Rock Dusting Attributes

The importance of rock dust to prevent explosions

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Since 1900, gas or dust explosions in U.S. underground coal mines have claimed more than 11,500 lives. This statistic reflects the catastrophic nature of underground explosions. Take, for instance, the last disastrous explosion in 2010 when 29 miners lost their lives with only two surviving from their injuries. These events can occur with little warning, providing mineworkers with no chance to escape.

Historically, catastrophic mine explosions have occurred during the dry winter months when risk conditions increase. The Mine Safety and Health Administration[1] (MSHA) previously issued winter alerts on their website with a checklist of winter preparations. However, mine explosions can occur at any time of the year (www.msha.gov/data-reports/mine-disaster-investigations-2000). The requirement for 80% incombustible content is mandated (eCFR:30 CFR Part 75 Subpart E-Combustible Materials and Rock Dusting) to render coal dust inert. Rock dust attributes and rock dust maintenance are important, especially in the dry winter months when the moist underground entries can dry out. Let's examine the basic mechanics of a propagating explosion to understand why rock dust attributes matter.

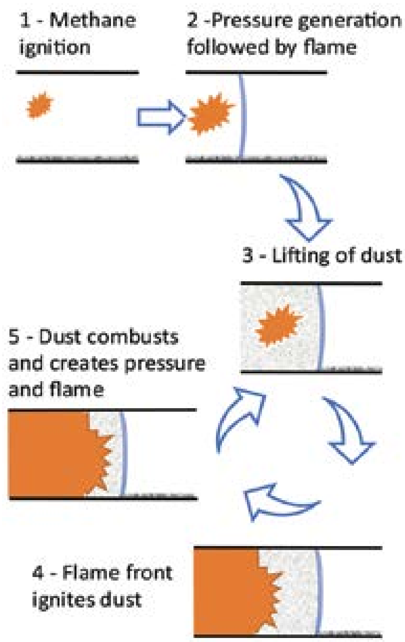
Explosion Propagation

A dust explosion is similar to a fire, except it requires two additional elements. Like fire and the well-known fire triangle, a dust explosion requires a source of fuel, a supply of oxygen and an ignition. A dust explosion also requires confinement and dispersion, forming the dust explosion pentagon. Coal dust is the source of fuel. Oxygen in the underground mine atmosphere provides the oxidant, and the ignition is usually due to a spark or flame igniting methane. The underground mine entries provide system confinement. However, the source of dispersion may not be so obvious and needs a bit more explanation.

The dust explosion pentagon showing the five required components for a dust explosion.

The expansion of gasses due to the methane ignition produces a pressure wave (small relative to the ignition of coal dust), which then lifts dust from the surroundings and becomes the dispersion source. For example, if a spark from cutting coal should ignite a small pocket of methane, this could be the source of ignition and dust dispersion. The flame following the pressure wave then ignites the dispersed dust, completing the dust explosion pentagon.

The process does not necessarily stop here. The coal dust ignition produces more pressure due to expanding gasses. This in turn disperses more dust in front of the flame, which can be ignited, further propagating the explosion. The explosion will continue until one of the five components of the dust explosion pentagon is removed. Hence, rock dust application and maintenance are required in underground coal mines to maintain 80% incombustible content. This eliminates or reduces the fuel component. Rock dust can limit the amount of combustible coal dust lifted, and it acts as a heat sink and blocks radiant energy transfer to interrupt this process. Effective rock dust application is proven to prevent and mitigate coal dust explosions.



Explosion propagation starts with an ignition (1) which generates a pressure front (2) that lifts dusts from surfaces (3). The following flame front ignites the lifted coal dust (4) which then combusts, producing more pressure and flame (5). This process can then repeat in a loop through steps 3-5 continuing the propagation of the explosion throughout mine workings until an element of the dust explosion pentagon is removed.

Rock Dust

Legislation included definitions of rock dust dating to at least 1952. Currently, 30 CFR 75.2 defines rock dust. A review of the definition will reveal the importance of each requirement in the prevention of coal dust explosions to ensure the safety and health of miners.

The definition stated that rock dust should be inert material such as limestone, shale, dolomite and such. The fuel source should also be limited and therefore the definition has an additional requirement of no more than 5% combustible matter. This is to ensure the rock dust does not significantly contribute to the fuel source.

The last compositional requirement is to prevent respiratory diseases. The silica content requirement is to be no more than a total of 4% free and combined silica (SiO_2). NIOSH considers rock dust itself to be a nuisance dust and should not contribute to any other health hazard. However, rock dust is included in coal mine respirable dust determination and is applicable to the 1.5 mg/m^3 standard (eCFR: 30 CFR Part 70-Mandatory Health Standards - Underground Coal Mines).

The definition stated that rock dust should be "preferably light-colored." There is no evidence that color affects how rock dust functions. Although the light color could help to visually assess the relative amounts of rock dust present or if more needs to be applied.

Even if the composition is correct, rock dust must meet the definition for particle size or it will not be effective. It is required to be 100% passing through a 20-mesh sieve (less than 850 microns) and 70% passing through a 200-mesh sieve (less than 75 microns). In 2011, NIOSH issued a hazard alert (HID 16[2]) about rock dust supplies not meeting the particle size requirement.

This size requirement is important in many ways. First, as explained previously, the pressure wave lifts the dust from all surfaces in a mine entry. Therefore, if the coal dust lifts, the rock dust must also lift to function and interrupt the explosion propagation cycle. Ideally, the rock dust should be the same size or smaller than the coal dust so it lifts with the coal dust. Also, typical limestone rock dust is twice as dense as coal dust and, therefore, more force is required to lift the same sized rock dust than coal dust. Second, the particle size of the rock dust affects how well it can function. The same mass of smaller particles have more collective surface area to act as a faster heat sink. Previous NIOSH research[3] indicated that a specific surface area of 2,600 cm^2/g is required to be effective and that removal of particles less than 10 microns renders the rock dust ineffective. Since the NIOSH issued a Hazard Alert in 2011, this alerted rock dust manufacturers to the importance of the size specification and are diligent in meeting the size requirements.

Since the rock dust needs to be able to lift and disperse with the coal dust, there is a requirement for "the particles of which when wetted and dried will not cohere to form a cake, which will not be dispersed into separate particles by a light blast of air." The rock dust must be able to lift in time with the coal dust to prevent the coal dust combustion. If the rock dust particles cannot lift separately, larger clumps of rock dust require more force to lift and do not supply the same surface area as individual particles. If this happens, the moisture-resistant coal dust can be lifted and combust before the rock dust. This issue was another focus of the 2011 NIOSH Hazard Alert.

Rock dust quickly absorbs moisture and can become non-dispersible. When rock dust dries, it most likely will cake, not be readily dispersed, and not function as intended. On the other hand, coal dust resists wetting and easily disperses in the presence of water. Dry explosive coal dust can settle on water or wet rock dust. If coal dust should lift while the rock dust does not, it would be as if no rock dust was present and a dust explosion could occur. The applied rock dust can absorb moisture during high humidity in the summer months and dry out during the winter resulting in conditions where wet or caked rock dust cannot disperse. What could result is an ineffective layer of rock dust that is caked or clumped and non-dispersible. If moisture-resistant coal dust is layered on top of this clumpy wet or caked rock dust, the rock dust is ineffective and only the float dust will be dispersed by a pressure wave. The source of fuel is supplied again. Properly sized rock dust needs to be applied and be easily dispersible for it to be effective.

A blast of air disperse a layer of water-resistant coal dust on top of moisture-absorbing non-dispersible rock dust.

Improved Rock Dust

NIOSH worked with rock dust manufacturers to develop rock dusts that resist moisture and caking. Anti-caking additives treat these new rock dusts to render them moisture resistant. These additives, traditionally used as fluidizing agents in other industries, are typically a fatty acid such as stearic acid or oleic acid. The anti-caking treatments are added in very small amounts (< 1%). These new dusts can be applied with existing equipment and require no new technologies or investments to utilize. These additives have been tested by NIOSH and are shown to be safe.

Since the additives are typically fatty acids, which are combustible, NIOSH conducted laboratory testing using a 20-L chamber[4] to determine if the additives affected the inerting potential of the rock dust. In these studies, the treated rock dusts inerted coal dust at the same levels as the traditional untreated rock dust. NIOSH conducted large-scale testing at the Central Mining Institute in Poland,[5] which indicates that these treated rock dusts are at least as effective as untreated rock dusts in preventing and suppressing coal dust explosions. In fact, some results indicated the treated rock dust may be more effective.

NIOSH researchers have observed applications of some of these treated rock dusts in the Bruceton Experimental Mine over successive seasons and cycles of moisture exposure and drying.[3] These rock dusts resist wetting and remain dispersible after several seasons. In laboratory dispersion testing, the treated rock dusts still lift with a small burst of air after being exposed for long periods of time to water.

Although potential health concerns about the additives were raised, NIOSH research indicates that these concerns are not justified. The NIOSH Health Effects Laboratory Division[6] tested two different treated rock dusts and the results indicate that the treatments do not pose a respiratory hazard.

Since other industries typically used the anti-caking additives to improve fluidity, some concerns about using such a treated rock dust include potential re-entrainment when using moisture-resistant rock dust in an operating section. The concern is about the impact it would have on respirable dust measurements. Testing[7] indicated that some respirable dust measurements were higher downwind after a vehicle traveled through treated rock dust on the mine floor. The application of a surfactant mixed with water can suppress the anti-caking properties of the treated rock dusts. However, this is counter to the original purpose of the rock dust treatment. Therefore, treated rock dusts may be best used in areas with little-to-no traffic such as bleeder entries, tailgate entries, belt entries, returns, and remote areas by seals. A treated dust may also be beneficial when using mechanical means to regularly rock dust inaccessible mined-out areas since it does not tend to clump and could prevent clogging of equipment.

Best Practices

When dry winter weather approaches, a review of best practices for rock dust quality and rock dust application are important. In addition to maintaining 80% rock dust in all areas and within 40 ft of the face, it is recommended to maintain the effectiveness and integrity of all rock dust in all rock dusted areas of the coal mine. This includes rock dusting downwind of mining and to keep the bleeder entries well rock dusted. Tailgates and immediate returns should also be continuously rock dusted. Treated rock dusts are well suited for use in these areas and could prevent clumping and mechanical malfunctions during continuous applications. Rock dust meeting the 30 CFR 75.2 regulatory definition should be sufficiently applied to maintain 80% incombustible content on all underground surfaces and remain dispersible in all mine areas to prevent any potential ignitions from transitioning into large catastrophic events.

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Disclaimer

The findings and conclusions in this paper are those of the author and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of any company or product does not constitute endorsement by NIOSH.

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