE\text{-}MILD}$) = 0.95

Weather factor ($F_{L\ LABORATORY\text{-}MILD}$) = 0.98

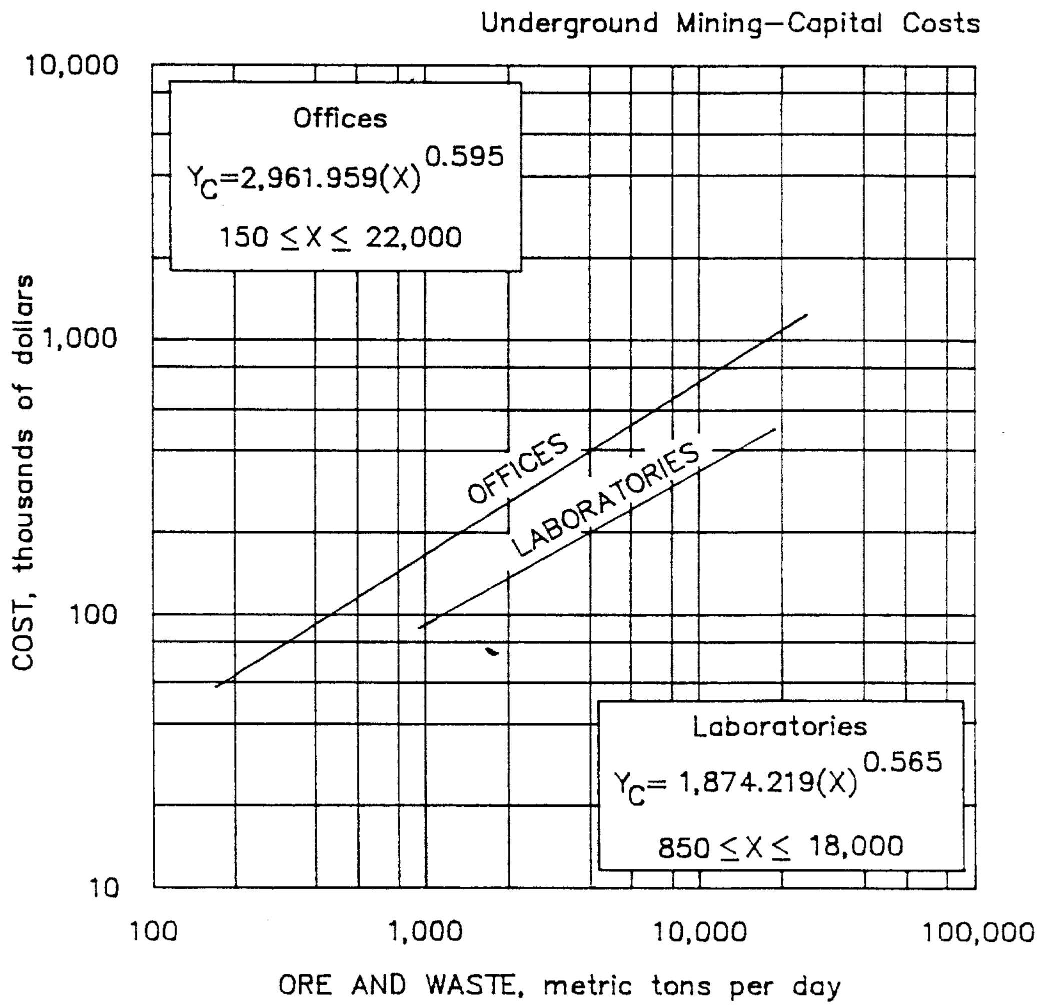
Severe areas:

Weather factor ($F_{L\ OFFICE\text{-}SEVERE}$) = 1.07

Weather factor ($F_{L\ LABORATORY\text{-}SEVERE}$) = 1.04



4.2.5.6.a Offices and laboratories



4.2.5.6.b Offices and laboratories

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.7. PORTABLE POWER GENERATION

This section is to be used in conjunction with section 5.2.4.8. when electrical power is unavailable through a commercial power utility company or when it would be uneconomical to run power distribution facilities to the user. No adjustments are necessary for the mine or mineral processing plant electrical system [sections 2.2.4.2., 4.2.5.3., and 6.1.8.4. (IC 9143)] because output power matches the power input to the mine/processing plant transformer-switchgear substations.

The cost shown is for acquisition and installation of the primary power source, either a horizontal-diesel or a gas-turbine operated generator. The cost curve is based on a single 60-Hz, three-phase electrical generator providing all power at the rated kilowatt output. This section should be included in the mine and/or mineral processing plant capital cost totals.

BASE CURVE

The total capital cost is based on a single cost curve having an average continuous power output (X), in kilowatts. The curve is valid for generators between 18 to 23,600 kW. The curve includes all costs associated with the acquisition, transportation, and installation of single-unit generators.

To convert from kilovolt amperes (kV•A) demand to kilowatt (kW) power output, estimate power factor (PF). This may vary from 0.80 for electric motor circuits to 1.00 for electric light circuits. The kilowatt power output is then determined by kV•A x PF = kW.

The costs derived from the curves are a combination of the following costs:

	Horizontal diesel (18 to 2,900 kW)	Gas turbine (2,900 to 23,600 kW)
Installation labor cost..........	21%	21%
Installation materials cost......	20%	20%
Purchased equipment cost.........	58%	59%
Freight cost.....................	1%	-

Installation is assumed to be half labor and half materials.

The total diesel powered portable power generation capital cost is $(Y_{C\ DIESEL}) = 797.574(X)^{0.876}$ and is distributed as follows:

(L) <u>Installation Labor Cost</u> $(Y_{L\ DIESEL}) = 167.491(X)^{0.876}$

(S) <u>Installation Materials Cost</u> $(Y_{S\ DIESEL}) = 159.514(X)^{0.876}$

(E) <u>Purchased Equipment Cost</u> $(Y_{E\ DIESEL}) = 470.568(X)^{0.876}$

The total turbine-powered portable power generation capital cost is $(Y_{C\ TURBINE}) = 2{,}251.219(X)^{0.872}$ and is distributed as follows:

(L) Installation Labor Cost $(Y_{L\ TURBINE}) = 472.756(X)^{0.872}$

(S) Installation Materials Cost $(Y_{S\ TURBINE}) = 450.244(X)^{0.872}$

(E) Purchased Equipment Cost $(Y_{E\ TURBINE}) = 1328.219(X)^{0.872}$

Power Output Determination For surface mine power output (kW), see Electrical System (section 2.2.4.2.). For underground mine and mineral processing plant power demand (kV·A), see Electrical System [sections 4.2.5.3. and 6.1.8.4. (IC 9143)].

ADJUSTMENT FACTORS

Power Rate If power is to be supplied by more than one unit, 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 curve. After the unit-cost has been calculated, the cost must be multiplied by the total number of units used.

Power Source If geography or economics necessitate multiple power sites to support mines and mineral processing plants, portable power cost should be estimated separately for each site using this section.

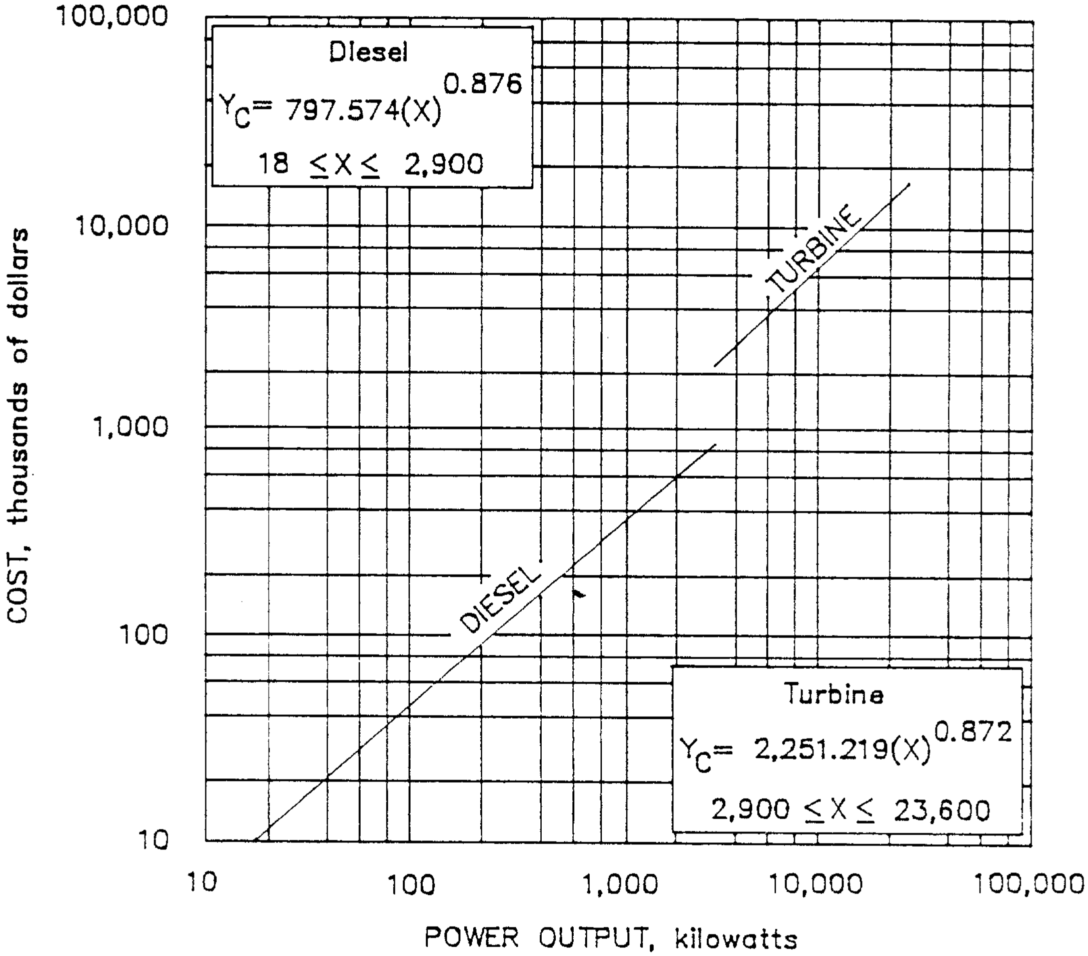
Shift Adjustment Adjustment for the number of operating shifts is implicit in the choice of the average continuous power output.

Economic Life The normal economic life for generators is 25,000 h for units rated at 1,100-kW output or greater and ranges from 11,000 to 17,500 h for units rated at less than 1,100-kW output.

If the units are operated at standby rates, roughly 10% over capacity, the economic life would decrease by 50%.

If high-sulfur fuels are used, the economic life would be decreased by 25%.

Underground Mining—Capital Costs



4.2.5.7. Portable power generation

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.8. REPAIR SHOPS AND WAREHOUSES

In this section underground and surface facilities for repairing and ware- housing mine equipment and supplies are presented separately. Total capital cost is the summation of the two categories. If a mine's primary haulage system utilizes trackless equipment with an adit entry and/or has all repair shops and warehouses located on the surface and underground, the estimator should refer to section 2.2.4.7. (Surface Mine Repair Shops and Warehouses).

BASE CURVES

Repair shop and warehouse capital cost curves include all costs associated with acquisition, installation, and equipping of repair shops and warehouses for an underground mining operation. Repair shops are adequately equipped to maintain and repair virtually all mine equipment.

The total capital cost is based on a single cost curve having an area (X), in square meters of floor space or on a single cost curve having a production rate (T), in metric tons ore and waste mined per day (a typical waste tonnage of 10% is assumed; if this percentage is substantially exceeded, the total tonnage should be used for T). The curve is valid for areas between 40 and 17,000 m^2 (300 to 3,400 m^2 for underground facilities and 40 to 17,000 m^2 for surface facilities), or 300 to 63,000 mtpd, operating two mining shifts per day.

SURFACE REPAIR SHOP AND WAREHOUSE FACILITIES

The surface facilities capital costs are based on single-story steel building construction for Denver, CO, area weather requirements. If surface repair shop and warehouse space requirements are known the capital cost estimate may be made directly by consulting the curve (the curve is valid for areas between 40 and 17,000 m^2). If surface repair shop and warehouse space requirements are not known, they can be estimated from the following equation:

Square meters = $0.500(T)^{0.952}$
where: T = ore and waste mined, in metric tons per day.

The final surface repair shop and warehouse cost derived from the curve is a combination of the following costs:

	Small (40 to 9,000 m^2)	Large (9,000 to 17,000 m^2)
Construction labor cost.....	34%	42%
Construction supply cost....	42%	51%
Purchased equipment cost....	24%	7%

The total surface repair shop and warehouse capital cost is
$(Y_{C\ SURFACE\text{-}SQUARE\ METERS}) = 1,089.174(X)^{0.856}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L \text{ SURF-SM-SQ M}) = 272.294(X)^{0.856}$
(S) Construction Supply Cost $(Y_S \text{ SURF-SM-SQ M}) = 337.644(X)^{0.856}$
(E) Purchased Equipment Cost $(Y_E \text{ SURF-SM-SQ M}) = 479.237(X)^{0.856}$

(L) Construction Labor Cost $(Y_L \text{ SURF-LG-SQ M}) = 457.453(X)^{0.856}$
(S) Construction Supply Cost $(Y_S \text{ SURF-LG-SQ M}) = 555.479(X)^{0.856}$
(E) Purchased Equipment Cost $(Y_E \text{ SURF-LG-SQ M}) = 76.242(X)^{0.856}$

(L) Construction Labor Cost $(Y_L \text{ SURF-AVG-SQ M}) = 370.319(X)^{0.856}$
(S) Construction Supply Cost $(Y_S \text{ SURF-AVG-SQ M}) = 446.561(X)^{0.856}$
(E) Purchased Equipment Cost $(Y_E \text{ SURF-AVG-SQ M}) = 272.294(X)^{0.856}$

The total surface repair shop and warehouse capital cost is $(Y_C \text{ SURFACE-MTPD}) = 862.559(T)^{0.792}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L \text{ SURF-SM-MTPD}) = 362.275(T)^{0.792}$
(S) Construction Supply Cost $(Y_S \text{ SURF-SM-MTPD}) = 267.393(T)^{0.792}$
(E) Purchased Equipment Cost $(Y_E \text{ SURF-SM-MTPD}) = 379.526(T)^{0.792}$

(L) Construction Labor Cost $(Y_L \text{ SURF-LG-MTPD}) = 521.676(T)^{0.792}$
(S) Construction Supply Cost $(Y_S \text{ SURF-LG-MTPD}) = 439.905(T)^{0.792}$
(E) Purchased Equipment Cost $(Y_E \text{ SURF-LG-MTPD}) = 60.379(T)^{0.792}$

(L) Construction Labor Cost $(Y_L \text{ SURF-AVG-MTPD}) = 293.270(T)^{0.792}$
(S) Construction Supply Cost $(Y_S \text{ SURF-AVG-MTPD}) = 353.649(T)^{0.792}$
(E) Purchased Equipment Cost $(Y_E \text{ SURF-AVG-MTPD}) = 215.640(T)^{0.792}$

UNDERGROUND REPAIR SHOP AND WAREHOUSE FACILITIES

Underground facility costs are based on excavating and equipping well-illuminated, painted, and concrete-floored repair shops and warehouses. If underground repair shop and warehouse space requirements are known the capital cost estimate may be made directly by consulting the curve (the curve is valid for areas between 300 to 3,400 m^2). If space requirements are not known they can be estimated from the following equation:

Square meters = $53.646(T)^{0.376}$
where: T = ore and waste mined, in metric tons per day.

The final underground repair shop and warehouse cost derived from the curve is a combination of the following costs:

	Small (300 to 2,300 m^2)	Large (2,300 to 3,400 m^2)
Construction labor cost.....	23%	21%
Construction supply cost....	30%	29%
Purchased equipment cost....	47%	50%

The total underground repair shop and warehouse capital cost is $(Y_C \text{ UNDERGROUND-SQUARE METER}) = 79.664(X)^{1.189}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ UG\text{-}SM\text{-}SQ\ M}) = 20.713(X)^{1.189}$
(S) Construction Supply Cost $(Y_{S\ UG\text{-}SM\text{-}SQ\ M}) = 31.866(X)^{1.189}$
(E) Purchased Equipment Cost $(Y_{E\ UG\text{-}SM\text{-}SQ\ M}) = 27.086(X)^{1.189}$

(L) Construction Labor Cost $(Y_{L\ UG\text{-}LG\text{-}SQ\ M}) = 16.729(X)^{1.189}$
(S) Construction Supply Cost $(Y_{S\ UG\text{-}LG\text{-}SQ\ M}) = 23.103(X)^{1.189}$
(E) Purchased Equipment Cost $(Y_{E\ UG\text{-}LG\text{-}SQ\ M}) = 39.832(X)^{1.189}$

(L) Construction Labor Cost $(Y_{L\ UG\text{-}AVG\text{-}SQ\ M}) = 18.323(X)^{1.189}$
(S) Construction Supply Cost $(Y_{S\ UG\text{-}AVG\text{-}SQ\ M}) = 25.492(X)^{1.189}$
(E) Purchased Equipment Cost $(Y_{E\ UG\text{-}AVG\text{-}SQ\ M}) = 35.849(X)^{1.189}$

The total underground repair shop and warehouse capital cost is $(Y_{C\ UNDERGROUND\text{-}MTPD}) = 8{,}425.625(T)^{0.457}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ UG\text{-}SM\text{-}MTPD}) = 2{,}190.663(T)^{0.457}$
(S) Construction Supply Cost $(Y_{S\ UG\text{-}SM\text{-}MTPD}) = 3{,}370.250(T)^{0.457}$
(E) Purchased Equipment Cost $(Y_{E\ UG\text{-}SM\text{-}MTPD}) = 2{,}864.712(T)^{0.457}$

(L) Construction Labor Cost $(Y_{L\ UG\text{-}LG\text{-}MTPD}) = 1{,}769.381(T)^{0.457}$
(S) Construction Supply Cost $(Y_{S\ UG\text{-}LG\text{-}MTPD}) = 2{,}443.431(T)^{0.457}$
(E) Purchased Equipment Cost $(Y_{E\ UG\text{-}LG\text{-}MTPD}) = 4{,}212.813(T)^{0.457}$

(L) Construction Labor Cost $(Y_{L\ UG\text{-}AVG\text{-}MTPD}) = 1{,}937.894(T)^{0.457}$
(S) Construction Supply Cost $(Y_{S\ UG\text{-}AVG\text{-}MTPD}) = 2{,}696.200(T)0.457$
(E) Purchased Equipment Cost $(Y_{E\ UG\text{-}AVG\text{-}MTPD}) = 3{,}791.531(T)^{0.457}$

ADJUSTMENT FACTORS

Weather Factor For underground mines with surface facilities located in climates that vary from the Denver, CO, area, multiply labor and supplies portions of the costs obtained from the surface facilities curve by the following factors:

Mild areas:

Labor factor $(F_{L\ SURFACE\text{-}MILD}) = 0.94$

Supplies factor $(F_{S\ SURFACE\text{-}MILD}) = 0.94$

Severe areas:

Labor factor $(F_{L\ SURFACE\text{-}SEVERE}) = 1.08$

Supplies factor $(F_{S\ SURFACE\text{-}SEVERE}) = 1.08$

Room-and-Pillar Mine Factor For room and pillar mines with underground facilities emplaced in mined out areas, multiply the costs obtained from the curves by the following factors:

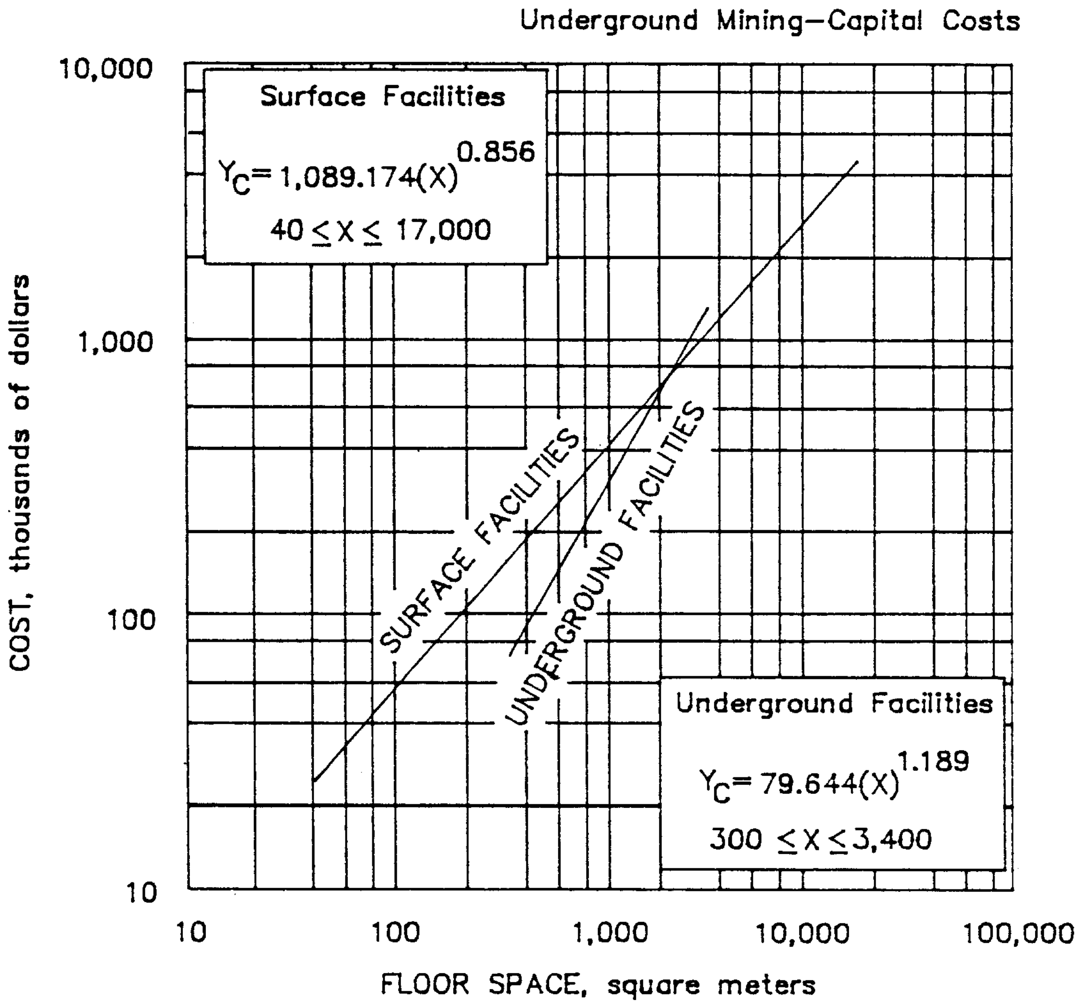
Labor factor $(F_{L\ R\&P\ MINED\ OUT\ AREAS}) = 0.48$

Supplies factor $(F_{S\ R\&P\ MINED\ OUT\ AREAS}) = 0.41$

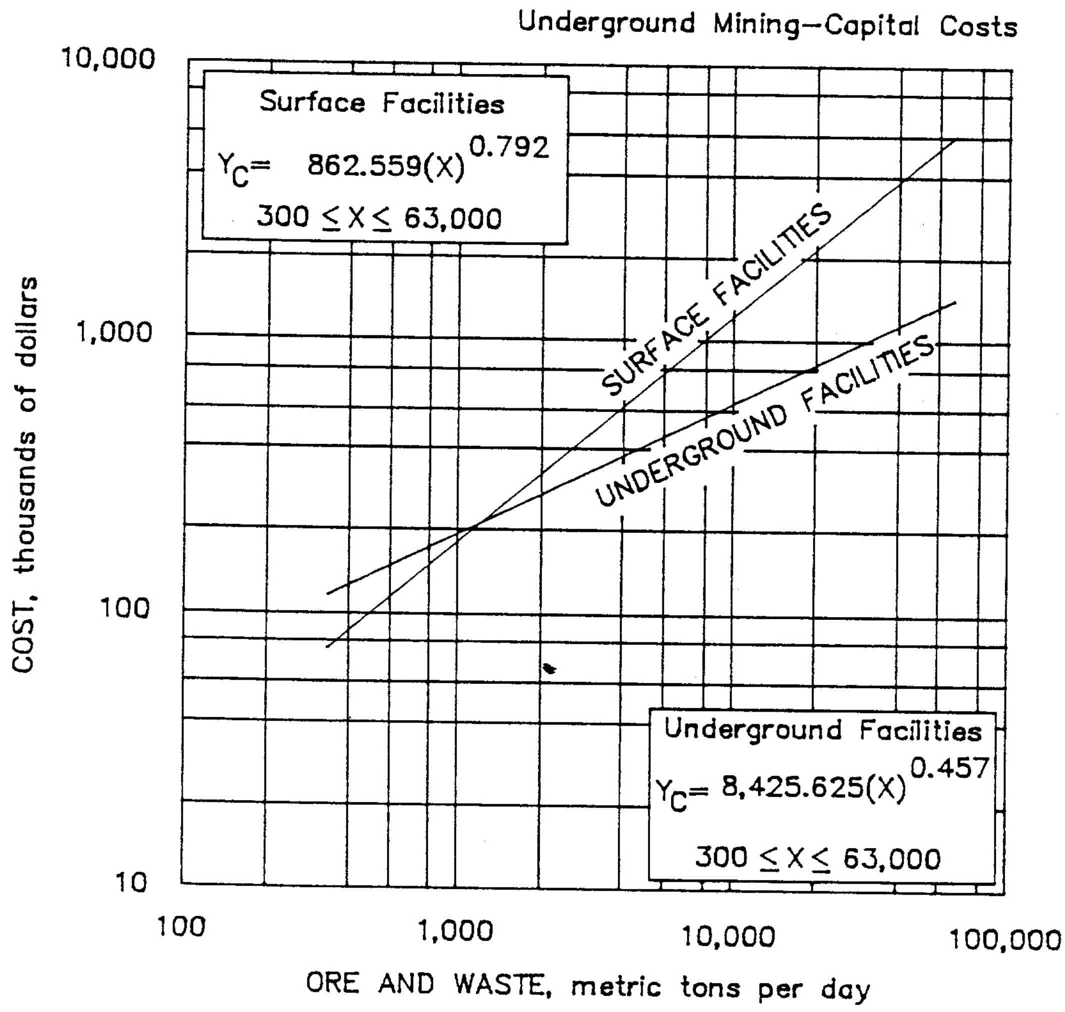
Multilevel Mine Factor Multilevel mines commonly have satellite shops on each active producing level for equipment maintenance and minor repairs. The cost for satellite repair shops is

Satellite repair shops cost $(Y_S) = (N)9.710(T)^{0.914}$
where N = number of active producing levels,
and T = ore mined, in metric tons per day.

Add the cost for satellite repair shops to the costs obtained from the curves to obtain a total cost.



4.2.5.8.a Repair shops and warehouses



4.2.5.8.b Repair shops and warehouses

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.9. STOCKPILE STORAGE FACILITIES

A stockpile storage facility provides sufficient storage capacity for a material until it can be further processed. A storage facility may also provide adequate reserve material to dampen surges in the material supply. Examples of materials stockpiled are smelter flux, coal, and coarse ore. For this base curve, capital cost is correlated to the live storage capacity of the stockpile facility. Live storage capacity of a stockpile is normally about 25% of the total stockpile capacity and 150% of the daily stockpile reclaim rate. The stockpile storage facility capital cost includes all costs associated with acquisition and installation of stockpiling conveyors, reclaim tunnels, reclaim feeders, and reclaim conveyors.

BASE CURVE

The total capital cost is based on a single cost curve having a live storage capacity (X), in metric tons. The curve is valid for capacities of 3,000 to 300,000 mt, operating two shifts per day.

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

Construction labor cost.......	13%
Construction supply cost......	36%
Purchased equipment cost......	51%

A typical breakdown of the major cost components is:

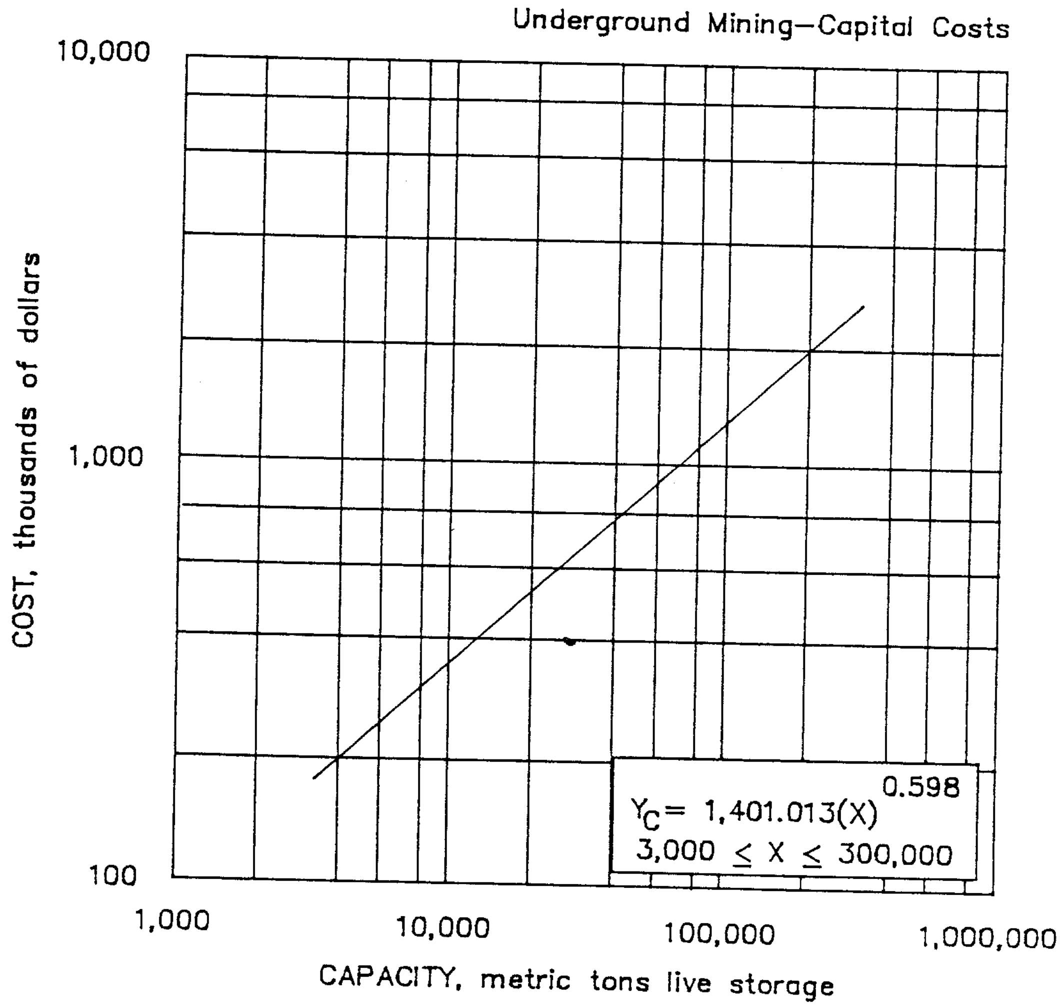
Reclaim feeders...............	14%
Stockpiling conveyor..........	23%
Reclaim tunnels...............	31%
Reclaim conveyors.............	32%

The total stockpile storage facility capital cost is $(Y_C) = 1,401.013(X)^{0.598}$ and is distributed as follows:

(L) Construction labor cost $(Y_L) = 182.132(X)^{0.598}$

(S) Construction supply cost $(Y_S) = 504.365(X)^{0.598}$

(E) Purchased equipment cost $(Y_E) = 714.516(X)^{0.598}$



4.2.5.9. Stockpile storage facilities

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.10. SURFACE BUILDINGS

Surface building capital costs cover the general support facilities required for the mining operation. The buildings are single-story construction. The total capital cost is based on a single cost curve having a combined floor space (X), in square meters or having a production rate (T), in total metric tons of ore and waste per day. The curve is valid for areas of 20 to 20,000 m^2, or production rates of 290 to 12,000 mtpd, operating three shifts per day.

BASE CURVE

Through use of the base curve, the evaluator may determine the total cost of all buildings covered in this category. These buildings include the change house, powder magazines, lamproom, first aid room, guard house, and security fences. The determined cost encompasses construction material, construction labor, as well as purchase and installation of the building fixtures.

If the total required floor space is not known, the final cost may be estimated by first determining the staffing or labor requirements needed based on the number of metric tons to be mined each day. In a three-shift-per-day operation, the surface building area needed equals approximately 2.23 m^2 for each individual employed in the mining operation. By taking the daily tonnage mined and dividing that number by the appropriate tonnage per worker ratio found in the tabluation on the following page, one derives an estimate of the daily labor requirements. If this value is further divided by three shifts per day and the resultant answer multiplied by 2.23, an estimate of the square meter requirements for surface buildings can be achieved.

Square meters requirement $(X_S) = 0.743(T/R)$
where T = ore and waste mined, in metric tons per day,
and R = metric tons per worker-shift ratio (see tabluation on following page).

The final answer is then entered into the square meters base curve equation.

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

Construction labor cost.......	32%
Construction supply cost......	51%
Purchased equipment cost......	17%

The total surface buildings capital cost is $(Y_{C\ SQUARE\ METERS}) = 8,987.000(X)^{0.684}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \mathrm{SQUARE\ METERS}}) = 2,875.840(X)^{0.684}$

(S) Construction Supply Cost $(Y_{S\ \mathrm{SQUARE\ METERS}}) = 4,583.370(X)^{0.684}$

(E) Purchased Equipment Cost $(Y_{E\ \mathrm{SQUARE\ METERS}}) = 1,527.790(X)^{0.684}$

The total surface buildings capital cost is $(Y_{C\ \mathrm{MTPD}}) = 13,552.211(T)^{0.436}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \mathrm{MTPD}}) = 4,336.708(T)^{0.436}$

(S) Construction Supply Cost $(Y_{S\ \mathrm{MTPD}}) = 6,911.628(T)^{0.436}$

(E) Purchased Equipment Cost $(Y_{E\ \mathrm{MTPD}}) = 2,303.876(T)^{0.436}$

Productivity of mining methods

Method	Metric tons/worker-shift ratio	
	Normal	High
Room and pillar........	27-45	45-64
Sublevel caving........	18-36	36-45
Block caving...........	14-36	36-45
Sublevel stoping.......	14-27	36-45
Cut and fill mining....	9-18	27-36
Shrinkage stoping......	4.5- 9	18-25
Square set mining......	1- 3	9-14
		NAp

NAp Not applicable.

Source: Modified from Society of Mining Engineers AIME Underground Mining Methods Handbook, ed. by W.A. Hustrulid, 1982, p. 109.

ADJUSTMENT FACTORS

Joint Facility Factor If mine and mill share these facilities it is important to reduce the capital cost of the mine section appropriately. To determine the capital cost in this instance, calculate the total space requirements for both mine and mill and the percentage each facility requires. The amount to be accounted to mine capital cost can be then calculated, using the base curve, from the mine's percentage of the total space requirements.

Weather Factor For surface buildings located in climates that vary from the Denver, CO, area, multiply the labor and supplies costs obtained from the curves by the following factors:

Mild areas:

Labor factor $(F_{L\ \mathrm{MILD}}) = 0.960$

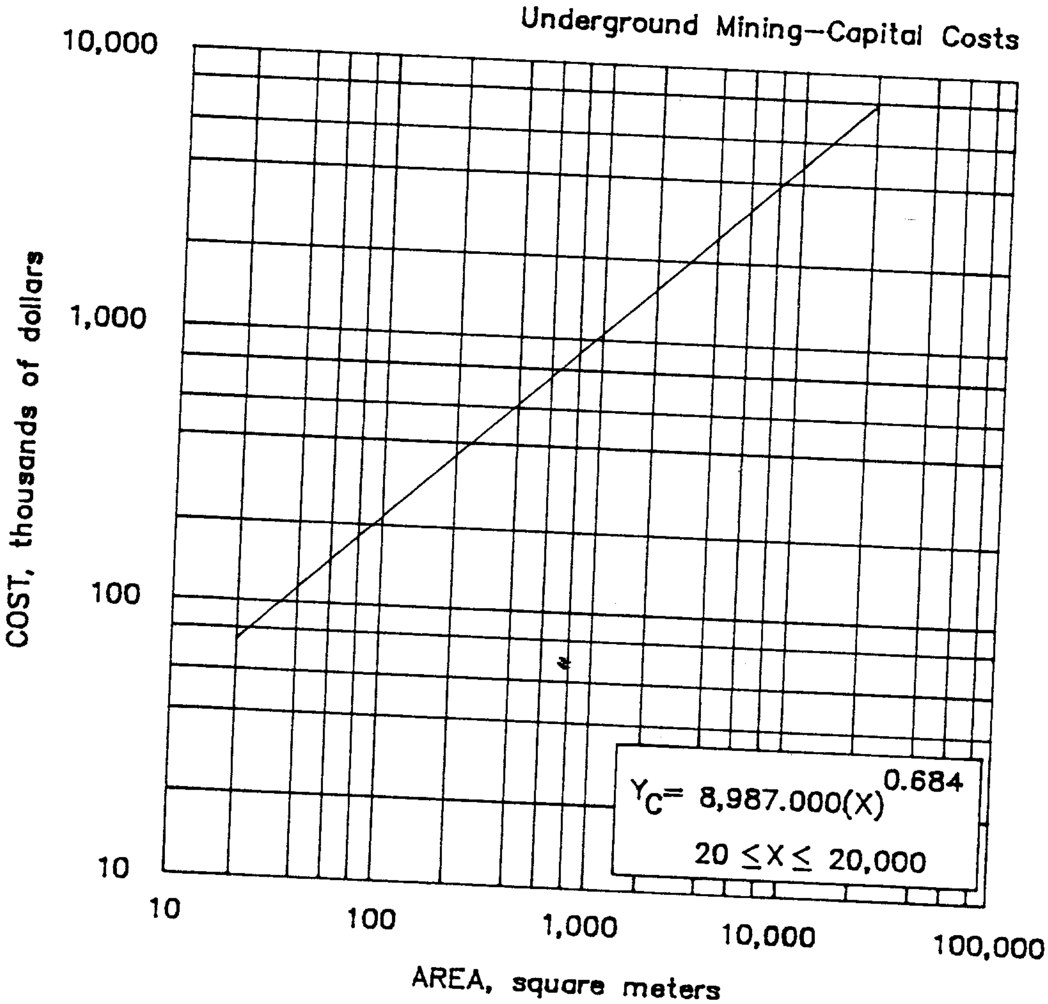
Supply factor $(F_{S\ \mathrm{MILD}}) = 0.940$

Severe areas:

Labor factor $(F_{L\ \mathrm{SEVERE}}) = 1.080$

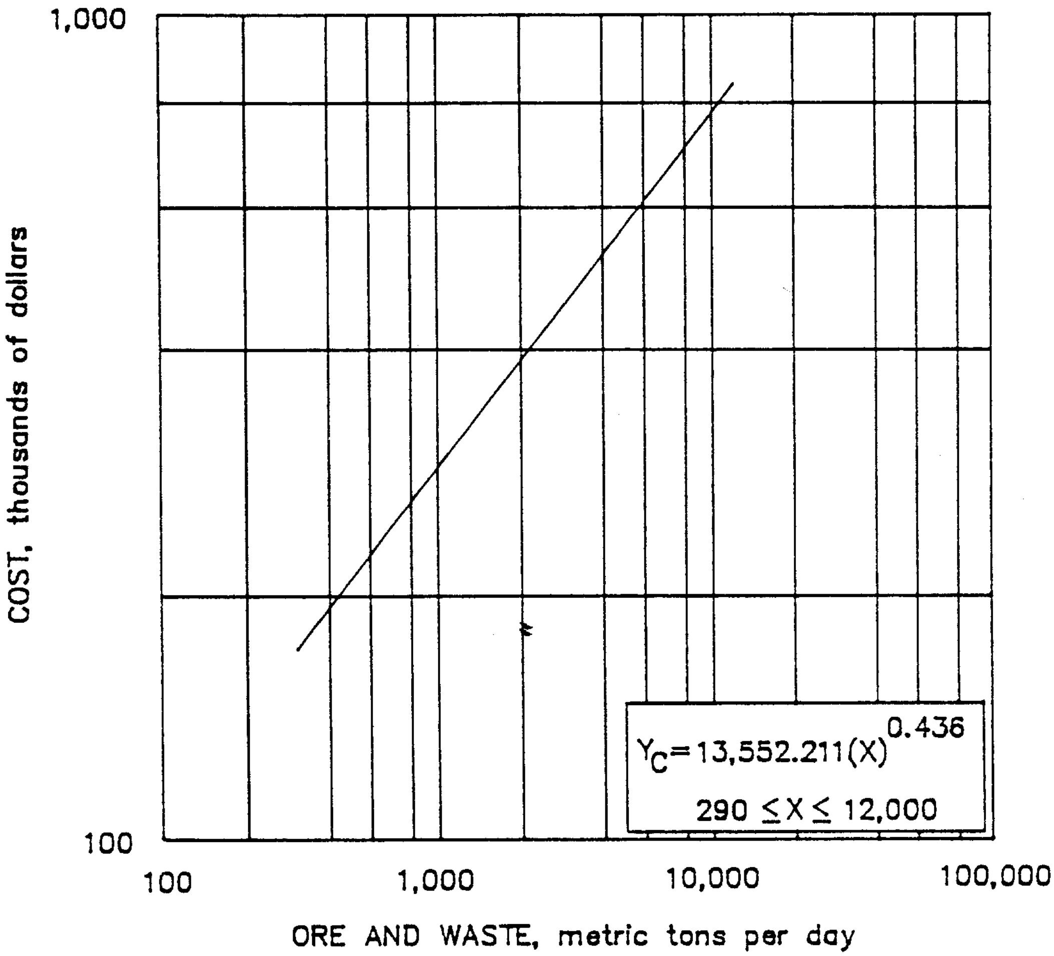
Supply factor $(F_{S\ \mathrm{SEVERE}}) = 1.080$

Shift Factor Where a proposed mine will be operating less than three shifts per day, the surface building requirements will rise a fractional amount. The additional floor space for the change house should be determined and included with the value used in the base curve equation.



4.2.5.10.a Surface buildings

Underground Mining—Capital Costs



4.2.5.10.b Surface buildings

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.11. VENTILATION SYSTEM

Mine ventilation system capital and operating costs are dependent on the energy to move a quantity of air through a mine. Some factors that determine mine air quantity, measured in cubic meters per minute, are the number of personnel underground, diesel equipment operation, presence or absence of methane, and air temperature and humidity. Energy, measured in kilowatts, required to move an air quantity through a mine is dependent on the mine's pressure head or mine head, measured in pascals. Factors that affect mine head are airway length, airway perimeter, airway perimeter roughness, air velocity, and overall configuration of the airways.

Costs derived using this cost-equation are valid for proposed or recently opened mines. For older, more complex ventilation systems with numerous shafts, levels, and working areas, more reliable costs may be determined by obtaining the actual equipment and installation cost data from the mine owner and equipment manufacturers.

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 per metric ton (m^3/min/mt)	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 CURVE

Total cost is based on a single cost curve having a mine air quantity demand (X), in cubic meters per minute. The curve is valid between 1,000 and 60,000 m^3/min, operating three shifts per day. The excavation cost for airways (i.e. drifts, crosscuts, shafts, and/or raises) are not included in this curve and should be derived in section 4.2.1., Preproduction Development.

The ventilation curve cost includes the installed cost of the main ventilation system and acquisition cost of auxiliary ventilation equipment. Main system installation includes the cost of labor, fans, foundations, motors, ductwork, bulkheads, and air doors.

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

Construction labor cost........	19%
Construction supply cost.......	13%
Purchased equipment cost.......	68%

The total ventilation system capital cost is $(Y_C) = 278{,}119.058e^{0.00004(X)}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 52{,}842.621e^{0.00004(X)}$

(S) Construction Supply Cost $(Y_S) = 36{,}155.478e^{0.00004(X)}$

(E) Purchased Equipment Cost $(Y_E) = 189{,}120.959e^{0.00004(X)}$

ADJUSTMENT FACTORS

Air-Cooling and Air-Warming Factors Depending on climatic and/or underground conditions, mine air may need to be warmed and/or cooled. If a ventilation system supplies intake air through a service shaft and outside temperatures go below 0C (32F) for an extended period of time, air-warming is necessary. Air-cooling plants are used when mine air wet-bulb and dry-bulb temperatures are near or above 27C (80F) because of a hot climate, high wall rock temperatures, and/or high water temperatures.

If air cooling is required, multiply the cost obtained from the ventilation system curves by the following factors:

Labor factor $(F_{L\ COOLING}) = 1.10$

Supply factor $(F_{S\ COOLING}) = 1.15$

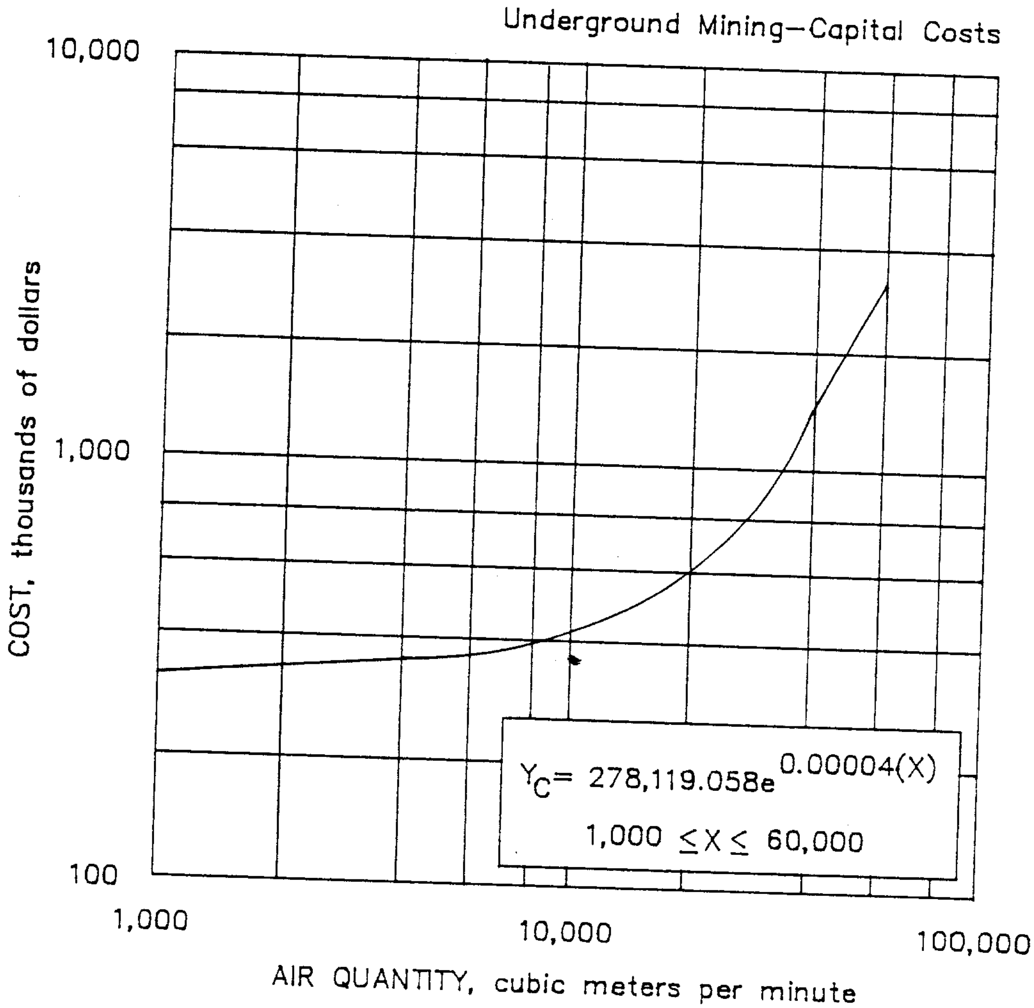
Purchased equipment factor $(F_{E\ COOLING}) = 1.30$

If air warming is required, multiply the cost obtained from the ventilation system curves by the following factors:

Labor factor $(F_{L\ WARMING}) = 1.10$

Supply factor $(F_{S\ WARMING}) = 1.11$

Purchased equipment factor $(F_{E\ WARMING}) = 1.10$



4.2.5.11. Ventilation system

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

4.2.5.12.1. WATER AND DRAINAGE SYSTEM
DRAINAGE AND DISPOSAL SYSTEM

The capital cost of a drainage system is based upon the volume of water pumped daily from the underground workings. The system is composed of pumping equipment, pipes, connectors, valves, sumps, service adits and pumping stations, formwork, concrete flooring, miscellaneous wiring, and maintenance equipment. Discharged water is pumped through piping to a surface mill or tailings pond.

BASE CURVE

The total capital cost is based on a single curve having a water discharge rate (X), in cubic meters per day. The curve is valid for pumping operations between 600 and 20,000 m^3/d, operating 24 h/d. A standard pumping height of 610 m (2,000 ft) is used. Allowances have been made for pumping head versus pumping height. As individual cases will invariably require adjustment for depth, an appropriate factor is given in the adjustments section below.

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

Construction labor cost.......	15%
Construction supply cost......	19%
Purchased equipment cost......	66%

The total drainage supply system capital cost is $(Y_C) = 1{,}093.057(X)^{0.690}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 163.959(X)^{0.690}$

(S) Construction Supply Cost $(Y_S) = 207.681(X)^{0.690}$

(E) Purchased Equipment Cost $(Y_E) = 721.418(X)^{0.690}$

ADJUSTMENT FACTORS

Total Pumping Height When pumping heights differ from the 610 m (2,000 ft) standard used here, multiply the costs obtained from the drainage and disposal curves by the following factor:

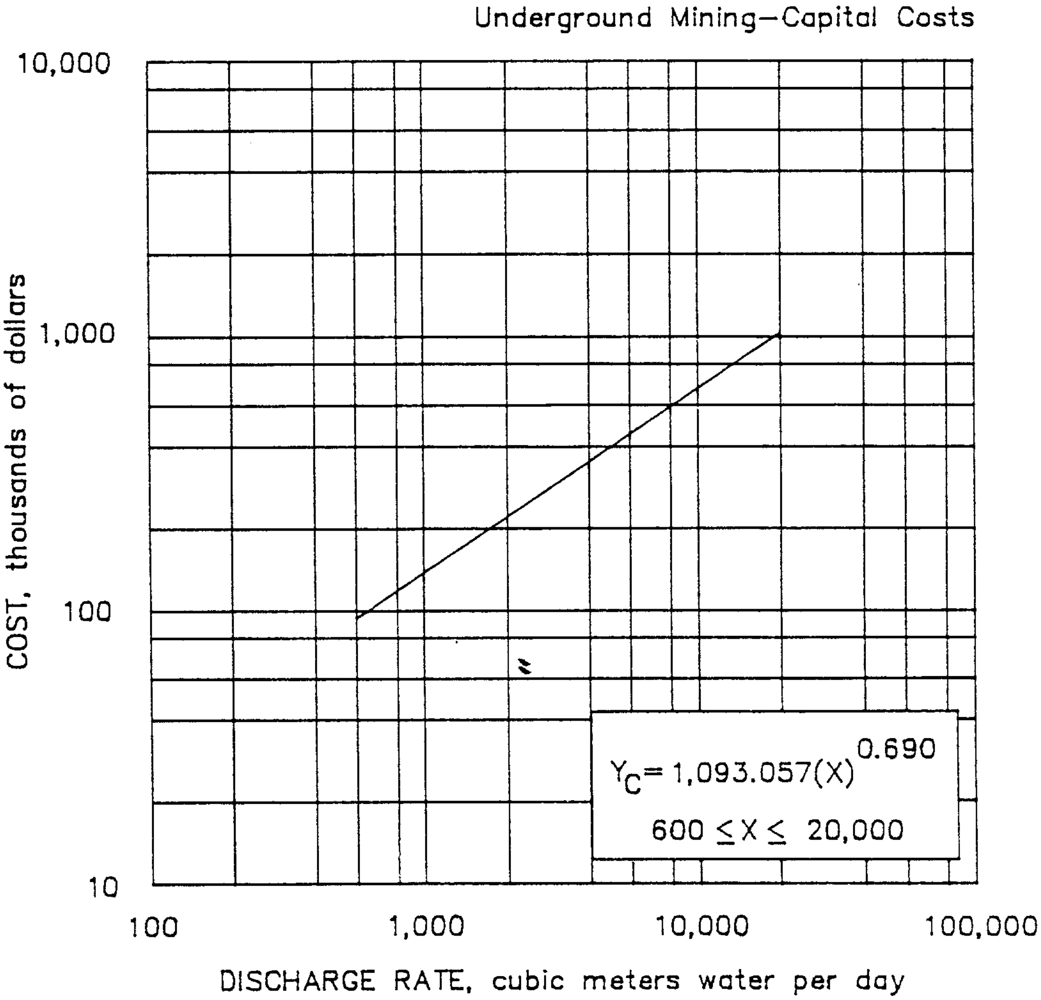
Height factor $(F_H) = 0.642e^{0.0008(H)}$
where: H = actual pumping head, in meters.

Horizontal Drainage Factor If drainage water is collected, and initial settling occurs in sumps located in the mine prior to pumping the water out through the portal of an adit (rather than up a shaft), multiply the costs obtained from the drainage and disposal curves by the following factor:

Horizontal drainage factor $(F_{D\ SETTLING}) = 0.37$
This cost is distributed 36% for labor, 44% for supplies, and 20% for equipment.

If drainage water is pumped directly out of an adit portal without initial settling, multiply the costs obtained from the drainage and disposal curves by the following factor:

Horizontal drainage factor $(F_{D\ NO\ SETTLING}) = 0.22$
This cost is distributed 32% for labor, 39% for supplies, and 29% for equipment.



4.2.5.12.1. Water and drainage system
DRAINAGE AND DISPOSAL SYSTEM

4.2. UNDERGROUND MINING--CAPITAL COSTS

4.2.5. MINE PLANT GENERAL OPERATIONS

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

The capital cost of a water supply system is based on volume demand and includes a method for collection, storage, and distribution of water. A mine and mill near to each other typically use the same water system. Water systems capable of supplying up to 125 m^3/h (550 gal/min) of makeup water usually comprise a system of wells, storage tanks at the mine site, and distribution lines between the various use locations. Larger systems generally include long, large-diameter pipelines and/or an earthen dike reservoir. The capital cost of the first of these cases is discussed in this section as it is typical of an underground mine or a small combined mine and mill complex using less than 125 m^3 of makeup water per hour. Capital cost for larger joint-use mine-mill systems can be calculated in section 6.1.8.14 (IC 9143).

If water quantity requirements are known and are less than 125 m^3/h, consult the base curve directly. 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 = metric tons ore mined per day

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

Mill quantity requirements should be estimated from section 7.1.8.14.2. (IC 9143). Capital cost for an isolated mine (i.e., no adjacent mill) is derived directly from the base curve. For a joint-use system, combine mine and mill requirements and derive the total capital cost from the appropriate curve.

BASE CURVE

Total cost is based on a single cost curve having water requirements (X), in cubic meters per day. The curve is valid for water volumes between 40 and 2,000 m^3/d, operating two shifts per day. The curve includes all costs associated with completion of wells, purchase and installation of pumps, storage tanks, and surface distribution lines.

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

Construction labor cost.......	37%
Construction supply cost......	55%
Purchased equipment cost......	8%

The total water supply system capital cost is $(Y_C) = 1,477.799(X)^{0.693}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 546.786(X)^{0.693}$

(S) Construction Supply Cost $(Y_S) = 812.789(X)^{0.693}$

(E) Purchased Equipment Cost $(Y_E) = 118.224(X)^{0.693}$

ADJUSTMENT FACTORS

Mine Drainage Factor The user should be aware that mine and/or mill water requirements can be fully or at least partially met by mine drainage. Based on percentage of the system requirements supplied by mine drainage, construction supply cost should be reduced up to 29% and construction labor cost should be reduced up to 43% (i.e., if 40% of the system quantity is supplied by drainage, reduce supplies by 0.40 x 29% = 11.6% and labor by 0.40 x 43% = 17.2%).

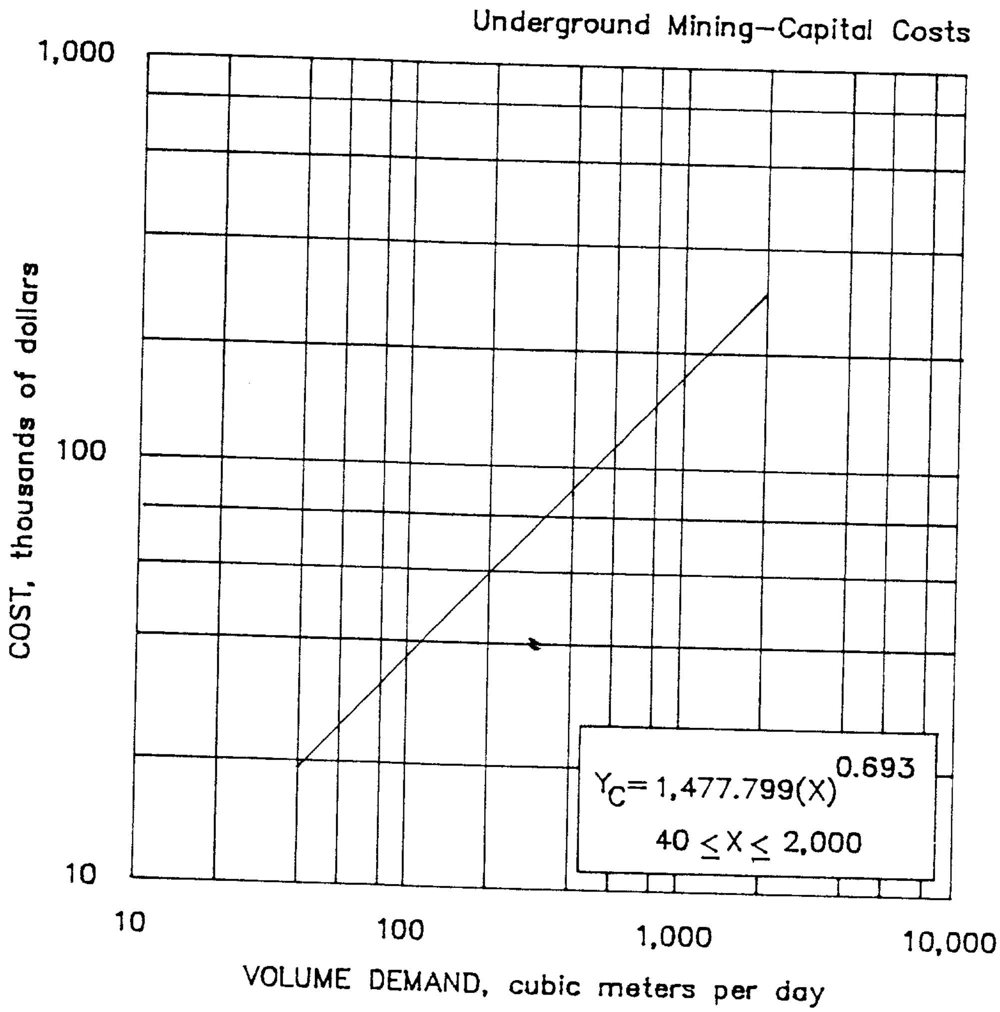
Joint-Use Factor After deriving the joint-use water system capital cost from the appropriate curve using the combined mine and mill water quantity requirements, allocate mine capital cost versus mill capital cost based on the percentage of water quantity demand (i.e., if the mine requires 10% of the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

Purchased Water Factor If water is currently being purchased from an existing municipal system, the costs for completion of the wells and installation of the pumps should be removed from the capital cost total. Multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.91$

Supply factor $(F_S) = 0.94$

Purchased equipment factor $(F_E) = 0.00$
This will completely eliminate the equipment portion of the curve.



4.2.5.12.2. Water and disposal system
WATER SUPPLY SYSTEM (MAKEUP WATER)