ENGINEERING AND MINING JOURNAL

Part 1 of a two-part article

Inspiration's design for clean air

Stan Dayton, Editor-in-chief

ALREADY EQUIPPED WITH ONE OF THE WORLD'S most complete copper metallurgical installations, Arizona's fully integrated Inspiration Consolidated Copper Co. plunged deeply into air pollution abatement with a $54 million expenditure for a new electric smelter and double absorption sulphuric acid plant—both containing some of the largest componentry of their type anywhere.

For Inspiration, which ranks on the lower end of the size scale among US primary copper producers, the drive for absolute and final compliance with air standards was one more in a long list of bold and heady maneuvers that have characterized the company since it sprang to life in 1911. The dollars poured into the project (the equivalent of over three times the company's 1973 net income, and 60% of the year's gross income) were essentially chasing clean air—not an immediate return on investment.

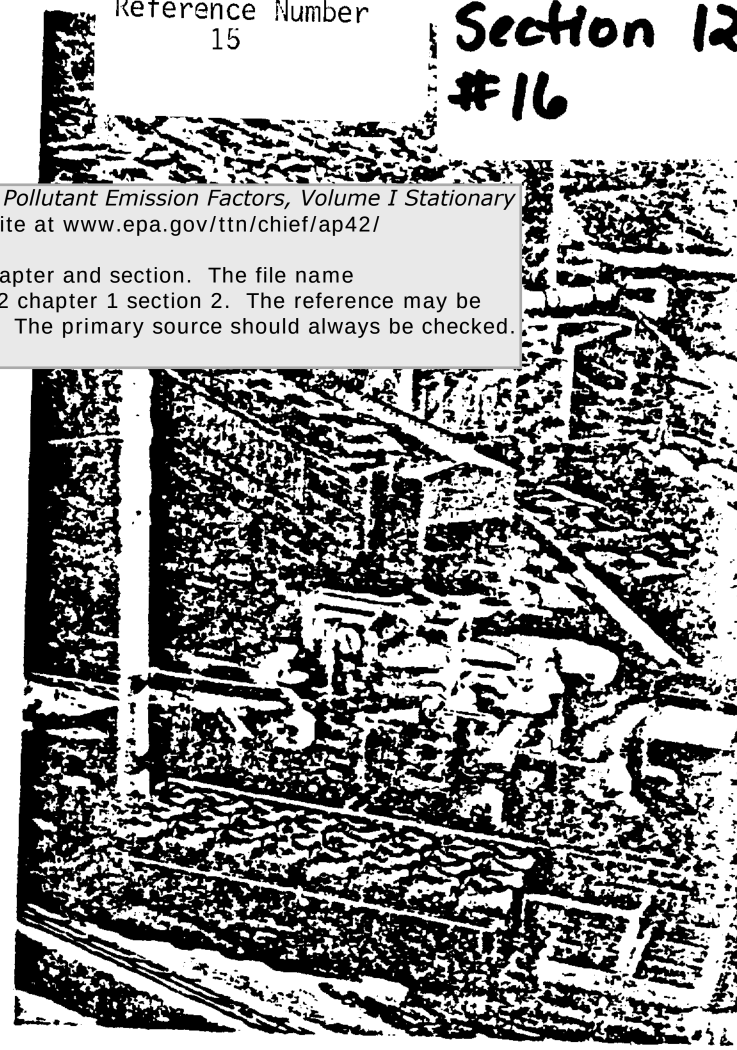
As financially painful as this may seem, the new plants are also a solid hedge against the future and are expected to yield hidden benefits. Such accrual, however, will depend on management ingenuity—a "long suit" at Inspiration—and the shape of future events in the smelter-short US copper economy, which could also soon be facing a shortage of mined copper.

Last month the new smelter, equipped with an Elkem 51-mva furnace and five siphon converters of Hoboken-Overpelt design, started phasing in the production line as a replacement for an older, reverberatory, Peirce-Smith converter installation handling a green charge. The latter, built in 1915, modernized, and acquired from The Anaconda Co.'s former International Smelting and Refining Co., was an efficient, low-cost producer of anode copper. However, it presented a near-hopeless prospect for meeting a Federal 90% sulphur recovery goal, even with extensive modification and tightening of the gas handling system—not to mention the expense for an add-on SO_2 recovery plant.

Coupled to the new smelter—which handles 1,500 tpd of copper concentrates and copper precipitates of Inspiration and toll origin—is a "showcase" 1,330-tpd Lurgi acid train fed from an elaborate collection system that "dry cleans and launders" electric furnace and siphon converter offgases.

The new project places Inspiration first among western US copper smelters in the race to meet the Federal Environmental Protection Agency's idealistic 90% sulphur recovery goal for stationary plants. The replacement system will enable mothballing of the present smelter as a reserve asset.

Editor's note: This report drew freely on the experience of many past and current Inspiration staff members, their reports, and their contributions to the literature. Top management has been generous in releasing information and lending encouragement in publication. If E/MJ has overlooked due acknowledgement of sources in the rush to get into print, the editors apologize for any oversight.

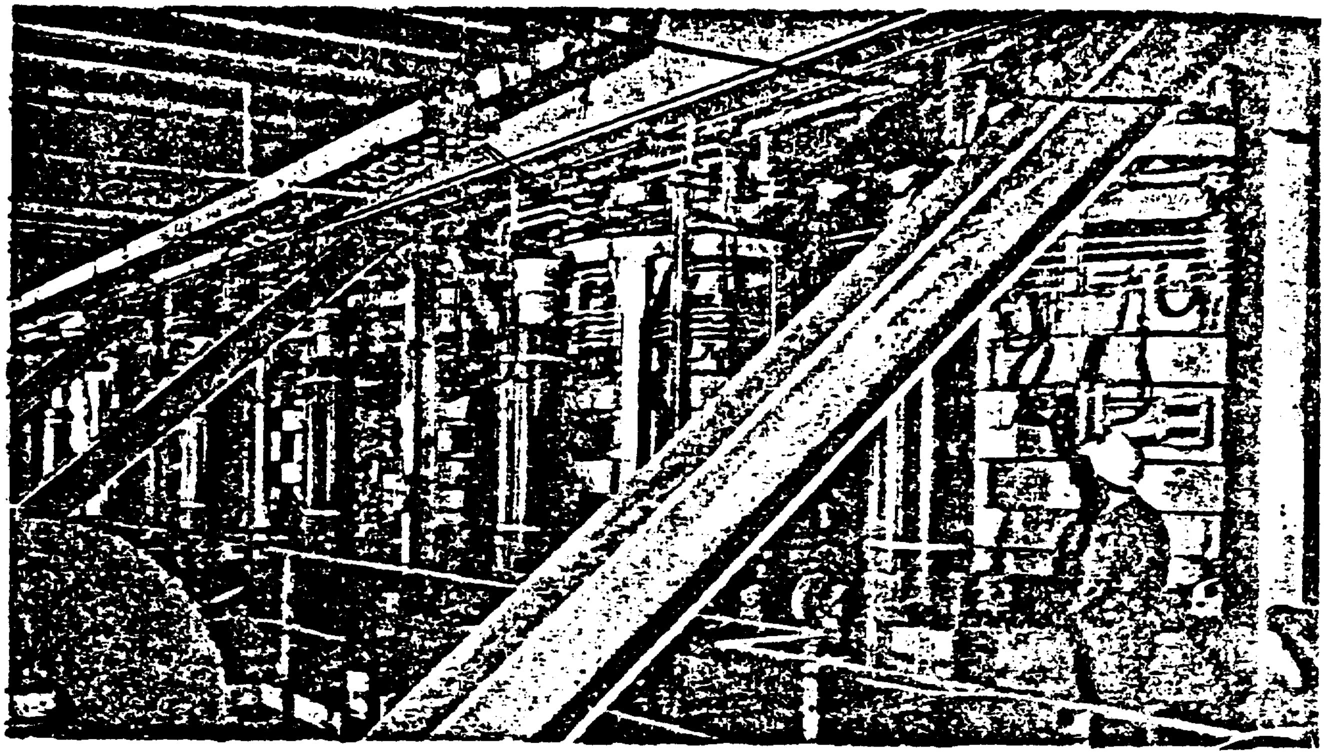


New copper smelting technology introduced to US weds a Norwegian electric matte furnace with Belgian siphon converters. All units pipe metallurgical gas to a West German double absorption acid plant in lower foreground. Electric furnace is housed in building under precipitators and discharge end of elevated dryer. New converter aisle is normal to the furnace structure and joins the older smelter.

An investment in the future

What has Inspiration gained from its efforts (other than empty praise from a fickle public for being socially responsive to environmental demands)?

- It has stretched its oxide and sulphide ore reserves at In-



Clamps and slip ring gear for the six self-baking electrodes on the furnace control the feed rate to compensate for daily consumption of 6 to 10 in. of casing and carbon. Floor level of the photo is about 25 ft above arched furnace roof.

spiration Div. mines in porphyry ore formation by providing a source of low cost acid supply that more than meets its needs.

■ Inspiration is creating future copper reserves from rock in its holdings which today is worthless because it is submarginal for recovery.

■ The acid supply increases the productive potential of the company, and makes development more feasible for new properties now under investigation (such as one at Safford, Ariz.).

■ The company has gained an "antiseptically" clean new smelting system which theoretically should achieve production costs comparable to the old plant, and which lends itself to closer automatic control of matte smelting and matte conversion conditions.

■ Inspiration has moved in the direction of relatively stable energy costs for metal making, becoming more dependent on electric power and less reliant on natural gas or fuel oil.

■ Perhaps most important, the financial commitment to clean air is part of the company's past, and Inspiration can now turn its efforts to solidifying and expanding its resource base without the distraction of shooting at erratically moving targets for air emissions. During the process, it has established a tight matte smelting installation from which a 4-6% SO_2 gas can be pulled to blend with a 6-9% gas from the converters—products rich enough for acid making. In-plant emission of sulphur dioxide will also be dramatically lowered, making the total working environment more pleasant.

It is expected that the plant will experience normal startup difficulties because it involves new systems, more sophisticated than those employed in the old smelter. The technology is new in this country, and of course there is the matter of gaining practical operating and trouble-shooting experience by crews that have received theoretical training in the technology, systems, and procedures, as well as the basics of copper smelting. In the wings, however, is the present smelter, which can function as a production line safety valve during possible emergencies in the new plant.

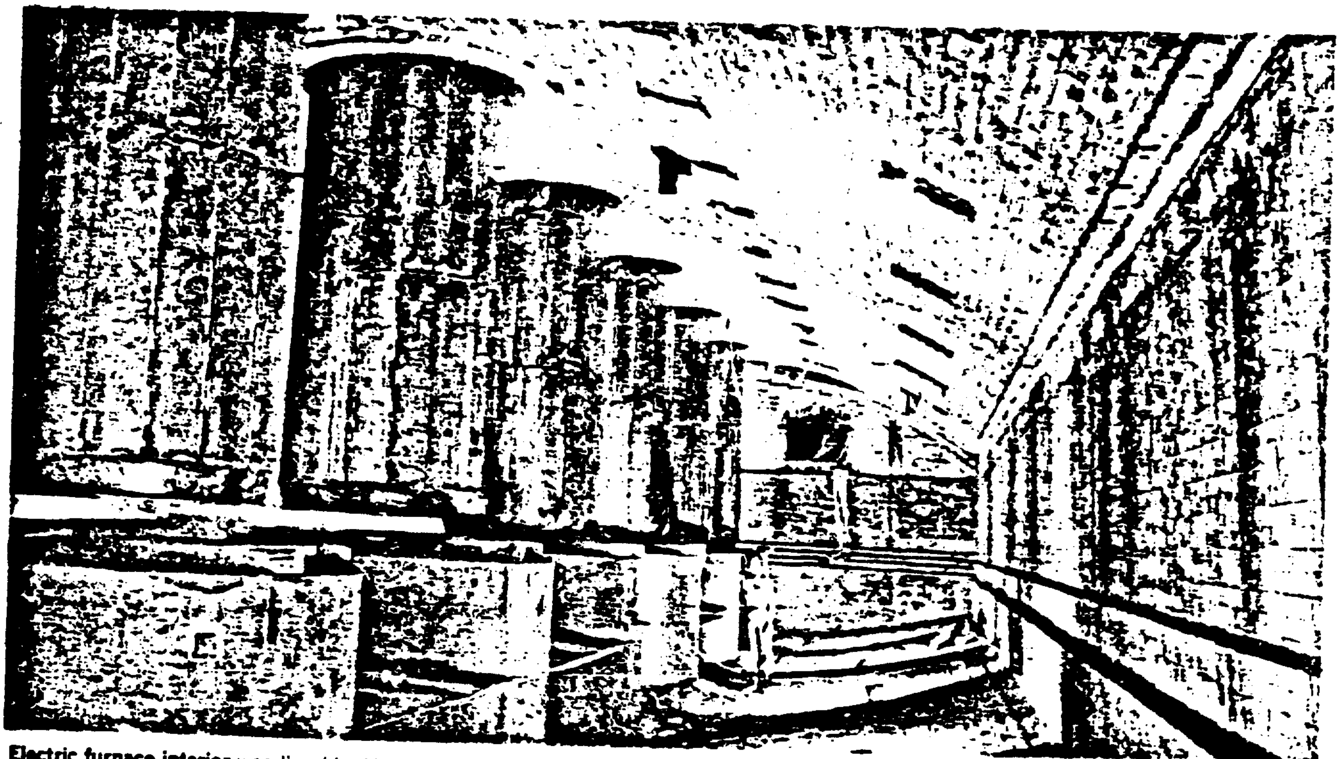
How Inspiration settled on the new system

At the present smelter, roughly 10% of the sulphur comes off a 32-ft-wide by 110-ft-long reverberatory at 265,000 scfm in a dilute gas stream of 0.5-0.8% SO_2. The remaining 90% is contained in 160,000 scfm of 1.5% SO_2 converter gases.

Before air quality legislation, Inspiration was examining a sulphur removal method under an agreement with Golden Cycle Corp. The work had been nursed along through bench scale to a mini-pilot scale using an SO_2 absorbing reagent swept by a weak gas stream. The process had a potential for concentrating sulphur dioxide into a manageable gas volume of sufficient strength for acid making. When air quality control rules were dropped on the copper smelting industry, it was apparent that this investigation, through January of 1971, left far too little time for development to commercial scale within the time frame allowed for compliance.

Alternatives were scanned on an increasingly urgent basis, including tightening the current plant to minimize air infiltration and using undershot oxygen, or combustion air enrichment. Other, newer methods were considered, such as the Worcra and Noranda processes, but in 1970 both of these had to be considered not fully proven. Other possibilities included fluid bed roasting, flash smelting and oxygen smelting in converters, and electric matte smelting with downstream converters. Because Inspiration's production of cement copper is growing, and because a portion of the sulphide mineralization is made up of chalcocite, it was thought that even with toll input of chalcopyrite concentrates, the sulphur content of the charge would be deficient for flash smelting or fluid bed roasting prior to electric smelting.

A breakthrough occurred when Inspiration negotiated a large block of interruptible electric power from the Salt River Project at an acceptable price, lying between the cheap but deteriorating supply of natural gas and the more expensive fuel oil substituted during natural gas shortages. By March 1971 the company had committed itself to the pursuit of the electric matte smelting option using a dried green feed.



Electric furnace interior was lined by Harbison-Walker with 292,571 bricks. The 38-ft sprung arch roof contains concentrate feed ports and openings for electrode casing over coke cans on floor. Endwall port is for converter slag return.

Next came an evaluation of the converter system. The electric furnace could have been installed to deliver matte to the existing converter aisle. This is equipped with three 13 x 23-ft and one 12 x 20-ft Peirce Smith units and two Great Falls 12-ft-dia converters, a 13 x 20-ft natural-gas-fired refining furnace, and a 21-ft-dia casting wheel for 1,200-lb copper anodes. The old converter building was inadequate for support of the massive hooding that would have been required for tightening of the gas recovery system.

The expense of beefing up the old structure, which would have considerably lengthened the flue run to the acid plant, began to make an extension of the old converter aisle toward the acid site look more attractive. There were also obvious advantages in separating construction work from active metal making operations.

Figuring strongly in the logic were natural advantages of the Belgian Metallurgie Hoboken-Overpelt siphon converters, which had the capability of limiting extraneous air dilution of exit gases. They offered potential savings in capital and operating costs for gas handling and cleaning systems. Furthermore, the gas production would be more consistent because silica flux, matte, and cold dope (converter slag, shells, etc.) could be fed without interrupting the converter blow. By October of 1971 it was agreed to go with the siphon converter concept.

It had been decided early to use acid making to strip the sulphur from the gas stream. In this respect, Inspiration enjoys a somewhat unique tactical advantage. The company consumes large quantities of acid in its ore recovery operations—currently about 600 tpd. Since not many other copper producers have a need for acid in such proportions, those with smelters find themselves in an awkward position. If they rely upon acid recovery, currently considered the most reliably proven system for fixing sulphur in a metallurgical gas stream, they may face either a surplus of acid or perhaps no market at all for the product. This sorry state of affairs begins to take on some ridiculous dimensions because all excess acid must be neutralized with lime or limestone and wasted as gypsum. In essence, this trades an air pollution problem for a solid waste disposal problem—solid waste that exacts a toll of over a ton of mined limestone per ton of acid to be wasted.

Therefore, the two fundamental items that shaped Inspiration's attack on air quality were the availability of reasonably priced electric power and the ability to absorb internally a large portion of the acid produced. In adopting its new game plan, Inspiration abandoned some $7 million in capital improvements to the old smelter during the early 1970s.

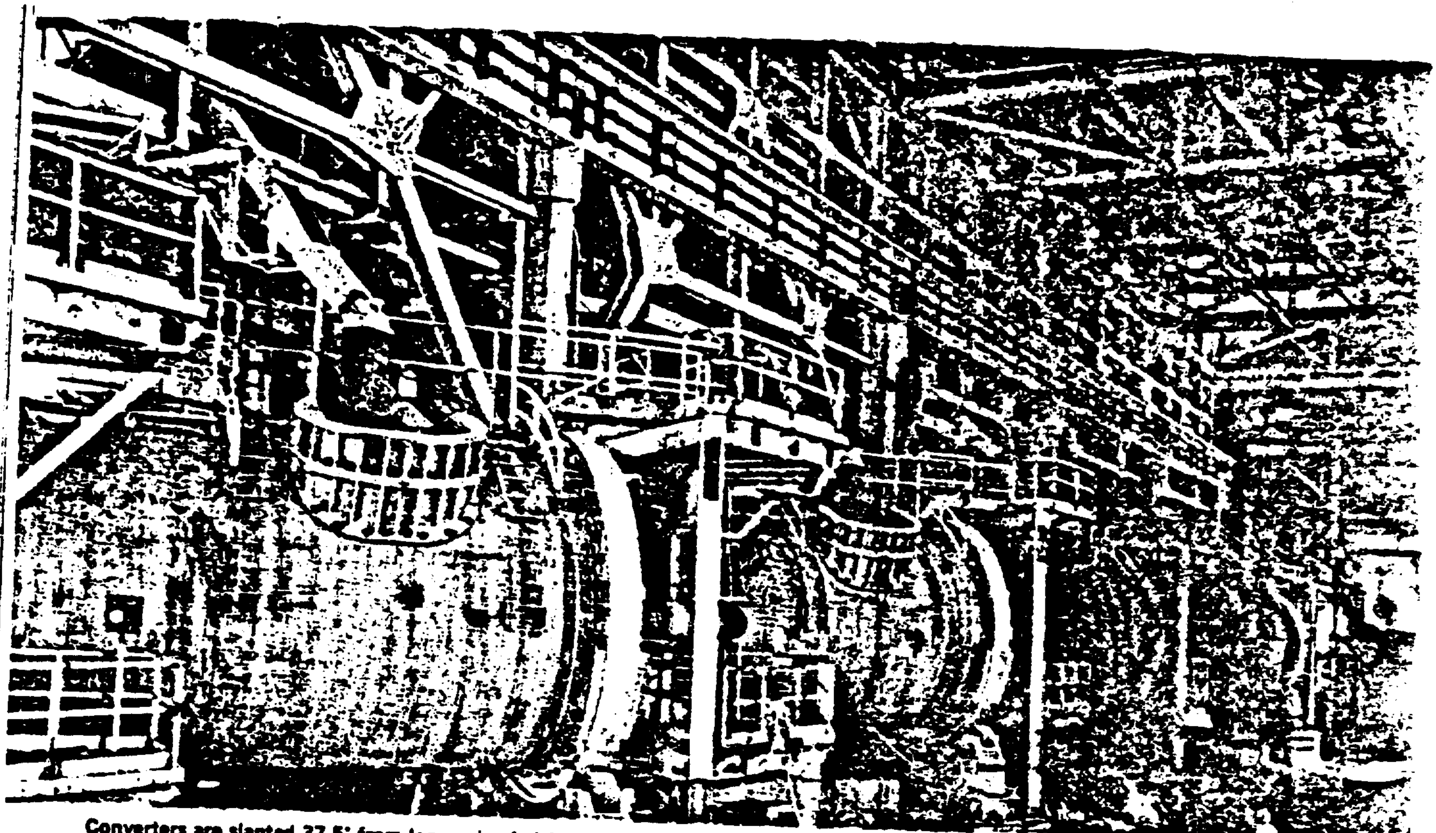
Fitting the new facilities to the existing system

The new plant makes use of existing facilities for materials receiving and crushing, as well as the fire refining and anode casting section in the converter aisle of the old smelter. New construction occupies an offset blocked T, oriented so that the wing housing the new converter aisle extends that of the old smelter. The remaining wing, normal to the converter aisle, houses the electric furnace, transformers, electrode paste handling, and furnace feed from the dryer. The control room, located on the furnace feed floor, affords a panoramic view of the converter aisle.

The new plant will be operating about 40% on Inspiration feed and 60% on toll-processed material. The electric matte furnace is designed for a daily diet of 1,821 tons of feed composed about as follows: 1,500 tpd of concentrate, 148 tpd of cold dope, 123 tpd of silica flux, and 50 tpd of limestone.

Inspiration feed and toll concentrate (with copper precipitates) are bedded in an enclosed building on a concrete slab in two parallel 6,000-ton piles by means of an overhead tripper conveyor system. Lime is needed for the electric furnace and is added as minus ¼-in. material in the bedding plant. The bed mixture is reclaimed by front-end loaders which deliver it to a 24-in. wet charge belt equipped with a continuous weighing system. Wet concentrate with silica flux, as required, and reverts are conveyed to a 550-ton wet charge bin.

A screening installation is used to provide the converters with sized plus ¼ in., minus 2-in. cold dope and silica. This



Converters are slanted 37.5° from long axis of aisle, putting mouths under craneway for matte charging and slag skimming. Retractable chutes feed both flux and reverts. Aisleway for the old smelter is visible in the background, far right.

system also handles and sizes matte smelter reverts to minus ¼-in. for the electric furnace. The feed preparation used for the new plant varies somewhat from the mix blended for the reverberatory system. Formerly, flux, concentrates, and precipitates were interlayered in the bedding building, and the old furnace was fed a wet charge. Reverts were recycled directly to the converters.

The mix delivered to the wet charge bin in the new system has a moisture content of 9% to 12%. It must be taken to a bone-dry condition, largely to prevent explosions that may range from a mild bump to something of a damaging proportion. Experience elsewhere has shown that serious eruptions can occur in an electric furnace when the charge contains free moisture. For efficient operation, electric matte furnaces run best with the bath completely covered with solid charge. If moist charge caves or sloughs into the bath, an eruption may follow.

Considered only from the aspects of the material and moisture load, Inspiration invested in a rather large 16-ft-dia by 80-ft-long Fuller rotary dryer with a fully insulated, but unlined, stainless 316L steel shell. It is designed to reduce the moisture content to 0.1% to 0.3%. Fired by either natural gas or heavy fuel oil, the dryer helps conserve power consumption in the electric furnace. However, the main factor considered in its sizing was relief from the dust load carryover.

Most materials handled by the smelter are finely divided and become very dusty when dried. They are easily swept by a fast-moving stream of gases. In order to hold the particulate load of dryer gases within reasonable limits, the unit was designed to keep gas velocities low while taking advantage of dryer residence time. It has been calculated that 20%, or less, of the solids will be entrained in the gas stream.

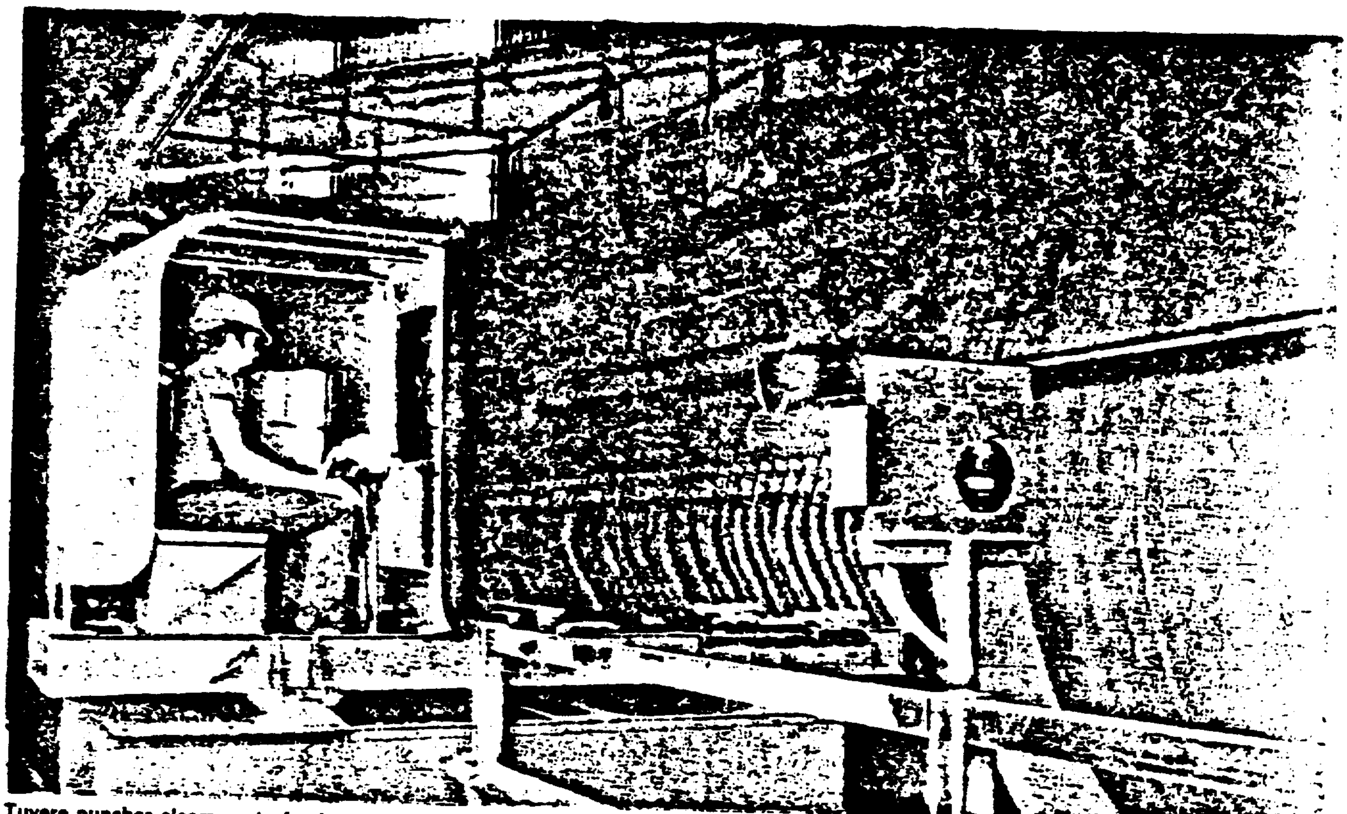
The dryer is concurrently fired from Peabody burners. The exit gas is maintained above the dew point for a cleaning system consisting of a pair of Dracco cyclones and a high-efficiency baghouse before it is vented to the atmosphere. The dried charge is a very abrasive mixture that can become aerated to form a fluid, free-flowing mass. To minimize problems in handling this difficult material, the dryer was elevated on a concrete pier to bring the discharge point as close as possible to a pair of 700-ton-capacity furnace feed bins, located on the charging floor above the slag tapping endwall of the furnace. Both are totally enclosed structures vented into the dryer dust collection system.

The Elkem electric furnace is the largest copper matting furnace in the world. Measuring 34 ft wide by 117 ft long (ID), the furnace is equipped with six in-line, self-baking carbon electrodes, 71 in. in dia, that enter the furnace along the centerline of the sprung arch roof. They dip into the molten slag layer. Heat for smelting is generated by resistance of the slag to the submerged arc between electrode pairs.

On the charging floor, a twin system is employed. Dried feed is reclaimed from each 700-ton bin by a 6-ft-long variable speed screw feeder which augers the charge to a 22-in.-wide, four-speed drag conveyor extending 114 ft, nearly the length of the furnace. Each bin features this arrangement, one serving the east and the other the west side of the electrode line. Each totally enclosed drag conveyor delivers the charge to a series of 15 feed spouts that enter the furnace roof. Seven of these spouts are near the line of electrodes, and the other eight are near the furnace sidewall. The charge in the spout enters the furnace through an arc gate and then a weighted tilt gate, sequenced so that a seal is maintained on the furnace. The end spout is open at all times. Most of the charge will be introduced in the line of spouts nearest the electrodes; the remaining 10% to 20% will enter the line near the furnace sidewalls.

About the world's largest electric copper furnace

The inverted, double-arch bottom of the furnace and the end and sidewalls, to a point above the bath line, are of basic



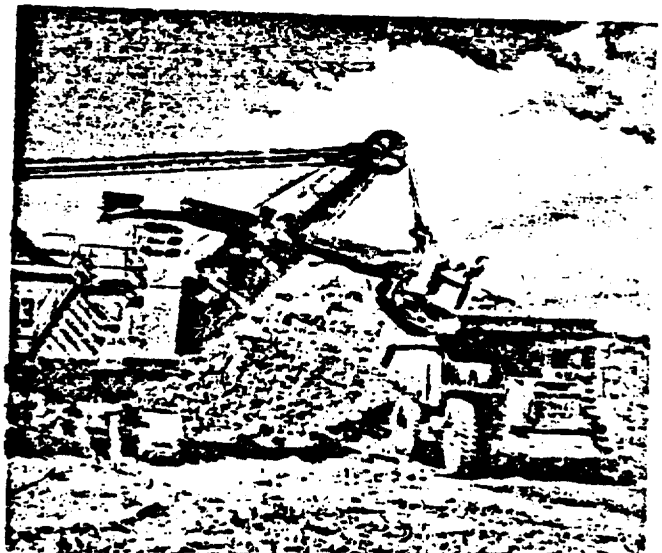
Tuyere puncher clears ports for introduction of blast air at 20 psi from bustle. Puncher is Gaspe-type, mounted on rails. This view is photographed from side opposite the photo at left. Siphon housing for converter gas is shown at right.

brick construction. Above the bath, the upper-side and endwalls and the sprung arch roof contain firebrick. The furnace is supported on concrete piers. Vertical steel columns and tie rods clamp the sidewalls and provide additional structural support. The unit operates with 30 in. of matte and a 60-in. slag layer.

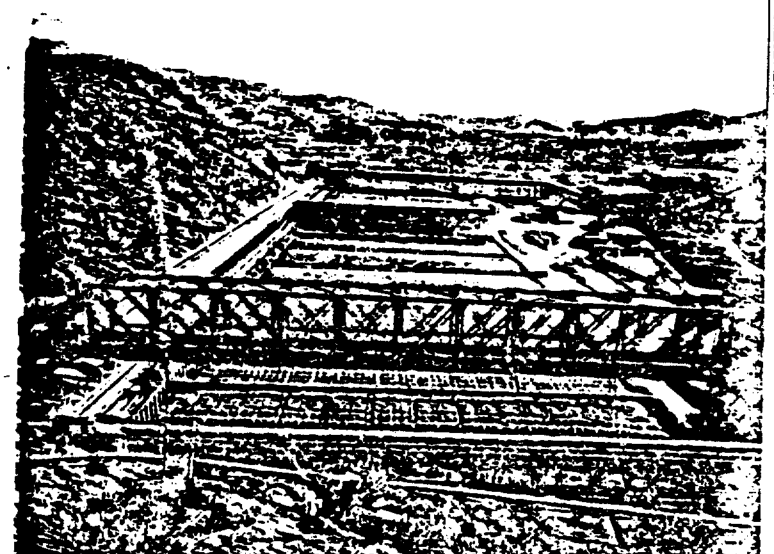
The endwalls of the furnace are water cooled. The sidewalls and bottom are air cooled from a set of three blowers, rated at 118,000 cfm each, on each side of the furnace at the ground level. Normally, two operate on each side and one is on standby. Air sweeps under the furnace, up the sidewalls and exhausts through the roof, changing the atmosphere once a minute.

Electric power is delivered to Inspiration at 115 kv and stepped down to 22.9 kv in a new substation rated at 56,000 kva. The transformer vault, located on the furnace charging floor, takes 22.9-kv power on the primary side of three single-phase transformers with a total rating of 51,000 kva.

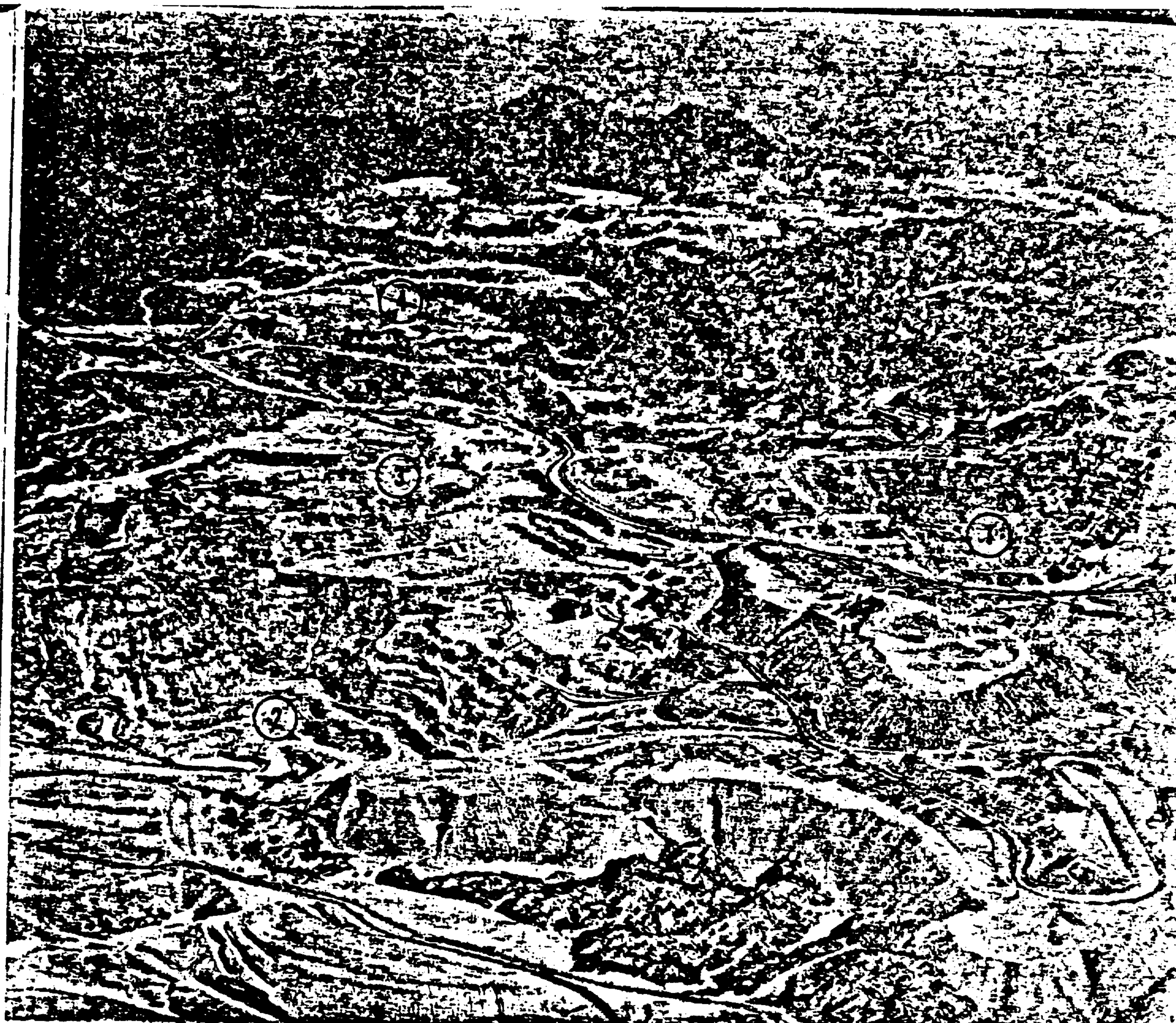
The electric furnace transformers reduce the voltage to the operating level required for slag resistance operation. They are connected to the furnace electrodes by means of a bus bar and flexible cable arrangement leading to a copper contact



All Inspiration ore is surface mined—most by shovels and trucks, such as this 10-yd P&H and 75-ton Dart hauler. Several types of ore with variable mineral content are treated.



Vat leaching plant is first recovery step for two ore types. High oxide ore is leached and discarded. Mixed oxides and sulphides are leached, and residue then goes to sulphide flotation.



Inspiration Div. producing mines include: 1) Thornton, 2) Live Oak, 3) Red Hill, and 4) Willow Springs. Leach vats are at far rim of Thornton, near the electrowinning and electrolytic refineries and associated wash water and cementation launders.

shoe below the electrode slip ring. The slip ring permits automatic adjustment of the electrode position according to the desired power input. A full range of operating voltages is available, and the power input will not exceed 11.5 kw per sq ft of hearth area. The bus bars are contained in an enclosed duct, which is under pressure to maintain a dust free atmosphere. If the transformers should develop a leak, the oil is drained out of the building and away from the electrical atmosphere.

Electrode paste for the Soderberg self-baking electrodes is delivered to the smelter in 1-ton blocks having the following specifications: fixed carbon 75.4%, volatile matter 11-12%, and ash 7.6%. The blocks have a density of approximately 1.6 gm per cc, and become fluid at 80° to 100°C. The electrode clamps and slipping mechanisms, which act on the steel casing housing the carbon, are the reverse of the arrangement used elsewhere. At Inspiration, the clamps are spring loaded in a closed position and can be opened only by the application of hydraulic power to 100-ton jacks for purposes of positioning. The slip rate, based on power input requirements, is normally handled automatically, but the system is equipped with a manual override from a remote station.

The upper floor of the furnace building is arranged for electrode paste handling and the assembly of steel casing for the carbon blocks. The floor is serviced from an elevator for delivery of carbon blocks and flat 12-gauge steel plates. New casing is assembled in sections standing 5 ft 11 in. in height by first punching the sides of 18 plates to shape fins pointing inward, then rolling them to the proper radius. The shaped and punched sections are then joined into a finished cylindrical section by an automatic welding machine. As casing and carbon are consumed, a new casing section is mounted and welded to the shortened assembly. A hoist then loads the carbon blocks into the empty casing.

The big dividend: an enriched exit gas

Electric furnace matte smelting eliminates the dilution of reaction gases by the large volume of combustion products associated with fuel-fired furnaces. This makes it possible to pull a 4-6% SO_2 gas stream from the furnace into the uptake positioned in the furnace roof near the matte tap endwall—a marked contrast to the weak 0.5-0.8% SO_2 coming off the reverberatory furnace.

The furnace endwall panels, two slag tap blocks, four matte tap blocks, and six electrode contact clamps are water-cooled from a 1,200-gpm pumping, distribution, and return system. The six electrode compression rings are water cooled by a separate 300-gpm pumping and circulation network.

Slag and matte tapping

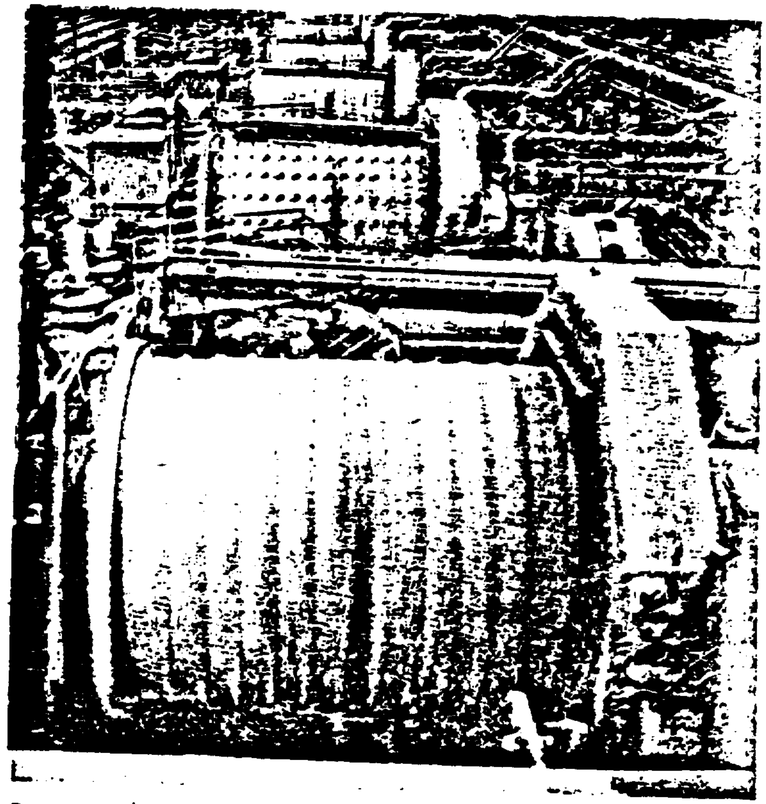
Slag is skimmed from one of two tap holes in the endwall of the furnace. A pair of launders, sloped close to 19%, delivers the slag to a set of 600-cu-ft pots, and at the rated capacity, the slag handling will amount to about 980 tpd. The pots will be hauled to the dump by trucks of special design. The slag end of the furnace is equipped with a Joy tapping machine with a mud gun assembly for opening and replugging the slag skimming hole.

The matte endwall faces the converter aisle, parallel to the longitudinal axis of the latter. This endwall contains four holes for drawing off matte into two pairs of launders that take a modified V-shape in plan.

At the two junctions, the matte flows into one of two swivel spoons. Four 300-cu-ft ladles are positioned in a sand pit at the matte end. As a ladle is filled, the swivel spoon is tilted to a slight reverse slope, accumulating matte in the spoon. It is then pivoted to a new position over an empty ladle and down-tilted. Rotation and tilt of the swivel spoon is handled by air-actuated cylinders.

The converter is equipped with two 75-ton, two-hook P&H overhead bridge cranes. A clever leap-frog winch arrangement, installed near the junction of the two buildings, allows the position of the new cranes to be interchanged on the same track connecting the two converter aisles. The converter aisleway serving the reverberatory furnace contains cranes with a 40-ton main hoist and two 20-ton auxiliary hoists for the 175-cu-ft ladles in use there.

At the nominal rated capacity of the new smelter, over 1,200 tpd of matte will be tapped through the endwall. Converter slag is returned through the matte tap endwall from ladles that empty into two launders entering the furnace on 10 ft 6 in. centers about 10 ft above the matte tap holes.



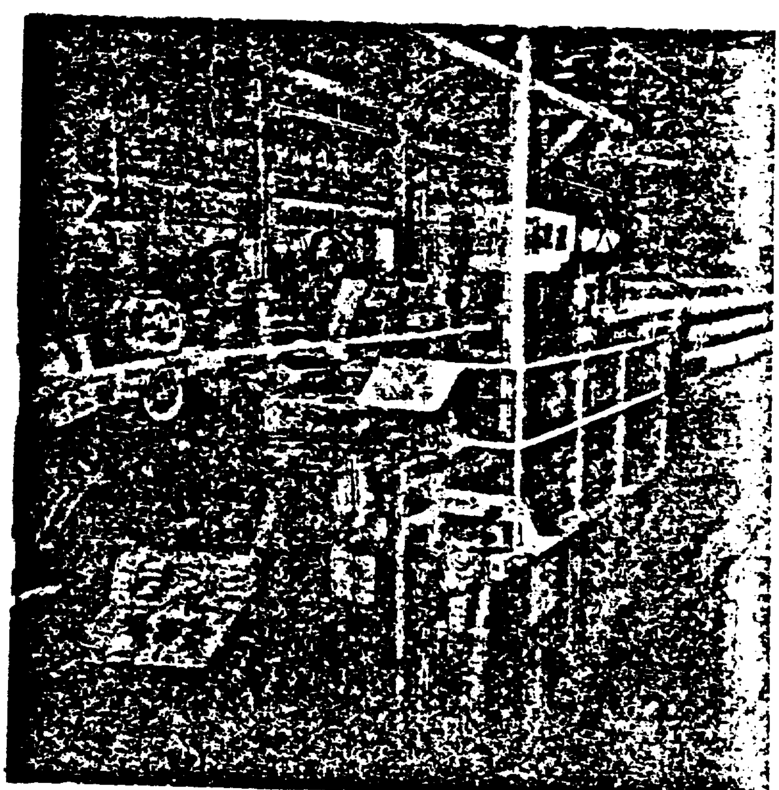
Ball mill line at Inspiration concentrator takes direct-fed higher sulphide ore and leached dual process ore from vats.

Siphon converters tightly sealed

The siphon converters, 14 ft dia by 38 ft long, are considered the equivalent of 14 × 32-ft Peirce Smith converters. The five Hoboken-Overpelts are equipped with automatic draft control, 52 tuyeres on 6-in. centers, a tight converter flue and gas cleaning system, and a charge mouth of 20 to 25 sq ft. This opening is small by comparison with standard converters. The reaction end of the vessel, measuring 32 ft long, is extended by the siphon which is totally enclosed and dammed from the reaction zone to contain the bath. The casing for this extension contains a raised roof to siphon off the gases. It is also equipped with a counterweight to compensate for the asymmetry of the vessel.

A horizontal 9-ft-dia concentric cylinder taps the siphon on the rotary centerline of the converter unit, conducting the offgases to a dust settling chamber and the gas uptake. A proprietary gas-tight seal and joint links the rotating portion of the vessel assembly with a stationary section which enters the dust chamber. The entire converter assembly from endwall to the dust chamber and uptake measures about 75 ft long.

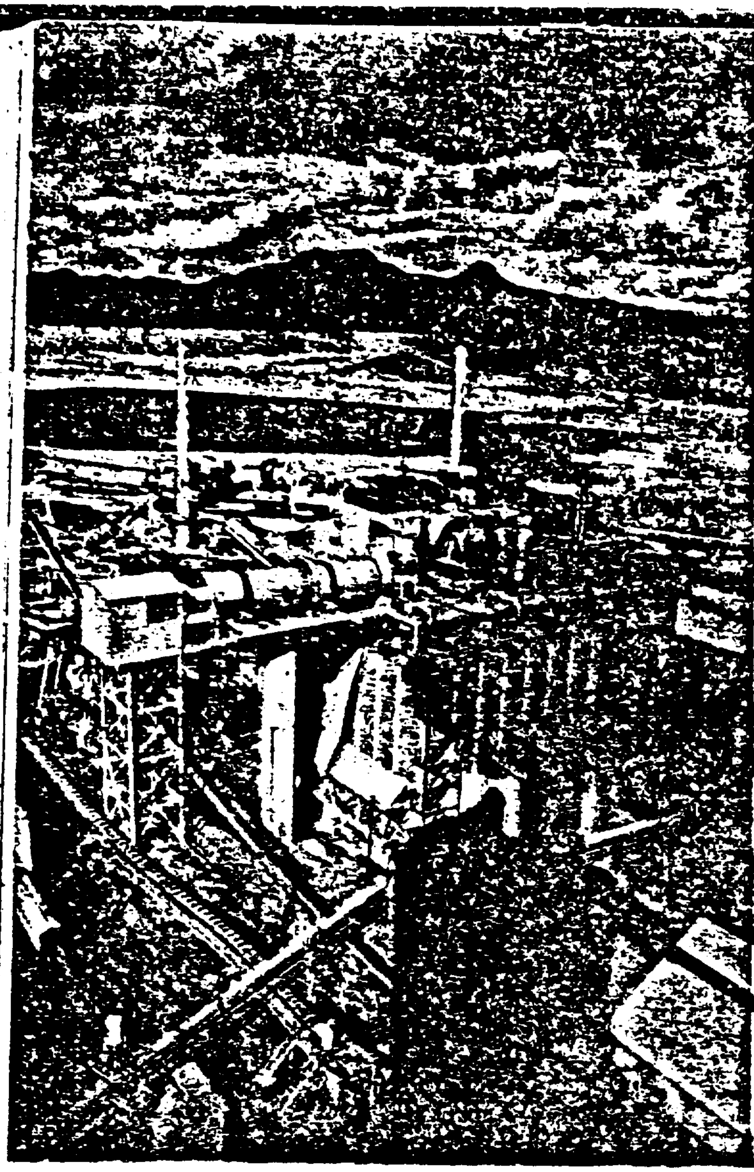
It is anticipated that each siphon converter, equipped with 1½-in. tuyeres, will be unable to take an air blast in the bath much in excess of 20,000 scfm without tending to plug the siphon.



Southwire continuous cast plant turns out 5/16-in.-dia rod from electrowon and electrorefined Inspiration cathodes.

The Hoboken-Overpelt converters are installed on 55-ft centers in a unique "en echelon" pattern slanted at 37.5° from the converter aisle craneway. This arrangement places each converter mouth under the crane aisle for ladle servicing. The siphon end and gas uptake system of each converter extends outside the craneway in a lateral extension of the building. By freeing the exit gas handling system from the path of crane travel, it has been possible to use a simpler and more desirable design for the gas uptake and initial cooling system since it has unencumbered headroom. The converter platforms are equipped with Gaspe-type Heath & Sherwood tuyere punching machines.

Individual dampers installed in the flue system behind each



Clean air project panorama shows elevated dryer, furnace building, and acid plant with emergency and tail gas stacks.

converter are automatically controlled. Regulation of the dampers maintains an approximate zero pressure across the mouth of the converter. The Hobokens will, in fact, hardly tend to puff at the mouth, thus preventing gas escape and minimizing the intrusion of dilution air. The latter two effects are among the big advantages claimed for the siphon converter. Reduced gas escape will obviously improve in-plant working conditions, and SO_2, concentrated in a manageable gas stream, is a more desirable acid plant feed.

How copper conversion is handled

Each Inspiration converter is equipped with separate 80-ton capacity cold dope and silica bins. Both bins are equipped with variable-speed feeder belts which deliver sized, plus ¼-in., minus 2-in. products to an adjustable downspout. This system is able to feed flux or cold dope to the converter while the tuyeres are submerged and the converter is blowing. Matte can also be ladled into the converter during a blow. Such flexibility assists in achieving an optimum gas grade for delivery to the acid plant.

Since the converters must now be geared to efficient acid making, as well as blister copper recovery, the operating strategy of Inspiration's seasoned converter crews will require some reorientation. A new objective is in effect at the operation—to maintain as smooth a gas flow as possible in a volume that has a concentrated SO_2 content for the acid plant. The latter will run more efficiently if surging volumes and SO_2 grades are reduced.

Of the five converters, four will be in service while one is down for repairs. The converters will be cycled so that one hot converter will be on standby, and the other three will be in operation and blowing a large percentage of the time. The three on blows are staggered so that one is on its copper or finishing blow while the other two are at differing stages of slag blowing. Matte is tapped from the electric furnace for the hot standby converter as the unit on the copper blow nears its end point. The fourth converter can then start a slag blow, and the finished converter can be down-turned for pouring blister copper. The hot blister can be transferred via the craneway to the existing anode refining furnace at the near end of the old converter aisle. Alternatively, the blister can be cast into 6,000-lb cakes.

The converters on slag blows are periodically turned down to skim slag for return to the electric furnace. When the smelter is at its nominal rated capacity, about 600 tpd of converter slag will be returned to the electric furnace. A fan of 40,000-cfm capacity ventilates the matte tap end of the furnace.

From a materials handling view, the converter aisleway, the reaction vessels and their work platforms, the associated gas handling equipment, and the feed arrangements for fluxing and reverts present a clean, uncluttered design which lends a feeling of spaciousness to the interior. The ground floor of the aisle is concreted, but contains appropriate gravel pits under splash areas, such as the converter mouths and the matte tap and slag return area of the electric furnace. The aisleway also contains a preheat station that can accommodate three ladles along the wall to the west of gravel pit at the matte tap section. Between the preheat and matte tap pits, a ladle crust breaker ram has been mounted.

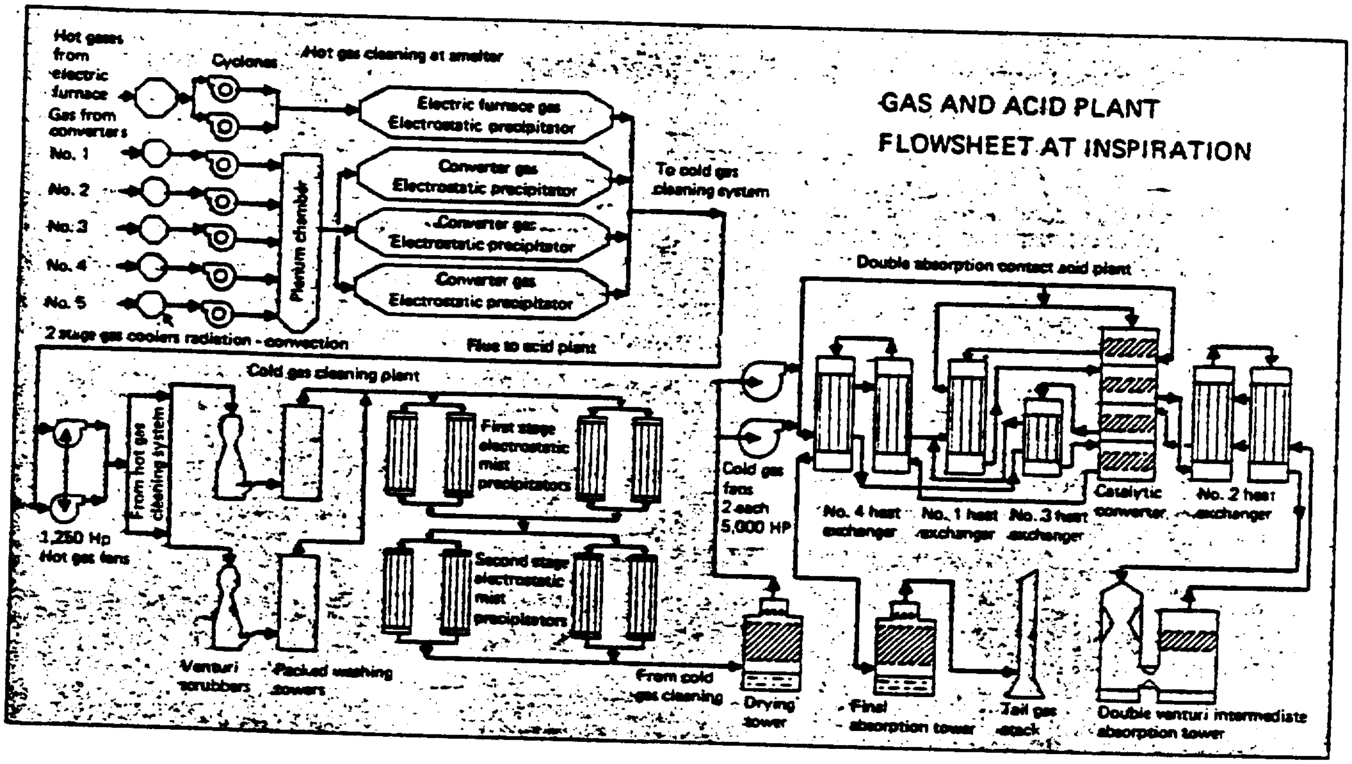
Gas handling: a two-part excercise

Electric furnace and converter gases are processed in separate hot cleaning systems designed for high-efficiency recovery of particulates. The final exhaust from the hot gas cleaning system is drawn through a 90-in.-dia flue to the acid plant where the stream enters a cold gas cleaning installation.

The electric furnace generates an approximate average of 30,000 scfm of gas at 1,300°F. It leaves the furnace through an uptake hood serving an American Schack Co. model, 14 ft sq by 65 ft high, vertical radiation and shot-cleaned convection cooler. The radiation section features water-wall construction. On leaving the convection cooler, the gas has a temperature of about 850°F. A coupled flue on the furnace building roof delivers the gas to one of two Ducon dust cyclones arranged in parallel. It is estimated that a peak 6,700 lb per hr of particulates can reach the cyclones, which are designed to drop 80% of the dust load. Cycloned gas enters a high-velocity flue linked with a Research Cottrell electrostatic precipitator, which has a design specification of 98% collection efficiency.

On entering the Cottrell, the gas has been cooled to about 750°F. With some air infiltration in the system up through the electrostatic precipitator, an estimated volume of 38,000 scfm of gas from the electric furnace hot gas cleaning system is delivered through a 48-in. flue to the insulated duct leading to the acid plant.

Converter gases are handled in much the same way. At peak volume, each converter will produce about 23,000 scfm of gas at 2,200°F, which is swept from the dust chamber to a vertical American Schack water-wall radiation and shot-cleaned convection cooler. The gas leaves the radiation section at about 1,200°F and exits the convection cooler at about 900°F. It is then cleaned in a Ducon cyclone (one per converter), and five 46-in. flues deliver the cycloned converter gases to a mixing plenum chamber which serves three Research Cottrell electrostatic precipitators in parallel.



GAS AND ACID PLANT FLOWSHEET AT INSPIRATION

The converter cyclones are also designed to separate 80% of the dust carryover in the gas stream. The electrostatic precipitators on the converter system are each designed to handle 34,000 scfm of gas with a maximum temperature of 750°F at 95% collection efficiency. All electrostatic precipitators for the furnace and converters are ganged on the roof of the furnace building. Electrostatic precipitator gases from the converter system are ducted in 48-in. insulated lines into the 90-in. main delivering gas to the acid plant.

Dust from the precipitators and plenum chamber is collected by screw conveyors and transported to a bin at ground level next to the furnace building or to the furnace feed bins.

The draft to pull electric furnace and converter gases through the hot cleaning system is created by two 1,250-hp hot gas fans, each rated for 70,000 scfm. A total of about 140,000 scfm of gas will be drawn to the acid plant from the hot gas cleaning system of the electric furnace and the three converters that are on-line. All flues in the hot gas handling installation are high-velocity ducts which convey gas at speeds of 4,000 to 7,000 fpm to minimize the settling of dust in the flues. The gas delivered to cold gas cleaning at the acid plant should be about 550°F.

Cold gas cleaning

The merged gas streams from the smelter are piped 430 ft in the 90-in. main to the cold gas cleaning system at the acid plant. Here, the gas is split between a pair of venturi scrubbers, flowing concurrently with 25% sulphuric acid solution down through the units into the lower end of two packed washing and cooling towers.

A bleed stream from the acid wash solution goes through a set of settling tanks to remove sludge so that the circulating acid can be adjusted to about 0.5% solids content. Some of the acid is bled to SO_2 strippers. Stripper gas joins the smelter gas stream entering the packed towers. The 25% acid from the stripper is recovered for use in an agitation leach and CCD circuit for slimes at the Inspiration concentrator.

A 1% washing acid circulates through the packed towers countercurrently to the gas flow. This solution passes through graphite tube and shell coolers. The condensed water from the gases is ducted from the washing tower overflow to the sump of the venturi scrubber.

Cooled gases from the packed towers at about 104°F are combined and enter eight electrostatic mist precipitators, furnished by Plastic Design and Engineering. They are arranged in two stages, with four units in parallel composing each stage. This final gas cleaning renders an optically clear stream for the adjacent acid plant.

Making acid in a quality plant

To attain the desired degree of SO_2 recovery, a more expensive double-absorption contact system, furnished by American Lurgi, was selected for acid making. Clean gas from the cold cleaning system contains about 7% SO_2. It is pulled through a drying tower countercurrently to a flow of 93-96% sulphuric acid by a pair of downstream, 5,000-hp Allis Chalmers blowers in parallel.

From the blowers, the gas enters the conversion and absorption system. The Lurgi plant is equipped with a total of four V_2O_5 catalyst beds for converting SO_2 to SO_3. Four Cyclotherm heat exchanger installations, two of them containing two vessels in series, maintain proper gas temperatures for conversion and absorption. Top bed gases from the catalytic converter are cooled in one heat exchanger. Gases leaving the second bed are cooled by two heat exchangers in series before going to the intermediate double venturi type absorber. With over 80% of the SO_2 converted to SO_3, the heat-exchanged, second-bed gases flow concurrently with acid from the top of the intermediate absorber down through the unit. This helps conserve heat required for the catalytic reaction in the third state of conversion.

The weak offgas from the absorber returns to the catalytic converter after it is further heated in the shell of the set of exchangers handling second-bed gases. Containing less than 2% SO_2, this weak gas passes through the third and fourth catalyst beds, with a single heat exchange taking place between them. The gas from the fourth bed enters two heat exchangers in series and then the final absorption tower. Off-gas from the

Who's who among contractors and suppliers for Inspiration's clean air project

A truly international composite, the major components of Inspiration's air pollution abatement program include: a US-supplied rotary dryer; a Norwegian-designed electric furnace; five siphon converters of Belgian design and US manufacture; a US-supplied hot gas cleaning system; a cold gas cleaning system with US and German equipment; and an acid plant of West German design, executed with German, UK, and US equipment.

The primary engineering contractor for the project was Treadwell Corp., of New York City. Treadwell collaborated with and worked under the direction of the Inspiration engineering staff, headed by chief engineer, E. E. Burton; Dale Rudolph, former smelter superintendent; and Paul Musgrove, current smelter superintendent. The project evolved under the guidance of R. C. Cole, now vice president; the late Henry Allen, formerly general manager; and Doug Middleton, current general manager and vice president. Top corporate decision makers, H. Myles Jacob, chairman, and Richard R. Hyde, president, bore the brunt of shaping final approval for the project. Earl Marble, a consulting metallurgist; John White, former chief engineer; and Ken Larson, project engineer, all made important contributions.

Construction in the electric furnace and converter area was handled by Davy-Powergas of Lakeland, Fla. The cold gas cleaning system and acid plant were built under a turnkey contract with American Lurgi Corp., which employed the services of Lurgi Gesellschaften, Frankfurt, West Germany, and Lurgi-Knost Inc., Baton Rouge, La.

The electric furnace was designed by Elkem AS, of Norway, and the siphon converters are a proprietary design of Metallurgie Hoboken-Overpelt, of Belgium.

Inspiration hired 12 prospective instrument-mechanic trainees in June 1973 and put them through a training program set up by the electrical engineering department of Eastern Arizona Junior College. The course, conducted at the company site, included 350 hr of class-room instruction and 7 months of informal on-the-job training.

In addition, the company interviewed a number of two-year-level college students, and hired nine of them as coordinating supervisors. One member of this group was a young woman with four years of biology. The prospective coordinating supervisors were assigned to shift foremen for two months in the reverberatory, converter, fire refining, and anode casting sections of the old smelter, to learn the operations. They also attended the pneumatic, fluid, and electronic portions of the instrumentation courses.

The coordinating supervisors also attended process lectures on the basics of smelting and acid making, and they were instructed in details of the new plant—its mechanics and its operation. The group was sent to The Anaconda Co.'s Weed Heights, Nev., acid plant for a period to observe operations.

As shift foremen at the old smelter were freed, the trained coordinating supervisors began briefing them on the new smelter. Last December, acid plant operators were selected and trained by the foremen and coordinating supervisors. Hourly personnel such as slag skimmers, punchers, and cranemen practiced with the new equipment during periods when they could be relieved of duties at the old smelter.

final absorption tower goes to the 200-ft-high tail gas stack.

Nominal monohydrate acid production, without allowances for losses, will be 1,330 tpd in the plant, which has the capability of producing either 93% or 98% acid. The final product will be delivered to a 10,000-ton storage system.

Steam plant recovers waste heat

An ingenious system recovers waste heat from furnace and converter gas cooling stages and utilizes it to generate steam in a plant designed by Treadwell Corp. as part of its overall engineering contract.

High pressure, high temperature water (500°F at 1,000 psi) circulates in a closed loop system through the water jackets on the American Schack radiation coolers handling electric furnace and converter offgases. Heat is removed from this closed recirculation system and converted to steam in steam generators. A peak total of 126,000 lb per hr of steam will be generated. The steam is used to drive turbines supplying blast air to the converters and to drive the pumps which recirculate the high pressure water through the radiation coolers. Any excess steam can be fed to the Inspiration power plant.

Maintaining the cooling water at 500°F will keep the offgases above the dew point and out of the corrosion range. The system includes water treatment facilities to supply treated water to the steam plant.

In conclusion

The new smelter-acid installation is a highly sophisticated system with two control centers. The nerve center for the smelter commands a sweeping view of the converters and furnace. This control room houses the instruments which monitor and control furnace and converter operating conditions. Temperature indicator and recorder panels track sensitive points in the system, including concentrate feed, hot gases, and cooling water. Functioning of equipment, which is operated either automatically or manually by local operators, is also monitored in the smelter control room.

A Du Pont 460 photometric analyzer monitors the SO_2 content of effluent gases at seven locations. A paging system links the smelter control center, the acid plant control center, and the smelter cranemen for telephone communications.

Inspiration's engineers and management have launched a modern new recovery system and introduced new technology to the US. They are joined by the contractors and suppliers in a justifiable feeling of pride in this achievement. □

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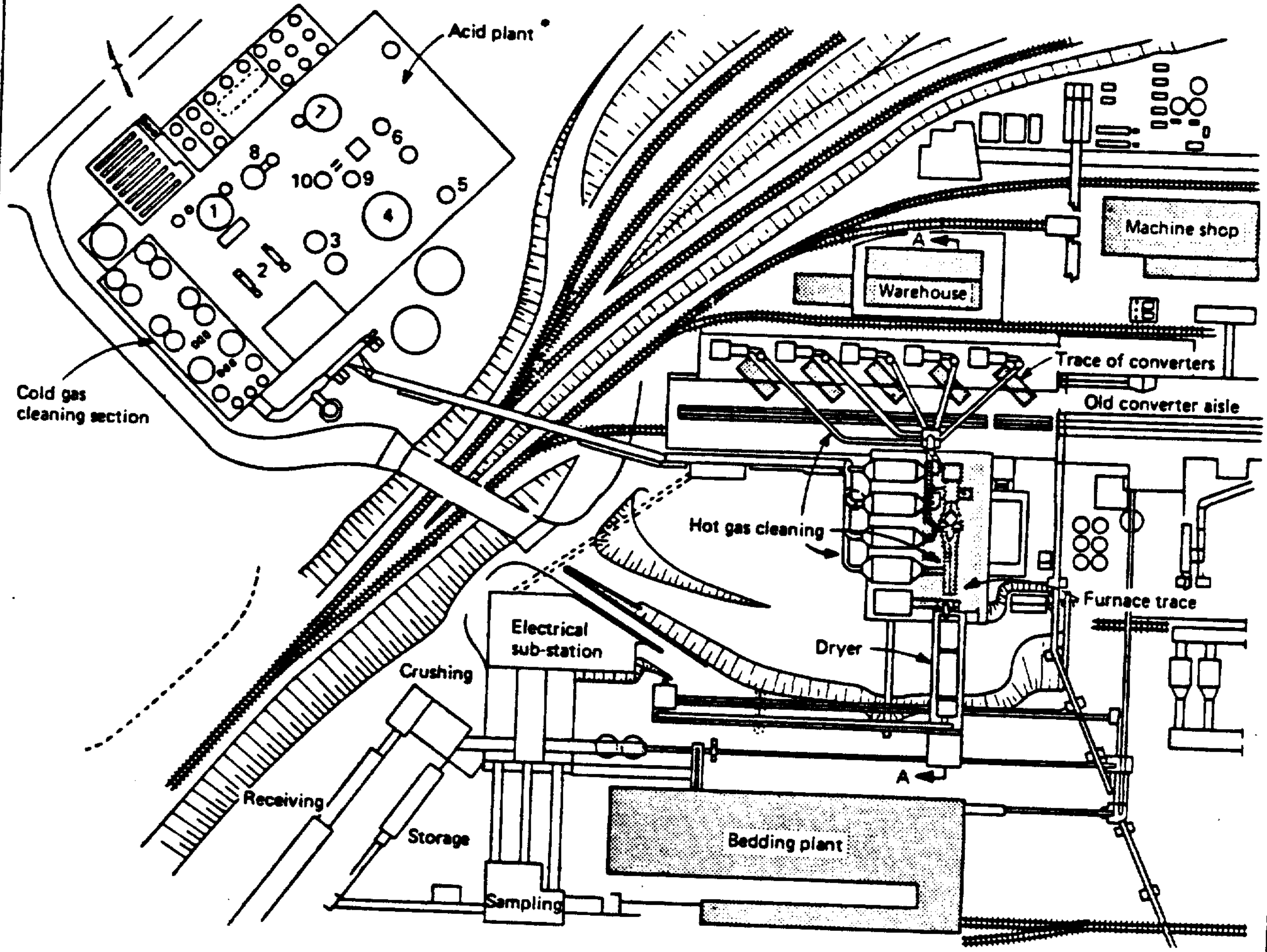
2) Gonzales, J., Lira, M., and Vargas, E., "The Paipote Copper Smelter of Empresa Nacional de Mineria," 1972 AIME meeting.
3) Salat, S. J., Treadwell Corp., unpublished description of Inspiration's new copper smelter.

Coming in August: A profile of Inspiration mining and processing from ore to finished copper rod.

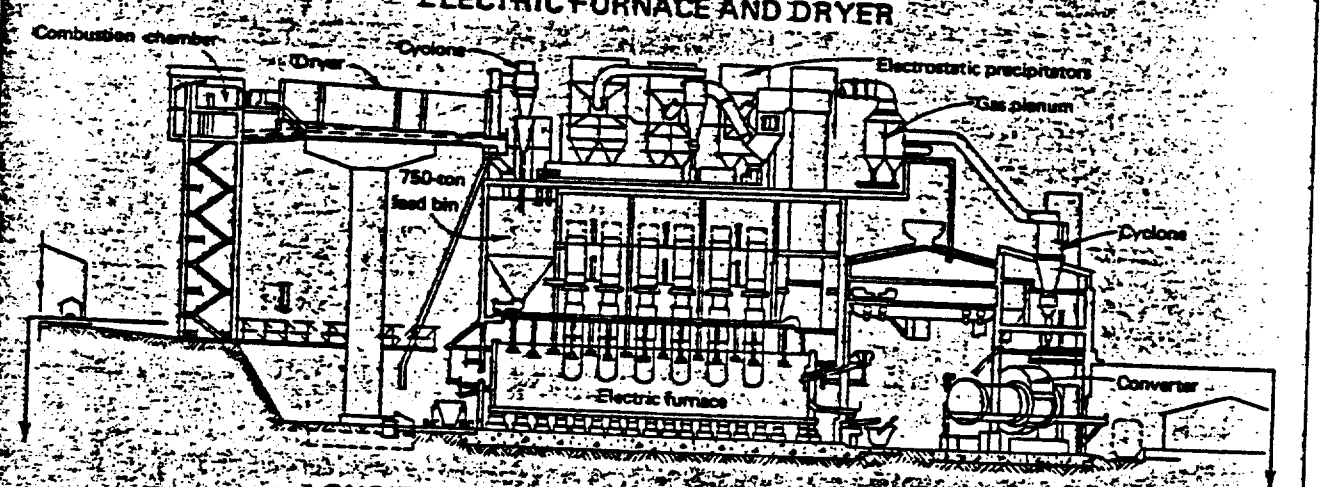
GENERAL PLOT PLAN OF INSPIRATION ELECTRIC SMELTER AND ACID PLANT



*Acid plant

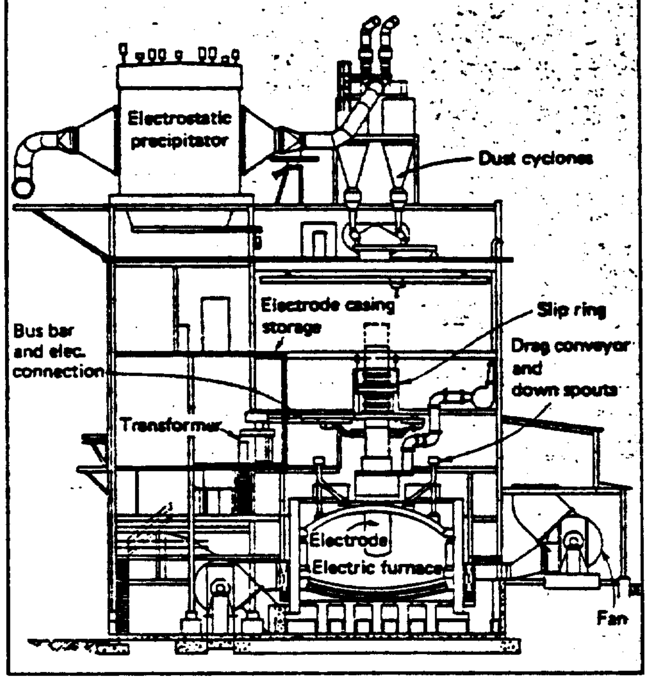
1. Drying tower
2. Gas blowers
3. Heat exchanger No. 2
4. Converter
5. Heat exchanger No. 1
6. Heat exchanger No. 4
7. Final absorption tower
8. Intermediate absorption tower
9. Heat exchanger No. 3
10. Oil tank

ELECTRIC FURNACE AND DRYER

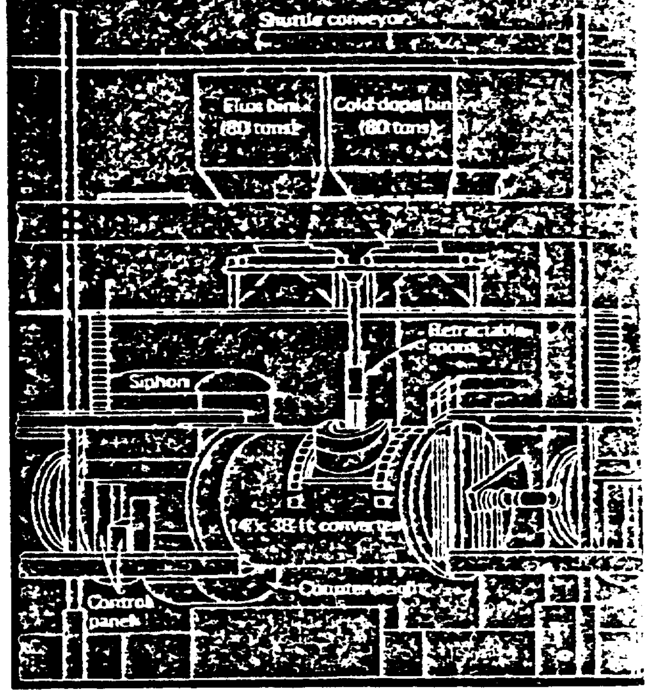


LONGITUDINAL SECTION A-A FROM PLOT PLAN

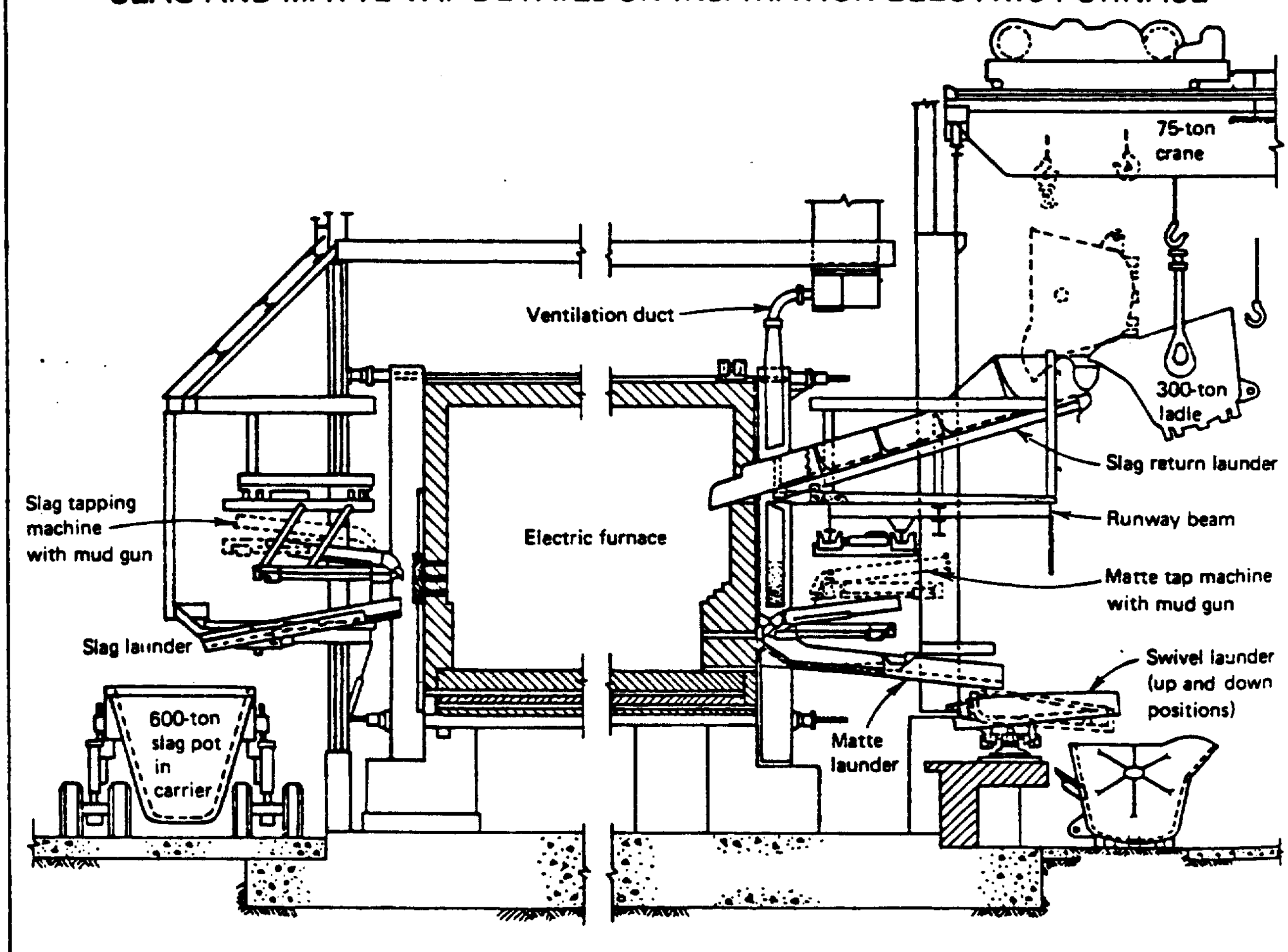
CROSS SECTION, ELECTRIC FURNACE BUILDING AT INSPIRATION



TYPICAL CONVERTER INSTALLATION AT INSPIRATION



SLAG AND MATTE TAP DETAILS ON INSPIRATION ELECTRIC FURNACE



Inspiration panorama reveals a cross section of operations. Shown at left are: 1) Thornton open pit; 2) primary crusher location; 3) tertiary crushing plant; 4) leaching vats; 5) wash water and pregnant solution holding vats; 6) iron launders; and 7) electrolytic tankhouse which contains both electrowinning and electrorefining cells.

Part 2: Inspiration Copper (ore to rod)

Mining program aims at growth opportunities

Stan Dayton, Editor-in-chief, and **Daniel Jackson, Jr.**, Western editor

WITH COMPLETION OF A NEW smelter and acid plant which aimed at clean air (E/MJ, June 1974, p 85), Inspiration Consolidated Copper Co. has turned its attention to new revenue-generating programs in Arizona and elsewhere. Important elements among these include:

- Development of the Joe Bush group of claims in the Miami area—a sizable mineralized body of copper that is on a common boundary line with property owned by Cities Service Co.'s Miami Copper Operation, with Inspiration's wholly owned share equated at 49 million tons.
- Development and equipping of the Sanchez copper orebody in the Safford, Ariz., area.
- Expansion of the Ox-Hide treatment plant—a scraper mining and heap leaching operation.
- The development of coal properties and other mining opportunities outside of Arizona, and expansion of Inspiration concentrator capacity.

Inspiration has been mining copper-bearing ore underground and on the surface in the Globe-Miami area of Arizona, and more recently along the Gila River drainage at Christmas, midway between Globe and Hayden.

Today the company mines five types of ores for its recovery plants—four from Inspiration area mines in a porphyry environment and a fifth type at Christmas, where copper oxides in a carbonate host required the development of a satisfactory recovery method.

Inspiration ores include: 1) high-oxide, low-sulphide ore for vat leaching and discard of leached residue; 2) mixed oxide-sulphide copper ore, handled by a dual process system of vat leaching followed by flotation of the leached residue for recovery of the sulphide fraction; 3) high sulphide-low oxide copper ore which is directed to the sulphide flotation concentrator; and 4) a low oxide-minor sulphide ore programmed for heap leaching and cementation in iron launders.

The company also utilizes leaching-in-place, recovering copper from acidified waters from old underground workings. It is also equipped with one of the most complete metallurgical plants in the world, employing practically every known commercial recovery method. The only major exception is the coupling of leaching and solvent extraction of copper with electrowinning. Even that process has been piloted by Inspiration and will probably figure strongly in future recovery systems.

While Inspiration earned its reputation with hydrometallurgical processing methods, it may well be that the mining department, which must meet a demand for segregating various ore types, is the stiffening agent in the company's backbone.

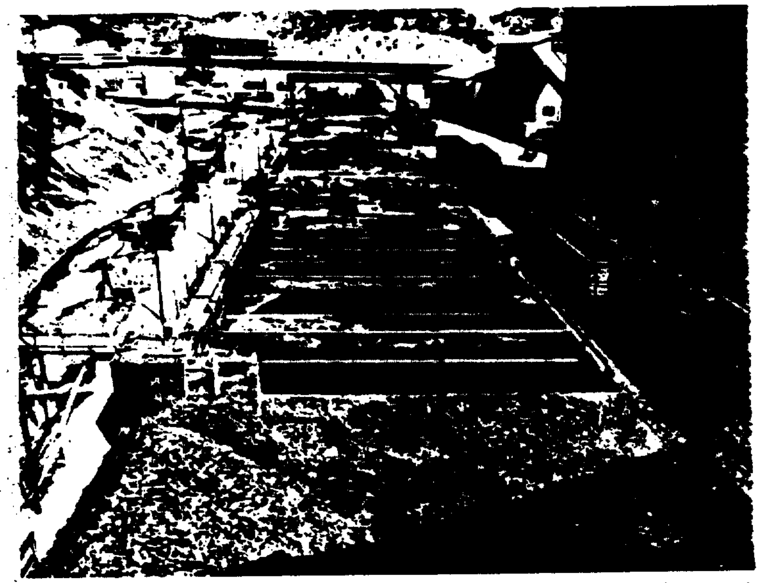
Geology of the Inspiration mines

The Inspiration orebody has a strike length of slightly over 12,000 ft. Its width ranges from 2,000 to 4,000 ft, averaging nearly 3,000 ft, and the thickness varies from 40 to 900 ft. Although mined in separate units and severed by faults, the ore matrix is essentially one zone of mineralization, and is thus regarded as one of the great orebodies of the world.

General trend of its strike is east-northeast, and it lies along the northern contact of a prominent bulge of intrusive igneous rock. Ore-grade mineralization is in schist, granite, and granite porphyry. In general, the schist-intrusive contact dips steeply to the south.

In the east end of the orebody, mineralization tends to follow the northwest trend of the schistosity. Farther west, sulphide veinlets tend to cut across the schistosity and dip southerly toward the intrusive. In general, the more massive schist beds are better mineralized. There is no constant system of orientation of veinlets in the intrusives.

In common with most other porphyry copper deposits, the Inspiration orebody has a threefold vertical distribution of



Iron launders at leach plant precipitate copper from various wash waters circulating through leaching vats shown in background.

Christmas concentrator treats an oxidized copper ore in a carbonate gangue. Photo shows two of three mills and part of flotation.

ore mineralization. A leached zone overlies a zone of supergene enrichment, averaging about 300 ft in thickness, and below that is the protore, which is generally too low in grade to be mineable.

A plan for growth

Inspiration Div. open-pit mines set a new high for total ore and waste removal in 1973—over 25 million tons. Ore production for in-plant treatment was approximately 25,000 tpd. Ratio of waste removed per ton of ore mined was 1.94. Production came from the Thornton, Live Oak, and Red Hill pits. The concentrator treated 6,710,000 tons of ore, 46% of which was a sulphide-bearing residue from prior vat leaching and 54% a predominantly sulphide ore which bypassed the leaching operation. The vat leaching plant treated 2,960,000 tons of dual process (mixed oxide-sulphide) ore and 1,702,000 tons of low sulphide-high oxide feed known as leach and discard ore.

To handle this tonnage economically, Inspiration updated mining equipment by replacing older units before they became obsolete and inefficient. New equipment included one 100-ton and seven 85-ton diesel-powered haulage trucks, a 10-cu-yd electric shovel, and a truck-mounted rotary drill. Nine additional 85-ton trucks are scheduled for delivery this year to further improve efficiency.

The new $2.3 million Willow Springs heap leaching project, now on stream, will further increase mine output. Copper production from this operation will gradually increase to an annual rate of 10 million lb.

Preproduction development of the Joe Bush mine is expected to get underway this year also. Under agreement with Cities Service Co., Inspiration will mine and treat, on a royalty basis, a sizable amount of ore on Cities Service property adjacent to Inspiration's Joe Bush claims.

This agreement also will enable Inspiration to mine approximately 49 million tons of its own material which could not have been moved without disturbing the common boundary. An increase in the estimated ore reserves of Inspiration area mines, from 1.9 billion lb of recoverable copper at the end of 1972 to 2.2 billion lb at the end of 1973, stems in large measure from this project.

Mineral suite is complicated

Normal mining operations at Inspiration are complicated by such factors as long up-grade hauls, problems in supplying several types of ore to the plant, and mining intimately mixed ore and waste in areas previously block-caved by underground mining.

Although Inspiration's mines have much in common with other southwestern open pits of the US in the application of mining equipment and techniques, the company has unusual production and ore scheduling problems. It must produce three distinct types of ore, along with two types of heap-leaching material, in addition to stripping barren waste.

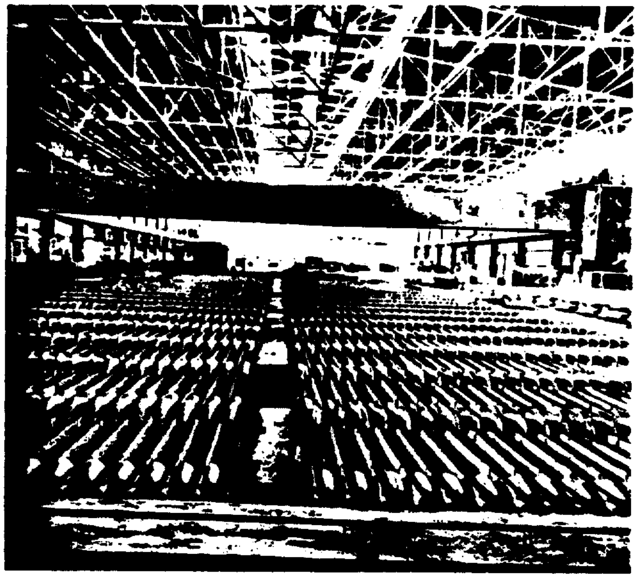
The three types of plant feed are: 1) leach and discard ore, containing acid soluble copper minerals, 2) direct mill feed sulphides, and 3) dual process ore—treated first by vat leaching and then flotation of leaching plant tails.

In addition to supplying three types of ore, the mining department schedules certain waste for heap leaching as part of its activities. Sandwiched among these routines, mining crews must arrange to dump barren waste in non-leachable areas. Actually, five products must be separated continually on the basis of ore control information. This complex set of tasks is followed by still another step: for every 10,000-ton vat of "discard" (oxide ore that is vat leached), the mining department must, at the completion of the leaching cycle, dispatch a fleet of haul trucks to dispose of tailings.

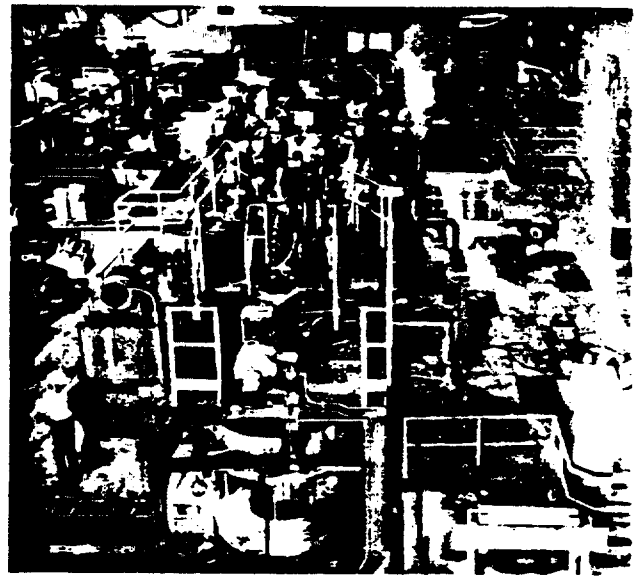
These problems do not appear too difficult, especially since non-leachable overburden is encountered at the surface, leachable waste on upper benches, and oxide ores on intermediate levels that phase into dual process (mixed oxide-sulphide) ores at lower horizons, leaving direct mill feed sulphides at depth. However, the situation is not that simple. Sulphide ores, for example, not only exist high in the column in certain areas, but previous mining by block caving has also produced subsidence in large blocks of ground. This results in pipes of ore and waste throughout the mine. Frequently all ore types may be encountered in close approximation, all on the same bench. These complexities make production scheduling at Inspiration's mines a real challenge.

Scheduling the mining cycle

Ore reserves are continually updated by the mine engineering and geological departments. Development drilling, blasthole drilling, and analysis of recoveries from immediate past mining are used to supply management with a detailed



Electrolytic plant is equipped for both electrowinning of copper from pregnant vat leach solution and refining of smelter anodes.



Continuous cast copper rod is rolled to 5/16-in. dia in processing line consisting of Asarco melting furnace and a Southwire system.

analysis of all available reserves. This, in turn, is fitted to the overall plant capabilities and modified by economic consideration to fulfill annual goals.

The mine operates on long-range commitments, including a five-year schedule, annual production goals, and quarterly and monthly mining plans approved by management. A 20-year plan is also in effect.

The mining department is grouped into four areas of activity: engineering, mining operations, dump leaching, and maintenance. Working closely with engineering, the operations group must receive commitments from maintenance for minimum levels of availability for all necessary equipment, to meet production requirements of both plant and dump leaching.

Currently, Inspiration's schedule is 27,500 tpd ore and 64,500 tpd waste. Ore is broken down into an average of 6,800 tpd dual, 7,200 tpd leach and discard, and 13,500 tpd sulphide. Since all dual also goes to the concentrator, this amounts to a mill feed of 20,700 tpd.

The leaching plant generally keeps 12 tanks in circuit on a nine-day cycle. To maintain this rate of production in the leaching plant (six discard tanks per 12-tank cycle), one fleet of haul trucks is committed to the leaching plant approximately 50% of the time.

The mine runs three shifts, seven days a week, with four equally staffed crews. Each crew works 21 shifts every four weeks, providing equal strength of crews, even rotation, equal distribution of scheduled overtime, no short changes, one long change each four weeks, and one crew off at all times for emergency call-outs.

Mining sequence

Inspiration has three active mines combined into one operation: the Thornton pit on the east, Live Oak on the west, and Red Hill just north of the Live Oak.

Distribution of shovels indicates fairly well the rate of production from these three divisions. Production equipment consists of eight electric shovels, three 10-cu-yd loaders and 41 haul trucks, divided into four major fleets. The Thornton pit is equipped with 5- and 6-cu-yd shovels, Live Oak with an 8-cu-yd shovel, and Red Hill with one 5-, one 6-, and three 10-cu-yd shovels distributed in the pit from the 4,050 to the 3,750 bench.

Each pit is developed initially by one main haul road breaking off to 50-ft benches. These benches in turn are split into 25-ft benches wherever loaders are intended to be used or sorting is required. Pits have both 50- and 25-ft benches.

Production crews are scheduled to run five loading units each shift, with crews consisting of four two-men shovel crews, one loader operator, three wheel dozer operators, two pitmen, three water truck drivers, and 26 haul truck drivers. Although it is desirable to operate four shovels and one loader each shift, it is necessary to schedule a second and even a third loader in place of shovels to provide required plant feed, or maintain some particular development schedule. When discarding from the leaching plant, one unit is shut down in the pit.

Loading capacities of various units in well fragmented bench blasts have recently averaged the following tonnages:

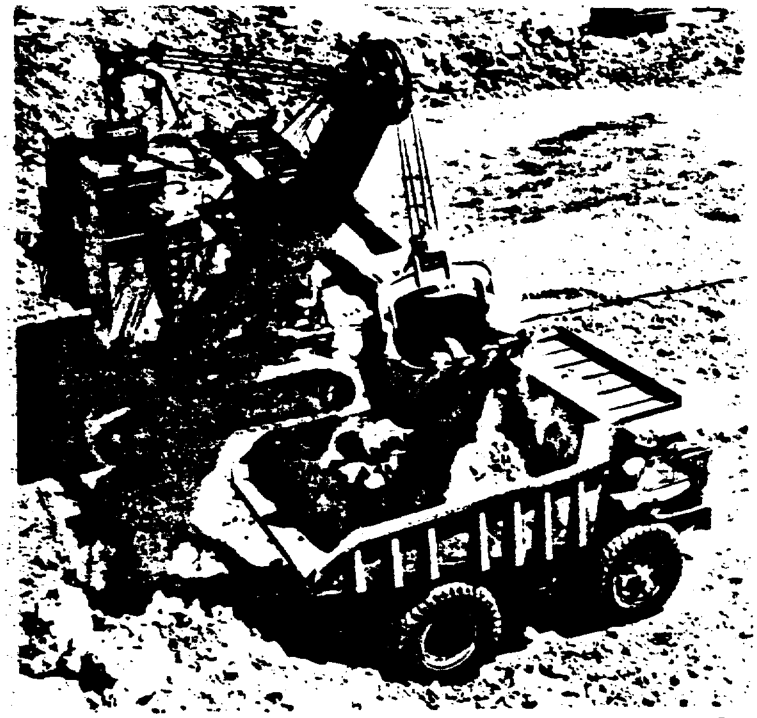
Units	Tons per shift
10-cu-yd shovels	12,000
8-cu-yd shovels	8,000
6-cu-yd shovels	6,500
5-cu-yd shovels	5,000
10-cu-yd loaders	55,600

Frequently it is possible to dig undercut material, or other ground badly broken by movement, without blasting. While this reduces unit capacities by 10% to 15%, it greatly improves sorting and is a useful technique. The haulage fleet consists of:

One 105-ton 2772 Dart
Eight 85-ton 85-C Wabcos
Three 85-ton M-85 Lectrahauls
One 85-ton prototype test unit
11 75-ton 2662 Darts
17 40-ton 37SL Darts

This mix provides a weighted mean-haul capacity of 65 tons per unit. Considering the average lengths of hauls and the mean capacity of loading units, a calculated production potential of 120,000 tpd is available. So far, however, the high has been a little over 116,000 tpd.

Running ore haulers too lightly covered (to insure proper grade proportioning), cleaning up final toes, and frequent



Variety of earthmoving systems are used at Inspiration mines. This team is a 10-yd P&H electric shovel and a Wabco 85-ton truck.

At Christmas mine, loading and hauling units are Cat 988's and 35-ton trucks; the operation is geared for about 5,000 tpd of ore.

shovel moves reduce shovel efficiency. Although loading is planned for 105 shifts per week, scheduled discard and predictable absenteeism, along with unpredictable downtime, reduces this to an average of 94 shifts per week.

Rock breaking at Inspiration is conventional. Blastholes are bored by three Chicago Pneumatic 750 truck-mounted rotary rigs, which average 550 ft per shift of 9-in. hole. Drilling is scheduled on two shifts, seven days per week. ANFO is used for dry holes, and bagged slurry for wet holes. About 15% of the holes require slurry. All blasting agents are bagged in 50-lb units. The mine will be converting to ANFO bulk loading later this year. Some 3.5 million lb of explosives are used annually and it takes 1 lb of explosive to break 4.5 tons of rock. Only 70% of rock requires blasting, because much of the undercut material digs readily with the large shovels.

Secondary blasting is a very minor part of the operation, but when necessary, 2½-in. percussion holes are drilled with a truck-mounted jumbo. The holes are shot with 2 x 12-in. stick powder at the end of the day shift, when danger of fly rock is minimized.

Building haulage roads, drill roads, and maintaining benches is accomplished with three D-9 bulldozers and one D-8. Three Cat No. 16 motor graders operate 15 shifts per week. Haul road berms and bench and road repairs are maintained by use of a 6-cu-yd Cat 988 loader.

Flood waters which cannot be diverted around the perimeter of the pits are drained to the bottom levels, where they gradually seep into old underground workings. Eventually these solutions are pumped to the surface from either the Live Oak or Inspiration shafts for recovery of copper. Surface sumps are occasionally necessary. They are pumped by four 200-ft-head, 500-gpm trailer-mounted portable pumps.

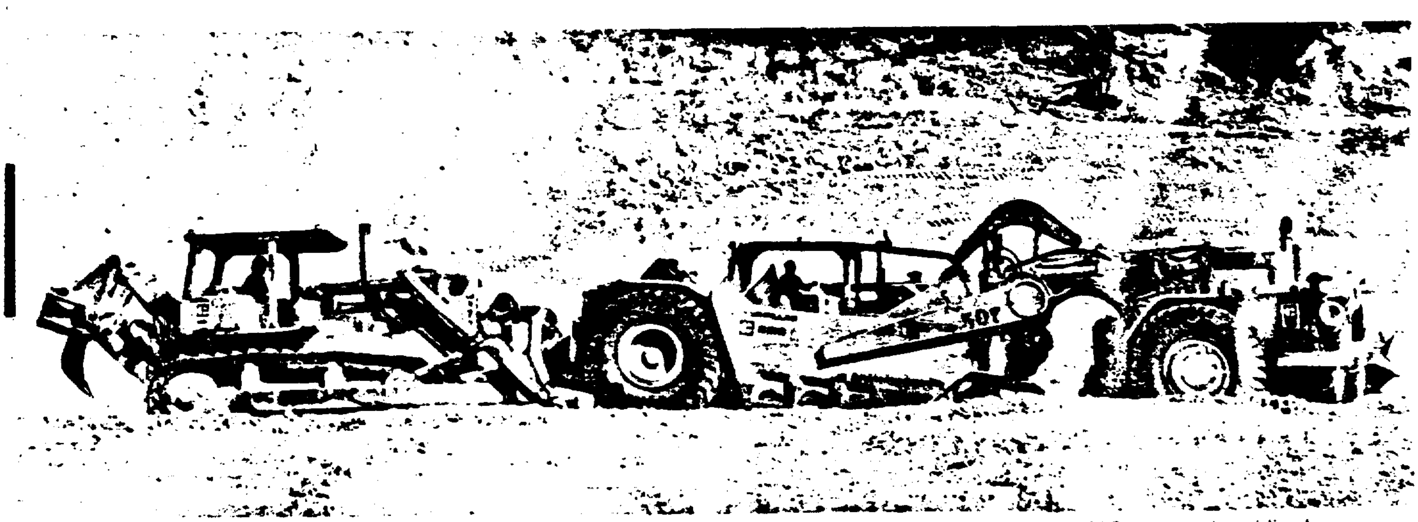
Heap and waste dump leaching

Heap leaching of low-grade copper ore and mineralized waste dumps produced 16,395,000 lb of copper at Inspiration's operation in 1973.

Leaching-in-depth is also employed at Inspiration area mines. In this system, acid solution is delivered to mineralized zones below the capping of old block-caved areas through drill holes cased with rigid plastic pipes. This practice provides additional pregnant solution that is pumped from the shafts for treatment in iron launders.

Crushing and conveying

Inspiration's crushing operation is emerging from an ambitious revamping program. It all began a few years ago with



Ox-Hide pit, about 3 mi from central Inspiration area mines, pairs Cat D-9 rippers and push-loaded 631C scrapers in oxidized ore.

the design of a new tertiary crusher installation consisting of four Nordberg 7-ft Shorthead cone crushers, eight 6 x 16-ft double-deck screens, two 72-in. duplex spiral classifiers and fourteen 12-in. cyclones, along with approximately 4,000 ft of conveyor.

Shortly after construction started on the tertiary crusher, the company began work on a new primary crusher facility which included a 40-ft-dia concrete silo and a 54 x 74-in. crusher equipped with a 450-hp wound-rotor motor. The silo was built then backfilled with waste around its perimeter to accommodate three trucks at one time.

Inspiration's crushing schedule is based on 2½ shifts six days a week and two shifts on the seventh day. This builds in a 4-hr maintenance period every day except the seventh, when 8 hr are available for major repair or servicing of the crushing and conveying system. Of the daily 20-hr crusher schedule, available time amounts to about 18 hr. This means that the crushing system must average 1,530 tph. The maximum rate sustained for any length of time is 2,000 tph. Generally, 1,800 tph is the rate that Inspiration tries to maintain.

To deliver this tonnage, production equipment in use will consist of one 10- and one 8-cu-yd shovel; two 6-cu-yd units, or one 6-cu-yd unit plus one loader; two loaders or two 5-cu-yd shovels, and about one-half the production of one other small unit. However, since the larger units are seldom in ore, management usually ends up operating two and three units in ore in some staggered sequence, thus sacrificing shovel efficiency to gain quality control in ore blending.

The new primary crusher reduces ore to 6½- to 7-in. size for storage in the 6,500-ton ore bins. Of this capacity, 4,000 tons of space is reserved for sulphide ore and 2,500 tons for oxide. From the bins the ore is conveyed to the secondary circuit, consisting of two 7-ft standard cone crushers which reduce the feed to minus ¾ in. Secondary storage capacity also amounts to 6,500 tons, with a similar distribution of storage for sulphides and oxides.

Minus ¾-in. ore is conveyed to the tertiary plant and stored in 1,500-ton storage bins for final reduction to minus ⅜ in. This crushing plant supplies feed for the concentrator and the leach plant.

When treating ore for leaching, the washing circuit is operated with repulp and rinse water on the double deck vibrating screens. The top deck has ⅜-in. openings and the bottom deck is 12 mesh. Slurry containing the major portion of 200-mesh slimes is rinsed through the bottom deck and pumped through hydrocyclones which make a 200-mesh split. The overflow is pumped to the slimes leach plant. The cyclone underflow is washed and dewatered in spiral classifiers. The minus ⅜-in. screen fraction as well as the deslimed dual process and discard ores should contain no more than 2% minus 200-mesh material for efficient vat leaching.

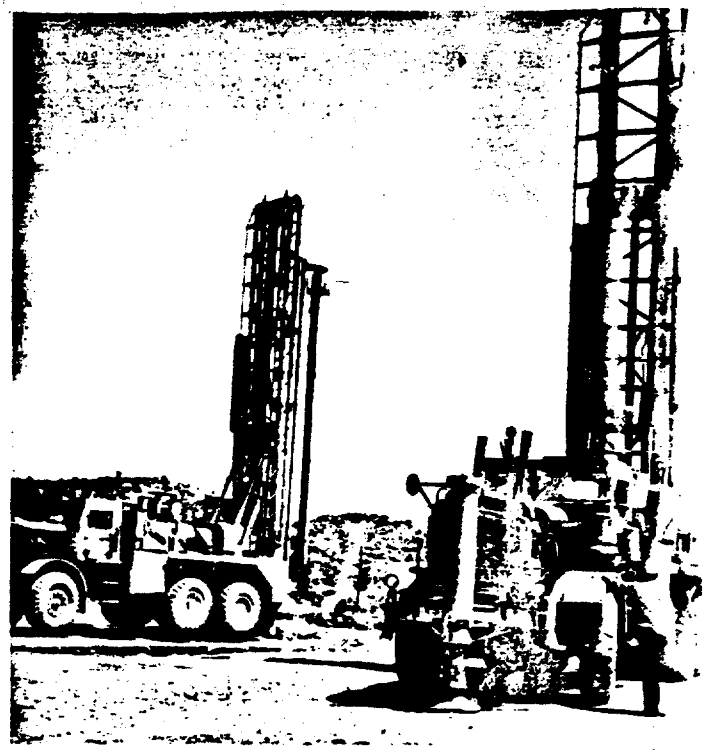
Mill feed is presently being deslimed as a dust control measure, but a number of alternative tests are being conducted by Inspiration to control dust, with good success reported in several areas.

Ox-Hide heap-leaching operation

The Ox-Hide mine, situated approximately 5 mi to the west of the main pits, is a scraper-mining, heap-leaching operation with an iron precipitating plant for recovery of copper from pregnant solution. The cement copper produced at Ox-Hide is trucked to Inspiration's smelter.

With mining of the upper Ox-Hide orebody almost completed last year, extraction at the lower Ox-Hide pit began. Copper production in 1973 was 8,713,000 lb. Production goal is set at 35,000 lb per day.

Nine scraper loaders and five bulldozers mine the lower Ox-Hide orebody. Push-loaded scrapers bed the ore on leach pads in 15-ft lifts. The total height of a pad is determined by the contour of the surface. Before building a new lift, the surface of the dump is ripped with a dozer to improve percolation. Completed bed sections are irrigated from a surface trickler system to distribute sulphuric acid solution over the entire area. The Ox-Hide operation has constructed a number of these pads to produce pregnant copper solutions for circulation through a set of launders loaded with detinned, shredded cans.



Rotary blasthole drills bore 9-in. holes shot by ANFO if dry, or slurry if wet. These units are Chicago Pneumatic model 750's.

A small solvent extraction circuit and tankhouse for electrowinning of copper cathodes from purified solution has been operated on a pilot scale using pregnant solutions from Ox-Hide. Operated intermittently over a period of time, these tests have equipped personnel with a working knowledge of this recovery system.

Geology of the Christmas mine

Inspiration's Christmas mine is approximately 7 mi north of Winkelman, Ariz. Rock types exposed in the mine area are Cretaceous andesites which overlie Paleozoic sediments. Youngest sediment exposed in the pits is the Naco limestone. Current mining operations are contained within this limestone. Underlying the Naco limestone is the Escabrosa limestone, which is thick bedded crystalline limestone intruded by a diorite sill. This latter limestone overlies the Devonian Martin limestone, which is thin-bedded and shaley. Below the Devonian, there is approximately 100 ft of Cambrian sediments. Located below the Cambrian sediments is the Troy quartzite of Precambrian age. These sedimentary rocks and Cretaceous andesites have been intruded by quartz biotite-diorite porphyry in essentially a series of dike forms which have more or less converged on an east-west trend within the pit area.

Alteration of the sedimentary beds created zones of favorable ore deposition in the sediments north and south of the contacts with the diorite. From the mine area eastward, there are two major structures—the Christmas and Joker faults, which strike north and northwest, respectively. Both exhibit considerable post-ore movement. The Christmas fault downdropped the sediments approximately 1,200 ft, exposing them in a wedge between the two faults. To the east, the Joker fault downdropped the formations to an unknown depth, but it is

Dump leaching pad at Live Oak pit is bedded and sectioned for the introduction of leaching solutions.

estimated that a total displacement of the Christmas-Joker fault system is approximately 2,500 ft.

The Christmas was originally developed for underground extraction of copper sulphide ore at depth to supply a 4,000-tpd flotation plant. Plagued with continuing problems, underground output was supplemented with a small open pit in 1964 after research devised a means of achieving a satisfactory flotation recovery of oxidized copper minerals carried in the near surface zone. The limestone host ruled out acid leaching of the oxide ore fraction. In 1966 the open pit became the sole source of ore supply and the underground mine was closed, although it will be worked in the future.

Today, open-pit ore recovery is centered in the phenocryst limestone. South of the sedimentary-igneous contact, the best ore between the faulted flanks is a zone extending 3 ft to 500 ft from the contact. A similar zone occurs on the north side of the contact. The average grade of ore is 0.75% copper although the cutoff grade for mining will be 0.3% recoverable copper.

The mineral assemblage at Christmas consists of various zones of moderate sulphides containing mostly pyrite, chalcopyrite, bornite, and magnetite. Very little secondary enrichment is present in the mine zone. Fairly strong oxidized areas are present around old underground stopes with fair to moderate chrysocolla and malachite.

Christmas mining program

Copper production at the Christmas mine totaled 19,800,000 lb in 1973, compared to 22,200,000 lb in 1972. The decrease was reportedly caused by lower copper content of ores treated. Ratio of waste removed per ton ore mined rose from 5.00 to 5.77. A production rate of 5,500 tpd of ore and 27,500 tpd of waste is maintained.

Equipment replacements were the highlights of Christmas operations in 1973, with capital expenditures totaling $2,108,000. New equipment included ten 35-ton trucks, two 6-cu-yd front-end loaders, and two truck-mounted blasthole drills.

Primary drilling is done with three rotary rigs that sink 7⅞- and 6¾-in. blastholes. Holes are spaced on a 10 x 12-ft pattern and drilled to a depth of 23 ft, allowing for 3 ft of sub-drilling to maintain a 30-ft face. Approximately 40 drill shifts are required per week. Average penetration rate is 500 ft per shift. ANFO is used as the blasting agent, providing a powder factor of 0.40 lb of ANFO per ton of rock.

Broken material is loaded into the 35-ton haulage trucks with 6-cu-yd front-end loaders at an average rate of 3,230 tons per machine shift. Hauler productivity is 2,441 tons of ore per truck-shift over a roadway profile that averages 2,000 ft in the pit, with a 60-ft climb to a 2,800-ft section of plus 2% grade, and finally 3,600 ft of plus 9% grade to the crushing

Irrigation system at Live Oak leach dump sprays acidified solution on low grade copper oxide.

plant. The average haulage distance for waste and leach material is 2,000 ft at a maximum grade of 8%.

All production is hauled to the McDonald shaft area (which served the former underground mine) and discharged onto a 5 x 5-in. 150-ton grizzly hopper. Oversized material is broken with a Kent air ram mounted on a Savage knuckle-boom installed alongside the hopper. This will be replaced with a jaw crusher. Coarse ore is stored in a 1,000-ton bin, then passes through two stages of screening and crushing in Allis-Chalmers gyratory and Hydrocone crushers to produce a 5% plus ¾-in. material. This product is conveyed to a 20,000-ton storage building.

Countercurrent flotation

The concentrator grinding section consists of an open-circuited 11 x 16-ft rod mill followed by two 11½ x 14-ft overflow ball mills, both in closed circuit with cyclones. Designed originally to treat 4,000 tpd, the mill now treats about 5,400 tpd of copper concentrate at its current feed rate. The concentrate is trucked to the Inspiration smelter.

Metallurgical advances achieved by the combined efforts of Christmas and Inspiration research personnel have made it possible to treat ore of higher than normal oxide copper content with satisfactory results. Some of this ore had been stockpiled until a means of treating it profitably was developed.

Ore at plus ¾ in. is delivered to the grinding section. Discharge from the rod mill flows via floor launder and splitter box at 60-70% solids to the two ball mills.

Ball mill cyclone overflow goes to three Agitair rougher rows of 24 cells each. These cells are operated in a countercurrent method. Rougher concentrate is pumped to a 9 x 14-ft ball mill via 10-in. cyclones for regrind, and rougher tails are pumped to cyclones for a sand-slime separation and flotation.

There are three rows of 22-cell Agitair machines, with one row for sand flotation and two for slimes flotation. Concentrate from these rows joins the rougher concentrate in the regrind system. The regrind cyclone overflow goes to the first cleaners. A portion of the first cleaner concentrate is considered final concentrate. The remaining first cleaner concentrate is pumped to the second and third cleaners.

The first cleaner tails flow through 10 cells of scavenger, with the scavenger concentrate joining the regrind system. Scavenger tails can join the sand-slime circuit or go directly to tailings.

All cells are operated countercurrently to reduce the volume sent to the regrind circuit and to lower the insol content. When milling a mixed oxide-sulphide ore, rougher flotation tailing is sulphidized, and the sand-slime flotation tailing is also sulphidized with NaHS.

MIBC is used as the frother. Reagents 404 and Z-6 are added as collectors through timer solenoid devices. The 404 is added to the rod mill while Z-6 is stage-added at various points. The sulphidizing reagent (NaHS) is metered by a Leeds and Northrup redox system using Pt-Ag-AgCl electrodes primarily at the sand-slime section although it can be added to a distributor when fine native copper is present.

Lime for pH control is introduced at the rod mill. There are times when chalcanthite ($CuSO_4$) is present in the ore, and the lime control must be carefully monitored so that the L & N metering system is not misled into adding too little or too much NaHS when the "natural" millivolt of the ore pulp changes.

Leach and electrolytic plant: the cross link in recovery

Widely acclaimed for its pioneering in copper hydrometallurgy, Inspiration has demonstrated a remarkable ability to adjust its vat leach plant and electrolytic tankhouse to changes in the mineral content of its orebodies. At times the modification called for near-heroic measures to rescue the system from the brink of technical obsolescence as the mineral makeup changed at various mining horizons.

Inspiration's past is dotted with personalities who quietly devised new techniques for preserving the integrity of the hydrometallurgical sections when subtle changes in ore feed characteristics became troublesome. This materials and solution handling center has built a high degree of flexibility into the copper recovery system at Inspiration. It has also made possible the recovery of metal from sub-ores that might otherwise have been bypassed.

Today the leach plant consists of 13 lead-lined leach vats, each measuring 175 ft x 67.5 ft x 18.5 ft deep, with associated bedding and reclaiming equipment. Twelve of these are in service, while the 13th is now used to stockpile straight sulphide feed for the concentrator. Another set of lead-lined concrete tanks is at an interface among the leach vats, the electrolytic tankhouse, and a series of cementation launders. This set of 10 tanks stores pregnant solution for the tankhouse and various wash water solutions from the leach vats.

The iron launders precipitate copper from weak acid wash solutions on shredded, de-tinned cans. The cementation circuit is equipped with agitators to redissolve some of the cement copper for "sweetening" the pregnant tankhouse electrolyte when the oxide content of the leach ores is too low to sustain satisfactory copper content. There is also a flotation system for upgrading an 80% cement copper to 97% or 98.5% if desired.

The 140-cell electrolytic tankhouse is sectioned so that 24 cells electrowin copper from pregnant leach solution, 96 cells electrorefine copper from the unusually large 1,200-lb anodes cast at the smelter, and 18 cells make starter sheets for both electrowinning and electrorefining.

The original leach system

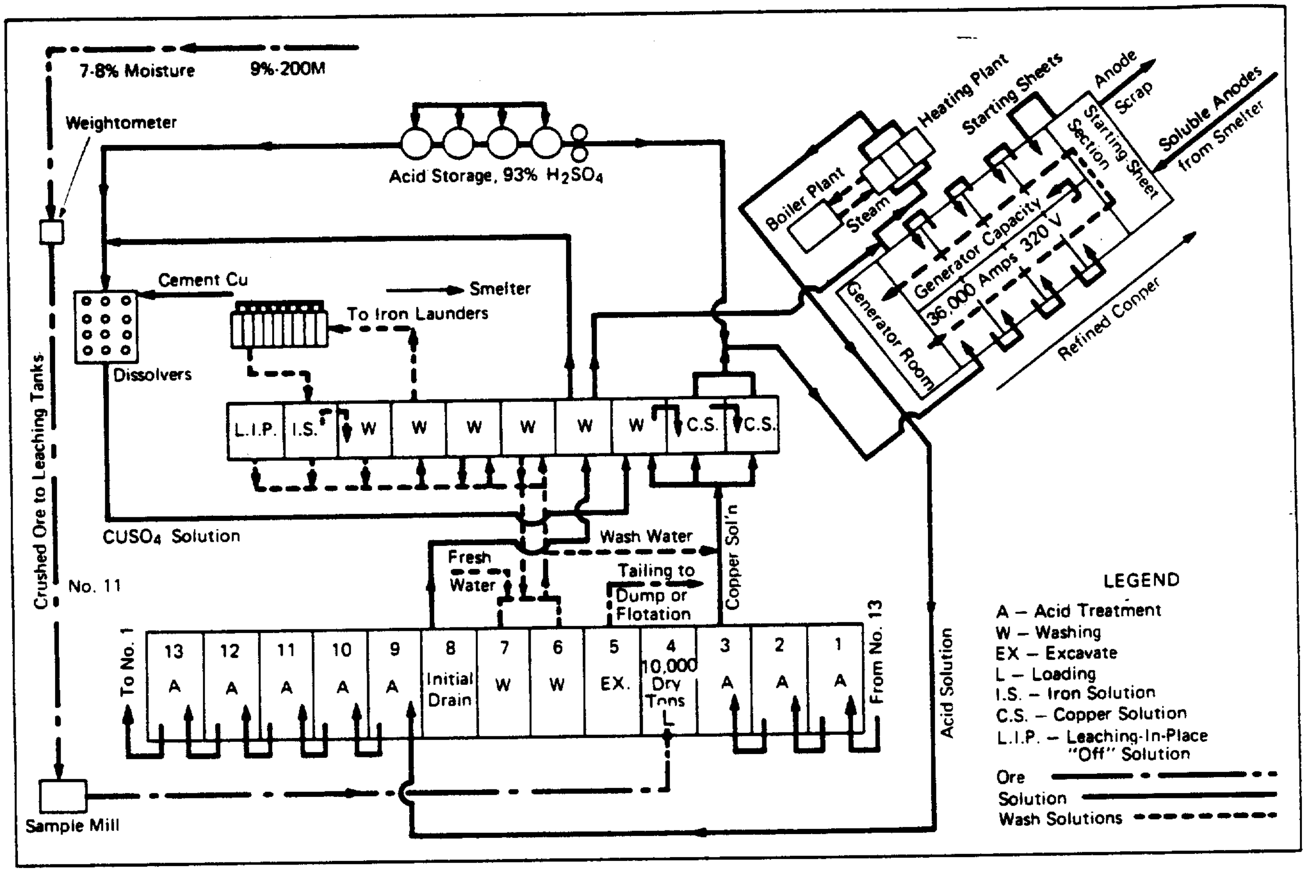
To a casual observer, the current Inspiration facilities probably do not look much different than when they were first installed in 1926. The tankhouse did burn in 1944 and was replaced. In 1960, an 80-cell addition was made to the tankhouse. But there has been a marked change in treatment. The original, "classic" acid ferric sulphate leach on which the plant was started has been abandoned. This leaching system handled mixed oxide and sulphide ores so well that the flotation plant was closed. Most of the sulphide ore fraction at that time was composed of chalcocite, and the ferric sulphate-rich solutions were capable of taking the copper into solution.

The plant was initially designed to treat 7,500 tpd of mixed 1.2% copper—60% as oxide and 40% as sulphide—from block caving. With small modifications, it was later able to handle up to 9,600 tpd of 1% copper in a reversed sulphide-oxide ratio of 60% to 40%. One of the early improvements was the addition of a desliming section in the crushing plant to improve percolation of leach and wash solutions through the bed of ore in the vats.

Later, as the sulphide content continued to increase, it became apparent that a problem existed with the ferric sulphate balance. Chalcocite is attacked by ferric sulphate in an acid solution. Ferrous iron was supplied to the system by the iron launders, but oxidation of the sulphate salt to the ferric state

General arrangement, leaching cementation and electrolytic plant, Inspiration Consolidated Copper Co.

(Solution flow illustrative for ferric sulphate leach, and not for dual process and leach and discard system in use in 1974.)



is related in terms of time and capacity to the electrodeposition of copper on the cathodes when stoichiometric amounts of oxygen are theoretically released at the anode. As the sulphide content of the feed increased, it became apparent that this locked electrolytic cycle could result in insufficient copper in the pregnant solution for regeneration of ample ferric sulphate.

Leach plant and electrolytic data, Inspiration Consolidated Copper Co.

	Feed rate, tpd	% Cu oxide	% Cu sulphide	% Total Cu
Leaching				
Dual ore	7,200	0.3	0.4	0.7
Leach and discard	6,800	0.5	0.2	0.7

	Cu conc., gm/liter	H_2SO_4, gm/liter	Fe++, gm/liter	Fe+++, gm/liter
Pregnant solution to tankhouse	25-30	15-20	3.8	0.7
Spent solution from tankhouse	23-28	16-21	2.8	1.7

Solution assays on and off leach plant iron launder system:

	Gm/liter On	Gm/liter Off
Cu	3.2	0.05
H_2SO_4	2.0	Nil
Fe++	6.4	9.9
Fe+++	0.2	Nil

This prompted the installation of agitators in the cementation circuit to leach cement copper and thereby increase the concentration of copper reporting to electrowinning. At the time, about 20% of the copper input to leaching was recovered by cementation. The 15 dissolvers were especially designed to provide intense agitation under extremely oxidizing conditions. Each contains a rotor similar to a Fagergren flotation machine in 6-ft-dia tanks 12 ft high.

Dual process yields a refinery bonus

When block caving was phased out in favor of open-pit mining during the period 1948-54, it was known that the chalcopyrite content of mined ore would increase. Once more the hydrometallurgy had to undergo an overhaul in manipulation because chalcopyrite is insoluble in an acid ferric sulphate leach. In 1957 the current dual process system of a straight acid leach followed by flotation of the leached residue was adopted. This necessitated rehabilitation of the concentrator—a $6 million program. Until adoption of the dual process leach, the entire capacity of the electrolytic plant was directed to electrowinning. The dual process system produced some spectacular results at the electrolytic tankhouse.

Current efficiency improved in electrowinning because copper precipitation on the cathodes was unslowed by redissolution of metallic copper by ferric sulphate. The diminished copper load reporting to electrowinning created surplus tankhouse capacity. This was soon filled when Inspiration installed an anode casting wheel at the smelter, then operated by International Smelting and Refining Co. The switch of surplus tankhouse capacity to electrorefining permitted the use of higher current density with greater current efficiency than possible in electrowinning. Output of cathode copper surged from 29,500 tpy to 45,000 tpy within three years of the changeover to the dual process.

Evolution is still going on at Inspiration. With the opening of more surface ore in the various area mines, the proportion of high oxide, low sulphide ore has been increasing. The opportunity for selectively mining various ore types also contributed to this trend. Today, the vat leaching system is now split between dual process ores and the "leach and discard ores"—mainly oxides with only minor or trace amounts of copper sulphides.

At present about 30% of the copper recovered in this leaching system is in electrowon cathodes, and 70% shows up as cement copper. The ore crushing schedule directs about 50% of the mine feed directly to the concentrator (high sulphide, low oxide): less than 30% is dual process ore (mixed oxide-sulphide); and more than 20% is leach and discard. Representative feed tonnages amount to about 7,200 tpd dual ore and 6,800 tpd to leach and discard. Tankhouse cathode output is now up to 74,000 tpy, as the production dividend from switching cells from electrowinning to electrorefining continues.

Tankhouse data

	Electrowinning	Electrorefining	Starters
Concentrate(gm/liter)			
Cu	25-30	50-55	35.0
H_2SO_4	15-20	200	160
Fe^{+++}	0.7-1.7	-	Nil
Total Fe	4.5	0.75	0.40
Current			
Amps	36,000	42,000	36,000
Amps/sq ft	14.0	23.5*	18.0
Current efficiency (%)	68	90	96
Anodes			
Life (days)	10 (years)	27	31
Size (length, width, thickness; in.)	44 x 42 x ½	42½ x 38½ x 2¼	46 x 42½ x 2¼
Cathodes			
Dimensions, in.	42 x 44	42 x 44	42 x 44
Weight (final), lb	120	225	15
Replaced after (days)	5	7	1

*This figure applies to the new refinery; the old section current density is 20.7 amps per sq ft.

The cycle: four-day leach, two-day wash

The lead lining of the leach vats is protected against sagging by a timber curtain, consisting of a series of vertical posts backed by 2-in. horizontal planking. The posts are butted into the floor and snubbed against the inside walls of the tanks. The tanks are equipped with a false timber bottom above the lead-lined concrete. Serving as a filter floor, this false bottom consists of 2-in. planks drilled with fifteen ⅜-in. holes per sq ft. Overlying this floor is a series of 4 x 6-in. timbers spaced on 4-ft centers and extending parallel to the long dimension. They protect the filter floor during excavation of residue by the mechanical digging equipment. Each tank will accept about 10,500 tons of deslimed minus ⅜-in. feed.

Fresh ore is bedded in an empty vat from a tripper conveyor on a loading bridge which spans the tank. The bridge travels on rails over the line of 13 vats. The tripper on the bridge automatically reverses when it reaches the endwall of a vat and at the same time the bridge moves forward 2½ ft until it reaches a sidewall. In this manner the charge is introduced in a series of rows about 3 ft thick until the tank is filled.

Solutions enter the vat through a 14-in. lead pipe which taps the tank below the filter floor at an endwall. The concrete floor slopes to the center and toward the endwall containing this pipe. To arrange the tanks in series for leaching and washing, an overflow launder is located at the vat endwall opposite the solution entry pipe. These launders are connected to the suction side of a pump system serving a downstream vat. The valving and piping system allows overflow solution to return on itself through the bottom entry for extended leach or wash periods. Solution can also be drained from the vat through the bottom entry.

Roughly half the vats are loaded with dual process ore, and the remainder handle leach and discard material. The distribution depends on availability of leach and discard material. The leach cycle for each ore is similar and consumes about nine days, including about three days for filling, digging and repairing the vat.

The leach time amounts to about four days, and two days are required to complete the washing cycle. In each circuit the valving and solution distribution system is normally adjusted to provide a countercurrent flow of leach and wash waters. In other words, a freshly filled vat is covered with weak acid solution that has moved downstream in the leach series. Strong acid, return electrolyte (adjusted by bleed or make-up at the holding tanks) covers the oldest vat in the leach cycle. This is the vat next scheduled for washing. The vats are normally covered by upward percolation.

Following a series of washes to remove traces of copper, the vat is drained and excavated. A Link Belt mechanical bucket wheel excavator, mounted on a bridge crane, digs dual process ore at a rate up to 1,800 tph. It discharges to a six-belt, 48-in. wide overland conveyor, 6,300 ft long, which terminates at the concentrator. Leach and discard residue is dug by a 17-yd clamshell suspended from another traveling bridge. This unit empties to 35-ton haulers which transport the leached material to a dump.

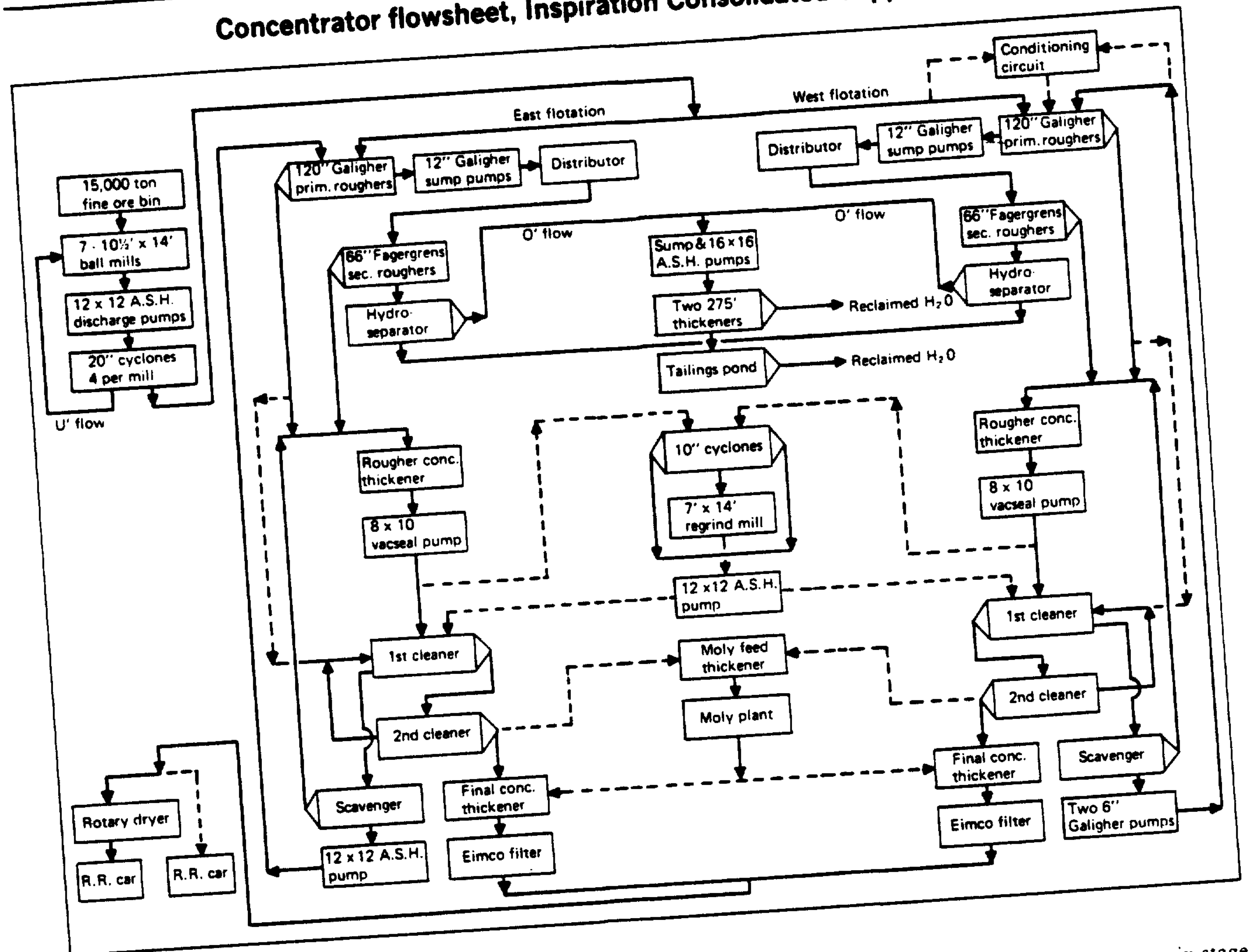
Concentrator: treats mined sulphides . . . scavenges leached ore

Perhaps the most notable feature of Inspiration's current 20,000 dry tpd concentrator is its two identical circuits downstream from grinding. They permit controlled commercial scale testing of the metallurgical response of ore to new ideas in one circuit, against a standard in the other circuit. Other noteworthy features include an air blast system for shaking down hangups in the fine ore bin and a slimes treatment section that handles fines washed from dual process ores at the tertiary crushing plant.

For students of modern nonferrous milling, however, Inspiration's concentrator is immersed in nostalgia. The original plant, built in 1915 and started in 1917 at 18,000 tpd, was the biggest in the world at that time and was the first large-scale operation designed to use ball mills for grinding and the first to employ flotation for recovery (the Callow cell). After closure of the plant from 1930 to 1957 because of changing ore characteristics, the current flowsheet was retrofitted to that 1915 building shell.

Today the concentrator diets on minus ⅜-in. feed composed of approximately 50% direct milling high sulphide ore; the remainder is dual process (mixed oxide-sulphide) ore from which all but minor amounts of the oxides have been recovered by vat leaching. The direct milling sulphide ore is mineralized predominantly by chalcocite, with minute quan-

Concentrator flowsheet, Inspiration Consolidated Copper Co.



tities of other sulphides. It also carries minor amounts of copper oxides that are uneconomical to leach. The dual process ore contains mostly chalcocite and minor quantities of chalcopyrite, with very little pyrite. The dual ore, deslimed by washing before it enters the vat leaching plant, arrives at the mill at a pH of 3.5 to 4.0.

Both types of ore are delivered to the mill by a six-stage, 48-in.-wide overland conveyor, 6,300 ft long. The ore is spread by a semi-manually controlled tripper along a 300-ft-long suspended catenary fine ore bin of 15,000-ton capacity. The ore is drawn from the bottom of the bin by twenty-one 60-in. feeder belts and each of the seven ball mills is served from three draw points. For each mill, feeder belts load a 20-in.-wide collector conveyor which discharges to a 24-in. inclined feed belt. The ore is weighed in transit on the feed belt by a Transweigh belt scale and is remotely recorded on a daily chart and a totalizer.

Both wet dual ore and the dry direct-milling ore are interbedded in the catenary bin. At times this mixture becomes quite sticky, causing the feed to chimney from the draw points, with hangups of ore in the bin at abnormally high angles of repose. These hangups were formerly knocked down by water lancing, but excessive use of water resulted in mud runs to the belt floor below. To free the ore, several ideas were proposed. Finally a 30-day trial with a Long-Airdox air blast system installed on bin segments serving two ball mills produced results justifying a permanent system over the entire bin.

Installed in 1971, the Long-Airdox system uses a six-stage compressor that can develop air pressure to 12,000 psi. High pressure air at 6,000 psi is discharged into the bin through nozzles in a series of piston-controlled, high strength alloy steel cartridges. The system between the compressor and the discharge cartridge consists of a receiver, steel tubing to move air from the receiver to the cartridge, and valves to control the loading and discharging of each cartridge. The concussive force from a discharging cartridge is similar to the explosion of half a stick of dynamite. Each of the 21 draw points has two cartridges, called "shotguns," and each shotgun has its own control valve.

As a result of the air blast system, live storage was increased from a minimum of 4 hr, or 3,500 tons, to a maximum of 10 hr and 8,500 tons. The added live capacity was translated into increased throughput at the concentrator and smoothed the overall scheduling of ores through the crusher and leaching plant.

The seven ball mills are 10½ x 14-ft, grate discharge, trunion overflow Allis Chalmers units driven by 1,070-hp GE motors. The mills turn at 18.76 rpm with a ball load of 142,000 lb. Steel balls, 2½-in. in diameter, are added daily to each ball mill at the rate of 1 lb per ton of ore ground. Each mill can grind approximately 3,000 dry tpd, and the final flotation feed is controlled to 8% plus 48 mesh.

The discharged pulp of each mill is pumped to a cluster of four 20-in. Krebs cyclones by a 12 x 12-in. Allen Sherman Hoff rubber-lined, variable drive Hydroseal pump. The cyclones have 7½-in. vortexes and 3-in. apexes. The overflow is flotation feed and the underflow returns to the ball mill.

Alkalinity of the flotation feed is maintained automatically at the ball mill using Minneapolis Honeywell III recorders and controllers which have a pH range of 6 to 13. The pH probe signals are amplified for the recorder-controllers.

Twin flotation circuits allow controlled testing

Flotation is divided between east and west side circuits, with each receiving half the feed. Each section contains a primary rougher row of six Galigher 120-in. flotation cells, easily capable of 10,000 tpd and, by crowding, up to 12,000 tpd. Top speed of the impellers is 1,160 fpm and froth depth is normally maintained at 8 to 10 in. Tails from each primary rougher row are pumped to a secondary distributor which feeds seven rows of No. 66 Fagergren cells. Each row contains 12 cells. Cyclone overflow from grinding can bypass the flotation primaries if necessary. Top speed of the Fagergren secondary flotation is 1,460 fpm.

Minerec 898 collector is added ahead of the primary and secondary roughers at a rate of approximately 0.03 lb per ton of ore. The frother is a mixture of MIBC-UCON 65 in a 75:25 ratio. Consumption is approximately 0.0466 lb per ton of feed.

A handy feature of the two identical flotation sections is that plant-wide tests of reagents or processes can be easily performed by experimenting on one side while using the other as a standard.

Four rows of Agitair flotation cells, grouped as a unit, have been divided so that east side and west side roughers and secondaries have their own cleaners and recleaners. Each flotation circuit is also followed downstream with its own rougher concentrate thickener, final concentrate thickener, and final concentrate filter. The cleaner scavenger tails are pumped back to the head of each respective primary rougher.

Past practice has been to regrind the rougher concentrates in a 7½ x 14-ft Allis-Chalmers overflow mill in closed circuit with two 10-in. Krebs cyclones. Tests are now underway, however, to determine the necessity of this step by using the regrind mill for only one side of the flotation process. The concentrates from the scavengers are directed to the rougher concentrate thickeners, where they are recombined with the rougher concentrate from the respective sides.

The mill is equipped with a molybdenum flotation circuit that operates periodically to pull a moly concentrate from copper concentrate when values warrant recovery. Otherwise, the final copper concentrate is sent to 80-ft thickeners, then filtered in one of two 6-ft, eight-disc Eimco filters. The filter cake ranges from 20% to 25% moisture and is fed to a 5½-ft-dia, gas or oil-fired rotary kiln, 24 ft long. Feed end air temperature is 1,200°F and the discharge air temperature is 400°F. Dried concentrate, at 10% moisture, is belt conveyed at 160°F into a railroad car for delivery to the smelter. A fringe benefit of the dryer is a balling or pelletizing action which takes place while the moisture is being removed.

How tailing is handled

Concentrator tailings from the secondary roughers are sent to hydroseparators, where the sands are dropped at about 59% solids and fed to the tailings line. Hydroseparator overflow is directed to a sump, where it is pumped to one of two 275-ft thickeners. The thickener overflow is clean reclaimed water recovered at approximately 235 gal per ton of ore ground. This water is recycled to the ball mills. Underflow of the tailing thickeners, at 50% solids, is sent back to the concentrator, where it recombines with the hydroseparator underflow on its way to the tailings dam.

Active tailing disposal is handled through a 24-in. Transite pipe manifold on the perimeter of a dam. This pressurized line is tapped by valved 3-in. feeder pipes on approximate 30-ft centers which empty to the pond side of the berm of the dam. As the tailing is discharged over the berm, the sand portion drops out immediately and the slimes flow toward a decant chimney centrally located within the pond. Clean water reaching the chimney is recovered at the rate of 100 gal per ton, and is subsequently pumped back to the mill. When a dam is filled to a 5-ft depth, tailing is diverted to another dam while the inactive dam is dried and raised another 5 ft by using a ¾-yd dragline.

Slimes treated by flotation and acid leach

An additional section of the concentrator treats slimes which are removed from dual process ore before it is bedded in Inspiration's vat leaching plant. These slimes are treated for sulphide flotation in two rows of 12-cell Fagergren 66-in. roughers. The rougher concentrate is then sent to two rows of three-cell Fagergren primary cleaners, followed by a two-cell row of Fagergren secondary cleaners. The cleaner tails are pumped back to the slimes rougher feed, while the cleaner concentrates join the mill concentrates in the moly plant.

The tails from the rougher flotation rows are sent to a 200-ft thickener and then to one of three storage tanks serving a leach and wash system for recovery of copper oxides. Pulp is fed from the storage tanks into three agitators, connected in series. Concentrated sulphuric acid is added to the slurry before it reaches the first of three agitators.

The discharge of the third agitator flows to the first of four countercurrent decantation (CCD) 150-ft thickeners, where the pulp is washed and the pregnant copper solution is decanted off. The underflow of the first thickener advances successively through a second, third, and fourth thickener while the overflow moves from the fourth to the third, second, and first thickener.

Pregnant copper solution, overflowing the first thickener, flows to iron launders where cement copper is recovered. The iron launder off-solution is returned to the fourth thickener as wash solution. The underflow from the fourth thickener is sent to special tailings dams where the iron contaminated water is controlled and allowed to evaporate to avoid stream pollution.

Rod plant: downstream integration with a fabricated product

Possibly one of the most fundamental steps taken by Inspiration was the decision to fully integrate its production from rock to copper rod. With the establishment of a continuous melting, casting, and rolling (CMCR) plant in 1969, near Miami, Ariz., this colorful "little" copper producer became the first in the US to adopt a sophisticated fabrication system using the Asarco continuous melting furnace and Southwire Continuous Rod (SCR) process. This move was also significant in that it made Inspiration the first US primary copper producer with a mine-site copper rod capability.

Inspiration's CMCR plant had a briefly troubled start but soon settled into a modest single-shift, five-day production pattern. Today it operates continuously during three shifts on a five-day work week, producing approximately 10 million lb of 5/16-in. copper rod a month with a crew of 55 men (including the metallurgist, technicians, and plant management).

Located 3 mi from the electrolytic tankhouse, the CMCR plant receives bundled 42 x 44-in. copper cathodes delivered by rail. The bundles, each averaging about 4,000 lb, are removed from the rail cars by a forklift truck and placed on a slat conveyor which can store five bundles. Under a timed, automatic sequence, the slat conveyor delivers a single cathode bundle to a short conveyor suspended from a 5-ton hoist. As the cathodes are automatically raised 23 ft above the plant floor, the conveyor rotates 90° to feed a bundle to the Asarco shaft furnace. A closed circuit television system allows an operator to observe the charge level in the melting furnace and adjust the conveyor and elevator time cycles accordingly.

This furnace, a patented design of American Smelting and Refining Co., is ideally suited for the feed end of a continuous rod plant. It contains a sloped hearth and thus has no molten bath of metal. The furnace can be started cold and begin melting copper within an hour. The flow of copper from the hearth can be stopped within 3 min, and a hot furnace can start supplying molten copper almost instantaneously.

The melting rate of the furnace is easily controlled by adjustment of the firing rate. A high fuel efficiency is gained through countercurrent flow of metal and gases in the shaft. The silicon carbide lining of the Asarco furnace has demonstrated an excellent resistance to the thermal shock to which the unit is frequently subjected. Rated at 22 tph, the melting unit at Inspiration is fired from natural gas introduced through 15 burners arranged in two rows. The gas-to-air ratio at the burners is set to maintain a slightly reducing atmosphere in the furnace. The combustion air is preheated to about 600°F.

As copper melts, it runs down the sloped hearth into a 16-ft-long fired launder which conducts the melt to a tilted Lindberg, 15-ton-capacity holding furnace. The gas-air mixture at the launder is controlled to hold the desired oxygen level in the copper. The cylindrical holding furnace provides surge capacity for an 84-in.-dia vertical casting wheel. The rate of flow from the furnace is controlled by rotation of the unit about an eccentric axis.

Copper flowing from the holding furnace is carried by a 24-ft fired launder to a closed tundish (pot) which holds the melt temperature at about 2,040°F. The tundish empties to a grooved casting wheel through a small spout equipped with a metering pin that modulates the flow.

The grooved rim of the rotating casting wheel has an inner trapezoidal, cross-sectional area of 4 sq in. It is wrapped along 239° of its circumference with an "endless" flat steel band which is returned to the tundish feed point around a set of rollers (see diagram). Water sprayed on the inner rim of the wheel a[illegible] the surface of the steel band at controlled rates cools and solidifies the molten copper. The copper bar leaves the wheel at about 1,800°F and passes over a powered roller conveyor into a pinch roll and through a rotary shear. The shear crops 3-ft-long segments if there is a maladjustment in the feed alignment to the rolling mill. Cropped bars drop to a slat conveyor and are collected in tote bins for recycle to the melting furnace.

Before rolling, the bar is conditioned by pneumatically operated cutters which remove ragged edges. Wire brushes remove loose cuttings and scale from the four sides of the bar. The rolling train, made by Morgan Construction Co., consists of three mills. The first two are breakdown or rougher stands with 12-in. rolls. The finishing mill contains 10 stands of 8-in. rolls. The roll pass schedule employs alternating oval and round sequences for hot working of the copper.

Soluble oil coolant is sprayed directly on roll grooves in the mill. A low pressure fog spray in the Morgan stands helps minimize corrosion of the hot rod. The cast bar from the casting wheel enters the rolling mill at about 40 fpm and exits at its finished 5/16-in. diameter at roughly 2,000 fpm. This amounts to a normal production of 20 tph.

When the rod leaves the mill, it enters a tube where it is cleaned with an alkaline solution. Formerly the rod was pickled in this tube by a 2% sulphuric acid solution, but the new reagent has greatly improved quality control of surface characteristics of the rod. The quench in the cleaning solution lasts about 1 sec. The rod is then rinsed with water and sprayed with a protective wax coating.

Finished rod leaving the continuous line enters a programmed coiling system which loops it on pallets in maximum 72-in.-dia and minimum 36-in. bundles. Endless coils are built up to 20,000 lb, although customer handling capacity is the only limitation on weight. Most coils weigh between 10,000 and 15,000 lb. When the desired coil weight is collected on the pallet, the rod is cut and a set of fins collect the loops temporarily while the full pallet is automatically moved from the collection over a set of rollers. Just as soon as an empty pallet is positioned in the receiver space, the fins open, dropping the rod gathered during the changeover. Finished coils are weighed and loaded on trucks or in freight cars by forklifts for shipment.

A quality control laboratory is maintained to run physical tests, including electrical conductivity, elongation, tensile strength, spring elongation, recrystallization temperature, and twist tests. In addition, the product is sampled to determine the oxygen and sulphur content, plus complete spectrochemical analyses.

"Inspirod" produced at the CMCR plant in Arizona represents one more benchmark in Inspiration's history. □

Continuous melting, casting and rolling system, Inspiration Consolidated Copper Co.