Andy Pearson

Working at the Extremes

BY ANDY PEARSON, PH.D., C.ENG., FELLOW ASHRAE

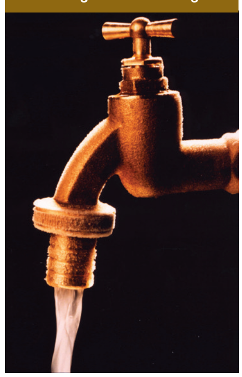
Of all precious metals, gold is the king. Others may be less common or more expensive but gold captures the imagination like no other. It is remarkably commonplace, albeit in very small quantities, being used in printed circuits, electrical contacts, dental implants and sun visors as well as jewelry and coinage. Despite this widespread usage there is remarkably little of it in the world, with the total output ever produced throughout history estimated to be equivalent to a cube of 82 ft (25 m) on each side. Annual gold production would be a cube of 14 ft (4.3 m) on each side; about the size of my office.

It is highly valued because of its non-corrosive nature and high electrical conductivity as well as its lustrous appearance and ability to be worked into beautiful shapes and exceptionally thin films. As a result we go to great lengths (and depths) to find it. The 10 deepest mines in the world, up to 13,120 ft (4,000 m) deep, are all gold mines, and seven of them are in South Africa.

Mining at these extreme depths presents huge technical challenges, not least in keeping the working environment viable for the miners. The geothermal heat in the rocks can reach 140°F (60°C) and so it is impossible to cool the ventilation air sufficiently to compensate for this. In addition the pressurization effect of the depth also heats the air by up to 29° (16 K) and moisture absorption in the hot air raises the wet-bulb temperature to lethal levels above 95°F (35°C). At these temperatures, sweating doesn't work and the body gains heat from the surroundings, rather than losing it.

It is therefore necessary to provide cooling at depth, with multi-thousand ton (multi MW) chillers including fully resilient standby systems to ensure security of cooling supply. Chillers need to fit into very compact spaces and typically centrifugal compressors with R-134a have been used for this application below ground with R-134a centrifugal or ammonia screw compressors augmenting the cooling at ground level. Surface-based chillers can provide cooling down to about 6,500 ft (2000 m) by blowing cold air down the shaft but for deeper mines other strategies are required. This usually means underground chillers, but pressures on equipment efficiency, space below ground and impending refrigerant phase-out have prompted the mining companies to look for other cooling solutions over the last 30 years.

All that glisters is not gold.



One novel solution is the use of flake ice or ice slurries to augment the cooling systems. The ice can be dropped down the shaft, providing cooling as it melts, although the pumps required to draw the meltwater back out of the mine must develop a head of 5,800 psi (400 bar) to bring the water back to the surface. In some systems the ice is made using large ammonia plants on the surface, but in others a "vacuum ice machine" uses a large centrifugal or axial compressor to lower the pressure of water to its triple point pressure of 29.75 inches of vacuum (611 Pa absolute). This causes solid micropellets of ice to form in the water, creating an unusual pumpable fluid with an apparently very high sensible heat capacity. In practice it is very difficult to pump the slurry if more than 30% of the water is frozen so the cooling capacity is significantly less than for flake ice. The future of deep mine cooling is one area where the path ahead is not clear in terms of technology choices, so more innovation is required.

I am indebted to my friend, Jim Calm, for much of the detail included in this column and I know he'd not let me forget it if I failed to tip my hat. Thanks, Jim. ■

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