Atmospheric Fogging in Underground Mine Airways

by A.D.S. Gillies and M.A. Schimmelpfennig

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M.J. McPherson

Having worked on the thermodynamics of air/liquid-water mixtures passing through the surface fans of deep mines, I find this paper of great interest and congratulate the authors on producing it. There are two matters, however, deserving discussion.

First, the authors have described the classical theory of fog formation with fogging occurring at "supersaturation." In fact, the process of fog formation begins well below 100% humidity. The more strongly hygroscopic nuclei in the atmosphere will attract water molecules and begin to grow at a relative humidity perhaps as low as 70%. The process is a dynamic one with both condensation and evaporation taking place throughout the mixture on microscopic liquid surfaces. As saturation is approached, the rate of condensation accelerates rapidly producing the familiar reduction in visibility.

Hygroscopic nuclei are present in all natural atmospheres and under the appropriate conditions of pressure and temperature, will produce clean fogs. However, if the air is polluted by particulates from combustion or other processes then the resultant coagulation with growing liquid particles may produce dense (and sometimes photochemical) smogs. It is this process that is likely to occur in underground mines when moist air is cooled below dew point.

Second, the authors have summarized very well the individual measures that might alleviate the problem. In particular, I agree that neither heating nor refrigerating the air, by themselves, provides a satisfactory solution. However, there is a combination of these that provides a neat and effective control of fog formation. This involves a small, self-contained refrigeration unit within a duct but without the usual external heat rejection facility. The air is cooled below dew point and, hence, dehumidified on passing over the cold evaporator coils. The heat from the condenser is rejected back into the air downstream from the water eliminator, as shown in Fig. 1. The duct configuration can be designed to create good mixing at the outlet.

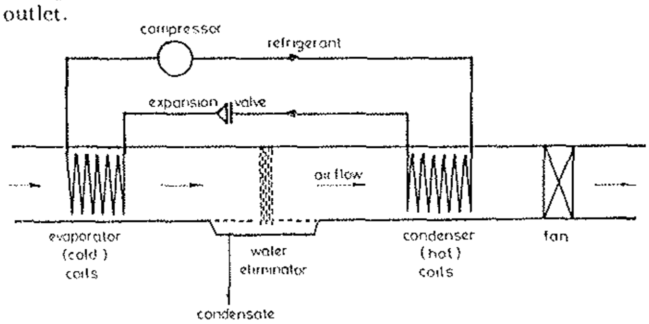

Fig. 1—Diagrammatic representation of cooler/dehumidifier/heater unit

I have used a climatic simulation program to illustrate the effect, assuming a 500-m (1,640 ft) long airway of cross section 60 m^2 (645 sq ft), an airflow of 9 m^3/s (318 cu ft per sec), inlet conditions of 19/19.25°C (66/67°F) wet bulb/dry bulb temperatures, a virgin rock temperature of 17°C (63°F) and typical rock thermal properties for a hard-rock mine. I have also assumed that 10% of the rock surface is wet. Figure 2 shows the variation in temperatures along the airway if no measures are taken. The relative humidity remains close to 100% and condensation will occur throughout the length of the airway.

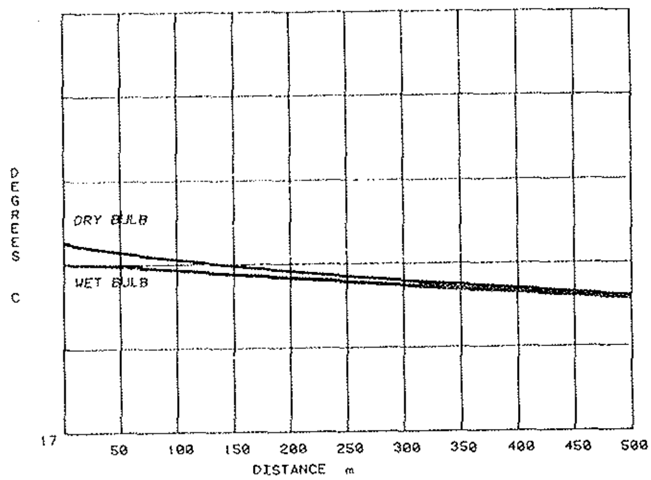

Fig. 2—Computer simulation of wet and dry bulb temperatures before the dehumidifier unit is installed (condensation throughout).

Before any such installation is designed, the exercise must, of course, be repeated for each location with accurate data. However, this example demonstrates the potential of the system. The idea is not new — the principle is sometimes used in air-conditioning plants for buildings.

Figure 3 shows the effect of removing 30 kw of heat by evaporator coils sited 40 m (131 ft) along the airway and rejecting that heat (plus another 10 kw of compressor and fan power) into the air at 60 m (197 ft). Condensate water is produced, at a rate of 0.45 L/min (0.12 gpm). The result of this sequential cooling/dehumidification/heating process is to separate the wet and dry bulb temperatures along the length of the airway. The relative humidity increases from 80% at the duct outlet to 92% at 500 m (1,640 ft). The airway is maintained free from fog.

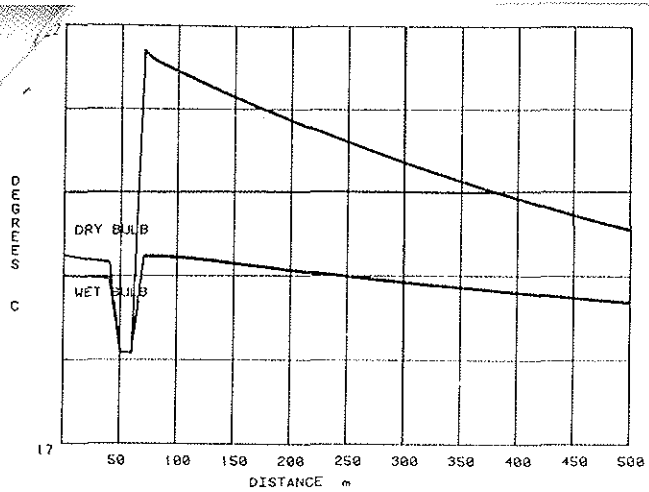

Fig. 3—Computer simulation of wet and dry bulb temperatures with dehumidifier at 40-60 m (131-197 ft). Airway is maintained free of condensation.

DISCUSSION

Copper and Its Byproducts

by M. Lonoff

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G. Campbell

The paper by M. Lonoff looks at the importance of byproduct prices on copper production. The paper develops several interesting points on this topic, but there are some points in the theoretical discussion that could use further development. A couple of these theoretical topics will be considered here using the paper's framework of assumptions without concern about how realistic the assumptions are for the copper industry.

Lonoff's theoretical model is based on a static, homogenous world where all copper/byproduct deposits are identical, and these deposits are the main source of these metals. Due to the importance of the byproducts to the production decision, the term coproducts will be substituted for the term byproducts to reflect more accurately this condition. The conclusion is drawn that a rise in coproduct prices necessitates a decrease in copper prices because copper production is increased as a consequence of increased coproduct production. The observation that real world behavior does not always follow this pattern is dismissed as "speculation."

However, it can be easily shown that within this simple framework market forces might create the observed behavior. The key question to be answered is what causes coproduct prices to rise. Three possible cases will be used as illustrations. The first case is the one implicity assumed by Lonoff. Here, the demand for coproducts increases at all prices (an outward parallel shift of the demand curve) with the demand for copper remaining constant. As reported in the paper, the results are higher coproduct prices, an increase in coproduct production, and lower copper prices due to the resulting increase in copper production. The second case is when the supply of coproducts are constrained—leading to higher market prices. Copper production, as required by the simple model, is also reduced which

Reply by M. Lonoff

Campbell's comments give me an opportunity to clarify a few points in "Copper and Its Byproducts." That paper examined the affect of byproducts on the copper market and considered the relative riskiness of multi-metal deposits from an investment standpoint. That brief note made no attempt to be exhaustive. Nevertheless, Campbell's comments miss the point of the paper and necessitate a response.

My "theoretical model" was static and I freely conceded after introducing the assumption of identical deposits that "none of the assumptions hold." These simplifying assumptions allowed me to bound the possible effects of higher byproduct prices on the copper price by assuming identical deposits and computing average price effects. I took great pains to subsequently explain that since deposits are not identical the identity of the marginal deposit might change due to byproduct price changes. In this case, average price affects will overstate the affect of byproducts on copper prices.

According to Campbell, I dismiss as speculation any "real world behavior that does not always follow this pattern" (of metals prices moving in opposite directions). In the byproducts paper I noted that gold, copper, and silver price movements often parallel each other on an intra-day or day-to-day basis. Such movements are largely due to market anticipation of or reaction to changes in interest rates that affect carrying costs of metals stocks. Other movements may be due to anticipated changes in available supply or physical requirements. I loosely grouped these effects as speculative. To distinguish this statement from the main thrust of the paper, I contined "In the long run if gold and silver prices remain high the equilibrium copper price will be lower." The paper set out long run equilibrium conditions rather than attempting to explain price movements on a daily basis or on a year-to-year basis.