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

PRINTED: 08/08/2002

ARIZONA DEPARTMENT OF MINES AND MINERAL RESOURCES AZMILS DATA

PRIMARY NAME: SIERRITA MINE

ALTERNATE NAMES:
SIERRITA OPEN PIT
CYPRUS SIERRITA

PIMA COUNTY MILS NUMBER: 243

LOCATION: TOWNSHIP 18 S RANGE 12 E SECTION 7 QUARTER SE
LATITUDE: N 31DEG 52MIN 17SEC LONGITUDE: W 111DEG 08MIN 53SEC
TOPO MAP NAME: BATAMOTE HILLS - 7.5 MIN

CURRENT STATUS: PRODUCER

COMMODITY:
COPPER SULFIDE
MOLYBDENUM SULFIDE
SILVER
GOLD
RHENIUM

BIBLIOGRAPHY:
ADMMR SIERRITA MINE FILE
E&MJ AUG. 1970, JUNE 1975, P. 98,
E&MJ AUG. 1970, P 70, FLOT-MILL-FEED CAP

DUVAL SIERRITA CORPORATION

Economic Geology, Volume 77, November 1982, Number 7, "Contrasting Evolutions of Hydrothermal Alteration in Quartz Monzonite and Quartz Diorite Wall Rocks at the Sierrita Porphyry Copper Deposit, Arizona, By R.K. Preece III and R.E. Beane, Page 1621.

ARIZONA DEPARTMENT OF MINES AND MINERAL RESOURCES

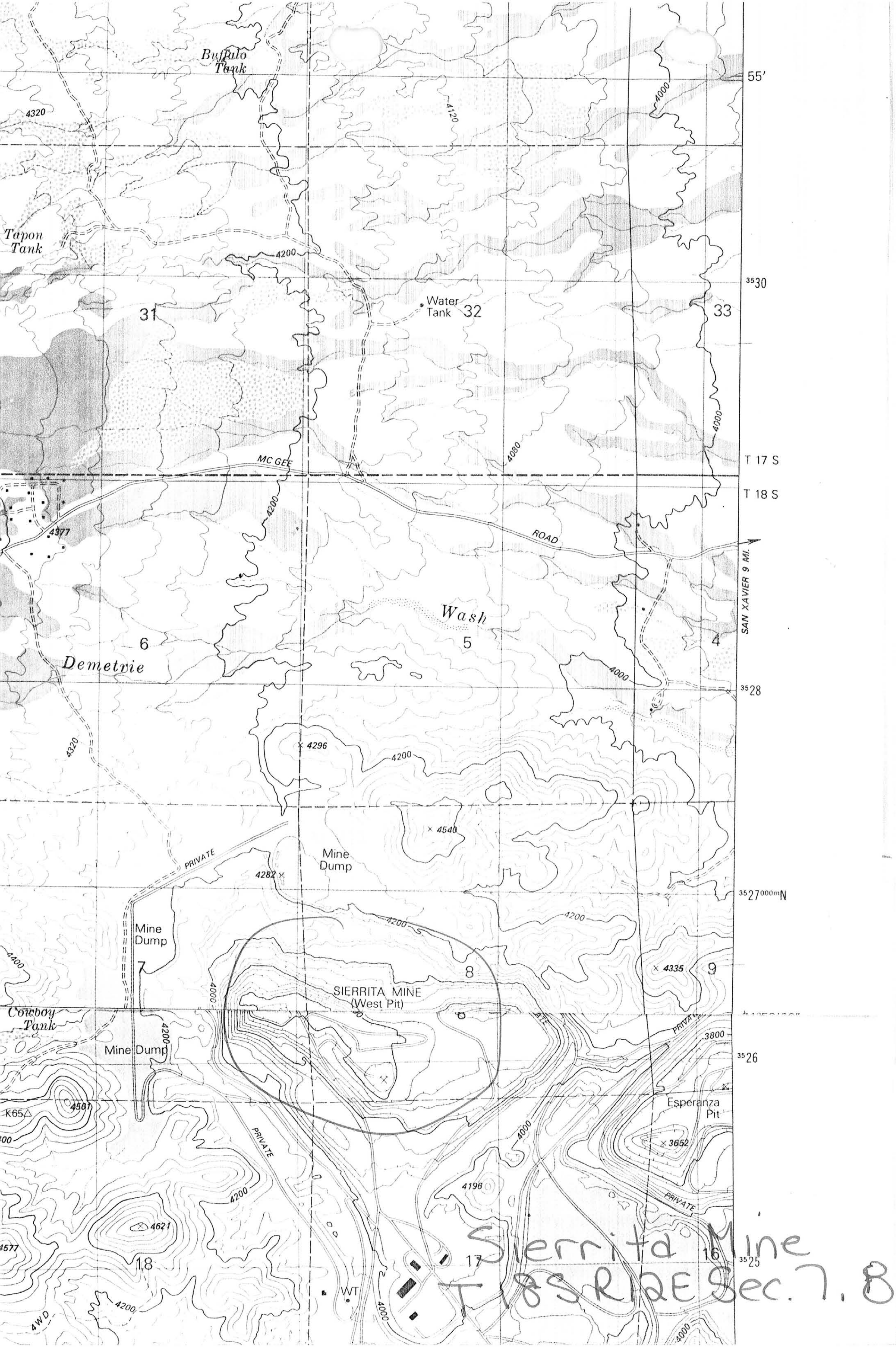
INFORMATION FROM MINE CARDS IN MUSEUM

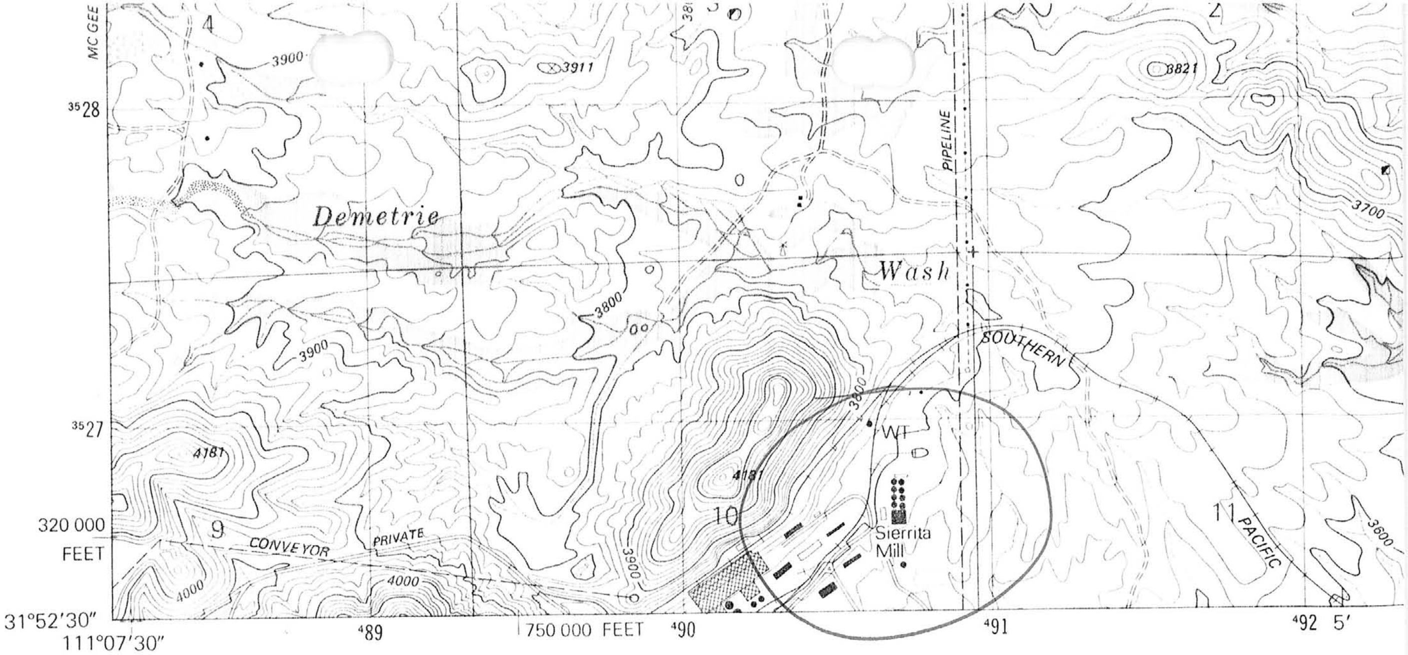
ARIZONA
PIMA
~~PINAL~~ COUNTY

(DUVAL) SIERRITA MINE

MM 2655 FERRO-MOLYBDENUM ALLOY
2656 SLAG

MILS # 243
1-AKA
Sierrita mine file


Buffalo Tank
55′
4320
4120
4000
Tapon Tank
4200
3530
Water Tank
31
32
33
4000
T 17 S
T 18 S
MC GEE
ROAD
4080
4200
4377
SAN XAVIER 9 MI.
Wash
6
5
4
Demetrie
4000
3528
4320
4296
4200
4540
PRIVATE
Mine Dump
4282
3527000mN
4200
4200
Mine Dump
4400
8
4335
9
7
SIERRITA MINE
(West Pit)
4000
Cowboy Tank
4200
Mine Dump
3800
3526
4567
K65
Esperanza Pit
PRIVATE
3652
4000
4200
4196
PRIVATE
4621
4577
18
17
16
3525
WT
4000
4200
4WD
4000
Sierrita Mine
T18S R12E Sec. 7, 8



(BATAMOTE HILLS)
3747 I SW

Mapped, edited, and published by the Geological Survey

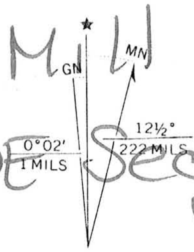
Control by USGS and NOS/NOAA

Topography by photogrammetric methods from aerial photographs taken 1975. Field checked 1976
Map edited 1981

Projection and 10,000-foot grid ticks: Arizona coordinate system, central zone (transverse Mercator)
1000-meter Universal Transverse Mercator grid, zone 12
1927 North American Datum
To place on the predicted North American Datum 1983 move the projection lines 7 meters south and 62 meters east as shown by dashed corner ticks

Fine red dashed lines indicate selected fence and field lines where

Sierrita Mill
T18S R12E Sec. 10
S2



UTM GRID AND 1981 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

Twin Buttes 7.5'

DUVAL SIERRITA CORPORATION

RI 8070, p. 3

Skillings Mining Review, December 30, 1967, p. 16
" " " January 20, 1968, p. 18
" " " February 17, 1968, p. 12
" " " March 23, 1974, p. 19
" " " May 18, 1974, p. 15
" " " July 13, 1974, p. 1, 16-20 (mine blasting)
" " " November 9, 1974, p. 28 (conveyor belting)
" " " February 22, 1975, p. 19 (personnel)

Mining Engineering, February, 1968, p. 21
" " April, 1968, p. 28
" " April, 1973, p. 42
" " June, 1974, p. 55
" " December, 1974, p. 65 (crushing parameters)
" " January, 1975, p. 50 (personnel)

E/MJ, Vol. 164, No. 8, August, 1963
" February, 1968, p. 161
" June, 1973, p. 38
" January, 1975, p. 78

Mining Congress Journal, June, 1968, p. 19
" " " November, 1974, p. 108 (steel cable belting for mine)

The Mines Magazine, October, 1970, p. 4-10

Mining Magazine (London), March, 1971, p. 192
" " June, 1974, p. 469 (personnel)

Mining Annual Review 1974, p. 307

Economic Geology, Volume 75, Aug. 1980, #5, "The Evolution of Fracture-Related Permeability within the Ruby Star Granodiorite, Sierrita Porphyry Copper Deposit, Pima Co., Az. by Frederick M. Haynes and S.R. Titley, Page 673.

ABSTRACTED FROM ADMMR ACTIVE MINES DIRECTORY, 1992 Pima

CYPRUS COPPER COMPANY
(A subsidiary of Cyprus Minerals Company)

P. O. Box 1126, Green Valley, AZ 85622 - Phone 628-4000.

Cyprus Sierrita Corp.
Sierrita T18S R12E Secs. 7, 8, 9, 10, 16, 17
Twin Buttes T18S R13E Sec. 5

P.O. Box 527, Green Valley, AZ 85622 - Phone 791-2950 and 625-4800 - Employees: 1130 plus 50 Triple Nichol Inc. contract employees - Sierrita, Esperanza and Twin Buttes open pit copper-molybdenum mines - 95,000 TPD concentrator - The inactive Esperanza open pit - 17,500 TPD concentrator - Ferromolybdenum plant - Rhenium plant - Oxide leach, solvent extraction - electrowinning plant - Dump leach, solvent extraction - electrowing plant - Located 30 miles south of Tucson.

Vice President & General Manager Gene Consalus
Manager, Administration Mark Wilson
Manager, Mining D. L. Prahl
Manager, Metallurgical Processing M. H. Khan
Manager, Human Resources Craig Patrick
Plant Manager Bob Comstock
Mine Superintendent Leon Hardy
Oxide Superintendent Ramon Hernandez

ABSTRACTED FROM ADMMR ACTIVE MINES DIRECTORY, 1991

CYPRUS COPPER COMPANY
(A subsidiary of Cyprus Minerals Company)

P. O. Box 1126, Green Valley, AZ 85622 - Phone 628-4000.
Executive Vice President .... James C. Compton
Vice President Technical Services ....Ron Kellner
Cyprus Sierrita Corp.
Sierrita T18S R12E Secs. 7, 8, 9, 10, 16, 17
P.O. Box 527, Green Valley, AZ 85622 - Phone 791-2950 and 625-4800 - Employees: 942 - Sierrita open pit copper-molybdenum mine - 1,000 TPD concentrator - The inactive Esperanza open pit - 17,500 TPD concentrator - Ferromolybdenum plant - Rhenium plant - Dump leach - Solvent extraction - electrowinning plant - Located 32 miles south of Tucson.
Vice President & General Manager .... T.J. O'Neil
Manager, Administration .... Mark Wison
Manager, Mining .... D.L. Prahl
Manager, Copper Operations .... Bob Comstock
Manager, Molybdenum Operations .... M.H. Khan
Manager, Human Resources .... Craig Patrick
Mine Superintendent .... Leon Hardy

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ABSTRACTED FROM ADMMR ACTIVE MINES DIRECTORY, 1989

Cyprus Sierrita Corp.

Sierrita T18S R12E Secs. 7,8,9, 10,16 & 17

P.O. Box 527, Green Valley 85622 - Phone 791-2950 and 625-4800 - Employees 942 - Sierrita open pit copper-molybdenum mine - 1,000 TPD concentrator - The inactive Esperanza open pit - 17,500 TPD concentrator - Ferromolybdenum plant - Rhenium plant - Dump leach - Solvent extraction- electrowinning plant - Located 32 miles south of Tucson.

Vice President & General Manager	T.J. O'Neil
Manager, Administration	K.D. Comer
Manager, Mining	D.L. Prahl
Manager, Copper Operations	R.R. Dorfler
Manager, Molybdenum Operations	M.H. Khan
Manager, Human Resources	A.J. Murray

ABSTRACTED FROM ADMMR ACTIVE MINES DIRECTORY, 1988

CYPRUS COPPER COMPANY

9100 E. Mineral Circle, P.O. Box 3299, Englewood, CO 80112 - Phone (303) 643-5000.

Executive Vice President .... F. Steve Mooney
Vice President & Controller .... Daniel Zang

Sierrita T18S R12E Secs. 7,8,9, 16 & 17

P.O. Box 527, Green Valley 85622 - Phone 791-2950 and 625-4800 - Employees 859 - Sierrita open pit copper-molybdenum mine - 1,000 TPD concentrator - The inactive Esperanza open pit - 17,500 TPD concentrator - Ferromolybdenum plant - Rhenium plant - Dump leach cementation plant - Solvent extraction-electrowinning plant - Located 32 miles south of Tucson.

Vice President & General Manager .... C.G. Janes
Manager, Administration .... Don Murray Jr.
Manager, Mining .... W.A. Gibson
Manager, Copper Operations .... R.R. Borfler
Manager, Molybdenum Operations .... Michael Fraser
Manager, Human Resources .... A.J. Murray

Janet Napolitano
Governor

ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

1110 West Washington Street • Phoenix, Arizona 85007
(602) 771-2300 • www.azdeq.gov

Stephen A. Owens
Director

SIERRITA (P) PIMA

NOTICE OF THE PRELIMINARY DECISION TO ISSUE AN INDIVIDUAL AQUIFER PROTECTION PERMIT

Public Notice No. 02B-06APP

Published on July 7, 2005
In the Arizona Business Gazette

Pursuant to Arizona Administrative Code, Title 18, Chapter 9, Article 1, the Director of the Arizona Department of Environmental Quality (ADEQ) intends to issue an individual Aquifer Protection Permit to the following applicant:

Phelps Dodge Sierrita Incorporated Mine
6200 West Duval Mine Road
Green Valley, Arizona 85622

Phelps Dodge Sierrita Incorporated Mine
Aquifer Protection Permit (APP) No. P-101679

The Phelps Dodge Sierrita Mine is located near the Town of Green Valley, Arizona, in Pima County, over groundwater of the Upper Santa Cruz Basin, as described below using the Gila and Salt River Baseline and Meridian:

Sections 8, 9, 13, 16, 17, 19, 20, and 21; parts of Sections 3-7, 10, 11, 14, 15, 18, and 24; Township 18 South, Range 12 East.
Sections 17-20, 29; and parts of Sections 16, 21, 28, and 30; Township 18 South, Range 13 East.

The permit will authorize activities related to the Phelps Dodge Sierrita Mine mining operations. The permitted operations include open-pit copper mining and related leaching operations, and related molybdenum producing operations. Permitted facilities include leach rock deposition areas; leach solution ponds, dams, sumps, impoundments, and associated conveyance systems; and stormwater, process overflow and upset condition impoundments.

On August 17th, 2005, beginning at 9:30 a.m. ADEQ will conduct an Open House and Public Comment Hearing at the Desert Hills Social Center, located at 3660 South Camino Del Sol, Green Valley, Arizona.

Open House

At 9:30 a.m., prior to the Public Comment Hearing, ADEQ will conduct an Open House in order for the public to discuss the Sierrita Mine draft Aquifer Protection Permit (APP) with ADEQ staff members.

Public Comment Hearing

Beginning at 10:30 a.m., ADEQ will conduct a Public Comment Hearing to accept comments from the general public regarding the Sierrita Mine draft APP.

The draft permit, Fact Sheet, and related documentation are available for public review, Monday through Friday, 8:30 a.m. to 4:30 p.m., at ADEQ, 1110 West Washington Street, Records Management Center, Phoenix, Arizona, 85007. Please call (602) 771-4380, or e-mail at RecordsCenter@azdeq.gov, to schedule an appointment to review the file.

Persons may submit comments on the proposed action, in writing, to Jeff Emde, ADEQ, 1110 West Washington Street, MC 5415B-3, Phoenix, AZ 85007 within forty-five (45) days from the date of this notice.

DUVAL - SIERRITA CORP

NJN WR 1/17/86: It was reported that Duval Corp. Sierrita MIne (f) Pima Co. has been processing 1 8.000 tons of ore thru its crushing plant and mill.

MG WR 5/2/86: Attempted to visit new managers at the Sierrita mine but they were not available. Did drop off some ADMMR publications. The name of the operating company is Cyprus Sierrita Corporation.

Duval-Sierrita Corp.

Vito Brussolo stopped at office to update his activities. He will continue at Duval's Sierrita Mine, however, his title has been changed to Engineer Consultant with General Services Administration. VBD WR 6/11/76

Jim McCarty, Duval's Manager at Battle Mountain, Nevada called re: laws regulating the treatment and sale of gold saying they had closed the copper mine but had acquired a 10 million ton gold property. GW WR 12/14/77 a.p.

MG WR 9/18/81: The Duval Corp. is constructing a rhenium extraction plant at Sierrita mine (Pima County). Plans are to recover rhenium from off-gases produced in roasting MoS_2.

NJN WR 1/7/83: It was reported that some of Duval's precipitates from Sierrita are being shipped to Battle Mountain, Nevada. There they are redissolved. Some of this solution goes to make $CuSO_4$ for the moly flotation circuits, while the rest is run thru Battle Mountains' SX plant to produce cathode copper.

KAP WR 12/9/83

A paper on Duval's rhenium recovery circuit was given at the AZ Conference of the AIME meeting in Tucson on Dec. 5, 1983. Some details of interest include the following: Current copper ore production at hthe mine is running between 42,000 and 72,000 tons per day at 0.35% copper and 0.03%Mo. Rhenium is recovered from the flue dust produced at the molybdenum roasting plant where MoS_2 is converted to MoO_3. Before roasting the molybdenum concentrate contains 180 ppm rhenium. Approximately 10 pounds of rhenium per day is obtained from the acid mist reduction circuit of the roaster flue gas treatment plant. The contained rhenium in the acid colledted from mist reducer is extracted by resin ion exchange methods nand purified by successsive pecipitate steps to produce reagent grade ammonium perheniate. The plant is currently idle due to depressed consumption of the rhenium product.

MG WR 12/21/1984: ASARCO is looking at the Sierrita mine (Pima Co.) as a possible purchase from Duval.

DUVAL SIERRITA CORPORATION PIMA COUNTY

Dir. of Mining - August 1971 - 1,250 employees.

Duval-Sierrita near capacity. GWI QR 9/71

The Duval Sierrita Mine was in full production. GWIQR Oct-Dec '71

Sierrita continues production having reached full production. GWI QR Jan.-March'72

Active Mine List - October 1972 - Empl. 1250 (1971 figures 25,727,195 T Ore, 46,568,480 T Waste, 63,049 T Cu)

Kaiser-Marconaflo are supposed to be experimenting at Duval Sierrita. GWI WR 7/9/74

Tucson Star carried an article regarding Pima County Board of Supervisors approving law suit against State to attempt to force an increase in mine valuations at Sierrite, Twin Buttes and Pima mines. The law firm selected by County is Johnson, Hayes and Dowdall, Ltd. The attorney handling the case is Anthony D. Terry of Phoenix. The County's expert witness will be Alfred Patrick, Jr., Professor of Mineral Economics at Colorado School of Mines. VBD WR 10/9/74

Duval Sierrita mine visit with K. Lamb, Bob Zache and Don Jones. Took pit tour and examined large boulders for drilling contest. GWI WR 12/17/74

Trip through Duval Sierrita mine and mill and the new moly smelter. GWI WR 3/8/75

Vito Angelo Brussolo phoned that Duval Sierrita had mined 100,000 TPD under a new set up. GWI WR 7/21/75

Mine visit - Duval Sierrita mine. Tour through all of the facilities except the new clear plant. GWI WR 1/20/76

Bill Hardwick, John Jett & I drove to the Duval-Sierrita operation south of Tucson where we were met by Gerry Irvin and Vito Brussolo, U.S. Engineer for Strategic Services Copper stockpile, and the man who recommended that the Federal Government participate in the development of this orebody. The government loan is nearly paid off. Mr Burssolo gave us a tour of all facilities except the new clear plant which is being operated on an experimental basis and is off limits to everyone except those working in the plant. VBD WR 1/20/76

DUVAL SIERRITA CORPORATION

Duval announced that the Duval Sierrita operation would be scheduled for 72,000 tpd with primary expenditures rising from $88 to $100,000,000. This is supposed to be the largest single mill installation in the U.S. The railroad has been completed from Anaconda spur to the Duval property. GWI QR 12-1968

Duval Sierrita is going up ahead of schedule. GWI QR 3-1969

Active Mine List April 1969 - 542 men - S. H. Martin, Res. Mgr., Box 125, Sahuarita

Duval Sierrita construction and planning was going along as scheduled. GWI QR 9-1969

Duval is about ready to start milling at its new Sierrita pit south of Tucson, Arizona. This is a planned 72,000 tpd milling operation with an average feed grade of 0.35 percent copper and 0.036 percent molybdenum. Total stripping ratio will be 1.53 to 1.0 at Sierrita. Taken from World Mining 12-69 p. 29

Active Mine List Oct. 1969 - 558 men - J.P. McCarty, Res. Mgr. Duval Corp.

Duval Sierrita began production. By fall this should be Arizona's largest tonnage producer of copper ore. (not copper) GWI QR 4-1-70

Active Mine List May 1970 - 889 men - J. P. McCarty, Res. Mgr.

Mr. Kenrick L. Lamb is now Mine Supt. at Sierrita. FTJ WR 5-6-70

The Duval Sierrita Mine was dedicated during the quarter. GWI QR 6-30-70

Arizona with 53 percent of the copper produced in 1970 was followed by Utah, New Mexico, Montana, and Nevada, and Michigan. The Duval Sierrita mine in Arizona, owned by Pennzoil United Corp., was dedicated in June and achieved capacity production of 65,000 tons of ore per day in October. Development of this mine was partly financed by loans from the Government that will be repaid by deliveries of refined copper to the national stockpile. Taken from Mineral Industry Survey "Copper in 1970" 12-17-70

Active Mine List Oct. 1970 - 1102 men - J.P. McCarty, Res. Mgr.

The Pima District Mines continued their large production rate. Duval Sierrita is working out the bugs in the new mill. GWI QR 10-1-70

Production at Duval Sierrita was approaching rated capacity. GWI QR 4-1-71

SIERRITA (P) PIMA

phelps dodge Sierrita Inc. 6200 W. Duval Mine Road • P. O. Box 527 • Green Valley, AZ 85622-0527
(520) 648-8500

Arizona Conference of SME

2002 Spring Mineral Processing Meeting

Expert Grinding Control at Phelps Dodge Sierrita

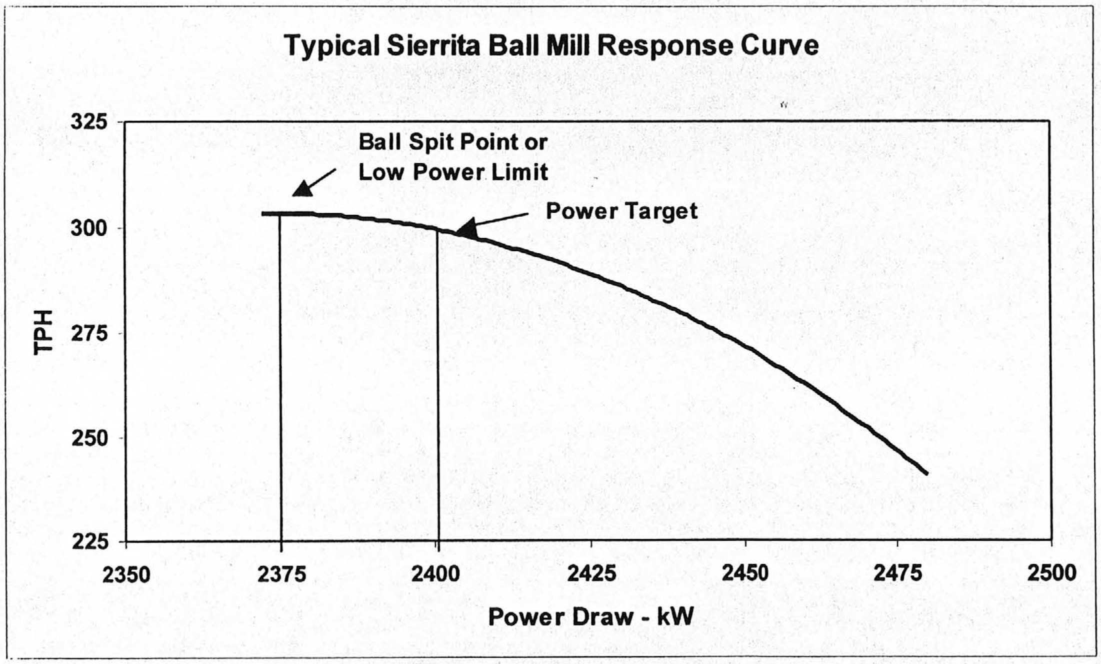
James Rumph
Chief Metallurgist

phelps dodge Sierrita Inc. 6200 W. Duval Mine Road • P. O. Box 527 • Green Valley, AZ 85622-0527
(520) 648-8500

Expert Grinding Control at Phelps Dodge Sierrita

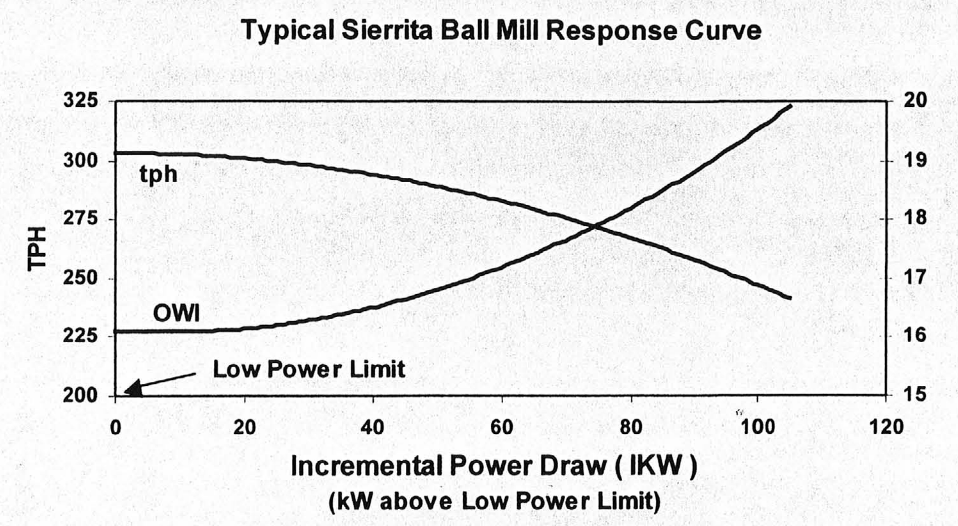
Introduction and History

Primary ball mill grinding control at Sierrita has, as it has in many locations, been a gradual evolution. However, throughout this evolution, there was a fundamental shortcoming in all of the strategies attempted and/or implemented. Sierrita has, in the last 9 months, developed a means to address this shortcoming. It is that advance that this paper will discuss. But, in order to do this, it is necessary first to briefly discuss historical strategies. Accordingly, a typical throughput vs. power draw response curve for a Sierrita mill follows.



As can be seen, throughput rates drop more and more rapidly with increasing power draw. Though some slight improvements in grind are seen with the lower throughputs, they are not sufficient to offset the throughput loss, and the grinding efficiency drops proportionately. All operating strategies, including the current one, are based on driving the power down by increasing the feed rate. The goal is to achieve as low a power draw, with as high a throughput, as possible. Sierrita's ball mills are overflow mills and the lowest power to which they can be pushed, which is called the Low Power Limit, is that power at which the mills eject, or "spit", grinding balls. In practice, it is not feasible to operate right at the Low Power Limit since minor process deviations lead to ball spitting. Sierrita's current target is to operate at 25 kW above the Low Power Limit.

Since each of the 16 ball mills spit balls at a different power level, it is necessary to view this response curve in terms of kW above the point at which the specific mill spits balls or kW above the Low Power Limit. This will be called the Incremental Power Draw or IKW. The chart below shows Throughput and Operating Work Index as a function of the Incremental Power Draw. As can be seen, the Operating Work Index increases dramatically at higher Incremental Power Draws, quickly leading to uneconomic operation.



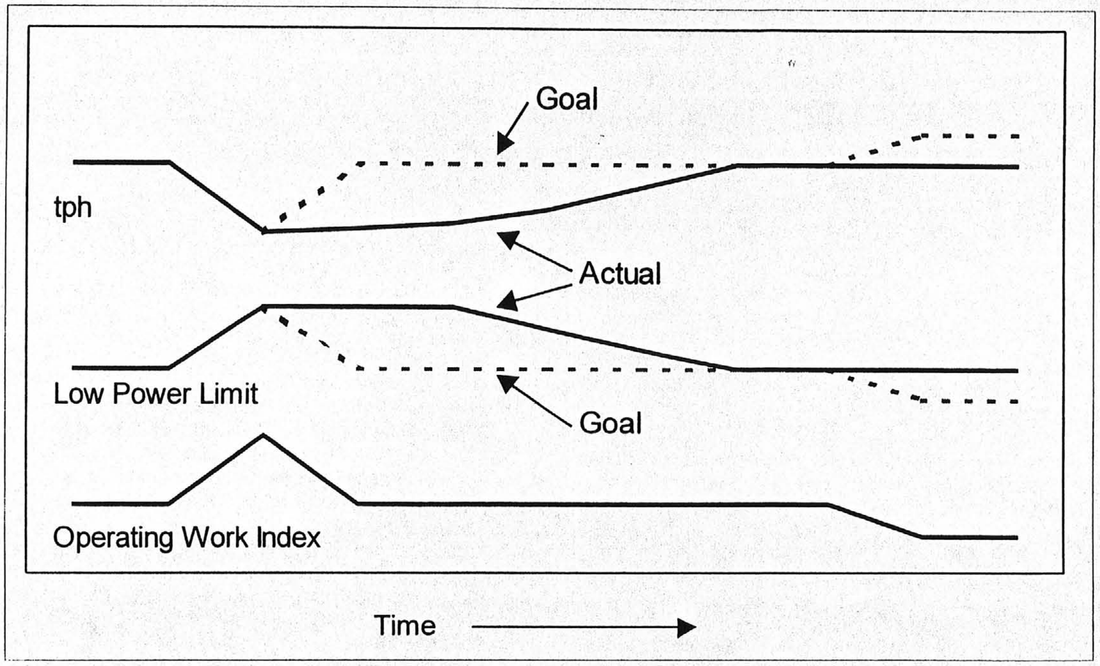
Earlier it was noted that all grinding control strategies ever used at Sierrita had a fundamental shortcoming. This was an inability to measure the Low Power Limit as frequently as needed. The Low Power Limit could only be measured by overloading the mill, making it spit balls, and noting the power draw at that point. This resulted in a minor process upset, wasted grinding media, and the cost of hauling the spit media out of the concentrator. And this limit is constantly changing. In harder ore, the mills spit balls at significantly higher power draws than in softer ores. And other factors affect the ball spit point as well. These include liner age, ball charge level, ore feed size, ore feed size distribution (% fines), and probably many others.

During normal operations, it was not uncommon for the Low Power Limit to have to be moved up 45 kW in a 24 hour period due to ball spitting caused by harder ore. And there was no mechanism in place to move it back down quickly when the rock became softer. Operators might note higher throughputs and push the Low Power Limit lower but this was very time consuming and the operators would have no good measure of how big an adjustment to make. Operating practice at the time was to overload, and force to spit balls, only those mills which had not spit for 7 days. Thus, the mills would continue to operate at elevated Low Power Limits, often for days, well after the ore had become softer. As a result, the mills were often operating at a true Incremental Power Draw of 30 – 70 kW instead of the target of 25 kW. From the relationship depicted on the above chart, it is apparent that significant throughput was lost in this way. This was the state of grinding control through May of 2001.

Years earlier, in 1993, a modern distributed control system (DCS) had been installed in the Sierrita concentrator. Very shortly after that, supervisory grinding control capability had also been acquired in the form of a rules-based expert system utilizing Gensym Corporation's G2 software running on HP 9000 workstations. Over the ensuing 2 years, two approaches to grinding control were developed concurrently, one self-contained within the DCS platform and a second residing on the supervisory G2 platform interfacing with the DCS. These were tested against each other and found to be equivalent in terms of grinding efficiency. Neither system addressed the shortcoming already outlined. Subsequently, due to ease of use and operator familiarity, the DCS system was adopted and the G2 supervisory hardware languished in a back office of the Sierrita Metallurgical Laboratory. These computers were not turned off or disconnected but simply idled for the next 5-6 years.

Low Power Limit Tuning

Then, in June of 2001, following the addition of two metallurgists to the Metallurgical Laboratory staff, sufficient resources became available to once again address grinding control. The goal was to measure the ore work index and ramp the Low Power Limit up as the ore got harder. This would prevent ball spitting and process upsets. Then, as the ore got softer, the Low Power Limit would be ramped back down to take immediate advantage of the increased throughput capability with softer ore. This is depicted on the chart below.



However, this required a real time measurement of work index. This requirement was complicated by the fact that there was no real time measurement of either feed size or product size. Particle Size Monitors have been tried several times over Sierrita's history and were found to be unreliable and hard to maintain.

Though measurement of the work **index** was problematic, it was possible to measure work **input**, i.e. kW-hrs per ton, on a real time basis. However, Sierrita's operating practice was to use the cyclone overflow density to adjust mill throughput to match the ore supply from the mine and crushing plant. Therefore, when the ore supply was limited, cyclone overflow densities were lowered by the operator which provided a finer grind with commensurate lower throughputs. Thus, production would be optimized by obtaining higher metal recoveries on the limited ore available. Then, when the ore supply was abundant, densities were raised which would provide coarser grinds but sufficiently higher throughputs to more than offset the reduced recoveries and thereby increase metal production. This adjustment of mill throughputs had an obvious, and significant, impact on the work **input**, thus rendering it useless as a measure of work **index**.

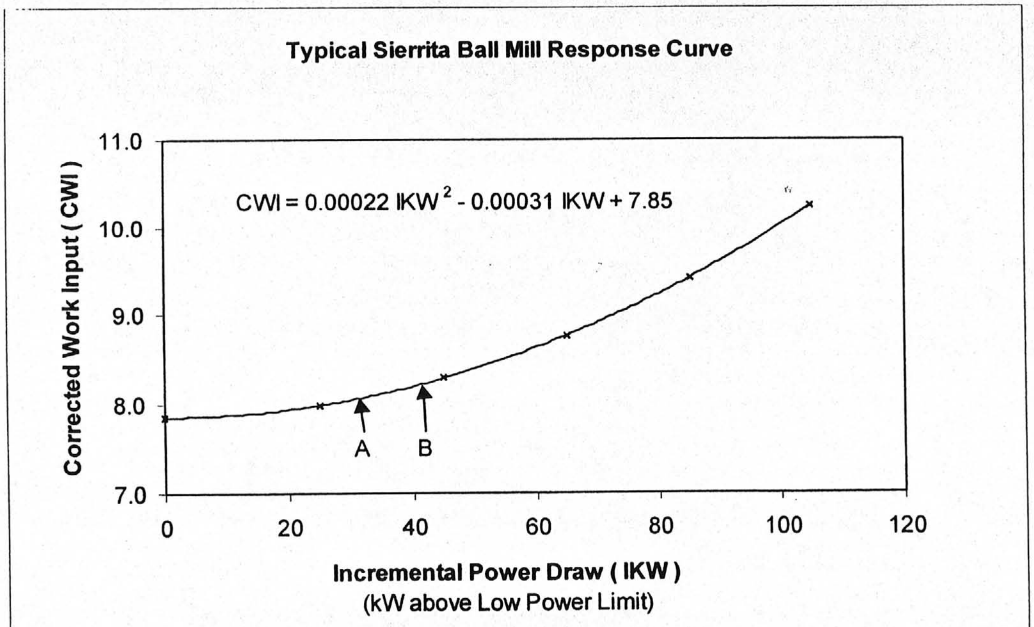
This obstacle was overcome through the use of the cyclone overflow density as an empirical measure of product size. From prior work, the impact of cyclone overflow density on product size and throughput was moderately well established. This allowed a "Corrected Work Input" to be calculated on a real time basis. This was simply the work input in kW-hrs/ton with a correction factor added based on the cyclone overflow density. After some trial and error with the correction factor, a Corrected Work Input was obtained which remained relatively constant through the range of cyclone overflow density changes and corresponding throughput changes. The impact of feed size was simply ignored in the calculation under the belief that, since Sierrita's crushing circuit is closed, it would be sufficiently consistent as to not introduce undue variability. In practice, the Corrected Work Input was typically half the magnitude of the operating work index but proved to be a sufficiently good relative measure of the work index to serve the purpose.

In this way, adjustment of the Low Power Limit based on ore hardness became possible. This came to be called Low Power Limit Tuning. With this strategy, a ball mill would be periodically overloaded and made to spit balls. The operator would then electronically initiate a grind-out of the mill. This would both unload the mill and cause the DCS to automatically note the power draw and Corrected Work Input (CWI) at that point. These would constitute the "baselines" for the Low Power Limit and the Corrected Work Input, respectively. Subsequently, as the actual Corrected Work Input varied from the baseline Corrected Work Input, the actual Low Power Limit would be modified from the baseline Low Power Limit. The mill power targets would be changed accordingly so as to stay always 25 kW above the Low Power Limit.

Since all grinding control then in use was self-contained within the DCS, the initial programming for Low Power Limit Tuning was implemented on the DCS. It was first implemented on a single ball mill on a test basis and was moderately successful. The Low Power Limit during normal operation was now tuned according to ore hardness and so more accurately represented, day in and day out, the actual point at which the mill would spit balls. As a result, the number of process upsets was reduced and throughput was modestly improved. However, Low Power Limit Tuning did not completely address the shortcoming of an inability to measure the Low Power Limit as frequently as needed. The many other secondary factors affecting the ball spit point still led to inaccuracies requiring periodic "recalibration" of the Low Power Limit baselines. As before, this could only be done by periodically overloading the mill and causing it to spit balls.

Work Input Derivative Grinding Expert Tuning (WIDGET)

At the same time as some measure of success with Low Power Limit Tuning was being realized on a single test mill, an idea was conceived for addressing the need for periodic recalibration of the baselines. Shown below is a chart depicting the same relationship shown previously with the difference that the Operating Work Index shown on the prior chart has now been replaced by the Corrected Work Input.



As can be seen, the Corrected Work Input is very flat at the Low Power Limit then curves upward more and more steeply with increasing Power Draw. The concept was that perhaps the mill power setpoint could be raised a small amount, thereby moving the mill's operation from point A to point B, as shown above. The resulting change in the Corrected Work Input could be measured and the slope of the curve at that point could be calculated by dividing the increase in the Corrected Work Input by the amount the power was raised to induce that increase. The entire curve can be described by a second order polynomial equation, as shown on the c[illegible] y taking the derivative of this equation, an e[illegible] defining the slope of the curve as a function of the incremental Power Draw (IKW) is obtained.

$$\left(\frac{dCWI}{dIKW}\right) = (2)(0.00022)(IKW) - (0.00031)$$

or

$$\left(\frac{dCWI}{dIKW}\right) = 0.00044\,IKW - 0.00031$$

Then, by solving this equation for the Incremental Power Draw (IKW), an equation describing the Incremental Power Draw as a function of the slope is obtained.

$$IKW = \frac{\left(\frac{dCWI}{dIKW}\right) + 0.00031}{0.00044}$$

or

$$IKW = 2273\left(\frac{dCWI}{dIKW}\right) + 0.70$$

Thus, by measuring the slope (dCWI/dIKW), the Incremental Power Draw at that point would be known which, in turn, would define the Low Power Limit. For instance, if the IKW determined in the aforementioned fashion was 40 kW and the average power draw during the test was 2390 kW (the average of the actual power draw at "A" and at "B"), the new Low Power Limit would be 2390 – 40 or 2350 kW. This would be the Low Power Limit at the time the test was conducted, i.e. under the ore conditions extant at the time of the test. As such, it would constitute the Low Power Limit baseline for subsequent Low Power Limit tuning. The new baseline Corrected Work Input is the Corrected Work Input at an Incremental Power Draw of 0. As such, it is the intercept in the polynomial equation on the previous chart. However, this equation represents the CWI-IKW relationship at one point in time and so, due to changes over time, the intercept, or baseline Corrected Work Input, must be recalculated as part of each measurement. This is done by inputting the IKW result into the polynomial equation shown on the chart along with the average Corrected Work Input at "A" and at "B" (8.0 in the example shown below).

$$CWI = 0.00022\,IKW^2 - 0.00031\,IKW + \text{New Baseline CWI}$$

$$8.0 = 0.00022\,(40)^2 - 0.00031\,(40) + \text{New Baseline CWI}$$

$$\text{New Baseline CWI} = 7.66$$

Since it was the derivative of the Work Input curve that was being used, this concept became known as Work Input Derivative Grinding Expert Tuning or WIDGET. It was hoped that, in this way, the baselines could be determined without the need to overload the mill and spit balls. Therefore, these recalibrations could be conducted more frequently. Low Power Limit Tuning would then be in effect throughout the period between baseline recalibrations by WIDGET. This combination would provide a Low Power Limit which would be more accurate or, viewed another way, accurate a higher proportion of the time. This would have the effect of both lowering grinding power consumption and increasing throughput.

Having established the base relationships, the next hurdle was the actual programming to test the concept in operation. As mentioned earlier, all of the expert grinding control programming then in use resided on the DCS including the test mill utilizing Low Power Limit Tuning. However, with the added complexity of the WIDGET programming, implementation of these strategies on the DCS would be, at best, very difficult. Therefore, the focus turned to the G2 supervisory control system acquired many years earlier. This was still operational and, fortunately, there was a metallurgist on staff familiar with that system's programming protocol. The [illegible]t agreement with the software supplier had e[illegible]some years prior so there was no help forthcomi[illegible]n that quarter.

The initial programming of both Low Power Limit Tuning and WIDGET was subsequently conducted followed by four months of testing and fine tuning. Early in the testing phase, the developers' worst fears were realized when it became apparent that all of the mills did not operate on the same curve. In addition, even the response curve of the individual mills changed with time. It is now believed that this is caused by differences in the ball charge levels. Ultimately, this was dealt with by making the WIDGET strategy "adaptive". Shown below is the equation described earlier.

$$\mathrm{IKW} = 2273\left(\frac{\mathrm{dCWI}}{\mathrm{dIKW}}\right) + 0.70$$

The intercept of this equation (+ 0.70) is so small that it is insignificant in the calculation of IKW. It serves only to assure the developers that the slope of the Corrected Work Input curve is 0 or flat at or near 0 incremental kilowatts, in this case at 0.7 IKW. This validates the experimental data on which the equation is founded. When the intercept is discarded, the shape of the work index curve for a given mill is described by a single factor, the slope (2273). The strategy was made to be adaptive by adjusting this slope based on the results of the WIDGET tests. If a WIDGET test result showed a small IKW indicating the mill was overloaded, the slope would be adjusted upward and vice versa if the test result showed an unloaded mill. In this way, after many WIDGET tests, the slope would approach the actual slope for that mill at that time.

In practice, the amount by which the power is raised during a WIDGET test is 15 kW resulting in a throughput drop during the test of typically 2 - 8 tph. The test takes from 60 to 90 minutes to complete as the mill must reach equilibrium at the new setting for an accurate result to be obtained. Much of the throughput lost during the test is regained as the mill puts on extra tonnage to bring the power back down after completion. The tests are conducted at an average 10 hour interval. Thus, the baselines are recalibrated 2 – 3 times per day compared to once per 5 –7 days under the old strategy.

Results

These strategies were developed over a several month period on the 8 ball mills which comprise "A" section of the Sierrita concentrator. Hence, it was impossible to do a "before" vs. "after" estimate of the strategies' effectiveness due to changes which occurred during that period. However, in mid November of 2001, the strategies were implemented on "B" side. There had been only minor modifications to the strategy after October 1. Therefore, it was possible to compare the two sections' performance relative to each other for the six week period before and after implementation on "B" side. This analysis showed that, relative to "A" side, the power draw on the "B" side mills was reduced 0.6% resulting in annual savings of about $80,000 at full production. Concurrently, grinding efficiency improved by 1.9 %. Therefore, grinding capacity was increased by the difference, or 1.3 %. If taken in product size alone, this represents $325,000 annually in improved recoveries, again at full production. If the grinding capacity gain is utilized for higher throughputs, the annual benefit is somewhat larger.

In conclusion, utilizing existing and somewhat outdated equipment, with no capital expenditure, grinding control improvements were achieved that are estimated to improve Sierrita's Net Cash Flow by $400,000 annually.

SIERRITA/PIMA

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(520) 648-8500

Arizona Conference Mineral Processing Technical Division Spring Meeting

Phelps Dodge Sierrita

Saturday, June 8, 2002

Agenda

9:30	Welcoming Remarks - Steve Koski
9:40	Introduction to the Sierrita Concentrator - Kevin Purdy
10:00	Sandvik H8000 Hydrocone Crusher Development at Sierrita - Loren Thompsen
10:20	Reliability Centered Maintenance at Work on #0 and #15 Mills - Bobby Durham
10:45	Break
11:00	Expert Grinding Control at Phelps Dodge Sierrita - Jim Rumph
11:20	Molybdenum Plant Flowsheet Modifications - Jim Yingst
11:40	Caterpillar History Video
12:00	Lunch
1:00	Tour

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Crushing and Conveying Equipment List

101	Primary Ore Crushers	Two Svedala Mark II 60" X 89" gyratory crushers with Hydroset mantle setting system. 800 hp motors, 6" open side setting, 1-13/16" eccentric throw, and 300 live ton surge bins at crusher discharge. 3,500 stph capacity per crusher.
102	Primary Pan Feeders	Two 72" pan feeders with Hagglund hydraulic drives.
103	A-2 Conveyor B-2 Conveyor	60", one 1250 hp drive, 2770' total belt length. 60", one 1250 hp drive, 3740' total belt length.
104	A-3 Conveyor B-3 Conveyor	54", 3 drives, 1,500 hp total, 6950' total belt length. 60", 2 drives, 600 hp total, 6930' total belt length.
105	B-4 Stacker	60", one 600 hp drive, 425 ' total belt length.
119	Coarse Ore Reclaim Pan Feeders	Eight Stephen-Adamson 48" pan feeders (two per secondary) with variable speed drives. Capacity of each pan feeder is 1,300 stph.
120	Secondary Feed Belts	Four 42" conveyors driven by 100 HP motors at 600 FPM. Capacity 2,000 STPH each belt.
121	Scalping Screens	Four Svedala Multislope 10' X 20', 80 HP double-deck vibrating screens with steel framed corded rubber panels. Top decks have 2" x 2" openings. Bottom decks have 13 mm x 40 mm slots.
122	Secondary Crushers	Four Allis-Chalmers 1384 EHD Hydrocone crushers with Hydroset mantle setting system. 750 hp drive motors, 1 3/4" throw, maximum capacity 1,600 stph.

123	Secondary Crusher Discharge Screens	Four Allis Chalmers 8' x 16', 50 hp double-deck vibrating screens with steel-backed rubber decks. Top decks have 1 1/8" x 4" oval slots, bottom decks have 9/16" x 3" slots.
126	Tertiary Crusher Feed Belts	Ten 60" conveyors driven by 10 hp motors through gear reduction, variable frequency speed controllers.
127	Tertiary Crushers	Nine Allis Chalmers 384 Hydrocone crushers with Hydroset mantle setting system. 700 hp motors, 1 3/4" (45 mm) throw. One Sandvik H8000 Hydrocone crusher with 800 hp motor, 70 mm throw.
128	Tertiary Crusher Finishing Screens	Ten Tyler F-900 Ty-Rock 6' x 16', 25 hp single deck vibrating screens with 9/16" x 4" slots in steel-backed rubber panels.
129	7A Conveyor	One 3,000 stph 60" belt conveyor driven by a 150 hp motor at 370 ft/min. With Dings magnet for tramp metal removal.
130	7A Bin	90 tons live storage.
133	7B Secondary and Tertiary Oversize Belt	One 6,200 stph 60" steel cable belt conveyor driven by a 700 hp motor at 900 ft/min.
134	7C Tertiary Bin Feed Belt	One 6,200 stph 60" steel cable belt conveyor driven by a 900 hp motor at 900 ft/min.
135	Tertiary Feed Bin	3,200 tons live storage.
136	8B Secondary and Tertiary Product Belt	One 6,800 stph 60" steel cable belt conveyor driven by two 600 hp motors at 900 ft/min.
139	Magnets	Four Dings magnets
140	Metal Detector	Four Tectron metal detectors
141, 143	7A1 and 7A2 Belt Feeders	

142, 144	Intermediate Finishing Screens	Allis Chalmers 8' x 16' double deck vibrating screens with steel backed rubber decks. Top decks have 1 3/4" square holes, bottom decks have 9/16" x 3" slots.
145	E11 Conveyor	72" variable speed feeder.
146	#11 Tertiary Crusher	Sandvik H8000 Hydrocone crusher with 800 hp motor, 70 mm throw.
147	E16 Conveyor	60" belt
148	E16 - EC-1	Drop box
149	EC-1 Conveyor	60" cable belt
151	#11 Tertiary Finishing Screens	Svedala Low Head 10' x 24' single deck vibrating screens. Steel backed rubber decks with 1/2" by 4" slots.
	Coarse Ore Stockpile	40,000 tons live storage, 120,000 tons total.
	Belt Scales	Seven Ramsey load transducer scales with totalizers.
	Dust Collectors	Eleven at the fine crushing plant, one each at the primary crushers, #11 tertiary, scalping screens, and 8B-8C drop box.

Phelps Dodge Sierrita Inc.

Grinding and Bulk Flotation Equipment List

601	Fine Ore Bin	72,000 tons live storage
602	Feeder Belts	Three per mill on mills 0, 1, 14, and 15. Four per mill on all other mills. 42" belts traveling 15-30 ft./min. with variable frequency drives.
603	Collector Belts	One per mill, 30" wide traveling 206 ft./min.
604	Feed Conveyor	One per mill, 30" wide traveling 272 ft./min.
605	Ball Mills	Sixteen 16 ½ ft. diameter x 19' long Allis Chalmers overflow ball mills with double scoop feeders. Speed: 72% of critical (13.8 rpm). Shell Liners: Double wave and "hump and bump" supplied by ME. Ball Level: 42% Ball Charge: 50% 3" and 50% 4" grinding balls supplied by Nucor and Border, with approximately 5.0 tons added to each mill Monday through Friday. Motor: 3000 hp, 150 rpm, Type AK synchronous direct drive electric motor. Trommel Screen: One per mill with three 2' long panels which have 1" x 3" openings.
606	Cyclone Feed Pump Box	Two per mill, 9' deep
607	Cyclone Feed Pump	Two per mill, one for each cyclone feed pump box. One Thomas J-36 pump, 300 hp, 310 rpm, and one GIW LSA 39 pump, 300 hp, 310 rpm, all with variable frequency drives.
608	Cyclones	Three per mill, Krebs D-33B cyclones, each with 8" apex and 14" vortex finder.

609	Dust Collector	One per mill, Ducon Dynamic Type Uw-4, Model III, wet slurry dust collector for feeder belts.
610	Rougher Flotation Cells	Sections 1 and 12: Eight 500 cu. ft. Wemco cells, arranged 2-3-3. Sections 13-15: Three 1000 cu. ft. Wemco cells, arranged 1-2, followed by eight 500 cu. ft. Wemco cells (Denver DR cells in section 14), arranged 2-3-3. Sections 0, 2-11: Three banks of 10 Denver DR 100 cu. ft. cells each, arranged 1-1-2-2-4.
611	Regrind Discharge Sumps	One per side
612	Regrind Cyclone Feed Pumps	Four 10 x 12 ASH pumps, two on standby.
613	Regrind Cyclones	Eight per side, Krebs D-10LB with 7.8 sq. in. inlet, 3.5 in. vortex finder, and 2" apex.
614	Regrind Ball Mills	One per side, Hardinge 11' diameter x 18' long overflow mill. Speed: 60% of critical (14.2 rpm) Shell Liners: Rubber. Ball Level: To maintain 525 KW power draw. Ball Charge: 1 ½" grinding balls. Motor: 800 hp, 720 rpm synchronous motor.
615	Tailing Thickeners	Four thickeners, two per side. Dorr Oliver Type 12253 center drive, 350' diameter with 23.5' depth at center, 8' depth at side.
616	Column Flotation Distributor	Two distributors, one per side. Overflow distributor with six discharge compartments.
617	Column Flotation Cells	Twelve 7' diameter by 50' tall cells of Cyprus design. Air sparged by stainless steel tubes with 1/8" holes. Two levels of 6 tubes each. Froth washed by drip pans, approximately 100 gpm per cell.
618	Copper-Molybdenum Concentrate Thickeners	Two Eimco 100' diameter thickeners with CX extra heavy duty mechanisms. Depth at center 15' 3.5".

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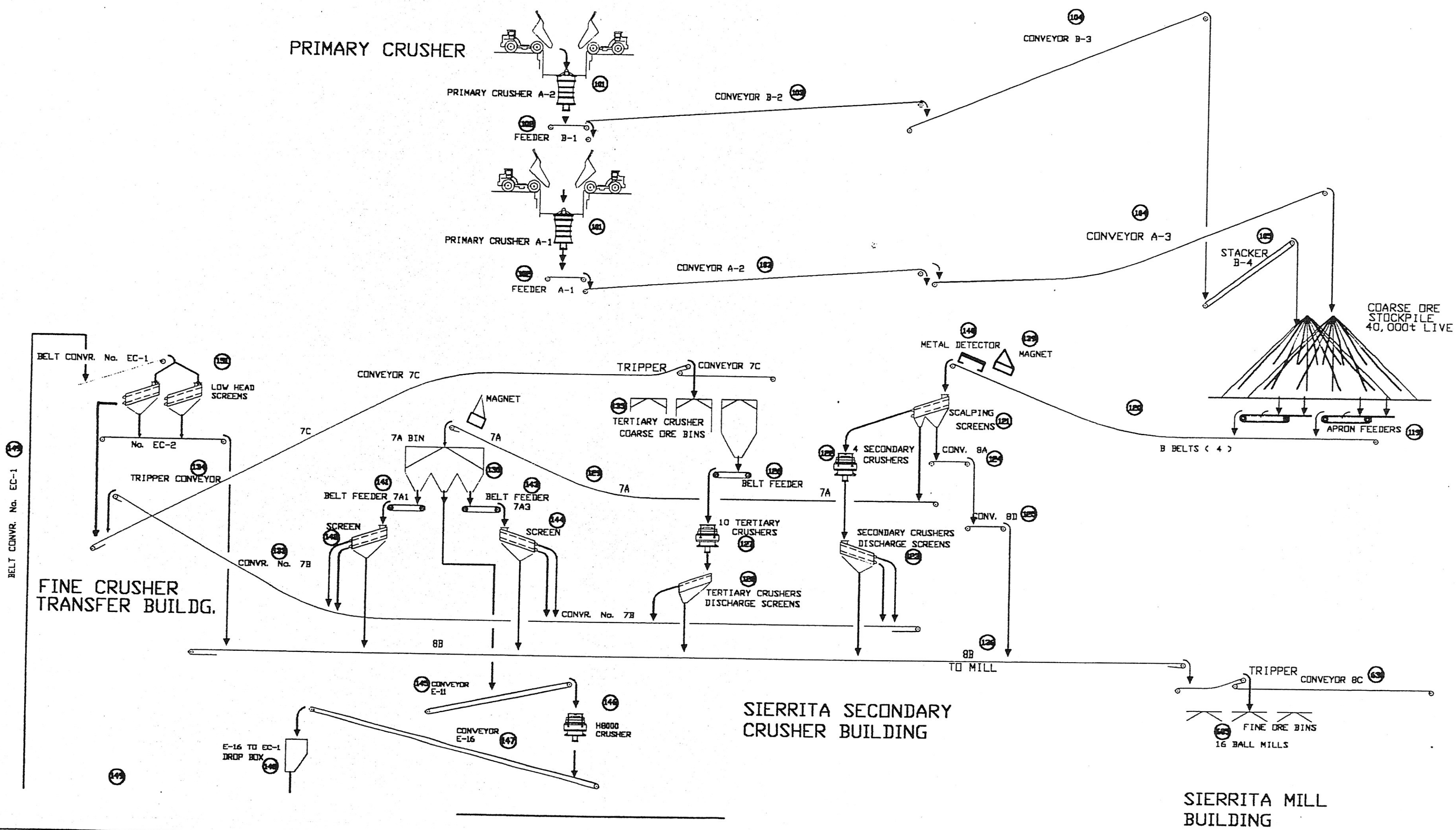
Copper-Molybdenum Separation Circuit Equipment List

A	Copper-Molybdenum Concentrate Thickeners	Two Eimco 100' diameter thickeners with CX extra heavy duty mechanisms. Depth at center 15' 3.5".
B	Rougher Flotation in Series	Three 12-cell banks of Denver DR 100 cu. ft. rougher flotation cells modified with Wemco agitators. Banks 2 and 3 are covered, and nitrogen is added to those cells, maintaining a slight positive pressure.
D	Copper Concentrate Thickener	One Eimco 125' diameter thickener with CX extra heavy duty mechanism. Depth at center 15' 3.5".
E	Copper Filters	Three Outomec CC45 ceramic disk filters. Each filter has 15 disks and each disk has 16 segments.
G	Cleaner Flotation	One bank of 6 Wemco 100 cu. ft. cells and one bank of 8 Denver DR 100 cu. ft. cells. Only one bank is used at a time.
I	Recleaner Flotation	Five 36" diameter x 47' tall column flotation cells with atomizing spray nozzle spargers.
J	Regrind Mill	One 5' diameter x 7' Denver Equipment ball mill charged with ½" grinding balls.
J1	Regrind Cyclone	One Krebs D-10B with 7.8 sq. in. inlet, 3.5 in. vortex finder, and 2" apex.
K	Re-recleaner Flotation	One bank of 4 Denver DR 40 cu. ft. flotation cells.
L	Molybdenum Concentrate Filter	One Larox PF25A1 belt pressure filter.
M	Filter Surge Tank	One 15' 8" diameter by 18' deep tank with agitator.

N	Molybdenum Concentrate Dryers	Two Holoflite Type [illegible]20-6 dryers, each with 2 screws, 16" diameter x 20' long.
	Final Cleaner Flotation	Fourteen 24 cu. ft. Hazen Quinn 15-18 flotation cells, arranged in three separate stages of 6-4-4.

619	Scavenger Flotation Cells	Two 3-cell banks, one bank per side, 500 cu. ft. Wemco cells, arranged 1-2.
620	Belt Scales	One per mill, digital PLC strain gauge belt scale.
621	Sump Level Probes	Two for each cyclone feed pump box, Milltronics DPL ultrasonic probe.
624	Copper Concentrate Thickener	One Eimco 125' diameter thickener with CX extra heavy duty mechanism. Depth at center 15' 3.5".
626	Rougher Concentrate Sump	One per side.
627	Rougher Concentrate Transfer Pump	Four 10 x 10 ASH pumps (2 per side), two on standby.
628	Regrind Cyclone Overflow Pump	Four 10 x 10 ASH pumps (2 per mill), two on standby.
629	Coarse Cleaner Flotation Cells	Three banks of four Denver DR 300 cu. ft. cells, arranged 2-2.
	Rougher Flotation Blowers	Four Buffalo Forge Type R, Size 89, 3400 cfm blowers with 400 hp motors.

CURRENT SIERRITA CRUSHER CIRCUIT



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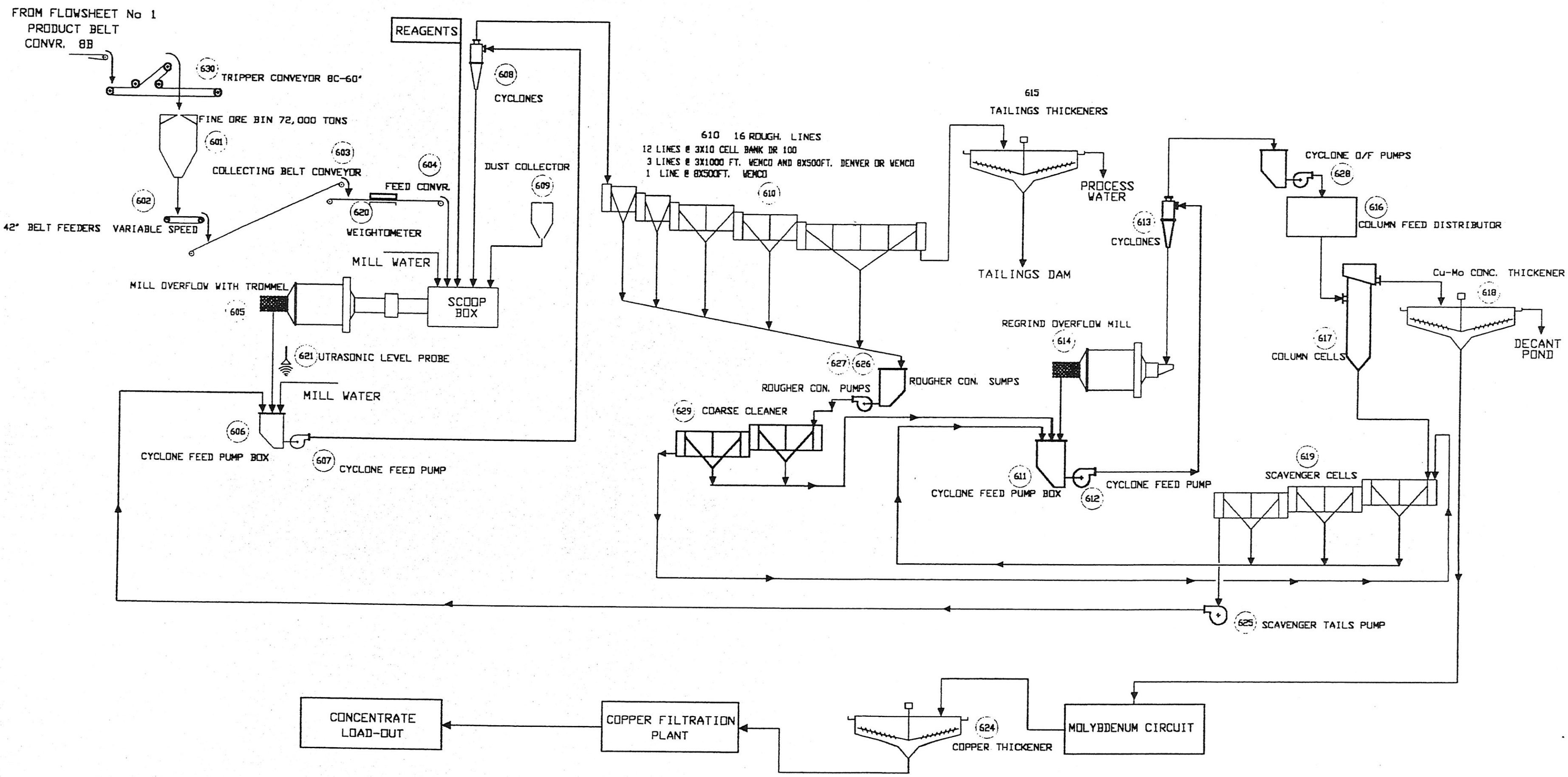
SIERRITA CRUSHING CIRCUIT

CURRENT SIERRITA GRINDING AND BULK FLOTATION CIRCUIT



REFERENCES	REFERENCES	REVISIONS	REVISIONS

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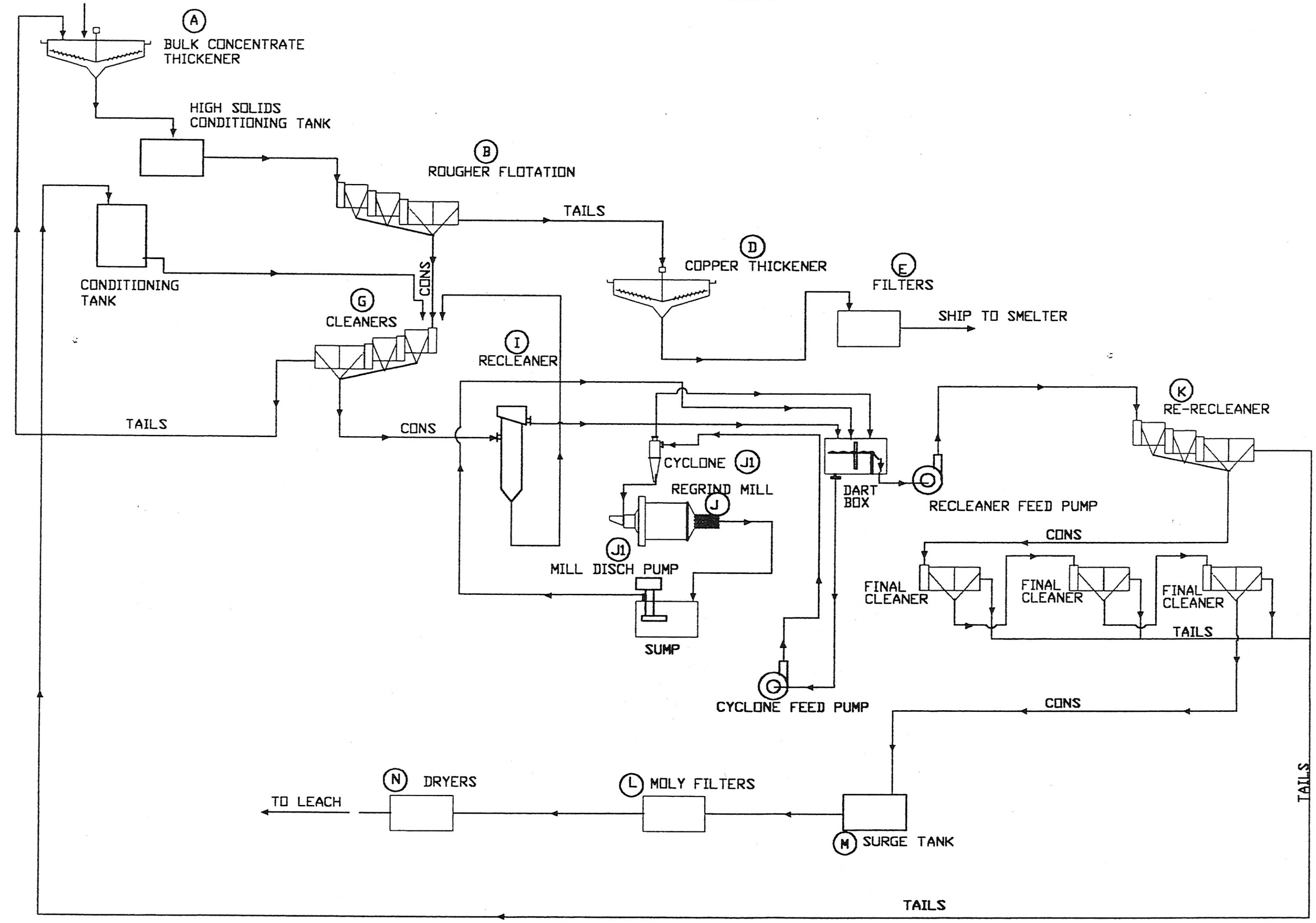
SIERRITA GRINDING AND BULK FLOTATION CIRCUIT

SIERRITA MOLYBDENUM SEPERATION FLOTATION CIRCUIT



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Sierrita Mine (f)
Pima Co.

NEWS RELEASE

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Phelps Dodge Notifies Chino, Tyrone and Sierrita Operations of Possible Production Curtailments

PHOENIX, Ariz., January 25, 2001 – Phelps Dodge Corporation (NYSE: PD) today announced that it will notify all 2,350 employees of its Chino and Tyrone, N.M., and Sierrita, Ariz., operations of the possibility of production curtailments. The company attributes high energy-related costs as the primary threat to continuing production at the New Mexico facilities, and a combination of low molybdenum prices and high energy costs as the reason for notification of Sierrita employees.

Phelps Dodge Chairman, President and CEO J. Steven Whisler, said: "The electricity crisis in California, and its impact on energy prices, had a significant impact on our fourth quarter 2000 results, with our U.S. electricity, diesel fuel and natural gas costs 65 percent higher than in the fourth quarter of 1999. Our Chino, Tyrone and Sierrita operations are the most energy-cost sensitive in the Phelps Dodge portfolio. After a review of the near-term market outlook for energy prices and a thorough analysis of the molybdenum market, we believe it necessary to notify our employees that we may not be able to maintain production cost-effectively at the Chino, Tyrone or Sierrita operations. The situation remains fluid and we have not reached final decisions about curtailments at any of these facilities.

"Until the California power crisis is resolved its negative impact on industrial facilities in surrounding states, including our New Mexico and Arizona operations, will be huge in terms of additional plant closings and employee layoffs. In the meantime, Phelps Dodge will continue to work aggressively, diligently and creatively to pursue every opportunity to minimize the impact of these extraordinary circumstances on our businesses and our employees."

Employees will receive Worker Adjustment and Retraining Notification (WARN) Act letters by mail this week advising them that temporary production curtailments could become effective following a legally required, 60-day notification period. The unions which represent some of the employees at Chino also will receive WARN Act notices this week.

The company will closely monitor the energy and molybdenum markets throughout the 60-day period to determine whether curtailment actions may be necessary at any of the three facilities. No details about possible production curtailments will be provided unless final decisions to curtail production have been made by the company.

In 2000, Chino Mines Company produced 271 million pounds of copper through its workforce of about 990 people. Copper production at Phelps Dodge Tyrone, Inc. was 159 million pounds in 2000; the operation employs a full-time workforce of nearly 620 people. Phelps Dodge Sierrita, Inc. produced 245 million pounds of copper and 22 million pounds of molybdenum in 2000, and employs approximately 740 full-time employees.

Phelps Dodge Corporation is the world's second largest producer of copper. The company also is the world's largest producer of continuous-cast copper rod and molybdenum, and is among the largest producers of carbon black and magnet wire. Phelps Dodge has operations and investments in mines and manufacturing facilities in 27 countries and employs approximately 15,500 people worldwide.

For related Phelps Dodge news, refer to the company's fourth quarter and full year 2000 earnings press release issued today.

This news release contains forward-looking statements, as that term is defined in the Private Securities Litigation Reform Act of 1995. In addition to the risks and uncertainties noted in this news release, there are certain factors that could cause results to differ materially from those anticipated by some of the statements made. These factors are listed in Management's Discussion and Analysis in the company's most recently filed annual report on Form 10-K for the fiscal year ended December 31, 1999, and quarterly report on Form 10-Q for the fiscal quarter ended September 30, 2000.

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Arizona Department of Mines and Mineral Resources

Verbal Information Summary

Date: October 20, 1995 **Engineer: Nyal Niemuth**

Notes from talk by Jeff Clevenger President, Cyprus Climax Metals Co. to Maricopa Section SME on 10/19/1995.

The talk reviewed Cyprus' copper and molybdenum operations worldwide during the last couple of years, with a focus on cost cutting activities and modernization projects. Below are some comments on the Arizona operations.

General Comments: Cyprus company goal: to significantly increase productivity, reduce the number of employees. How? eliminate unproductive tasks, institute a bonus system for every employee, share cost/price information. At Sierrita the first year of this system resulted in a 20% bonus.

Other goals: 1) invest and modernize the mines. Replace the truck/shovel fleet with 240 ton trucks and 50 cubic yard shovels, 2) increase reserves, 3) produce copper at a cost of 60 cents per pound (at $3 LB molybdenum credit.) Through the end of 1994 73% of the company's truck fleet has been replaced. 11 more trucks replaced since then. The company has achieved a 50% increase in tons milled per man shift and a 50% increase in copper produced per employee. Reserves were increased by raising the copper price used in 1992 from $.65 to $.90 per pound. and the purchase of El Abra in 1994. When the grade turned out to be lower at El Abra Chile, they got the Chilean government to triple the area of the concession (future exploration potential) and grant a huge water allotment to the mine. In moly they were able to cut out $30 MM, mainly through the AMAX merger.

Comments on individual Arizona mines:

Bagdad (f) Yavapai Co. A 1 billion ton resource of 0.38 Cu and 0.028 Mo exists. A new technology, a water flush crusher was installed that takes 20% of oversize for autogenous mill, water flushes fines to floatation circuit. This increased capacity from 75,000 to 80,000 ton per day.

Sierrita (f) Pima Co. CRU International rates Sierrita as the most efficient copper mine in the world and it operates at the lowest grade for a milling operation, 0.28%. A current experiment at Sierrita is a 50-50 joint venture between Cyprus and the vendor. It involves one set of high pressure rolls used for crushing. With it a higher percentage of fines go directly to float cells without grinding. It appears 40% of product may bypass the ball mills. The cost of maintenance on the rolls is still unknown and will be a deciding factor in their success.

Cyprus received $9 per pound for moly in the 2nd quarter of 95, resulting in a cash cost of producing copper of $.07 per pound. Sierrita has both an moly roaster as well as a leach circuit to remove copper from off specification concentrates.

Twin Buttes (f) Pima Co. Cyprus is studying Twin Buttes as underground mine but its iffy as it is high cost even with the high 1.75% Cu grades. Part of the problem is that the ore isn't compatible with the ore at Sierrita so it requires a separate circuit or its own mill.

Lakeshore (f) Pinal Co. Cyprus bought the property to get the roaster due to a worldwide shortage of smelting capacity at the time, now the roaster is shutdown. The property has a 600 MM ton leach resource at 0.5% Cu, but it has a high acid consumption. As an open pit heap leach it can produce 40 to 50 MM lb. per year but at a high cost. A feasibility study is underway to see if it remains a permanent producer.

Inspiration [aka Miami (f)] Gila Co. Cyprus bought the property to acquire the smelter and refinery. When first operated SRP was able to provide cheap electric rates for the electric furnace. When the electric went up Cyprus installed a ISA melt furnace that initially had problems with the off gases hood. A redesign of the hood making it vertical (less heat build up) and increasing the temperature and pressure of the cooling tubes was completed in February of 95 and there have been no further problems. A $280 MM was invested in ISA technology for the electrolytic refinery (annual capacity of 150 MM lb). It uses stainless steel starter sheets. The new technology results in a savings $.02 per pound at the refinery and overall the refinery is now about $.05 per pound cheaper than a custom facility.

Mineral Park (f) Mohave Co. Installed a portable SX-EW plant. In situ leach research project is underway.

PZL DATALINE

News and information updating Pennzoil Company operations and activities

DUVAL ANNOUNCES PRODUCTION CUTBACKS

Houston - June 15, 1982 - Duval Corp., the mining subsidiary of Pennzoil Co., announced today that because of continuing weakness in demand, it will further reduce copper and molybdenum production at its Sierrita property effective July 1.

The company's Esperanza and Mineral Park copper and molybdenum properties will remain closed.

The Sierrita mine and mill complex, which has been operating at the reduced rate of 80,000 tons of ore per day, will be further curtailed to approximately 40,000 tons per day. Under this reduced production rate, about 35 percent of capacity, Duval will continue to meet the copper and molybdenum requirements of contract customers.

Duval is continuing a 32-hour work week in an effort to provide employment for the maximum number of workers. Under this plan, 850 of the current work force of 1500 will be retained.

Those employees subject to lay-off will be furloughed indefinitely and will receive severance benefits of one week for each year of past service with the company. This severance benefit will be in the form of an income supplement and insurance coverage which, with other benefits, maintains the employee's income at 70 percent of normal compensation while payments are being made.

PENNZOIL COMPANY
A Natural Resources Company

For additional information contact:
Investor Relations (713) 236-7914 • Public Relations (713) 236-7536 • Pennzoil Place • P.O. Box 2967 • Houston, Texas 77001

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These voluntary payments, although not contractually required, are being made in recognition of past services and in an effort to mitigate the hardship resulting from this further reduction in force.

Duval's Sierrita and Esperanza mines are located 30 miles southwest of Tucson and the Mineral Park mine is located near Kingman, Ariz.

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Field Trip Oct 16, 1979
Annual SME-AIME meeting
AB
JC

DUVAL CORPORATION

OPERATING DATA

SIERRITA/ESPERANZA/CLEAR COMPLEX

There are three separate facilities - they are Sierrita mine and mill - Esperanza mine and mill and the CLEAR facility. These operations are all interrelated for materials flow and supervisory control. Within the last year, Sierrita and Esperanza mines have been combined for operating purposes.

Some of the concentrate from Sierrita is used to feed the newly developed CLEAR Plant which then produces about 100 MTD of copper in the form of high grade crystals - about 99.5 Cu. The bulk of concentrate produced, in excess of 25,000 short tons per month, is shipped to custom smelters, mainly ASARCO.

About 25,000 lbs. of copper per day is produced by dump leaching of oxide type ore at Esperanza.

Following are some operating statistics:

TOTAL EMPLOYEES - complex - 2,600

MONTHLY PAYROLL - $5.0 million approximately, including 39% benefits costs

MONTHLY POWER COSTS - $3.0 million approximately

TOTAL MONTHLY OPERATING COSTS - $15 million approximately

PRODUCTION MONTHLY:

Copper - approximately 19,000,000 lbs. contained in concentrates at 25% Cu. and as precip. at 75% Cu.

Molybdenum - approximately 1,600,000 lbs.

Silver - get credit for about 100,000 ozs. of silver per month contained in the copper concentrates.

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Operating Data - Cont'd.

The beginning wage, inexperienced laborer, is $8.15 per hour.

Benefits paid for by the Company include basic life insurance, medical care insurance, retirement programs, disability leave benefits and dental care benefits. All of these medical or dental plans apply to employees and their dependents. The total benefits package amounts to 39% of salaries and wages.

Ours is an experienced, mature work force with a termination ratio less than 1% per month. All are recruited from the Tucson area.

Our supervisory group is mature and experienced with about one supervisor for each twelve employees.

October 3, 1979

H. L. Shively

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Duval

Sierrita

A Summary of the CLEAR Process

Walter W. Fisher

Arizona Bureau of Mines
The University of Arizona

January 13, 1976

The CLEAR process consists of a series of hydrometallurgical steps by which a copper sulfide concentrate is solublized, the copper is recovered by electrolysis and the lixiviant is regenerated by electrolysis and autoclave oxidation. The process has been developed by the Duval Corp. and has been assigned U.S. Patents 3,785,944 and 3,879,272. A plant designed to produce 32,000 tons of copper per year is currently in the midst of startup at the Duval Sierrita operation south of Tucson. CLEAR stands for "copper leaching electrolysis and regeneration". The description of the process that follows has been taken from the patents. The chemical reactions have been written in their simplest form. For purposes of process stoichiometry, they may be combined to represent the overall process chemistry.

Figure 1 is a simple schematic diagram illustrating the unit operations in the process. The CLEAR process consists of four basic chemical steps: 1 the primary extraction step denoted as reduction stage, step A, 2 a reduction step to insure that all copper is in the cuprous state denoted as reduction stage, step B, 3 the electrolysis step in which copper is recovered and the lixiviant is partially regenerated, and 4 the final extraction and regeneration step denoted as the oxidation and regeneration stage. The aqueous phase in the process is a nearly saturated chloride solution.

The lixiviant in the primary extraction stage typically contains: H_2O - 1000 mols, $CuCl_2$ - 19.5 mols, KCl - 43.5 mols, NaCl - 80.5 mols and $FeCl_3$ - 4.0 mols. The extractant is cupric chloride which reacts with chalcopyrite according to equation 1. A minor amount of extraction

$$CuFeS_2 + 3CuCl_2 \longrightarrow 4CuCl + FeCl_2 + 2S \qquad (1)$$

is achieved by ferric chloride according to equation 2. The chalcopyrite

$$CuFeS_2 + 3FeCl_3 \longrightarrow CuCl + 4FeCl_2 + 2S \qquad (2)$$

concentrate is not completely decomposed in the primary extraction step

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and the residue from this step passes on to the final extraction stage. The primary extraction process is carried out in a closed vessel (not a pressure vessel) at 107°C.

After liquid-solid separation, the solution from the primary extraction is subjected to a reduction stage in which any cupric chloride not consumed in the extraction is reduced to cuprous chloride prior to the electrowinning step. Although this step may be accomplished by a number of reductants (SO_2, SO_3, Fe, etc.), the preferred reductant is scrap or cement copper. The reaction occurring in this stage is given by equation 3. This reaction also takes place at 107°C in a closed vessel.

$$CuCl_2 + Cu^o \longrightarrow 2CuCl \tag{3}$$

The solution from the reduction stage is passed through a heat exchanger to reduce its temperature to the range 30 to 60°C and through a filter to remove unreacted reductant. The cooled and purified solution then enters the electrolysis stage. Electrolysis is carried out in a diaphram cell of the general form illustrated in figure 2. At the cathode cuprous chloride is reduced to form copper by reaction 4. At the anode cuprous chloride is oxidized to form cupric chloride according to equation 5. The overall cell reaction is given by equation 6. The electrolysis is

$$CuCl + e \longrightarrow Cu^o + Cl^- \tag{4}$$

$$CuCl + Cl^- \longrightarrow CuCl_2 + e \tag{5}$$

$$2CuCl \longrightarrow Cu^o + CuCl_2 \tag{6}$$

carried out in the temperature range 30 to 60°C.

The partially regenerated solution from electrolysis is sent to the final extraction and regeneration stage where extraction of copper from the chalcopyrite is completed, cupric chloride is regenerated, the iron is oxidized to ferric, part of the sulfur is oxidized to sulfate, and most of the iron is hydrolyzed and precipitated. This stage is operated at 140°C and 60 psig oxygen pressure in an agitated pressure vessel. The reactions that may occur in this stage are summarized in equations 7 through 10. In addition to the iron oxide precipitated, excess sulfate in the system forms

$$2CuFeS_2 + 5/2\ O_2 + 10HCl \longrightarrow 2CuCl_2 + 2FeCl_3 + 5H_2O \tag{7}$$

$$2CuCl + 1/2\ O_2 + 2HCl \longrightarrow 2CuCl_2 + H_2O \tag{8}$$

$$2FeCl_2 + 1/2\ O_2 + 2HCl \longrightarrow 2FeCl_3 + H_2O \tag{9}$$

$$FeCl_3 + 3H_2O \longrightarrow Fe(OH)_3 + 3HCl \tag{10}$$

a "jarosite" type compound with iron and is also precipitated. After solid-liquid separation, the solution from this extraction stage is recycled as the fresh lixiviant for the primary extraction stage. The residue contains insoluble material, iron oxides (with some sulfate) and the sulfur not oxidized to sulfate.

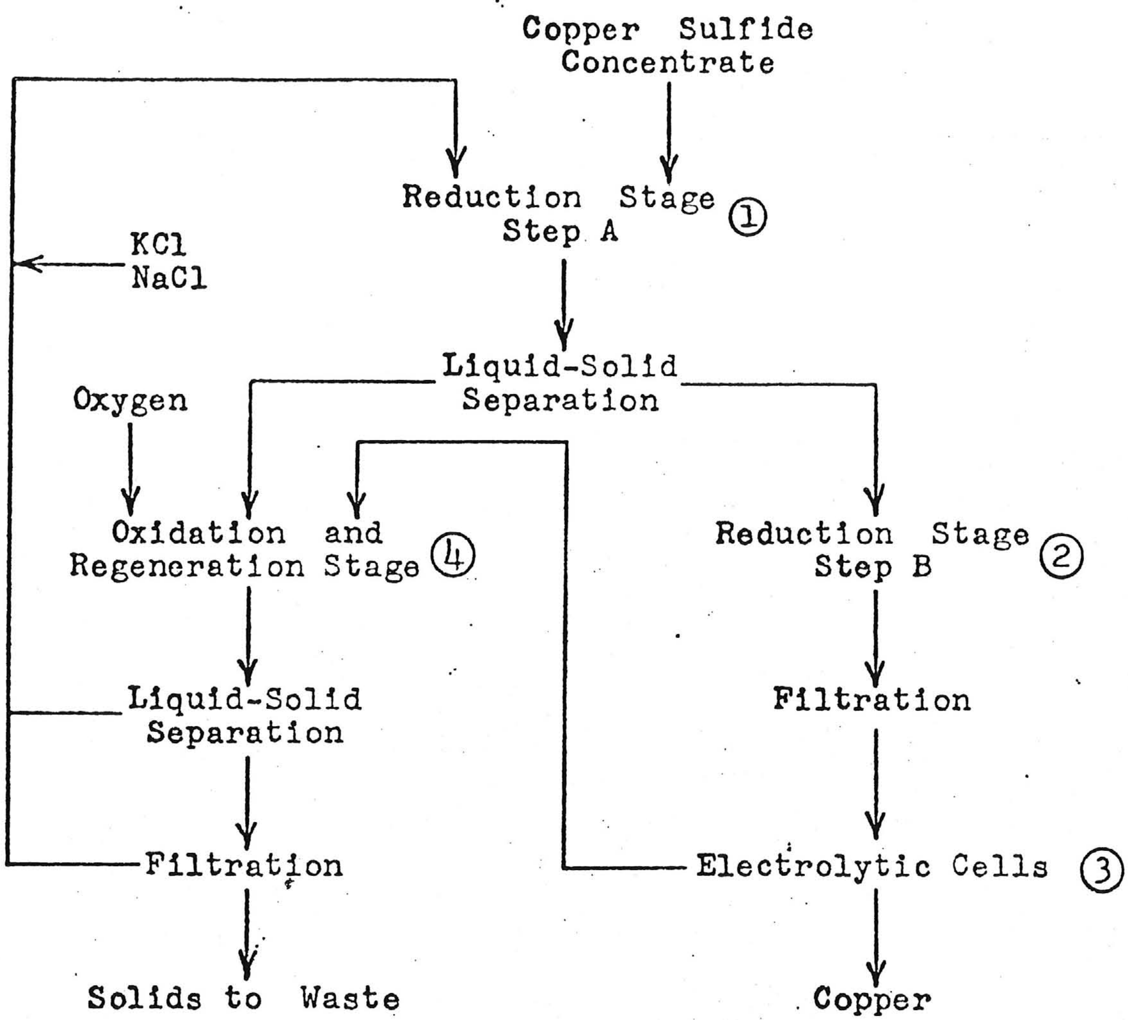

Figure 1. Schematic diagram of the CLEAR process.

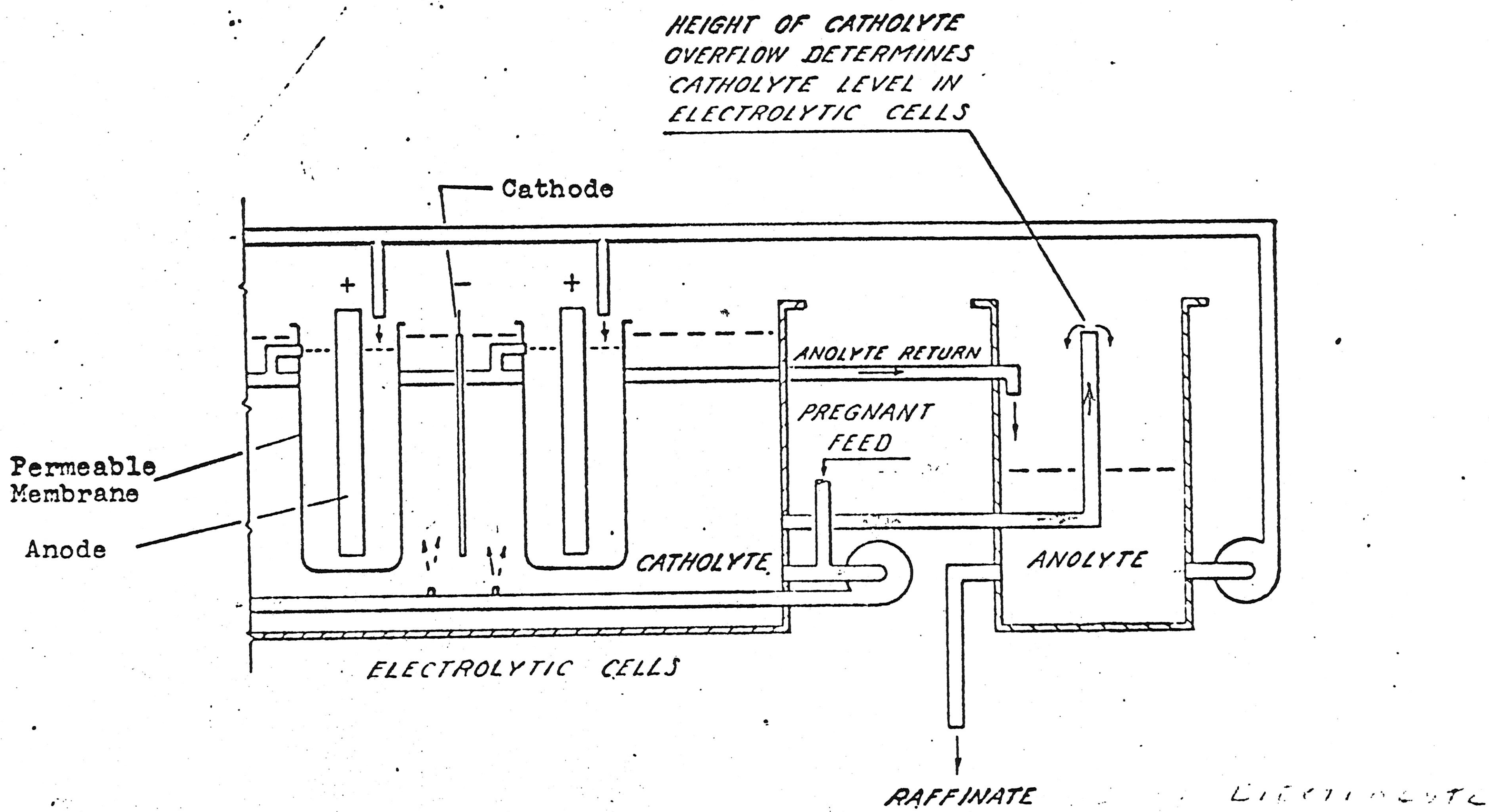

Figure 2. Diagram illustrating the diaphram cell. Taken from U.S. Patent 3,785,944.

…NA DEPARTMENT OF M… …ESOURCES
Mineral Building, Fairgrounds
Phoenix, Arizona

1. Information from: V. A. Brussolo
   Address: Federal Building Tucson
2. Mine: Duval Sierrita
3. No. of Claims - Patented ?
   Unpatented ?
4. Location: Twin Buttes District
5. Sec ____ Tp ____ Range ____
6. Mining District ____
7. Owner: Duval Sierrita Corp -
8. Address: Tucson Ariz
9. Operating Co.: Duval-Sierrita
10. Address: Same.
11. President: ____
12. Gen. Mgr.: S. H. Martin
13. Principal Metals: Cu Mo
14. No. Employed: ____
15. Mill, Type & Capacity: 72,000 T.P.D. Projected
16. Present Operations: (a) Down ☐ (b) Assessment work ☐ (c) Exploration ☐ Development ☐ (d) Production ☐ (e) Rate ____ tpd.
17. New Work Planned: ____
18. Miscl. Notes: Trip thru mine area & plant. ore stock pile & dump. then thru new crushing plant mill & new office. interviewed Mr. Martin in his office.
    Work is progressing on schedule.

Date: 6-26-69 GW Irvin (Signature) (Field Engineer)

BA

DEPARTMENT OF MINERAL RESOURCES

STATE OF ARIZONA

FIELD ENGINEERS REPORT

Mine Sierrita Project

Date April 14, 1965

District Pima (Twin Buttes) District, Pima Co.

Engineer Axel L. Johnson

Subject: Field Engineers Report. Information from Tom Jancic

References: Reports of Aug. 25, 1964 and April 16, 1964

Location: See April 16, 1964 report

Owners: " " " " "

Option to Purchase: Duval Corporation

Past History: See April 16, 1964 report

Number of Claims: About 200 unpatented claims

Principal Minerals: Copper ore with some molybdenum

Present Mining Activity: Exploration by diamond drilling.

4 diamond drills are now working 3 shifts each - 2 rigs by Empire Drilling Co., Phoenix, and 1 rig each by Metler Bros. Drilling Co. and Boyles Bros.

It is expected that the drilling will be finished in about 2 months. After this, the exploration results will be evaluated.

F. H. Buchella Jr. has been appointed chief mine engineer for Duval Sierrita Corp. a subsidiary of Duval Corp. That was formed to develop and operate the Sierrita copper-molybdenum property adjacent to its Esperanza mine in Pima County, Arizona. Since last summer Mr. Buchella has been serving as assistant mines manager to Duval Corp. Taken from Skillings Mining Review 3/2/68

Active Mine list 4/1968 - 200 men working, S. H. Martin, Res. Mgr. P.O. Box 125 Sahuarita

Active Mines List 10/1968- 502 men working.

Duval- Sierrita is going ahead with their new mine and mill preparation. The old Canoa Ranch was purchased so as to assure the company of a water supply.

GWI Quarterly Report June 1968

The two mines scheduled to begin producing next year are Duval Sierrita Mine and Anaconda Twin Buttes Mine. Duval has signed a contract to ship up to 25,000 tons of concentrates to the smelter each month. As yet, Anaconda has not disclosed what amount of concentrates it would ship for processing.

Taken from Ariz. Prof. Engr. 10/1968

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DEPARTMENT OF MINERAL RESOURCES
STATE OF ARIZONA
FIELD ENGINEERS REPORT

Mine Sierrita Project Date Aug. 25, 1964

District Pima (Twin Buttes) District, Pima Co. Engineer Axel L. Johnson

Subject: Field Engineers Report. Information from Tom Jancic

References Report of April 16, 1964, and previous reports.

Location Approx. Secs. 5 & 6 -- T 18 S -- R 12 E. About 1 1/2 miles NW of the Esperanza pit.

Owners See report of April 16, 1964.

Option to Purchase Duval Corp.

Past History See report of April 15, 1964.

Present Activity All exploration activity has been discontinued for the time being. Mr. Jancic gave the reason for this as litigation among the owners of the claims in regard to respective ownership.

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DEPARTMENT OF MINERAL RESOURCES

STATE OF ARIZONA

FIELD ENGINEERS REPORT

Mine Sierrita Project Date April 16, 1964

District Pima (Twin Buttes) District, Pima Co. Engineer Axel L. Johnson

Subject: Field Engineers Report. Information from F. H. Buchella, Jr., Mine Engineer

References Reports of May 29, 1963, and Oct. 8, 1963.

Location Approx. Sections 5 & 6 -- T 18 S -- R 12 E. About 1 1/2 miles NW of the Esperanza pit.

Owners Most of the claims are owned by Sierrita Mining & Ranching Co., which in turn is owned by the McGee family. A few are reported to be owned by C. Darrel Wilson, et. al.

Option to Purchase Duval Corporation

Past History (1) Bear Creek Mining Co. obtained an option to purchase this property in late 1962 or early 1963, and proceeded to drill about 100 drill holes, and to sink 3 prospect shafts, 50, 30, and 30 ft. deep respectively.

(2) Bear Creek discontinued the diamond drilling about May 1, 1963 in order to evaluate the information obtained from the drill logs and other exploration work.

(3) Bear Creek, after estimating the ore reserves and the grade of the ore, decided to drop their option on the property.

(4) The property was later optioned to Duval Corp.

Number of Claims Reported to be about 200 unpatented claims.

Principal Minerals Copper ore, with some molybdenum.

Present Mining Activity Exploration by diamond drilling.

Proposed Plans Mr. Buchella states that Duval Corp. expects to find a sizeable ore body of sufficient grade, which they can mill at the Esperanza mill. He stated that they can handle a smaller ore body and one of lower grade than Kennecott, because they already have a mill within 2 or 3 miles, equipped with a molly circuit, for milling the ore.

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DEPARTMENT OF MINERAL RESOURCES

STATE OF ARIZONA

FIELD ENGINEERS REPORT

Mine 'Sierrita Project

Date Oct. 8, 1963

District Pima (Twin Buttes) District, Pima Co.

Engineer Axel L. Johnson

Subject: Field Engineers Report. Information from Jackson Clark, Bear Creek Mining Co.

References Report of May 29, 1963

Present Activity Exploration work was discontinued some time ago. Company is now evaluating the information which they have obtained from recent drilling. A decision of future plans will be made following a complete study of this information.

Active - October 1963

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Not for publicati

DEPARTMENT OF MINERAL RESOURCES
STATE OF ARIZONA
FIELD ENGINEERS REPORT

Mine Sierrita Project Date May 29, 1963

District Pima (Twin Buttes) District, Pima Co. Engineer Axel L. Johnson

Subject: Field Engineers Report. Information from Jackson Clark, Bear Creek Mining Co.

Location Approximately Sections 5 & 6 -- T 18 S -- R 12 E.
About 1 1/2 miles NW of the Esperanza Mine operated by Duval Corp.

Owners Several owners are involved. Most of the claims are reported to be owned by the McGee family and Darrel Wilson.

Option to Purchase Bear Creek Mining Co., 2601 N. 1st Ave., Tucson.
Tom Walthier, Manager
This is reported to be a 5 year option taken out in 1961.

Number of Claims About 200 unpatented claims held by the owners listed above, et. al.
A State prospecting permit on 1/2 section (320 acres)

Principal Minerals Copper ores.

Present Mining Activity Diamond drilling with 4 drill rigs, until about 1 month ago. The drilling was stopped until the drill logs on the drilling to date have been examined, plotted and estimated, and computations made on ore reserves.

Past History & Production None.

Old Mine Workings None.

Review of Recent Operations For some time, until about one month ago, 4 diamond drills were operated on contract by Joy Drilling Co. Mr. Clark reported that about 100 drill holes were put down on the property during that time. In addition, 3 prospect shafts were sunk , one being 50 ft. in depth, and the other two about 30 ft.

Proposed Plans Company will do more drilling later on, if the results to date are interprpeted to be satisfactory.

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DEPARTMENT OF MINERAL RESOURCES
STATE OF ARIZONA
FIELD ENGINEERS REPORT

Mine Twin Buttes Project by Bear Creek Date Dec. 18, 1962

District Pima (Twin Buttes) District, Pima Co. Engineer Axel L. Johnson

Subject: Field Engineers Report. Information from Jackson L. Clark, Bear Creek Mining Co.

References Report of Dec. 12, 1961

Present Status Mr. Clark informed the field engineer that exploration work in the Twin Buttes District is in the process of being terminated permanently, and that their options to purchase are being dropped.

Reason given --- not enough ore of commercial grade was discovered.

This does not apply to their claims and options north and west of Esperanza Mine of Duval Sulphur. In that area (approximately Secs 5,6,7 & 8 -- T 18 S - R 12 E) exploration work will be continued.

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DEPARTMENT OF MINERAL RESOURCES
STATE OF ARIZONA
FIELD ENGINEERS REPORT

Mine Twin Buttes Project by Bear Creek Date Dec. 12, 1961

District Pima (Twin Buttes) District, Pima Co. Engineer Axel L. Johnson

Subject: Field Engineers Report. Information from Tom Walthier, SW District Manager

Location Approx. Secs. 13, 24, & 25 -- T 17 S - R 12 E & Secs. 18, 19, & 30 -- T 17 S R 13 E. The area lies south of Helmet Peak and north of Twin Buttes, and extends on both sides of the San Xavier-Twin Buttes road.

Number of Claims Bear Creek Mining Co. has acquired options on several hundred claims in this area from various parties (Mr. Walthier roughly estimated 300). According to Mr. Walthier, very few claims were staked out by the Bear Creek Mining Co.

Options to purchase have been acquired from the following parties: Dan Chilson (now his estate), C. Darrel Wilson, Russel Todd, George Edwards, et. al. The options were for 5 years, and have over two years remaining.

Owners See description above.

Principal Minerals Copper ore.

Present Activity Diamond drilling is being done by Joy Drilling Co. on contract. At the present time 2 diamond drills are operating in the area.

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File

& Scott
[illegible] Miller

FERROMOLYBDENUM PLANT

INTRODUCTION:

Ferromolybdenum production began at Duval Corporation in February, 1975. The Sierrita Ferromolybdenum Plant is one of three currently operating in the United States. Ferromolybdenum is a ferroalloy which considerably increases the mechanical and physical properties of steels. It is preferred to molybdenum trioxide because the contained molybdenum is in a metallic state and there is less dust and volitalization losses occur upon addition. A thermite type reaction is used to produce ferromolybdenum. The exothermic reaction of aluminum and silicon reducing molybdenum trioxide generates enough heat to form molten reaction products. Iron is added to alloy with the molybdenum and slagging agents are added to produce a fluid, low melting point slag. A plant process flow diagram is shown in Figure 1 and a equipment list in Table 2. Listed below are some pertinent general operating statistics.

	Current	July 1
1. Kilograms of molybdenum converted per month	40,000	103,000
2. Kilograms of ferromolybdenum produced	62,500	161,000
3. Number of burns per month	45	115
4. Expected recovery	97%	

5. Ferromolybdenum grade and size specifications

Molybdenum	60.00% to 64.00%	Copper	0.20% Maximum
Carbon	0.10% Maximum	Silicon	1.00% Maximum
Sulphur	0.15% Maximum	Balance	Iron
Phosphorus	0.05% Maximum		

SIZES

Furnace	minus 1 inch to plus 4 mesh
Ladle	4 mesh to plus 20 mesh
Small Ladle	minus 20 mesh

PRINCIPLES AND OPERATING PARAMETERS:

Ferromolybdenum production is accomplished primarily through several oxidation-reduction reactions and is controlled by the affinity of the metals involved for oxygen. This affinity decreases in the order of aluminum, silicon, iron, molybdenum. Thus, the order in which the primary reactions occur are:

$$MoO_3 + 2Al = Mo + Al_2O_3 \qquad \Delta H = -221.8 \text{ Kcal}$$

$$MoO_3 + \frac{3}{2} Si = Mo + \frac{3}{2} SiO_2 \qquad \Delta H = -145.8 \text{ Kcal}$$

$$2\ FeO + Si = 2\ Fe + SiO_2 \qquad \Delta H = -89.7 \text{ Kcal}$$

The heat of reactions ($-\Delta H$) indicate that the reactions are extremely exothermic. In theory, silicon alone will reduce molybdenum trioxide and produce enough heat from molten products. In practice, this reaction is very difficult to initiate. The reduction of molybdenum trioxide with aluminum is very easy to initiate and proceeds very rapidly with tremendous heat evolution. By controlling the ratio of aluminum to silicon used, the kinetics and heat generated during the reduction of molybdenum can be controlled. At present, this ratio varies from 1:4.8 to 1:6.5 and is dependent upon the grade of MoO_3 concentrate, the amount of slagging agents used, and the amount and type of recycle added. A 3 to 5 minute reaction time is an indication of acceptable heat generation. Burn times at Sierrita have varied from 1.25 to 30 minutes but are becoming more consistent as experience with the reaction develops.

The total amount of aluminum and silicon used determines the total amount of heat generated. A normal burn containing 1500 kilograms of molybdenum trioxide will generate approximately 6.3 million BTU. This heat is primarily utilized in melting the charge although considerable radiation heat loss can occur.

The final temperature of the molten bath is dependent on the total amount of heat generated, the heat required to melt the charge, and the heat loss to the surroundings. A 3300°F to 3500°F bath temperature at the conclusion of reaction is desired. Within this temperature range, satisfactory ferromolybdenum-slag separation will occur with minimal losses of molybdenum to the slag as an oxide. The final bath temperature has been difficult to predict and control.

The ferromolybdenum alloy produced contains 60 to 64% molybdenum and 35 to 39% iron and has a melting point of about 2630°F. The iron alloyed with the molybdenum is derived from three sources:

70% from ferrosilicon
20% from reduction of iron oxide
10% from iron powder

A combination of 75% ferrosilicon (75% silicon) and 15% ferrosilicon is used to obtain the simultaneous balancing of necessary reducing agent and required iron.

Slag composition must be controlled Acid insoluble material in the molybdenum trioxide concentrate and the silicon dioxide and aluminum oxide formed in the reduction of molybdenum trioxide report to the slag. Lime, iron oxide, and calcium floride are added to adjust the slag composition to produce a relatively low melting point, fluid slag. The slag composition is approximately 62% SiO_2, 15% CaO, 12% FeO, 8% Al_2O_3, and 3% CaF_2. The melting point of this slag is approximately 2900°F.

PLANT OPERATION:

A typical production burn mixture is comprised of the following ingredients:

1500 Kg Molybdenum trioxide concentrate (62% Mo)
465 Kg 75% Ferrosilicon
350 Kg 15% Ferrosilicon

300 Kg Iron oxide
225 Kg Lime
70 Kg Aluminum powder
50 Kg Iron powder
45.5 Kg Calcium Floride

The ferromolybdenum metal produced from this mix will weigh approximately 1455 kilograms and assay 62% molybdenum.

All raw materials used in the production process, with the exception of lime and sand, are stored in a reagent warehouse in the plant. The 15% ferrosilicon, 75% ferrosilicon, and iron oxide are transferred as needed, from the reagent warehouse via a bucket elevator and screw conveyor to the appropriate charging bins. Lime and sand are stored in bins outside the building and are transferred into the plant by screw conveyors. Molybdenum trioxide concentrate stored in the roaster storage area is pneumatically conveyed 700 feet into its charging bin in the ferromolybdenum building.

Ferromolybdenum is produced on a batch basis. The process begins by charging the required materials into a blender. The molybdenum trioxide, lime, 75% ferrosilicon, 15% ferrosilicon, and iron oxide are charged employing an automatic Ramsey batch weighing system. The calcium floride, aluminum, and iron powder are weighed and charged manually into the blending shell. The charged shell is placed in the mixer frame and blended for fifteen minutes. After blending, the mix is discharged into the firing mold.

The mold, illustrated in Figure 2, consists of an eight foot square box with two foot high sides. A layer of refractory brick is placed on the bottom of the box. Two chains are laid on top of these bricks and extend up and over the top corners of the box. The chains are used to facilitate removing the button from the box after the mixture has reacted and cooled.

Sand is poured on top of the bricks and chains. An iron ring is placed on top of the sand and back filled with additional sand. On top of this, a refractory lined ring is placed centered around and above the iron ring. The blended mixture is charged into the mold filling the lower iron ring and a portion of the refractory ring. The metal ring and a portion of the sand are sacrificial and melt into and around the charge during the reaction. The refractory ring can be used several times before relining is necessary.

After the mix has been charged into the mold, the firing box is transferred to the firing area. The mix is leveled and a starter mix consisting of magnesium, aluminum, potassium nitrate, and iron oxide is sprinkled over the charge. The fume hood is moved into place and the mixture is ignited by dropping a railroad flare onto the charge surface. The starter mix ignites readily and generates enough heat to ignite the actual charge.

Very little gas is evolved from a normal burn. Gassing increases with the amount of water or lime containing limestone being introduced into the mix. Lime becoming hydrated is one source of water that must be closely monitored.

Those gases evolved from the reaction and entrained dust are collected and pass through cyclones and a baghouse. The dust collected is recycled to subsequent burns. There are essentially no visible emissions exiting the exhaust stack.

The reacted burn is allowed to cool at least 16 hours before it is removed from the mold box. At this time, the button center is still above 1500°F. The button is placed in a quench tank and the tank is slowly filled with water. This shock cooling with water will cause fracture to occur along the slag-ferromolybdenum interface. The button remains in the quench tank for 30 to 60 minutes, after which it is removed and placed on the floor. The button, still about 1000°F in the center, is allowed to cool another 24 hours before the slag is separated from the ferromolybdenum slab.

The button, see Figure 3, consists of approximately ten inches of slag on top of 2 1/2 to 3 inches of ferromolybdenum. About 1 to 1 1/2 inches of sand is fused to the bottom side of the ferromolybdenum slab. The slag and ferromolybdenum are separated by hand using sledge hammers. The clean ferromolybdenum is manually broken into minus eight inch chunks and is stored in hoppers prior to crushing. The slag, containing less than 1% molybdenum, is discarded.

The ferromolybdenum crushing circuit consists of three Kue-Ken jaw crushers. The primary crusher is fed by a vibrating feeder. Product from the primary crusher is transferred by belt to the secondary crusher. The product from this crusher is transferred to a three deck vibrating screen. The oversize material from the screen is transferred to the tertiary crusher. The product from this crusher is returned to the screen. The three final products discharging from the screen are furnace size (-1, +1/4 inch), ladle size (-1/4 inch, +20 mesh), and small ladle size (-20 mesh).

The ferromolybdenum products are packaged in 5 1/2 gallon cans containing 200 pounds of ferromolybdenum per can. Twelve cans are placed on a pallet, covered with shrink wrap and shipped as final product.

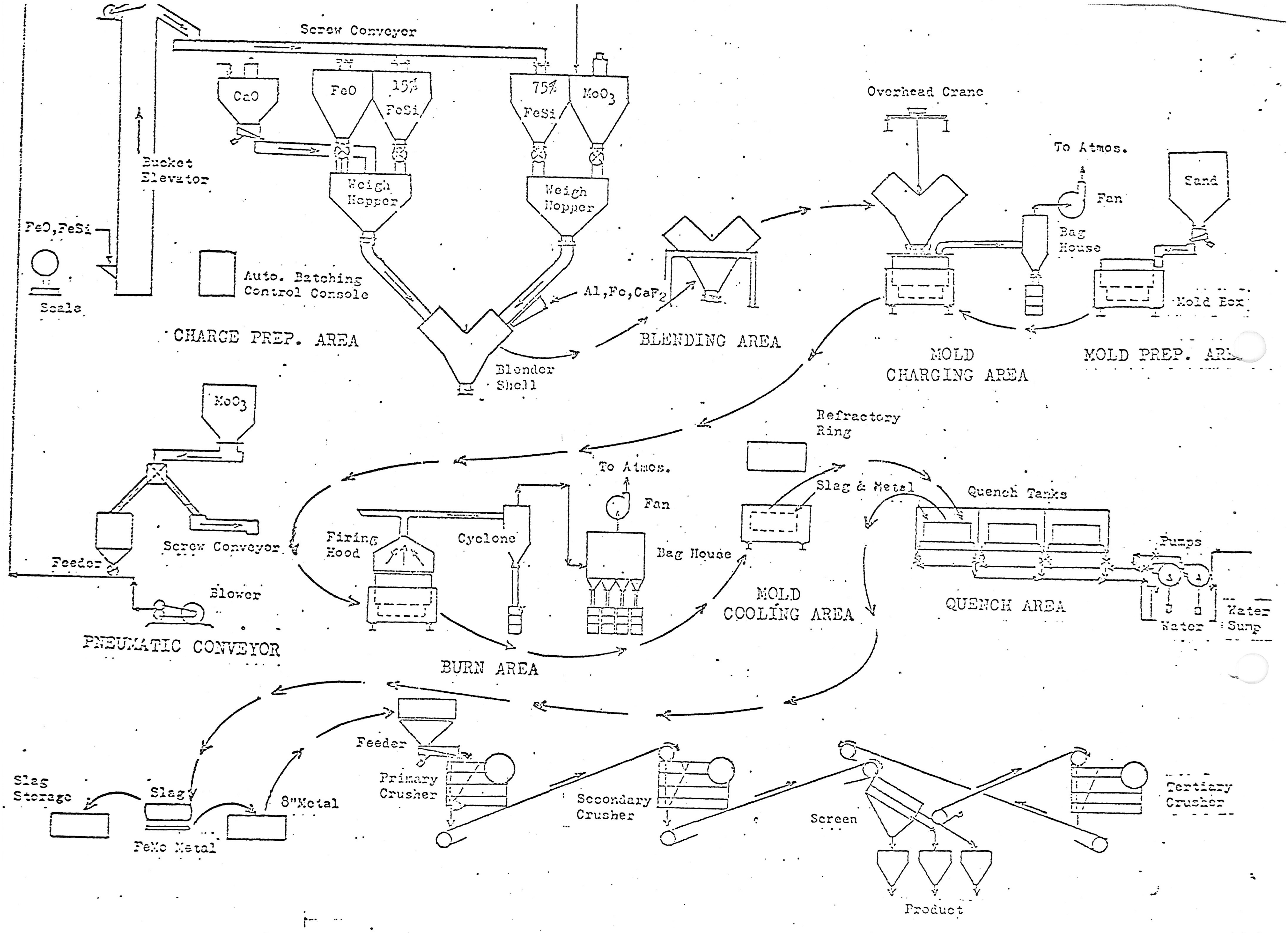
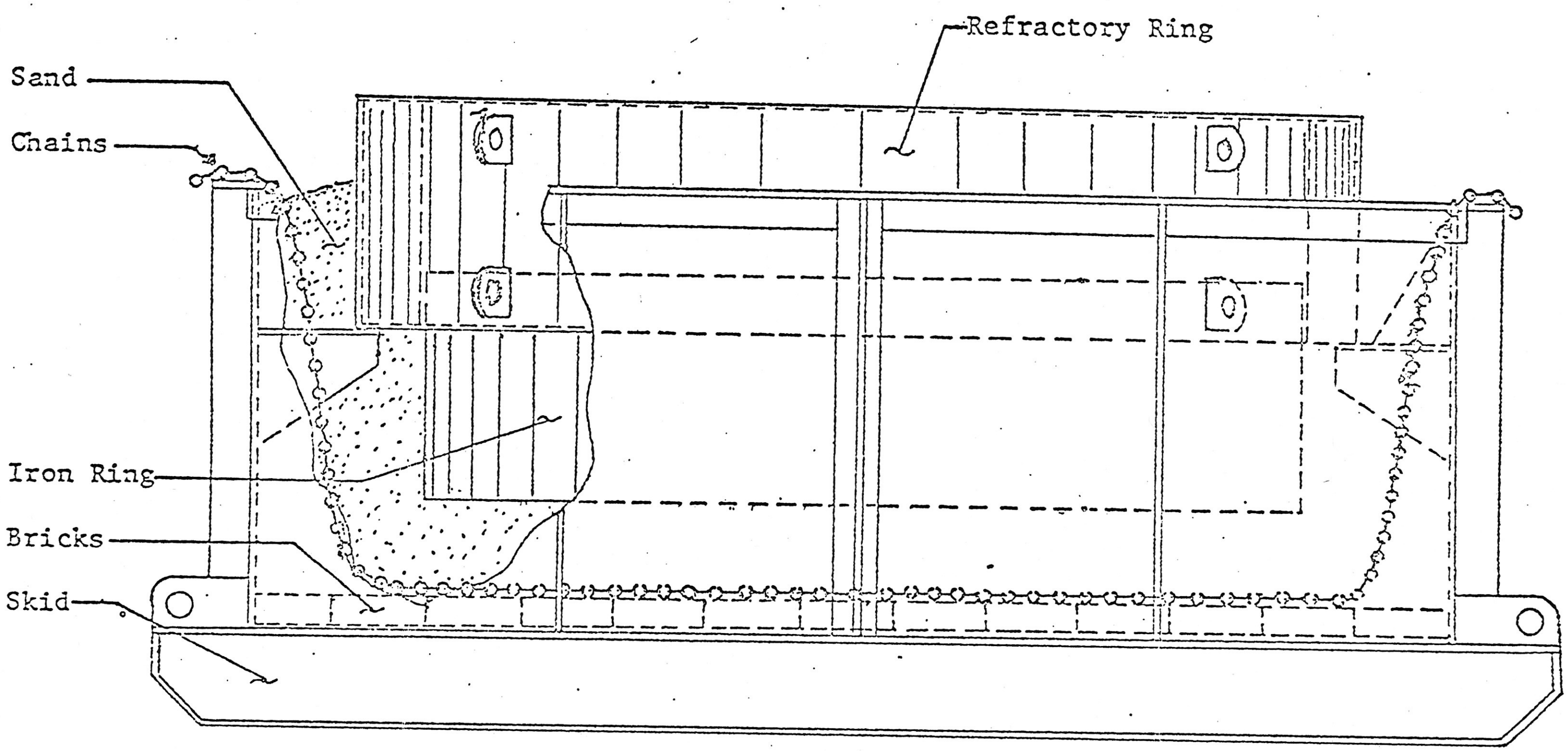


FIGURE 1: PROCESS FLOW DIAGRAM - FERROMOLYBDENUM PLANT - DUVAL CORPORATION



Mold Box

FIGURE 2: Mold Box Scale: 3/4" = 1'-0"

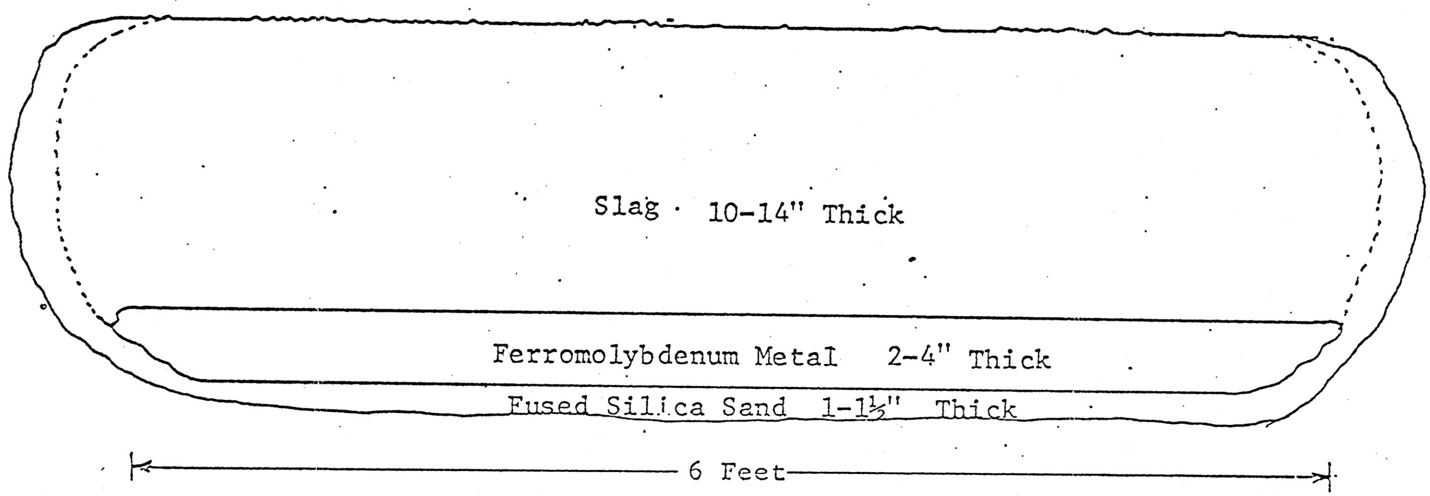


FIGURE 3: Button

TABLE 1

SIERRITA FERROMOLYBDENUM PLANT EQUIPMENT LIST

1.	Pneumatic MoO_3 Conveyor	Carter Day Company design
2.	Feeders	Syntron F440
3.	Bucket Elevator	9 3/4" X 35' Continental Gin Co.
4.	Weigh Hopper	50 cu. ft.
5.	Weigh Hopper	20 cu. ft.
6.	Batching System	Ramsey Engineering Company Designed Auto Batching System
7.	Batching Dust Collector	Mikro-Pulsaire Model 16S-830
8.	Blender	Patterson-Kelley Co. Twin Shell 75 cu. ft. Blender.
9.	Dust Cyclone	Buell dual 54" cyclone
10.	Fan	Sheldon Industrial Size 402 Type BB-26
11.	Baghouse	Norfelt Model He-33-6
12.	Primary Crusher	10 X 24" Kue-Ken Jaw Crusher
13.	Secondary Crusher	6 X 16" Kue-Ken Jaw Crusher
14.	Tertiary Crusher	3 X 12" Kue-Ken Jaw Crusher
15.	Screen	Tyler Ty-Rocket Vibrating screen, Type 330, 3 Deck.
16.	Hoppers	1/2 Cu. Yd. chase self dumping hoppers
17.	Bridge Crane	P & H 10 Ton 55 ft. span
18.	Fork Lift	Tow motor, U50B, 8000 lb.