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Technology News

No. 489 Milestones in Mining Safety and Health Technology May 2001

Reducing the Danger of Explosions in Sealed Areas (Gobs) in Mines

Objective

To identify techniques to reduce the probability of gob gas explosions.

Background

In the last 6 years, seven explosions of methane and/or coal dust occurred within worked-out, sealed areas (gobs) of underground U.S. coal mines. These explosions, believed to have been started by lightning, destroyed many mine seals and caused much damage external to the sealed area. Three of these gob gas explosions occurred in one mine in Alabama over a 3-year period. Fortunately, the explosion forces and the toxic gases that vented from the sealed gob area did not cause fatalities or injuries, but they destroyed several large seals. If miners had been inspecting or working near these areas, the potential for serious injury and/or death would have been high. The United Mine Workers of America and the Mine Safety and Health Administration (MSHA) requested that the National Institute for Occupational Safety and Health (NIOSH) help identify the mechanisms for lightning penetration into the gob and recommend ways to reduce the probability of occurrence of future explosions from such lightning penetrations into sealed areas of underground coal mines.

Because three of the explosions occurred in a single mine, special attention was focused on these particular explosions. The first occurred in April 1994 in a sealed area, which enclosed about 1.35 square miles of abandoned workings (gob). This explosion destroyed 3 of the 38 seals that surrounded the gob. These seals were less than 2,000 ft away from three 4.5-in-diam steel-cased test wells that extended from the surface into the mine entry. At the time of the explosion, the National Lightning Detection Network (NLDN) verified 12 lightning strikes within 10 miles of the mine, including several above the gob. After the 1994 explosion, the damaged seals were rebuilt using an acceptable seal design capable of withstanding a 20-psi explosion, as required by 30 CFR 75.335. On January 26, 1996, a second gob explosion destroyed five more cementitious pumpable seals less than 2,000 ft away from those destroyed in 1994 and even closer to the steel-cased wells. The NLDN verified 72 lightning strikes in the area of this second gob explosion. Compressive strength analyses of fragments from the destroyed seals showed that strengths ranged from 11 to 138 psi, with an average of 83 psi. This is over 100 psi below the minimum 200-psi compressive strength requirement for cementitious pumpable seals. These seals were again replaced. On July 9, 1997, the third and most violent explosion occurred in the same vicinity of the last two explosions. Three more cementitious pumpable seals were destroyed, including one newer seal that exceeded the minimum 200-psi compressive strength requirement. The NLDN verified 695 lightning strikes above the mine during the time in which the explosion occurred. MSHA's

Figure 1.—Lightning can ignite methane in sealed areas of mines.

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accident investigation report indicated that the maximum pressure (propagating forces) of this explosion exceeded 20 psi. The current seal construction regulations, which relate to all suitable underground seal designs, assume that an explosion occurring in the gob will not be stronger than 20-psi pressure. However, if a large flammable gas volume exists in the gob, the resulting explosion pressure can be >20 psi.

Approach

Two conditions are necessary for an explosion to occur: (1) a fuel-air mixture with a fuel concentration in the flammable (explosible) range and (2) an effective source of ignition for that mixture. If the source of ignition, in this case presumed to be the lightning, cannot be eliminated, then the only alternative is to eliminate flammable concentrations or reduce the volume of the flammable mixture present in the sealed area. If the gob atmosphere contains methane concentrations greatly above the upper flammable limit of 15% methane, it will be unaffected by lightning or by other potential sources that might exist in the gob. Other ignition sources could include the sudden discharge of old batteries, roof falls, and spontaneous combustion. After the third explosion in the same gob area in the Alabama mine, all parties agreed to pressure balance the sealed gob area in order to reduce the leakage of air into the gob and therefore to increase the concentration of methane in the gob to well above the upper flammable limit. By reducing the average differential pressure from 3 in to about 0.46 in of water gauge across the gob, the average volumetric air leakage into the sealed area was reduced by a factor of 2.5. This reduction in seal leakage greatly reduced the probability of formation of a large volume of flammable methane-air mixture in the gob.

Results

The sealed gob area was pressure balanced in July 1997, and the methane concentrations in the gob were monitored by MSHA through February 2000. The gas samples from behind the seals indicated methane levels >20%. This is well above the upper flammable limit. During this same period, several severe storms, accompanied by lightning, passed over the gob area without apparently triggering a gob explosion. One storm was so severe that an imbedded tornado passed over the mine, ripping the doors from the ventilation fan without disturbing the gob. To date, it seems that the combination of constructing suitable seals that met the requirements of the CFR, coupled with pressure balancing of the sealed gob, helped reduce gas leakage and minimized the formation of a flammable methane-air mixture in the gob.

Recommendations

Minimizing pressure differentials across seals should be considered an essential part of the overall strategy for sealing gobs. Reducing the pressure differential reduces the air leakage through the seal and thus reduces the formation of large flammable methane-air volumes in the gob. Any wires or metal conductors, including steel-cased wells, that connect the surface and the gob area should be removed. These contribute to the transfer of energy into the mine. If possible, nonconductive well casings should be used. In addition, old batteries, which are another potential ignition source, should not be left behind in the gob. During the sealing process, adequate rock dust (80% incombustible) should be used both inside and outside of the sealed areas to reduce the contribution of coal dust to a methane explosion.

For More Information

For more information on these findings, contact Michael J. Sapko or Kenneth L. Cashdollar, NIOSH Pittsburgh Research Laboratory, P.O. Box 18070, Cochrans Mill Rd., Pittsburgh, PA 15236-0070, phone: (412) 386-6619 or (412) 386-6753, fax: (412) 386-6718, e-mail: **msapko@cdc.gov** or **kcashdollar@cdc.gov**. In addition, "MSHA Accident Investigation Report, Non-Injury Explosion, Oak Grove Mine, July 9, 1997" by Doniece Scott and Clete R. Stephan describes the various pressure-balancing techniques for all seals and other safety aspects that need to be addressed when using this approach.