

PAPRs in longwall mines is mediated by the high velocities of air customarily found there. Those velocities are not comparable to the air velocities experienced in most industry sectors nor in those represented in the studies used to determine the APF of 25, nor in the majority of studies submitted by Energy West in 1997.

The headgate and tailgate air velocities observed by MSHA at 55 longwall MMUs were reviewed in 1999. These velocities ranged from 365 to 1,645 fpm and from 200 to 1,400 fpm, respectively. More importantly, headgate velocities at 60 percent of the MMUs exceeded 500 fpm and some 18 percent exceeded 800 fpm. Approximately 55 percent of tailgate velocities exceeded 500 fpm and 11 percent exceeded 800 fpm.

Laboratory and in-mine studies (EPF studies) show that air velocity is the single biggest factor affecting the degree of respiratory protection provided by a PAPR. While important at longwall MMUs, air velocity does not significantly affect PAPR performance at non-longwall MMUs where the velocity of air provided to control methane and respirable dust is normally less than 100 fpm. There, the primary concern is the PAPR's ability to protect the miner from exposure to excessive quartz levels. Cecala, *et al.*, (1981) found protection of Racal® Airstream helmets to be inversely related to ambient air velocity in both laboratory and in-mine settings (*Ibid*). In other words, increased air velocity leads to decreased effectiveness of the PAPR.

The expected degree of workplace respiratory protection that would be provided by a properly functioning PAPR is also affected by the orientation of the helmet to the airflow. Cecala's wind tunnel tests clearly showed that, at the higher airflow rates, helmet efficiency was greatest when facing directly against the airflow and was reduced when the helmet was oriented in other directions. This is extremely important since miners are more likely to orient their heads at an angle to the airflow, or to face downwind, than to face directly into the airflow.

Cecala's in-mine testing of the PAPRs produced an EPF confirming the inverse relationship between air velocity and the level of protection provided by PAPRs shown during wind tunnel testing. Under air-velocity conditions less than 400 fpm, the Airstream helmet averaged a respirable dust reduction of 84 percent, which is equivalent to an EPF of 6.4. However, under higher air-velocity conditions (1,200 fpm), the helmet's dust reduction performance decreased significantly, averaging only

49 percent, which is equivalent to an EPF of 2. The higher face air-velocity conditions in this study best represent the higher velocities observed on longwalls. Today, the face air velocity in over 60 percent of the longwall MMUs exceed 500 fpm (MSHA, October 1999). Thus, it is critical to take into account the air velocity conditions when determining a PF for PAPRs used in underground coal mines.

Other researchers have reported that helmeted PAPR systems are vulnerable to inward leakage into the wearer's breathing zone (Howie, *et al.*, 1987; Sherwood, 1991). For example, Howie, *et al.*, found that increasing airflow velocities from approximately 400 to 800 fpm doubled the inward leakage of the helmet when the airflow impinged on the wearer's head only, and increased the leakage further when the airflow impinged on the wearer's body and head (Howie, 1987). Subsequent testing of a redesigned unit at a wind velocity of approximately 700 fpm showed decreased inward leakage, yielding a PF of 6.3. This met the target PF of 5, which was subsequently proposed by the European Community to be the standard for powered helmet respirators.

More recent studies conducted by Bhaskar, *et al.* (1994) at four western longwall MMUs indicated that, under these workplace conditions, PAPRs had an average dust reduction efficiency of 83.8 percent (*Ibid.*). Although a different sampling procedure was employed, this result is consistent with the performance (average value of 84 percent) obtained by Cecala, *et al.*, under air-velocity conditions less than 400 fpm. During the test period, Bhaskar reported headgate face velocities ranging from 345 to 500 fpm, with approximately 88 percent of the recorded velocities falling below 500 fpm. The tailgate face velocities ranged from 280 to 550 fpm and only one exceeded 500 fpm. None of these tests were conducted under face-velocity conditions that exceeded 800 fpm. As such, this study provides information on their effectiveness at lower velocity applications (*i.e.*, under 500 fpm).

In summary, there is consensus among studies that the effectiveness of the PAPR is reduced when air velocities are increased. The Cecala (1981) study alone, provided reasonable estimates of the degree of respiratory protection that PAPRs would provide to a wearer working on a longwall MMU where the face velocity exceeds 800 fpm. Consequently, this study provides the best data from which to estimate PAPR performance or the PF that should be assigned to PAPRs authorized for a

particular MMU. As discussed elsewhere in this proposed rule, MSHA is proposing to allow the use of PAPRs only as a supplementary control measure after all feasible engineering controls have been applied to reduce exposure to the lowest possible level. In our view, these measures, when properly applied and maintained, will control respirable dust to a level reasonably near the applicable dust standard. Therefore, it would not be in the miner's best interest or necessary for compliance purposes to apply the highest PF suggested by these studies. Accordingly, MSHA is proposing that a PF factor of 4 be applied when using a PAPR under air velocity conditions of 400 fpm or less and a PF of 2 when the air velocity is equal or exceeds 800 fpm. This approach recognizes the increased level of respiratory protection that PAPRs afford at lower air velocities and, based on our engineering judgement, will allow operators to achieve compliance with the applicable dust standard on longwalls and other MMUs. Furthermore, the level of protection provided by a properly used PAPR will assure miners that they are being protected from overexposure.

For example, if the air velocity to be maintained in the headgate and tailgate of a longwall MMU ventilated head to tail is 400 fpm and 300 fpm, respectively, then PAPRs used there would be assigned a PF of 4. If on the other hand, the ventilation plan calls for 850 fpm to be maintained in the headgate location and 450 fpm in the tailgate location, then the applicable PF would equal 2. Because of the lack of data on PAPR performance under air-velocity conditions ranging between 400 fpm and 800 fpm, MSHA has proposed that, whenever plan velocities fall in that range, PAPRs used in the MMU be assigned a corresponding PF falling between 2 and 4 which would be determined using an interpolation formula [$2 \times (800/\text{air velocity})$]. For example, if the air velocity to be maintained in the headgate location is 700 fpm, then the applicable PF would equal 2.3 [$2 \times 800\text{fpm}/700\text{fpm}$].

The following example is meant to illustrate the application of the PF to determine the dust concentration to which the wearer of a PAPR is expected to be exposed. Assume for purposes of the example that the applicable dust standard is 1.5 mg/m³ and the airborne concentration of respirable dust is 2.6 mg/m³. Therefore, using a PAPR with a PF =4 is expected to reduce the miner's exposure to 0.65 mg/m³ (2.6 mg/m³ /4).

The range of PFs that MSHA will allow to be assigned to PAPRs under this proposed rule will provide a margin