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Collecting representative dust samples: A comparison of various sampling methods in underground coal mines

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ABSTRACT

Former methods used in the U.S. to assess hazardous and explosible coal dust date back to the 1950s. As mining technologies advanced, so too have the hazards. Given the results of the recent coal dust particle size survey and full-scale experimental mine explosion tests, the National Institute for Occupational Safety and Health (NIOSH) recommended a new minimum standard, in the absence of background methane, of 80% total incombustible content (TIC) be required in the intake airways of bituminous coal mines, replacing the previous 65% TIC requirement. Most important to monitoring and maintaining the 80% TIC is the ability to effectively collect and analyze representative dust samples that would likely disperse and participate in dust explosion propagation. Research has shown that dust suspended on elevated surfaces is usually finer, more reactive, and more readily dispersible while floor deposits of dust are generally coarser and more difficult to disperse given the same blast of air. The roof, rib, and floor portions of the dust samples were collected and analyzed for incombustible content separately and the results were compared to a band sample of the roof, rib, and floor components. Results indicate that the roof and rib dust samples should be kept separate from floor dust samples and considered individually for analyses. The various experimental collection methods are detailed along with preferred sampling approaches that improve the detectability of potentially hazardous accumulations of explosible dust.

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1. Introduction

Research has shown conclusively that as the average size of coal dust particles decreases, the explosion hazard increases (Cybulski, 1975; Michelis, 1998; Cain, 2003; NIOSH, 2010). Recent dust survey results show that the coal dust found in mines today is much finer than in mines of the 1920s (Sapko et al., 2007). Given the results of the recent coal dust particle size survey and subsequent full-scale Lake Lynn Experimental Mine (LLEM) explosion tests, the National Institute for Occupational Safety and Health (NIOSH) recommended a new standard of 80% total incombustible content (TIC) be required in the intake airways of bituminous coal mines to replace the existing 65% TIC requirement (NIOSH, 2010). To determine compliance with the 80% TIC requirement, mine operators and MSHA inspectors regularly collect dust mixtures at various distances along mine entries, measure the TIC, and compare the results to the minimum 80% TIC requirement. The sampling method of collecting a combined band sample using a brush and pan to gather an approximately 15-cm (6-in) wide strip of dust from the roof, ribs, and floor has evolved over many years. With the implementation of the new 80% TIC requirement and with increased mechanization, is the current band sample approach still the best method to detect potential dangerous accumulation of explosible coal and rock dust mixtures?

Owings et al. (1940) stated "Because of differences in quantity, fineness, and composition, samples should be taken in pairs at any one place; one from the roadway and one from the roof and ribs. A true picture of the dust conditions cannot be obtained otherwise" and "…Tests indicate that essentially no amount of rock dust on the floor will stop an explosion traveling through the very finely divided coal dust dislodged from overhead surfaces".

Saltsman and Grumer (1975) indicated that "the roof-rib noncombustible content cannot be predicted from or indirectly equated to, its corresponding 15-cm (6-in) floor sample" and "If the combustible content of the rib-roof dust is considered hazardous, it should be analyzed separately." It was noted that the roof-rib weight fractions of the band samples were small enough to have little effect on the TIC of the total band sample and should be analyzed separately. Nagy et al. (1965) originally stated and Sapko et al. (1987) later confirmed that small amounts of float coal dust

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on the roof and ribs plays a key role in explosion propagation independent of the TIC on the floor.

The Mine Safety and Health Administration (MSHA) collected mine dust samples at least every 150 m (500 ft) of new development from mines within all eleven bituminous Coal Mine Safety and Health Districts to assess explosible coal dust conditions. The dust samples were routinely collected by MSHA mine inspectors to assess compliance with 30 CFR 75.403. The sampling method required a perimeter band sample to be collected and combined from the roof, rib, and up to 2.5 cm (1 in) deep from the floor. The samples were then sent to the MSHA National Air and Gas Laboratory at Mt. Hope, WV, and analyzed for total incombustible content (TIC). The TIC included measurements of the moisture in the as-received samples, the ash in the coal, and the rock dust content. In 2013, MSHA proposed and enacted a sampling protocol change to allow for the collection of roof and rib sample as one sample and a separate collection of a 3-mm ($^1/_8$-in) deep floor sample. MSHA states:

> Based on inspectors evaluation band samples may be split at any location where coal dust is visible on the roof, ribs, structures or suspended items. Issue a citation if either of these samples from a band are non-compliant with the incombustible content requirements in § 75.403. In areas where the roof/ribs/and mine floor are uniformly rock dusted only a single band sample is needed (MSHA, 2013).

This protocol is similar to that of New South Wales and still allows for the roof, rib, and floor dust to be mixed and collected as one combined band sample based upon visual inspection and inspector discretion (NSW, 2006). However, Nagy (1981) has stated “An observer cannot estimate with precision the exact percentage of incombustible in a mine dust sample. The difference between visual estimation and chemical analysis ranged from −17.5 to +27.5 percentage points of incombustible for rib and roof samples (102 samples). The difference between visual estimation and chemical analysis ranged from −22.5 to +22.5 percentage points of incombustible for floor samples (107 samples).” Therefore, is an inspector's visual discretion adequate for determining if the roof/rib dust can or should be mixed with the floor dust for analysis?

2. Experiments

2.1. Former methods for collection of representative dust samples

Prior to 2013, sampling practices for determining compliance required samples be collected at least every 150 m (500 ft) of mine entry (MSHA, 2008) as the mine face advanced. An inspector would use a brush to collect the rock dust and coal dust present on the roof, rib, and up to 2.5 cm (1-in) deep on the floor. The brush and pan method is detailed later for the rib and floor. The brush and pan method is used by MSHA to collect a dust sample from the roof also. The roof, rib, and floor sample would be combined together as a perimeter band sample. The use of ground control fixtures such as mesh could interfere with the collection of a representative band sample from the ribs and roof. With the mesh on the ribs, it could be difficult for inspectors to brush the dust from the ribs into a pan for sample collection. The space between the mesh and strata could allow the dust to fall behind the mesh or to be swept away by the ventilation airflow rather than to be collected. During previous sampling studies, the dust on the roof was sampled only in mines with a roof that could be accessed without the aid of a ladder or extended sampling equipment. In mines where the roof was beyond reach, a sample from the roof was not collected. In high roof mines, it was acceptable to take a sample of the floor and ribs to the maximum height that it could be done safely and practically (MSHA, 2008). Therefore if coal dust were present on the roof and rib and/or any mesh support above the reach of the inspector, in these instances, it would not be collected for analysis and a potential explosion hazard could go undetected. Also, when combining a limited quantity roof and rib sample with a 2.5 cm deep floor dust sample, the potential coal dust explosion hazard could easily go undetected if the floor was preferentially rock dusted.

The sampling methods have remained the same except the new MSHA sampling protocol (MSHA, 2013) allows for the roof and rib portions to be collected and analyzed separately from the floor portion based upon a visual evaluation of the uniformity of the rock dust application.

2.2. Sampling techniques

Various sampling techniques were evaluated in the NIOSH Office of Mine Safety and Health Research (OMSHR) Bruceton Experimental Mine in an attempt to obtain the best and most representative dust sample from an entry. Rock dust was generously applied with a pneumatic rock duster to the entry's roof, ribs, and floor. A fine layer of Pittsburgh pulverized coal (PPC) dust (coal dust containing ~80% particles <75 μm) was then applied in the same manner. The techniques that were deemed most successful are described in more length in the following 2.3 Field sampling protocol section.

2.3. Field sampling protocol

A total of nine mines were visited by NIOSH researchers to include different mining methods, coal seams, and conditions. On each visit, a four- or five-person team accompanied mine personnel to the advancing development section or longwall. At each sample location, a series of samples would be collected from the roof, ribs, and floor with each portion of the entry being collected and analyzed separately. In other words, the rib dust was not mixed with the roof dust or the floor dust to create an overall perimeter “band” sample.

All of the samples were passed through a 10-mesh sieve within the mine before transferring the sample to the NIOSH laboratory. Once at the laboratory, the sample bags were opened so the samples could air dry until constant mass was achieved. The samples were passed through a 20-mesh sieve and then weighed to obtain the total amount of sample collected. After the samples were weighed, a low temperature ashing (LTA) analysis was conducted (Cain, 2003). Only the percent incombustible content (% IC) is reported − not the % as-received moisture.

2.4. Roof samples

At each sample location, a roof sample was collected using a 20-cm (8-in) diameter bowl fitted with a 14-cm (5.5 in) wide brush in the center (Fig. 1). The 14-cm wide brush was inserted and affixed to the bowl so that the approximately 2.5 cm long bristles of half of the brush extended above the bowl lip. A threaded mop handle bracket was attached to the bottom of the bowl. This allowed the user to hold the bowl by the handle and drag the bristles across the roof. The bowl was then able to collect the dust dispersed by the bristles. The threaded head and handle could also be fitted with a telescoping handle to allow for samplings in areas beyond a user's reach (Fig. 2). Even in entries with high ventilation velocities and/or locations above belt conveyors, 14-cm wide samples of dust were successfully collected with minimum dust loss using the bowl with brush sampling device. If the first 14-cm wide pass did not appear