CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
1520 West Adams St.
Phoenix, AZ 85007
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

Source Unknown

CHAPTER 3

LAKESHORE

INTRODUCTION

The Lakeshore Property is located on the Papago Indian Reservation in Pinal County, Arizona, 28 miles south of Casa Grande (figures 3-1, 3-2). In 1969 the El Paso Natural Gas Company considered it a major porphyry-type copper deposit containing an estimated 500 million tons of commercial ore averaging 0.75% copper.

For the purposes of analysis, knowledge of the deposit and geology of the area are assumed limited to drill hole and outcrop information available in 1969.

In 1968 El Paso began negotiating with Hecla Mining Company with respect to a joint venture at Lakeshore, offering Hecla an opportunity to obtain a 50% interest in the property, in the development stage, and later to become the operator - with El Paso sharing. This analysis tests the attractiveness of the joint venture to Hecla, assuming Hecla desires a discounted cash flow rate of return of at least 9 percent from such a venture. The cost of capital in Hecla is approximately 7 percent.

This project consists of 3 properties encompassing 10,500 acres. It includes 3 patented lode mining claims covering 62 acres known as the Treasure State Claims; three patented and 19 unpatented lode mining claims covering 400 acres, known as the Drake Claims; and 3,717 acres known as the Papago Leases, as well as 6,325 more acres held under a business lease from the Papago Tribe. In addition, the project has a permit authorizing the production of water from the Papago Lands.

Earlier, much of this property was owned by Transarizona Resources, Inc., which developed a relatively small open-pit oxide copper ore body on the Treasure State group of claims. A copper segregation process for the beneficiation of oxide copper ores produced from the open pit was developed; however, ores were not economically amenable to customary acid leaching processes. There were technical difficulties, and Transarizona was forced into receivership. In the late 1960's El Paso Natural Gas Company acquired the properties and undertook a program of geological and geophysical investigations, followed by extensive exploratory drilling of the adjacent lands held under Indian leases. This resulted in the discovery of the major copper deposit, which lies at a greater depth and to the west of the original near-surface ore-body.

The Treasure State and Drake Claims are leased with a buy-out option price of $500,000, that can be paid out of royalties. The Papago Leases were acquired by El Paso for a bonus of $200,000 and specified royalties. The total annual royalty to be paid, based on three leasing arrangements, is equivalent to 9.0% of the gross revenue from sale of copper at Lakeshore. In addition, $50,000 a year is to be paid to the Papago Tribe during the preproduction period. El Paso's exploratory drilling costs and other expenses, to include studies and pilot plants, plus the bonus to the Papago Tribe, amount to $6,200,000. These figures may differ from the actual data pertaining to Hecla arrangements. They are assumed as a basis for this analysis only.

There appear to be no climatic weather restrictions in this area. Anticipated on-stream time is 330 days per year for operations.

The presence of two other large copper mines in the region has attracted labor to the area. The labor market is deemed adequate. There are also knowledgeable and sympathetic local government officials. State and local taxes do not appear to be burdensome.

Transportation in the form of both road and railroad are available. The American Smelting and Refining Company's Hayden smelter is relatively near in eastern Arizona. From Lakeshore, copper cathodes and cement copper, in pellets, are transported by truck to a loading station being erected on the main line of the Southern Pacific R.R. in Casa Grande. Facilities are also being constructed at this site to transfer incoming coal and other supplies from rail cars to trucks (figure 3-2).

Power is purchased from the Papago Tribal Utility Authority and will be supplied by the Arizona Public Service Company. A 230-kva line has been built a distance of 9.3 miles from the Arizona Public Service system to Lakeshore.

To supplement two existing shallow wells on the property, a 1,000-ft. deep well is being drilled to provide an estimated 3,000 gallons of water per minute.

DESCRIPTION OF THE PROJECT

Geology

The general geologic setting of the deposit is similar in many respects to that of other poprhyry-type copper deposits in the southwestern United States. The terrain is typical southwestern desert, formed upon a flatly sloping piedmont surface south of Casa Grande. It extends from the southwesterly flank of the Slate Mountains to the north-trending Santa Rosa Wash, about three miles to the west. The deposit has not been completely delineated, but reserves are estimated to be more than 470 million tons averaging 0.75% copper. Minor amounts of molybdenum, gold and silver are present in the sulfide ores. In this area, the Lakeshore ore-body is approximately 6,000 feet long by 2,500 feet wide, with the long axis trending generally north-south. The deposit is a classical porphyry consisting of three zones: the uppermost is designated as the disseminated oxide zone, the central core being the disseminated sulfide zone, and the lowest being the tactite zone (figure 3-3).

In 1969 the deposit was developed by a total of 101 drill holes, with about 150,000 feet of drilling, both rotary and diamond.

The disseminated sulfide sone represents the original deposit. The mineralization of this zone is typical copper-iron sulfides (chalcopyrite, pyrite, chalcocite and bornite). The zone has an average thickness of 500 feet and is contained in andesite and porphyry rocks. Proven ore in this zone was estimated to be 241 million tons of 0.70% copper in 1969.

The disseminated oxide zone overlays the sulfide zone; it occurs from the surface to depths of over 1,000 feet, with an average depth of 500 feet and an average thickness of about 550 feet. The mineralization here is a result of oxidation and leaching of a secondarily enriched chalcocite blanket in the original deposit. The matrix is andesite and porphyry rocks. Drilling in 1969 indicated 207 million tons of 0.71% copper in this zone.

The tactite zone is an underlying layer of altered Precambrian and Paleozoic sediments with an average thickness of 63 feet. The heat from the subvolcanic intrusion which altered these sedimentary rocks caused a remobilization of the chalcopyrite (and pyrite) crystals into the sedimentary layer, resulting in significant sulfide enrichment. Reserves in the tactite zone in 1969 were estimated to be 23,600,000 tons with an average grade of 1.69% copper.

The tonnage and grade of the Lakeshore deposit compare favorably with that of other major porphyry-type copper deposits in the Southwest. Because of its large size and "layered" characteristics, the deposit lends itself to mechanized underground mining techniques.

Mining

The underground mining of the Lakeshore ore-body is by panel caving methods. Sulfide and oxide ore are mined concurrently from two distinct but related underground operations. Sulfide ore is mined by a continuous panel-caving method and transported to an underground primary crusher. After coarse crushing, the sulfide ore is moved to the surface coarse ore stockpile on a 42-inch, 7,200 ft. belt conveyer installed in one of two parallel 15-degree declines. The other decline is equipped with a hoist and is used to transport men and supplies into the mine. Oxide ore is also being mined by a panel-caving method but is hoisted to the surface through a 14-ft.

circular shaft. On the surface the ore is passed through a primary crusher, then hauled by truck to the coarse ore stockpile area (figures 3-4, 3-5, 3-6).

The oxide ore and the sulfide ore are alternately reclaimed from the coarse ore storage stockpile and are then further reduced in particle size in a 17,500 TPD fine crushing plant.

In the initial analysis it was assumed that there would be 5-years of development and construction and that mining of the disseminated oxide zone and the tactite (enriched sulfide) zone would be accomplished at the beginning of operations. It was expected that the tactite zone would be mined out in 7 years at which time mining would begin on the disseminated sulfide zone. Both the tactite and the oxide ores are higher in copper content than the porphyry-type ore.

Panel caving has been used successfully on large low grade deposits and is currently employed on a porphyry copper deposit on the San Manuel Mine in Pinal County. Caving methods are highly efficient with respect to this type of deposit, using gravity to break the ore thus minimizing drilling and blasting. For purposes of the cost estimate, similarity with San Manuel costs is assumed except that at San Manuel development costs are spread over a larger tonnage of ore because of the greater thickness of ore above development cuts.

In the tactite zone haulage is by 5-cubic yard ST5 Scooptrams from the draw points to the railroad haulage level and from there to an ore pocket. At the ore pocket, the ore is crushed to 6-inch size with a 42-inch Nordberg gyratory crusher and then conveyed to the surface on a 42-inch belt. In the tactite zone, mining will be by the same footwall panel front-caving method used in San Manuel.

In the disseminated oxide zone, a panel caving method will be used similar to the method at the Climax Molybdenum mine in Lake County, Colorado. In this system, ore is slushed directly into railroad cars for haulage to a central loading pocket. From the ore pocket, the oxide ore is hoisted to the surface in a skip.

Development costs for the system involve access drifts, shafts, and declines. Initially, all haulage to the surface was planned through the two declines driven on a 15-degree slope. Estimated cost of the declines in 1969 dollars using $2 per cubic foot excavated, was $3 million. For oxide ore production, it became necessary to sink a 1,000-ft. shaft 14 feet in diameter. At $1,000/ft., the estimated cost of the shaft was $1 million. Additionally, over 10,000 feet of bored ventilation, service, and materials shafts had to be installed at an estimated finished cost of $1 million, including installation of utilities. Further underground excavation, conveyors, railroad and hoisting facilities were estimated to cost $2 million. This makes our estimated total cost of improvements in the mine itself approximately $7 million in 1969 dollars.

Metallurgy

To complement the mining operation, an ore-processing complex produces electrowon copper cathodes and cement copper; the plant contains six different metallurgical facilities. Initial design is based on an estimated feed of approximately 9,500 tons of tactite ore for the concentrator and 6,500 tons of oxide ore for the vat leaching plant, per day. Annual production capacity as announced by Hecla should total nearly 65,000 tons of marketable metal, consisting of 35,000 tons of contained copper in cement form and 30,000 tons of cathode copper.

The planned process for the Lakeshore project is unique. It is a combination of Roast-Leach-Electrowin (R-L-E) for the sulfide ore and vat leaching-cementation for the oxide ore. Both processes have been employed successfully in separate operations. The R-L-E process is being used in both Zambia and Zaire; a leaching-cementation system is employed by Ranchers Exploration at their mine in Miami, Arizona. By combining the two processes to take advantage of the oxide-sulfide nature of the ore-body, many of the problems and limitations of the individual processes can be solved. For instance, both the roasting and electrowinning phases produce excess sulfuric acid that can be used in the vat leaching process. Insoluble copper from the sulfide leach goes with the hematite concentrate to the sponge iron plant and is recovered in the cementation process. Any precious metals are also carried in this concentrate.

Pilot plant operations processing five tons per day of concentrates confirmed the theoretical expectations of the R-L-E process. A flotation pilot plant for the sulfide ore was constructed by El Paso, utilizing ore from mine development as feed; it also confirmed theoretical results. No pilot plant was constructed for the vat leaching-cementation process; laboratory bench tests were deemed adequate to define this phase of the project. Problems in scaling up from bench test to production facility in vat leaching are well understood.

From the test work, both in the laboratory and in the pilot plants, expected recovery from the overall process is approximately 90 percent. The majority of losses will be in the flotation system. Minimum losses will occur in the R-L-E process, as the insoluble loss in the leach residue goes to the sponge iron plant and the losses in the spent electrolyte are pumped to the vat leaching phase. Soluble loss in the R-L-E is expected to be negligible.

Figure 3-7 is a schematic flow sheet of the Lakeshore process. It leads to an equipment list for the operations, and to cost and horsepower estimates. A factored capital cost estimate is approximately \$109,000,000 in 1969 dollars. (Hecla stated in its 1969 annual report that the development of the property would involve capital expenditures of approximately \$100,000,000.)

This capital expenditure reflects the original estimate in 1969. Since 1969 the Marshall and Swift index of mining and milling equipment costs has increased from 284.5 in 1969 to 478.5 in the second quarter of 1976. Therefore the cost of \$100 million in 1969 would be updated using a factor of

1.68 to $168 million. The actual cost in the project will approach nearly $200 million reflecting not only inflation but problems and delays in the project.

Major Technical Problems 1969-1976

The original mining plan provided for all ore coming out of the two declines. This plan had to be changed because of difficulties in keeping the ore passes open. This was a major factor in delaying production from the planned late 1973 startup date to early 1975, a delay of 18 months and resulting in extra costs. A second major problem arose when underground caving problems in the sulfide mine forced reduced sizes of openings, interfered with ore transfer and prevented full production.

There have been a number of process problems. Expected recovery in the leach tanks was 97-percent, but there have been difficulties in achieving it. These problems arise mainly from scaling up pilot plant work to full-scale production.

The design of the system using hydrometallurgical techniques has virtually eliminated pollution problems. Roaster gasses are used for sulfuric acid production. Residue from the roaster which contains 44 percent iron and 2.1 percent copper is sent to a filter plant, then to the sponge iron plant. In the sponge iron plant the residue is made into pellets which are hardened, then metallized.

The metallization plant produces pellets with a 55 percent iron content, also carrying the copper and the precious metals from the circuit. These sponge iron pellets go to the cementation plant and the iron is replaced by copper. The expected product is 55 percent cement copper. Here is where one of the greatest technical problems has developed. ASARCO, buyer of the cement copper, determined after the plant was completed that the cement copper would have to be furnished to the smelter in the form of pellets in order to feed them directly to the copper converters. This required the addition of the pelletizing plant for the cement copper. However, it was impossible to pelletize the cement copper because of the high moisture content (30 percent) which is very difficult to eliminate. In early 1977, it is being turned over by front-end loaders to drive out the moisture from the stockpile. This handling breaks down the copper pellets and dilutes the final product to approximately 40 percent copper, 0.05 ounces of gold per ton, and 3.5 ounces of silver per ton. All of these problems were not anticipated when the original feasibility studies of 1969 were made.

MARKETING

The final products from the Lakeshore project are two different forms of copper: cathode and cement. The cathode copper from the electrowinning process is typically 99.9% copper, a commercial grade. It could be sold on the open market at the spot price but Narrangesett Wire Company, a subsidiary of El Paso Natural Gas Company, has agreed to purchase all of the cathode copper production from the Lakeshore process at current market price.

The cement copper, a product of the vat leaching circuit, has a contained copper assay varying from 75 to 90 percent; this product requires further refining before commercial sale. It is shipped to ASARCO (60 percent to Hayden, 30 percent to El Paso, and 10 percent to Tacoma smelters). A combination of high treatment charges on the cement copper (approximately $50/ton for smelting and refining) plus the cost of handling, rehandling and dilution have had a strong impact on the economics of the project.

The smelter schedule for payment is based on the assay value of the cement concentrate. The smelter deducts 1.5% of copper produced, and then pays 100% of the remaining copper at the current market price less 5 cents a pound.

ENVIRONMENTAL FACTORS

Because of environmental pressures, it was unlikely that existing custom smelters would be able to process the copper sulfide flotation concentrate that the mine will produce in large quantity. This necessitated a new system for processing concentrates to salable metal products at the mine site. Factors governing the selection of the new process were: ability to meet pollution control standards today and in the foreseeable future; to take advantage of the fact that the ore-body consists of both oxidized and sulfide mineral portions; to produce standard marketable copper cathodes and to be adaptable to relatively small scale operations with minimum loss of efficiency. Pilot tests have proved that the processing should be successful and meet environmental protection standards.

From an environmental standpoint the overall Lakeshore process is expected to be "clean", compared to other copper producing facilities in existence. Estimated noxious effluent output is minimal. In the planned process, sulfide gases, a problem with pyrometallurgical plants, are converted to sulfuric acid and utilized in leaching. Also, the plant site is located away from any major metropolitan area; noise and dust pollution should not be a problem. Nevertheless, baseline data are being gathered for comparison with future surveys.

A major concern is tailings disposal and ground subsidence. There is sufficient desert land available, however, to accomodate this problem. No delays are expected because of environmental restrictions.

ECONOMIC ANALYSIS 1969

For the purpose of this analysis we assume demand for copper to increase at an annual rate of 4 percent in the long term and a copper price of 50 cents per pound.

The cash flow analysis for the Lakeshore project is based on the original assumption of a five-year preproduction period (1969-1975) and a 15-year mine life, with full production beginning in 1975. Actual reserves exist for a much longer period, probably at least 28 years. but most economic projections for more than 20 years have marginal value.

Assumptions with respect to the analysis are as follows:

1. All preproduction mining costs are expensed.

2. The tactite zone will be mined first, for a period of seven years. In later years, sulfide ore will be produced from the disseminated sulfide zone.

3. All initial investment is made prior to 1975, and full production starts in 1975.

4. The percentage depletion allowance for copper will continue at the current rate, 15%.

5. From 1969 on, copper prices are increased from 50 cents per pound at a constant annual rate of 4%; all copper produced at Lakeshore can be sold.

6. Total operating costs will inflate at a constant rate of 6% per year.

7. Replacement of worn-out equipment is done at original cost, by the end of the last year of its life time.

8. Working capital is fully recovered at the end of operations.

9. U.S. corporation tax is 48% of taxable income; state and local taxes amount to another 3% of taxable income.

10. Recovery of working capital and income from salvage are not taxable. The project will not obtain any capital investment allowances.

11. A contract can be negotiated for the supply of required coal and utilities with an escalation rate of not more than 6% annually.

Manning requirements and labor costs are estimated as follows:

Personnel	Total	Annual Cost
Production Labor	500	$ 7,937,000
Maintenance Labor	350	3,675,000
Engineering & Construction	135	1,535,000
Utility Men	65	715,000
Salaried Personnel	150	2,475,000
Totals	1,200	$16,337,000

Mining development costs total $7,000,000; these costs are expensed during the preproduction period. Completed studies, pilot plants, bonus, and past exploration costs amount to a total of $6,200,000. This latter amount has been expensed but must be recaptured for tax purposes. It will be matched by an equal amount of depletion in 1975. Additional drilling costs are approximately $5,000,000 in the preproduction period.

Total plant cost has been estimated at $109,031,000 in 1969 dollars. Depreciation is based on straight-line; annual depreciation for fifteen years is $7,268,800.

No external financing is required.

Figure 3-8 shows the total cash flows for the project through 1989. The analysis indicates a present value of $3,440,000 for the project at a 9% discount rate. The DCF-ROR is approximately 9.5%.

The feasibility study has shown that the project's estimated rate of return after taxes will meet the company's assumed policy of at least a 9% ROR, which would support a recommendation for Hecla Mining Company to join El Paso in the joint venture during 1969.

The cash flows and the rate of return are drastically affected by two key assumptions: (1) that prices will rise at 4% per year and that costs will rise at 6% per year after 1969. Actually the industry has seen some 15% increases in cost and some drastic fluctuations in price. Copper is selling at 68 cents a pound at this writing, February, 1977. In terms of 1977 costs, a price of 80 to 90 cents appears necessary to justify new projects today.

HECLA MINING COMPANY

This part of the case study is an evaluation of the financial position of the Hecla Mining Company for the years 1969-1975. Emphasis is given to the company's investment in Lakeshore and its effect on the firm during the period under review.

Background

Hecla is a leading U.S. silver producer. It has interests in several mines in Idaho's Coeur D'Alene district and normally derives about half of its net income from silver operations. Volatile world silver quotations, therefore, have had a significant impact on the company's annual profits.

The firm has a 50% interest in the Lakeshore Copper Project, which now is expected to reach full production in the second quarter of 1977. A relatively large investment has gone into the project, and long-range prospects for the company are dependent on the success of this mining venture. However, earnings will continue to mirror movements in silver prices until the Lakeshore property begins to make a meaningful contribution.

Fundamental Position

Hecla is a major silver producer, mainly through the wholly owned Lucky Friday Mine and the company's 33.2% interest in the Sunshine Unit Area, both in the Coeur d'Alene district in Idaho. Interests in several other properties are held, and the company conducts substantial exploration activities.

Hecla, during 1975, produced 4.2 million ounces of silver, or about 12% of total U.S. production, 22,200 tons of lead, 6,600 tons of zinc, 1,200 ounces of gold and about 500 tons of copper. Silver accounted for 62.3% of sales income, lead 26.4%, zinc 8.6%, antimony 1.6%, copper 0.9%, and other, 0.2%.

Production from the Lucky Friday Mine in 1975 was 173,245 tons of ore grading 14.96 ounces of silver per ton, 10.71% lead and 1.29% zinc. Ore reserves at the end of 1975 were 539,000 tons.

A 33.25% interest is held in the Unit Area property operated by Sunshine Mining. Hecla's share of 1975 production was 62,034 tons of ore assaying 23.97 ounces of silver per ton. Its share of the reserves was 312,000 tons at year end.

Hecla operates and owns a 30% interest in the Star-Morning Unit Area in Idaho; its share of 1975 output there was 84,648 tons of ore assaying 2.49 ounces of silver per ton, 5.00% lead and 5.64% zinc. Its share of reserves at the end of 1975 was 390,000 tons.

The company also has a 35.4% equity interest in Granduc Mines, Ltd., whose British Columbia copper property is leased to ASARCO, Inc. and Newmont Mining for development. Ore reserves at the end of 1975 were 19,606,000 tons of ore averaging 1.69% copper before dilution.

A wholly-owned subsidiary, Ace Concrete Co., is a producer of ready-mix concrete and sand and gravel, in the Spokane, Washington, area.

Hecla has owned the 50% interest in the Lakeshore copper property since 1969 and is the operator of the property. El Paso Natural Gas Company holds the remaining 50%. Production at the Lakeshore mine and metallurgical plants will gradually build up to 65,000 tons per year of copper contained in electrowon cathode and copper precipitates. Operations began in January 1976 on a limited scale. Agreements have been reached for the treatment of the copper precipitates by ASARCO, which will purchase 60% of the copper under a long-term arrangement. Hecla has utilized bank loans to finance its share of the Lakeshore investment.

In mid-1976 nearly $48.0 million in debt was outstanding, under a revised $53.0 million revolving credit agreement. Cash dividends have been omitted since Hecla's March 1970 payment. Seven annual 2% stock dividends have since been declared. In 1975 there were 15,772 shareholders, with 6,717,578 shares outstanding ($0.25 par). El Paso Natural Gas subsidiary owns about 17%. The company has approximately 2,500 employees.

Near-Term Prospects

Hecla's estimated sales for 1976 are expected to rise to nearly $40.0 million, from the $29.3 million of 1975. However, the company is expecting a loss for 1976 because of the operating losses during the buildup of production at Lakeshore to full capacity and reduced operating levels at Granduc Mines.

A resumption in sales growth in its major metals is anticipated for the near term, although silver prices weakened somewhat last year; quotes are expected to remain volatile. Hecla's silver revenues were reduced by a strike at the Sunshine Unit Area in 1976. Lead and zinc revenues should improve as the economic recovery progresses although escalating costs of mining and smelter treatment are partially off-setting.

Financial Strength

Figures 3-9 through 3-11 show the trend of designated financial ratios for Hecla during the period 1969-1975. Tables 3-1 through 3-3 compare Hecla with mining industry medians in selected areas, and compare Hecla's standing in the miscellaneous metals industry group, which includes such companies as ASARCO, AMAX, and Texasgulf.

Hecla's sales and profits were irregular during the period (Table 3-1). There was a large decrease in sales in 1972, a great improvement in 1974, but poor results in 1975. A large drop in profits in 1971 followed the industry trend, but profits continued to fall in 1972 although the industry change in profits was upward. After improvement in 1973-74, profits fell in 1975.

Sales per dollar of shareholders' equity were off the industry median in every year, with the largest difference in 1975.

Returns on sales for Hecla were greater each year than the industry median; the smallest difference was 15% vs 13% in 1972. However, return on shareholders' equity declined in 1969-72 in relation to the industry's performance, reaching a low of 6% in 1972.

Sales per employee were well below the industry median for the whole period. This ratio declined from $23,438 in 1969 to $14,652 in 1975. Assets per employee were also below the industry median each year; however, there was a general increase in this category overall - from $42.462 in 1969 to $54,562 in 1975.

TABLE 3-1.

Hecla Comparison with Mining Industry as a Whole.

	1969	1970	1971	1972	1973	1974	1975
Changes in Sales (%)							
Industry Median	12	10	-	24	42	61	8
HECLA	19	1	-2	-14	-2	45	1
Changes in Profits (%)							
Industry Median	-11	14	-13	4	48	100	-8
HECLA	5	-3	-23	-16	39	99	-30
Sales per $ of Shareholder Equity ($)							
Industry Median	1.18	1.21	.90	.78	1.12	1.66	1.83
HECLA	.60	.55	.50	.41	.37	.46	.43
Return on Shareholder Equity (%)							
Industry Median	12	14	12	10	16	23	16
HECLA	12	11	8	6	8	14	9
Return on Sales (%)							
Industry Median	12	13	12	13	15	13	12
HECLA	20	20	15	15	21	29	20
Assets per employee ($)							
Industry Median	90,465	70,910	83,885	84,291	130,015	147,852	114,898
HECLA	42,462	44,651	44,004	50,375	42,922	50,819	54,562
Sales Per Employee ($)							
Industry Median	54,835	46,199	49,353	51,496	71,074	96,378	91,380
HECLA	23,433	21,075	17,591	14,106	10,503	14,280	11,652

Note: base data from annual reports of the Hecla Mining Company and Fortune.

Table 3-2 indicates that Hecla's annual growth rates for the period 1964-1974 compare unfavorably with other companies in its industry group, except in net operating assets and invested capital (which can be related primarily to the large investment in the Lakeshore Property).

TABLE 3-2.

Annual Growth Rates for 1964-1974: Selected Companies

Per Share Data*

	Sales	Net Income	Earnings	Cash Flow	Net on Assets	Invested Capital
HECLA	-1	-4	-5	-5	15	13
AMAX INC	10	7	6	8	13	13
ASARCO INC	8	8	7	9	10	11
CHROMALLOY	26	15	13	19	27	25
FOOTE MINERAL	13	3	8	12	13	11
HANNA MINING	6	4	4	5	3	8
INTL NICKEL	9	5	5	7	12	12
NEWMONT MNG	35	12	12	15	60	18
TEXASGULF	17	16	15	19	16	14
Weighted Average	11	7	7	9	14	13

*Least square growth rate

NOTE: Data from Financial Dynamics Services, Investors Management Sciences, Inc., 1975.

Table 3-3 shows Hecla's position in its industry group in selected areas. Its percentage of industry categories is small. Hecla did not improve its position relative to the other companies during the ten-year period.

TABLE 3-3.
Industry Group Comparison
As % of Industry Group*

	Sales				Pretax Income				Cash Flow				Gross Assets			
	1964	1969	1972	1974	1964	1969	1972	1974	1964	1969	1972	1974	1964	1969	1972	1974
HECLA	1	1	1	0	2	1	1	1	2	1	1	1	1	1	1	1
AMAX INC.	23	25	22	18	14	15	16	14	17	17	18	16	18	20	19	19
ASARCO INC.	32	25	19	21	17	20	12	11	17	20	13	14	20	16	13	14
CHROMALLOY	1	19	13	12	1	4	7	3	1	4	6	4	1	4	6	6
FOOTE MINERAL	1	3	3	2	0	1	1	1	1	1	1	1	1	3	2	1
HANNA MINING	7	6	6	4	5	5	9	3	6	6	8	3	6	6	5	4
INTERNATIONAL NICKEL	30	22	23	26	51	28	28	38	48	26	30	34	39	33	33	32
NEWMONT MINING	1	2	6	8	6	11	17	11	5	11	13	12	6	7	11	11
TEXASGULF	4	8	6	9	3	13	9	18	4	14	10	16	9	11	10	11

*Metals-Miscellaneous

NOTE: Data from Financial Dynamics Services, Investors Management Sciences, Inc., 1975.

HISTORICAL DEVELOPMENT OF THE PROJECT

On 11 February 1969, Hecla and El Paso Natural Gas Company entered into an agreement for the development of the Lakeshore property. This acquisition was considered a major step forward for Hecla in its continuing expansion efforts in the non-ferrous metals field; it was to strengthen the company on a long-term basis. The company indicated, however, that it would be confronted with substantial borrowing during a period of historically high interest rates for financing the Lakeshore venture.

The project was described as a major-size, porphyry-type deposit. Hecla's examination had commenced in October 1968; it led to the agreements by which Hecla acquired the 50% interest. Hecla agreed to operate the property; and advance all funds required to bring the property into production.

The company's participation in development of the Lakeshore property was estimated then to involve future capital expenditures of approximately $100,000,000.

In 1970 the firm announced as its major achievement the progress realized in planning and development at the Lakeshore copper property. It anticipated that the first development ore would be extracted in mid-1971. The cost of the Lakeshore property, plant and equipment was placed at $15,876,826 for Hecla at year end, with all financing coming from internal company resources. Hecla's goal was to assure the long-term future of the company as an independent and diversified producer of non-ferrous metals.

The first indications of a funds problem came in 1970. Lower prices in silver, lead, and zinc affected net income at Hecla. A stock dividend of 2% was paid in August 1970 as compared to cash dividends of 70 cents per share paid in 1969. This assisted in conserving funds needed for financing preproduction costs at the Lakeshore copper property. Also, there were losses connected with Hecla's planned program of buying silver futures, minus $431,000 during the year; provision was made for possible additional after-tax losses of $700,000. There was a decrease in net working capital of $1,137,893 which followed a decrease of $2,334,122 the year before.

The investment in the Lakeshore copper property was $26,367,728 at the end of 1971. A revised estimate of the ultimate cost of the project was $125,000,000. The company made interim financing agreements with several banks to provide loans up to an aggregate of $11,000,000 and additional interim financing was contemplated. Anticipated startup was late 1974.

Difficulties increased for Hecla in 1972. There were equity losses in Granduc Mines, Ltd. and an extraordinary charge of $545,000 related to Hecla's portion of rescue and rehabilitation costs at the disatrous Sunshine mine fire in May. There was a loss of operating income from the Sunshine mine during the last eight months of the year, decreased production from the Lucky Friday Mine, increased treatment charges by smelters, and increased labor and supply costs without sufficient off-setting increases in metal prices.

In 1972, a credit agreement was reached with major commercial banks to provide the firm with up to $42.0 million in revolving credit loans. Upon completion of the development and construction period at Lakeshore, the revolving credit loans were to be converted into 5-year term notes, payable in semi-annual installments. The credit agreement for Hecla contained certain restrictions on the payment of cash dividends, and required maintenance of a consolidated net worth of $42.0 million.

There was a new agreement with El Paso Natural Gas Co., providing for joint participation in financing development at Lakeshore. Each company was to advance equal amounts of the estimated total pre-production cost, including start-up costs and working capital, of $140,0 million. Startup was in early 1975. The Lakeshore property continued as "Hecla's most important venture," even though copper in 1972 represented only 6.2% of sales income. Silver (37.8%) and lead (34.8%) continued to make up most of the company's sales.

Fixed assets (properties, plant, and equipment) had increased to $55,684,721, of which $45,280,918 pertained to Lakeshore.

Good progress in mine development and plant construction was attained at Lakeshore during 1973. Metallurgical plant design was 78% completed at year end. Firm purchase agreements were completed for nearly all process machinery and for most plant construction materials. The work force increased from 748 persons to 1,131 by year end. The mine was projected to come into full production of approximately 65,000 tons of copper per annum beginning in mid-1975. The total costs of the project were now estimated to reach $170,000,000, including working capital. Company borrowings amounted to $11,340,000 at year end and the credit agreement with participating banks was amended to increase the available loan funds for Lakeshore to $48.0 million. The company was required to maintain an average of $4,500,000 in compensating balances with the lending banks.

Under the amended agreement El Paso provided all funds for development of the Lakeshore property from 1 January 1973 until it equalled certain defined expenditures contributed by Hecla through 31 December 1972. Thereafter, Hecla and El Paso would share all costs equally. The estimated cost of the project increased from $140.0 million to $170.0 million because of a change in oxide ore mining plans, a higher final cost estimate for a sponge iron plant, addition of a pelletizing plant, a six-month extension of the plant start-up date and an increase in projected required working capital. Hecla's cumulative investment in the Lakeshore copper property was $51,545,414 at year end 1973. Interest expense and commitment fees incurred in connection with the credit agreement during the construction period were being capitalized as part of the project cost.

At Lakeshore, there were problems with late material and equipment deliveries and a shortage of experienced miners during 1974. El Paso participated in financing the project, newly estimated to be $185,000,000. Hecla's share exclusive of interest, was expected to be $30,000,000. Company borrowings amounted to $20,640,000.

At 1974 yearend Lakeshore mine preproduction work was 75% completed, design of the surface metallurgical plant facilities was 83% completed. However, plant start-up was moved to the third quarter of 1975. The mine was being developed to produce 9,000 tons per day of sulfide ore and 6,000 tons per day of oxide ore.

In 1975 Hecla's sales of concentrates and products was approximately $29.3 million, up slightly over 1974, but net income dropped from $8.4 million that year to $5.9 million in 1975. The decrease was primarily attributable to lower silver prices, substantially increased operating and smelter treatment costs, a reduction in net gain from sale of securities, and a significant increase in the company's share in equity net losses of 35.4% owned Granduc Mines, Ltd.

At Lakeshore, preproduction mine development and plant construction were 95% completed at year end. Start-up of the operation was to begin in January 1976. Cement copper was to be pelletized and shipped to smelters of ASARCO, sixty percent of this copper to be sold to ASARCO and forty percent returned on toll and marketed through Brandeis, Goldschmidt & Co., Inc., metal merchants. The Southwire Company was to take the cathode copper.

Hecla announced that at the then current copper price, the Lakeshore mine operation would not realize a profit. Total project expenditures to end 1975 were $177,771,000, including working capital and start-up costs.

Hecla borrowings for its share of costs at Lakeshore amounted to $43.2 million at end of 1975. The remainder of its share of costs was financed out of current earnings. The average weighted interest rate, including commitment fees paid during the year, was 8.72%.

Table 3-4 summarizes Heclas' sources and uses of funds over the entire period of Lakeshore exploration and development, 1966-75. It vividly illustrates the appetite of the Lakeshore project for Hecla operating and borrowed funds.

Table 3-4.

Sources and Uses of Funds
Hecla Mining Co.,
Cumulative 1966-75, million dollars

Sources of working capital	Million dollars	Percent of total
Net income	51.3	40
Depreciation, depletion, amortization	4.3	3
Increase in deferred income taxes	17.1	13
Bank borrowings	43.2	33
Sales of securities	6.2	5
Decrease in assets (principally Granduc)	2.3	2
All other	5.5	4
Total	129.9	100
Uses of Working Capital		
Purchase of stock (Sunshine, Day, Granduc)	3.9	3
Dividends	13.6	10
Lakeshore investment	94.1	72
Advance royalty payments, Lakeshore	2.0	2
Other property additions	6.7	5
Payment on notes to banks	4.3	3
Net increase in other assets	0.4	1
Net increase in working capital	4.8	4
Total	129.8	100

The technical and financial development of the Lakeshore project from the first drill hole through production are summarized in the following summary and in figures 3-12 and 3-13.

SUMMARY OF LAKESHORE PROJECT DEVELOPMENT

1966 Discovery, El Paso Natural Gas, prefeasibility studies.

1967-68 Diamond drilling by El Paso, examination by Hecla.

1969 (1)* Agreements El Paso-Hecla-Papago Indian Tribe. Hecla gets 50% interest for 1,000,000 shares. Papago Indian Tribe leases on a royalty basis. Hecla operator and to advance all funds required to develop the property. Net income to be divided equally. Pre-feasibility indicates 470 million tons, 0.75% Cu 3,000 ft. by 4,000 ft. Drilling: 101 holes, 150,000 ft. Twin declines started. Bulk samples of oxide taken for leach test. Metallurgical testing of sulfide completed. Preliminary engineering assigned to P.J. Expected project cost: $100 million.

1970 (2)* Planning and engineering, underground development, leach testing and pilot plant treatment, water and power development consideration of mine and processing alternatives, financial studies. Surface drilling 234,000 ft. Declines 63% completed.

1971 Drilling: 59,000 ft. (cumulative 319,000 ft.). Declines 80% completed plus cross cuts. Old El Paso segregation plant coverted to pilot plant. Pilot roast-leach-electrowin plant completed. Pilot oxide-ore-leach plant neary complete. Surface construcion work: office, changehouse, warehouse, water system, power supply. Preliminary engineering report, Parsons-Jurden Corp. Engineering contracts let for detailed design. (Completion due - mid-1972.) Production estimated late 1974.

1972 (3)* Credit agreement (Dec.) (Prior borrowing of $9 million under interim financing.) Revolving credit loans up to $42 million (includes refinancing interim loans) and compensating balances. Upon completion of development and contruction revolving credit converted into 5-year term notes. New arrangement with El Paso for joint participation in financing effective upon receipt of favorable tax rulings from IRS. El Paso to contribute expenditures to equal Hecla. Total project cost estimate: $140 million.

1973 (4)* Declines complete, 45,000 ft. of underground openings complete. Sulfide orebody is developed. Oxide orebody development delayed by poor ground conditions. Decision to hoist oxide ore through separate shaft instead of ore pass transfer to decline. Work on vertical shaft underway. Drilling 17,000 ft. to explore lease and surrounding claims. Cumulative drilling 388,000 ft. Process development work for metallurgical plant completed except for some vat leach work. Design engineering continued.

Metallurg. l plant 78% complete (Dec.). ..w arrangement with El Paso effective Jan. Joint participation. All funds from El Paso until investment equal to Hecla. Project cost estimate $170 million. Costs including working capital. Cost increased due to change in oxide ore mining plans, higher cost than anticipated for the sponge iron plant, addition of pelletizing plant, six month delay in start-up date, increased working capital. Start-up scheduled mid-1975. Outstanding Hecla loans (Dec.) $11.3 million. Amended credit agreement (Dec.) increases available loans from $42 million to $48 million.

1974 (5)* Delays in equipment deliveries, shortages of materials and supplies. Mine preproduction work 75% complete (Dec.). Plant facilities 83% complete (Dec.). Support facilities 96% complete (Dec.). Plant startup schedule 3 Qrt. 1975. Rate 65,000 tons/year, 30,000 tpy of copper in cathodes and 55,000 tpy of precipitates to contain 35,000 tons of copper (64%). Total project cost estimate: $185 million. Higher due to higher mine development costs and one month extension on start-up. Plan to mine the thin high grade sulfide (tactite) first, thicker, lower grade portion later; oxide simultaneously with sulfide. Cathode copper to go directly to fabricators of copper wire, tubing, etc. (Southwire). Cement copper to ASARCO smelters. Funding of the project Hecla/El Paso equalized early in 1974. Borrowings total $20.6 million (Hecla). Credit agreement contains restrictions on payment of cash dividends and requires maintenance of consolidated net worth of $48 million. Interest and fees in connection with the credit agreement are capitalized.

1975 (6)* Preproduction mine development and plant construction 95% complete. First shipment of copper cathodes Jan. 26, 1976. At the 1975 price for copper the operation will not realize a profit (avg. producer price 63.54 cents per pound in 1975). Start-up began in January. Production plans 11,000 tons per day sulfide ore and 6,450 tons per day oxide ore. Both ore flows to 17,500 TPD fine ore crushing plant. Oxide ore to 6,450 TPD vat leaching plant which produces 55,000 TPY of precipitates containing 35,000 TPY copper metal. Sulfide ore treated in 11,000 TPD flotation concentrator producing 430 TPD of concentrate. Concentrate is treated in a roasting, leaching and electrowinning plant to produce 30,000 TPY of electrowon cathode copper. Roasting produces 200 TPD of by-product sulfuric acid which is consumed in leaching. The 250 TPD of leach residue to filtered and converted to sponge iron for use in precipitating iron from the vat leaching solutions.

(7)* Full production rate expected during 1976. Cement copper is shipped to ASARCO smelters (60% sold to ASARCO under a long term agreement, 40% marketed through Brandeis Goldschmidt & Co. Inc.

* Numbers in parenthesis refer to project development shown in

figure 3-.2.

DISCUSSION

In its industry group, the Hecla Mining Company represents only about 1% in sales, pre-tax income, cash flow and gross assets, for the period 1964-1974. It is not one of the larger firms.

For the ten-year period, Hecla had negative growth rates in sales, net income and earnings. However, the company has grown in net operating assets and invested capital, mainly because of its participation with El Paso in the Lakeshore project.

The Lakeshore copper property has proved to be much more costly than anticipated, and is late coming into production. Initially, the project was to represent an investment of approximately $100,000,000 and to begin production in 1974, with the first development ore to be extracted in mid-1971. The 1975 estimate of the ultimate preproduction cost was $195,000,000, including start-up costs and $8,300,000 of working capital. It was estimated that additional working capital of approximately $10.0 million would be required to finance in-process and in-transit materials and accounts receivable. Full production is not expected before mid-1977.

Through 1971 Hecla financed the Lakeshore project with internal funds. As a result the company stopped paying cash dividends in 1970 and has paid a 2% stock dividend in August of each year, 1970-1976. At end of 1975 the average number of shares outstanding was over 6,700,000: in 1966 there had been only 2,456,654 shares outstanding. In 1972 it was necessary to obtain debt financing. Hecla's investment in the Lakeshore property in 1975 totaled $104,300,000 with related borrowings of $43,200,000 outstanding at year end.

Overall, the effect of the Lakeshore project to date has been debt acquisition, stock dilution, halt of cash dividends, decreases in working capital (1969-72), and the buildup of assets not yet matched by a corresponding increase in sales. These problems can be traced to the current depressed condition of copper prices and to the technical and marketing problems of Lakeshore.

The number of employees at Hecla has increased from 900 in 1969 to more than 2,500 by the end of 1975. This is reflected in the ratios of sales to employees and assets to employees. Industry ratios were up, especially in 1970-74; but Hecla's sales-to-employee figures were down. Its assets to employee ratio was relatively the same in 1970-75, since assets and number of employees were both increasing at this time. Sales and profit changes were lower in the late 1960's and early 1970's, since there was no contribution from Lakeshore and there were adverse effects from price pressures, price controls, the Sunshine Mine fire disaster in 1972, and unprofitable operations of Granduc Mines. There was a favorable change in 1974, primarily due to significantly improved silver and lead prices, which more than offset increased operating and smelter treatment costs. This trend was reversed in 1975-76 with net operating losses at Lakeshore.

A strong featur. ,f the company has been its pr..it margin, which has been consistently higher than the industry median. Its main weakness seems to be in not significantly increasing its sales. Sales of concentrates and products in 1966 were $21.4 million; by 1975 sales were still only $29.3 million.

The firm's lack of real growth, in part due to its large investment in the Lakeshore project without any returns to date, is shown in its declining net income per share.

In today's stockmarket (January 1977), the Hecla Mining Company's common is selling at approximately $12 a share. Its range for 1976 was $10.80 to $17.25 with a price-earnings ratio of 14. The estimated cash value of the stock dividend in 1975 was $0.37. The book value of a capital share in 1975 was $9.96. Evidently, investors in general must believe that the company will have more than a normal rate of growth in the future, possibly because of the Lakeshore mine coming on stream. More than a nominal contribution from the Lakeshore Property is going to be required for Hecla to improve its financial position and growth rate. This contribution, in turn, will require a recovery in copper prices, an industry wide problem. At the present copper price, the Lakeshore mine operation will not realize a profit.

ECONOMIC FEASIBILITY 1976

The following rate of return (DCF-ROR) computation is based on realistic estimates of cash flows of the Lakeshore project for the years 1969-1990. It is not known what rate of return was actually expected by Hecla, or what assumptions were used in 1969 and earlier, with respect to the Lakeshore project. It seems reasonable to infer that cost estimates of required venture capital were greatly underestimated. In addition, todays' unexpectedly low copper prices are an added burden on the project. Assuming copper prices increase 10% each year and operating costs increase 6% each year, the estimated DCF-ROR for the project is 5 to 6% on an investment of $185.0 million. The 1976 "hindsight" analysis of cash flows rate of return and present value is summarized graphically in figure 3-14. At a capitalization rate of 11% the project would have a Net Present Value (NPV) of minus $47.9 million. Conditions must be quite different from the future Hecla projected when it was determining whether or not to invest in the Lakeshore Project in 1969. Copper prices were trending upward then, and the recent recession and period of rapid inflation had not set in.

Another point to consider, looking backward, is whether the Hecla Mining Company chose the right field in which to "diversify." For spreading or eliminating risk, the company under ideal circumstances might have wanted an uncorrelated project. But, copper is fairly closely related to the firm's other non-ferrous products. Price trends for silver, copper, lead and zinc were all closely related between 1965 and 1975. Returns on investments in projects closely related to the firm's basic products and markets could be expected to be highly correlated to returns on the remainder of the firm's assets.

One might ask at this point why Hecla has continued with the Lakeshore project. Looking at the situation in 1975, and considering all prior costs associated with Lakeshore as "sunk costs," the picture probably looked brighter for Hecla, especially with improvements in the economies of the United States and the rest of the world. If in 1974-75 it was assumed an additional $35.0 million, including start-up costs and working capital, was needed to be invested by Hecla and El Paso in Lakeshore, that the trend of copper prices would be upward (say 6% a year), that operating costs would rise about 4% a year, and that at least 47,000 tons-per-year of copper could be produced, an estimated DCF-ROR of more than 50% could be expected on the additional investment. In addition, cash flows are high in the early years of production, which would allow for the payoff of the loans incurred in financing the project. The 1976 incremental investment analysis is summarized graphically in figure 3 15.

CONCLUSIONS

Hecla's large investment in the Lakeshore copper property has weakened its financial position in the 1970's; however, its current ratio remains satisfactory and its profit margins are good. Its diversification efforts have not yet been fruitful, but the Lakeshore project has the potential to add to the future strength of the company by recovering a great part of the relatively large investment required in the last five years.

The firm's future profits are closely tied to the movements in silver prices, and will come to depend more and more on the recovery of copper prices.

ASSUMPTIONS FOR ANALYSIS 1976

"Hindsight" Feasibility Analysis

1. The tactite zone of Lakeshore will be mined first, and the zone will last through seven years. In later years, sulfide ore will be produced from the disseminated sulfide zone.

2. All initial investment is made prior to mid-1976, and full production starts mid-1976. Realistic tonnage if 47,000 TPY of copper; if 65,000 TPY are reached, results are more favorable.

3. Percentage depletion allowance for copper continues, at 15%.

4. Copper prices will rise at a constant annual rate of 10%; all copper at Lakeshore can be sold.

5. Operating costs (less depreciation) will inflate at a constant rate of 6% a year after 1976.

6. Replacement worn-out equipment is done at original cost, by the end of the last year of its life.

7. The estimated equipment replacement schedule, with salvage value, is as shown for investment and salvage after 1976.

8. Working capital is fully recovered at the end of operations in 1990.

9. U.S. corporation tax is 48% of taxable income; state tax amounts to another 3% of taxable income.

10. Manning requirements and labor costs in 1976 are estimated at a total of 1,200 personnel and $16,337,000, respectively.

11. Mining development costs are $7 million; these costs will be expensed during the preproduction period. Completed studies, pilot plants, bonuses, and past exploration costs amount to a total of $6,200,000; the latter amount has been expensed but must be recaptured for tax purposes. It will be matched by an equal amount of depletion foregone in 1976-1977. Additional drilling costs will be approximately $5 million in the preproduction period.

12. Total capitalized cost has been estimated at $185,000,000. Depreciation is based on straight-line annual depreciation for fifteen years is approximately $12,333,000.

13. Bank loans are negotiable; no major interest charges are considered in operating years.

14. Allocated General and Administrative costs and estimated selling and delivery costs are computed at $1,000,000 a year.

ASSUMPTIONS FOR ANALYSIS 1976
"Hindsight Incremental Investment Analysis

1. The tactite zone of Lakeshore will be mined first, and the zone will last through seven years. In later years, sulfide ore will be produced from the disseminated sulfide zone.

2. Additional investment of approximately $35 million (including starting costs and working capital) is made prior to mid-1976, and full production starts mid-1976. All other investment considered as "sunk cost."

3. Percentage depletion allowances for copper continue at 15%.

4. Copper prices will rise at a constant annual rate of 6%; all copper at Lakeshore can be sold.

5. Operating costs (less depreciation) will inflate at a constant rate of 4% a year; in 1975, initial annual cost was estimated at $34,417,000.

6. Replacement of worn-out equipment is done at original cost, by the end of the last year of its life time. The estimated equipment replacement schedule, with salvage value, is as shown for investment and salvage after 1976.

7. Working capital is fully recovered at the end of operations in 1990.

8. U.S. corporation tax is 48% of taxable income; state taxes amount to another 3% of taxable income.

9. Manning requirements and labor costs in 1976 are estimated at a total of 1,200 personnel and $16,337,000, respectively.

10. Completed studies, pilot plants, bonuses, and exploration costs before 1975 amounted to a total of $6,200,000; the latter amount was expensed but must be recaptured for tax purposes. It is matched by an equal amount of depletion foregone in 1976-1977.

11. Annual depreciation for fifteen years is approximately $12,333,000, assuming total investment of $185.0 million.

12. Net income losses in 1983-1990 provide tax benefits.

13. Bank loans can be paid off in even amounts from cash flows in period 1977-1982; interest charge is 8.72%

CURRENT DEVELOPMENTS

Operating losses at Hecla's Lakeshore project were expected to continue into the fourth quarter of 1976, due to high start-up costs. Stockholders were told by the company that full production in both oxide and sulfide mines may not be a reality until the second quarter of 1977. (Production levels had reached 50% of capacity by mid-1976.)

The total cost of the project to July 1, 1976 was $198.0 million, including $11.0 million of working capital. An additional $9.0 million of working capital was estimated to be required by the end of 1976.

In October 1975 Lakeshore's oxide mine was reported operating close to rated capacity; however, the sulfide mine reached only 50% due to problems in controlling the caving of the ore.

It has been indicated that without an increase in the current level of copper prices, it will not be possible for Hecla to recover its total investment in the project. Profitable operations, however, will allow Hecla to pay off financial obligations incurred in funding the project.

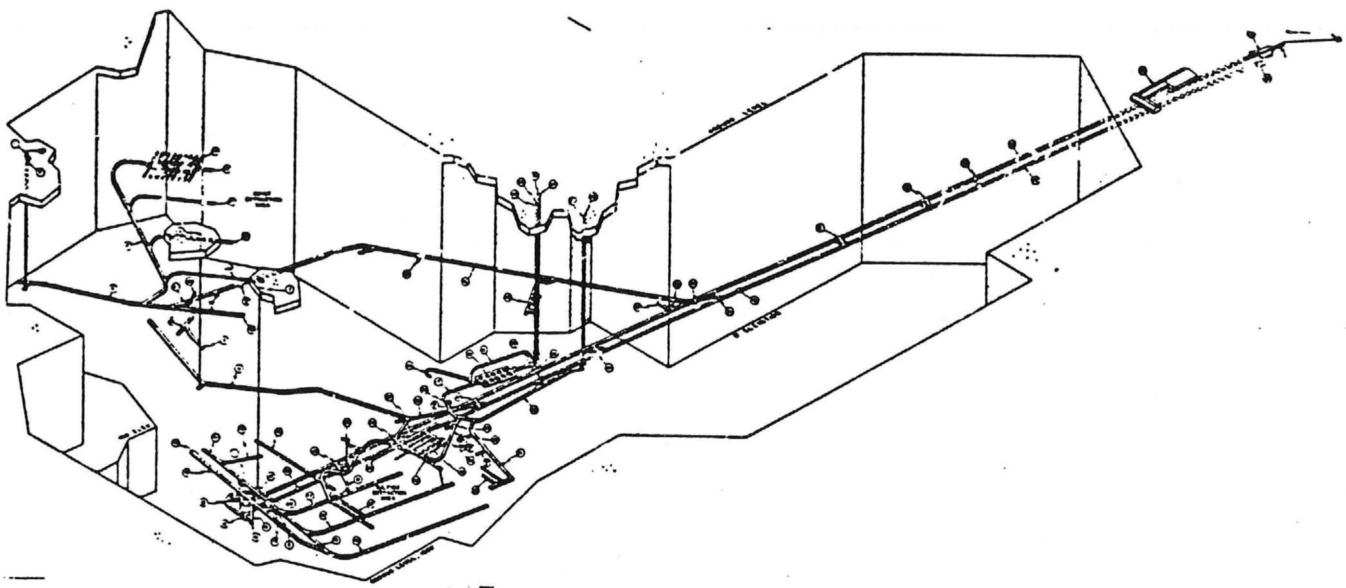

FIGURE 3-6 ISOMETRIC OF FINAL UNDERGROUND DEVELOPMENT
(Source: Hecla Mining Co.)

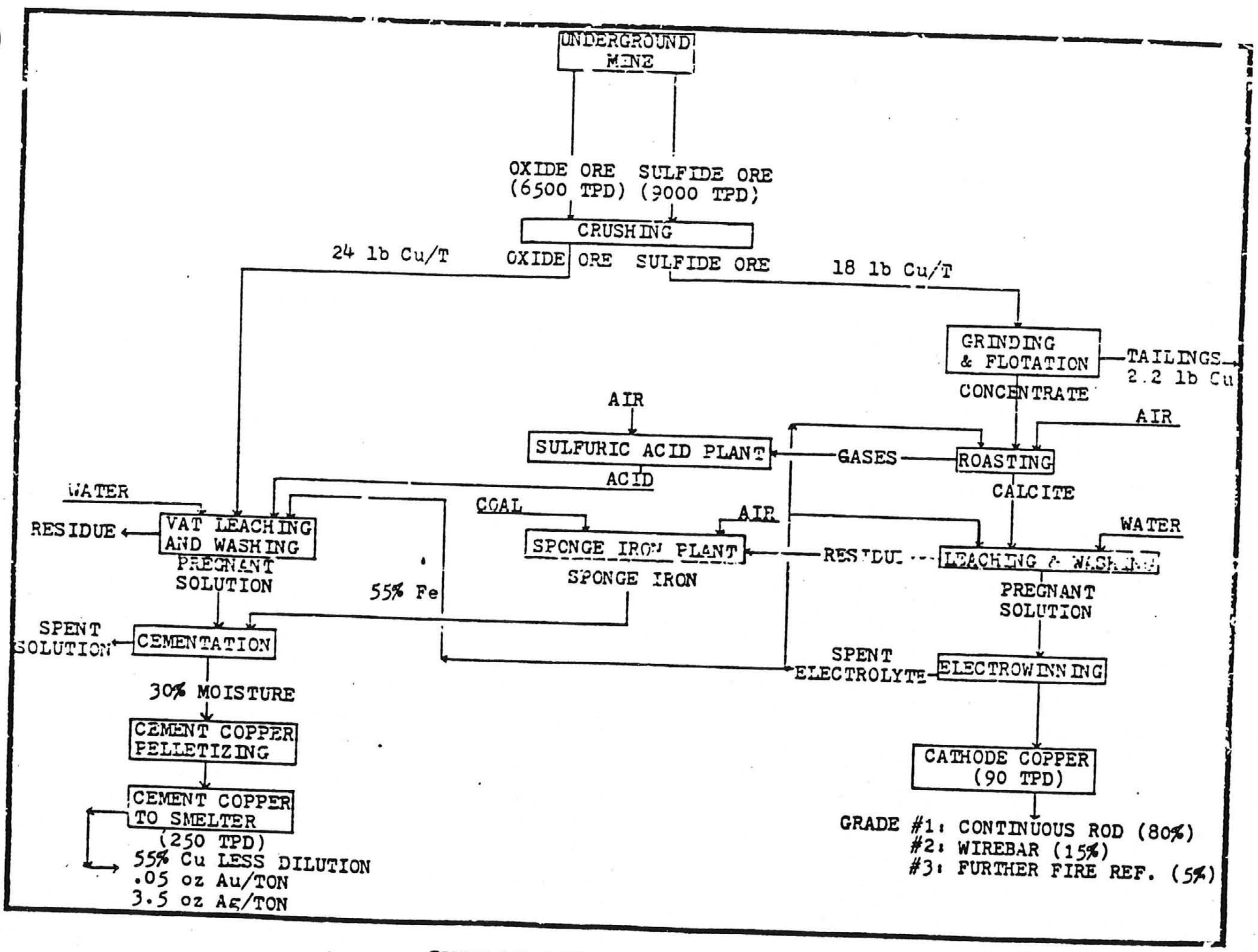

FIGURE 3-7 LAKESHORE PLANT FLOWSHEET

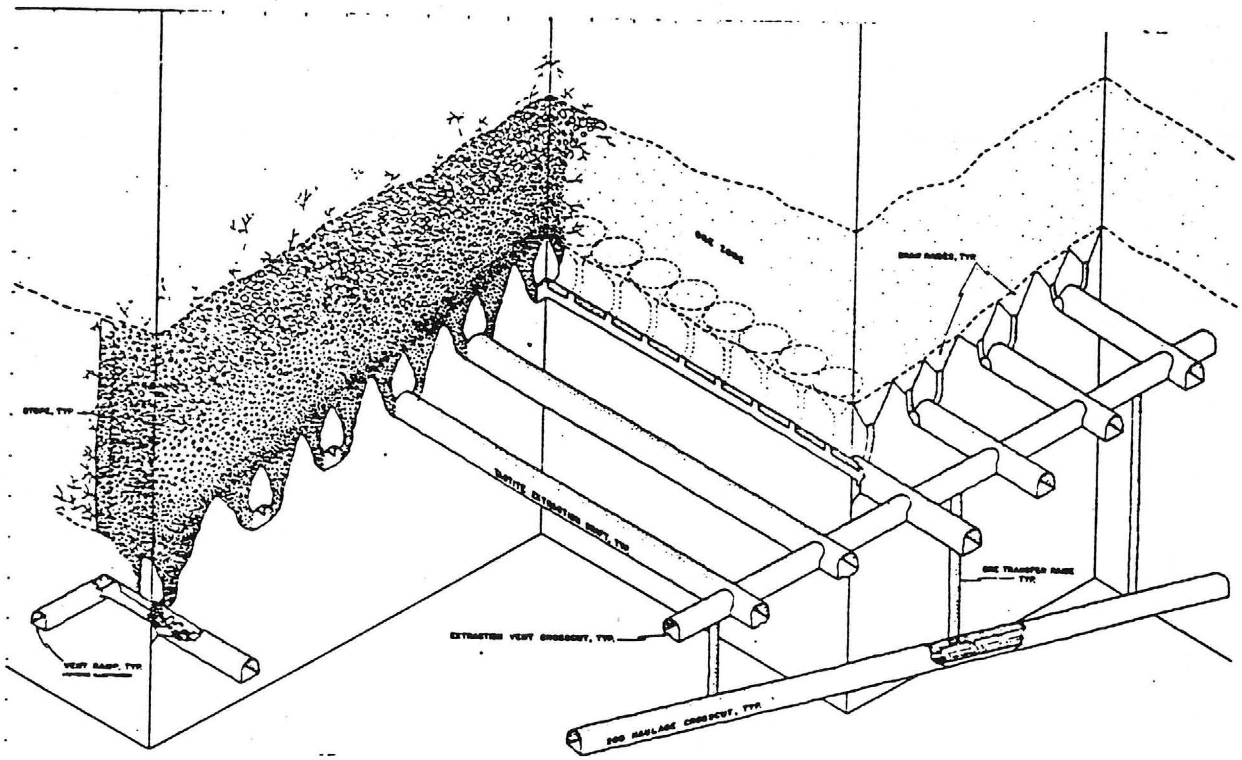

FIGURE 3-4 ISOMETRIC OF SULFIDE CAVING SYSTEM

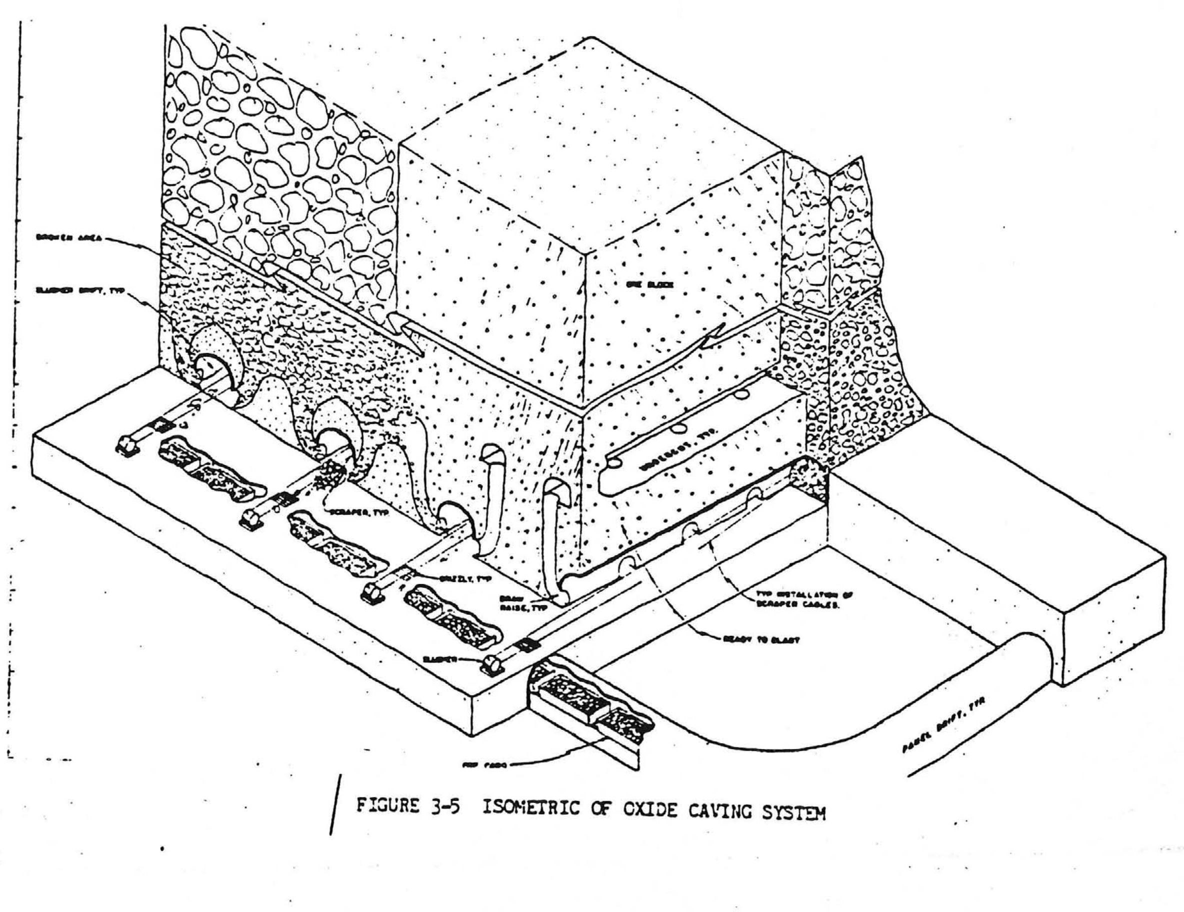

FIGURE 3-5 ISOMETRIC OF OXIDE CAVING SYSTEM

AFTER - DETAILED ESTIMATE (15%)

1969	1976	1979 wrote off project loss $195 million
	$47.9	
	5%	

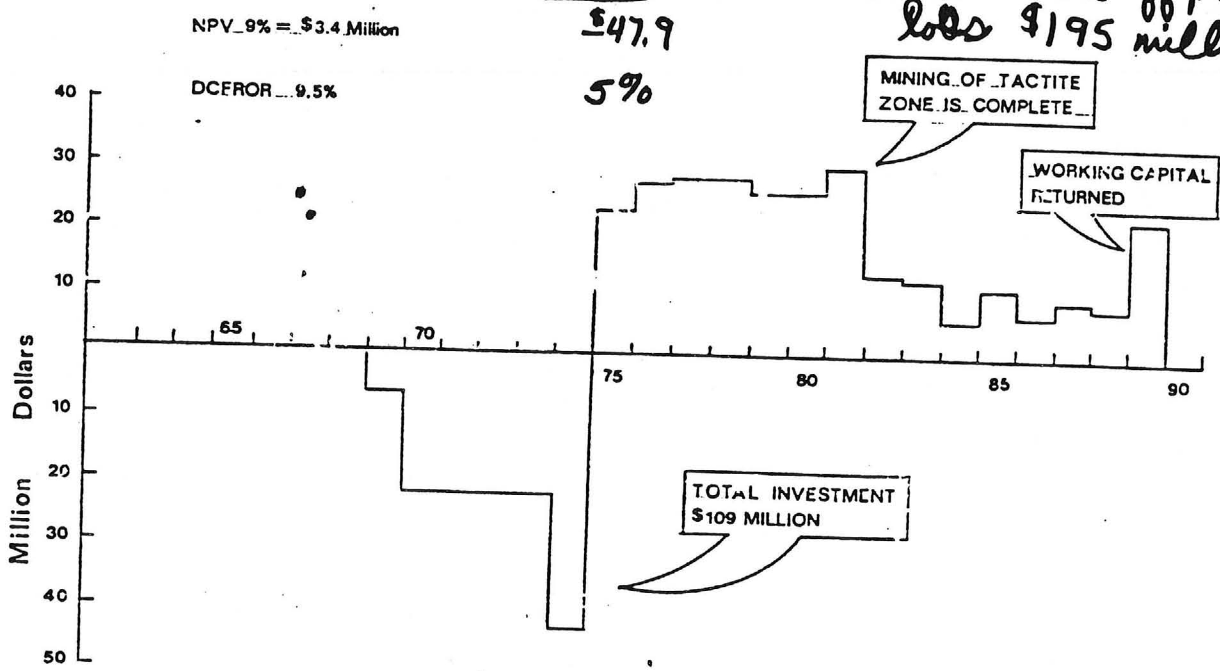

FIGURE 3-8 LAKESHORE CASH FLOWS—1969 ANALYSIS

1969	COST	EST.	$160 MILLION
1972	"	"	$140 MILLION
1974	"	"	195 MILLION
1975	"	"	195 MILLION

DELAYS — GROUND WEIGHT (18 MONTHS)
— INCORRECT MINE DESIGN (EXTRA COSTS, LOST PRODUCTION)
— PROCESS PLANT (SCALE UP FROM PILOT PLANT TO FULL SCALE)
— PROCESS PLANT NEED TO PELLETIZE CEMENT COPPER FOR SMELTER FEED

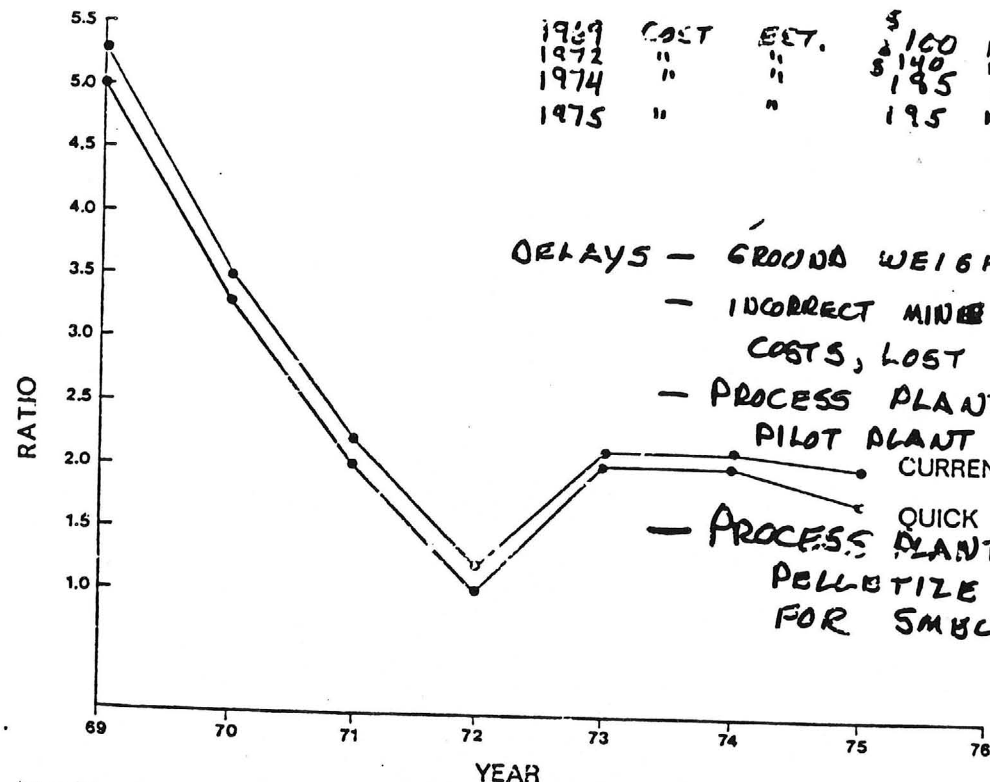

FIGURE 3-9 LIQUIDITY RATIOS—HECLA

	MILLIONS TONS		FEED GRADE		RECOV		MILLIONS POUNDS	MARKET PRICE		REVENUES
ANTICIPATED	5.250	X	.70	X	97%	=	71.259	X $.85/#	=	$60.57 MILLION
ACTUAL'	3.150	X	.65	X	94%	=	38.493	X $.75/#	=	$28.87 MILLION
DIFFERENCE	67%		7%		3%			13%		210%

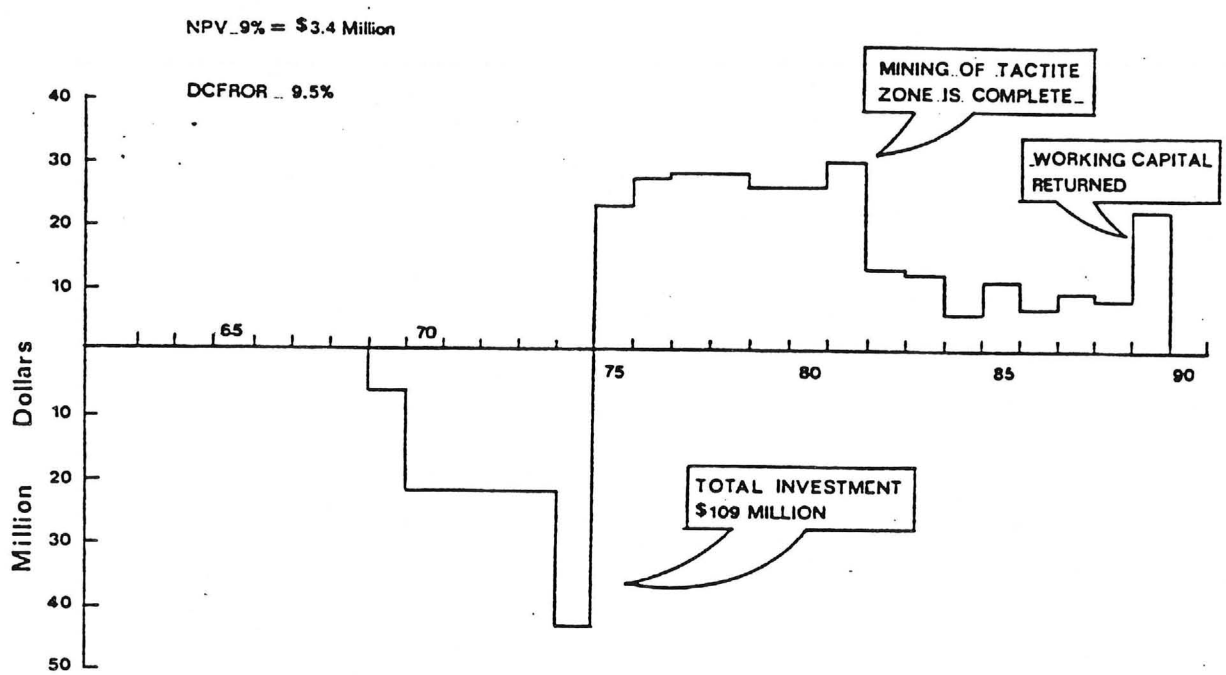

FIGURE 3-8 LAKESHORE CASH FLOWS—1969 ANALYSIS

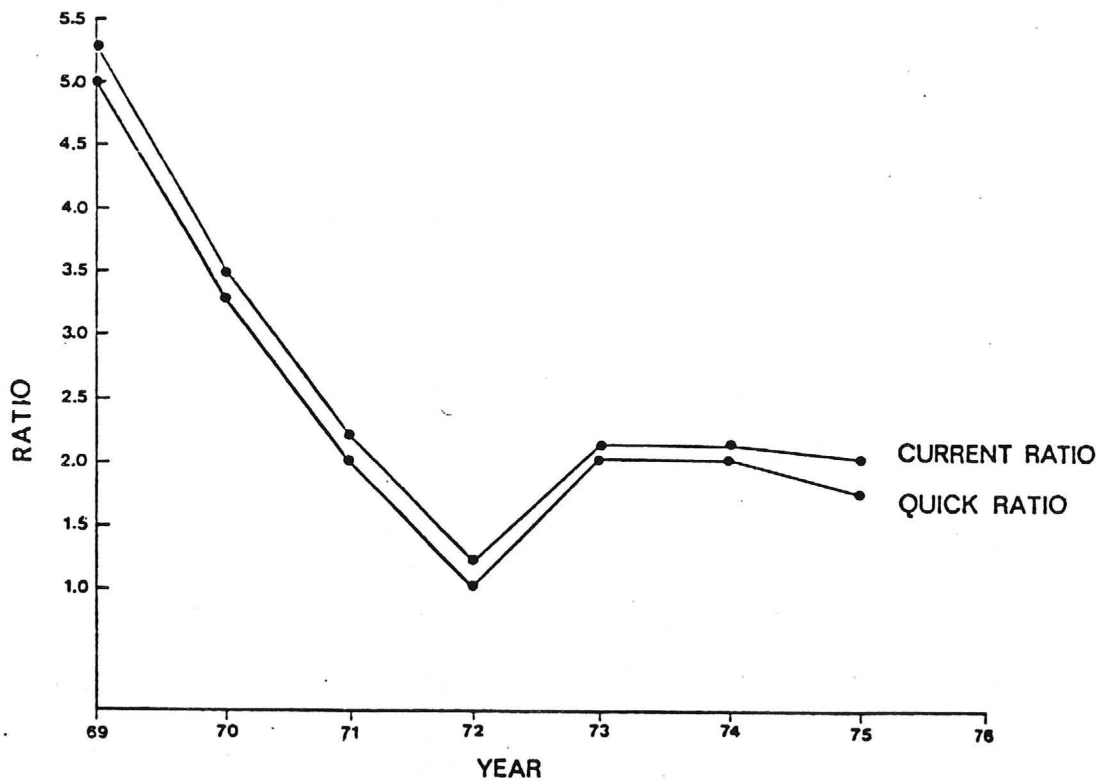

FIGURE 3-9 LIQUIDITY RATIOS—HECLA

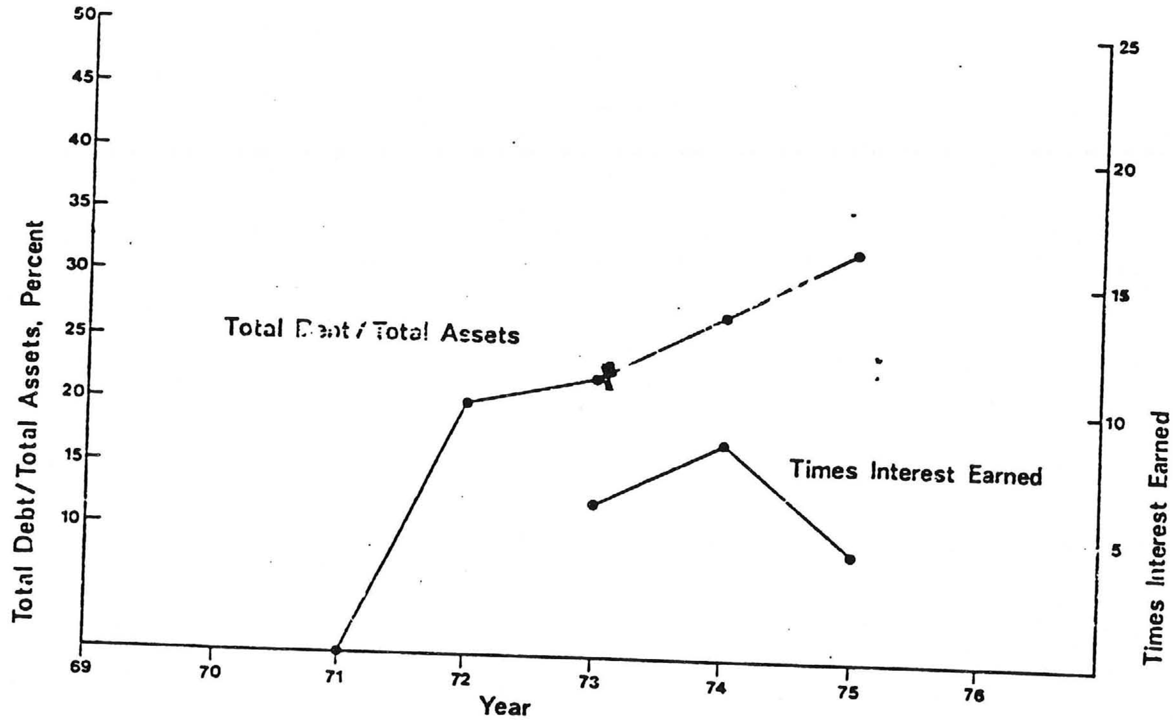

FIGURE 3-10 LEVERAGE RATIOS—HECLA

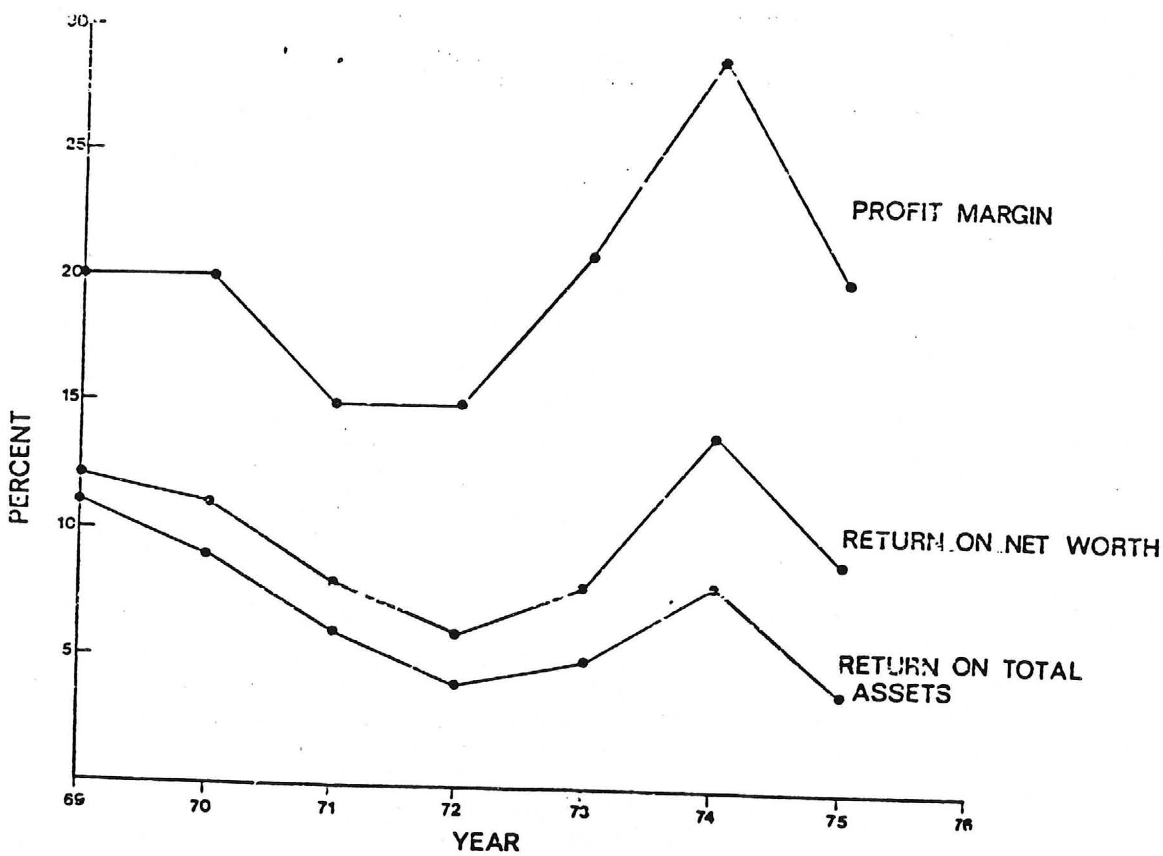

FIGURE 3-11 PROFITABILITY RATIOS—HECLA

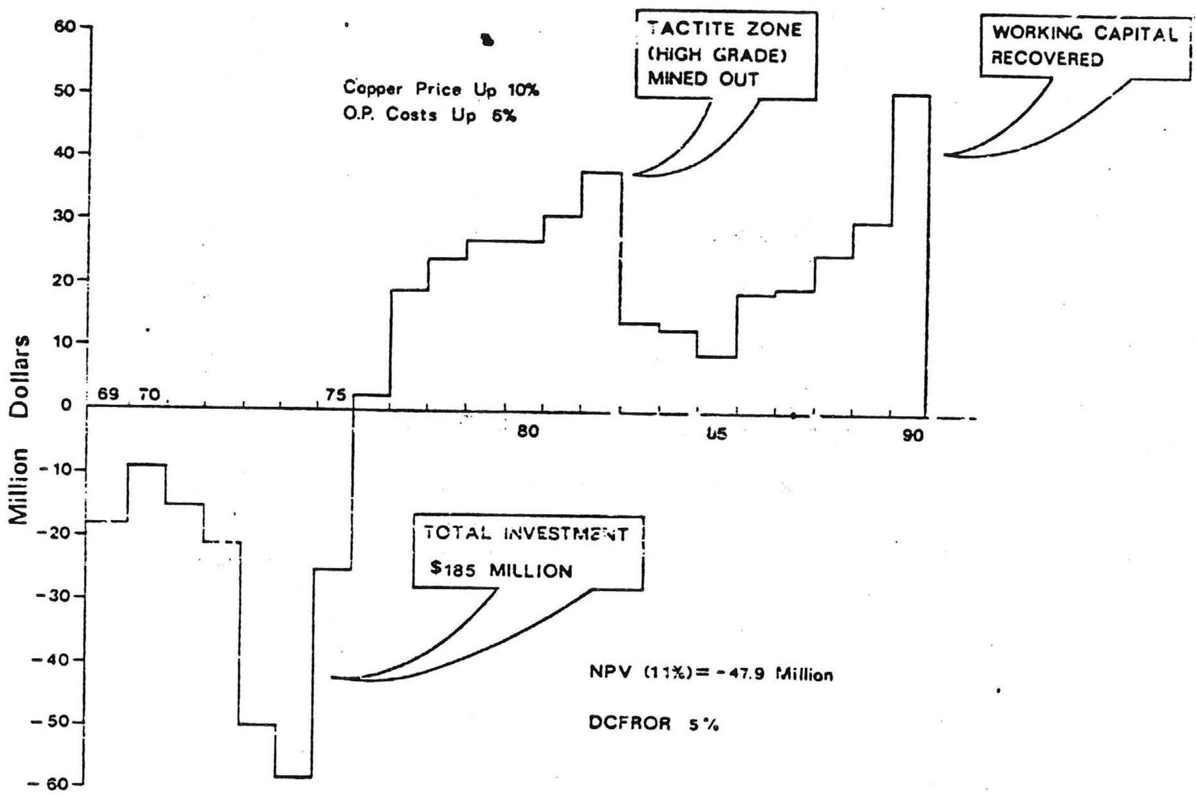

FIGURE 3-14 CASH FLOWS, LAKESHORE "HINDSIGHT" ANALYSIS, 1975

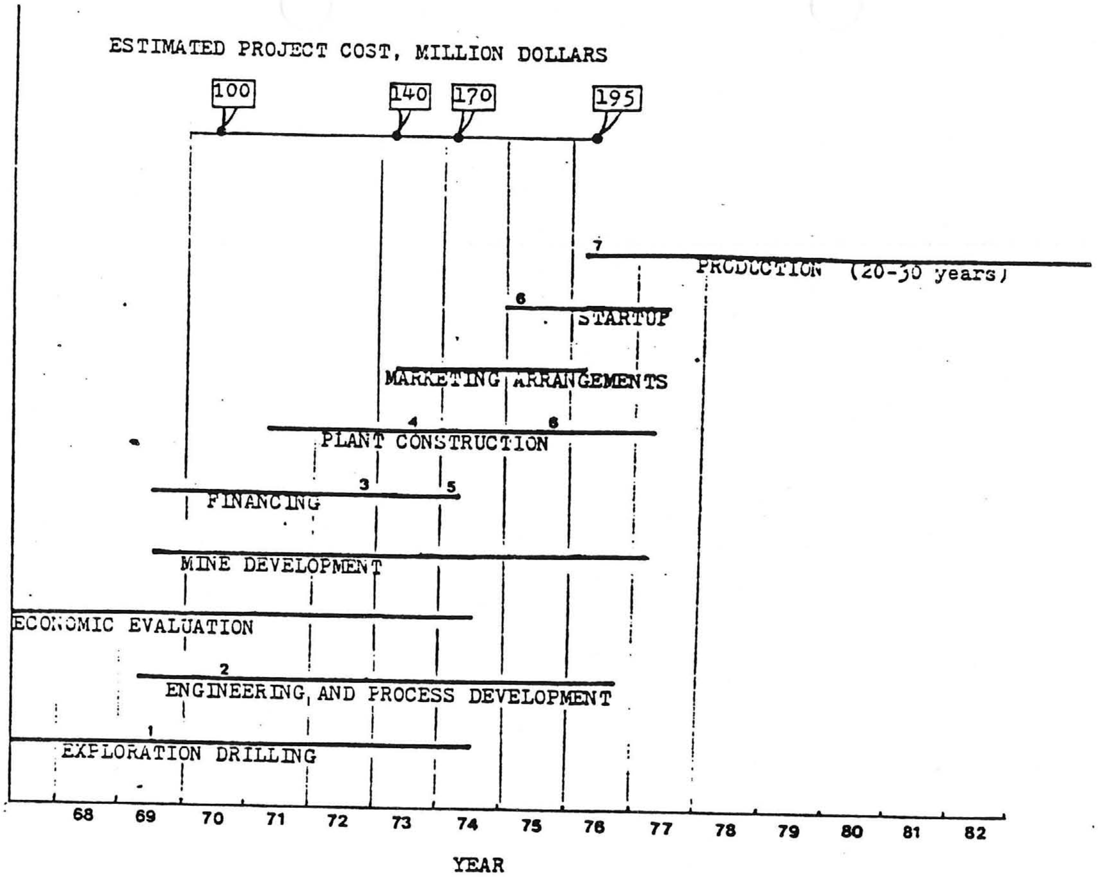

FIGURE 3-12 PROJECT DEVELOPMENT—LAKESHORE

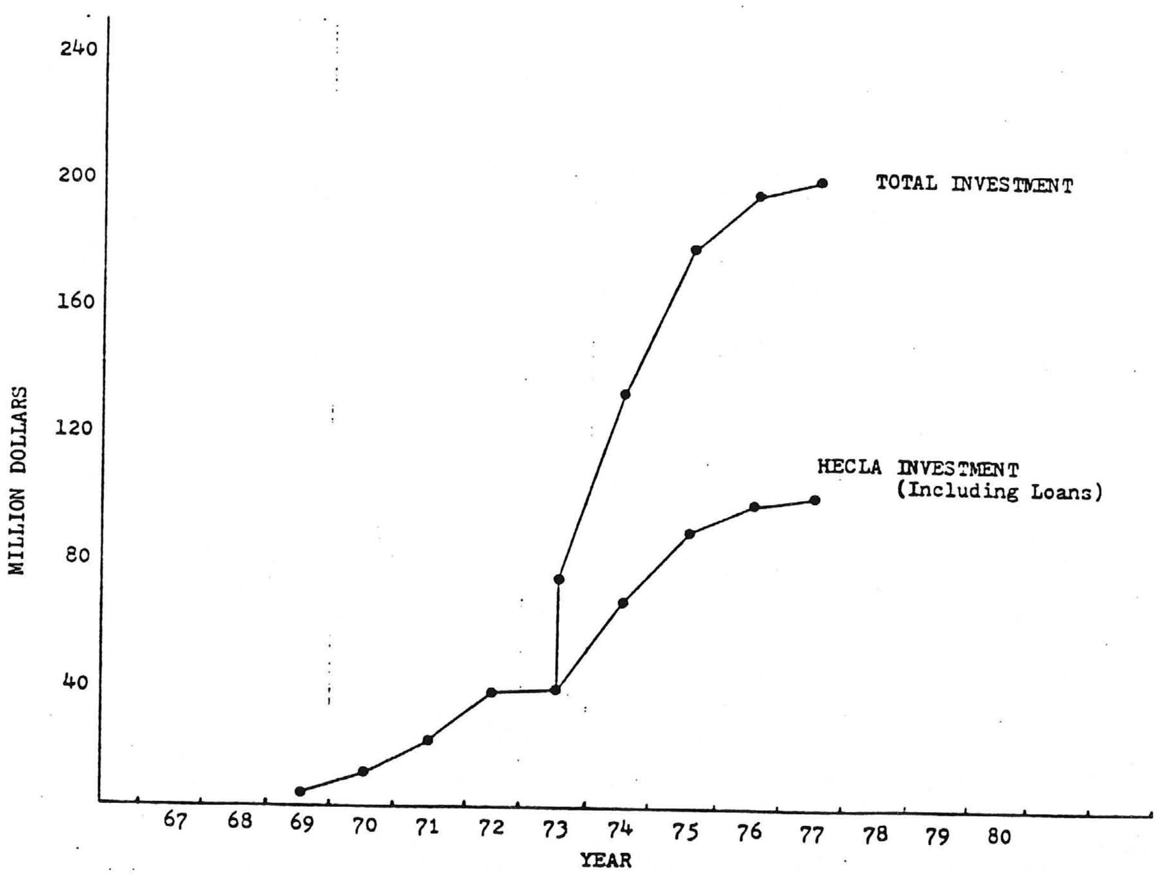

FIGURE 3-13 CUMULATIVE INVESTMENT—LAKESHORE

Hecla is expecte to incur an overall loss for 1976. Long-range prospects still depend on the success of the copper project, and trends in silver prices will continue to have a major impact on Hecla's overall profits.

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QUESTIONS

1. In view of the cyclical nature of copper prices, the nature of underground mining operations, and the requirement for complex ore-processing at Lakeshore, what assumptions and expected rate of return would have been necessary for you to recommend that Hecla enter the joint venture?

2. What are the similarities and differences in considerations with respect to a mining venture in the United States (like Lakeshore) and one in a foreign country (like Cuaj Peru)?Would you trade a financial interest in Cuajone for an equal one in Lakeshore? Justify your answer with a summary of the risks involved.

3. Do U.S. income tax laws and regulations favor an investment in mining in the United States or in a foreign country? Explain.

4. As a banker, what factors would you examine closely in reviewing an Hecla request for a loan to support Lakeshore?

5. What aspects of the operation at Lakeshore were most affected by inflation in the 1970's?

6. What are your estimates of future copper prices and operating costs at Lakeshore? How will they impact on the profits of Hecla?

7. Was there a point in time that Hecla could have withdrawn from the project at Lakeshore? Would you have recommended it? Explain.

8. How do the earnings and benefits of the "average" Lakeshore employee compare with those of a SPCC employee in Peru?

9. What changes in the price and cost ssumptions would you make in evaluation of the Lakeshore deposit?

10. Do you think that some of the mining,processing and marketing problems encountered in the development of Lakeshore could have been avoided? What strategies might have helped?

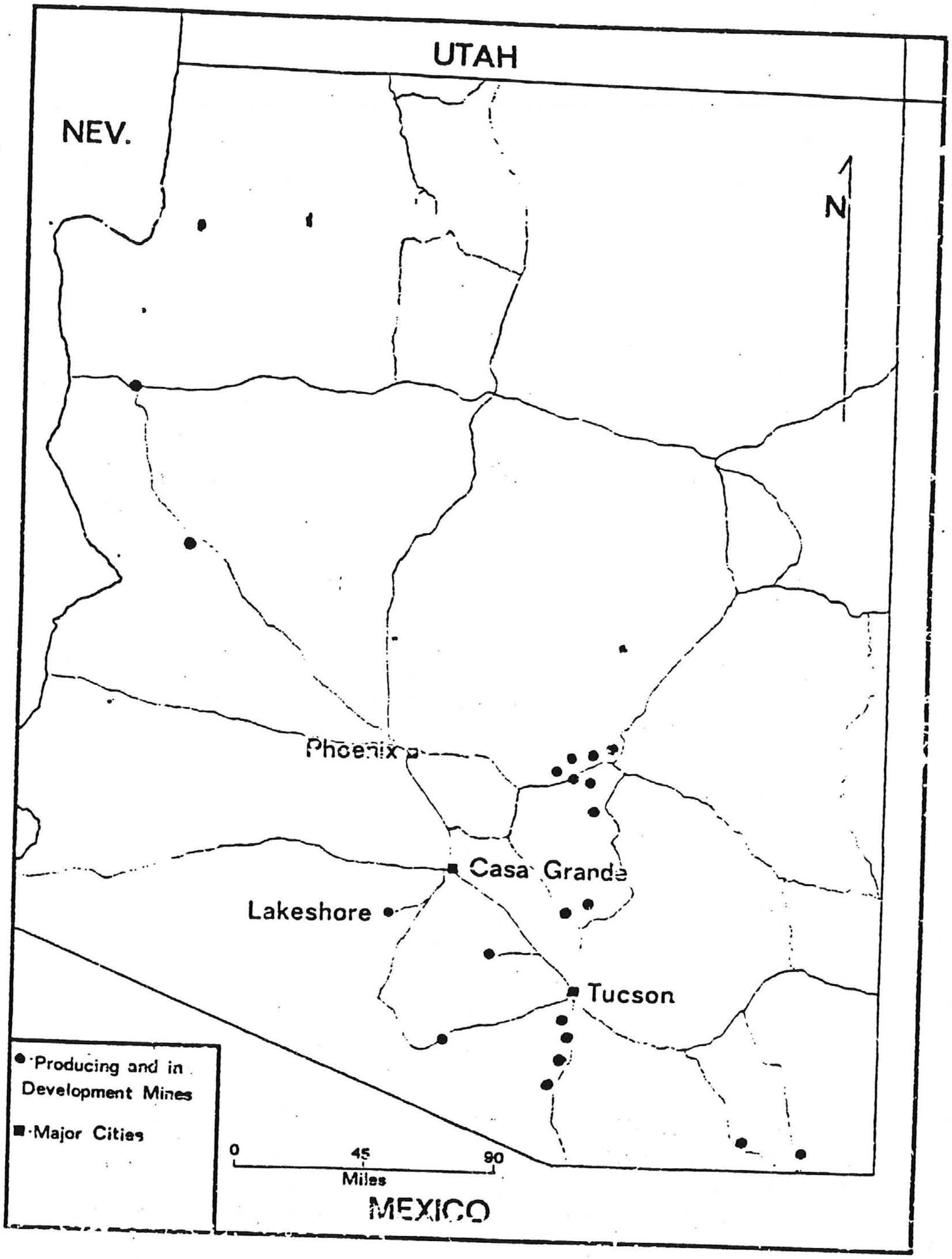

FIGURE 3-1 ARIZONA COPPER MINES

11. Do you think the assumption with regard to salvage on this project is warranted? Explain.

12. Given the importance of the Lakeshore project to the economic survival of Hecla,do you think that too much unproven technology was built into the project? Explain.

13. What copper price is needed to make the Lakeshore project "economic?

14. Do you think that Hecla should have diversified in commodities other than copper?

15. .What strategies are open to Hecla when the high grade ore runs out?

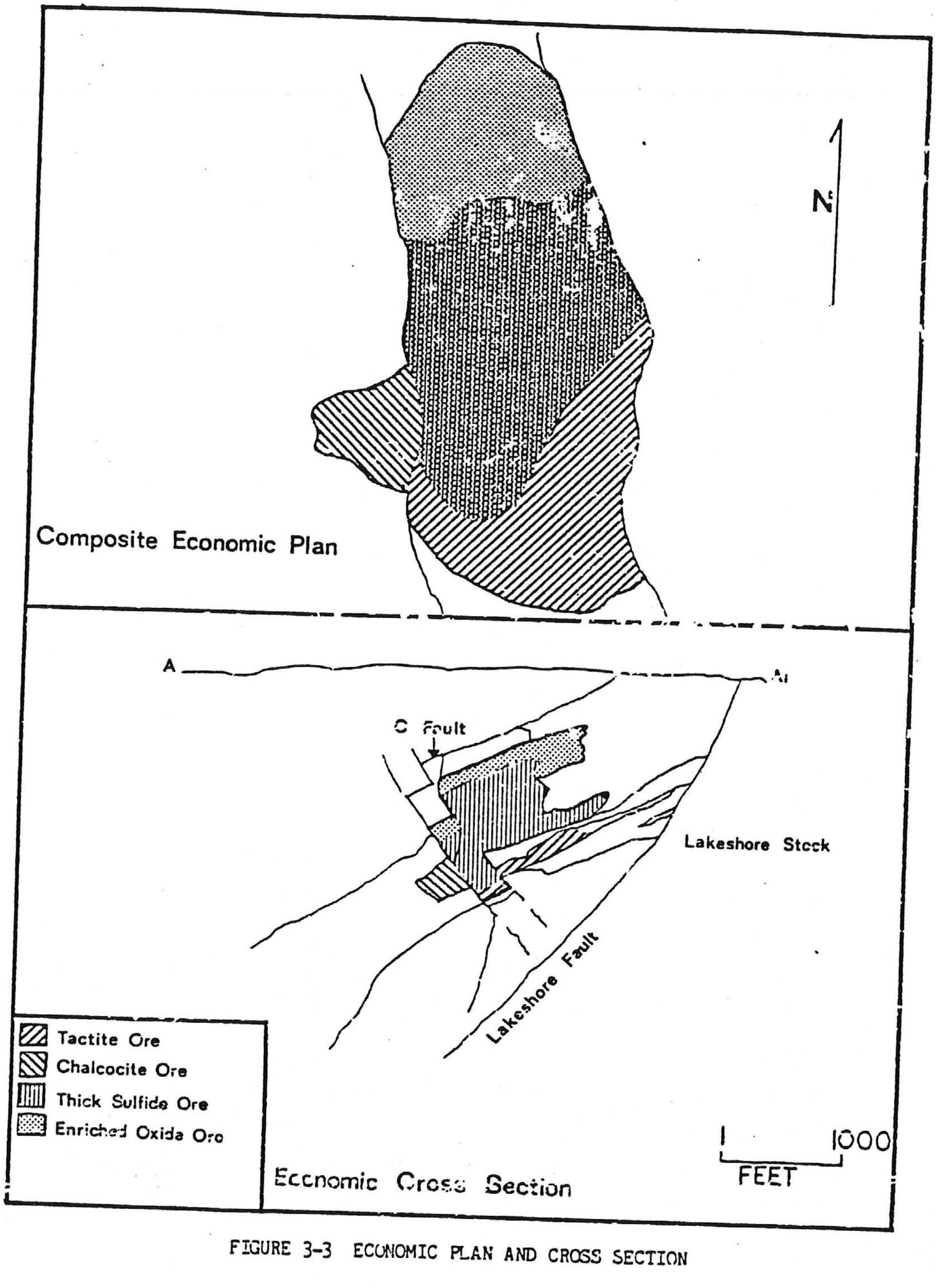

FIGURE 3-3 ECONOMIC PLAN AND CROSS SECTION

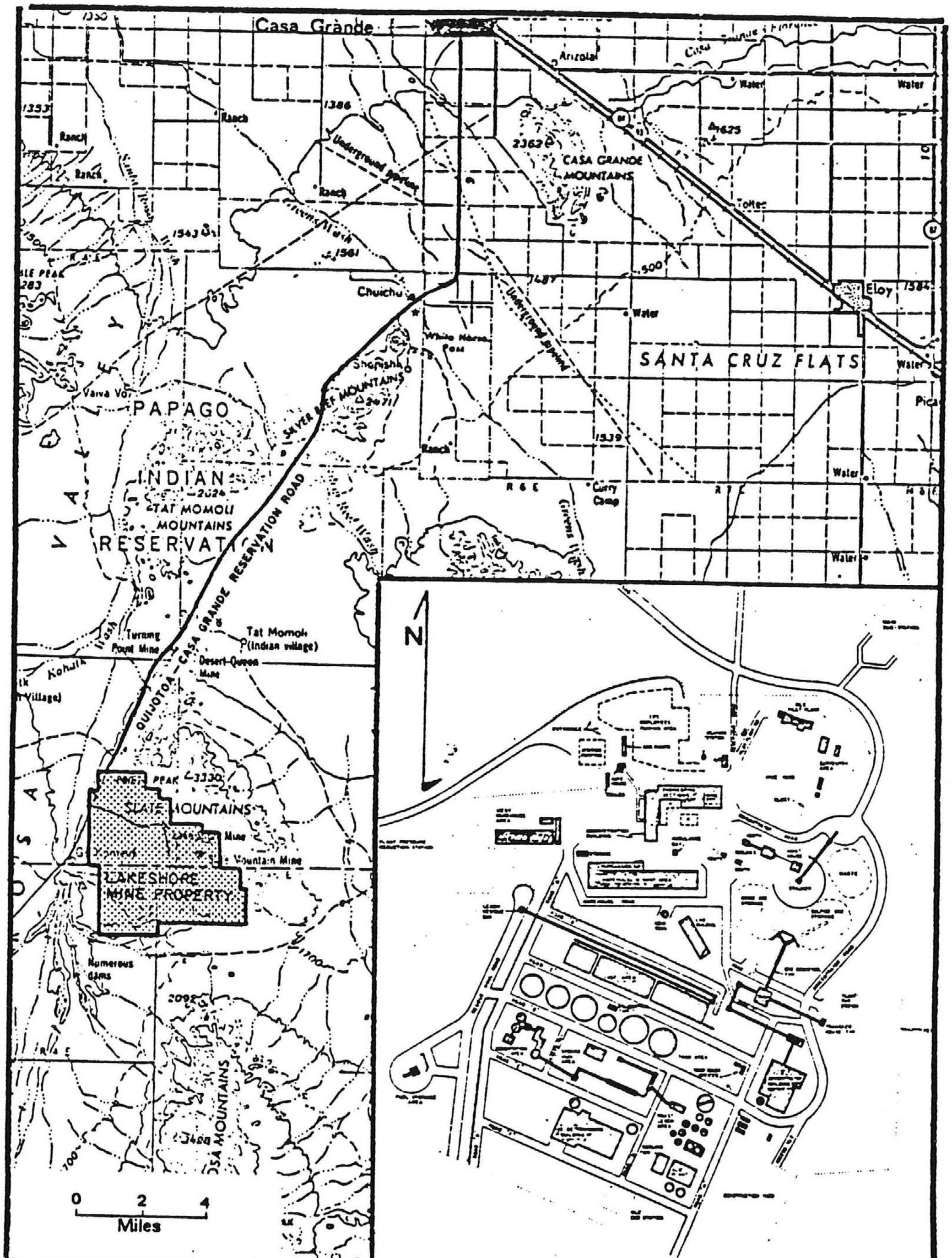

FIGURE 3-2 LOCATION AND PLANT AREA, LAKESHORE PROJECT

Dup

WISSER AND COX
CONSULTING GEOLOGISTS
55 NEW MONTGOMERY STREET
SAN FRANCISCO
PHONE YUKON 2-1436

SUMMARY REPORT OF MAY 1, 1957
Transarizona Resources, Inc.

LAKESHORE COPPER PROJECT

FOLDER #1

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Copy 1 of 8

WISSER AND COX
CONSULTING GEOLOGISTS
55 NEW MONTGOMERY STREET
SAN FRANCISCO
PHONE YUKON 2-1436

CONTENTS

ILLUSTRATIONS

FOR SUPPORTING DATA SEE FOLDER #2

*

WISSER AND COX
CONSULTING GEOLOGISTS
55 NEW MONTGOMERY STREET
SAN FRANCISCO
PHONE YUKON 2-1436

June 4, 1957

Mr. J. D. Mason, President
Transcontinental Resources, Ltd.
1158 Melville Street
Vancouver, British Columbia

Dear Sir:

We hand you herewith the original and five (5) identical duplicates of a summary report current to May 1, 1957 on the Lakeshore Copper project. Since preparing this report, investigation of an iron by-product has been undertaken which bids fair to increase the outcome per ton by an amount between one and three dollars per ton. A report covering markets, processing costs and iron reserves will be completed by June 12, 1957.

An exploration proposal covering Transarizona holdings has been prepared for your consideration and is forwarded under separate cover.

Respectfully submitted,

Manning W. Cox

Manning W. Cox

*

WISSER AND COX

CONSULTING GEOLOGISTS

LAKESHORE PROPERTY

TRANSARIZONA PROJECT

May 1, 1957

SUMMARY:

Transarizona Resources, Incorporated, controls three miles along a mineralized intrusive contact south of the Slate Mountains in Pinal County, Arizona. Oxidized copper deposits with a high magnetite content in calcareous rocks, occur in five areas on Transarizona property. At the Lakeshore ore body there is drilled off, with a 1500' length, 2 million tons grading 1.76% copper after allowance for open pit mining dilution. The association of copper with magnetite allows other ore bodies to be preliminarily located by geophysical means. Eight magnetic anomalies along a mineralized contact remain to be explored; of these two are known to contain copper-magnetite mineralization. The mineralized belt extends two miles to the south and an additional mile to the north beyond the Lakeshore property. Application has been made to the Papago Indian tribe for a prospecting permit for these and other favorable mineralized areas in the surrounding 36 square-mile region.

Metallurgical work done in a cooperative program with the U. S. Bureau of Mines has developed a process combining a conditioning roast with flotation to recover more than 90% of the total copper into a marketable metallic copper flotation concentrate. Preliminary cost estimates, based on laboratory scale pilot plant, indicate a direct cost of copper of not to exceed 14.4¢ per pound before write-offs and cost of marketing. Including write-off and open smelter schedule marketing, the estimated cost of copper is 21¢ per pound.

Capital requirements to bring the Lakeshore property into production are estimated at $1,300,000 in plant erection, service facilities and operating capital.

Because this is a process untried at a commercial scale and because substantial exploration possibilities remain at Lakeshore, it is recommended that a minimum of $150,000 be expended in pilot plant metallurgical work and in further exploration at the Lakeshore property. Pilot plant work should be done at a scale of not less than 50 tons per day. Exploration work should comprise both airborne geophysical and diamond drilling on the known anomalies.

Presuming that such expenditure substantiates the preliminary cost estimates now possible, there is indicated an operating margin of 8.65¢ per pound of copper or $2.51 per ton ore. On a 330,000 tons per year basis, there will be an annual operatingprofit of $871,000.00. The time necessary to recapture the expenditures will be 1.5 years. There will remain 1,510,000 tons of ore at the end of the recapture period which should yield a profit of $4,000,000. Because these figures include write-offs over the total life of 6.0 years, the ratio of profit to investment is 4.0 to 1. This proforma estimate is made with a price of copper at 30¢ per pound. For each 1¢ change in the copper market, price,

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the proforma operating profit varies by $100,000per year. This proforma estimate is based solely on proven reserves without regard to probable ore or exploration possibilities definitely known. No provision is made herein for income taxes.

Therefore, subject to confirmation of these estimates by pilot plant work, the Lakeshore property appears to have good profitability and to be a legitimate and reasonably conceived mining venture.

REAL ESTATE: There is attached hereto a map of Arizona locating the Lakeshore property and a general index map of the Lakeshore area, showing the property held by Transarizona. Briefly, reviewing the ownership status, there are five underlying agreements which are controlled by Transarizona Resources.

The first of these is the Treasure State option in which Transarizona holds an undivided 85% interest from Freeman and McClure. The option is for an indefinite period of time from the Treasure State Mining Company, a Montanta corporation. It calls for a minimum royalty payment of $1000 per month and production royalties on a sliding scale ranging from 2½ to 12½% depending upon the price of copper. The takeout price on a royalty basis is $400,000; the take out price on a cash basis is $300,000. There has been paid under this option to the end of April, 1957, $8000. Payments fall due on the 8th of each month. They are made to the First National Bank of Arizona, Phoenix, Arizona, as escrow agent.

Transarizona is the beneficiary of an 85% undivided interest in that Indian land lease held by Freeman and McClure, originally comprising the S½ of section 25 and the N½ of section 25, T10S, R4E, Gila Meridian, lying in Pinal County, Arizona, entirely within the Papago Indian Reservation. This lease is ratified by the Secretary of the Interior and is a standard-form Indian lease, calling for a 10% royalty with no take-out price on mineral production. There are certain minimum annual rentals under this lease which, although complicated, aggregate about $1500 a year. There was paid as a bonus for this lease, $5,8000 to the Papago tribe. On May 3, 1957 the Papago tribe ratified a proposal to exchange part of this land for adjoining lands as indicated on the attached index map. The reason for this exchange being the greater probability of mineral on these lands. In order to effect this transaction it was necessary to pay the Indians an additional bonus of $2400. The land exchange must still be ratified by the Secretary of the Interior.

Transarizona Resources holds directly an option from Theodore Drake of Coolidge, Arizona on the Slate group of 3 patented and 19 unpatended claims. The Drake option must be exercised on or before the 19th day of June, 1957. Thereafter a minimum monthly royalty of $250 per month is due on or before the 10th day of each month. Royalties under this lease are 10% of the net smelter returns. The takeout price is as follows: When the lessee shall have paid the lessor a total of $151,000 in royalties or advance royalties, he shall be granted an option to purchase the properties for $5000. Under the underlying Freeman-McClure-Transarizona agreement, Freeman and McClure automatically acquire 10% interest in this Slateoption.

Transarizona holds an undivided 85% interest in a water prospecting permit granted by the Papago tribe to all of the lands within a radius of three miles of the collar of the Arizona shaft, as indicated by dashed line on the attached

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index map. This can be interpreted as an exclusive right to prospect for water, but is not necessarily so.

Transarizona and Freeman and McClure have made application for a prospecting permit on 1 township or 36 square miles surrounding the Lakeshore mine. This, as shown on the attached map, is divided into four quarter townships. Und er the rules which now apply to Indian lands, this must be placed for public bidding. We have made such a request to have the lands brought to public bidding and it probably will be 60 days to 4 months before such bidding actually can take place. It is important therefore that as little publicity be given to this venture as possible, until such time as the lands are bid for and obtained.

The pertinent items as to location, accessibility and available facilities at the Lakeshore property are as follows:

1. Property is located 26 miles south of Casa Grande on a first order gravel road which is under contract to be paved during 1957. When the paving is completed, the property will then lie 1½ miles from mile 25 of the Casa Grande-Sells paved highway.

2. The area is flat or gently sloping desert and it is feasible to build a road with very little expense to any part of the area. There is no surface water. There is very little surface vegetation except desert plants.

3. The nearest rail shipping point is the Southern Pacific Railroad main line at Casa Grande, Arizona.

4. There is no telephone available or possible at the property.

5. The closest power lines are 20 miles airline from the property.

6. The closest gas line is the main 8-inch line to Ajo which passes 11 miles north of the property in Santa Rosa Wash. The property can be served either by the Tucson Gas Company, if a plant were to be built in Pima County, or by the Natural Gas Service Company or Arizona if it is located in Pinal County. You will note that the county line more or less bisects the existing property.

7. An adequate supply of Papago Indian labor is available. There is very little skilled labor in the area.

8. Adequate warehouse stocks for most machinery are carried in Casa Grande. Major mining supply houses are located in Tucson and Phoenix which are not more than ½ hour by air from the property.

9. It is feasible to build a light plane air strip with minimum expense at the property.

10. Two existing test wells, both intersecting more than 200 feet of water saturated gravels and a pumping well three miles distant from the property lead us to believe that an adequate water supply can be developed. However, we have not conducted pumping tests and until such tests are conducted, it will not be positive to state the precise amount of water available. We are guided in these thoughts by the opinion expressed on our behalf by the U. S, Geological Survey Ground Water Division geologist in charge, Leo H. Heindl.

11. The climate of the area is the usual southwest Arizona desert climate. It is even temperatured in winter with occasional flooding storms. It is hot-temperatured reaching 115 degrees or higher during the summer, with occasional rain storms and flash floods to be expected in August and September. In general, however, the climate is agreeable and not unduly severe. Frosts are unknown.

WORK PERFORMED

Physical work has been performed on the Lakeshore property itself, other than Metallurgical work, during the periods May 18 to September 20, 1956 and March 15 to date. The work done may be divided into six categories.

Surveying

Starting with the U. S. land subdivision monuments, a close transit chain traverse of third order accuracy, has been carried around the original Treasure State claims and Indian lease, resulting in the final location of 6 permanent bench marks from which surveying may be taken off in any direction. Transit control has been extended to the south over the Slate group. There is no transit control to the north. A topographic map of the Lakeshore mine area has been prepared. A geologic and planimetric map of the Slate mine is in preparation.

Geological Work

A reconnaissance of the entire 50 square mile area around Lakeshore, on a scale of 1 inch equals 1/2 mile was completed by M. W. Cox. A detailed geologic map of the original holdings on the scale of 1" to 200' has been completed. A detailed geologic map of the Slate group area, at 1" - 200' is in progress. Detailed geologic maps of the mine workings and a composite geologic map of the areas immediately surrounding the Lakeshore mine on a scale of 1" - 40' has been completed. The results of this work has, and will be portrayed on plans and sections.

Geophysical Work

A ground magnetometer survey utilizing a Schmidt type magnetometer has been completed on the original square mile Indian lease, the more or less 1/2 square mile area immediately north of the lease and a similar survey is in progress on the Slate group. Part of this work was done in contract by United Geophysical Corporation, the balance by Scott Allen, Lyle Dunn and Sid Ellis.

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employees of Transcontinental Resources. The work is in varied orders of precision. In the center block the traverses are 200 feet apart, with 40 and 100 foot ground stations. In the south end a similar grid is in progress. In the north end, the traverses are 300 feet apart with 200 foot center ground stations. Further geophysical work in the north end is indicated.

Physical Exploration

Three types of physical exploration have been conducted on the property; underground work, drilling and trenching. Two deep trenches, put just north and south of the main shaft at the Lakeshore property involved the moving of some 15,000 yards of aluvium and the mining of 2700 tons of ore for test purposes. The greater part of this ore is still available at the property for testing. These trenches had a maximum depth of 40 feet and a maximum length of 400 feet. They are detailed and summarized in the summary report of September 15, 1956. Additional shallow trenching has been done by bulldozers in the Slate group in connection with the magnetometer work. This trenching is simply to clean up old pits and known mineralized outcrops for geologic mapping.

Underground work consisted of erecting a temporary headframe, slabbing for sampling purposes, two crosscurts on the 152 level and hoisting some 23 tons of broken rock for leach testing.

Drilling by Transarizona was all performed by dry rotary methods. Transarizona and its predecessor, Consolidated Uranium, have drilled a total of some 90 holes in the main area and an additional 11 holes in the surrounding area for exploration purposes. All the results of this drilling, maps, cross-section and detailed assay plans and drill logs, are reported in the summary report of September 15, 1956, and will not be repeated herein.

Metallurgical Work

During the first period of activity, detailed investigation of all the possible varieties of sulphuric acid leaching of Lakeshore ores were investigated. These activities came to a complete stop on September 20th. They may be most charitably reviewed by saying that technically trickle or heap leaching was the most successful, but at such a high cost per pound of copper that economically the processes are not applicable to Lakeshore ores. At this time, segregation metallurgical work was begun which has been very successful and it is reviewed separately in this summary report.

Planning and Estimation

In the summary report of September 15, 1956, there were gathered together, in as complete a form as feasible, all of the cost estimates necessary for mining and processing plants and operating information. This information is not repeated herein except to utilize the results thereof as they are applicable to the changed economical conditions imposed by segregation metallurgy. On January 20, 1957 outcome and capital requirements for Lakeshore property were reviewed.

* They are again reviewed herein as a result of theseprevious detailed studies.

GEOLOGY & NATURE OF ORE DEPOSITS:

The Lakeshore copper property lies on the southwest flank of the Slate Mountains in the Sonora desert province of Arizona. It lies some 20 miles northwest of the Silver Bell mine of American Smelting & Refining Company, which in turn lies some 20 miles northwest of the copper properties of Pima Mining Company, Banner Mining Company and Duval Sulphur Company in the Sierrita Mountains. The Slate Mountains are composed of preCambrian achists overlain by a think sequence of limestones, quartzites and shales. These include members of the Apache, Martin, Escabrosa and Naco formations of preCambrian or lower Paleozoic age. Overlying the limestones with marked unconformity are 5,000 to 10,000 of clastic and volcanic rocks of Cretaceous (?) age. All of these rocks are invaded by a quartz monzonite stock, having an area exposed to the surface of roughly 3 square miles.

South of the Lakeshore Mountains is a wide desert flat between Slate Mountains and the Santa Rosa Mountains. Santa Rosa Mountains are underlain by preCambrian gneisses and dioritic rocks that are overlain unconformably by a thick boulder conglomerate of undated, but probably Cretaceous, age.

While in general the mountains ranges trend north-south the structural trends of the region are definitely northwest. Interior structure of the ranges is not reflected in their shape. Their shape is due to very recent range front faulting which is entirely post-ore in age. Both the Santa Rosa and Slate Mountains are rugged in topography, arising a maximum of 1500 feet about the general desert area. The bedrock slope in the general front pediments of the range is 200-500 feet per mile. However, the surface slope on pediments and aluvium is only 50-100 feet to the mile, so that at a distance of 1 to 2 miles from the range front, the bedrock is buried beneath 200-500 feet or more of aluvium.

As may be seen on the attached general index map, strong northwest faulting breaking homoclinal dips in the sedimentary and volcanic rocks is intruded by quartz monzonite and satelite intrustions. The western margin of the quartz-monzonite intrusive is very strongly faulted and closely sheared in a number of places. This contact can be followed for a distance of about 3½ miles. The general faults zones into which the monzonite is intruded can be either traced or inferred an additional mile and a half to the north and 2 miles to the south.

Mineralization occurs along this general northwest, southeast trend for the entire distance known. Within the intrusive mass, there is some disseminated copper mineralization in the north end of the known belt, and numerous quartz-chalcopyrite, tetrahedrite veins with a northwest strike within the monzonite. However, the monzonite in itself is not very heavily mineralized, and it can, in no place visible at the surface, be described as a possible "porphyry" disseminated mineralized mass. The principal mineralization occurs on the faulted zones on the west side of the intrusive and in limestone, shald and quartzite contacts to the west of the monzonite. Two types of mineralization are present; - chalcopyrite-magnetite scarns in the limestone-shale rocks, now almost completely oxidized, and quartz-copper mineral veinlets, now completely oxidized,

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which appear to originally have been quartz, cholcopyrite, pyrite veinlets, with a very low pyrite and sulfur content. Intense breaking along the mineralized zone has resulted in extremely deep weathering. Little or no sulfides have been found to the depth of exploration which is 575 feet in one area. Because of the limey and argillaceous gangue in which copper has been deposited, the copper has not been transported but fixed as silicate, carbonate, metallic copper, copper oxides, with probably very little transportation.

The principal ore body is the Lakeshore deposit which is in oxidized stock work zone whose shape is determined by faulting and shearing along the quartz-monzonite contact. It is elongated in a north-south direction, dips to the east underneath the monzonite. The ore body has a high magnetite content and is easily discernable from magnetic geophysical work.

Scarn and replacement type copper deposits are known at the Isabella, Slate and three other properties southeast of the Slate mine.

In the general vacinity of Lakeshore and to the north and south are a large number of more or less east-west tension veins ranging from a few inches to a few feet in width and containing complex mineralization in a quartz gangue. Pyrite, chalcopyrite, galena and spahalerite are either visible or can be inferred in the gossans from those veins. While none of these deposits seen are in themselves commercially valuable, they do indicate the strong continuation of mineralization both in the north and south of the area where copper mineralization of commercial importance is known. Similar quartz gossan veins are found along the flanks of the Santa Rosa mountains to the south. Because of the distribution of limestones, Cretaceous volcanics and pre-Cambrian gneisses across the valley between the Slate Mountains and the Santa Rosa Mountains, it is necessary to infer strong regional structures in this area. The area has no outcrop other than a few isolated hills of limestones.

PROVEN RESERVES:

There are no changes in the proven reserves at the Lakeshore mine from the summary report of September 15, 1956. After allowance for dilution and mining, to a maximum depth of 250 feet, and within the area completely drilled, there was estimated at that time 1,528,000 tons grading 1.76% copper with an average waste: ore ratio of 1.3 to 1. To this may be added, as proven ore, in the extension of the pit to an additional 40-foot depth and the extension of the pit from section N-385 to section N-764, 510,000 tons with a 1.75% grade after mining dilution. In round figures, therefore, the proven reserve at the Lakeshore property is at this time 2,000,000 tons grading 1.76% copper minable as an open pit with approximately a 1.30 to 1 waste/ore ratio.

EXPLORATION POSSIBILITIES:

We feel that a fair statement is that exploration possibilities for substantially larger tonnages of the same type of ore known at the Lakeshore mine and for ores amenable to segregation metallurgy in the limestones are excellent.

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Within the same geological zone as occurs the Lakeshore ore body, magnetometer work indicates at least eight other magnetic targets of exploration interest. During the 1956 work, two of these targets were explored indicating the magnetometer anomalies reflected copper magnetite mineralization of considerable size and of a grade comparable to the Lakeshore ore body. No further work has been done on these largely because they are in a limestone gangue and at that time the metallurgical process visualized sulphuric acid leaching which would not be applicable to limestone ores.

A little mver three miles of the favorable quartz monzonite-sediment contact is now controlled by Transarizona Resources. This same contact extends to the north and the south, at least a mile and a half in each direction. There is known mineralization at the north end of the Transarizona property, in the Slate group of the Transarizona property and known mineralization at least a mile to the south of the Slate group. While it is not possible to make a tonnage estimate of inferred ore at this time, one should realize that the order of manitude visualized will be in the range of a few million tons of grade similar to that at Lakeshore. It is entirely possible, however, that several such ore bodies may be found and that the ultimate reserves of the area may well reach 10 million tons or more.

At the completion of the geological and magnetometer work now in progress, targets for exploration drilling may be selected. This drilling can in large measure be done with rotary methods, but in some areas it may be necessary to diamond drill. The amount of drilling which is required, requires an economic judgment as to how much drilling ought to be done and what reserves ought to be indicated or disproven prior to building a plant in this area. It would appear that a minimum of $40,000 to $50,000 in drilling presents itself at this time.

Up to this point we have discussed possibilities in what might be determined the Lakeshore mineral belt, the larger part of which is now controlled by Transarizona Resources. There are, as outlined under general description of geology, interesting exploration possibilities within the four 1/4 townships indicated on the attached index map. We suggest that if this ground becomes available to us for exploration that airborne surveying should be undertaken. This should involve complete photography of the area, preferably in color, preparation of an index map and flying by electromagnetic and magnetic methods of about 18 square miles of the immediately adjoining area to the south and some to the north. The principal type of mineralization which may be expected is more or less the sort of thing found in Lakeshore, that is, copper-magnetite and quartz-chalcopyrite mineralization that is deeply oxidized. However, it is not without possibility that concealed within the valley flats to the south of Lakeshore is a second porphyry intrusive such as is visible at the Lakeshore mine and it cannot be ruled out that porphyry or disseminated type minealization may be encountered in this area.

Both the southwest slope of Slate Mountains and the northeast slope of Santa Rosa Mountains contain innumerable small copper showings. The presence

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of so much smoke in an area and the fact that the principal mineralization in this area and many other areas of the southwest, such as the Pima, Duval and San Manuel areas lies along the range fronts, all combine to indicate that the ground between Lakeshore mine on the north end of the Santa Rosa Mountains is extremely interesting from a long range exploration standpoint.

MINING METHODS AND COSTS:

Methods applicable to the Lakeshore property are fully discussed in the summary report of September 15, 1956. They may be summarized by stating that the ore body is of such a shape as to be amenable to low cost open pit mining, a very small amount of initial stripping is necessary to begin operations. The ore is proven to break easily into reasonable sized fragments, to drill easily and to take a very low powder consumption. Preliminary pit plans were drawn up on September 15; no further work has been done along this line nor is any other work necessary until such time as a decision to place the property in production is made.

It is estimated that it will be necessary to move a maximum of 500,000 yards from the known Lakeshore ore body and a minimum of 150,000 yards in order to start production. We estimate that this may be contracted for a price not to exceed 30¢ a yard including placing a minimum of 100,000 yards in tank base heaps and diversion dams. We have previously assumed that all of the yardage will be stipped initially, and we therefore allocated a distributed cost of 10¢ per ton of ore against this yardage.

In the summary report for September 15, 1956, we estimated a direct cost per ton handled during the first year of 61¢ a ton, and thereafter a 46¢ per ton, assuming that the company does its own mining. We have discussed the basis of these bids with numerous contractors and feel that a contract price per ton of ore delivered to the crusher of somewhere around $1.30 a ton will be realized. We will hereafter use this figure for estimating purposes. The details of these estimates are contained in the report of September 15.

METALLURGICAL METHODS AND COSTS:

Since the details of the flow sheet best suited to Lakeshore ore have yet to be determined, it is necessary to outline the possibilities and to make a selection of the most probable flow sheet for estimating purposes.

The various combinations of methods which seem reasonable at the present time are as follows: (1) segregation-furnacing followe by flotation to yield a metallic copper product for the smelting market. (2) segregation roasting followed by ammonia leaching to yield pure metallic copper for the metal powder market. (3) from either of the above, a by-product of magnetite concentrate which may be nodulized for the iron-ore market, or reduced to metallic iron for the sponge iron market for use as a precipitant in the leaching plants at the major copper properties of the Southwest. In oder to have a basis for estimating we are using the first possibility, that is, calcining followed by flotation as the method which will be followed. We will assume that iron can be marketed as a by-product, but will estimate the outcome therefrom separately.

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Details of these various possibilities and their detailed costs are included in the analysis of segregarion metallurgy which accompanies this memorandum.

There are a number of areas of probably improvement of metallurgy over test data as of this date. First is substitution of Aerofall grinding for conventional pre-stage crushing. Information submitted to us by Aerofall engineers indicates that it is entirely feasible to take pit run material to a -65 mesh in an Aerofall mill with a crushing cost of not to exceed 20¢ a ton. This is not much over half the estimated cost of grinding in a conventional mill, and in addition has the advantage from our standpoint that the effluent material from the mill will be completely dry and it will not be necessary to artificially dry it prior to feeding it to the furnace. We do not yet know the maximum through put rate and the lowest fuel in put rate to the calcining furnaces. This will be determined by further metallurgical work. We are not yet certain of the best degree of grind and the optimum flotation conditions which are best determined by pilot plant work on at least a 50-ton basis. While flotation metallurgy results to date have been excellent, we feel they can still be improved. Of course, if the ammonia leaching work being done at the University of British Columbia indicates the probability of making, in open vessels without pressure, a good extraction of copper and it's precipitation by hydrogen as metallic copper, this may completely eliminate flotation from an economic standpoint alone.

MARKETING OF PRODUCTS:

A very decided unknown in the Lakeshore outcome is the best market for products to be made. Two products are possible - copper and iron. Discussing first the copper, we have two possibilities.

There is an assured market for copper concentrates at some one of the 10 smelters in the general southwestern United States. In this event, however, one may anticipate a minimum of 4½ and a maximum of 6½ a pound of copper marketing charge. Since Lakeshore will produce somewhere between 40 and 50 tons a day of 30% copper concentrate by flotation, there will be no problem of finding a smelting outlet for this amount. Any larger amount of copper might be very difficult to find smelter room.

The preparation of copper metal powders and copper chemicals either from the flotation concentrate or directly from a precipitate, made by Dr. Forward in the ammonia leaching process, offers other markets which would return a higher cents per pound of copper manufactured to the Lakeshore operation. The magnitude of such markets is not great, however, it is probably that not all of the Lakeshore production could be marketed even to the most favorable circumstances in western United States as copper powder for chemical and paint processing.

There are two possible markets for iron as a by-product from the Lakeshore property. You will note that it is probably that roughly 10% by weight of the feed to the plant will result as an iron concentrate. If this material is
* nodulized, it will become a premium grade of premium character feed for blast furnace operations and can be marketed as iron ore at somewhere around $17

to $18 a ton. If however the finely divided concentrates were reduced with coke to spone iron they could be marketed at a value of about $35 a ton for precipitation of copper in acid leaching circuits. The market for such material is almost unlimited in the southwest at the present time since the price of tin cans for this purpose has now reached $45 a ton, f.o.b. Globe, Arizona.

CAPITAL INVESTMENT:

We see no reason to change the estimate made on January 20,1957 of plant costs for the Lakeshroe property which is repeated herewith.

Capital required for a 1000 ton per day (330,000 tons per year) plant at Lakeshore mine is divided into 3 categories: It is presumed that risk capital to the onset of actual plant layout is elsewhere apportioned only partly - against Lakeshore property.

1.	Cost of Treatment Plant (no allowance for Iron reclaiming) As Detailed	$ 905,500.00
2.	Operating Capital - 60 days -	250,000.00
3.	Service & Inventory	
	(a.) Gas Line	90,000.00
	(b.) Inventory	50,000.00
	Total Capital required to install and operate Lakeshore Plant	$1,295,500.00

PROFORMA OUTCOME:

In view of the uncertainties inherent in a new metallurgical process, any estimate of outcome is made under a group of assumptions. The assumptions made are as follows: (1) the operation will be on a 330-day per year basis, (2) mining will be done by contract at 1000 tons per day, (3) metallurgy will utilize conventional grinding and furnacing followed by flotation. No installation will be made to recover iron at the initiation of operations. With these assumptions the following proforma outcome seems reasonable.

Investment: $1,300,000

*

Projected Revenue:

Net Smelter returns, open contract fob mine, per ton mill feed, @ 30¢/# Cu and 90% recovery - - - - - - - - -	$ 7.66/ton	24.50¢/# Cu
Less - operating costs, including royalty payments, and depreciation- - - - -	5.022/ton	15.85¢
Operating profit before depletion and income taxes - - - - - - - - - - - - - - - - - -	2.64/ton	8.[illegible]5¢/# Cu

@1000 tons per day (330,000 tons/ years)
Annual Operating Profit is: $871,200.00

Payout period: 1.5 years
Proven Reserves depleted during payout period: 490,000 tons
Proven Reserves remaining: 1,510,000 tons

Profit: (1,510,000 x $2.64) - $4,000,000.00
Profit period: 4.5 years.

Total production period, proven reserves: 6.0 years
Ratio of profit to investment: 4/1

Notes:
1. For each 1¢ change in copper market price pro forma profit varies $100,000.00 per year.
2. Pro Forma based solely on proven reserves without regard to probable ore and exploration possibilities definitely known on present properties.
3. Depreciation recovers initial investment over life of 6.0 years.

Respectfully submitted,

Manning W. Cox

Manning W. Cox, for

WISSER & COX, Consulting Geologists

*

WISSER AND COX

CONSULTING GEOLOGISTS

COPPER SEGREGATION PROCESS - METALLURGY

SUMMARY REPORT

TO

MAY 1, 1957

SUMMARY STATEMENT

PROCESS:

The segregation process for non-sulfide copper ores involves heating the finely crushed ores with controlled amounts of salt, coke and water to 700° C by means of an indirect fired stainless steel rotary calciner to maintain a controlled atmosphere. The ore is held at temperature for 12-15 minutes, then cooled to minus 200°C before water quenching. Copper is chemically converted from the oxide, sulfate, silicate or carbonate form to the metallic state with the presence of the coke or carbon monoxide.

The process was developed by Minerals Separation, Ltd. and Union Miniere du Hant Kantanga between 1924 and 1931; it was patent protected. Together with the U. S. Bureau of Mines, we have been working on this process since September, 1956 and have developed a number of improvements in processing and appplication. We, therefore, are now applying for patent protection outside of the United States.

DEVELOPMENT & RESULTS:

Work begun in September 1956 using nickel alloy "bombs" containing a 500 gram charge. These bombs were revolved over natural gas burners and brought up to 700° C, the ore charge, with the reagents pre-mixed, was then introduced. The "bomb" was then continuously revolved over the flame with the temperature maintained at 700° for one hour. The bomb and charge was then cooled in a water bath. The bombs were sealed for control of atmosphere during quenching. Some 60 tests were made to work out the optimum for the reagents, temperature, particle size, time, etc.

A 6 inch "Pilot Plant" rotary furnace was then installed to see if the "bomb" tests could be duplicated in continuous feed equipment. This plant was run on a batch basis for several months to learn furnace characteristics and mechanical problems. A grinding and flotation circuit was then incorporated into the "Pilot Plant" and run in conjunction with the 6 inch furnace on a continuous basis.

The continuous "Pilot Plant" tests have been run on a representative sample from the Lakeshore Mine designated at #440 Head. The above tests have given an extraction of 88 to 90% of the copper. The most recent Pilot Plant Test #15A was run on a continuous basis from 10:00 A.M. - 2:00 P.M. on April 25, 1957. The feed size to the furnace was -10 mesh with a retention time of 15 minutes at 700° C. (25% ore cross-section in tube). The furnaced product was ground to about 70% minus 200 mesh and then floated. Reagents to the furnace were 0.8% Coke - 1.7% NaCl and 3% H_2O/. The reagents used in flotation were 0.02

ppt 404 - 1.06 ppt xanthate 350 - 0.04 ppt, MIBC - 4.04 ppt Lime. Results were as follows:

PRODUCT	%Cu	%Fe	RATES	%RECOVERY
Furnace Feed	2.09	23.0	1.155 lbs/min	
Class. O'flow	2.40	24.4	1.03 " " -29.0% solids	
Flot. Tails	0.31	22.6	1.01 " " -20.76 "	
Concentrates (One cleaning Only)	21.6	11.0		89.01
Table Concentrate	0.11	68.0		52.00
Table Tails	0.37	15.0		

There are only enough cells in the pilot plant to make one cleaning on the concentrate. (See Flowsheet).

Dr. Frank Forward has done some preliminary testing using the "ammonia leach" process and has made an extraction of 88-90% of the copper in 30-60 minutes by grinding to 75% minus 200 mesh. It is a matter of comparing the economics of this process against the costs of flotation and smelting. A higher grade copper concentrate can be produced by the ammonia leach method or even a pure copper product. A study is being made of the precipitation of copper by SO_2 technique, H_2 precipitation and electrolysis. (See Dr. Forward's report)..

FUTURE PROGRAM

The future program is to set up a 24" Bartless-Snow indirect fired furnace in conjunction with a 50-60 ton grinding and flotation circuit and process 2000 tons of representative ore from the Lakeshore Mine. The purpose of setting up this larger Pilot Plant is to obtain accurate cost figures, to establish operating technique and to work out the mechanical handling problems. We now have available for lease a "24" Bartlett-Snow furnace owned by Calera Mines in Garfield, Utah. There is a 60-70 ton flotation plant available for lease in Tucson from Don Lieberman.

We also propose to set up a laboratory in conjunction with the above pilot plant to carry on test work on other copper ores and also to do testing on nickel ores.

More test work should be done on producing an iron concentrate as a bi-product either from tables or magnetic concentration or both. The Lakeshore ore contains between 15-20% Iron as magentite. A 68% iron concentrate has been made in the lab. from the tailings product. A study would also have to be made of the marketing possibilities for the iron.

ECONOMICS OF PROCESS - ESTIMATE

Using the reagent consumption from the test work to date and cost figures from furnace consultants and manufacturers, we would have a total furnacing cost of $1.21 per ton of ore. Using the reagent consumption from the flotation pilot plant we would have a flotation and grinding cost of $0.72 per ton of ore. It is reasonable to assume that the flotation reagent consumption would be lowered somewhat with a return of reagents from tailings thickener water. The ball and liner consumption will be very low per ton of ore since 50% plus of the furnaced material is minus 100 mesh.

Following is detail of Cost Estimates:

FURNACE OPERATION:

Fuel (gas) @ 2.5 million b.t.u./Ton @ 26.5¢ /M. cu. ft.	0.66
NaCl - 1.7% @ 7.00 /Ton	0.11
Coke - 0.8% @ 20.00 /Ton	0.16
Maintenance & Operation	0.28
	$ 1.21

GRINDING & FLOTATION:

(Power, Service & Overhead)
(not included - see Cox Report)

MIBC - 0.10 ppt	0.02
Kax - 350 - 1.0"	0.33
Lime - 4.0	0.04
Ball & Liner Consump.	0.08
Labor & Maintenance	0.25
	$ 0.72

FURNACE & VARIABLES TESTED.

The furnace used in the "Pilot Plant" operation is a test unit that was designed and built by the U. S. Bureau of Mines in Boulder City, and the Potash Corporation in Henderson, Nevada. The furnace was trucked to the U. S. B. M. test plant in Tucson, where it was re-designed and rebuilt for "salt-coke segregation" testing. The tube is 6" in diameter, constructed of stainless steel #316. The length of the tube inside of the fire box or "Heat Zone" is 5' 7". The furnace is force fed by means of a hopper and a "ribbon" screw feeder to maintain an air seal. The cooler section of the furnace consists of a length of 6" pipe 5' 8" long that is flanged to the stainless steel furnace tube. The feed from the cooler tube drops into a hopper that is kept under water for an air seal. (See Furnace Drawing). For the "Pilot Plant" operation, the water seal was accomplished in the well of an "Esperanza" drag classifier. The segregated or furnaced product was then conveyed, by means of the drag, to the ballmill.

* Many variables have been tested both in the lab tests and in the 6" pilot plant. Following are the variables tested to date:

1. Reagents - Salt & Coke: Various amounts of sale and coke and combinations thereof have been tried. The amount of salt required for Lakeshore ores is between 1.5 - 2.0%. On highly silicious ores we have used as low as 0.6% with good recovery. We used CP sodium chloride for the first testing but later found that a low grade salt was satisfactory. We are currently using a low grade salt tailing (92-93% NaCl) from Carlsbad, N.M. We have used petroleum coke produced by Great Lakes Carbon for most of the testing. The coke is ground to minus 48 mesh. We did try the Carter "fluid coke" but the results were inferior. This was probably due to the extreme fineness causing coke loss. Further testing should be done on low grade coal, etc. to determine the effect. The optimum for coke in Lakeshore ores is between 0.6 - 1.0%. The coke has been varied from 0.25 to 2.0%. The coke requirement is apparently controlled by the amount of reducable minerals present. The salt in this process apparently forms a copper chloride and the coke or carbon monoxide reduces the copper to metallic form.

2. Water: It has been found that the water content is fairly critical, or that is, has to be controlled within 1%. The water has been varied from 0. - 6%. The optimum for Lakeshore is between 2.5 - 3.5%. The water is apparently necessary to start the reaction in furnace.

3. Time: The retention time required at optimum temperature has not been firmly established. We have varied the retention time from 20 - 60 minutes. We are currently using a retention time in the heat zone of 30 minutes. This is approximately 16 minutes warm up and 14 minute retention at 700° C. Further test work should be done on this to determine just how much retention time is necessary at optimum temperature. If most of the heat zone could be used as warm up with a short time required at maximum temp. you would of course have much better fuel efficiency.

4. Temperature: The temperature has been varied from 600 - 850° C. The maximum temperature required on Lakeshore ores is 700° C. We are currently operating between 700 - 725° C. inside temperature. Sufficient test work has been done to fairly well establish the temperature optimum on Lakeshore ores.

5. Feed Rate & Ore Cross-Section: The feed rate has been varied in the 6" furnace from 38 - 100 pounds per hour. The controlling factor for feed rate is the ore cross-section possible. We have varied the ore cross-section from 10-30% of furnace tube. We currently have a 25% ore cross-section feed. Of course, the retention time will undoubtedly vary somewhat with the amount of cross-section. Further work is necessary to establish just what the maximum feed rate and ore cross-section is. Another controlling factor in practice, using a larger furnace, would be weight suspension.

* 6. Direct - Indirect Firing: The 6" pilot plant furnace now being used is an indirect fired unit. Some test work has been done in the small "bombs" attempting to simulate direct firing. No conclusive results have been reached to date. I think the main hazard with direct firing is the possibility of excess dust loss and that the necessary gases would be swept out. There is

the possibility, however, of pre-heating the material in a direct fired furnace and then adding the reagents and taking the material to an indirect-fired unit for segregation with atmosphere control. Further test work should be done along these lines since you would probably have better fuel efficiency.

PROPOSED SCHEDULE - FUTURE TESTING.

The program, as proposed for future process development, is to lease a 24" Bartlett & Snow rotary calciner and operate it for a period of 60 days and process about 2000 tons of Lakeshore ore. The above furnace to be incorporated into an existing grinding and flotation plant capable of milling 60-75 tons per day.

A 24" Bartlett & Snow rotary calciner is available for lease from Calera Mining Company in Garfield, Utah. We can lease this furnace for $2130.00 per month with an option to purchase with 90% of rental applying on purchase price if we should decide to buy it. A 60-75 ton flotation plant is available for lease from Don Lieberman in Tucson, Arizona. We can lease this mill for 4 months at $1500.00 per month. (See tentative lease agreements in supporting data and diagramatic sketch of Mill.)

The crushing facilities are not adequate in the Lieberman mill to crush the ore to minus 10 mesh. There is a portable contractors crushing plant owned by Pioneer Constructors that we have used in the past for crushing to 10 mesh. We have purchased 10 mesh screens for this plant. We plan to take advantage of the crushing area in the Lieberman mill to install and operate the 24" furnace. (See Drawing)

There is approximately 2000 tons of newly mined ore available at the mine for testing. This is a good representative sample of the ore body. Head sample #440 was cut from this 2000 ton ore pile.

The ore will be trucked to the portable crushing plant in Tucson and crushed to minus 10 mesh and then hauled to the Lieberman mill and stored for process testing. The Lieberman mill is located approx. 3 miles south of Tucson on the Tucson-Sells highway.

We plan to design the mill so that the furnaced product can be stored in a surge bin and then taken to the grinding and flotation circuit or pulled out for outside test work.

It is proposed to set up a small testing laboratory in conjunction with the "pilot plant" so that we can do test work on Lakeshore or other copper ores and also do some testing on nickel ores.

* The main purpose of setting up this larger "Pilot Plant" is to be able to arrive at some accurate cost figures, to establish operating technique and

to work out any mechanical handling problems. Also to determine the applicability of the process to nickel and other ores with the laboratory testing.

A breakdown of the estimated costs of the above program is attached.

Respectfully submitted,

G. A. Freeman

G. A. Freeman, Manager

TRANSARIZONA RESOURCES, INC.

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TRANSARIZONA RESOURCES, INC.

LAKESHORE COPPER PROJECT

Outcome Estimate
May 1, 1957

1. Metallurgical Assumption:

(a) Based on operating only 90% of possible time at 30¢/lb. copper price.
(b) 90% recovery into 40% concentrate from 1.76% Cu. in heads.
(c) Xanthate flotation following segregation reducing roast.

2. Settlement Assumptions

(a) A.S.& R. open smelter schedule rates - El Paso, Texas.
(This can be improved by negotiation.)

(b) Recovery calculations:

1. (1.76%) x (20#) x (0.90) = 31.7# Cu/T. of ore
2. 40% concentrate or (2.5x31.7#) = 79.3# Cu/T. of concentrate

(c) 100 ton mill heads $\frac{(79.3 \times 100)}{2,000}$ = 3.96 tons concentrate

(d) Payments:

(40% x 20# x 100) = (800#-20#) = 780# Cu/T. concentrate

(780 x 30¢-3¢ = (780 x 27¢) = $ 210.60 value per ton concen.

Deductions:

Smelting	$ 10.00				
Freight & Trucking	6.00	16.00	"	"	"
		$ 194.60	"	"	"

* Net smelter return per ton of millfeed $\frac{(194.60 \times 3.96)}{100}$ = 7.66

3. Operating Cost Estimate
(@ 330,000 Tons/year - 90% operating time)

	Per Ton	
Stripping	$ 0.06	
Mining (contracted)	1.30	
Plant Services including local management	0.36	
Power Plant	0.20	
Non-operating costs - includes royalty & Head Office	0.42	
Plant Operating:		
Crushing	0.30	
*Furnacing	1.21	
Grinding & flotation	0.72	
Total Direct Costs		$ 4.57
Plant depreciation @ 2,000,000 tons		0.452
Total Cost before Taxes		$ 5.022

4. Indicated Cost per Pound of Copper

Direct cost per pound	$\frac{(\$4.57)}{31.7}$	14.42/# Cu
Depreciation	$\frac{(\$0.452)}{31.7}$	1.43
Total cost of production		15.85
Smelting & Marketing cost - open schedule - estimated (This amount allows no decrease due to negotiations)		5.5
Maximum cost of copper		21.35¢/#Cu.

*

COST ESTIMATE ON PROCESSING PLANT FOR SEGREGATION PROCESS 1000 TONS PER DAY

LAKE SHORE MINE

The following equipment prices are based principally on "new" items purchased individually and the plant assembled at the mine site.

	Cost		H.P. Required	
Crushing Section & Storage:				
Primary crusher & Conveyors, etc. per estimate of 9/15/56.	$ 47,800		178	
Weightometers (2)	10,000			
Rolls & motors, 68" x 24", used	15,000		100	
Surge Bins & Conveyor Tunnels (2)	15,000			
Freight & installation	39,000	$ 126,800	___	278
Water Supply:				
Main pump, pipelines & 2 walls	$ 30,600		50	
1 - 200,000 gal. water tank, erected	6,000	36,600	___	50
Power Plant:				
750 H.P., Natural Gas, Direct Connected 2300 V. plus wiring, transformer equipment -				
2 Units @ $35,000	$ 70,000			
Freight & installation	20,000	90,000		
Furnace Plant:				
4 units per Murdoch estimate 1/10/57 - installed.	$150,000		60	
Feeders & reagent storage	10,000	160,000	___	60
Grinding Section:				
(40 t.p.h. - 10 M. to 100% - 65 M.)				
1 - 8' Hardinge mill, used	15,000		150	
1 - 60" Classifier or Cyclones	15,000		10	
Surge tanks & agitators	15,000		20	
Freight & installation	10,000	55,000	___	180
Flotation Section & Concentrate Storage				
Conditioning tanks & agitators (2)	$ 8,000		20	
10 - 48" Fagergren or Agitair roughers	20,000		50	
8 - 48" Sub.A - 18's Cleaners, (used)	10,000		20	
4 - 3" Denver vertical pumps	9,000		40	
Feeders, samplers, etc.	3,000			
1 - 10' x 20' Dorrco thickener (used)	5,000		5	
1 - 4 disk Eimco filter & vacuum pump	20,000		25	
Freight & Installations	20,000	95,000		160
Carried forward:		$ 563,400		728

	Cost		H.P. Required	
Brought forward:		$ 563,400		728
Tailings & Water Return:				
Return water tanks (2)	$ 4,000			
Return water pump & lines	6,000	10,000	15	15
Miscellaneous Plant Items (Est. 9/15/56)				
Shop, office & assay lab. equipment	25,000			
Transportation equipment	20,000			
Buildings:				
Main mill enclosure - 60' x 150' @ $6.00/sq.ft.	60,000			
Other plant buildings	36,000			
Add for larger powerhouse	4,000	145,000		—
Total Plant Estimate:		718,400		743
10% Contingency		71,600		
NET ESTIMATED PLANT COST:		$ 790,000		

If mining is contracted, additional exploration and loading equipment required for Company use:

1 - Exploration Rotary Drill & Auxiliary Equipment (new)	$ 60,000
1 - Front End Loader (new)	27,000
Mobile Maintenance Equipment	28,500
Total Additional Equipment:	$ 115,500

* * * * * * * * * * *

Maximum Estimated Plant Costs:

Mill Plant & Buildings	$ 790,000
Mine Plant	115,500
Total Plant Costs:	$ 905,500

*

March 4, 1957

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DEVELOPMENT OF THE ROAST-LEACH-ELECTROWIN PROCESS FOR LAKESHORE

Please file

W. A. Griffith
H. E. Day
T. S. Jordan
V. C. Nyman

Hecla Mining Company
Wallace, Idaho
October 24, 1973

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DEVELOPMENT OF THE ROAST-LEACH-ELECTROWIN PROCESS FOR LAKESHORE

W. A. Griffith
H. E. Day
T. S. Jordan
V. C. Nyman

Abstract

Hecla Mining Company has conducted an extensive six-stage experimental program to develop the application of sulfate roasting, leaching, and electrowinning to the production of cathode copper from the chalcopyrite flotation concentrate produced at its Lakeshore, Arizona mine. This program, culminating in the continuous operation of an integrated pilot plant producing one ton of high purity cathode per day, has defined the limitations of the process, revealed the important process variables and their effects, established the metallurgical performance at optimum process conditions, demonstrated the technical and economic feasibility of the process, and provided engineering data for the commercial plant now being designed. In the proper circumstances, this process appears to be a viable alternative to pyrometallurgical smelting and electrolytic refining of copper.

W. A. Griffith is Vice President - Metallurgy for Hecla Mining Company, Wallace, Idaho.

H. E. Day is Assistant to the Vice President - Metallurgy for Hecla Mining Company, Wallace, Idaho.

T. S. Jordan is Senior Process Engineer for Hecla Mining Company, Casa Grande, Arizona.

V. C. Nyman is Senior Engineer for Hecla Mining Company, Casa Grande, Arizona.

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Introduction

In 1969, Hecla Mining Company entered into an agreement to bring into production the Lakeshore Mine, a potential major new copper producer located on the Papago Indian Reservation in Pinal County, Arizona. Hecla recognized that environmental protection pressures made it unlikely that existing custom smelters would be able to agree to process the copper sulfide flotation concentrate which the mine would produce. Accordingly, Hecla considered it necessary to plan for processing this concentrate to salable metal products at the mine site. The process selected was the sulfate roast, leach, electrowinning process, now referred to as the R-L-E process.

It is the purpose of this paper to explain why this process was selected, to describe the process development program that demonstrated its technical and economic feasibility, and to summarize the results of that program.

Process Selection

The following criteria guided the process selection:

1. The process must meet the pollution control standards proposed at the time by federal and state environmental protection agencies, and must have a reasonable capability of adapting to more stringent standards should they be imposed in the future.

2. The process should take advantage of the fact that the ore body consisted of both oxidized and sulfide mineral portions that could be mined concurrently. Practically, this meant it must incorporate conversion of the sulfur in sulfide flotation concentrate to sulfuric acid for use in the treatment of the oxidized ores.

3. The process should produce standard marketable copper shapes.

4. The process should be adaptable to relatively small scale operations with minimum loss of efficiency.

5. The process must have been reduced to successful commercial use. Time was not available to develop and pioneer a new process, nor would this have been prudent business for Hecla Mining Company.

Of the several possibilities examined, the R-L-E process best met these criteria.

Process Description

The process, as we will use it, is best shown in the pilot plant flowsheet of Figure 1. It involves the slurry feeding of chalcopyrite copper concentrate into a fluid bed roaster wherein a sulfating roast is conducted by proper control of air and temperature. In a commercial plant, the roaster gases, after dust removal and cooling, will be converted into concentrated sulfuric acid in

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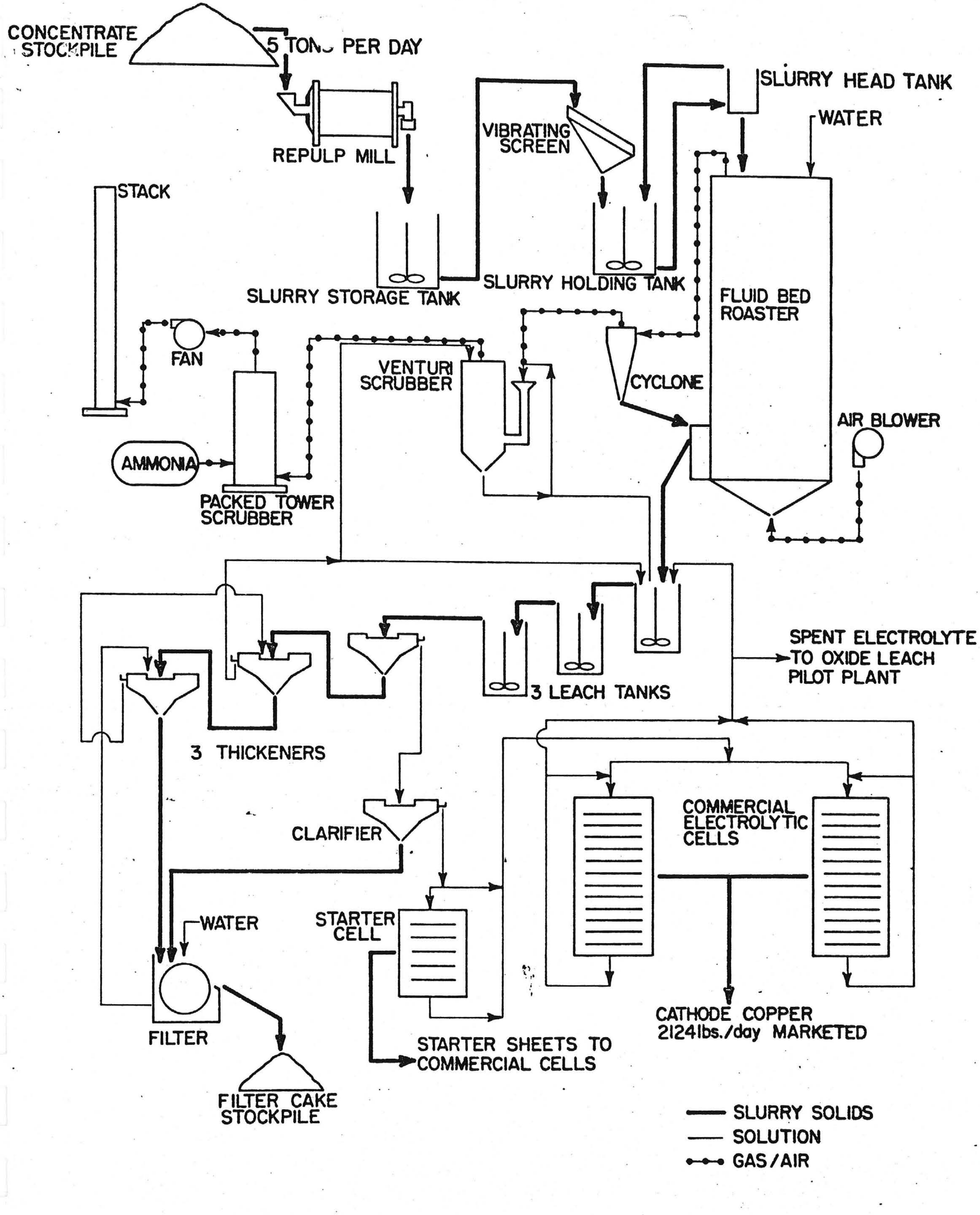


FLOWSHEET ROAST-LEACH-ELECTROWINNING PILOT PLANT

*

FIGURE 1

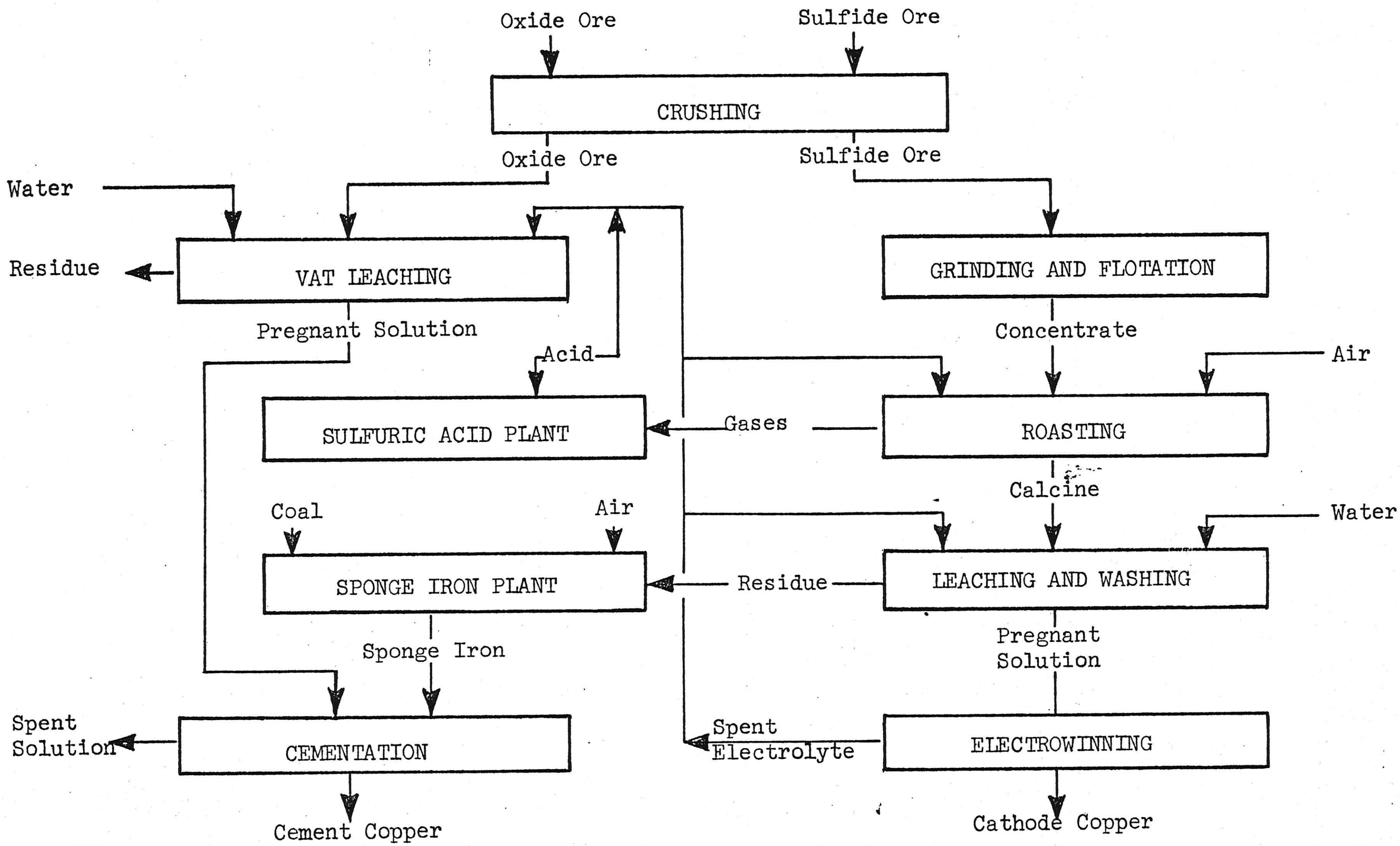
a conventional contact acid plant. The calcine is hot quenched and leached in acidic spent electrolyte from electrowinning. The leach slurry is separated into a clear pregnant solution and a barren filter cake in a conventional counter current decantation and filtration circuit. Starter sheets are prepared from the pregnant solution by electro-deposition on stainless steel blanks, and copper is recovered as electrolytic cathode by deposition on copper starter sheets. Spent electrolyte is recycled to leaching or is bled from the circuit.

The process meets all selection criteria. The only gaseous effluent is a roaster gas stream that is concentrated enough for conversion into sulfuric acid at reasonable cost. The remaining sulfur, except for a normal acid plant exhaust stream, leaves the system as a spent electrolyte bleed. Concentrated sulfuric acid manufactured from the gas stream and spent electrolyte, which is essentially a dilute acid product, are used in oxide ore leaching. Both conventional pyrometallurgical smelting and electrolytic refining are by-passed to produce electrolytic cathode copper. The R-L-E process suffers less loss of efficiency as scale of operations is reduced than does pyrometallurgical smelting.

The R-L-E process is not new. It has been extensively described in the metallurgical literature and the basic patent utilizing a fluid bed roaster was issued in 1957[1]. Although the process has not been used commercially in North America, it was successfully piloted by Bagdad Copper Company and Dorr-Oliver, Inc. in 1957[2]. Subsequent process development work abroad led to successful commercial installations in Zambia and Zaire, with over 300,000 metric tons of copper now being produced annually by this type of process in Zaire alone.

The process has basic limitations or disadvantages which are well known. Copper recovery is generally slightly lower than that achieved in reverberatory smelting, converting, and electrolytic refining. Precious metals in the sulfide concentrate are lost in the leach residue. Disposal of relatively large volumes of copper bearing acidic spent electrolyte is required, since more acid is generated in the electrolysis than is required in leaching. Although roaster gases are of a strength adequate for autothermal conversion to sulfuric acid, the gas strength is near the lower limit for autothermal operation. Because of the limitations, the process is applicable only where the limitations are not economically important or where low cost solutions to them can be developed.

In the Lakeshore application, relatively simple means are available to overcome these deficiencies. This is best shown by the overall process flowsheet for the Lakeshore project (Figure 2). All of the concentrated sulfuric acid produced from roaster gases will be used in vat leaching of oxide ore. The vat leaching operation will also absorb the spent electrolyte bleed from electrowinning, utilizing the acid and recovering the contained copper by cementation. The leach residue, which is a hematite concentrate containing unrecovered copper and precious metals, will be converted into sponge iron. The sponge iron will be used in the copper cementation operation, with resulting



LAKESHORE PROJECT-PLANT FLOWSHEET

FIGURE 2

recovery of precious metals and any copper not dissolved in the R-L-E process. All of the weaknesses of the R-L-E system are thus protected against in Hecla's plans.

The Process Development Program

Objectives

Although the R-L-E process relies on proved technology and did not, therefore, involve the invention or discovery and development of new techniques, it did require a considerable experimental program. The objectives of this program were as follows:

1. To determine what metallurgical performance might reasonably be expected from this process on our feed material.

2. To develop an understanding of the important process variables and their interactions adequate for control and reasonable optimization of process performance.

3. To obtain engineering data adequate for plant design and for reliable estimation of capital and operating costs.

4. To develop the nucleus of an operating force skilled in such operations.

Experimental Plan

With these objectives in mind, Hecla and Hazen Research, Inc. worked together to plan and carry out an appropriate program. The program, with respect to this part of the processing, had six phases:

1. Selection of a "stand-in" concentrate.

2. Laboratory roasting experimentation.

3. Six-inch fluid bed reactor experimentation.

4. Two-foot fluid bed reactor experimentation.

5. Continuous leach-electrowinning experimentation.

6. Integrated five-ton per day pilot operations.

The first three phases were carried out by Hazen's staff. The fourth and fifth phases were performed by teams of Hecla and Hazen staff working in Hazen facilities at Golden, Colorado. The final pilot plant was designed, built, and operated by Hecla personnel at the mine site.

Any part of this extensive process development effort could in itself be the subject of an interesting technical paper. The present paper can only outline the program and summarize the significant findings.

Selection of a "Stand-In" Concentrate

The entire experimental program was complicated by the fact that the only Hecla Lakeshore concentrate available for experimental use until after startup of the final pilot plant was a few hundred grams from laboratory batch flotation tests on diamond drill core samples. The solution to this problem was to find a "stand-in" concentrate available in adequate quantities to serve in place of Lakeshore concentrate through the early phases of experimentation. In order to select such a substitute, the chemical and mineralogical characteristics, particle size distributions, and roasting behaviors of several available concentrates were compared to those of the available samples of Lakeshore concentrate. This work established that the concentrate being produced commercially by Pima Mining Company from its mine near Tucson, Arizona, is similar to Lakeshore concentrate in chemical composition and mineralogy, as shown in Tables I and II. The Pima concentrate contains slightly more of some of the impurities likely to be harmful in electrowinning and is normally slightly coarser in particle size. It was shown also to behave similarly to Lakeshore concentrate in laboratory sulfate roasting experiments. This material, made available to us through the kind cooperation of Pima Mining Company, became our "stand-in" concentrate.

Laboratory Roasting Experimentation

Some exploratory laboratory roasting experiments were performed at various temperatures and gas compositions on both Lakeshore and Pima concentrate in a small, rotating, Vycor tube furnace. Copper leach extractions from the calcines were only about 90%, but indicated that the two concentrates behaved similarly. This work demonstrated that it is difficult, if not impossible, to duplicate fluid bed roasting conditions in batch laboratory experiments. The next phase of the program was undertaken in spite of the poor extractions obtained.

Six-Inch Roaster Experimentation

A series of semi-continuous exploratory roasting tests were made on Pima concentrate in a six-inch diameter fluid bed roaster. The roaster was equipped with external heating, a single-stage dry cyclone, and a bag dust collector for the cyclone overflow. Dry feed was introduced into the fluidizing air stream. Bed overflow and dust cyclone underflow products were periodically

*

Table I - Comparative Chemical Analyses of Concentrates

Constituent	Concentration, %	
	Lakeshore Concentrate	Pima Concentrate
Cu	24.7 %	26.9 %
Fe	26.7 %	29.7 %
Total S	30.0 %	31.3 %
Zn	0.63 %	0.86 %
Pb	0.047%	0.18 %
As	0.01 %	0.02 %
Sb	0.25 %	0.60 %
Bi	0.025%	0.009%
Mo	0.044%	0.14 %
MgO	4.5 %	0.03 %
CaO	1.6 %	1.64 %
Al_2O_3	7.0 %	0.93 %
SiO_2	5.7 %	4.94 %
CO_2	0.39 %	0.60 %
Acid Insol	13.1 %	8.1 %

Table II - Visual Mineral Estimates

Mineral	Estimated Volume, %	
	Lakeshore Concentrate	Pima Concentrate
Chalcopyrite	70±	75-80
Pyrite	5-7	5- 7
Sphalerite	2-3	1- 2
Chalcocite	0.5-1.5	0.3-0.5
Covellite	Trace	Trace
Bornite	0.5-1	0.5- 1
Molybdenite	Trace	Trace
Native Copper	0.2-0.3	N.D.
Cuprite	0.1-0.2	<0.1
Magnetite	1-2	0.1-0.2
Tetrahedrite-Tennantite	0.5	0.3-0.5
Hematite	0.2-0.3	Trace
Quartz	1-2	- -
Talc and Chlorites	10-15	8-10
Sericite	2-3	- -
Epidote and Diopside	0.2-0.5	N.D.
Galena	N.D.	0.3-0.5

*

removed from their respective collection hoppers and subjected to standardized leach evaluation tests for water soluble and acid soluble constituents. Although the roasting reaction is exothermic, the heat loss in this small unit was such that supplemental heat was necessary.

Experiments were made at various roasting temperature levels over the range of 650° to 750°C., and at ratios of feed sulfur to air over the range 0.09 to 0.115. Each of these test runs was generally over eight hours duration.

The furnace proved difficult to control, materials balances were poor, and data obtained were therefore of questionable accuracy. Nevertheless, they showed that roasting could be controlled so that 97% of the copper and only 2.4% of the contained iron in the bed overflow product was rendered acid soluble, while generating a gas containing over 5% combined sulfur oxides. These experiments confirmed that roasting temperature and the ratio of feed sulfur to fluidizing air are the process control variables of greatest practical importance, and provided indications of the nature of their effects and interactions. They also demonstrated that at a normal space rate of about 1.5 feet per second, about half of the product would be recovered as cyclone underflow product. Mineralogical studies of the roaster products showed that most of the insoluble copper remaining was copper sulfides in various stages of incomplete decomposition, with no significant ferrite formation except at high temperatures.

Probably the most disturbing result of these experiments was the indication that only about 90% of the copper, but over 10% of the iron, in the cyclone underflow was acid soluble. This finding made it apparent that improvement of performance on this portion of the product was essential to a successful R-L-E operation.

Two-Foot Fluid Bed Reactor Experimentation

The encouraging results from the six-inch roaster were followed by continuous runs in a fluid bed reactor large enough to be slurry fed and to operate autothermally. This unit had a reaction chamber two feet in diameter inside the refractory and six feet three inches in height above the tuyere openings. It was equipped with a system for feeding slurry at about 70% solids by weight, utilizing compressed air and a special nozzle to obtain proper distribution of the feed over the fluid bed surface. The unit was equipped with a bed overflow for coarse product, a single stage dry cyclone for recovery of fine product, and a wet scrubber system for recovery of dust from the cyclone overflow. Temperature control was by water injection.

The particular objectives of this phase of the work were to learn to handle slurry feeding, to develop a solution to the problem of poor leach results on that portion of the product recovered from the dry cyclone, to develop a better understanding of the chemistry and the important process variables, to produce enough calcine for continuous pilot leach-electrowinning operations, and to obtain data adequate for design of the final pilot plant.

This work demonstrated that slurry feeding, properly conducted, is feasible for this process and is the preferred system.

Investigations conducted during this phase of the experimentation also established that a satisfactory solution to the poor solubilization of copper in the cyclone underflow product is recycle of this product, together with the bed overflow stream, to a small secondary fluid bed reactor for retreatment. Further decomposition of the unreacted sulfides occur during this treatment, as well as agglomeration of the fines. The testwork also indicated that heating of the secondary chamber reduced solubilization of iron.

Experimental runs over the temperature range 665°C. to 710°C., over the air ratio range of 0.080-0.127 pounds of sulfur per pound of air at space rates of 1.5 and 2.0 feet per second, with and without product retreatment, and with and without heating of the retreatment reactor were conducted. Over fifty tons of Pima concentrate were processed during a three-month period, with the calcine being stocked for leach-electrowinning experiments. These experiments showed that under proper operating conditions, 95% of the copper was rendered acid soluble.

Continuous Leach-Electrowinning Experimentation

The roasting experimentation having demonstrated that a calcine could be produced from which a high leach extraction of copper could be obtained, attention was turned to the leaching and electrowinning operations of the process.

The particular objectives of this phase of the work were to determine what recovery of copper could be obtained from the calcine by leaching with spent electrolyte, to determine what quality of copper could be produced from the resulting pregnant solution, to check the effects of accumulation of impurities in the electrolyte, to learn how to make starter sheets, to develop an understanding of the important process variables, and to obtain the data necessary to design an integrated pilot plant.

It was realized that only in a continuous operation, with recycle of solutions and consequent build-up of impurities, could industrial practice be simulated adequately. Accordingly, a small scale continuous pilot operation was assembled in Hazen's facilities. This pilot operation included a series of leach tanks, a liquid-solid separation operation, pregnant electrolyte polishing filters, a starting sheet cell, an electrowinning cell, and facilities for recycling and bleeding spent electrolyte. The starting sheet cell did not actually produce starter sheets for the electrowinning cell, but it did allow experimentation in starter sheet production and provided the drop in electrolyte copper content that would exist in practice. The electrowinning cell contained two commercial size cathodes and three anodes. The plant had a capacity of about 13 pounds of calcine per hour, and operated continuously for about four months, producing about 5,000 pounds of copper.

During these investigations, the usual leaching variables of time, temperature, acidity, etc., were investigated. Also, a variety of electrowinning variables was studied, including variations in current density over the range 14-20 amps per square foot, in-cell copper concentrations over the range 15-35 gpl copper, additive utilization, effects of various electrolyte impurities, and electrolyte flow characteristics. These pilot operations and associated bench scale experiments provided data on acid consumptions in leaching, leach extractions, current efficiencies, bleed requirements to maintain acidity, thickener and filter capacities, and other information necessary to define a flowsheet and design the final pilot plant. More importantly, they demonstrated that copper cathode of a quality equivalent to that of electrolytically refined copper could be produced.

Integrated Five TPD Pilot Plant

The final phase of the process development program was operation of a continuous completely integrated pilot plant including all of the unit operations of the process. Such a pilot plant was considered essential to provide the information necessary for design of a commercial plant, and to reduce the risks involved in such a venture to a reasonable level.

Although the smaller scale experimentation had been extensive, a number of technical questions had not been answered. Roasting had not been tested on a scale large enough for smooth operations, for collection of good information on the nature of dust collection problems, or for testing of some additional hypotheses as to how cyclone underflow dust should best be retreated. In view of the problems so commonly encountered with dust collection systems on fluid bed reactor gas streams, it was considered particularly important that the complete gas cleaning system be piloted on a roaster large enough so that dust loadings would approximate those of commercial installations. A wet gas cleaning system having been decided upon, it was essential to determine that all of the scrubber effluents could be absorbed in the leaching circuit. It was considered essential to operate under conditions that would reveal problems associated with normal variations in the composition of feed concentrate. The effects of discharge of hot calcine directly into the leaching circuit had to be tested. The counter-current decantation system had not been precisely defined nor tested, previous operations having been done on too small a scale. All small scale electrowinning had been done on filtered electrolyte and it was necessary to determine if less expensive clarification would suffice. In view of the many conflicting views in the industry as to the importance of flow rates and circulation patterns in electrolytic cells, it was considered desirable to minimize scale-up risks by operating a prototype commercial cell, and to demonstrate that quality copper could be made. It was important to demonstrate the production and use of starter sheets. It was necessary to determine what kind of electrolyte temperature control system was required.

It was also necessary to make residue for sponge iron experiments and to make a quantity of cathodes for market development.

All of the previous work having been done with "stand-in" Pima concentrate, there remained the acid test of demonstrating performance of the process on Hecla Lakeshore concentrate.

In addition to these individual technical matters, it was necessary to demonstrate overall metallurgical and operating performance under conditions that approached industrial practice. There was also a tremendous amount of engineering design data to be collected for design of a commercial plant and the need to develop a skilled operating crew, who could start up and operate a commercial plant.

Hecla chose to design, build, and operate this pilot plant with its own forces, even though staff weaknesses were recognized in all three of these areas. It was anticipated that any mistakes made would be more than compensated for by the value of the education that Hecla's staff would derive from these efforts.

The pilot plant flowsheet is shown in Figure 1. The roaster is a Dorr-Oliver fluosolids unit designed to Hecla specifications, is full commercial height, and is essentially a vertical segment of a commercial unit with extra insulation to keep the heat balance near that of a commercial unit. The roaster is provided with a slurry feed storage system of the same 10 days capacity planned for commercial operations, and equipped with a screening and feeding system similar to that contemplated. Instrumentation systems for draft, temperature, and feed control are also identical to those planned for the commercial plant. The entire gas cleaning system of a commercial plant, up to the feed entry to an acid plant mist precipitator, is also included. This includes a dry cyclone with facilities for underflow retreatment, the cyclone being purposely sized for low efficiency to simulate commercial plant operations. It also includes a wet vortex scrubber and cooling tower, equipped with heat exchangers and an evaporative cooling tower. Purely in the interest of good citizenship, the pilot plant gas cleaning stream is also equipped with an ammonia absorption tower to remove the sulfur dioxide that would be removed commercially in a sulfuric acid plant.

The leaching and washing circuit is equipped with leach tanks of three different construction materials for test purposes, with a three-stage counter current decantation thickener system, a residue wash filter, and a clarifier.

The tankhouse itself is fitted with a starter sheet cell and two full size prototype commercial electrolytic cells. These employ the Barber-Webb Paraliner and antimonial lead anodes that will be used commercially. The tankhouse is, of course, also equipped with all of the necessary rectifiers, bus bar, pumps, tankage, instrumentation, and other appurtenances necessary to serve the cells.

*

This pilot plant treats five tons of sulfide flotation concentrate per day, and normally produces 1.06 tons of copper per day in the form of cathodes. It is operated by a crew of 22 men, including two engineers, one of whom was associated with the earlier experimentation. Technical work is handled by a separate staff organization. The plant was in operation from September, 1971 until February, 1973, and normally operated 90% of available operating time. The plant was started up on Pima concentrate and then shifted over to Hecla Lakeshore concentrate when it became available from concurrent pilot concentrator operation working on development ore. The only noticeable effects of this change in feed material was an increase in the moisture content of the washed leach residue filter cake.

An extensive program of exploration of variations in process conditions has been carried out in the pilot plant to further our understanding of the technology and to better define optimum conditions. Performance at these conditions has been determined. An improved system of retreatment of the roaster cyclone underflow dust has been developed. Operating techniques have been established, and design information adequate for plant design has been collected.

There were actually very few surprises in this pilot operation, but there were enough unexpected discoveries to confirm the wisdom of including this step in the program.

Process Results

The Process Variables

In any process of even modest complexity there are an almost infinite number of process variables and interactions of potential importance. In a process development program aimed at getting into production, there is no way that one can research them all, but fortunately generally only a few are of great importance metallurgically or economically. In the case of the R-L-E process, our work has established that the important variables are:

1. Roaster space rate.
2. Roaster temperature.
3. Roaster feed sulfur to air ratio.
4. Pregnant electrolyte temperature.
5. Current density.
6. Spent electrolyte composition.

*

These and some others have been investigated in this pilot plant program, with results described below.

Effects of Process Variables

Space rate is defined as fluidizing air velocity expressed in feet per second, in the fluidized bed section of the roaster above the bed. The effects of variations in space rate are largely physical. Changes in space rate primarily affect roaster capacity and dust loading of roaster gases. With a given roaster, variations in space rate are equivalent to variations in air input. Since, as will be shown later, control of process metallurgical results requires maintenance of a reasonably constant ratio between concentrate sulfur input and air input, space rate determines capacity. Space rates over the range 1.5 to 2.0 feet per second, were explored and 1.75 feet per second was adopted as a design basis. There are no significant variations in metallurgical performance attributable to space rate variations in this range. As a result of variations in the dust loading of the gases, there is a variation in the proportion of the total roaster product which is recovered via the dry dust cyclone. With proper cyclone product retreatment, this presents no problem.

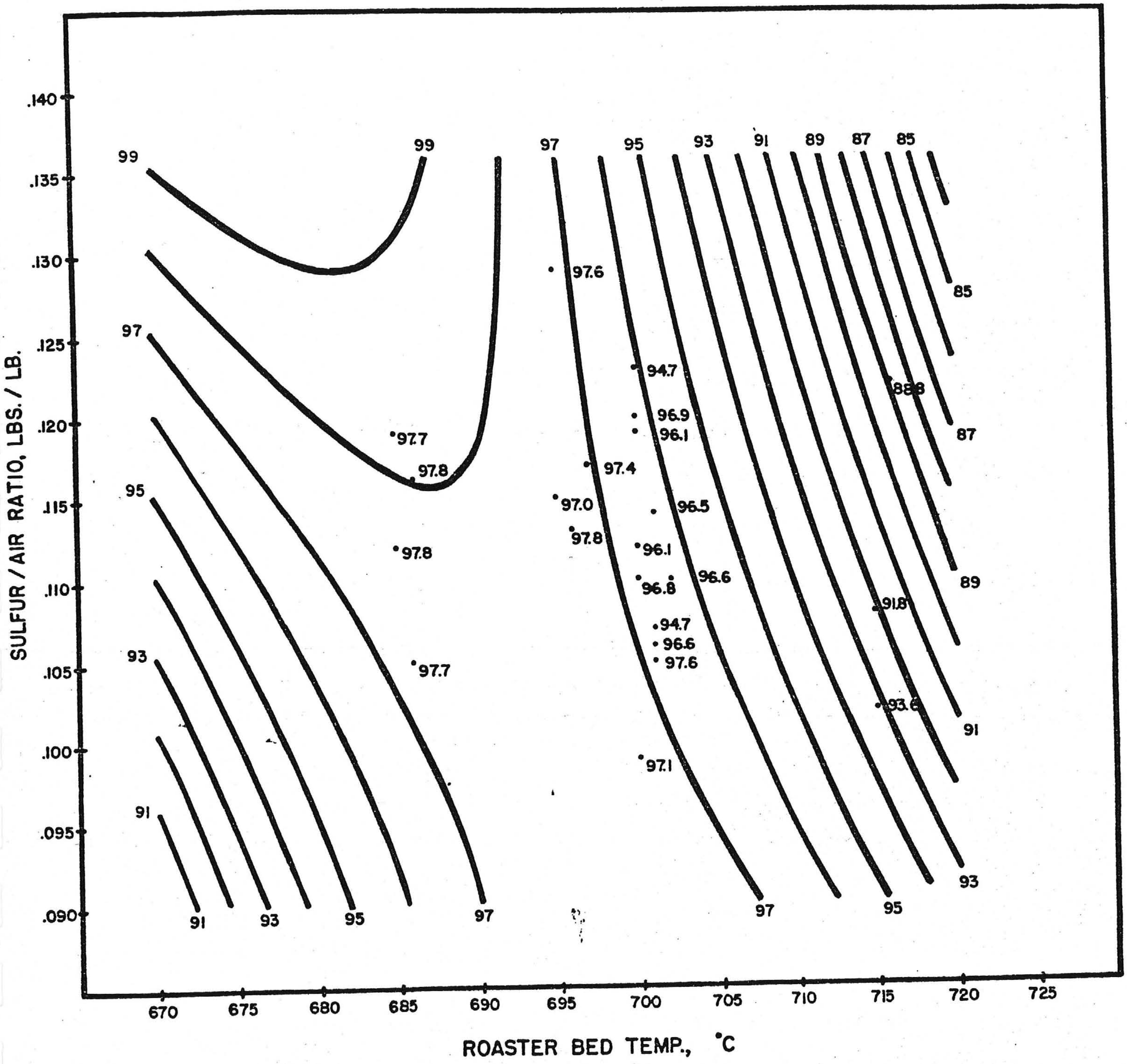
The ability to vary the space rate over the indicated range provides flexibility to meet changing production demands.

Temperature and Sulfur to Air Ratio - Although the chemistry of sulfate roasting of chalcopyrite may be quite complex, and even imperfectly understood, as a practical matter control of the process hinges upon control of temperature and upon control of the ratio of feed concentrate to fluidizing air. More precisely, it is the ratio of feed sulfur to fluidizing air which must be controlled in order to accommodate normal variations in concentrate composition.

Since the effects of changes in each of these variables is different at different levels of the other, a true understanding of process performance requires a knowledge of their interactions. These effects are therefore best shown by response surface.

Response surfaces showing the effects of variations in temperature and of variations in sulfur to air ratio on copper leach extraction from the calcine, iron leach extraction from the calcine, and sulfur dioxide content of the roaster gases are shown in Figures 3, 4, and 5. These response surfaces for copper and iron leach extraction are for the final product of a roaster operation in which the cyclone underflow product is recycled for retreatment with the bed overflow product. Response surfaces for the bed overflow product alone, or the cyclone underflow product alone are quite different. The cyclone underflow product, which constitutes 50% to 70% of the total product, is highly dependent upon retreatment procedure and can have a considerable influence upon the overall effect of the variables.

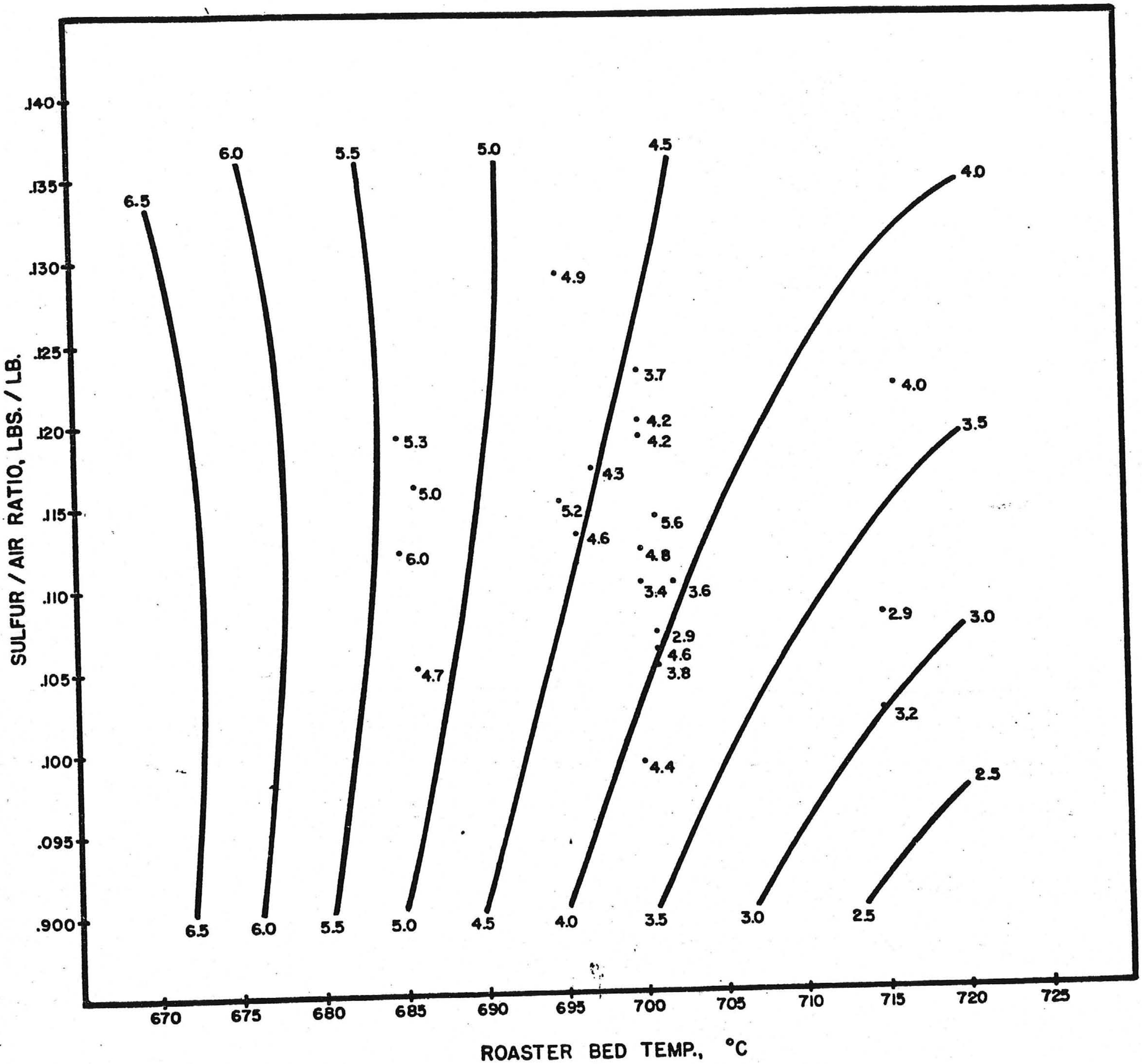
*



THE EFFECTS OF VARIATIONS IN ROASTER BED TEMPERATURE AND IN SULFUR TO AIR RATIO ON % COPPER DISSOLVED

FIGURE 3

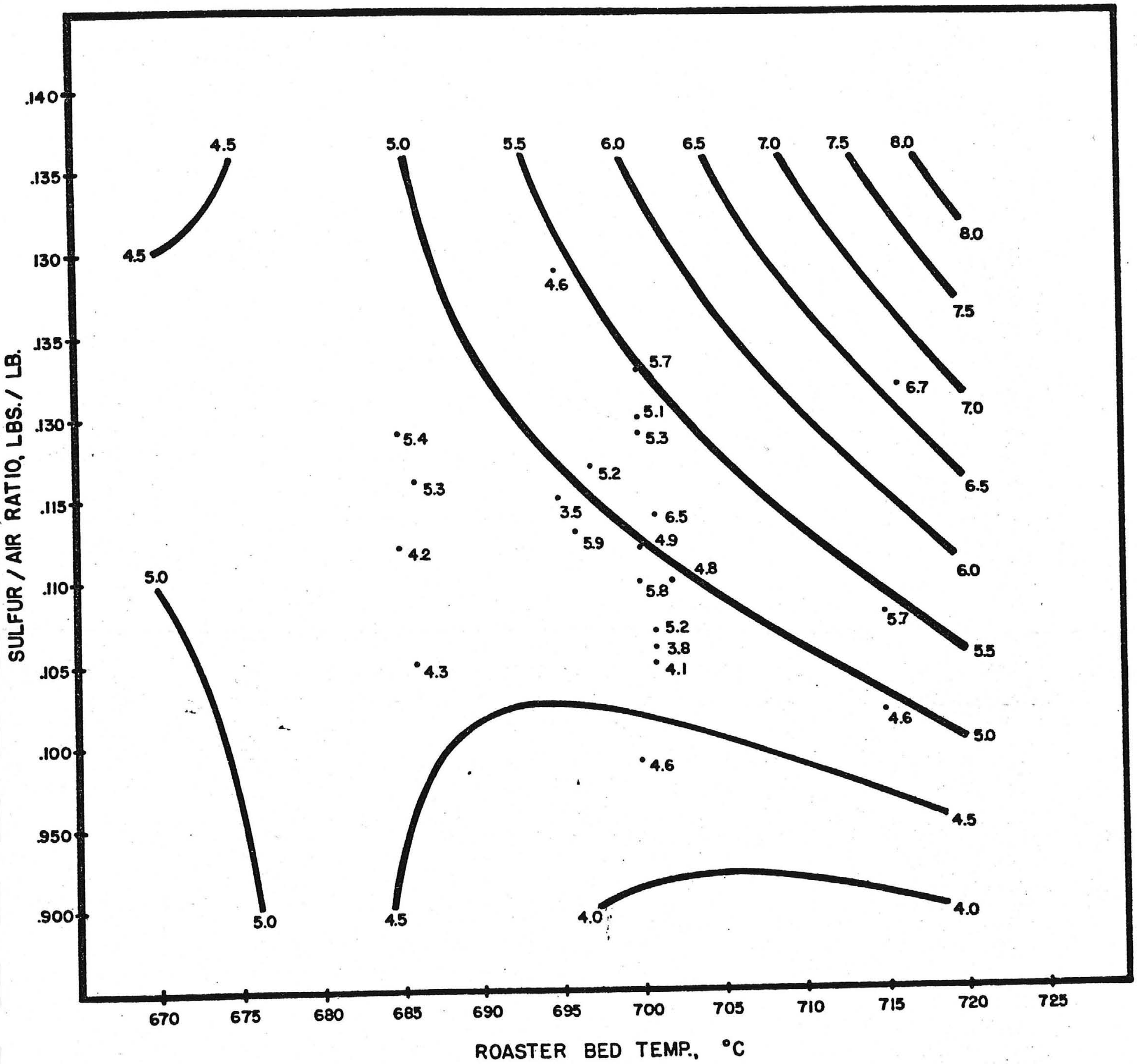
*



THE EFFECTS OF VARIATIONS IN ROASTER BED TEMPERATURE AND IN SULFUR TO AIR RATIO ON % IRON DISSOLVED

FIGURE 4

*



THE EFFECTS OF VARIATIONS IN ROASTER BED TEMPERATURE AND IN SULFUR TO AIR RATIO ON % SO IN EXIT GAS

FIGURE 5

The response surfaces for copper and iron leach extraction are based upon standard laboratory batch leach tests used for evaluation of roaster performance, and these leach extractions may not be exactly the same as those observed in the continuous pilot plant leach circuit.

The response surface of copper leach extraction, Figure 3, shows that under the process conditions employed, copper extraction is largely determined by temperature, allowing a wide range of latitude in sulfur to air ratio. Copper extraction increases as temperature decreases, but levels off in the 690° to 700°C. range.

The response surface of iron leach extraction, Figure 4, shows iron extractions to increase as temperature decreases and is affected hardly at all by sulfur to air ratio changes in the temperature range of interest.

The response surface for SO_2 concentration in the roaster gas, Figure 5, shows a general increase in gas strength as the sulfur to air ratio increases and as the temperature increases.

These response surfaces were obtained by calculating the quadratic equation with the two independent variables of temperature and sulfur to air ratio using data from 22 runs, each run being of about 6 days duration. The constants obtained are given in Table III.

Pregnant Electrolyte Temperature - Probably the single most important discovery resulting from operation of the integrated pilot plant was the discovery of the harmful effects of the combination of high electrolyte temperature and high iron concentrations in the electrolyte. The high electrolyte temperature (65°C.) was at least in part the result of quenching hot calcine in electrolyte. The harmful effects of this combination were corrosion of cathode hanger straps and of stainless steel starter sheet blanks. Corrosion of cathode hanger straps became so severe during one period of operation that 100% of the cathodes were being removed from the cell before the end of their normal deposition cycle. Installation of water heat exchangers to hold electrolyte temperature below 45°C. solved the problem. The effects of electrolyte cooling are striking and cathode dropping is no problem when proper temperature control is maintained.

Current Density and Spent Electrolyte Concentration - When the pilot plant was designed, information available to Hecla pertaining to the current density that could be employed in making good quality electrowon copper was the rule of thumb that each gram per liter of copper in the electrolyte allowed one ampere per square foot. Thus, if electrolyte was to be stripped to 15 gpl copper, 15 amps per square foot could be used, and at 20 gpl copper, 20 amps per square foot. This rule was developed by a sifting of many conflicting statements made in the technical literature and by knowledgeable people in the industry, coupled with some experimentation during earlier electrowinning operations. Pilot operations have confirmed that this is a satisfactory concept

*

Table III

Constants for Equations of Contours Shown in Figures 3, 4, and 5

$$Z = C_0 + C_1X + C_2Y + C_3X^2 + C_4XY + C_5Y^2$$

X = Roaster temperature $\frac{^\circ C}{1000}$

Y = Ratio lbs. sulfur/lbs. air

Z =	% Copper Dissolved	% Iron Dissolved	% SO_2 in Gas Stream
when:			
C_0 =	+89.725	+6.767	+3.532
C_1 =	+27.788	-6.374	-3.486
C_2 =	+9.861	+0.427	+5.774
C_3 =	-24.145	+1.691	+2.873
C_4 =	-19.604	+2.281	+4.174
C_5 =	-0.525	-0.758	-5.835

*

over the normal range of interest in what might be called conventional electrolytic cells. Experimentation with current densities up to 20 amps per square foot and with spent electrolyte at 15 grams copper per liter has established that current density can be increased to 17-18 amps per square foot without harm to copper quality.

Metallurgical Performance

Studies of the process variables, such as those described above, led to selection of optimum conditions for the process with an accuracy adequate for design of the commercial plant. The metallurgical results demonstrated for these near optimum conditions and projected for the commercial plant are summarized in Table IV. The data given are the mean and range of results for eleven test periods, covering a two-month period of continuous operations. Also included, as a matter of interest, are metallurgical performance data projected for this pilot plant before it was built and operated. The data show that the process will be able to operate at a higher sulfur to air ratio than originally anticipated, which means a smaller roaster, and that one reasonably may expect recovery of more copper as cathode. Although the electrowinning current efficiency is lower than expected, the experimentation established that electrowinning can operate at a slightly higher current density so that no resulting increase in tankhouse size is indicated.

The quality of the electrowon copper being produced is shown by the analysis of Table V. It compares very favorably with the analyses of recognized brands of electrolytically refined cathode.

Conclusions

Overall, the pilot plant results are good confirmation of expectations. The real proof of the success of any process development program is a successful commercial plant, and this proof remains to be seen. At this point in time, Hecla Mining Company feels that the process development program has been a success. It has provided a firm estimate of commercial plant metallurgical results and costs, a wealth of design information for the commercial installations, a stock of the cathode product, and an undeniable demonstration of the technical viability of the process. Equally important, it leaves Hecla with a knowledgeable staff and the nucleus of an experienced operating crew to start up and operate such a plant.

Needless to say, a program of this magnitude involved many people and organizations in addition to the authors. We are particularly indebted to the fine professional staff of Hazen Research, Inc., especially to Mr. Peter N. Thomas of that organization. We also owe a debt of gratitude to the staff of Parsons-Jurden Corporation for advice and suggestions, to many others in the industry who contributed to our knowledge, especially to Bagdad Copper

Table IV - R-L-E Metallurgical Results

	Projected	Observed Average[1]	Observed Range
Process Conditions			
Roaster temperature, °F.	685	---	685 - 700
Sulfur/air ratio	0.103	---	0.11-0.12
Space rate, ft./sec.	1.75	---	1.50-2.00
Leach acidity, g/l H_2SO_4	20	---	10 - 20
Leach time, hours	3	3	- -
Current density, asf	15	16.1	14.4-19.8
Spent electrolyte strength, gpl Cu	15	15.1	13.7-16.3
Feed Composition, %			
Cu	27.3	26.5	25.1-27.2
Fe	27.2	26.5	23.8-28.0
S	31.0	30.4	28.7-31.2
Process Results			
Percentage of feed Cu electrowon	78.2	80.2	77.5-83.3
Insoluble loss of feed Cu lost in leach residue	5.0	3.8	2.9- 4.9
Soluble loss of feed Cu in leach residue	0.1	<0.05	0- 0.2
Percentage of feed Cu to bleed	16.7	16.0	13.0-19.2
Total	100.0	100.0	
Percentage of feed Cu dissolved	95.0	96.2	95.1-97.3
Percentage of feed Fe dissolved	3.75	4.6	2.8- 6.0
% SO_2 in roaster gas (dry basis)	- -	5.0	4.1- 6.5
% SO_2 + SO_3 in roaster gas	5.9	5.2	4.3- 6.8
Pregnant solution composition Cu, gpl	55.0	56.7	51.2-64.8
Fe, gpl	3.5	3.7	3.4- 4.2
Current efficiency, %	85.5	76.2	71.5-85.2

1/ Average results of 66 days of operation at near optimum conditions.

Table V - Typical Analysis of Lakeshore Electrowon Copper Cathodes

Cu	99.94 %
O	0.014 %
S	0.0044%
Ag	10 ppm
Fe	<5 ppm
Pb	5 ppm
Sb	<2 ppm
Si	4 ppm
Se	1.4 ppm
Te	<2 ppm

*

Company, Nchanga Consolidated Mines, Ltd., Roan Consolidated Mines, Ltd., and La Generale Congolaise des Minerais. Above all, the authors are indebted to the metallurgical staff and plant operators of Hecla Mining Company, and to a corporate management with vision and courage to back such an activity.

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J. ALLEN OVERTON, JR., EXECUTIVE VICE PRESIDENT

DISCOVERY AND INITIAL DEVELOPMENT OF THE LAKESHORE DEPOSIT IN ARIZONA*

by

H. E. Harper
Vice President - Exploration
Hecla Mining Co., Wallace, Idaho

and

John R. Reynolds
Superintendent of Exploration - Mining Division
El Paso Natural Gas Co., El Paso, Texas

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