

LARGE-SCALE DUST EXPLOSIONS: TREATED VS. NON-TREATED ROCK DUST

M. L. Harris, NIOSH, Pittsburgh, PA  
M. J. Sapko, NIOSH, Pittsburgh, PA  
Z. Dyduch, Central Mining Institute, Mikiłów, Poland  
K. Cybulski, Central Mining Institute, Mikiłów, Poland  
R. Hildebrandt, Central Mining Institute, Mikiłów, Poland  
G. V. Goodman, NIOSH, Pittsburgh, PA

ABSTRACT

Past research showed that bituminous coal dust remains dry and dispersible in the presence of moisture. Rock dust must disperse with the coal dust to effectively inert a propagating coal dust explosion. Non-treated rock dust readily absorbs moisture, limiting its dispersibility, while anti-caking treated rock dusts can remain dry. The National Institute for Occupational Safety and Health contracted the Central Mining Institute in Poland to conduct large-scale testing in their Experimental Mine Barbara to determine if a treated rock dust can be as effective as non-treated rock dust in attenuating or quenching coal dust explosions under the same experimental conditions.

INTRODUCTION

One of the goals of the National Institute for Occupational Safety and Health (NIOSH) is to conduct research to reduce the risk of mine disasters and provide workplace solutions to reduce the risks associated with accumulations of combustible and explosible materials; the most common form of which is the generation of coal dust during the mining process and its subsequent distribution downwind. Dispersible rock dust is a primary defense for preventing coal dust explosion propagation in underground coal mines, and its properties are defined in 30 CFR 75.2. "Pulverized limestone, dolomite, gypsum, anhydrite, shale, adobe, or other inert material, preferably light colored, 100 percent of which will pass through a sieve having 20 meshes per linear inch and 70 percent or more of which will pass through a sieve having 200 meshes per linear inch; 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; and which does not contain more than 5 percent combustible matter or more than a total of 4 percent free and combined silica (SiO<sub>2</sub>), or, where the Secretary finds that such silica concentrations are not available, which does not contain more than 5 percent of free and combined silica."

An earlier NIOSH investigation of rock dust revealed two significant concerns with the supply of rock dust to U.S. coal mines: 1) insufficient particles <200 mesh (75 μm) and 2) all rock dusts when wetted and dried formed cakes and were not easily dispersed with a light blast of air (1).

Past research by the U.S. Bureau of Mines and others showed that bituminous coal dust remains dry and dispersible in the presence of moisture (2). Rock dust must also be dispersible in concert with the coal dust to effectively inert a propagating coal dust explosion (3, 4, 5, 6). Non-treated rock dust, however, readily absorbs moisture, limiting its dispersibility, while a rock dust treated with long-chain fatty acids (such as stearic acid) can remain dry and dispersible. Stearin-treated rock dust has been used in British coal mines (7) and is commonly used in Polish coal mines.

Traditionally, testing in large-scale explosion research facilities has been required to validate laboratory-scale explosibility results and to provide supporting data for decision making regarding explosion safety in underground coal mines. Due to the closure of the Lake Lynn

Experimental Mine, the Central Mining Institute (CMI) of Poland was used as an alternate facility to compare the relative effectiveness of a treated anti-caking rock dust, equally sized, to a non-treated rock dust under the same experimental test conditions. The Central Mining Institute near Mikołow, Poland, operates Experimental Mine Barbara (EMB). Fundamental research has been conducted in the EMB on a large-scale basis since 1925 to address the explosive danger of coal dust, firedamp and flammable fire gases (3). Such research includes examining the main explosion parameters, rock dust suppression effects, initiator effects, accumulations of fire damp, barriers, etc.

This paper presents the results from large-scale explosion experiments conducted at CMI to help answer the question "Will treated rock dust be as effective as non-treated rock dust in attenuating or quenching coal dust explosions under the same experimental test conditions?"

TEST METHOD

The rock dusts used in the EMB tests were obtained from Labtar (Tarnów Opolski, Poland) which supplies treated and non-treated rock dusts to coal mines in Poland (8, 9). The coal dusts used were a medium-sized dust, termed d38, for the propagation zone and a finer-sized dust, termed d96, for the ignition boost, both Barbara seam coal.

To characterize the full particle size distributions, NIOSH used a Beckman Coulter (B-C) LS 13320 laser diffraction particle size analyzer equipped with a Tornado Dry Powder air dispersion system. NIOSH researchers followed the analysis procedure recommended by the manufacturer (10, 11, 12).

The Polish d38 coal dust is a standard coal dust used at the EMB for dust explosion research. The B-C mass-mean diameter of the Polish d38 coal dust is 124.9 μm. Its particle size distribution is listed in Table 1.

Table 1. Particle size distribution of the Polish d38 coal dust.

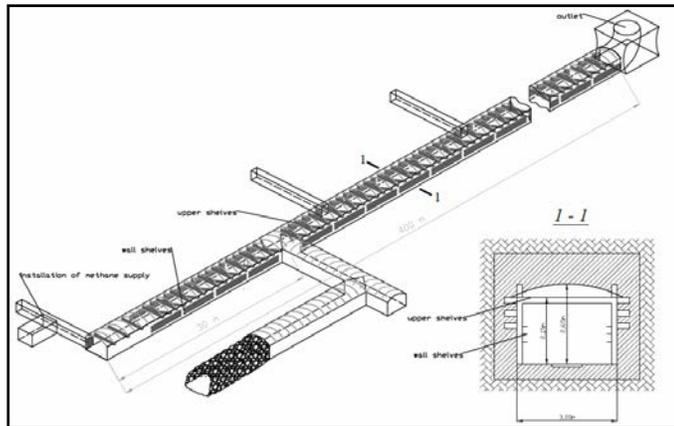
Mesh Size	μm	B-C % <
635	20	6.2
400	38	13.6
200	75	33.6
60	250	91.6
20	850	100.0

Table 2 shows the particle size distributions of the Polish rock dusts as determined by the B-C instrument. The Polish non-treated rock dust features a mass-mean diameter of 38 μm and the Polish treated rock dust features a mass-mean diameter of 28 μm.

The large-scale dust explosions were conducted in the underground experimental facility at the EMB of the Central Mining Institute. The facility consists of a network of experimental galleries equipped with a measuring system and utilities to initiate dust explosions. Figure 1 shows an outline of the experimental gallery network.

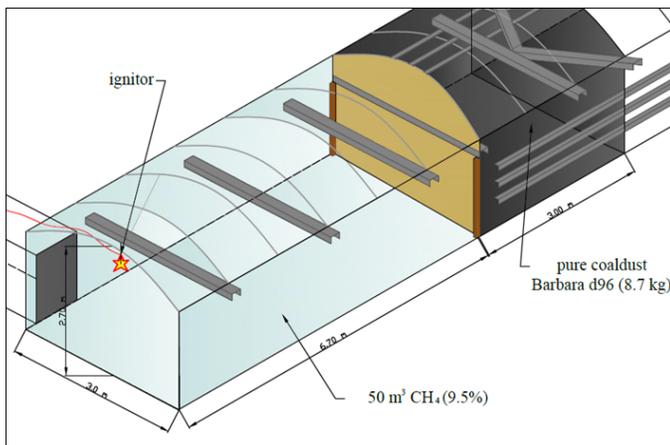
**Table 2.** Particle size distributions of the treated and non-treated Polish rock dust.

Mesh Size	$\mu\text{m}$ ,	Non-treated Polish Rock Dust	Treated Polish Rock Dust
		B-C % <	B-C % <
635	20	64.9	70.5
400	38	72.3	79.1
200	75	81.5	88.7
60	250	99.7	99.9
20	850	100.0	100.0



**Figure 1.** Layout of the 400-m long experimental gallery in the Experimental Mine Barbara, Poland.

This renowned facility consists of 200-m and 400-m underground entries having a cross-sectional area of  $7.5\text{ m}^2$ . Explosions of dust mixtures were carried out in the 400-m experimental gallery with a cross-section of  $7.5\text{ m}^2$  (3 m wide and 2.5 m high). The blind-end region contains a gas supply and mixing chamber from where the gas mixture is released into the front end of the gallery and initiated by a 10 kJ chemical ignitor. Multiple ignition tests were conducted without any coal dust and rock dust to determine the reproducibility of the initial explosion pressures generated. The results of this initial testing showed the need to increase the strength of the ignition and subsequent propagation by adding 8.7 kg of fine d96 for a 3 m distance immediately outby the ignition zone (Figure 2).

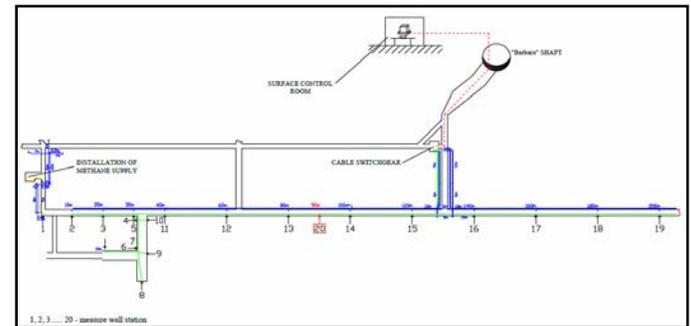


**Figure 2.** Layout of the methane and coal dust ignitions.

Along the gallery walls, measurement panels containing pressure transducers and flame sensors were positioned (Figure 3). Data was collected at distances of 20 m, 30 m, 40 m, 60 m, 100 m, 120 m, 160 m, and 200 m from the end of the methane ignition zone.

The tests and conditions are listed in Table 3 for the treated rock dust (TRD) and non-treated rock dust (NTRD). All tests were conducted using a coal dust concentration of  $220\text{ g/m}^3$ . The nominal

percentage total incombustible content (TIC) includes the water and ash content of the coal as well as the rock dust. Two-thirds of the 165 kg dust mass was uniformly applied to the roof shelving while the remaining dust was applied to the wall shelves.



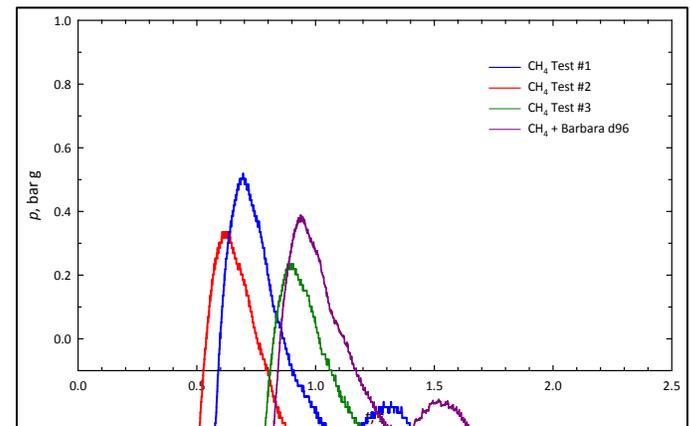
**Figure 3.** A Diagram of the registration system and the location of the measurement panels.

**Table 3.** Test conditions at the Experimental Mine Barbara. The ignition coal boost is the addition of 8.7 kg of coal dust adjacent to the baffle for approximately 3 m.

Test	Rock Dust Type	Nominal % TIC	Ignition
1	TRD	60	methane
2	NTRD	60	methane
3	TRD	60	methane with d38 coal boost
4	TRD	50	methane with d96 coal boost
5	NTRD	50	methane with d96 coal boost
6	TRD	50	methane with d96 coal boost
7	NTRD	50	methane with d96 coal boost
8	TRD	50	methane with d96 coal boost
9	NTRD	50	methane with d96 coal boost
10	NTRD	60	methane
11	TRD	60	methane

## RESULTS

As shown in Figure 4, the methane-only ignition tests have fairly good repeatability. A final methane-only test was conducted with the 3 m of fine d96 coal dust added immediately outby the methane zone. The pressure trace of this test was consistent with those of the first three methane-only tests. The cause of the observed offsets along the horizontal axis is not known but may be due to the path of the signal initiating the ignitor which runs over 100 m from the surface.



**Figure 4.** Ignition pressure histories measured at 20 m.

Figure 5 displays the pressure histories at each measurement location for Test #3, 60% TRD. This typical example shows the advance of the explosion down the entry as each of the pressure peaks occur with the explosion losing strength with distance. The positive portion of the pressure curve (duration) shortens with distance when the reflected shock wave reverses the airflow.

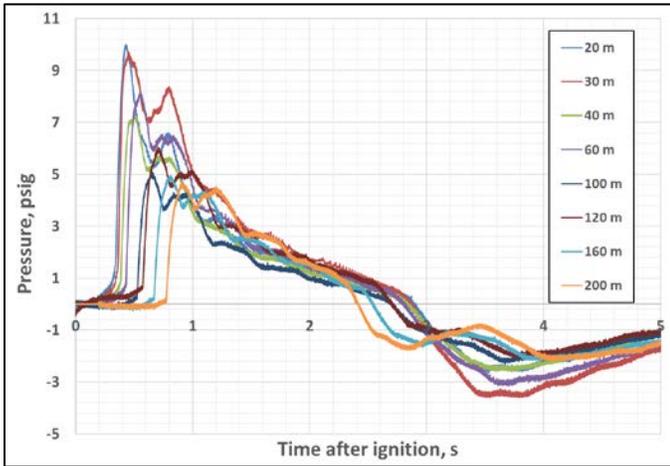


Figure 5. A typical example of pressure histories at each measurement location. This is Test #3.

The strength of the explosion can be examined by considering the pressure impulses at each measurement location. The pressure impulse is the integral from the moment when the explosion pressure exceeds 10% of its maximum value until the time that the pressure drops below 0 bar g. In order to account for the varying ignition strength influences, the pressure impulse at each measurement location is normalized by the ignition pressure impulse. This scaled impulse is equal to the pressure impulse divided by the ignition pressure impulse. The ignition pressure impulse,  $I_{p,ig}$ , is measured at 20 m, before the dusted zone and its influence, and is the positive integral of the curve until it reaches its first maximum pressure in the pressure history. See the inset of Figure 6 for an illustration of the ignition pressure impulse,  $I_{p,ig}$ . By using this definition of ignition pressure impulse, the effects of the reflected pressure wave (and associated dust from the dust zone) are not included. The scaled pressure impulses at each measurement location are shown for each test in Figure 6.

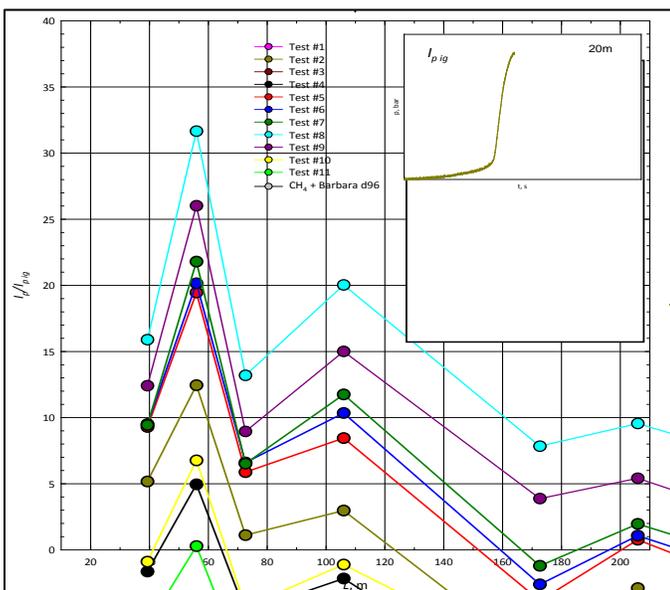


Figure 6. Scaled pressure impulses for each test at each measurement location.

To compare inerting properties of TRD and NTRD dusts, average values of scaled impulses have been calculated for the similar mixtures of coal/rock dust (50 % and 60% TIC). The tests are listed in Table 4. The smaller average impulse indicates greater explosion intensity reduction. For example, at the 50% TIC nominal concentration, the average explosion intensity for the treated rock dust (15.6) is slightly lower than that of the NTRD (16.7). At 60% TIC, the average explosion intensity of 7.7 for the TRD is lower than the average impulse of 11.8 for the NTRD. These averages also suggest that the performance of TRD increases with increasing rock dust percentage.

Table 4. Listing of average impulses at 100 m when using 60% and 50% TIC of treated and non-treated rock dusts.

Nominal % TIC	Type of Rock Dust	Average Impulse at 100 m ( $I_p/I_{p,ig}$ )
60%	TRD	7.7
60%	NTRD	11.8
50%	TRD	15.6
50%	NTRD	16.7

To further examine the consequence of rock dust treatment on inerting effectiveness, the average scaled pressure impulses were compared at each set of test conditions (nominal % TIC, TRD vs. NTRD). Figure 7 shows this data where each data point represents the average scaled impulse at each of the 8 measurement locations along the test gallery (20, 30, 40, 60, 100, 120, 160, and 200 m outby the methane zone). This graph reveals that the 50% TRD mixture is slightly more effective at inerting than the 50% NTRD mixture; although the differences are likely not significant given the width of the standard deviation bars. If the treated and NTRD/coal dust mixtures had equivalent inerting effectiveness, the markers would fall along the black diagonal line. However, the NTRD scaled pressure impulses are consistently larger than the scaled pressure impulses for the TRD at the same measurement locations. In tests with a 60% nominal %TIC, the data shows a greater inerting advantage with the TRD compared to the NTRD. This data implies improved inerting performance on behalf of the TRD at the higher concentration, especially considering that these tests were conducted in higher relative humidity, ranging from 75% – 92%.

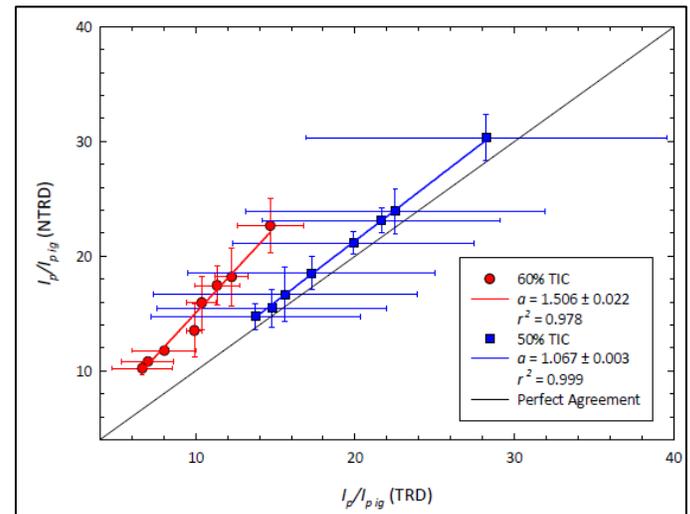


Figure 7. A comparison of the scaled pressure impulses at each measurement location. Error bars represent standard deviations of the averages.

Based upon the results from this limited testing, the capability of a TRD to suppress a coal dust explosion is at least as good as that of a NTRD. For larger values of nominal % TIC, the capability seems to be even better. Based on the preliminary laboratory tests conducted in NIOSH's 20-L chamber, there is no physical reason for uniform coal dust/TRD mixtures to be less explosible than those of coal dust/NTRD. The difference may be explained by the differences in dispersibility of the rock dusts; in that for similar tests, an explosion pressure wave

may produce a cloud having a larger treated rock dust content than non-treated rock dust content, especially if the humidity in the gallery is high. It was observed that at high humidities, non-treated rock dust tended to agglomerate even during distribution of the dust mixtures on the ribs and shelves. Large agglomerates are difficult to entrain and the dust cloud formed during an explosion test would likely contain less rock dust than present in the initial mixture.

#### **SUMMARY**

The National Institute for Occupational Safety and Health (NIOSH) conducts research to reduce the risk of mine disasters and provide workplace solutions to reduce the risks associated with accumulations of combustible and explosible materials. A series of large-scale tests were conducted at the Polish Experimental Mine Barbara (EMB) to compare the relative inerting effectiveness of an untreated rock dust to that of a rock dust treated to resist moisture absorption.

The treated rock dust appeared to perform as well as the untreated rock dust at a nominal % TIC of 50%. At a nominal % TIC value of 60%, the treated rock dust appeared to be even more effective since the scaled pressure impulses and their standard deviations were smaller than that of the non-treated rock dust. Therefore, it would appear that the rock dust treated for anti-caking is, at least, as effective as the non-treated rock dust for attenuating a propagating coal dust explosion. Preliminary results indicate that this stearate treated non-caking rock dust is both consistent with the anti-caking intent of 30 CFR 75.2 and performed better than a similar sized non-treated rock dust under the same large-scale experimental test conditions.

This study was limited by the amount of testing that could be conducted at EMB given the financial constraints for this effort. Additional testing would further confirm the statistical differences in effectiveness between the treated and non-treated rock dusts. Since the typical rock dusting practice is an intermittent batch operation, stratified layers of coal and rock dust may exist. Therefore, future testing should address the remaining questions regarding how layering of the coal and rock dusts could affect the performance of the treated and untreated rock dust in dry and wet conditions.

#### **DISCLAIMER**

Mention of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health. The findings and conclusions in this paper are those of the authors and do not necessarily represent the views of NIOSH.

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