New application of directional drilling and gas-enhanced foam for suppression of abandoned underground coal mine fires

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According to the Office of Surface Mining Reclamation and Enforcement, Abandoned Mine Land Inventory System, in 2013 there were 98 underground mine fires in nine states. This is considered to be an underestimate for the actual number of fires nationwide. Many mine fires are started by people burning trash where the coal seam or an abandoned coal mine is close to the surface. Other fire ignition sources include lightning and forest fires. Once ignited, a coal mine fire can easily spread into the remaining coal pillars and mine entries. Once established, the fire creates its own ventilation system supporting further combustion by drawing air down into the workings through unsealed mine shafts, fractures and surface subsidence depressions. As the coal left in the workings from the past mining operations burns, the mine void can collapse, causing subsidence and creating dangerous voids, damaging overlying surface structures and roadways. The products of combustion include smoke and noxious fumes such as carbon monoxide gas. These products are released to the atmosphere through fractures that develop within the ground surface, killing vegetation and creating serious health hazards (Richmond, 2017).

Figure 1

Smoke and steam emanating from cracks in a highway in Centralia, PA.

Abandoned mine fires, if left uncontrolled, can burn for years and, in fact, one of the most well-known mine fires in the United States is the mine fire in the Borough of Centralia, PA, that began on May 27, 1962. Reportedly, officials decided to clean up the local landfill for the upcoming Memorial Day holiday by burning the garbage on the site. Unfortunately, the landfill was located on the site of an abandoned strip-pit mine on the edge of the Borough (Dekok, 2009). The strip pit had been left open after being excavated around 1935 and was approximately 23 m (75 ft) wide and 15 m (50 ft) deep. It is believed that the lack of a properly constructed noncombustible shale barrier in the strip pit enabled the fire to spread to adjacent carbonaceous refuse material and then to nearby coal mine workings (PA DEP, 2017). As time went on, the fire grew and spread under the Borough and directly affected the residents despite various efforts to extinguish the fire by the state and federal governments (Fig.1). In 1984, a voluntary program was begun to move residents from their homes. Many accepted buyout offers for their properties and moved elsewhere and after leaving, their homes were demolished. In 1992, the state used eminent domain to take control of all the property within the Borough. In 2013, after years of litigation, the eight remaining residents were allowed to stay for as long as they lived. Today, only a few buildings remain within the Borough (Centralia, PA, 2014). This fire has been burning for more than 55 years.

The longest burning coal fire, which may have been started around 6,000 years ago in New South Wales, Australia, is still smoldering (Fig. 2). Burning Mountain, also known as Mount Wingen, has been smoldering for about 6,000 years without stop. Just below the ground surface in New South Wales, a coal seam has been burning and slowly moving south along the mountain at a rate of 1 m/a (3 ft/year). In its history, the fire has covered a total area of 6.5 km (40 miles), making it the oldest continuous coal fire in the world. Most assumed the fire was caused by volcanic activity,

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