Site Visit Reports to Mines and Mineral Processing Facilities

Technical Background Document Supporting the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes

Office of Solid Waste (1995)

Memorandum

To: Phase IV Supplemental Rulemaking RCRA Docket No. F-95-PH4A-FFFFF

From: Van E. Housman

Subject: Site Visit Report - Wastes From the Production of Titanium Tetrachloride, DuPont Antioch CA Facility, July 31, 1995.

Date: November 13, 1995

The following individual were present on the site visit DuPont's facility. EPA HQ: Van Housman, Ron Brown; EPA Region 9: Dennis Geiser, Duong Nguyen, Jean Daniel; California DTSC: Vajie MotiaFord; DuPont: Dimitris Argyriou, Brian Coleman.

This facility is a major chemical manufacturing plant, producing chlorofluorohydocarbons, titanium pigments, and other products (see DTSC inspection report for further details).

Synthetic rutile, comprising 85% TiO_2, 12% FeO, and small amounts of aluminum and silicon, is received from Australia and South Africa in the form of crushed slag from smelting operations. The type of smelting that produced the rutile is not known. DuPont documents also refer to this as a "ilmenite-type ore" (see DuPont January 26, 1987 memo), which is reacted with chlorine in the presence of coke in a chlorinator vessel. Titanium tetrachloride and other metal chlorides are formed. Iron chloride waste acids are generate at the rate of approximately 30,000 tons per year and typically would be classified as hazardous because of corrosivity. This iron chloride acid waste, which previously was deepwell injected or landfilled on-site, is stored in a tank and then piped to a separate area for treatment. At the treatment area, the waste acids are mixed with Portland cement in an underground concrete pit (about 20 feet in diameter and several feet deep) to produce a material referred to as "Sierra-Crete". This mixing results in a vigorous exothermic reaction between $FeCl_3$ and $Ca(OH)_2$ to produce FeOOH and $CaCl_2$. The reaction has the physical appearance of boiling mud. The produced Sierra-Crete has a dirt- or soil-like physical appearance.

The cost of producing Sierra Crete is approximately $80 per ton. DuPont sells Sierra Crete for $3 per ton to local companies for use as road base material.

About 16,000 tons of Sierra Crete are stored on the ground at any one time.

Waste hydrochloric acid is generated by the reactors' scrubbing system. The hydrochloric acid is treated with sodium hydroxide to produce sodium chloride waste, which is discharged through a NPDES permit, and magnesium hydroxide which is landfilled on-site. The quantities of these wastes are not known.

The chlorinator vessel, where the rutile is reacted with chlorine gas, is cleaned every two years to remove impurities. Residues from the chlorinator bed are removed and sent to an off-site landfill. The location of this landfill, and quantities of waste shipped there, were not provided. According to DuPont, these residues do not fail the hazardous characteristic test.

Memorandum

To: Phase IV Supplemental Rulemaking RCRA Docket No. F-95-PH4A-FFFFF

From: Van E. Housman

Subject: Site Visit Report - Small Volume Wastes From the McLaughlin Gold Mine (Homestake), Lower Lake California, August 1, 1995.

Date: November 13, 1995

The following individuals were present on the site visit to the McLaughlin mine. EPA HQ: Van Housman, Keith Brown; EPA Region 9: Dennis Geiser, Barry Cofer, Jean Daniel, Tony Terrel, Karoa Morimoto, Latha Rajagopalan; California DTSC: Vajie MotiaFord; Homestake: Ray Krause.

The facility process description, including the carbon-in-pulp, carbon-in-leach (CIP/CIL) circuit can be found in the attached McLaughlin Mine General Information Summary. The ultimate waste discharge for all circuit operations is the tailings pond.

On-site laboratories are used to perform analytical testing of mining ores and process fluids. A variety of reagents, including cyanide, acid, and bases are used. All laboratory drains are discharged to a sump which is then pumped to the CIP/CIL circuit tanks. The amount of gold or other recoverable minerals present in these wastes is unknown.

Crucibles and cupels used in the assaying of ores, crucibles from the induction furnace, and spent bricks from the autoclave operation are sent to the crusher where they re-enter the CIP/CIL circuit tanks. These materials are stored on the ground for indefinite periods of time prior to re-entering the process. The length of storage varies.

Mercury is vaporized, condensed, and collected as part of the gold smelting process. Mercury quench water from the gold retorting furnace is pumped back to the CIP/CIL circuit. The amount of gold or other recoverable minerals present in this waste is unknown. Slag from the gold smelting operation is re-smelted on-site to recover gold. When a batch of slag is found to contain little recoverable gold, the slag is sent to the crusher grinder where it enters the CIP/CIL circuit.

Acid washing wastes from carbon stripping are stored in a plastic tank in the process building prior to being pumped to the CIP/CIL circuit. The amount of gold or other recoverable minerals present in this waste is unknown.

Baghouse dusts high in lead content from several facility operations are sent back through the CIP/CIL circuit. The amount of gold or other recoverable minerals present in this waste is unknown.

The only hazardous wastes reportedly shipped off-site are organic solvents such as methyl ethyl ketone.

Memorandum

To: Phase IV Supplemental Rulemaking RCRA Docket No. F-95-PH4A-FFFFF

From: Van E. Housman

Subject: Site Visit Report - Small Volume Wastes From the Rand Mine, Randsburg California, August 3, 1995.

Date: November 13, 1995

The following individuals were present on the site visit at the Rand Mine. EPA HQ: Van Housman, Keith Brown; EPA Region 9: Dennis Geiser, Barry Cofer, Clint Seiter; Glamis Gold Co.: Sonja Manuel, T.W. Naylor.

The Rand mine is a traditional cyanide heap leach operation. Ore is mined from the Yellow Aster pit and the Baltic pit and placed on lined heap leach pad for cyanide leaching. Gold is collected on carbon and electrowon on steel wool. The gold-laden steel wool is smelted on-site to produce dore' gold bars. The following is a description of management practices of small volume wastes generated at this mine.

As part of the gold/steel wool smelting process, sodium nitrate, silica, and borax are added as fluxes to remove impurities to form a slag. A slag is generated for each pour. About 20 lb of slag are generated per 1000 oz. of gold. The slag is collected after each pour in 55-gallon drums and has the appearance of shiny black glass or obsidian. On average, the slag can be re-melted three times before the recoverable gold in the slag is diminished. The slag is then placed in 55-gallon drums and manifested off-site as D008 (for lead) hazardous waste. This waste is currently shipped to the Marine Shale facility in Louisiana.

Spent solution from the electrowinning cells are pumped back to the barren pond. This spent solution contains caustic and cyanide values.

Cupels from precious metals assaying have been sent to a recycling facility in California. Currently, these cupels are placed in 55-gallon drums and shipped as D008 hazardous waste to the Ensco West Inc. hazardous waste landfill in Wilmington, CA. Hazardous waste cupels are generated at the rate of approximately 1,700 pounds. Baghouse dusts from the assaying furnaces, generated at the rate of 1 to 2 55-gallon drums per year, are similarly shipped to the Ensco facility as hazardous wastes.

For RCRA Docket F95-PH4P-FFFFF (Phase IV Land Disposal Restrictions Proposed Rule)

Note

To: Steve Hoffman, Acting Chief, Special Waste Branch

From: Van Housman, Chemical Engineer

Date: July 22, 1995

Re: Trip Report - May 17, 1995 Site Visit to Newmont Gold Corporation, North Operations Facilities, Carlin Nevada.

Attendees:

Van Housman, Chemical Engineer, EPA Office of Solid Waste
phone 703 308-8419

John Mudge, Manager of Environmental Compliance, Newmont Gold Co.
phone 702 778-4210

The following is a description of selected facility processes at Newmont Gold Co. North Operations Facility based upon site observations and discussions with John Mudge, Manager of Environmental Compliance for Newmont Gold Co.

Retort and Electrowinning Operations

The retort operations are one of the last in a sequence of numerous steps taken to produce Newmont's primary final product--gold dore' bars. A gold cyanide solution, which has been stripped from the carbon, is electrowon on steel wool cathodes. The cyanide solution, now barren, is drained off and sent to the cyanide leach circuit. A sludge forms at the bottom of the electrowinning cell. This sludge is filtered and sent to the retort to recover precious metals. The gold/steel wool cathode is then digested with sulfuric acid to dissolve the steel, leaving a solid gold residue. The waste sulfuric acid and digested steel wool solution is discharged to the tailings slurry. The gold solids are filtered under vacuum through diatomaceous earth. The gold filter cake is then sent to the retort furnace where it is subjected to 1,200F for 14 hours. After retorting, a flux of silica and borax is added and the gold is smelted in an induction furnace. A slag is generated from this smelting and sent to the CIL ball mill for crushing and grinding and gold recovery. Newmont estimates that the gold slag has between 50 to 100 oz. per ton of recoverable gold.

During this retorting process mercury gas is vaporized from the gold filter cake. The mercury gas is quenched with a direct contact water spray and condenses to form liquid mercury which is then collected in flasks and sold to a mercury refiner. Approximately one ton per month of liquid mercury product is generated in this manner. The waste mercury quench water, generated at the rate of 20 to 30 gallons per minute, is pumped to and mixed with the CIL circuit.

After the retort process, a silica and borax flux is added to the gold in a smelting induction furnace. It is from this induction furnace that gold dore' bars are poured. The slag produced from this smelting has between 50 to 100 ounces of gold per ton and is collected and sent to the ball mill where it is crushed and recycled into the CIL circuit.

CIL Stripping

Carbon loaded with gold is sent to a washing vessel where a hydrochloric acid solution is used to dissolve various impurities. These impurities, commonly calcium, copper, lead, nickel and others, block the active sites on the carbon which are available to attract a chelated cyanide/gold molecule. The gold stays on the carbon during this acid washing process. The waste acid waste solution is pumped back to the CIL circuit at an unknown generation rate.

The next step is an elution process in which hot cyanide/sodium hydroxide solution (230F under 30 to 40 psi) removes the gold from the carbon. Then hot fresh water is pumped through the carbon to complete this elution step. This gold rich solution is then sent to the electrowinning/steel wool recovery process. The carbon, now devoid of most gold, is sent to an on-site regeneration kiln and recycled. Carbon fines, which have 2 to 3 ounces of gold per ton are shipped off-site for gold recovery.

Laboratory Wastes

An on-site laboratory is used to assay ore samples and perform analysis of a variety of solutions related to the CIL circuit. Over 200,000 assays per month are performed at this laboratory. In the assaying process, an ore sample is melted with a pre-measured amount of lead in a crucible and allowed to cool. A lead button forms at the bottom of the crucible and is broken away from the remaining gangue. This lead button has in it the gold from the ore sample.

The lead button is then placed in a cupel and melted. The lead reports to the walls of the cupel and bead of gold remains in the bottom of the cupel. A measured amount of silver is added so that the bead can be more easily seen and

handled. This bead is then digested with aqua regia (a concentrated solution of hydrochloric and nitric acids) and the resulting solution undergoes atomic absorption analysis to determine the amount of gold present.
The waste crucibles and cupels fail the hazardous characteristic for lead and are placed in a dumpster and manifested as a hazardous waste to a permitted TSD facility in Colorado. The waste generation rate is unknown.

Laboratory wastes that contain quantities of cyanide are sent to the CIL circuit. The quantities and characterization of wastes sent to the CIL circuit in this manner are not known.

Laboratory waste that contain organic solvents are sent to a permitted TSD facility in Salt Lake City. The quantities and characterization of organic solvent wastes are not known.

Sulfide Roaster

Newmont uses a sulfide roaster to oxidize the sulfides for a particular ore type to make the gold in the ore more amenable to cyanide leaching. In this process, 1.5 percent sulfide ore is sent to a crusher/grinder and then to a roaster where it is roasted at 1,000F. Sulfur dioxide gas and dust emitted from the roaster is cycled through an electrostatic precipitator to remove the solids. The dust from the precipitator is sent to a quench tank and then to a lime neutralization tank. The resulting slurry is thickened and the solids are sent to the CIL circuit for gold recovery while the liquids are sent to the quench cooling pond for re-use.

The SO2 gas is cycled through a vanadium pentoxide catalyst process to produce 98 percent sulfuric acid at the rate of 500 tons per day. This product grade sulfuric acid is sold to the nearby American Barrick gold mine for use in acidifying ore prior to its autoclaving operation, or to other markets. The rate of generation and the management practice of spent vanadium pentoxide catalyst is not known. The rate of generation and the management practice of acid plant blowdown is not known.

MEMORANDUM

Subject: Trip Report -- Site Visit To Magma Copper and Cyprus Miami Copper Mines

From: Jim O'Leary, Definition of Solid Waste Task Force
Van Housman, Chemical Engineer, Mining Waste Section

To: Jim Berlow, Director, Definition of Solid Waste Task Force
Matthew Straus, Director, Waste Management Division

Introduction

The purpose of this memorandum is to summarize the results of our site visit to the Magma Copper and Cyprus Miami mining and primary mineral processing operations outside of Tucson, Arizona the week of March 14.

As you know, the Definition of Solid Waste Task Force is proposing changes to the current definition of solid waste regulatory framework that could adversely affect primary mineral processing operations. Similarly, the Office of Solid Waste must develop treatment standards under the land disposal restriction (LDR) program for newly identified mineral processing wastes (i.e., primary mineral processing wastes that are no longer exempt under the Bevill exclusion.)

In response to industry concerns, and in preparation for developing LDR regulatory requirements for primary mineral processing wastes, we visited the Magma Copper and Cyprus Miami copper mining and mineral processing facilities to understand firsthand the processes and operations they undertake to produce copper and related products. Our site visits focused on three particular aspects of this industry: (1) how they process virgin ore, (2) what secondary materials are generated, and (3) how the secondary materials are subsequently managed.

Appendix A provides a detailed description of the mining and mineral processing operations we reviewed at Magma and Cyprus Miami. We have provided a detailed description of these operations, particularly Magma, to serve both as an educational tool for the uninitiated reader (and writer) and to use as a baseline for drawing conclusions on how proposed changes to the definition of solid waste may affect mineral processing operations.[1] To support and enhance

[1] Although emphasis is placed on Magma's operations, we also identify differences between Magma and Cypress Miami whenever appropriate.

our description, we borrow heavily from information developed in the Copper Technical Resource Document developed by the Mining Waste Section.

As part of this visit, we also met on the last day with several Magma Copper and Cyprus Miami officials and representatives from the American Mining Congress to review their operations and discuss with them our observations from the site visits to Magma Copper and Cyprus Miami.[2] As part of this last day, we also spent considerable time addressing issues they have with the proposed changes to the definition of solid waste.
Below is a summary of our observations.

Observations

Maximizing Copper Recovery Is Critical to the Primary Mineral Processing Industry. What is very clear to us from our visits to Magma Copper and Cyprus Miami is that the recovery of practically every secondary material is inherent to the primary mineral processing industry. The economics of mining and subsequent mineral processing, including beneficiation, is the most critical and overriding component of every business decision. The costs of production are significant. The capital investment in Magma alone is over $1 billion. Obtaining an adequate return on their investment means extracting out of the ore every possible ounce of copper. Recovery rates are critical. Therefore, recycling the slag, flue dust, reverts, etc. to obtain additional amounts of copper is an important business decision. In Magma's case, the recycling of slag is economical; for Cyprus Miami, extracting additional amounts of copper is not economical.

The metal content of virgin copper ore extracted at both sites averaged less than one percent. In other words, for every ton (2000 lbs.) of ore mined at Magma or Cyprus, only 20 lbs or less of copper is ultimately sold in commerce. Copper is currently trading at 90 - 95 cents per pound, or approximately $18.00 per ton of copper extracted.

Complicating this issue is market competition. Mineral processing is truly international in nature with metal prices set on the London Stock Exchange. A change of one penny in price, or to the costs of production, is significant to this industry. Therefore, the mining and mineral processing industry is very sensitive to regulations such as our proposed changes to the Definition of Solid Waste where significant economic impacts could occur.

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[2]These participants included John Fognani, Gibson, Dunn and Crutcher Lawyers; Rod Dwyer, American Mining Congress; Norm Greenwald, Magma Copper Consultant; and Les Darling, Cyprus Minerals.

Placement on the Land of Their Secondary Materials Is a Historical Industry Management Practice. Most of the secondary materials generated during the copper manufacturing process are placed on the land because they are either currently exempt materials and/or technical infeasibility prevents them from being placed any where else. Industry has argued that these materials are an inherent part of the production/extraction/reprocessing process. Our visit, we believe, validated that premise. However, the fundamental issue is how these materials are managed prior to being reprocessed.

This practice is a concern to us for two reasons. First, if certain materials that would otherwise be classified as a solid waste are allowed to be placed on the land, then how can one differentiate in any enforceable manner instances where the material is being stored only for purposes of discard. Similarly, if stored on the land, is not this the historical practice that has led to our Superfund sites.

Second, placement on the land contradicts somewhat the message sent to us by company and industry officials. That is, if the material is valuable to them, why are they sometimes placing it on the ground and letting rain and wind affect its disposition, particularly in those instances where it is technically feasible to store the material in a bunker or building.

The primary mineral processing industry is very concerned about the ultimate resolution of this issue because of the "slippery slope" impact of other materials stored on the ground. Industry is concerned that EPA's storage requirements will expand to include other re-processing operations and interfere with normal industry production practices. Unfortunately, their "slippery slope" is also our "slippery slope" because if not addressed properly, we could allow the inappropriate storage of materials on the ground.

There is a Significant Potential for the Copper Sector to Become Major Recyclers/Reclaimers of Metal Bearing Hazardous Wastes as Substitutes for Mineral Ores. The copper sector has significant capacity to accept these materials because of its investment in large scale pyrometallurgical (smelting) and hydrometallurgical (flotation, SX/EW, flue dust leaching plant) capital equipment. For example, Cyprus has been accepting F006 wastewater treatment sludges since 1984 and easily has the capacity to accept the national generation of this and similar wastes. Magma has the capacity to accept a variety of copper bearing acidic wastes in its SX/EW circuit. These technologies exist and have been proven to economically recover copper and precious metals.

However, there are several environmental and regulatory issues associated with this potential situation. For instance, will the management of these wastes at a primary mineral processing facility be equal in risk reduction to that of a

RCRA permitted treatment, storage and disposal facility (TSDF)? Is the lack of storage prior to recycling the major factor that should be weighed in granting a primary mineral processing facility regulatory relief relative to a commercial TSDF? How should the incremental risk posed by the recycling of secondary materials be measured? There also is the issue of consistency. Can we legitimately justify Category D requirements for a commercial recycler not storing prior to recycling and less stringent regulatory requirements for a manufacturing facility performing the same function in the same manner?

Today's Highly Integrated Recovery Operations Fail to Distinguish Effectively Bevill from Non-Bevill Circuits. At Cyprus, the electrolytic refinery bleed (a non-Bevill exempt waste) and the electrowinning circuit lead anode sludges (a Bevill exempt waste) are located in the same building. In fact, these two circuits are located side by side and are indistinguishable in many ways. Theoretically, one could draw a line down the center of this building and classify wastes from one side as being exempt while wastes from the other side would not be. The non-exempt bleed stream from the electrolytic refinery is placed in the exempt raffinate pond potentially jeopardizing its exemption. At the time the Bevill rules were written, EPA had very little knowledge of these highly integrated waste management and recovery practices. The issue is whether these Bevill distinctions are arbitrary and make sense in light of the goal of metals recovery from these waste streams.

In summary, the overall message we observed during our site visits was that the recycling of primary mineral processing materials is an inherent component of their manufacturing process. Similarly, the on-site recycling of materials such as flue dust, reverts, etc., as well as the intra-industry shipment of valuable materials is a natural component of every day processing and reprocessing designed to extract every possible ounce of metal.

However, there are issues with our Definition of Solid Waste Straw Proposal that not only affect the primary mineral processing industry, but all industries. In particular two areas stand out: (1) the no land placement of certain materials such as spent refractory bricks, and (2) the inter-industry shipment of secondary materials such as F006 that are currently exempt because these materials directly enter the manufacturing process and are not stored. Further analysis is necessary to resolve these generic issues.

Issues

As stated before, the major reason for our trip was to investigate firsthand issues raised by AMC and primary mineral processing companies concerning the impact of our Definition of Solid Waste Straw Proposal on their operations. In particular, the industry expressed concerned about the following issues:

- the regulatory status of emission control flue dust
- no land storage prohibition
- conditions for meeting our proposed "toxics along for the ride" (TAR) test
- reclamation/incidental processing of secondary materials
- intra-industry shipments
- inter-industry shipments

Below is our response to these issues. The following is a discussion of how specific waste streams and management practices would be addressed under various definition of solid waste Strawman proposals. It is not designed to interpret or classify waste streams under current EPA or state regulations.

Flue Dust From the Primary Mineral Processing Industry Either Will Be Classified as a Co-Product or Exempt Emission Control Residue. This classification will exist only when the flue dust is generated and recovered in a primary process with a cutoff at the ore grade level of the facility. In other words, the concentration of the primary mineral of concern in the flue dust must be equal to, or greater than, the concentration of the primary mineral in the ore grade.

The results from the site visit and discussions with mining officials clearly suggest that the recovery of flue dust from air pollution control equipment is an integral part of primary copper production. In many instances, the recoverable copper content of flue dust can be comparable to concentrate feedstock entering the smelter and much higher than run-of-the mine ore.

Modern primary copper smelters are designed and operated to generate, collect, and re-introduce flue dust back into the process. Economics generally control where in the process flue dust should be reintroduced. Magma provided us with a specific example of copper that can be recovered economically from flue dust in both the pyrometallurgical process (smelting) and the hydrometallurgical process; e.g., their new acid leach plant).

If the Above Conditions Are Met, Then the No Land Storage Prohibition For These Materials Would Not Apply. This decision results naturally when materials are handled as products or co-products in a manufacturing process. However, this issue is the most sensitive and complex of any we must address. The issue is consistency and the "slippery slope" syndrome that could result in the decision we ultimately choose to make regarding the placement of these or other materials on the ground. More specifically, the issue focuses on whether some of these materials can be stored on the ground, even temporarily.

We have no doubt that Magma and Cyprus' housekeeping practices appear somewhat inconsistent with the message conveyed to us to minimize losses of recoverable copper;e.g., the release of windblown flue dust (Magma more so than Cyprus). However, bunkers and semi-containment buildings have been constructed to store some of these materials before reprocessing them. As pointed out by Magma and Cyprus Miami officials, however, State officials can and have addressed this concern by requiring facilities to meet their own air pollution control and ground-water protection requirements. Since a major cornerstone of our system will be State flexibility in applying our requirements, we believe our concerns on this particular issue could be addressed on a site-by-site basis.

Allowing the States to address this issue is only one alternative. Another alternative is to work with the mineral processing industry and establish those instances where the only feasible choice available is temporary placement of the material on the ground. By feasible, we mean from a technical, economic and/or environmental viewpoint. A third alternative is to lift the no land placement ban on the primary mineral processing industry.

A fourth alternative is to implement a generic approach to the primary mineral processing industry and address issues related to both the definition of solid waste and the LDR program. Because the copper sector is relatively homogeneous in its mining and mineral processing methods, it appears worthwhile to examine whether a "best management practices" or some other technological regulatory approach is workable. This may include establishing a "profile" for certain recoverable waste streams (i.e., setting numerical ranges of recoverable copper content and contaminants in waste streams based upon current practices for specific recovery units), designating areas and time limits where temporary land storage takes place and establishing points of compliance for measuring releases of contaminants. This technological approach would have to be flexible enough to address changes in mineral technology.

"Toxics Along For The Ride" Requirements Can Be Met by Simply Producing Commercial Grade Products. Industry has expressed considerable criticism on our proposed "toxics along for the ride" test. Our objective has and continues to be that we ensure recycling of wastes in production processes do not make the ultimate product any worse from the standpoint of entrained contaminants than it would be if ordinary raw materials or feedstocks were utilized in production. The primary mineral processing industry should be able to readily pass this test by manufacturing products, such as copper cathodes, copper rod and sulfuric acid, that meet commercial grade specifications. More specifically, if a State ever challenged a primary mineral processing facility on this issue, the quality control/quality assurance procedures established at facilities such as Magma should be more than sufficient to pass a "TAR" test.

Land applied products, such as iron sulfide soil supplements and sulfuric acid used in the production of phosphate fertilizer, also should not pose a problem if commercial grade quality control procedures are maintained, and information pertaining to composition and impurities contained in these products is kept on hand.

In-Process Materials Returned to the Primary Production Process Are Co-Products or Intermediates. Specific examples in the primary mineral processing industry include slags, reverts and furnace bricks. While these materials require the interim step of being placed on the land for a short period of time before reintroduction into normal processing operations (e.g., crushing and grinding), these materials are equivalent in value within the industry to flue dust. That is, these materials hold considerable concentrations of ore equal to and most likely greater than the concentration of the ore grade material removed from the ground. They therefore are recycled to extract their monetary value rather than being discarded.

As stated above, the no land placement prohibition in our Straw Proposal could cause problems with this recommendation. If, for some reason, the above classification becomes unacceptable as our process continues, alternative concepts should be pursued, including those we previously identified. We believe solutions do exist, particularly for materials like reverts, furnace bricks, etc., where they appear to pose no threat to the environment because of their composition.

Valuable Materials, Such as Anode Slimes, Are Classified as Co-Products or Intermediates when Shipped Between Primary Mineral (Intra-Industry) Facilities for Further Processing. These materials therefore would not be classified as solid wastes. Copper concentrate is treated as a commodity that is traded between primary copper producers. Copper concentrate also contains naturally occurring precious metals that can be produced as an intermediate product or co-product.

(These precious metals are produced when copper anodes are electrolyticly refined to produce copper cathodes.) Some primary metal facilities have invested in process equipment to economically extract precious metals from captive as well as off-site producers of copper concentrate.

On a per unit basis, these precious metals can have economic value equal to or greater than the primary metal being produced. Business arrangements have been developed where these materials are shipped off-site to another primary mineral facility for further processing. Payment for these materials is made in the form of cash, precious metals credits applied towards processing costs, tolling agreements or toll concentrate shipments between buyer and seller. We may need to conduct further analyses on this subject to ensure that this dynamic situation is clear to all concerned parties.

Inter-Industry Shipment of Secondary Materials For Use as Supplemental Feedstock Are Not Solid Wastes When No Storage Is Involved. Stated differently, when secondary materials are shipped between industrial sectors and immediately fed into the production process for use as feedstock, they are not a solid waste. This exemption would not continue if more than 50 percent or more of the feedstock was received from off-site -- thus making the facility a secondary metals producer. The specific example discussed was the shipment of F006 to Cyprus Miami from another facility. Conversely, storage of the material prior to insertion into the recycling process will require either a Part B permit or compliance with our Category D (Commercial Recycler) requirements.

Situations of this type may prove difficult to implement as our process continues. For instance, how will we know if the material was sent for recycling-- a concern continually expressed by the states. This issue requires further discussion. We believe simple adjustments can probably be made. For instance, a condition of compliance, and therefore exemption, could be the requirement that the generator use a recyclable materials manifest in shipping his/her material to the primary mineral processor.

Based on our analysis, we believe these materials and processes should be exempt from the Definition of Solid Waste.
However, we believe the ultimate solution (and classification) for some of these materials can only result when we can address the issue of no land placement in an effective manner.

cc: Bob Hall
Steve Hoffman
Nancy Bacon Brown
Marilyn Goode

APPENDIX A

A SUMMARY OF MAGMA COPPER and CYPRUS MIAMI'S MINERAL PROCESSING OPERATIONS

Mining and Primary Mineral Processing Operations -- An Overview

Mining extraction, beneficiation and mineral processing operations are very interrelated processes linked together by the type of ore body. The type of ore will dictate, to a great extent, the most economical processes to use in extracting the material and subsequent beneficiation and processing operations.

Copper ore is of two types: oxide and sulfide. Oxide copper ores are usually mined through open pit or in-situ leaching operations. The copper metal content is then extracted through solvent extraction and electrowinning (SX/EW) processes which generate a copper cathode for subsequent processing at a copper rod plant.

Sulfide copper ores, conversely, are processed into copper rod more economically through smelting operations. As described in more detail below, several preliminary steps are necessary to prepare the mining ore for smelting, the most important step being to concentrate the ore into a dry cake for input into the smelter. Unlike oxide ores, however, sulfide ores generate sulfur dioxide gas as a coproduct in the smelting operation. Through chemical reactions with oxygen facilitated by catalysts, this sulfur dioxide gas is converted into commercial grade sulfuric acid for subsequent internal use and sale to external customers. More sulfuric acid is generated per pound of copper ore than copper rod.

Figure 1 provides an overview of mining and mineral processing operations at Magma Copper. At Magma, the mining operations conducted to extract a particular metal for commerce consists of three types: open pit, in-situ leaching and underground mining. (These are represented by the top box in each column.) At Magma, for example, there are three separate mineral operations. Ore mined at the open pit can either be placed on heap leach pads for subsequent solvent extraction/electrowinning (SX/EW) processing (hydrometallurgical process) of the pregnant leached solution (PLS) or, along with ore from the underground mine, eventually be sent to the smelter for copper recovery (pyrometallurgical process).

Dissolved copper is also extracted using in-situ leaching processes at Magma. As seen in Figure 1, the output from the in-situ leaching circuit (e.g., the PLS) follows the same circuits as ore placed on heap leach pads. The result of the SX/EW and smelting processes is cathode copper plates sent on to the copper rod plant for production of the finished product.

Cyprus Miami, conversely, extracts copper through an open-pit operation. This material is then trucked to a dump leach area where it follows a process similar to Magma's open pit operation. Cyprus Miami also receives copper concentrate from their other nearby mining operations and follow Magma's smelting processes to produce copper rod. (Figure 2 depicts Cyprus Miami's overall operations. Figure 3 depicts Cyprus Miami's smelting processes.)

Mining and Processing Sulfide Ores

Figure 4 provides an overview of mining and mineral processing operations for copper sulfide ore. In broad terms, while several steps are involved in the mining and beneficiation of the copper sulfide ore to produce a product for sale, these steps can be clustered into the following:(1) ore extraction, (2) beneficiation, (3) smelting, and (4) fabrication.

Ore Extraction

The first step is ore extraction. At Magma, sulfide ore is extracted through underground mining at depths of up to 4,000 feet below the surface. (Underground mining operations are used to mine deeper, and richer ore bodies. Factors influencing the choice of mining method include the size, shape, dip, continuity, depth, and grade of ore body; topography; tonnage; ore reserves; and geographic location.)

This ore body is approximately one billion tons, with about 56,000 tons per day hauled to the surface and transported to the mill for subsequent processing. At Magma, underground mine workings are located between 700 and approximately 4,000 feet below the surface and are accessed by four "production" shafts and three "service" shafts. The service shafts provide intake ventilation and supplies, while the production shafts are used to haul ore to the surface as well as serving as exhaust shafts. The ventilation system circulates up to 1 million cubic feet per minute of forced ventilation air into the underground mine workings. Production and service shaft activities at the mine site are monitored by computers in the mining surface control room.

The underground sulfide ore body is mined using the block-caving method, which entails blasting sections of the ore body above the grissly level (used to convey ore) and allowing gravity to collapse horizontal slices of ore. Ore falls through the grissly level and goes through a series of vertical or inclined shafts that transfer ore to the haulage level into ore cars. At the grissly level, very large pieces are reduced in size manually with a sledge hammer. A train of ore cars transfers the ore to dump pockets, where it is drawn up to the surface with five ton skips to the top of the production shafts, and dropped into coarse ore storage bins.

Prior to transport of the ore to the mill at Magma, the ore is subjected to primary crushing in one of four gyratory crushers located in the underground workings. Iron detectors are installed on conveyors for the removal of tramp iron that can interfere with the milling process. The ore is sent to receiving bins for transport to the mill in 100 ton capacity rail cars. Ore from the underground mine is generally sized to less than six inches. In some cases, the coarse ore may be shipped directly to the mill without primary crushing. A 20,000 ton coarse ore storage bin at the mill is used to store ore for holding prior to secondary and tertiary crushing. Relatively little waste rock is generated from underground mining compared to waste rock generated in a open pit.

Beneficiation

As seen in Figure 4, the steps following ore extraction consists first of crushing and grinding the sulfide ore found in the coarse ore storage bins, followed by copper flotation, separation of molybdenum from the resulting copper concentrate (at facilities where the recovery rate is usually greater than 1 percent), and storage and drying of the remaining copper concentrate for introduction as the primary raw ingredient into the smelting process operations. These steps are called beneficiation.

The first step in ore beneficiation is crushing and grinding, or size reduction operations. Crushing may be performed in two or three stages. Primary crushing systems consist of crushers, feeders, dust control systems, and conveyors used to transport ore to coarse ore storage. Primary crushing is often accomplished by a jaw or gyratory crusher, since these units can handle large rocks. The feed to primary crushers is generally mining ore. Primary crushing systems are located near or in the pit at surface mines or below the surface in underground mines.

Secondary and tertiary crushing usually are performed in surface facilities in cone crushers, although roll crushing or hammer mills are sometimes used. In these reduction stages, ore must be reduced to about .75 inches before being transported to a grinding mill.

Size separators (such as grizzlies and screens) control the size of the feed material between the crushing and grinding stages. Grizzlies are typically used for very coarse material. Screens mechanically separate ore sizes using a slotted or mesh surface that acts as a "go/no go" gauge.

Grinding is the last stage in the size reduction circuit. Here ore particles are reduced and classified into a uniformly sorted material between 20 and 200 mesh. Most copper facilities use a combination of rod and ball mills to grind sulfide ore. Rod mills use free steel rods in a rotating drum to grind the ore. A ball mill works by tumbling the ore against free steel balls and the lining of the mill.

Typically, grinding circuits are organized in series configurations. Each unit in the series produces successfully smaller material. Typically, crushed ore and water enter the rod mill. When the material is reduced to a certain size, it becomes suspended in the slurry. The fine material then floats out in the overflow from the mill. Oversize material passes to the ball mill for additional grinding. Undersize material moves to the next phase of beneficiation.

At Magma, for instance, ore from the coarse ore storage bins at the mill site is conveyed to a double deck screen, where undersized material (< 1 inch) is conveyed to fine ore bins, while oversized material (>1 inch) is sent to one of the cone crushers. The cone crushers discharge the ore to the surge bins which, in turn, convey the ore to a single deck vibrating screen for further sizing. Crushing is complete when the material is reduced in size to less than 1 inch.

The crushed ore is then conveyed into one of 13 automated wet grinding circuits, each with one rod mill and two ball mills. The rod and ball mills are cylindrical vessels filled with the ore and steel rods or balls that rotate on a horizontal axis grinding the ore. After initial grinding in the rod mills, ore is sent to a cyclone for sizing. Greater than 3mm material (the cyclone underflow) is transported to the ball mills for additional grinding. The hydrocyclone overflow, less than 3 mm material, is transferred to the pulp distributor flotation feed. Overall, the grinding circuits reduce the ore size to 80 percent passing 200 mesh.

<u>Copper Flotation</u>

The next step in the process is concentration. The purpose of concentration is to separate the valuable mineral from nonvaluable minerals. One of the advantages to the flotation method is that it makes the recovery of molybdenum viable at some facilities. The recovery of molybdenum, when the price is adequate, can provide a significant portion of a mine's revenue. In addition, to this product, most of the precious metals in copper concentrate are recovered in anode slimes during subsequent electrolytic refining steps.

The flotation process is similar to a large washing machine that keeps the particles in suspension through agitation. The ore is first conditioned with chemicals to make the copper minerals water-repellant without affecting the other minerals. Air is then pumped through the agitated slurry to produce a bubbly froth. The water repellant copper minerals are aerophillic, that is, they are attracted to air bubbles, to which they attach themselves, and then float to the top of the cell. As they reach the surface, the bubbles form a froth that overflows into a trough for collection.

The other noncopper minerals sink to the bottom of the cell and are removed for disposal to the tailings pond. At most facilities, thickening of tailings (i.e., removal of water) is a common step prior to pumping the thickened slurry to the tailings pond and ultimately disposing of the thickened slurry. Thickening minimizes the amount of water placed in the pond and the pond size. The thickened tailings retain sufficient water to allow them to flow in the tailings pipeline without undue wear on the transport system.

At Magma, there are two separate, two-stage froth flotation systems, one for ore and another for slag and other materials (e.g., refractory bricks). Cyprus does not reprocess their slag because the copper concentration is not economically feasible. At Magma, the incoming ore feed is approximately 0.6 percent copper; the incoming slag is 1.8 percent copper. Methylisobutyl carbonal (MIBC) is used as a frother in a flotation circuit. Collectors include sodium xanthate, fuel oil (jet fuel A, which is used as a molybdenum collector), and VS M8, a proprietary flotation agent containing carbon disulfide. The underflow from the flotation process is sent to the tailings thickener. The two types of flotation circuits, one for ore and one for slag, are exactly the same except that a different primary collector, Dithiosphate 55741, is used in slag flotation.

The concentrate from the flotation circuit contains approximately 30 percent copper. At Magma, this concentrate is sent to the molybdenum plant, while at other facilities such as Cyprus Miami, the concentrate is sent to the smelter for processing. Dewatering the concentrate in a thickener, then in disc or drum filters for final dewatering, produces a relatively dry product that is stored for further processing or shipment to another primary mineral processor for further use. The collected water is usually recycled to the milling circuit.

<u>Molybdenum Plant</u>

At Magma, the copper concentrate from flotation also contains approximately 1.0 percent molybdenum disulfide, a concentration high enough to generate a saleable co-product. The molybdenum plant consists of additional stages of flotation: one rougher stage, three cleaner stages, and five recleaner stages that separate the molybdenum from the copper concentrate. The copper concentrate is first added to rougher flotation cells, where sodium cyanide is used to suppress the copper. The molybdenum floats while the copper concentrate becomes underflow and is sent for drying and thickening prior to smelting. The overflow is sent on to additional cleaner and recleaner circuits. At the last recleaner circuit, 70 percent is sent for filtering and drying while the remaining 30 percent is returned to a filter at the beginning of the recleaner circuit. Filtering and drying produces a 95 percent molybdenum disulfide product, which is shipped offsite in 55-gallon drums and sold as molybdenite.

Copper Concentrate

At Magma, copper concentrate is dried in the "hydroseparator", and dewatered to 10 percent water. The water removed in the filtering/thickening operation is returned to the mill, and the dried copper concentrate is placed on conveyor belts and transported either to storage prior to smelting or directly to the flash furnace for smelting. The copper concentrate typically consists of 30 percent copper, 30 percent iron, and 30 percent sulfur and oxidizes. In both the dryer and on the conveyor, silica is added as flux for smelting.

In this stage, copper concentrate purchased off-site from other copper milling/flotation operations also may be added. This material is used both as a substitute and supplement for the copper concentrate produced at the original plant. This material is purchased or exchanged for other material (tolling agreements) to augment existing supplies and to optimize capacity of the smelter. Purchase prices depends on copper and precious metal content. These concentrates are blended to improve the ingredient composition of materials entering the smelting operation to optimize product recovery.

Processing Operations

Typical mineral processing operations include the smelter, the associated acid plant, the electrolytic refinery and the rod casting plant. Magma uses a flash furnace while Cyprus Miami uses ISA technology. Smelting operations at Magma consist of a flash furnace circuit and a converter furnace circuit. In the flash furnace, the reaction shaft maintains a fire in the center of the stack initiated by natural gas, and concentrate is sprinkled down around the sides. The sulfides react with oxygen to create a flash that melts all the ingredients of the charge on their way down a shaft into the settler. Gas containing dust and nearly 30 percent sulfur dioxide is transported through the uptake shaft into a waste heat boiler for cooling. The waste heat boilers remove heat from the gases for use in producing steam. The gases continue through the electrostatic precipitators and to the acid plant, which converts the sulfur dioxide-rich gases to sulfuric acid (a usable and/or saleable product.)

Copper matte from the flash furnace contains approximately 60 percent copper and is placed in ladles and transported to the "converter isle." The molten matte is poured into a converter, where further oxidation of sulfur and slagging of waste metals takes place over a period of seven to eight hours, until the matte reaches 99 percent copper. Copper matte is poured into empty cells in a 12 to 15 foot diameter converter.

From the converters, the molten copper, now called "blister," is transported (anode vessel) to the casting department, where it is fire-refined for final removal of sulfur and oxygen before being poured into molds to produce copper anodes for transport to the electrolytic refinery.

The ISA smelter at Cyprus produces anode copper in a similar fashion except that the converter slag contains much less copper. As a result, the ISA process does not produce slag that is economically recoverable. The ISA furnace also needs some natural gas or coal as a partial fuel source whereas the flash furnace is self sustaining (i.e., the burning of the sulfur in the ore supplies all the necessary heat.) Cyprus Miami smelter is 100 percent toll which means that 100 percent of the concentrate comes from offsite copper concentrate producers.

Electrolytic Refinery

At the electrolytic refinery, the anodes from the smelter, along with copper starter sheets, are placed in baths of an electrolyte made up of sulfuric acid and copper sulfate. An electrical current flows through the anodes and electrolyte to plate the copper from the anodes onto the starter sheets over a 12 day period. After 12 days, the cathode produced weighs approximately 365 pounds.

Rod Casting Plant

From the electrolytic refinery, the cathode sheets are placed into a melting shaft at Magma's and Cyprus' rod plant. The molten copper is drawn on a wheel around the shaft and fed into finishing roles with cutting solution. The rod is reduced down to 5/16-inch diameter. The drawing process is also a continuous cooling process. The rods are sprayed with sulfuric acid from the acid plant to remove oxide copper and are covered with a fine wax coating before being sent to a continuous coiling machine.

Acid Plant

The sulfur dioxide off gas from the flash furnace is sent to the acid plant. The gas stream from the converter scrubber is also sent to the acid plant. The acid plant cleans, dries, and converts sulfur dioxide into saleable grade sulfuric acid through catalytic conversion. The catalyst is vanadium pentoxide. Sulfuric acid is produced at 93 and 98 percent purity at Magma. Figure 5 displays the individual processes involved at Magma's acid plant.

New Flue Dust Leach Plant

Magma has constructed a new flue dust leaching (FDL) facility to recover copper from several smelter by product streams. Figure 6 summarizes the major processes involved in this facility. Feedstocks to FDL facility include flash furnace dust (20-25% Cu, 1.3% As) converter flue dust (80% Cu, .01% As), acidic bleed solution from the Lurgi scrubbers (3.6 g/l Cu, .4 g/l As, 3.5 g/l acid Ph 1.6) (Lurgi scrubbers these are pollution control devices for smelter converter offgas). These feedstock are stored in bins or slurry tanks prior to entering a series of 4 agitator leach vessels. Sulfuric acid at 93% concentration is added to dissolve the copper into solution. The remaining solids are thickened, washed, and filtered. The filter cake is sent back to the flash furnace for smelting.

The FDL has an adjacent small stand alone SX unit dedicated solely for the copper sulfate solution generated by the leaching process. The operation of this SX unit is conventional except that it produces an extremely concentrated copper sulfate solution that can easily be crystallized into commercial grade copper sulfate crystals. These crystals may be sold as is or sent to the large EX plant associated with the oxide circuit.

The entire FDL plant is lined with a concrete spill collection system. Underneath this are two synthetic liners.

Secondary Materials and Associated Management Practices Derived From Sulfide Ore Beneficiation and Production Processes

Secondary materials are also produced as a result of specific mining and beneficiation processes. Figure 7 incorporates the secondary materials derived from relevant sulfide ore extraction, beneficiation and production processes.

The first step in the process where a secondary material is derived is in the extraction of the underground ore. At Magma, the waste rock produced is usually left in place because of the small amounts generated. In other mining situations, however, the waste rock generated may be hauled to the surface and disposed.

Tailings from the copper and molybdenum flotation processes represent the next circuit where secondary materials are generated. Here tailings are generated at both the ore and slag circuits and sent via pipe to the tailings impoundment area. Tailings are generated at each of the flotation circuits in the concentrator and are fed to a hydroseparator. Underflow from the hydroseparator is sent to a repulper and on to the tailing distributor to various tailings dams. Overflow of the hydroseparator is directed to the tailings thickeners, where water is removed for reuse during flotation, and underflow is sent to the repulper and on to tailings distribution. Tailings generated during the flotation processes are excluded from RCRA regulation under the Bevill Amendment.

Smelting processes (e.g., flash furnace and converter) represent the circuits where many secondary materials are generated. These materials are slag, reverts/bricks, flue dust oxide scale, anode slimes and off-gases. All of these materials are reprocessed in various ways. When the copper concentrate enters the flash furnace and converter furnace, the copper is further concentrated by being separated from other materials. This material is called a slag. At Magma, the copper concentrate in the slag (1.8 percent) is sufficient to recycle economically. At Magma, 2,300 tons of slag is generated each day. Beneficiation of this slag recovers almost 90 percent of the copper values, and produces approximately 55 tons per day of copper anode.

Copper recovery from slag is dependent on the treatment of the material prior to beneficiation at the mill. As seen in Figure 5, slag from both the flash furnace and the converters is transported to the slag cooling area for gradual cooling. Slow cooling in the initial stages is imperative to allow pure particles to coalesce and crystallize. The initial cooling takes place in shallow unlined pits for 24 hours of air cooling, after which the slag is cooled with water for an additional 8 hours. The slag is then broken by bulldozers, transported to the mill for crushing. The material then enters its own flotation process for copper recovery.

Periodically, the brick linings of the smelting furnaces must be replaced because they have outlived their usefulness. When this occurs, the individual furnace is removed from service for repair and refurbishment. The brick linings, containing significant concentrations of copper are sent to a storage area over one mile from the smelter where they are hand-picked to recover the valuable copper.

The smelting bricks at Magma are stored on an unlined surface for months or years before the hand-picking occurs. After the visible copper is removed by hand, the bricks may be stored for additional months or years before being reprocessed through the crusher/flotation circuit.

Cyprus similarly picks through furnace bricks to remove visible copper and stores these bricks. However, Cyprus does not reprocess the smelting furnace bricks, which are left on the ground indefinitely. However, Cyprus stores its bricks from the converter furnaces on asphalt or concrete surfaces adjacent to the smelter. Some converter bricks are stored in the same building as the converter furnaces. These converter bricks have higher copper concentrations than furnace bricks and are reprocessed back through the smelter.

Both smelter furnace bricks and converter furnace bricks contain chromium as part of their refractory properties.

A similar situation occurs for the molten matte that is spilled in the process of being transferred to ladles from one part of the smelting process to another in the converter isle
(e.g., flash furnace to converter to anode vessel). This spilled material, or revert, also contains significant amounts of copper that is collected periodically and sent to a storage area for screening and reintroduction into the crushing/grinding circuit.

A third material generated during smelting operations is flue dust. Flue dust is recovered from flash furnace and converter electrostatic precipitators. This dust can contain up to 25 percent copper concentration. Because of its value, flue dust is reintroduced back into the flash furnace for reprocessing. This practice has existed for many years, even before many clean air regulations were promulgated.

Speiss

According to Magma, copper arsenic compounds called "speiss" are purchased from outside vendors to be added to the concentrate. Speiss comes from the smelting of lead and is the fraction from the molten lead that contains high concentrations of copper and arsenic. According to Magma, a certain concentration of arsenic apparently is needed to facilitate the electrolytic refining operation. The exact electrochemical properties of arsenic in this operation are not well known. Small amounts of speiss are mixed with the copper concentrate prior to entering the smelter. Vendors include sources in Mexico. Also, Kennecott Copper flue dusts are rich in arsenic and may be an alternative source of arsenic for Magma.

Acid Plant Wastes

Finally, sulfur dioxide rich off-gases are generated from the flash furnace and converter furnaces. Figure 5 depicts the deposition of these gases. As seen, off-gases from the converter vessels are processed in a Lurgi scrubber. The overflow from this process is sent to a tailings neutralization (mixer) tank and then discharged to the tailings impoundment. The underflow from the Lurgi scrubber, as well as the off-gas from the flash furnace is conveyed to the acid cleaning process where contaminants are removed. Acid plant blowdown is generated during this process and transferred via a pipeline to the tailings mixer tank.

Lead, arsenic, iron, and a variety of other contaminates are carried over with the sulfur dioxide gas and must be removed from the system through a blowdown process. Acid plant blowdown is generated and transferred via a pipeline to a mixer tank, where the blowdown is combined with the tailings for neutralization prior to being deposited in the tailings ponds. Magma plans to add lime in the future for the neutralization.

Cyprus has a similar acid plant. One notable exception is that acid plant blowdown from Cyprus is dried in concrete bunkers and then sold offsite for lead and bismuth recovery.

Spent vanadium pentoxide catalyst is either sent to recyclers, sent offsite as a hazardous waste, or disposed of onsite at both Magma and Cyprus.

Electrolytic Refinery

Electrolyte solution periodically becomes saturated with contaminants and has to be continuously bled off from the cells. This electrolytic bleed is sent to the raffinate pond near the heap leach to recover any copper values present.

Slimes collected at the bottom of the refining cells are collected in 55 gallon drums. These slimes contain gold, silver, palladium, and other precious metals. These drums are sold to precious metal producers for approximately $7,000 per drum.

Oxide Circuit Solvent Extraction/Electrowinning Process Operations

Copper produced through hydrometallurgical (solvent extraction/electrowinning) processes is usually derived from ore extracted from open pit mines that are placed in dumps or heaps for leaching a pregnant solution or pumped from in-situ mining operations. Figure 8 presents an overview of the major processes (circuits) involved in producing copper from these ore extraction processes. As seen, ore from the open pit is transported by truck to an area where it is dumped (or heaped) for further processing through leaching processes.

Through various gravity and collection systems, the leach from the heap or dump is collected in a pregnant leach solution (PLS) pond. The PLS in this pond is then pumped to a solvent extraction plant feed pond which also collects the PLS from in-situ mining operations. Using solvent extraction and electrowinning processes that are described in more detail below, cathode copper plates are produced (similar to the cathode copper plates in the pyrometallurgical process described above. Spent solution from the electrowinning process is returned to the raffinate pond, which in turn, provides the sulfuric acid solution necessary to leach the material at the heap leach and in-situ mining operation. A more detailed discussion follows.

Open Pit Mining

Open pit mining is the predominant method used today by the copper industry. This is due to inherently hugh production rates, relative safety, low costs and flexibility of operations. Open pit mining represents 83 percent of domestic mining capacity. Open pit mining is used to extract ore from deposits that are relatively near the surface. Open pit mine designs are based on the configuration of the ore body, the competence of the rock, and other factors. The mine shape is formed by a series of benches or terraces arranged in a spiral or in levels with interconnecting ramps. Open pit mines may reach several thousand feet below the surface. At Magma, ore extracted from the open pit is transported via large dump truck to a nearby area for heap leach operations. At Cyprus Miami, the ore is trucked to a dump leaching operation.

In-situ operations, conversely, extracts copper from subsurface ore deposits without excavation. Typically, the interstitial porosity and permeability of the rock are important factors in the circulation system. The solutions (mine water, sulfuric acids, or alkalines) are injected in wells and recovered by a nearby pump/production-well system. In some cases the ore may be prepared for leaching by blasting or hydraulic fracturing. These solutions oxidize the ore which leach the valuable materials. Production wells capture and pump pregnant solution from the formation to the leach or plant feed plant where copper metal is recovered by the solvent extraction/electrowinning (SX/EW) operation.

The in-situ leach method is gaining favor as a means of recovering additional copper from old mine workings (i.e., block-caved areas and backfilled stopes) from which the primary sulfide deposit was mined. These types of operations tend to leave behind considerable fractured, copper-bearing rock that is expensive to mine and recover by conventional means.

Heap Leaching

Heap leaching refers to the leaching of low-grade ore that has been deposited on a specially prepared, lined pad constructed using synthetic material, asphalt, or compacted clay. This ore is deposited in carefully designed, yet massive piles, that range in size from 20 feet to 100 feet in height. These heaps, contain between 1000,000 and 500,000 metric tons of ore. (At Magma, the heap leach pad is approximately 3,000 wide by 6,000 feet long, covering 230 acres.) Copper heaps are designed and operated to minimize truck traffic and bull-dozer work on the surface. This serves to reduce compaction resulting from these activities, thereby improving the impermeability of the heap.

The heap leaching cycle usually lasts between 60 and 180 days. Application of leaching solution is generally stopped after a specified period, which is dictated by the leaching cycle or when the copper content of the pregnant liquor falls below a predetermined concentration.

Under the influence of gravity, the leaching solution percolates down through the ore and carries dissolved copper along with it. When PLS reaches the bottom of the heap, it flows to a collection channel and/or holding pond. Holding ponds generally are located in natural drainage basins enclosed by a dam or excavated and bermed on level surfaces. The pregnant solution is pumped from the dam to the precipitation or solvent extraction plant, where copper is recovered from solution.
At Magma, PLS is collected in ditches along the side of the heap, where it is sent to the 5-million gallon capacity PLS pond and then onto the 10 million gallon capacity plant feed pond.

Heap leaching is generally suited to oxide ores for several reasons: usually oxide deposits are smaller than sulfide deposits; oxides leach more rapidly than sulfides; the oxide leachate has a higher copper content than the sulfide leachate; and high-grade refractory oxide ores are not recoverable in the standard sulfide flotation concentrator.

Copper Balance

The following is a summary on a monthly basis of copper produced from the SX/EW circuit:

7,500,000 lb from the heap leach
3,000,000 lb from in-situ
500,000 lb from refinery bleed electrolyte
10,000 lb from secondary outside sources

10,010,000 lb per month as final product copper cathode.

The design capacity for the SX/EW unit is 11,600,000 lb per month. In order to operate at full capacity, Magma is considering taking in other secondary copper bearing solutions depending on copper content, recoverability, and availability of supplies. Magma would develop a "profile" of potential recoverable materials. For example, Magma views the 60 g/l copper in the Gould solution as a very copper rich feedstock compared to the PLS feedstock solution which has about 2.0 g/l copper.

Solvent Extraction

The solvent extraction operation at Magma (and most other facilities) is a two-stage method. In the first stage, low-grade impure leach solutions containing copper, iron, and other based-metal ions are fed to the extraction stage mixer-settler. In the mixer, the aqueous solution is contacted with an active organic extractant in an organic diluent (usually kerosene) forming a copper-organic complex. The organic phase extractant is designed to extract only the desired metal ion, while impurities such as iron are left behind in the aqueous phase. The aqueous-organic dispersion is physically separated in a settler stage. These two stages of extraction are sufficient to remove 90 percent or more of the copper from leach solutions.

The barren aqueous solution, called raffinate, is recirculated back to the leaching units. (In Magma's case, the raffinate is first sent to a pond.) The loaded organic solution is transferred from the extraction section to the stripping section. The major advantage of solvent extraction is that the electrolyte solution it produces is almost free of impurities.

In the second stage, the loaded organic solution is stripped with concentrated sulfuric acid solution (spent electrolyte) to produce a clean, high-grade solution of copper for electrowinning. The loaded organic phase is mixed with a highly acidic electrolyte (returned from electrowinning), which strips the copper ions from the organic phase. Then the mixture is allowed to separate in settling tanks, where the barren organic solution can be recycled to the extraction stage. The copper-enriched, strong electrolyte flows from the stripping stages to the strong-electrolyte tanks, where it is pumped to the electrolyte filters for removal of the entrained organics or solids. The clarified, strong electrolyte (which is the concentrated sulfuric acid from the solvent extraction operation) flows to electrolyte circulation tanks, where it becomes electrolyte for the electrowinning tank house. At the tank house, copper is plated out of solution onto cathodes.

Electrowinning

Electrowinning is the method used to recover copper from the electrolyte solution produced by solvent extraction. Electrowinning uses inert anodes of lead or stainless steel, referred to as sheets. The electrochemical reaction at the lead-based anodes produces oxygen gas and sulfuric acid by electrolysis. Copper is plated on cathodes of stainless steel or on thin-copper starting sheets. The cathode copper is then shipped to a rod mill for fabrication. The spent acid is recycled and pumped back to the leaching operation, while some of the electrolyte is pumped to the solvent extraction strip-mixer settlers via the electrolyte heat exchangers.

Some mines, such as Cyprus, have enough acid naturally occurring in the dumps (from acid rock generation) that water is the only necessary lixivient. The piles at Magma are commonly referred to as heaps because they are similar to gold heap leaching to the extent that they are lined. Most other copper piles are called dump leaches because the ore is placed on unlined surfaces.

The pregnant leach solution (PLS) containing copper sulfate from the heap is collected in the PLS feed pond. Other inputs to the PLS feed pond comes from in-situ leaching, Gould solution, and in the future TNT filter cake. The heap supplies about 15,000 gpm solution as input to the SX plant, the in-situ supplies 2,500 gpm and the Gould solution supplies about 100,000 gallons per year.

The PLS is the feedstock to the solvent extraction circuit which uses 93% kerosine solvent and 7% prescriptive organic collector (a dioxime compound costing several thousand dollars per drum) to concentrate the copper sulfate in solution. The PLS copper concentrate is approximately 2.0 g/l, Fe is 2.5 to 3.0 g/l, and Al is 7.0 g/l. Small amounts of magnesium, manganese, and other compounds are also present.

The product of the solvent extraction (SX) plant is "rich" electrolyte which is the feedstock to the electrowinning facility ("tank house"). When the iron concentration becomes to high in the electrowinning cells, some solution is bled off and sent to the solvent extraction unit for further Cu recovery. (Aluminum sulfate is of high enough concentration in the PLS that Cyprus has considered recovering it for sale but has not yet done so.) After the copper has been won on copper cathodes, a "lean" (low concentration in copper) electrolyte is returned to the solvent extraction plant. Excess lean electrolyte from the solvent extraction unit is returned to the raffinate pond. The raffinate pond is the source of acid used in both the heap leach and in-situ operation; hence the cycle starts again.

Some oil from the solvent extraction unit spills over into the raffinate pond. This oil is collected by a skimming booms and skimmed off in batches. The oil is run through the clay filter press. The clean organic liquid from the filter press is returned to the solvent extraction unit whereas the solid spent clay filter cake is placed on the heap leach to recover any copper values. Some organic is lost due to evaporation and new organic is continually added. Twice in the last 4 years, all the organic phase from the solvent extraction units were run through the clay filter to re-condition the organic to optimal specifications.

Commercial grade cobalt is added to the electrolyte entering the electrowinning cells. The cobalt enhances the electrowinning process through properties not well understood.

Lead anodes in the electrowinning cells are gradually spent and are found as a sludge on the bottom of the cells. This lead anode sludge is collected and sent offsite for lead recovery.

Gould Solution

This is a material produced from the electrolytic refining of copper foil from a company in Chandler AZ. The copper foil producer takes in No.1 grade scrap copper, digests it with sulfuric acid, and generates a spent electrolyte solution from this process that contains 100 g/l sulfuric acid and 60 g/l copper. Once every quarter, 8 trucks holding about 4,000 gallons per truck ship the Gould solution to Magma which then adds this solution to the PLS feed pond.

TNT Filter Cakes

This is a newly proposed process in which Magma would take in filter cakes consisting of copper oxide mud from copper chloride etching solution from the production of circuit boards. This filter cake would be mixed with the PLS feed to the solvent extraction unit. Chemical characteristics or volumes of the TNT filter cake were not provided.

Secondary Materials Generated During SX/EW Operations

Several types of secondary materials are also generated during SX/EW process operations. Figure 9 superimposes those secondary materials on the process flow diagram displayed in Figure 8. As seen, much of the secondary materials emanate from the solvent extraction and electrowinning processes. The SX process generates a sludge or crud consisting of a solid stabilized emulsion of organic and aqueous solutions.

Grungies or gunk are the terms used to describe the emulsion that is present between the oil-aqueous interface in the SX unit. The emulsion can build up to such a degree that is significantly interferes with the SX operation. Various chemical methods have been used to "break" the emulsion into separate oil and aqueous phases so that the organic can be re-used and the copper in the aqueous phase can be recovered eventually in the electrowinning unit. However, it has been found that a physical centrifuge system is the most efficient and economical method. Gunk from the SX plant is drained off into a gunk tank where it then is put into a centrifuge which separates the liquids and solids from the organic phase. The liquids and solid are returned to the raffinate pond and the organic is returned back to the SX plant. The main purpose of this operation is to relieve the system of the emulsion and to recover the expensive organic solution.

At the electrowinning operation, electrolyte in the electrowinning cells becomes laden with soluble impurities and copper. When this occurs, the solution is removed and replaced with pure electrolyte to maintain the efficiency of the solution and prevent coprecipitation of the impurities at the cathode. The spent electrolyte is then recycled through purification.

Purification is done by electrowinning in liberator cells. Liberator cells are similar to normal electrolytic cells, but they have lead anodes in place of copper anodes. The electrolyte is cascaded through the liberator cells, and an electric current is applied. Copper in the solution is deposited on copper starting sheets. As the copper in the solution is depleted, the quality of the copper deposit is degraded. Liberator cathodes containing impurities are returned to the smelter to be melted and cast into anodes. Purified electrolyte is recycled to the electrolyte cells. Any bleed electrolyte is neutralized and sent back to the raffinate pond.

The result of the SX/EW processes is a spent leaching solution (raffinate) that has been stripped of copper but still has some carryover of the organic extraction/diluent. At Magma, the spent raffinate generated is sent back to the raffinate pond where it is once again applied to the heap leach for further leaching of copper.