Improved flow measurement
and control are key to efficiency

by Alena Johnson

Much of the copper being produced today uses heap leaching, where pure metal is extracted from the ore with a chemical process rather than smelting. This technique is deployed extensively in major copper producing areas including Chile, Peru and the southwestern United States.

Copper ore is excavated from the ground, crushed and then spread in uniform layers on a pad. A slow trickle of sulfuric acid is distributed over the pile, where it percolates to the bottom and a collection point. The acid leaches out the copper, along with other minerals, which can be extracted chemically. This process can be used at large sites producing 100 kt/a (110,000 stpy) and greater.

Production on a massive scale

Production at heap-leach sites is continuous and can operate on an enormous scale. The ore is fed into a crusher to break down the large pieces, and then it moves into an agglomerator to capture the fines and create more uniform particles. While in the agglomerator, the ore is mixed with acid for the first time, helping it to bind the fines into larger particles and starting the leaching process. The treated ore moves by conveyors to a stacker designed to spread it uniformly on the pad.

The size of the operation comes into perspective by considering a typical pad measures 1.6-km (1-mile) long and 0.8-km (0.5-miles) wide. Working day after day, the stacker creates individual piles or modules on the pad, each 122 x 61 m (400 by 200 ft) and 3 m (10 ft) deep. When one module is filled, it moves across the pad to the next, filling the area in one continuous pile. A completed row of modules spanning the width of the pad is a cell. Once the entire pad is covered, the process begins again laying down another 3-m (10-ft) layer, and it continues until the entire pad reaches its height limit which can be several hundred feet.

Once a new module is completed, technicians lay a network of plastic pipes over the surface in a pattern similar to agricultural drip irrigation installations. The diluted sulfuric acid, called raffinate, is pumped through the pipes so it can be distributed over the module, allowing the acid to soak through the ore and leach out copper as it percolates to the bottom. At the same time, approximately 35 to 45 percent of the acid is consumed by dissolving the calcite carrying the metal in the process. The raffinate reaching the bottom is now characterized as pregnant-leach solution (PLS) since it carries the copper the company is seeking to recover.

A continuous chemical process

The PLS is pumped into a storage pond and on to a solvent extraction process, where it is mixed with a hydrocarbon solution. The copper is chemically pulled into the hydrocarbon solution, separating it from the dissolved calcite. The process is then reversed using a new aqueous solution to pull the copper out of the hydrocarbon. This leaves behind undesired metals such as iron and other contaminants. This enriched electrolyte now has about 40 grams of copper per liter of solution, which can be electroplated onto a cathode as 99.999 percent pure copper. This approach eliminates the traditional smelting process.

This extraction process uses a series of interconnected fluid loops moving from stage to stage as all the chemicals are regenerated and used again. Keeping the flow constant and balanced in all sections is critical to cost-effective operation.

Distribution across millions of square feet

While the process itself is straightforward, getting it to work efficiently on such a large scale is easier said than done. The biggest challenge is getting the raffinate distributed uniformly over the entire ore bed, which can approach 929 Mm^3 (10 million sq ft). Ideally, the flow should be a constant trickle of 0.002 gpm/sq ft, spread evenly edge-to-edge over the enormous surface.

Theoretically, the drip irrigation system can provide the necessary uniformity, but only when the flow to each segment is nearly perfect. The problem most processors face is figuring out how much raffinate is being sent to each module. Adding instrumentation is a challenge, since everything installed on the surface has to be moveable.

The raffinate distribution is critical to efficiency. If it hits one area heavily, it will quickly leach out the copper, and then the rest of the raffinate will simply sink and be wasted on the layers of

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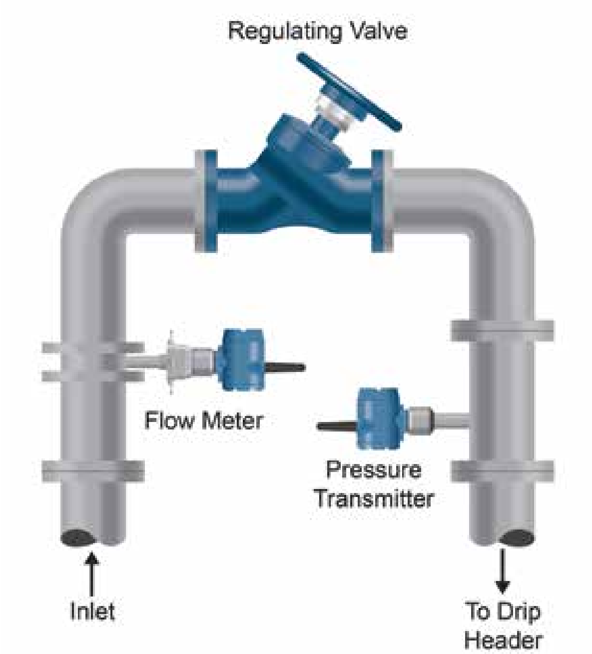
Figure 1

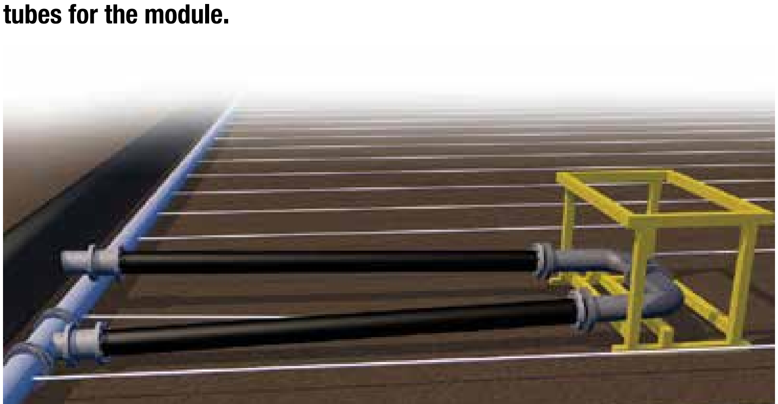
Each skid has a DP flow meter that can also measure incoming pressure, a manual regulating valve and a pressure transmitter after the valve. The U-shape works well with the header piping arrangement. Operators have to adjust the regulating valve by hand, but they can read the resulting values on the instrument displays along with the control room.



spent calcite. Eventually this flooding causes porosity and destabilizes the pile. Other areas with inadequate coverage will leave behind unrecovered copper. Hitting some average value where there are still highs and lows does not help. Effective, efficient and complete copper extraction depends on even distribution, one square foot at a time.

Figure 2

Each module has its own skid, so the complete pad needs 144 to cover. As this illustration shows, it is placed on top of the pile, often set right on top of the drip tubes. It connects the 25 cm (10-in.) raffinate supply pipe feeding the cell to the 10 cm (4-in.) header pipe supporting the drip tubes for the module.



Most sites try to balance the distribution manually, using operators walking the pile watching for flooded and dry spots. They move from module to module, tweaking flow-control valves and evaluating the flow visually. Since regenerated raffinate is fed to the entire pad from one enormous pipe, changes in one area affect the entire system, so by the time the operators reach one end, they have to start again, evening out all the earlier changes. Having operators walking around on an acid-soaked pile more than 31 m (100 ft) above the ground presents serious safety issues since the edges are often prone to landslides.

Monitoring for each module

At one heap leaching site, a team of engineers trying to improve efficiency concluded the most practical approach would be to control distribution module by module, which worked with the existing piping setup. Each row of modules received its raffinate supply through a 25-cm (10-in.) pipe, which is reduced to a 10-cm (4-in.) pipe serving as a header to the individual drip tubes. The strategy called for monitoring and controlling liquid flow at the point where it feeds the individual module using a portable instrumentation skid, but no existing design was available. Something new would have to be created, and the company brought the challenge to Emerson.

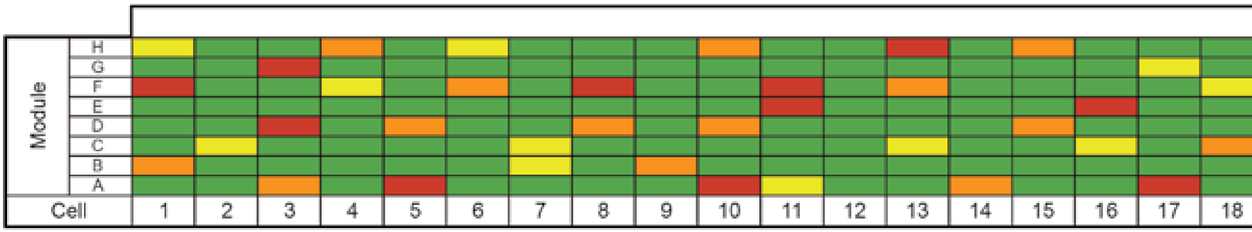
The working parameters presented to Emerson were not very complex, but they were detailed and demanding:

- Each skid unit must be interchangeable and modular, able to measure and control flow to one module on the larger pile.
- Functionally, the system must a) report incoming pressure, b) regulate pressure to the drip tubes, c) monitor and report flow to the drip tubes.
- The system must be self-powered and send its data using a wireless network — no cabling is possible.
- Each skid unit must be small and light enough for two operators to pick it up and place it on the back of one of the plant's ATVs. Nothing will be mounted permanently.
- All materials used in construction must be able to stand up to the elements year-round, plus constant exposure to diluted sulfuric acid.

None of these points individually presented a major technical challenge, but given the scale of the operation, everything had to be finalized before the units went into mass production.

Figure 3

Data from the skids are displayed using color coding to indicate the status of each module. Operators performing rounds know exactly which modules need attention. This illustration shows all 144 modules in use, but under normal operation, the modules being actively filled would be blanked out.



After some discussion, the practical basic design (Fig. 1) emerged:

- Each unit is built into an fiberglass reinforced polyester (FRP) frame to support the components, provide a base and allow stacking.
- There are three main components: an incoming differential pressure (DP) flowmeter, a pressure regulation valve and a pressure instrument to confirm accurate pressure to the drip lines.
- The components are arranged to allow easy access to the parts, and sufficient lengths of straight pipe for the flowmeter.
- All wetted and exposed components are made from stainless steel, FRP or a suitable polymer able to survive the environment.
- With a total weight of less than 54 kg (120 lbs), a skid is easy to load and carry on an ATV.
- While built close to the ground, the position of the flowmeter's antenna supports positive communication via the WirelessHART network from anywhere on the pile.

Data to inform operational decisions

Once the skid units started going into operation (Fig. 2), the plant quickly realized its biggest product had become data. With every unit sending its reports, there were more than 1.2 million data points created daily. Fortunately, part of the planning involved designing how this fire hose of data would be organized.

Using the existing module divisions on the pad, each module was assigned a specific skid number, and these were laid out within the control system. An accompanying HMI was designed to provide a visual map to indicate how even the flow was across the pad. With color-coded designations (Fig. 3), operators could tell at a glance which modules were dry, flooded or just right.

As time went on, the plant built up enough historical data to perform sophisticated analysis. The company created a quality score system based on an ideal pressure target using very strict performance expectations. A deviation of 0.05 psi from the ideal value at the skid causes a 1 percent score deduction. With so tight a measure, the plant thought it would be an accomplishment to run at better than 80 percent across the site. After using the new system for a few months, they routinely scored higher than 87 percent.

When spot deviations do occur, they are typically the result of clogging, a burst line or some other problem with the piping. With the new system, these issues can be spotted immediately and addressed. Previously, an operator would have to see the problem during rounds, assuming it was severe enough to be spotted. Now, any deviation from the ideal flow and pressure combination, which might be caused by a single drip tube being clogged or raffinate gushing out of a break, can be detected and reported as soon as it happens. Operators do not need to spend nearly as much time walking around on the pile.

Developing greater efficiency

The ability to operate an effective and economical heap leaching process depends on recovering the most product at the least cost. In leaching terms, this means using the lowest amount of acid distributed as uniformly as possible across the ore bed. Controlling and managing the distribution depends on effective instrumentation, as illustrated in this situation.

While the cost of producing and installing all those flow control skids was substantial, the payback provided by increased production over the working life of the site, along with all the less-measurable benefits, was more than enough to result in a return on investment of less than a year. The company has repeated the program at its other facilities and realized similar benefits. Moreover, when this pad ceases operation, the skids and other raffinate distribution equipment can simply be moved to the next site, at the same mine or another, extending its useful life. ■