Finding the effect of ventilation on conveyor belt fire suppression systems

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On June 1, 2004, the underground coal mine ventilation safety standards under the Code of Federal Regulations (Title 30, Part 75) became effective for the use of a conveyor belt entry as an intake air course to ventilate working sections.

These standards, also known as the Belt Air Rule, contained a section which limited the air velocity in the conveyor belt entry to no greater than 500 feet per minute unless otherwise approved by the US Mine Safety and Health Administration in the fire suppression system section of a mine’s ventilation plan.

The Belt Air Rule included a requirement dictating compatibility of air velocity with fire suppression systems. The final rule of limiting air velocity in the belt entry was challenged in the Court of Appeals for the District of Columbia Circuit. The court granted that petition and vacated the requirement on the air velocity cap, according to MSHA.

The removal of the air velocity cap from the final rule, paired with the compatibility requirement, led to a need for research on high air velocity’s influence on fire suppression system performance in belt entries.

Test data was needed that illustrated the relationship between fire suppression system performance and air velocity, especially with the increased use of wider belts in underground coal mines, so National Institute for Occupational Safety and Health and MSHA collaborated to obtain the data.

However, this work was initiated before the revised Belt Air Rule was promulgated on December 31, 2008, when 1000 fpm air velocity became a requirement. Four different types of fire suppression systems were evaluated in a large-scale fire tunnel: a water sprinkler, deluge-type water spray and two different types of dry chemical fire suppression systems.

The suppression systems are representative of the types used in underground coal mines in the United States, and the large-scale fire tests were conducted using fire-resistant rubber belt at a width of 72 inches meeting the outlines of Title 30, Code of Regulations, Part 18, section 18.65.

Each fire suppression system was tested at air velocities of 500-550 fpm and 1350-1500 fpm. A minimum of two tests were conducted at both air velocities for each system.

All experiments were conducted at one location, the NIOSH Fire Suppression Facility – a full-scale, state-of-the-art fire test facility located on the surface of the Lake Lynn Laboratory just southeast of Pittsburgh, Pennsylvania. The fire tunnel was T-shaped to simulate a main entry and crosscut. The former was 153 ft long and the crosscut was 40 ft long.

Each entry was 18 ft wide and 7 ft high, with the roof constructed of corrugated steel bridge planks, and the roof interior was coated with 2 in-thick fire-resistant material.

The ribs at the test site consisted of 8 in-thick solid concrete blocks coated with 1 in fire-resistant material, and the floor of the facility was made of reinforced concrete. A variable speed axial vane fan measuring 6 ft in diameter was installed at one end of the tunnel to provide ventilation.

The fan featured a pneumatic controller to adjust the fan blades in order to increase or decrease the air velocity, and produced an air velocity over the cross-section of the entry of 1500fpm.

Groups go to work

A 6 ft-wide fire-resistant rubber belt meeting 30 CFR Part 18.65 requirements was installed on the conveyor belt structure. Typically, the length of the belt ranged from 140-165 ft.

Thermocouples were then placed on the sensors used to detect the fire. For example, the dry chemical fire suppression system A used three point-type heat sensors to detect the fire, so thermocouples were placed on the end of each point-type heat sensor to determine which sensor activated the suppression system and at what temperature.

In the case of the water sprinkler system, thermocouples were placed on the sprinkler heads in the area where the fire would most likely activate it. To determine air velocity for the test, a handheld vane anemometer was positioned over the top belt over the drive area in the center of the belt and approximately 1 ft from the roof.

To ignite the belt, four natural gas burners connected in series were mounted about 6 in underneath the belt drive roller and across the belt's width. The gas was left on for 10-15 minutes before being shut off.

Visual observations were then taken using a control room video monitor or a side window portal on the tunnel to determine if the belt remained ignited after the gas was stopped. If it appeared the belt fire was not self-sustaining, the gas was turned back on to the burners until the belt was on fire and could sustain itself.

Each fire suppression system was installed according to the manufacturer's instructions or recommendations and, as applicable, armed before the belt was ignited.

Reviewing the results

Four different types of fire suppression systems were tested under two air velocity conditions, and two water-based fire suppression systems were able to suppress the fire under the test conditions. However, the amount of water needed to suppress the fire to the point where a miner could walk up to extinguish any smoldering belt was greater than current MSHA regulations require.

MSHA regulations only require 10 minutes of water supply to the suppression system with all sprinklers or water sprays open. In the test, and based on the visual evaluation, it was unlikely that either system would have suppressed the fire had the water been turned off to the system after 10 minutes.

The two dry chemical suppression systems provided mixed results. For example, System A did not extinguish the fire in either air-velocity condition. This system uses a nominal weight of 300 lb of dry chemical agent (monoammonium phosphate-based) and 40 nozzles to protect the 50 ft of drive area.

Additionally, the primary failure mechanism was damage to the hoses from the fire prior to system activation. Several of the nozzles in System A did not discharge any dry chemical agent because the hoses leading to the nozzles were severely fire damaged.

The dry chemical System B performed well at the lower air velocity. However, at the higher air velocity mixed results were obtained. System B required a nominal weight of 500 lb of dry chemical agent (monoammonium phosphate-based) and 64 nozzles to protect the 50 ft of drive area.

One of the higher air velocity tests resulted in the fire not being extinguished, and there was a malfunction with one of the four dry chemical supply tanks that resulted in one tank not discharging any chemical to connected nozzles. This malfunction, however, would not have affected the extinguishment of the fire because the nozzles were located outby (downwind) of the fire area.

The large-scale testing indicated the air velocity does, in fact, have a significant effect on the detection, activation, and suppression capabilities of the fire suppression system. The water-based systems each performed well under both sets of air velocity conditions, but required more time than the 10-minute requirement in 30 CFR. The dry chemical systems, however, did not perform as well, and resulted in failure to extinguish the test fires in some experiments.

Several factors may have contributed to the dry chemical system's poor performance under the test conditions. The ventilation rate not only affects the discharge pattern of the dry chemical agent, but also contributes greatly to the system's detection and actuation. The increased air velocity condition has a cooling effect on the detection mechanisms, and this can allow the fire to grow and propagate further – before the system detects and actuates the dry chemical to discharge.

The importance of early detection is imperative for any fire condition. The higher air velocity tests may have actually been larger fires by the time the system discharged, resulting in a more challenging suppression situation.

A combination of the larger fire conditions under high air velocity because of detector cooling, detection location, the transference of dry chemical by the ventilation, and overall fire suppression system design, all may have affected the performance of each system.