CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

METCON Research Inc.

1844 W. Grant Road, Suite 106
Tucson, Arizona 85745

Tel: (602) 623-1327
Telex 284623 KDE UR

8 August 1989
EI-052-89

A.F. Budge (Mining) Limited
4301 N. 75th St.
Suite 101
Scottsdale, AZ 85251

Attention: Dale H. Allen
Production Manager

Subject: Metcon Proposal No. M-186
Acid Leach Metallurgical Study

Dear Mr. Allen:

Pursuant to your instructions this proposal outlines the scope of work and the cost estimate for metallurgical testing to be performed on a copper ore sample from your property.

1.0 OBJECTIVE

The primary objective of this study is to determine the ore amenability to a sulfuric acid heap leach process. The metallurgical data developed may be used in a feasibility study to be performed on this project.

2.0 SCOPE OF WORK

The initial testing program discussed with you during our recent phone conversation is described below:

2.1 Ore Samples

A suite of 20 interval samples weighing approximately 40 to 60 pounds each will be provided by the client for bottle roll leach testing.

A representative composite sample prepared form coarse material with a weight ranging from 1000 to 1200 pounds will be prepared as specified by the client. The entire ore sample will be crushed to minus 2 inch then blended by the cone and quartering method, representative samples of ore will be split out for column leach testing and screen anlysis.

2.2 Bottle Roll Acid Leach Testing

One fourth of each interval sample will be split out then crushed (if necessary) to minus 1/2 inch. A representative sample weighing approximately 1 to 2 kg will be split out the crushed (if necessary) to minus 10 mesh. The sample is then blended and pulverized. A head sample and a 500 gram test charge are prepared for analysis and testing. The original samples will be saved for future testing.

The test charge will be leached on a bottle roll apparatus with a 100 gram per liter acid solution at a pH below 1.0 for 24 hours. The amount of copper solubilized will be determined by atomic absorption. The total copper, non-sulfide copper and iron will be assayed in the heads. The leach residue will be assayed for copper only.

2.3 Column Acid Leach

A series of 8 inch columns will be filled with approximately 200 pounds of crushed ore to a height of 6 ft. The ore is cured with a strong acid-ferric solution for 15 days, then leached with a 10 gram per liter acid and 3 gram per liter ferric solution at a pH below 1.5. The irrigation rate used for leaching is 0.0025 GPM per square foot. The estimated test duration is 120 days. The daily pregnant solutions obtained will be assayed for copper, iron and acid consumption and extraction will be monitored throughout the test.

Initially, three ore samples will be treated with a strong acid cure pretreatment. An additional test will be necessary for control.

3.0 ESTIMATED COST

The estimated cost associated with this testing program is as follows:

(20) Bottle roll leach tests	$ 5,000.00
(4) Column test set-up	800.00
(4) Leaching (column Operation) @ 120 days	19,200.00
(8) Screen analyses (feed and leach residue)	800.00
Analytical	1,000.00
Estimated project cost total	$26,800.00

A metallurgical report will be issued within two weeks of completion of the test work. Progress reports will be issued as required by the client.

Enclosed you will find a project description summary and project compliance agreement. Please sign and return the agreement. Should you have any questions in regards to the information contained herein please do not hesitate to contact us.

Very truly yours,

Eugenio Iasillo
Process Engineer

EI:rs
Enclosures

PROJECT COMPLIANCE AGREEMENT

I, ______________________________, an authorized representative of ____________________________, have reviewed the
(Company or Individual)

attached copies of METCON RESEARCH INC. proposal No. M-186, "Condition of Terms", "Project Description Summary", being in agreement with all said sections, do hereby authorize commencement of work as described and will comply with terms set forth before me this _______ day of _________________, 19____.

SIGNED BY: ________________________________
Name and Title

APPROVED BY: ________________________________
METCON RESEARCH INC.

METCON RESEARCH INC.

PROJECT DESCRIPTION SUMMARY

DATE: 8 August 1989

CLIENT: A.F. Budge (Mining) Limited

Address: 4301 N. 75th St.
Suite 101
Scottsdale, AZ 85251

This is to confirm that a project, with an Estimated (EST, NTE, FC)

amount of $ 26,800.00 to perform the following work:

A series of four column leach tests for approximately 120 days.

20 bottle roll leach tests, screen analyses and analytical work

associated with this study.

will be completed in an expeditious and timely fashion as per written METCON RESEARCH INC. Contract/Proposal No. M-186 .

Advance Deposit Required: $ 3,000.00 Date: 8-8-89 .

METCON RESEARCH INC.
1844 W. Grant Rd.
Suite 106
Tucson, AZ 85745

CONDITION OF TERMS

1) All ore samples and/or products resulting from a completed project will be returned to the client prior to 60 days from the completion date of that project. Completion of project constitutes issuance of report on that specific ore sample or samples.

Labor and direct costs accrued during the disposal of these ore products will be the client's responsibility and will be included in the final invoice issued to the client.

If previous arrangements have been made with METCON RESEARCH INC. for either maintaining or disposal of said sample, costs for a specific arrangement will be established and included in the project costs and billed accordingly.

METCON RESEARCH INC. may elect not to dispose of waste products resulting from materials furnished by client to METCON RESEARCH INC. for testing if METCON RESEARCH INC. believes that such materials contain hazardous materials that cannot be disposed of in hazardous waste facilities reasonably available to METCON RESEARCH INC. In this case, such waste products will be returned to client.

2) Invoices for labor, assays, and expenses will be billed according to the current rate schedule at the close of each month or at a timely termination date for the project.

Invoices are due and payable in full upon receipt.

Invoices unpaid at the close of the subsequent billing cycle will have a finance charge of 18 percent annually applied to the unpaid balance.

Proceedings for collection on an unpaid account balance will commence 60 days from last account payment. Collection costs will be added to the clients billing.

3) All contracts may be cancelled at any time provided, however that all labor, assays, and other expenses incurred by METCON RESEARCH INC. will be billed based on work actually performed as of the receipt of notice of cancellation including any fees and expenses required for terminating the project. Any cancellations 24 hours after acceptance by METCON RESEARCH INC. are subject to an additional cancellation fee of 10 percent of the amount of the original estimate.

4) A 10 percent of cost handling fee will be charged for all vendor purchases not advanced to METCON RESEARCH INC. at the onset of project.

DAWSON METALLURGICAL LABORATORIES, INC.

P.O. Box 7665
5217 Major Street
Murray, Utah 84107
Phone: 801-262-0922
Fax: 801-261-4681

January 16, 1990

Millsaps Mineral Service, Inc.
3865 Wasatch Boulevard
Room 2021
Salt Lake City, Utah 84109

Attention: Mr. Frank W. Millsaps

Subject: Cost Estimate For Column Leach Testing an Oxide Ore Sample.

Gentlemen:

Pursuant to discussions between Mr. Frank Millsaps and ourselves, we are pleased to present a cost estimate for column leach testing an oxide copper ore sample. It is our understanding that preliminary testing has already been performed to determine ore characteristics such as acid requirements, copper extractions, etc. The test work requested by Mr. Millsaps will determine the response of a large sample to simulated thin layer leaching for copper extraction by acid leaching samples in six (6) inch and 24 inch diameter ten (10) foot high test columns. The following specific tests were proposed:

- One each six (6) inch diameter by ten (10) foot high column leach of minus one inch sample.
- One each six (6) inch diameter by ten (10) foot high column leach of minus one inch sample agglomerated with sulfuric acid.
- One each 24 inch diameter by ten (10) foot high column leach of minus six inch sample.

Eight (8) each 55 gallon barrels of a single bulk sample (approximately 5600 pounds total of six (6) inch top-size) will be available for testing.

We are pleased to offer the following cost estimate, including analyses based on a 30 day leach cycle estimated by Mr. Millsaps.

I. Sample Preparation and Head Analyses

- Thoroughly mix contents of each drum into one large sample, air dry, and split out ¼ of sample (approximately 1400 pounds).

- Crush the 1400 pound split through one inch.
- Split out 200 pounds from the minus one inch material and crush through 3/8 inch. Split out 50 pounds of minus 3/8 inch material and crush through 20 mesh. Split out head samples from minus 20 mesh sample for total Cu, Oxide Cu, Fe, $CaCO_3$, and ICP scan.
- Store rejects of minus one inch and minus 3/8 inch.
- Store remaining 3/4 of large sample (6 inch top size) for large diameter (24 inch) column leach testing.

Cost. . . . . $ 1,500

II. Agglomeration Testing Minus One Inch Sample

Determine optimum acid and moisture requirements to produce stable, well-formed agglomerates on minus one inch samples.

Cost. . . . . $ 800

III. Small Diameter (Six Inch) Column Leaches

Determine copper extraction versus time for 60 kilograms of minus one inch sample in 6 inch diameter, 10 foot high columns. Perform one test on an unagglomerated sample and another test on a sample agglomerated with sulfuric acid. Monitor unagglomerated sample for both copper and iron.

Cost. . . . . $ 1,200/test, $2,400 total

IV. Large Diameter (24 Inch) Column Leach and Residue Assay Screen Analysis

Determine copper extraction versus time for minus 6 inch unagglomerated sample in a 24 inch diameter, 10 foot high column. Determine distribution of unleached copper by assay-screening column leach residue at 3 inch, 1 inch, 3/8 inch, 10 mesh, 35 mesh, and 100 mesh.

Cost. . . . . $ 3,500

Mr. Frank Millsaps
Millsaps Mineral Service, Inc.
January 16, 1990
Page -3-

V. Data Collection and Final Report

Cost. . . . . $ 1,000

Project Subtotal. . . . $ 9,200
Contingency . . . . $ 1,800
Grand Total $11,000

These costs represent our best estimate. Actual costs will be determined by the time required to perform the test work. Factors such as extended leach times, excessive material handling (due to clayey slimes in leach residues) may affect time requirements.

If you have any questions regarding this proposal, please call. We would be happy to work with you on this project.

Sincerely,

DAWSON METALLURGICAL LABORATORIES, INC.

Philip Thompson
Vice President

PT/fg

File No. Millsaps, Disk 1

MOUNTAIN STATES R&D INTERNATIONAL, INC.

A WORLD LEADER IN MINERAL TECHNOLOGY

MOUNTAIN STATES R & D INTERNATIONAL, INC.
EMPLOYEE OWNED CORPORATION
13801 E. BENSON HIGHWAY
P.O. BOX 310
VAIL, ARIZONA 85641

TEL. (602) 762-5364
TUCSON ONLY 624-7990
TELEX 9102502482 MSRD
TELEFAX 602-762-5717

January 22, 1990

Mr. Dale H. Allen
Production Manager
A. F. Budge Mining Ltd.
4301 N. 75th Street
Suite 101
Scottsdale, Az 85251

Subject: Column Leaching Of Budge Mining Copper Ore

Reference: MSRDI Proposal No. 0008

Dear Mr. Allen:

Pursuant to our meeting of January 11, 1990, Mountain States R&D International, Inc. (MSRDI) has prepared a proposal for the leaching of Korn Kob ore. The scope of work proposed includes the following key elements:

SCOPE OF WORK:

Budge Mining Ltd. will deliver approximately two tons of representative Korn Kob ore to MSRDI. The run of mine ore (approximately 6 inches) will be used to conduct two simulated heap leach tests in 4-inch diameter columns and one heap leach test in a 24-inch diameter column. The 4-inch column leach tests will be performed on ore crushed to one inch. The 24-inch column leach test will be performed on ore crushed to six inches. A copper assay screen analysis will be performed on a head sample of the ore for the 4 and 24-inch column leach tests. Ore decrepitation will be determined from the assay screen analyses at the termination of the leaching campaign.

An acid consumption test will be run on a pulverized ore sample to establish the maximum quantity of acid the ore will consume. The results of this test will be used to establish the amount of acid required for acid curing of one of the 4 inch diameter columns.
Prior to the application of the curing solution, the moisture content of the ore will be determined. After the moisture content of the ore is determined, cure solution containing 80 percent of the acid consumed during the acid consumption test will be applied to the ore. The quantity of cure solution used will be 10 percent of the weight of the ore. The 4-inch cured column will be allowed to stand seven days before leach solution is applied. The second 4-inch column will be leached in a conventional manner by the application of a pH 1.8 leach solution. The objective of the two, 4-inch column leach tests is to establish the most efficient and cost effective leach procedure. The 24-inch column will

then be run using the best of the two procedures. Acid and copper metallurgical balances will be conducted at the end of the leaching campaign. Copper recovery curves will be drawn and the amount of copper recovered from the individual screen fractions will be calculated.

COST ESTIMATE:

Cost Estimate For Two, 30-Day, 4-Inch Diameter Column Leach Tests

*Sample Handling and Preparation	$ 1,500.00
Head Screen Assay Analyses and Acid Consumption	350.00
Column Leaching and Maintenance	1,600.00
Assays (Cu, Fe^{+2}, Fe^{+3}, H_2SO_4)	1,210.00
Residue Screen Assay Analyses	300.00
Supervision, Clerical and Report Preparation	1,500.00
Contingency at 10 Percent	656.00
Total for Two, 4-Inch Columns	$ 7,116.00

*The sample preparation charges for the 24-inch column, have been included in the cost for sample preparation of the 4-inch columns.

Cost Estimate For One, 10-foot, 24-inch Column, Operated for 30 Days

Ore Loading	$ 500.00
Head Assay Screen Analyses	1,200.00
Ore Curing	250.00
Column Leaching and Maintenance	2,200.00
Assays (Cu, Fe^{+2}, Fe^{+3}, H_2SO_4)	810.00
Column Discharge	500.00
Residue Assay Screen Analyses	1,200.00
Supervision, Clerical and Report Preparation	2,000.00
Contingency at 10 percent	866.00
Total	$9,526.00

Remuneration for the work conducted will be billed on the basis of the actual time spent on the project in accordance with the MSRDI Rate Schedule 070189 attached. MSRDI will not exceed the budget specified without the authorization of Budge Mining Ltd.

Should this proposal be acceptable to Budge Mining Ltd., please sign the enclosed MSRDI Project Compliance Agreement and return it to us for our record.

Thank you for allowing us to present this proposal. We look forward to conducting this work.

Sincerely,

John McDonald
Vice President and Manager of Projects

JMcD/rrj

Enclosures: MSRDI Project Compliance Agreement

c.c. Frank W. Millsaps
3865 Wasatch Blvd.
Salt Lake City, Utah 85109

PROJECT COMPLIANCE AGREEMENT

I, Dale H. Allen, an authorized representative of

A. F. Budge Mining Ltd., have reviewed the attached
(Company or Individual)

copies of MSRDI proposal No. 0008, "Condition of Terms", Rate Schedule 070189, "Project Description Summary", being in agreement with all said sections, do hereby authorize commencement of work as described and will comply with terms set forth before me this ____ day of ______________, 19____.

SIGNED BY: ______________________________
Name and Title

APPROVED BY: Tony McDonald
MSRDI Representative

MOUNTAIN STATES R & D INTERNATIONAL, INC.

PROJECT DESCRIPTION SUMMARY

January 22, 1990

CLIENT: A. F. Budge Mining Ltd.

ADDRESS: 4301 N. 75th Street
Suite 101
Scottsdale, Az 85251

This is to confirm that a project, with an Estimated
(EST,NTE,FC)
amount of $ 16,642.00 to perform the following work:

Column Leaching of Budge Mining Copper Ore

will be completed in an expeditious and timely fashion as per written MSRDI Contract/Proposal No. 0008.

Advance Deposit Required: $ 6,000.00.

MOUNTAIN STATES R & D INTERNATIONAL, INC.
POST OFFICE BOX 310
VAIL, ARIZONA 85641

CONDITION OF TERMS

1) All ore samples and/or products resulting from a completed project will be returned to the client in not to exceed 60 days from the completion date of that project. Completion of project constitutes issuance of report on that specific ore sample or samples.

   Labor and direct costs accrued during the disposal of these ore products will be the client's responsibility and will be included in the final invoice issued to the client.

   If previous arrangements have been made with MSRDI for either maintaining or disposal of said sample, costs for a specific arrangement will be established and included in the project costs and billed accordingly.

   MSRDI may elect not to dispose of waste products resulting from materials furnished by client to MSRDI for testing if MSRDI believes that such materials contain hazardous materials that cannot be disposed of in hazardous waste facilities reasonably available to MSRDI in which case, such waste products may be returned to client.

2) Invoices for labor, assays, and expenses will be billed according to the current rate schedule at the close of each month or at a timely stopping point for the project.

   Invoices are due and payable in full upon receipt.

   Invoices unpaid at the close of the subsequent billing cycle will have a finance charge of 18% annually applied to the unpaid balance.

   Proceedings for collection on an unpaid account balance will commence 60 days from last account payment.

3) All contracts may be cancelled at any time provided, however that all labor, assays, and other expenses incurred by MSRDI will be billed based on work actually performed as of the receipt of notice of cancellation including any fees and expenses required for terminating the project. Any cancellations 24 hours after acceptance by MSRDI are subject to an additional cancellation fee of 10% of the amount of the original estimate.

4) A 10% of cost handling fee will be charged for all vendor purchases not advanced to MSRDI at the onset of project.

MOUNTAIN STATES R & D INTERNATIONAL, INC.
RATE SCHEDULE
070189

1.0 LABOR

1.1 PROFESSIONALS

Code	Position	$/HR
45J	JUNIOR PROCESS ENGINEER	45.00
55P	PROCESS ENGINEER I	55.00
65P	PROCESS ENGINEER II	65.00
85P	PROCESS ENGINEER III	85.00
90P	PROCESS ENGINEER IV	90.00
40L	LABORATORY SUPERVISOR	40.00
45M	LABORATORY MANAGER	45.00
30C	CHEMIST I	30.00
40C	CHEMIST II	40.00
45C	CHEMIST III	45.00
50C	CHEMIST IV	50.00
55C	CHIEF CHEMIST	60.00
40M	MINERALOGIST I	40.00
55M	MINERALOGIST II	55.00
55G	GEOLOGIST	55.00

1.2 TECHNICAL

Code	Position	$/HR
28T	TECHNICIAN I	28.00
30T	TECHNICIAN II	30.00
35T	TECHNICIAN III	35.00
40S	SENIOR TECHNICIAN	40.00
25L	LABORER	25.00
25M	MECHANIC I	25.00
28M	MECHANIC II	28.00
35M	MECHANIC III	35.00

1.3 ADMINISTRATION

Code	Position	$/HR
25S	SECRETARY I	25.00
28S	SECRETARY II	28.00
30S	SECRETARY III	30.00
30A	ACCOUNTANT I	30.00
35A	ACCOUNTANT II	35.00
50A	ACCOUNTANT III	50.00
30D	DATA PROCESSOR	30.00
30P	PURCHASING AGENT	30.00

2. ANALYTICAL DETERMINATIONS

Assays and elemental determinations as per analytical price list. (available upon request)

3. OTHER CHARGES

3.1 INDIRECTS

REPRODUCTIONS (XEROX COPIES)..........$0.12/COPY
TELEFAX (OUTGOING).....................$3.00/PAGE
(INCOMING).....................$2.00/PAGE
(Outgoing telefax charge plus telephone charge when placing an international call)

3.2 ESTIMATED INDIRECTS

Although MSRDI attempts to include in their costs, estimated charges for telephone, telex, reproductions, freight, out-of-pocket expenses, etc., it is not possible to include all charges. Therefore, charges incurred during the course of the project will be billed accordingly. A 10% handling charge will be assessed on all vendor purchases not advanced to MSRDI.

4. BILLINGS

4.1 INVOICES
Invoices will be mailed EOM, or upon project completion to include all current charges.

4.2 TERMS
Remittances are due and payable upon receipt.

4.3 FINANCE CHARGES
A finance charge of 18% annually will be added to unpaid balances at the beginning of the subsequent billing cycle.

(All prices subject to change without notice)

PROJECT COMPLIANCE AGREEMENT

I, Dale H. Allen, an authorized representative of A. F. Budge Mining Ltd. (Company or Individual), have reviewed the attached copies of MSRDI proposal No. 0008, "Condition of Terms", Rate Schedule 070189, "Project Description Summary", being in agreement with all said sections, do hereby authorize commencement of work as described and will comply with terms set forth before me this ____ day of ______________, 19____.

SIGNED BY: ______________________________
Name and Title

APPROVED BY: ______________________________
MSRDI Representative

MOUNTAIN STATES R & D INTERNATIONAL, INC.

PROJECT DESCRIPTION SUMMARY

January 22, 1990

CLIENT: A. F. Budge Mining Ltd.

ADDRESS: 4301 N. 75th Street
Suite 101
Scottsdale, Az 85251

This is to confirm that a project, with an Estimated (EST, NTE, FC) amount of $ 16,642.00 to perform the following work:

Column Leaching of Budge Mining Copper Ore

will be completed in an expeditious and timely fashion as per written MSRDI Contract/Proposal No. 0008.

Advance Deposit Required: $ 6,000.00.

MOUNTAIN STATES
R & D INTERNATIONAL, INC.

A WORLD LEADER IN MINERAL TECHNOLOGY

MOUNTAIN STATES R & D INTERNATIONAL, INC.
EMPLOYEE OWNED CORPORATION
13801 E. BENSON HIGHWAY
P.O. BOX 310
VAIL, ARIZONA 85641

TEL. (602) 762-5364
TUCSON ONLY 624-7990
TELEX 9102502482 MSRD
TELEFAX 602-762-5717

October 23, 1989

Mr. Dale Allen
A. F. Budge Mining, Ltd.
4310 North 75th Street
Suite 1010
Scottsdale, Arizona 85251

Subject: Estimated Column Leach Costs -- Korn Kobb

Dale:

For budgetary purposes, I am estimating the following costs:

> 4-inch column test, 30 day duration, assay copper only and screen/assay on residue: Estimated Cost $1,500.

> 24-inch column test, 30 day duration, assay copper only, screen/assay on head and residue: Estimated Cost $5,700.

Actual costs could vary, up or down, depending on sample received, test parameters, and/or assay requirements. When you have more data we can supply a detailed proposal which will be specific for your requirements.

If you have any questions, please call me. Thank you for your business; it is greatly appreciated.

Sincerely,

Rudy

Rudolph F. Fisher
Process Engineer

RFF/clp

To: John W. Norby

From: Dale H. Allen

Date: May 11, 1990

John:

Try these computations for determining an average grade (NOT cut-off grade - - where is my tape?) for each 20-ft. interval.

Operating Costs

Acid: $30.00 per ton = $0.015 per pound

Mining:

Ore - (including haulage, conveying and stacking) $1.35 per ton (Brown&Root)

Waste - $0.90 per ton (Brown&Root)

Total $2.25 per ton

SX-EW:

$0.30 per pound (Brown&Root) minus acid costs = $0.25 per pound

Considerations

1. The plant costs have to be based on each pound of copper recovered. For example, if we only recovered 1 pound of copper per ton of rock, and using the Brown & Root figures, the cost would be $0.25 per pound AND $0.25 per ton (not including acid costs).
The figure obtained from Frank M. was derived from a specific case where a certain grade and recovery was used.
Brown & Root's operating costs of $0.30 per pound also includes leaching, acid, operation plus G&A. Their acid costs are probably low (7 pounds acid per pound copper and $15 per ton of acid f.o.b. mine), so I backed those costs out. The $0.25 cost per pound is reasonable.

2. The copper recovery is based on recovery of total copper, not just acid soluble copper. The 70% recovery I gave you was for copper recovered over a relatively short period of time, i.e. 2 to 4 weeks. To be more realistic, over a period of 12 to 24 weeks, we should be able to recover 80% to 85% of the copper. For this exercise, I have used 75% recovery, which is still a conservative figure.

Let g = average grade (in % copper)

Income per ton = Mining cost per ton + Acid cost per ton + Plant cost per ton

(% rec x g/100 x 2000 x copper price) = (g/100 x 2000 x .015 x #acid per #Cu x % rec) + ($2.25) + ($0.25 x % rec x g/100 x 2000) at 75% recovery:

(g/100 x 1500 x copper price) - (g/100 x 22.5 x #acid) - (g/100 x $375)
= $2.25

g/100 ((1500 x copper price) - (22.5 x #acid) - $375) = $2.25

g ((1500 x copper price) - (22.5 x #acid) - $375) = $225

at 80% recovery:

g ((1600 x copper price) - (24 x #acid) - $400) = $225

Examples:

Copper price $0.80 per pound
Recovery of 75%
Using 10 pounds of acid per pound of copper

g ((1500 x $0.80) - (22.5 x 10) - $375) = $225

g = 225 / 600 = 0.375 % copper

At $0.80 per pound copper, 75% recovery and 14 pounds acid

g = 225 / 510 = 0.44 % copper

Copper price	Pounds of acid per pound copper	Grade @ 75% recovery		Grade @ 80% recovery
$0.65	10	0.60	% Cu	0.54
$0.80	10	0.38	% Cu	0.34
$0.90	10	0.30	% Cu	0.28
$1.00	10	0.25	% Cu	0.23
$1.20	10	0.19	% Cu	0.17

Looks a little better, huh???

Dl

[illegible]

MILLSAPS [illegible] SERVICE, INC

Facsimile Transmission

Date: [illegible]

To: [illegible] 702 [illegible] From: FAX # 801 278 3320

Name: [illegible] Frank W. Millsaps

Total Number of pages (including this page): 1

[illegible] reasonable [illegible] there are [illegible] and [illegible]

[illegible]

Frank

2/14/90

FRANK,

DALE ASKED YOU TO CONSIDER CUT-OFF GRADES BECAUSE [illegible] AND MINTEC (COMPUTER) ARE GOING TO DO [illegible] CALCULATIONS. I DO NOT HAVE THE DIFFERENT RESERVES AT REQUESTED CUT-OFFS BECAUSE WE HAVEN'T DONE THEM YET.

RESERVES AND CUT-OFF HAVE CIRCULAR REFINEMENT. I WAS ORIGINALLY GOING TO DO A SINGLE RESERVE WITH A REASONABLE CUT-OFF [illegible] [illegible] COST. BUT THE COST IS DETERMINED BY PROCESSING AND MINING METHOD WHICH IS DETERMINED BASED ON THE RESERVE, ETC.

THE [illegible] IS TO DETERMINE RESERVES FOR A REASONABLE RANGE OF CUT-OFFS (AND STRIP RATIO CUTOFFS ARE ANOTHER ENTIRE SUBJECT).

MY FIGURES INDICATE MUCH HIGHER GRADE CUT-OFFS SO PLEASE REVIEW THEM. HOPEFULLY THEY ARE OVERESTIMATES.

ACID COST CALCULATION

ASSUMPTIONS

ACID COST @ SAN MANUEL	$25 /ton
SAN MANUEL → [illegible] ROAD MILES	28 miles
Trucking rate	$0.10/mile/ton acid
Trucking contingency for bad road	$2.20/ton acid
[illegible]	85%
[illegible] consumption	[illegible] lb Acid / lb Cu
Deposit Grade ([illegible])	0.40% Cu

Cost of Delivered Acid

$25/ton [illegible] Manuel
[illegible] 2.80/ton [illegible] Cost
[illegible]/ton Trucking contingency

$30.00/ton Delivered

$30.00 / ton × [illegible] = [illegible] / lb Acid

$0.015 / lb Acid × [illegible] lb Acid / [illegible] Rec Cu × 0.85 lb Rec Cu / [illegible] lb Cu × 8 lb Cu / ton ore =

$1.02 Acid Cost / ton Ore

Meeting with Mike Sevokoski (2/13/90)

.25 - .29¢/lb operating cost (SX-EW-Leach)

.10 - .20 ¢/lb mining cost

EW - $1000 - $1250 x Ton Cu/year

SX - $820 x flowrate (2083 gpm)

SX 5¢/lb

EW 12¢/lb

Leaching - 15¢ (Acid) 5¢ operation

plant (12-13 people)

Organic Loss - 60 ppm mixed organic / 1000 gpm

Leaching - 0.0025 gpm/ft^2 (drippers)

Preg Solution - 2gm/l Cu

OPERATING COST / CUT-OFF GRADE CALCULATIONS

ASSUMPTIONS

STRIPPING RATIO 1:1

ORE MINING, HAULING & STACKING ON HEAPS .97 { $1.35 / Ton (B&R)

WASTE MINING 0.90 / Ton (B&R)

ACID COST (.161 leaching 46 ") $30 / Ton Delivered

trucks 1½ or 1½ 1.15 1.02 / Ton Ore

G & A (1½ miles conv.) .28 0.50 / Ton

CRUSHING (?) .21 0.35 / Ton

AGGLOMERATING (?) ~~0.50 / Ton~~

PROCESSING COSTS (EXCLUSIVE OF ACID) (.89) (1.19) (0.50 / Ton)

85% Recovery, 10% Dilution 3.95

Total $5.22 / Ton 6.00

.85 Recovery X .90 Dilution X Cutoff X $1.00 / lb = $5.22

Cutoff = 0.341 % Cu, 0.426 % Cu @ $.80 / lb Cu

Without Crushing or Agglomerating Operating cost = $4.37

4.57 .14 4.43 4.23

Cutoff = .286 % Cu 0.357 % Cu @ $.80 / lb Cu

.186 1.1 .19 .33

B&R = Brown & Root

THERE ARE WAYS TO LOWER COSTS IF NEED BE

1) JV W/ [illegible]
2) GET LOWER COST, LONGER TERM ACID CONTRACT ONCE HAVE ESTABLISHED RESERVE,
3) LOWER STRIPPING RATIO (AT EXPENSE OF TONS)
4) RAISE CUTOFF GRADE (AT EXPENSE OF TONS)
5) DRILL MORE RESERVES IN NORTH PIT.

[illegible]

FEB 15-19 DRILL CREW BREAK
20-Mar 2 2445 Additional Drill Footage in South Pit (7 holes)

[illegible] on Long break for Assays and Reserve estimates in South Pit Area

Scottsdale Office

John

Memo Summary: I asked you first!

COPPER SX-EW WORLDWIDE

P.G. Mahoney
W.N. Nahas

FLUOR DANIEL

COPPER SX-EW WORLDWIDE

P.G. Mahoney & W.N. Nahas
Fluor Daniel, Inc.

Ladies and Gentlemen:

We were pleased to be invited to review with you a topic of considerable importance to the copper industry and to all of us here working directly or indirectly for the mining industry.

As we all know, the development and commercial application of solvent extraction to the hydrometallurgical treatment of copper ores more than 20 years ago has proven to be the most significant technological breakthrough in copper processing. Today, high purity cathode copper can be produced for less than 30 cents per pound via the acid leach, solvent extraction and electrowinning route.

The recovery of the U.S. copper industry from its most severe recession of the early eighties can be largely attributed to the wise industry decision to maximize copper production through the construction of fast tracked SX-EW plants.

Basic Principles in Solvent Extraction - Electrowinning

Solvent extraction is used in metal recovery operations to selectively extract a metallic ion in solution from other metal ions present in solution. In copper solvent extraction, the aqueous solution would typically be an acid leach liquor containing cupric, ferric, ferrous, nickel, calcium, magnesium, aluminum and other ions primarily as sulfates.

The acid leach liquor is contacted with an immiscible organic phase containing an active extractant selective to copper over the other ionic metal species.

This reaction is sensitive to the hydrogen ion concentration in solution and can be reversed by contacting the loaded organic solvent with a high acid strength solution. This takes place in the stripping section of the solvent extraction system.

The organic and aqueous phases are immiscible thus a simple mixer-settler equipment is adequate to carry out both the extraction and stripping operations.

The main advantages of the system can be summarized as follows:

1. Copper is selectively extracted from an impure aqueous solution and transferred to the tankhouse electrolyte as concentrated pure copper sulfate solution.

2. The organic reagent is regenerated during stripping for return to the extraction section to recover more copper.

3. Acid is generated in the aqueous solution during extraction to extract more copper from the dumps.

4. Sulfuric acid is generated during electrowinning to strip more copper from the circulating organic solvent.

5. A 99.99 percent pure copper is produced by electrowinning which is marketable as refined copper without further processing.

A typical SX-EW plant thus consists of three closed loop circuits that only require make-up acid and organic solvent to maintain their operational effectiveness. The three loops are:

a. Leaching and the extraction section of SX
b. The organic solvent circulating between the two SX sections.
c. Electrowinning and the stripping section of SX

Typical SX-EW System

The slide provides a schematic illustration of a typical countercurrent mixer-settler liquid ion exchange system integrated with an electrowinning tankhouse. In this example, the solvent extraction unit consists of 2 extraction stages and a single stripping stage.

In the extraction section, an immiscible organic consisting of the active reagent usually diluted with kerosene is contacted with the copper bearing solution from leaching in the first stage mixer. The mixed two phases overflow into a settler and are allowed to separate. The clear organic overflowing the weir at the discharge end of the settler is referred to as the pregnant organic or loaded organic. It advances to the striping section mixer. The settled aqueous moves under the organic weir and overflows the subsequent weir. It advances to the second stage extraction mixer where it is contacted with stripped organic from the stripping settler. The organic overflowing the second stage settler advances countercurrently to the first stage extraction mixer, and the overflowing aqueous is returned back to leaching. It is referred to as the copper depleted aqueous raffinate.

In the stripping section, copper values are now contained in the organic phase referred to as the loaded organic. It is contacted with acidic spent electrolyte from the tankhouse causing the copper to transfer from the organic phase to the aqueous phase and produce a pregnant electrolyte solution suitable for treatment in electrolytic cells. The stripped organic is returned to the extraction section to repeat the cycle.

In the copper tankhouse, the pregnant electrolyte is circulated in electrolytic cells made up of insoluble lead anodes and copper starter sheet cathodes connected in series. Copper is won electrolytically from the circulating pregnant solution by deposition at the cathodes. Furthermore, the electrochemical reactions proceeding in the cells result in the formation of sulfuric acid in the electrolyte and the evolution of nascent oxygen at the anodes.

Solvent General Properties

For a solvent extraction reagent in copper application to be successful, it must have the following properties:

1. High selectivity for copper ion extraction from acid leach liquors.

2. Be applicable to a wide range of leach liquors.

3. High metal loading capacity.

4. Copper must easily strip under conditions consistent with conventional tankhouse acid concentration (150-180 g/l).

5. Good copper transfer kinetics.

6. Good stability under operating conditions (low hydrolysis and degradation).

7. Very low solubility in the aqueous phase.

8. High solubility in the kerosene diluent.

9. Stable emulsions should not be promoted when both phases are mixed.

10. Crud formation must not be enhanced.

11. Should not increase entrainment.

12. Should be safe to use.

13. Last but not least should have an acceptable cost.

Some of these properties impact the capital cost, for example, the completeness of copper extraction and its relationship to staging requirements. Other impact the operating cost such as reagent stability and organic entrainment while still others impact both operating and capital cost, as for example, the organic selectivity and its relationship to circuit size, production and tankhouse costs.

Development of Reagents in Copper SX Application

The first commercially available organic solvent designed specifically for the selective extraction of copper from dilute copper dump leach liquors was produced by General Mills Inc. (Henkel today). Designated LIX 63, the amine reagent became available in the early sixties. LIX 63 suffered from two drawbacks; first, the pH range was too high >2 to be applicable to most dump leach liquors and second its rejection of the ferric ion was not as good as was required. LIX 63 was followed by LIX 64, a substituted o-hydroxybenzophenone oxime. It was capable of extracting copper quite selectively at pH values as low as 1, however it still suffered from slow kinetics.

LIX 64 was followed by LIX 64N, which showed significantly improved kinetics of extraction over LIX 64 and was the most widely used reagent of the first generation solvent extraction plants.

Ketoxime Reagents

The ketoximes were the first reagents to be used commercially for the extraction of copper from dilute sulfuric acid leach liquors and were exclusively used for 12 years. The ketoximes exhibit the following properties:

1. Excellent phase separation.
2. Low entrainment losses to raffinate.
3. Do not promote excessive crud formation.

The use of ketoximes is, however, limited because of the following two shortcomings:

1. They are moderately strong copper extractants.
2. They have slow kinetics at cold temperatures.

Salicylaldoxime Reagents

The much stronger salicylaldoxime-based reagents were introduced to override the perceived shortcomings of the ketoximes. Plant configurations formerly with 4 or 3 extraction plus 3 or 2 stripping stages were dramatically reduced to 2+2 or 2+1 stages even for high copper tenor liquors at low pH. Leach liquors of up to 40 g/l copper at pH 1.5 are being treated so that almost any copper bearing liquor can be purified by solvent extraction. However, the reagents by themselves are such strong copper extractants that they are often used in combination with an equilibrium modifier, so they can be efficiently stripped with an acidic copper solution from which high quality copper can be electrowon.

The use of equilibrium modifiers leads, however, to the following shortcomings:

1. Reagent hydrolysis and degradation.
2. Transfer of iron to the tankhouse.
3. Organic losses because of entrainment of each phase in the other.
4. Higher crud formation.
5. Deleterious effects on certain materials of construction.

By 1988, the number of operating SX plants had almost tripled and the annual production increased to 600,000 tonnes from less than 200,000 tonnes installed capacity in 1979.

Ketoxime - Salicyladoxime Mixtures

The ketoxime - Salicyladoxime mixtures contain no added modifier. LIX 984, for example, is a mixture of LIX 860, a salicyladoxime reagent with LIX 84 ketoxime reagent. It combines the extractive strength and fast kinetics of the salicylaldoximes with the good physical performance and stability of the ketoximes.

Although the extractive strength of the mixtures is not quite so high as the modified salicyladoximes, it is considerably greater than the ketoximes. Copper transfer kinetics are a little slower than salicylaldoximes, but are still very fast. It is felt that the ketoxime functions as a modifier for the salicyladoxime portion in the strip side of the circuit. The separate extractants and their mixtures are highly selective for copper over iron from almost all available copper leach solutions. As a result, minimum tankhouse bleeds are needed for iron control.

Determination of the Number of Extraction and Stripping Stages

For a selected solvent, this is arrived at using the McCabe-Thiele binary diagram which will give the number of equilibrium extraction and stripping stages to reach a desired raffinate and pregnant electrolyte compositions.

The number of equilibrium stages may vary with the alteration of the external organic to aqueous ratio. The higher the ratio, the lower the number of required stages but the larger the size of mixers and settlers per stage. An economic trade-off study usually establishes the optimum number of extraction and stripping stages.

First Generation SX Plants

The first generation SX plants had the following design features:

1. Used ketoxime reagents such as LIX 64N which have slow kinetics and a limited application range.

2. Copper extraction selectivity, i.e. iron rejection was not as good as with present day aldoxime reagents.

3. Included 3 to 4 extraction and 2 to 3 stripping stages.

4. Used multiple train SX sections.

5. Had a single mixer per stage sized for 3 minutes retention time of the combined organic and aqueous flows.

6. Settlers were sized for a length to width ratio of 4 to 1 and a settling rate ranging from 1.5 to 1.75 gpm per square foot.

7. Total liquid inventory in settlers was 36 inches deep consisting of 9 inches organic phase and 27 inches aqueous phase.

8. Because settlers are substantially shallower but must have the same top level as that of the mixers for hydraulic head to be conserved, the settlers had to be supported on columns above ground level.

9. Used a double shrouded "pump-mix" impeller located in the middle of the mixing vessel with a feed draft tube extending from the tank bottom to the impeller suction side. Bluebird used separate pumps and mixers that resulted in too much organic entrainment.

10. Maintained internal organic to aqueous ratio of 1:1 by recycling the smaller flow phase from the settler back into the mixer.

11. To even the flow in the settler, two rows of "picket-fence" baffles made up of vertical bars were placed across the width of the settler. The first fence was usually located 1 meter from the mixer discharge, and the second midway into the settler length.

12. Mostly stainless steel material of construction was used for mixers, settlers, piping, fittings and control valves. Concrete structures with stainless steel linings were also used, and one plant used FRP mixers and settlers.

13. In some installations, heaters were installed to preheat the spent electrolyte feed to the stripping section; thus heat up the solvent extraction system during winter.

14. Coalescers were added to separate entrained organic from the pregnant electrolyte, and an extra settler to skim entrained organic from the aqueous raffinate.

First Generation EW Plants

The first generation EW plants have the following design features:

1. Include two major sections; a starter sheet section to produce copper starter sheets, and a commercial section to grow copper on starter sheets to terminal cathodes weight.

2. Cells are of reinforced concrete walls with wood plank false bottoms and plasticized PVC liners and buffer sheets. The Johnson Camp EW tankhouse was the only facility which used shop fabricated FRP cells because of its small cell size and short life expectancy.

3. Most cells use approximately 10 square feet cathode surface area.

4. Lead antimony anodes were used at the start but were later replaced by the superior corrosion resistant lead calcium anodes.

5. Cells are designed with adjustable discharge weirs to vary the electrolyte level hence prevent the breaking of starter sheet loops.

6. Rectifiers and cells are arranged to minimize the main bus total length of run and cost.

7. Intercell connection design evolved from a wood block with separators to the plastic capboards and lately the plastic capboards with ceramic separators.

8. The average current density in the starter sheet section is 18 amperes per square foot and 25 amperes per square foot in the commercial section.

9. The number of cathodes per cell varies from a low of 21 to as high as 69.

10. Starter sheets are grown in a single day cycle while commercial cathodes are harvested once every 5 to 7 days.

11. A continuous electrolyte bleed is practiced to keep the iron level from building up in solution. The bleed volume depends on the extent of iron transferred to the electrolyte.

12. The tankhouse bleed is usually directed to the first extraction mixer to recover its contained copper value for return to the electrowinning tankhouse.

13. A dedicated rectifier for the starter sheet section is preferred since it allows for current density control independent from the commercial section operating condition.

14. Cathodes are pulled live in order not to interrupt the flow of current to the cell. Every third cathode in the cell is harvested at a time with a strongback and replaced with stripped blanks or starter sheets. The procedure is twice repeated until the balance of cathodes in the cell are pulled and replaced.

15. Starter sheet preparation is done manually, semi-automatically or fully automatically depending on the size and capacity of a specific tankhouse.

16. Tankhouse layouts are developed to minimize the bridge travel distance and cycle time.

17. Tankhouse capacities vary from as low as 2800 mt/y to as high as 100,000 mt/y.

18. Starter sheet embossing is practiced to rigidize the surface for electrical short prevention.

19. Stainless steel siding is used to resist the corrosive mist condition inside the building.

20. Cell surfaces are covered with layers of floating plastic balls to suppress mist entrainment in the tankhouse.

21. Forced ventilation enhances the air quality inside the tankhouse building.

22. Floor surfaces are either covered with sulfur concretes or the concrete floor is coated with an acid resistant surface.

Second Generation SX Plants

The second generation SX plants started with the introduction of the much stronger salicylaldoxime-based reagents. These superior reagents first introduced by ICI - Acorga contributed to an appreciable reduction in the size and costs of solvent extraction plants. The following design improvements were implemented:

1. The number of extraction stages were reduced to 2 and stripping stages to 1 or 2.

2. The single train feed flow rate was dramatically increased to as high as 6000 gpm.

3. Much higher grade pregnant leach solutions (PLS) are presently processed.

4. Parallel and series mixer-settler configuration was introduced for low PLS aqueous solutions.

5. As high as 33% active organic reagent is used in one operating plant.

6. Multiple mixers arranged in series were introduced with auxiliary agitators rated for phase dispersion only.

7. Retention time in mixers was reduced because of the faster reagent kinetics.

8. Settler's specific flow rate was increased, hence reducing the overall area requirement for phase disengagement.

9. Settler's configuration was dramatically altered from long and narrow to wide and short. The new configuration reduces the dispersed phase velocity across the settler and maintains a linear flow regime.

10. The organic and aqueous depth in the settlers was measurably shortened reducing the overall settler height, the volume of inventoried liquid and the settler foundation and structural needs and costs.

11. Low profile settlers were also introduced further reducing their foundation and structural needs and costs.

12. Krebs of France introduced it's proprietary mixer-settler design which uses high settling rates of 4 to 6 gpm per square foot that substantially reduces the overall settler area and provides the following distinct advantages:

- Reduction in settler and hence SX plant size.
- Independence of agitation from pumping allowing optimum mixing conditions.
- Substantial savings in solvent inventory.
- Simplified layout and hence maintenance.
- Reduced piping and instrumentation.

13. Uncovered settlers were introduced and used in some cases.

14. An organic after settler stage for separation of entrained organic from the pregnant electrolyte has been used in some designs, while in another design, a column flotation cell was selected.

15. A dedicated storage tank area on concrete slab at lower elevation was incorporated into earlier designs and became an industry standard practice.

16. An entire SX-EW plant was enclosed under one roof because of severe cold climate conditions (Gibraltar in Canada).

Second Generation EW Plants

The most important design change of the second generation EW plants has been the introduction of Copper Refineries Ltd. direct copper plating technology as developed and first used at Mount Isa's refinery in Townsville, Australia. With the Mount Isa technology, copper is deposited on stainless steel blanks and allowed to grow enough in weight that conventional starter sheet preparation and use is no more required.

By adopting this technology, the tankhouse is designed with no starter sheet production section, hence starter sheet preparation and handling equipment are totally eliminated.

After copper growth to terminal weight onto stainless steel blanks, cathodes are pulled from the cells by a travelling overhead crane using a strongback and taken to the cathode stripping and blank preparation machine. In this machine, the cathodes are automatically washed, stripped, stacked and conveyed to weighing and handling stations. Stripping operation includes hammering with rubber mallets and high pressure air blasts or knife blades to dislodge the deposited copper from the stainless steel blanks. The edge and bottoms of the stripped stainless steel blanks are protected from ingress of copper by applying a thin layer of high melting point wax before they are returned to the cells.

Harvesting of cathodes using the direct plating technology is done every 7 to 11 days and the weight of grown copper ranges from 100 to 150 lbs per cathodes face. The current efficiency can be as high as 96 to 98 percent with low iron contained electrolytes because of the rigid stainless steel blanks which prevent short circuit conditions within the cells.

Other developments in new tankhouse designs include the use of precast concrete cells which reduce the tankhouse construction time and cost, and the switch over to hollow hanger bars to reduce their supply cost.

Solvent Extraction - Electrowinning Economics

Solvent Extraction Capital Cost

Factors that influence the capital cost of the SX section are:

1. The general site development and utility supply and installation.

2. The pregnant leach solution (PLS) ponds and pumps.

3. The raffinate pond.

4. The PLS feed flow rate to the SX plant.

5. The staging requirement for extraction and stripping, i.e. the total number of mixers and settlers.

6. The number of SX trains.

7. Materials of construction selection.

8. Storage tanks and pumps.

9. Organic and diluent initial fill.

10. Crud treatment system.

Electrowinning Capital Cost

Factors that influence the capital cost of the EW section are:

1. Degree of automation in starter sheet preparation and handling systems.

2. The design current density and the cells current efficiency.

3. Conventional or Mount Isa technology selection.

4. Materials of construction and degree of water proofing.

Operating Costs SX-EW

Operating costs presented in this paper are based on the following criteria:

1. Electrical Power at 7.5 cents/kWH
2. Sulfuric Acid at $50/ton
3. Operating labor at $15/hr
4. Organic reagent at approximately $6.50/lb
5. Organic diluent at $1.55/gallon
6. Anodes at $300 each
7. Cobalt at $12.50/lb
8. Maintenance labor and supplies as a percentage of capital cost

Operating costs exclude the following:

- Management overhead
- Taxes
- Royalties
- Marketing Costs
- Depreciation
- Depletion

The estimated total SX-EW direct operating costs is 18.6 cents/lb.

Review of Some World Copper SX-EW Plants

Close to 30 plants have been built since the first SX-EW facility of Ranchers Exploration and Development was constructed in Miami, Arizona in 1968. The total SX-EW installed capacity in the free world presently exceeds 600,000 metric tons. It is anticipated that the fast growth rate experienced in the last decade will be maintained if not surpassed as more applications to the technology are uncovered and used.

The following review provides salient features of some of the SX-EW plants built over the last 20 years.

1. Ranchers Exploration & Development, 1968

   This was the first commercial application of copper SX-EW. It included 3 extraction and 2 strip stages. Was also the first plant to use organic removal equipment for electrolyte purification and the only SX plant to use separate mixers and pumps. The plant has since ceased to exist.

2. Cyprus Bagdad, 1970

   This was the second SX-EW plant; the only one with 4 extraction and 3 stripping stages. Included 4 trains and used pump-mixer impellers. All vessels and piping are of stainless steel construction.

3. Zambia Consolidated Copper MInes, Zambia, 1974

First large flow plant rated at 3300 gpm/train. Includes 4 trains of 3 extraction, 2 stripping stages. First high tenor PLS feed (5 g/l). Uses concrete mixers-settlers with stainless steel lining. First multiple crane bay tankhouse consisting of 10 rows of cells in 5 bays. A total of 660 cells are installed including 98 starter sheet cells in 2 rows of 49 each.

4. Anamax Twin Buttes, Arizona, 1974

Feed is CCD washed solution from an agitated leach system. Consisted of 2 trains of 4 extraction, 2 stripping stages. First attempt to filter PLS feed and first two level tankhouse design using automated starter sheet preparation machine. The plant is no longer in operation.

5. Cyprus Johnson, Arizona, 1976

First SX-EW plant, using shop fabricated FRP vessels for mixers, settlers and cells. Consisted of 5 trains of 3 extraction, 2 stripping stages. Cells included only 21 cathodes each because of FRP weight limitations. The plant was dismantled and reconstructed at Sierrita.

6. Pinto Valley Copper Co., Miami, Arizona, 1976

First to install low profile settlers, and first to use multiple mixing chambers. Also first SX plant to dedicate a separate tank farm area below mixers-settlers' level. The tankhouse uses the Johnson Camp cells and same electrodes configuration.

7. Duval Corp. 1979

Plant is similar in design to Pinto Valley but uses more mixing chambers than any other SX plant.

8. Inspiration Copper Co., 1979

The first to use an aldoxime reagent in the U.S. High PLS feed tenor, high settler sizing flow rate and first distant SX plant from the tankhouse.

9. Centromin, Cerro de Pasco, Peru, 1981

First plant to treat mine water. Uses low profile settlers and multiple mix chambers. Semi-automated starter sheet preparation equipment are installed.

10. Phelps Dodge, Burro Chief, Tyrone, 1984

Consists of 2 trains of 2 extraction, 1 stripping stage. One of the largest SX plants in terms of PLS flow rate. Settlers have been tested at 50 percent above design flow rate and plant experiences very cold PLS solution. Uses a ketoxime modified aldoxime reagent. The entire SX plant uses 2 operators per shift. The tankhouse is designed with no starter sheet cells which are received from the El Paso refinery. This was resulted in significant cost savings. The tankhouse includes a rigidizing press for starter sheets to reduce cells short circuits. Experiences lowest direct operating cost of all SX-EW plants because of favorable power rates.

11. Magma Copper - San Manuel, 1985

Uses free-standing stainless steel settlers and multiple mix chambers with axial flow auxiliary mixers. Also uses a flotation column to recover entrained organic from the electrolyte. The tankhouse uses Mt. Isa's technology and an automatic cathode washing, stripping and blank preparation machine. The current efficiency is in the range of 96 to 98 percent because of the low iron content of the electrolyte and the rigidness of the cathode blanks. Higher current densities can also be maintained.

12. Gibraltar Mines, B.C. Canada, 1986

The entire SX-EW plant is under one roof. The first plant to ever use parallel-series SX configuration. Uses Mount Isa direct plating technology but because of small capacity perform manual cathode washing, striping and blank rewaxing.

Future Growth Outlook

Since the first commercial application of SX-EW, the proces has experienced solid industry acceptance and fast growth which has resulted in the construction of close to 30 plants in the free world in the last 20 years. Installed capacity has more than tripled in the last decade, i.e. the compounded annual growth for the process use was maintained at a rate close to 12 percent.

It is impossible to predict the future with certainty, however, it is fair to state that the momentum experienced in the past decade could be maintained or even surpassed if additional applications to the technology were to be established and implemented.

As the copper industry continues to explore ways to reduce costs, more emphasis will be given to the processing of copper sulfide minerals through hydrometallurgical techniques. This would undoubtedly increase the pace of SX-EW plants construction as well as increase the single unit capacity of the constructed facilities.

Additional future applications are forecast to include:

- In-situ leaching.
- Polymetallic sulfides hydrometallurgical processing.
- Bacterial leaching.

Future Technology Developments in Solvent Extraction

The only way to make a realistic prediction of future technological developments in a commodity is to do it on the basis of present day needs for improvements.

In the case of solvent extraction, three areas have been identified for future improvements.

1. The need exists for more development of reagents to further improve their copper selectivity and extraction/stripping kinetics, as well as further reduce their entrainment into the aqueous phases.

2. The ultimate mixer-settler configuration is visualized as a continuous countercurrent extractor or stripper providing the requisite number of equilibrium stages in a single vessel.

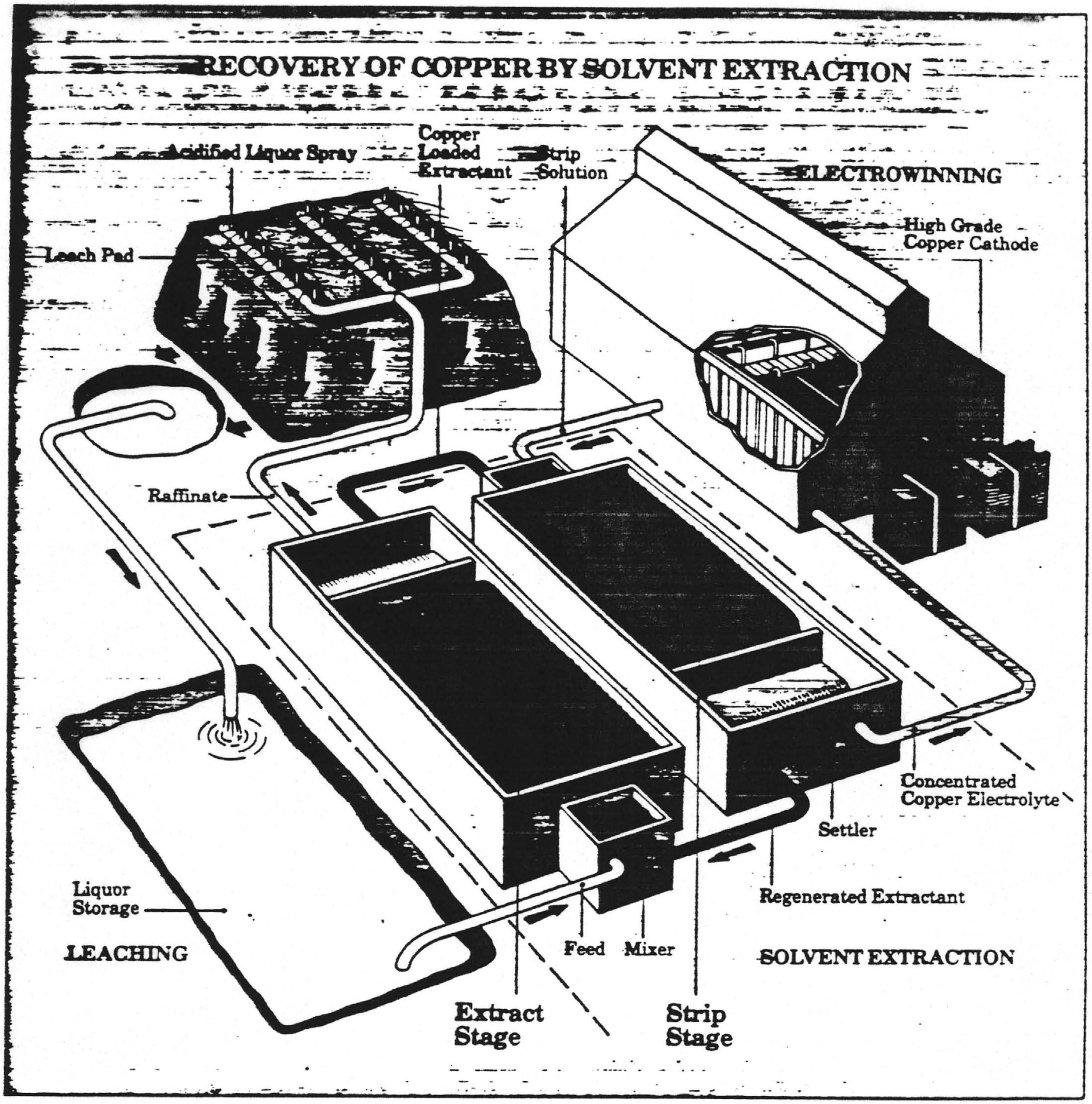
3. Impeller pump-mixers may eventually be replaced by static type mixers.

Future Technology Developments in Electrowinning

Soluble impurities in the electrolyte, particularly iron, impose a limitation on the present operating current density. Cells productivity would drastically increase and the tankhouse area and capital cost would markedly reduce if the operating current density could be substantially increased from present operating levels. This could only be achieved if an electrolyte purification proces were to be developed to allow for such high current density use.

With large capacity tankhouses, the need also exists for further equipment and process automation as well as computer scheduling of materials handling functions.

An area of environmental concern and need is the objectionable acid mist condition of most tankhouses. Mist elimination could only be accomplished if the oxygen generated at the anodes were to be collected in an enclosed cell design, evacuated for separation in a scrubber, and the scrubbed acid mist neutralized for disposal.


RECOVERY OF COPPER BY SOLVENT EXTRACTION
Acidified Liquor Spray
Copper
Loaded
Extractant
Strip
Solution
ELECTROWINNING
High Grade
Copper Cathode
Leach Pad
Raffinate
Concentrated
Copper Electrolyte
Settler
Regenerated Extractant
Liquor
Storage
LEACHING
Feed
Mixer
SOLVENT EXTRACTION
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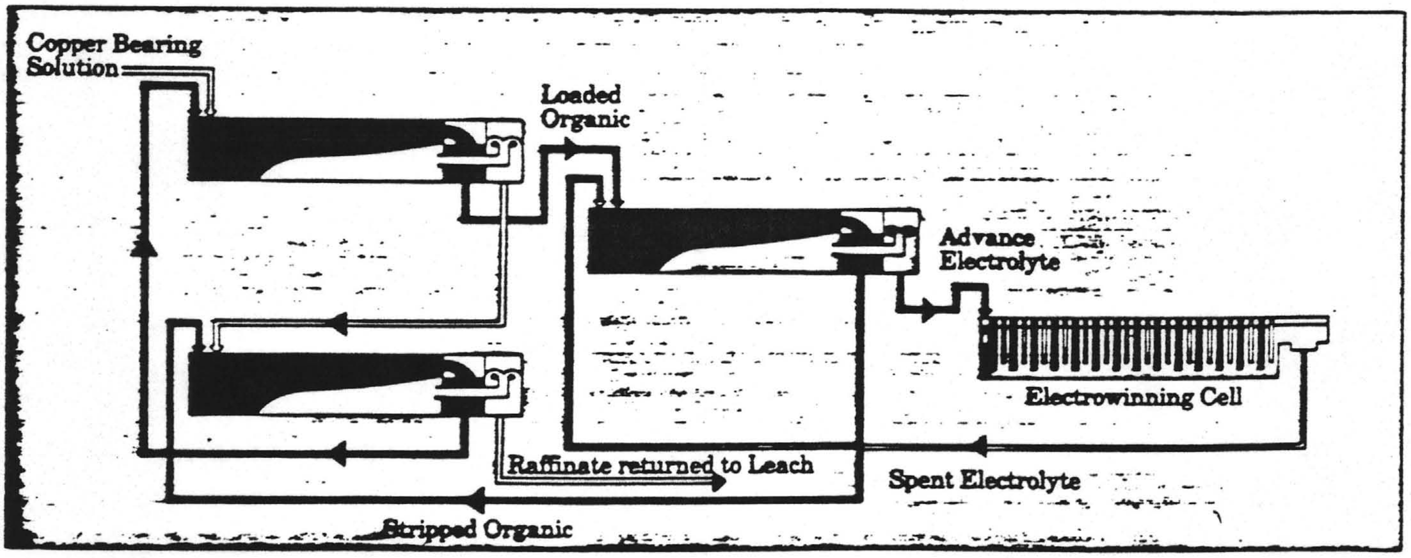
Stage


Copper Bearing
Solution
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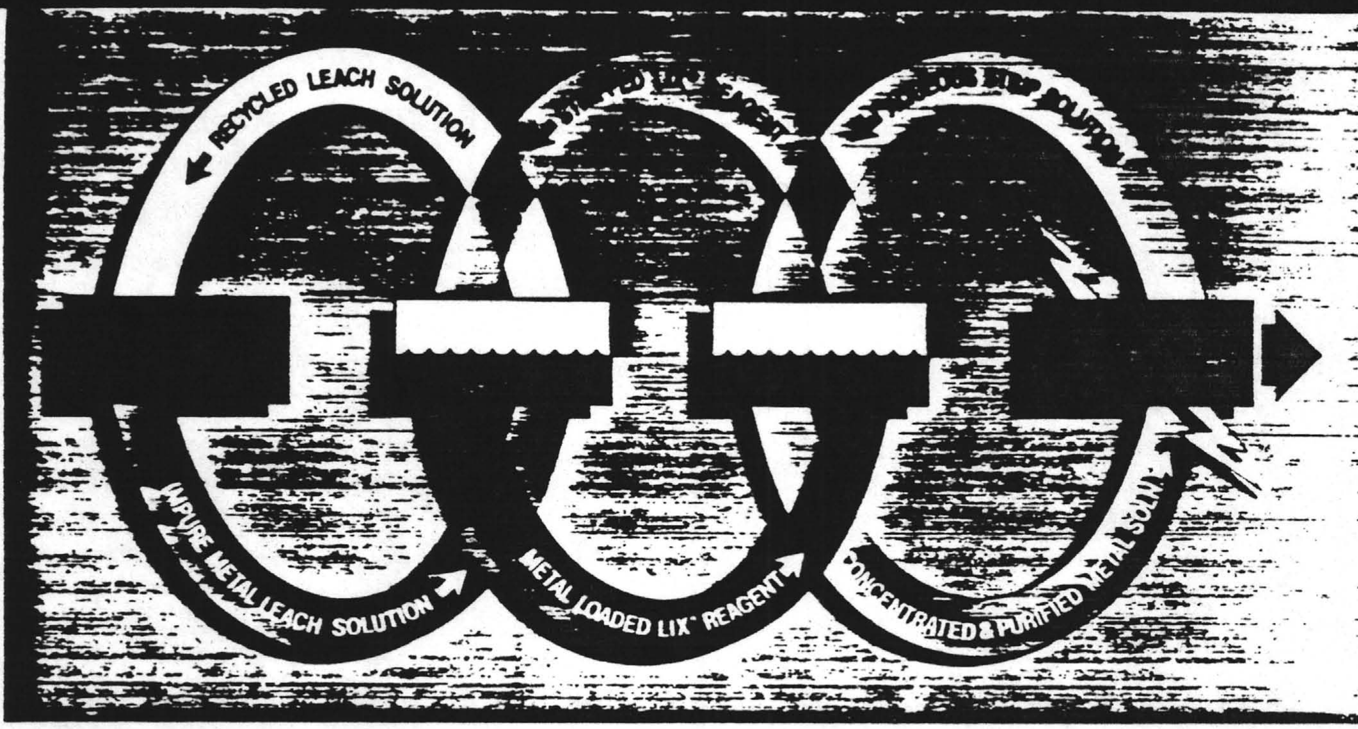
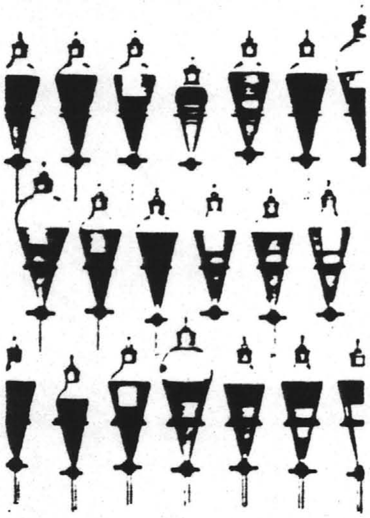
Organic
Advance
Electrolyte
Electrowinning Cell
Raffinate returned to Leach
Spent Electrolyte
Stripped Organic



Leadership means...
...customer service

is an integral part of all our operations at Henkel. Our international technical sales and marketing system assures an immediate response to customer requests and underlines our commitment to provide quality service world-wide. Among the many services we can provide are:

- Services for new SX plant construction
  - —Flow sheet analysis and pre-engineering feasibility studies
  - —Material balances and engineering design analysis
- Solvent extraction process instruction
  - —Videocassette tapes, available in both English and Spanish for in-house instruction
  - —Live seminars addressing various aspects of liquid ion exchange technology and training
- Solvent extraction technical services
  - —On-site personnel training and assistance in new plant start up
  - —Monitoring of SX reagent behavior in commercial SX plants
  - —Trouble shooting through physical and chemical analysis



...product choice, including the

widest selection of solvent extraction reagents for metal recovery systems in the industry. More than twenty different solvent extraction reagents of the Alamine®, Aliquat®, and LIX® trademarks have been engineered and produced to meet our customers' needs worldwide. The new LIX® 900 Series is another example of our growing and successful product line.

...quality and reliability

in our raw materials, our products, our processes and our services. This is the foundation upon which the Minerals Industry Division of Henkel Corporation has been built.

Henkel

ADVANTAGES OF COPPER SX-EW

- **Selective Copper Extraction**
- **Copper Solution Concentration**
- **Organic Solvent Regeneration for Reuse**
- **Sulfuric Acid Regeneration for Reuse**
- **High Quality Cathode Copper Production**

SOLVENT GENERAL PROPERTIES

- **High Copper Selectivity**
- **Broad Application Range**
- **High Copper Loading Capacity**
- **Ease of Copper Stripping**
- **Good Transfer Kinetics**
- **Good Stability**
- **Very Low Solubility In Aqueous Phase**
- **High Solubility In Diluent**
- **No Stable Emulsions Must Be Promoted**
- **Crud Formation Must Not Be Enhanced**
- **Entrainment Must Be Minimized**
- **Must be Safe To Use**
- **Cost Must Be Acceptable**

KETOXIME REAGENTS (Hydroxy Oximes)

- ❑ FIRST GENERATION REAGENTS

- ❑ USED FOR 12 YEARS

- ❑ PROPERTIES
  - Excellent Phase Separation
  - Low Entrainment Losses To Raffinate
  - Low Crud Formation

- ❑ SHORTCOMINGS
  - Moderately Strong Extractants
  - Limited Application Scope
  - Slow Kinetics At Low Temperatures

- ❑ TYPICAL REAGENTS
  - LIX 63, LIX 64, LIX 64 N, LIX 65 N, LIX 70, LIX 71, LIX 73, LIX 84 (SME 529)

SALICYLALDOXIME REAGENTS

- ❑ **SECOND GENERATION REAGENTS**

- ❑ **FIRST INTRODUCED BY ICI-ACORGA**

- ❑ **PROPERTIES**
  - **Strong Copper Extractants**
  - **Broad Application Range**
  - **Faster Kinetics Than Oximes**
  - **Require Modifers For Copper Stripping (Tridecanol or Nonylphenol)**

- ❑ **TYPICAL REAGENTS**
  - **Acorga PT-5050, Acorga M. 5640**
  - **LIX 860**

KETOXIME - ALDOXIME REAGENTS

- ❑ NO MODIFIER ADDED
- ❑ KETOXIME FUNCTIONS AS MODIFIER
- ❑ SLOWER KINETICS THAN ALDOXIMES
- ❑ LIX 984 ONLY MIXED REAGENT
  - Consists of LIX 860 with LIX 84

Relative Extraction Power of LIX 84 for Metals at pH 2.0

Metal	Relative Extraction Power
Cu(II)	Very strongly extracted
Fe(III)	Slightly extracted
Mo(VI)	Slightly extracted
V(V)	Slightly extracted
Zn(II)	Nil
Sn(II)	Nil
Ca(II)	Nil
Mg(II)	Nil
As(III)	Nil
Al(III)	Nil
Fe(II)	Nil
Si(IV)	Nil
Co(II)	Nil
Ni(II)	Nil

FIRST GENERATION SX PLANTS

- **Use Ketoxime Reagents**
- **Use 4+3 or 3+2 Stages**
- **Use Multiple SX Trains**
- **Use Single Mixer Per Stage**
- **Use 4 to 1 Settler Ratio**
- **Use Elevated Settlers**
- **Use Pump Mix Impeller**
- **Have Two Picket Fences in Settlers**
- **Use Mostly Stainless Steel**
- **Have Heaters Installed to Preheat SX System**
- **Use Coalescers to Separate Entrained Organic**

FIRST GENERATION EW PLANTS

- Include Two Cell Sections
- Use R.C. Cells with PVC Liners
- Use 10 Square Feet Cathodes
- Use Lead - Antimony Anodes
  or Lead - Calcium Anodes
- Cells Layout For Minimum Main Bus Run
- Use 21 to 69 Cathodes Per Cell
- Operate at 18 Amps/Ft^2 Starter Sheet Section
  and 25 Amps/Ft^2 Commercial Section
- Have Separate starter Sheet Rectifier

FIRST GENERATION EW PLANTS

- Harvesting Cycle Varies
- Live Harvesting is Practiced
- Electrolyte Bleed to First Extraction Mixer
- Automation Depends on Tankhouse Capacity
- Embossing to Rigidize Starter Sheets
- Stainless Steel Building Siding
- Plastic Ball Covers on Cell Surfaces
- Forced Ventilation to Clean Tankhouse Air
- Sulfur Concrete Floors or Acid Resistant Coatings

SECOND GENERATION SX PLANTS

- Use Aldoxime Reagents
- Process Much Higher grade PLS Liquors
- Use 2+2, 2+1 and 1+1 Stages
- Single Train Flow Up To 6000 GPM
- Use Parallel and Series Mixer-Settlers
- Use Multiple Mixers in Series
- Mixers-Settlers Sized For Higher Specific Flowrates
- Use Wide and Short Settlers
- Use Shallower and Low Profile Settlers
- Some Settlers Designed With No Roofs
- Use Dedicated Tank Area At Lower Elevation
- Use Organic Entrainment Separation Equipment
- New Equipment Design
    - Krebs Mixer Settler
    - Continuous Mixer Settler CMS

the equipment

KREBS has developed a mixer settler system with substantial improvements in design and performance.

The application of sound and yet simple engineering principles to basic solvent extraction has allowed KREBS to achieve a major cost breakthrough; not only are overall capital requirements and operating costs reduced but at the same time plant design is simplified.

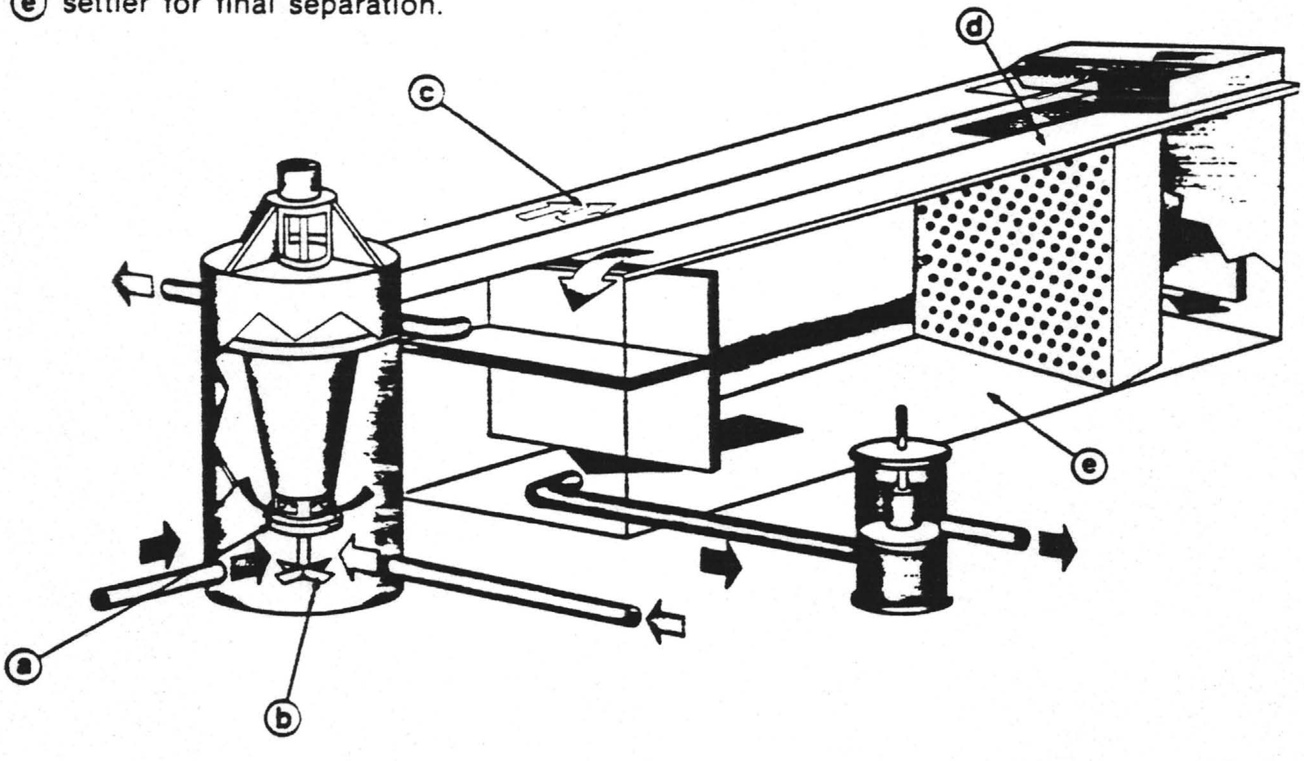
Ⓐ conical pump to provide liquid transfer and enhance phase coalescence

Ⓑ agitator selected on the basis of mixing requirements

Ⓒ superimposed launder providing further phase separation

Ⓓ removable covers

Ⓔ settler for final separation.



The heart of the system is the intensive coalescence (I. C.) of the phases obtained from centrifugal forces developed by the conical pump. Experience in the la[illegible]atory and in industrial plants has shown that the combination of [illegible]ical pump and superimposed launder allows a reduction of the settler area [illegible]e quarter to one-half of that normally required.

KREBS MIXER - SETTLER ADVANTAGES

- **Reduction in Settler Size**
- **Independence of Agitation From Pumping**
- **Savings in Solvent Inventory**
- **Reduced Piping and Instrumentation**

SECOND GENERATION EW PLANTS

- ❑ MT ISA DIRECT PLATING TECHNOLOGY INTRODUCED LEADING TO:
  - Elimination of Starter Sheet Preparation Section
  - Elimination of starter Sheet Preparation Equipment
  - Improved Current Efficiency
  - Increased Current Density
  - Reduced Operating Labor
  - Addition of Cathode Stripping and Blank Preparation Machine

- ❑ CONTINUED DEVELOPMENT OF LEAD ALLOY ANODES
  - Pb-Ca, Pb-Sn, Pb-Sr-Sn, Pb-Sb-Ag

- ❑ PRECAST CONCRETE CELLS ADOPTED

SX CAPITAL COST

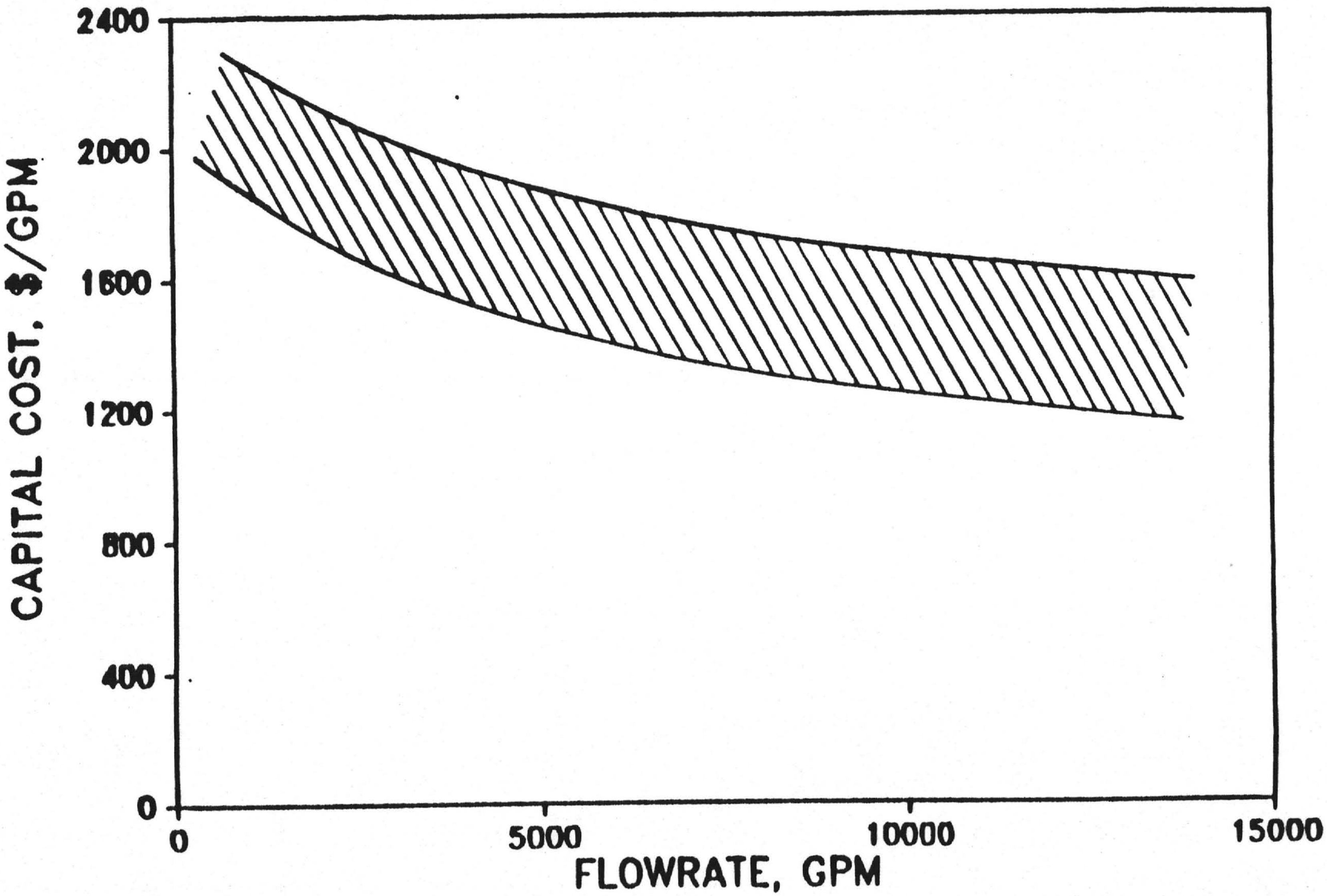
- FACTORS THAT INFLUENCE SX CAPITAL COST ARE:

  - General Site Development and Utility Installation
  - PLS Ponds and Pumps
  - Raffinate Pond
  - PLS Flowrate to SX Plant
  - Single or Multiple trains
  - Extraction and Stripping Staging Requirement
  - Materials of Construction
  - Organic Tanks and Pumps
  - Organic and Diluent Initial Fill
  - Crud Treatment System

SOLVENT EXTRACTION PLANT CAPITAL COSTS

	FLOWRATE		CAPITAL COST	
	GPM	CIRCUIT DEFINITION	$MILLIONS	$/GPM
CASE 1	600	2+1, 1-Train	1.3	2190
CASE 2	3300	2-Train, Ser./Par.	2.4	740
CASE 3	3000	2+1, 1-Train	5.5	1820
CASE 4	3000	ENCLOSED, Ser./Par.	4.6	1550
CASE 5	8000	2+1, 2-Trains	11.0	1380
CASE 6	8300	2+1, 2-Trains	13.4	1610
CASE 7	13100	2+1, 3-Trains	18.5	1410

SOLVENT EXTRACTION PLANT CAPITAL COSTS



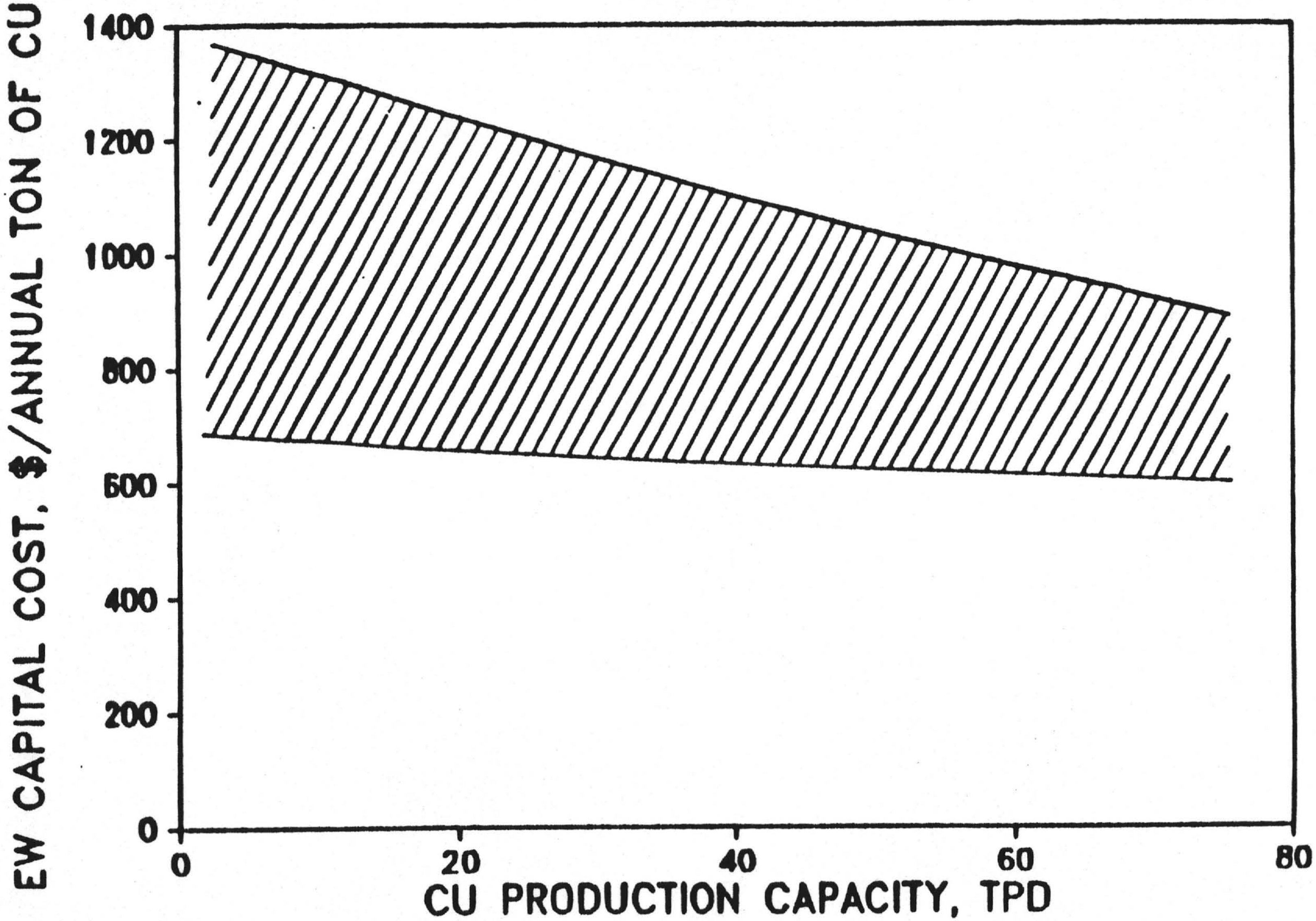
EW CAPITAL COST

- FACTORS THAT INFLUENCE EW CAPITAL COST ARE:
  - **Extent of Automation in Starter Sheet Preparation Equipment**
  - **Design Current density and Cells Current Efficiency**
  - **Conventional or Mount ISA Technology Selection**
  - **Materials of Construction and Degree of Weather Proofing**

EW CAPITAL COSTS

	Cu PRODUCTION TONS/DAY	CATHODE TYPE	CAPITAL COST. $MILLIONS	CAPITAL COST. $/ANN. TON of Cu
CASE 1	3.2	SS	1.3	1075
CASE 2	5.0	Cu. Import	1.3	700
CASE 3	15.0	Cu.	6.9	1260
CASE 4	13.8	SS	5.1	1020
CASE 5	45.5	Cu. Import	15.0	905
CASE 6	68.5	SS	19.4	775
CASE 7	63.8	Cu. Import	15.0	645

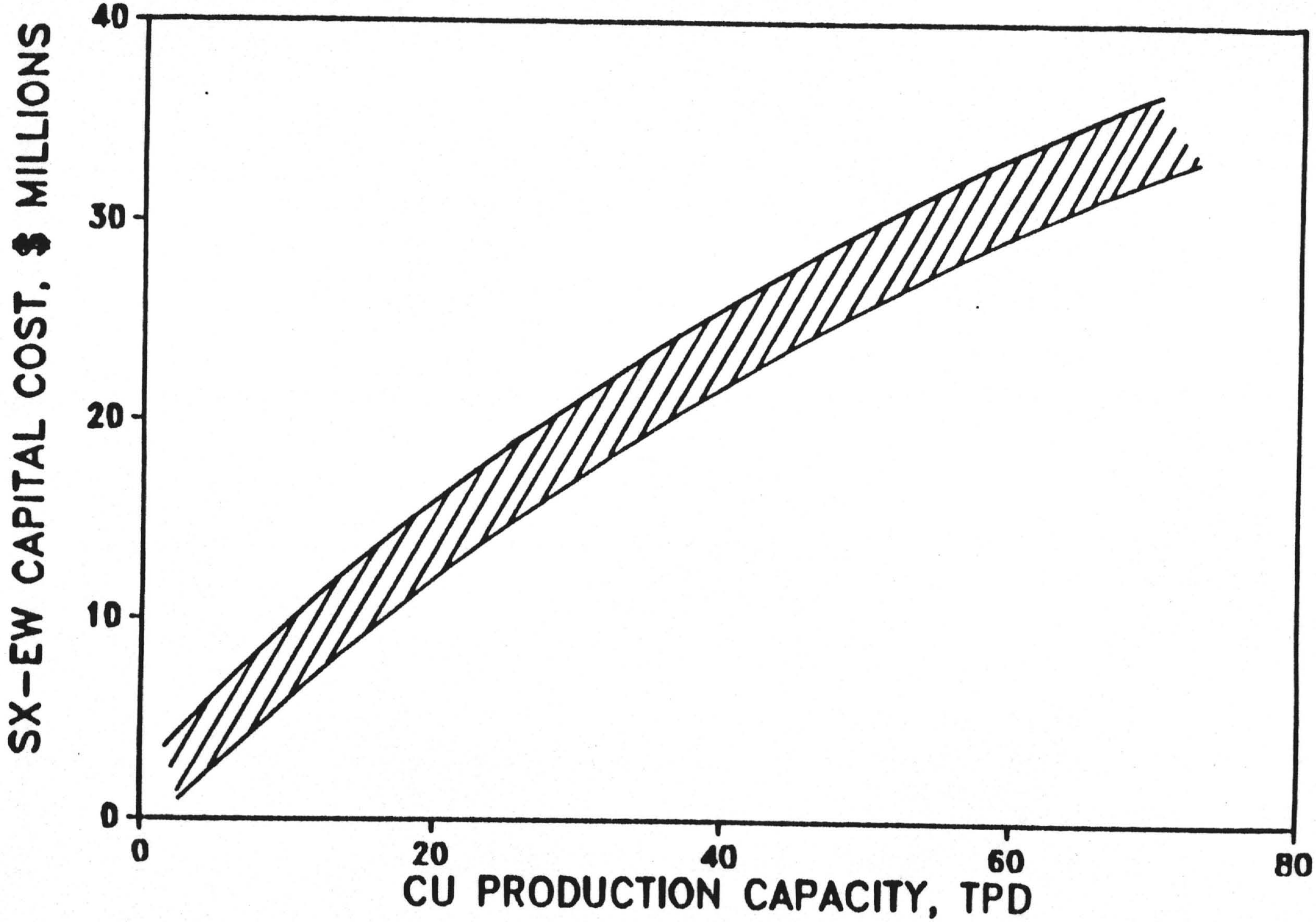
EW PLANT CAPITAL COSTS



SX-EW CAPITAL COSTS

	Cu PRODUCTION TONS/DAY	TOTAL CAPITAL COST. $MILLIONS	UNIT CAPITAL COST $/ANNUAL TON OF Cu
CASE 1	3.2	2.6	2180
CASE 2	5.0	3.7	2035
CASE 3	15.0	12.4	2255
CASE 4	13.8	9.8	1945
CASE 5	45.5	26.0	1570
CASE 6	68.5	32.7	1310
CASE 7	63.8	33.5	1435

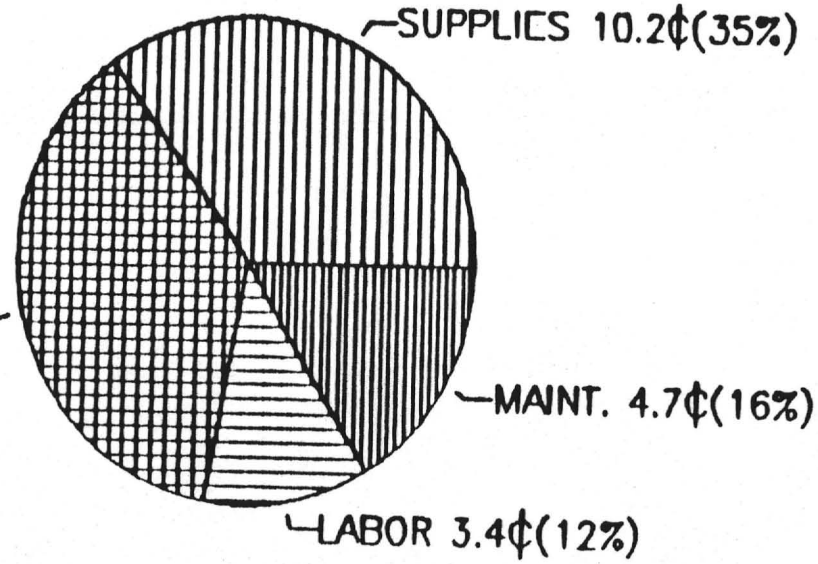
SX-EW CAPITAL COSTS



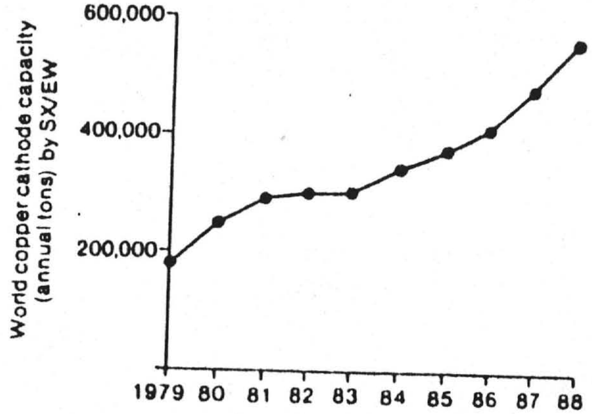
TYPICAL SX-EW DIRECT OPERATING COSTS

ITEM	UNIT	UNITS/TON OF CU	¢/LB. OF CU
SULFURIC ACID	LBS	573	0.7
ORGANIC DILUENT	GALS	12.9	1.0
ORGANIC REAGENT	LBS	3.5	1.1
COBALT	LBS	0.16	0.1
ANODES	EA	0.06	0.9
MISC. SX SUPPLIES	--	--	0.5
MISC. EW SUPPLIES	--	--	0.9
TOTAL SX-EW SUPPLIES			5.2
SX POWER	KW-HRS	388	1.5
EW POWER - MISC.	KW-HRS	14	0.1
EW POWER - RECTIFIERS	KW-HRS	1797	6.7
TOTAL SX-EW POWER		2199	8.3
SX LABOR	MH	1.2	0.9
EW LABOR	MH	2.0	1.5
TOTAL OPERATING LABOR			2.4
MAINTENANCE LABOR	MH	0.8	0.8
MAINTENANCE SUPPLIES	--	--	1.9
TOTAL MAINTENANCE			2.7
TOTAL SX-EW OPERATING COST			18.6

LEACH-SX-EW OPERATING COSTS



TOTAL 29.1¢/LB. OF CU



Growth of world copper cathode capacity by solvent extraction - electrowinning technology since the introduction of aldoxime reagents in 1979

APPENDIX I

WORLD COPPER SOLVENT EXTRACTION PLANTS
SEPTEMBER 1988

Company and Location	Start-up Date	Method of Leaching	Production Rate (mt/annum)	Feed Composition Cu tenor (g/l)	pH	Extractant	Diluent	No. of Streams	Aqueous Flow Rate per stream (m^3/hr)	Staging Extract	Staging Strip
Cyprus Bagdad, Arizona	1970	Dump leach	6 500	1.1	2.0	LIX 64N HS	Kermac 470B Chevron IES	4	190	4	3
Zambia Consolidated Copper Mines, Zambia	1974	Agitated tank leach of TAILINGS	100 000-120 000	5	1.9	ACORGA PT-5050 LIX 864/984	Escaid 100/ LSGO	4	750	3	2
ANAMAX Twin Buttes, Arizona	1974		CLOSED			(LIX & ACORGA)					
Cyprus Johnson, Arizona	1976		CLOSED PERMANENTLY			(LIX)					
Pinto Valley Copper Co. (Miami), Arizona	1976	In place leach	4 200	0.8	2.0	LIX 865	Phillips SX-7	2	320	3	2
Cerro Verde, Peru	1977	Dump Leach	33,000	2.7	2.0	LIX 64 NHS LIX 860	Local Kerosene	4	280	3	2
Duval Corp. Battle Mountain, Arizona	1979		CLOSED PERMANENTLY			(LIX)					
Inspiration CC Co. Arizona	1979	Heap Ferric Cure Leach	45 000	5.5	1.8	ACORGA M 5615 ACORGA P 5100	Chevron Ion Exchange Solvent	1	1020	2	2

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Asarco Ray Mine (formerly Kennecott) Arizona	1980	Dump Leach	39,000	5.0	1.8	ACORGA M.5397	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Heap Leach		0.96	2.2			2	680	1	1
Soc. Min Pudahuel, Chile	1980	Thin layer leaching	15,000	3.0	1.9	LIX 864	Escaid 100	3	200	2	1
Cia Minera de Cananea, Mexico	1980	Dump Leach	12,700	2.5	2.0	ACORGA M.5615 ACORGA P-5100 LIX 622	Hydrosol 1000	1	730	2	2
Centromin, Cerro de Pasco, Peru	1980	Mine Water	6 000	1.0	2.0	ACORGA P-5100 ACORGA M.5615	Local Kerosene	2	360	3	2
Pinto Valley Copper Co., (Pinto), Arizona	1981	Dump Leach	7 000	0.6	2.1	LIX 864	Phillips SX-7	2	700	2	2
Cyprus Casa Grande (was Noranda Lakeshore Arizona	1981	In-Situ Leach	6 000	1.5	1.6	ACORGA P-5100	Phillips SX-1	1	450	1	2
		Roast Leach	40 000	9.0	1.9			1	500	2	2
BHAS, Port Pirie S.Australia	1984	$Cl/SO_4/O_2$ Agitated Tank Leach	3 500	35.0	1.5	ACORGA P-5100	Shellsol 2046	1	20	2	2
Phelps Dodge, Burro Chief, Tyrone, New Mexico	1984	Dump Leach	39 000	2.6	2.0	LIX 984	Phillips SX-7	2	910	2	1
CODELCO-El Teniente Chile	1985	Mine water	5 000	1.2	3.0	ACORGA PT-5050 LIX 864	Escaid 100	1	340	2	2

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SEPTEMBER 1988

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Sunshine Mining, Idaho	1985	Agitated Tank	2 800	8.0	2.0	ACORGA PT-5050	Chevron IES	1	46	3	2
Magma, San Manuel Arizona	1985	Dump/ In-situ	46 000	1.7	2.0	LIX 622	Chevron IES	4	820	2	1
Gibraltar Mines Canada	1986	Dump Leach	6 000	1.0	2.0	ACORGA PT-5050	Shellsol 160	1	690	2	1
						ACORGA P-5100		1	690	1	1
Phelps Dodge Morenci, Arizona	1987	Dump Leach									
		IOS Plant	43 000	1.9	2.0	LIX 984	Phillips	2	1360	2	1
		Central	21 500	1.9	2.0	LIX 984	SX-7	1	1360	2	1
		S.W.Plant	9 000	0.4	2.5	ACORGA M.5640	" "	1	2720	3	1
										(series parallel)	
Tocopilla	1987	Heap Leach	1 500	8.0	1.5	ACORGA PT-5050	Escaid 100	1	24	2	1
Cyprus, Sierrita	1987	Dump leach	4 300	0.6	2.5	LIX 984	?	5	90	3	2
										(series parallel)	
CODELCO, Chuquicamata, Chile	1988	In-situ	80 000	6.0	2.0	ACORGA PT-5050	Shellsol 2046	1	1600	2	2
Roxby Downs/Olympic Dam, S.Australia	1988	Agitated Tank	3 500	1.0	1.1	LIX 622	Shellsol 2046	1	450	2	1
Phelps Dodge, Chino	1988	Dump leach	41 000	1.8	2.0	ACORGA M.5640	Phillips SX-7	2	1360	2	1

GROWTH OUTLOOK

- ❑ CAPACITY TO AT LEAST DOUBLE IN THE NEXT 10 YEARS

- ❑ TECHNOLOGY APPLICATION MAY BROADEN TO COVER:

    - In-Situ Leaching
    - Polymetallic Sulfides Processing
    - Bacterial Leaching

FUTURE SX TECHNOLOGY

- ❑ **IMPROVED REAGENTS FOR:**
  - **Better Copper Selectivity**
  - **Faster Kinetics**
  - **Less Phase Entrainment**

- ❑ **CONTINUOUS COUNTER CURRENT EQUILIBRIUM STAGE IN SINGLE VESSEL**

- ❑ **USE OF STATIC MIXERS**

- ❑ **USE OF ELECTROSTATIC PHASE SEPARATORS**

FUTURE EW TECHNOLOGY DEVELOPMENTS

- ❑ ELECTROLYTE PURIFICATION
- ❑ IMPROVED ELECTROLYTE DISTRIBUTION
- ❑ HIGH CURRENT DENSITY OPERATION
- ❑ INCREASED AUTOMATION
- ❑ COMPUTERIZED SCHEDULING AND MATERIALS HANDLING FUNCTIONS
- ❑ MIST COLLECTION AND SCRUBBING