



Influence of specific surface area on coal dust explosibility using the 20-L chamber

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ABSTRACT

The relationship between the explosion inerting effectiveness of rock dusts on coal dusts, as a function of the specific surface area (cm^2/g) of each component is examined through the use of 20-L explosion chamber testing. More specifically, a linear relationship is demonstrated for the rock dust to coal dust (or incombustible to combustible) content of such inerted mixtures with the specific surface area of the coal and the inverse of that area of the rock dust. Hence, the inerting effectiveness, defined as above, is more generally linearly dependent on the ratio of the two surface areas. The focus on specific surface areas, particularly of the rock dust, provide supporting data for minimum surface area requirements in addition to the 70% less than 200 mesh requirement specified in 30 CFR 75.2.

1. Introduction

Past studies (Amyotte et al., 1995; Amyotte, 1996; Dastidar et al., 2001; Cashdollar and Hertzberg, 1985; Cashdollar et al., 1987, 1989; Cashdollar, 1996, 2000; Harris et al., 2015; Cybulski, 1975; Man and Harris, 2014; Rice, 1911; Rice et al., 1927a, 1927b; Richmond et al., 1975; Sapko et al., 2000) have shown the influence of coal's volatility and particle size on its explosibility and rock dust inerting requirements. Such studies led to the formulation of the initial legal requirement that mine dust in bituminous coal mines (anthracite mines are exempted due to their much lower volatility) must have an inert content of at least 65% in entries and 80% in air return passageways (CFR, 2010). This distinction was due to two reasons: (1) the fineness of the coal dust that is carried by the ventilation currents into the returns, and (2) the finding from experimental mine studies, conducted in both the Bruceton Experimental Mine (BEM) and the larger entries at the Lake Lynn Experimental Mine (LLEM), that coal dust with 80% passing through a 200-mesh screen ($< 75 \mu\text{m}$) required an 80% total incombustible content to be non-explosible (Cashdollar et al., 2010). The total incombustible content was defined as including the ash component of the coal and any moisture in the inspector-collected mine sample.

The advent of newer mining machinery with higher shearing power produced finer coal particle sizes. Therefore, the original 65% requirement pertinent to coal sizes with 20% passing through 200-mesh

sieves was no longer adequate or realistic. Using data from an extensive survey of coal mines throughout the U.S. by the Mine Safety and Health Administration (MSHA), the National Institute for Occupational Safety and Health (NIOSH) found that the average of the mines sampled had coal dust containing about 40% passing through a 200-mesh screen, and many mines produced even finer coal dust (Cashdollar et al., 2010). The difference between the coal dust in mining entries and returns is thereby diminished. NIOSH therefore recommended that the minimum total incombustible content of mine dusts in both entries and returns be set at 80%. This was later codified into law in title 30 CFR 75.2 (CFR, 2011).

Recent studies have shown that the specific surface areas (SSAs) of both coal dusts and rock dusts are relevant to issues of the explosibility of their mixtures (Man and Harris, 2014; Harris et al., 2015). It is desirable, however, to have a more quantitative relationship at hand. This study is focused primarily on the coal dust surface area. Those surface areas were determined primarily for fractions of the pulverized Pittsburgh coal (PPC) that has been used over many years in studies reported by U. S. Bureau of Mines (USBM) and NIOSH researchers. The surface areas of fractions of a particular reference limestone rock dust are also at issue and will be quantitatively related to inerting efficiency. That reference rock dust, which meets the 30 CFR 75.2 size standard (70% through 200-mesh), is the one used to inert the fractions of the two types of coal dusts reported here, and is the one that has been used predominantly in the USBM and NIOSH 20-L chamber studies and at

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the NIOSH LLEM.

This study is based primarily on explosion tests of mixtures of the reference rock dust with high-volatility bituminous coal (37% volatiles, Pittsburgh Seam) and low-volatility bituminous coal (17% volatiles, Pocahontas (Poc) Seam No. 3) in the Pittsburgh Mining Research Division (PMRD) 20-L explosibility chamber. Both coals have a 6% ash content. Reference is also made to the seminal work in Poland by Cybulski (1975) on inerting Polish coal (the Wujek mine coal having 36% volatiles and 14% ash) by clay-slate rock dust in the Barbara mine gallery. The inerting concentration of rock dust (RD) in a rock dust – coal dust mixture in the 20-L chamber is the minimum RD content (mass %) that will provide a non-explosible mixture.

2. Experimental

2.1. Particle size/area measurement

The particle size distribution of the coals, limestone rock dust, and their size fractions that were tested was determined using a Beckman-Coulter LS 13 320 laser scattering instrument in its air entrainment mode of operation. The operating procedures recommended by the manufacturer were followed. This instrument measures the scattering of a 780-nm laser beam by the air-dispersed dust at various angles to the beam direction, and uses the Mie scattering theory to analyze the particles in terms of equivalent spherical particle scatterers. The complex index of refraction ($n + ik$) of both the particle and medium must be specified. For air, this is simply 1.00 without an imaginary (i) component ($k = 0$). For limestone rock dust, this is taken as 1.68 without an imaginary component ($k = 0$). This value, taken from handbooks for dolomite (CaMgCO_3) and aragonite (CaCO_3), is more appropriate for white (non-absorbing) dusts (CRC, 1984). Colored limestone will, however, have an imaginary component, $i \geq 0.1$. Inclusion of such an imaginary component could change the calculated specific surface area by 1–2% for $k = 0.1$ and 40% for $k = 0.5$. For coal, the complex refractive index has both a very significant imaginary component (it is strongly absorbing) and is not well characterized. It was taken as $1.80 + 0.3i$ as previously reported (Harris et al., 2015). This complex refractive index for bituminous coal is also cited by Menguc et al. (1994). The above values for limestone and coal are those listed by the instrument maker for CaCO_3 and carbon. The introduction of a degree of arbitrariness in the scattering parameters requires that analyses be based on consistency in these parameters. The significant differences observed when using different light-scattering instruments and using other SSA methods also mitigates against combining such data. The size distribution given by the laser scattering instrument is based on equivalent spherical scatterers, and the calculated specific surface area is based on the D_{32} surface averaged diameter

$$D_{32} = \frac{[\sum N_i d_i^3 \delta d]}{[\sum N_i d_i^2 \delta d]} \quad (1)$$

with N_i as the number of particles in that size range with a constant width, δd . The numerator is seen to be proportional to the total volume of the particles treated as spheres, while the denominator is seen to be proportional to the total surface area of the particles treated as smooth spheres.

This average diameter of an equivalent spherical particle and its density are then related to the SSA of such a collection of smooth spherical particles by

$$A = \frac{6}{\rho D_{32}(\text{cm})} = \frac{60,000}{\rho D_{32}(\mu\text{m})} \quad (2)$$

where A is the area in cm^2/g , ρ is the density in g/cm^3 , and D_{32} is the mean diameter in cm or μm . A (cm^2/g) is calculated from the area to volume ratio of spheres of $6\pi D^2/\pi D^3$, or $6/D$. This gives $6/\rho D_{32}$ as the surface area per gram of the particles. For the coals in question, the

Table 1

The inerting concentrations of the reference limestone rock dust (RD) with Pittsburgh Seam coal dusts (CD) expressed as the ratio %RD/%CD (Z) and %Incombustible/%Combustible (Z') in the rock dust-coal dust mixtures. The surface weighted average dust diameter (D_{32}) and specific surface areas, SSA (cm^2/g), of the dusts are given, as well as the ratio of the SSA of the coal to rock dusts ($A_{\text{cd}}/A_{\text{rd}}$). The numbers in parentheses alongside the coal and rock dust designations are the references to the data sources: (1) refers to recent data.

	%RD to Inert	% Incomb.	Z	Z'	D_{32} (μm)	SSA_{calc} (cm^2/g)	A_{cd} A_{rd}
Reference RD (1)	NA	100	NA	NA	7.4	3000	NA
PPC (1)	76	77.4	3.17	3.44	17	2700	0.90
Pgh coarse –60 m (1)	66	68.0	1.94	2.13	23	2000	0.67
Pgh coarse (1)	44	47.4	0.79	0.90	71	650	0.22

Coal Density $\rho = 1.3 \text{ g}/\text{cm}^3$; Limestone Density $\rho = 2.7 \text{ g}/\text{cm}^3$; $\text{SSA} = 60,000/\rho D_{32}$.

density is taken as $1.3 \text{ g}/\text{cm}^3$, while it is $2.7 \text{ g}/\text{cm}^3$ for the limestone rock dust.

It must be emphasized that this area is not equivalent to the area given by a BET measurement (multi-layer gas adsorption) which takes into account the surface roughness and crevices. The BET areas are consistently greater due to the fact that the particles in question are neither spherical nor smooth. However, the laser scattering instruments are in wider use and may be used for relative area measurements. Nor is it clear that the actual surface areas are as important as their geometric areas (πd^2 for a spherical surface and $\pi d^2/4$ for its scattering cross section). That is certainly the case for the radiation shielding effect of inert particles mixed with coal dust. Even the coal particle temperature rise and consequent liberation of fuel vapors by the advancing flame front is more a matter of particle size than actual surface area. While the surface reaction rate with air oxygen is a function of accessible surface area, that may be of less importance than the release of flammable volatiles from the particle interior i.e., collisions and consequent reaction between oxygen and fuel molecules in the gas phase are far more frequent than the collisions of oxygen molecules with coal particle surfaces.

The data on coal particle size relative to explosibility reported by Cashdollar (1996) and which is presented here is based on a combination of sieve analysis and Coulter counter measurements. The latter instrument featured the passage of individual particles in a stirred liquid through a small orifice into a counting cell. The counts were based on the effective volume and capacitance change in the cell due to the moving particle. The results can, therefore, not be directly compared to the laser scattering results, but can serve to relate the average particle size and surface area of both the coal and rock dusts with the inerting requirements for those sets of measurements. The 20-L chamber described in Cashdollar (1996) is the same as that used by NIOSH researchers in subsequent years, as is the criterion for explosibility.

The Blaine apparatus for surface area measurement, which involves air permeation through a packed bed of particles, was used by the Polish researchers (Cybulski, 1975) and is referenced here. The Blaine apparatus has the advantage of simplicity and low cost. It also appears to correlate with the more direct specific surface area measurement techniques, but can be more operator dependent.

2.2. Explosion chamber

The 20-L explosion chamber is a near-spherical steel chamber designed by the late Kenneth L. Cashdollar (Cashdollar and Hertzberg, 1985) and has been in use since 1982 by the USBM and NIOSH. It is also the default explosion chamber illustrated in the ASTM standard for measuring the minimum explosibility concentration of flammable

Table 2

The inerting concentrations of the reference limestone rock dust (RD) with Pittsburgh Seam coal dusts (CD) expressed as the ratio %RD/%CD (Z) and %Incombustible/%Combustible (Z') in the rock dust-coal dust mixtures. The surface weighted average dust diameter (D_{32}) and specific surface areas, SSA (cm^2/g), of the dusts are given, as well as the ratio of the SSA of the coal to rock dusts (A_{cd}/A_{rd}). The numbers in parentheses alongside the coal and rock dust designations are the references to the data sources: (2) refers to data from [Cashdollar \(1996\)](#) (Pittsburgh).

	%RD to Inert	% Incomb.	Z	Z'	D_{32} (μm)	$\text{SSA}_{(\text{calc})}$ (cm^2/g)	A_{cd}/A_{rd}
Reference RD (2)	NA	100	NA	NA	12	1850	NA
PGH 1–40mesh (2)	53	55.8	1.13	1.26	77	590	0.32
PGH2-70mesh (2)	68	69.9	2.13	2.32	37	1250	0.67
PGH3-PPC (2)	74	75.6	2.85	3.09	34	1400	0.73
PGH4-200mesh (2)	79	80.3	3.76	4.07	24	1900	1.04
PGH5-fines A (2)	83	84.0	4.88	5.26	16	2900	1.56
PGH6-fines B (2)	83	84.0	4.88	5.26	17	2700	1.47
PGH7-fines C (2)	87	87.8	6.69	7.18	12	3850	2.08

Coal Density $\rho = 1.3 \text{ g/cm}^3$; Limestone Density $\rho = 2.7 \text{ g/cm}^3$; SSA = $60,000/\rho D_{32}$.

Table 3

The inerting concentrations of the reference limestone rock dust (RD) with Pittsburgh Seam coal dusts (CD) expressed as the ratio %RD/%CD (Z) and %Incombustible/%Combustible (Z') in the rock dust-coal dust mixtures. The surface weighted average dust diameter (D_{32}) and specific surface areas, SSA (cm^2/g), of the dusts are given, as well as the ratio of the SSA of the coal to rock dusts (A_{cd}/A_{rd}). The numbers in parentheses alongside the coal and rock dust designations are the references to the data sources: (3) refers to data from [Cashdollar \(1996\)](#) (Pocahontas).

	%RD to Inert	% Incomb.	Z	Z'	D_{32} (μm)	$\text{SSA}_{(\text{calc})}$ (cm^2/g)	A_{cd}/A_{rd}
Reference RD (2)	NA	100	NA	NA	12	1850	NA
Poc-1 -120 mesh (3)	60	62.4	1.50	1.66	39	1200	0.64
Poc-2 (3)	64	66.2	1.78	1.96	19	2400	1.31
Poc-3 (3)	76	77.4	3.17	3.43	18	2600	1.38
Poc-4 (3)	78	79.3	3.55	3.84	17	2700	1.47
Poc-5 (3)	77	78.4	3.35	3.63	15	3100	1.66
Poc-6 (3)	82	83.1	4.56	4.91	11	4200	2.27
Poc-7 fines (3)	85	85.9	5.67	6.09	9	5100	2.77
Coarse Poc (3)	37	40.8	0.59	0.69	77	600	0.32

Coal Density $\rho = 1.3 \text{ g/cm}^3$; Limestone Density $\rho = 2.7 \text{ g/cm}^3$; SSA = $60,000/\rho D_{32}$.

Table 4

The Z and Z' values for the inerting by the reference rock dust fractions of the standard pulverized Pittsburgh (Bruceton) Seam coal (PPC) are given together with the specific surface areas (SSAs) of the coal and rock dust fractions. The inverse of the SSA of the rock dusts is given together with the ratio of the SSAs of the coal to rock dust (A_{cd}/A_{rd}). The numbers, as in [Tables 1–3](#), refer to the data sources; (4) is recent data.

	%RD to Inert	% Incomb.	Z	Z'	$\text{SSA}_{(\text{calc})}$ (cm^2/g)	$1/\text{SSA}$ (g/m^2)	A_{cd}/A_{rd}
PPC	NA	NA	NA	NA	2700	3.7	NA
RD < 10 μm (4)	70	71.8	2.33	2.55	5250	1.9	0.51
RD 10–20 μm (4)	70	71.8	2.33	2.55	2400	4.2	1.13
RD < 75 μm (4)	70	71.8	2.33				
RD 20–38 μm (4)	75	76.5	3.00	3.26	1100	9.1	2.45
RD 20–75 μm (4)	85	85.9	5.67	6.09	590	17.0	4.58
RD 38–53 μm (4)	85	85.9	5.67	6.09	480	20.8	5.63
RD38–75 μm (4)	85	85.9	5.67	6.09	390	25.6	6.92
RD 53–75 μm (4)	90	90.6	9.00	9.64	280	35.7	9.64
RD > 38 μm (4)	90	90.6	9.00	9.64	400	25.0	6.75
Ref. RD (4)	73	74.6	2.70	2.94	2500	4.0	1.08

Coal Density $\rho = 1.3 \text{ g/cm}^3$; Limestone Density $\rho = 2.7 \text{ g/cm}^3$; SSA = $60,000/\rho D_{32}$.

dusts, E 1515 ([ASTM, 2015a](#)). It features a milder and longer dispersion air pulse (10 vs 20 bar, and 300 vs 30 ms) to disperse the dust and form a uniform cloud, and a longer ignition delay time between the end of the air pulse and the ignition event (100 ms vs. ~30 ms) as compared to

the commercially available Kuhner/Siwek sphere. This chamber thus features less particle degradation due to the dispersion mechanism and less turbulence than the Kuhner analog. The latter is the default 20-L chamber described in ASTM E 1226 for use in measuring volume normalized maximum rates of pressure rise (K_{st}) and the explosion intensity classification (K_{st} class) of explosive dusts that are designed to be equivalent to 1-m³ chamber results ([ASTM, 2015b](#)).

The pyrotechnic igniters (from Fr. Sobbe, GmbH) used for the inerting studies reported here are 5 kJ in calorimetric energy. They produce a spray of incandescent particles when electrically ignited that are luminescent for about 120 ms. The pressure rise in the chamber due to the heating by the igniter alone (P_{ign}) is measured (five duplicates from a batch of igniters are used to arrive at an average value for the batch), and this average pressure rise is then subtracted from the total pressure of an explosion to arrive at the explosion pressure rise ($\Delta P_{expl} = P_{expl} - P_{ign} - P_{init}$) and the pressure ratio [PR = $(P_{expl} - P_{ign})/P_{init}$]. Here, P_{expl} is the maximum value with time of the absolute total explosion pressure, and P_{init} is the initial absolute chamber pressure immediately prior to ignition. Reliable measurements of the inerting ratios of rock dust to coal dust require the use of 3–5 duplicates at each of a range of coal dust loadings to discover the worst-case event. The criterion for judging whether an explosion has occurred is taken to be a pressure ratio (PR) ≥ 2 or a corrected pressure rise (ΔP_{expl}) of at least 1 bar. Relating the inerting values so obtained in this chamber to those obtained in the Kuhner chamber is yet to be adequately determined, although there is data to suggest that the results are similar for the Pittsburgh seam coal but not for the more friable Pocahontas No. 3 ([Dastidar et al., 1997](#)). In any case, the inerting results using the USBM chamber have been related to the results of large-scale explosions in the LLEM—i.e., the 20-L results were found to be lower by some 5% than the large-scale results. Therefore, this study may also be related to the results of a large-scale inerting study ([Cashdollar, 1996, 2000; Cashdollar and Hertzberg, 1989; Chawla et al., 1996; Dastidar et al., 2001; NIOSH, 2010; Sapko et al., 2000](#)).

3. Results and discussion

The results are summarized in [Tables 1–3](#). They relate the geometric specific surface areas (SSAs) of the coal dusts (CDs) to the rock dust content (% RD) needed to inert such mixtures using the reference RD. The SSAs are those calculated from the coal density and measured D_{32} values using equation (2). SSAs will be linearly related to the inerting mass ratio of RD to CD (Z) that is given in the tables. The mass ratio of incombustible to combustible content (Z') is also given as a more generalizable feature of RD inerting. The incombustible content includes the ash content of the coal together with the rock dust, while the ash is excluded from the combustible content of the coal. The ash content of the coal is 6% in the case of the Pittsburgh and Pocahontas coals as measured by the conventional ASTM standards for the

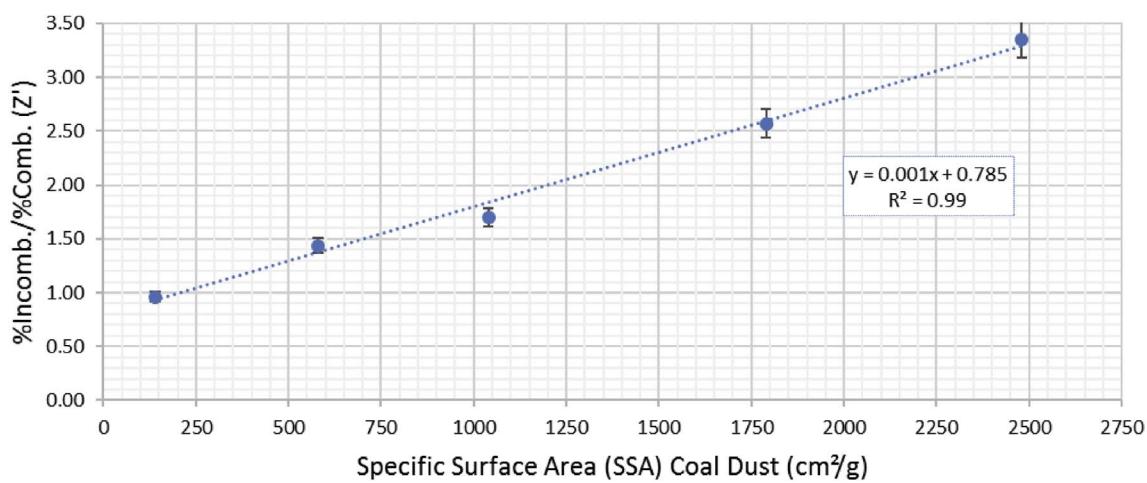


Fig. 1. Polish gallery data – Cybulski (1973): %Incomb./%Comb. (Z') to inert Polish coal fractions by clay-slate dust vs. SSA of coal dust.

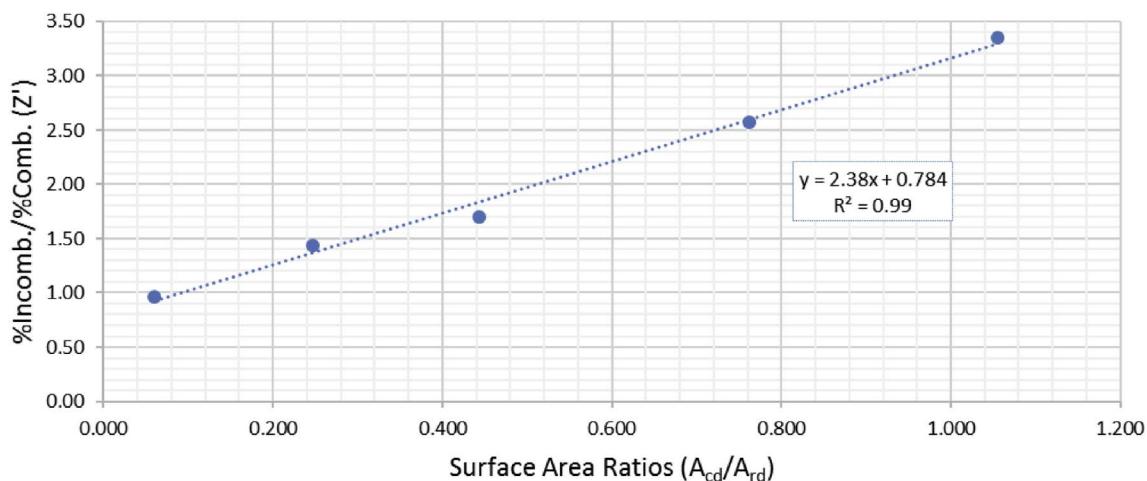


Fig. 2. Polish gallery data – Cybulski (1973): %Incomb./%Comb. (Z') to inert Polish coal fractions by clay-slate dust vs. surface area ratios of the coal and stone dusts (Acd/Ard).

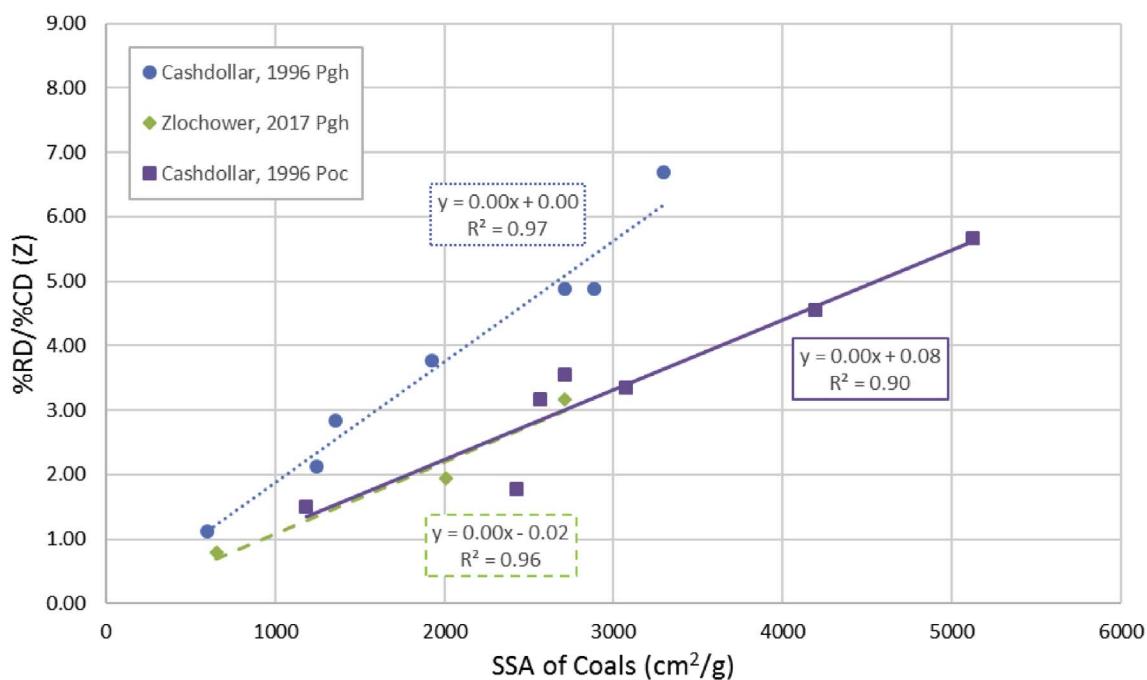


Fig. 3. %RD/%CD (Z) to inert coal fractions by the reference RD vs. the SSA of the coal dusts.

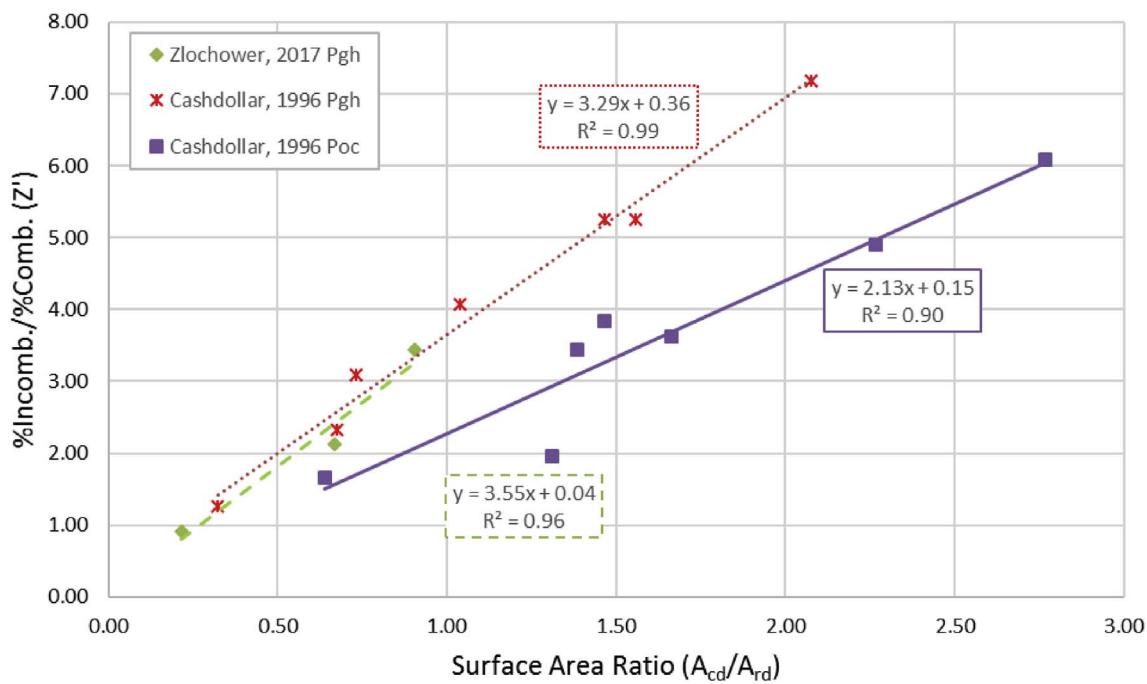


Fig. 4. %Incomb./%Comb. (Z') vs. surface area ratios (A_{cd}/A_{rd}) for reference RD inerting of coal fractions.

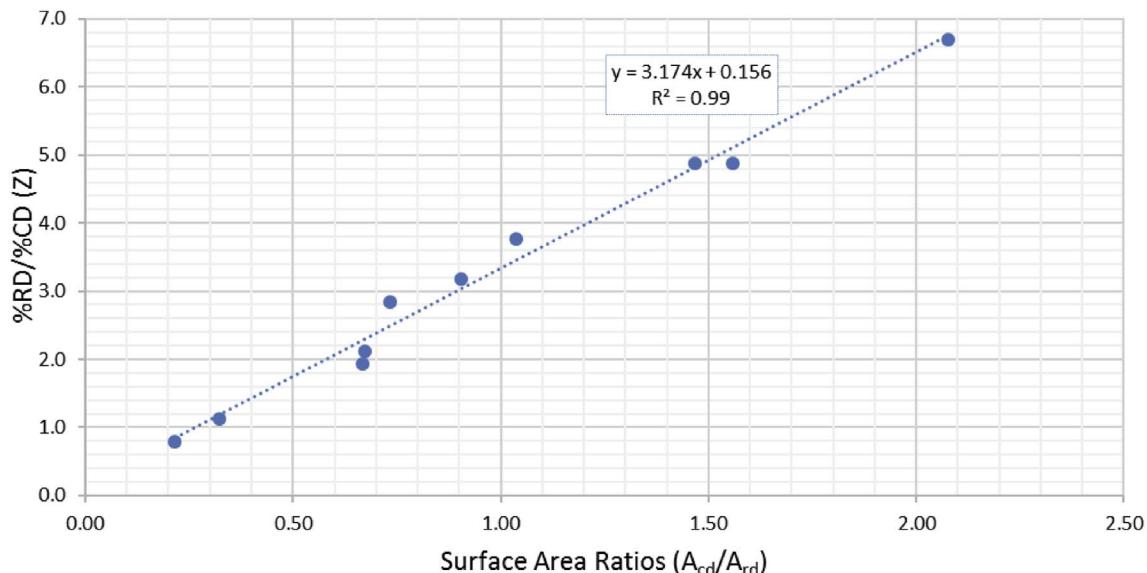


Fig. 5. %RD/%CD (Z) to inert Pgh coal dust fractions by the ref. RD vs. the surface area ratios (A_{cd}/A_{rd}) of the dusts – combined 1996 and 2015 data.

Proximate Analysis of coals and their ash content. The relationships of the rock and coal contents vs. the incombustible and combustible contents are given by:

$$\% \text{ incombustible} = \% \text{RD} + f_{cd} * \% \text{Ash} \quad (3a)$$

$$\% \text{ combustible} = \% \text{CD} - f_{cd} * \% \text{Ash} \quad (3b)$$

with f_{cd} as the mass fraction of CD in the mixture. The coal is considered to be dry, with the dusts having been kept in a desiccator cabinet with an anhydrous CaSO_4 desiccant. The ratio of the incombustible to combustible content of the mixture (Z') is proportional to the ratio of the rock dust mass (m_{rd}) to coal dust mass (m_{cd}), Z , and bears the same linear relationship with SSA and area ratios, as is evident from the following relationship:

$$Z' = \frac{(Z + f_a^c)}{(1 - f_a^c)} \quad (4)$$

where Z' is % Incombustible/% Combustible or the mass of incombustible material over the mass of combustible material (m_{incomb}/m_{comb}) (g/g), Z is %RD/%CD or m_{rd}/m_{cd} in the mixture, and f_a^c is the fraction of ash in the coal (0.06 for the two US coals considered). Equation (4) then becomes:

$$Z' = \frac{(Z + 0.06)}{0.94} \quad (5)$$

It should be noted that the inerting ratios (Z , Z'), and surface areas and area ratios of the coals designated (2) and (3) in Tables 2 and 3, respectively, are calculated from data on D_{32} and %RD to inert as reported in Cashdollar (1996). Those D_{32} values were determined from a combination of sieving and Coulter counter measurements, as

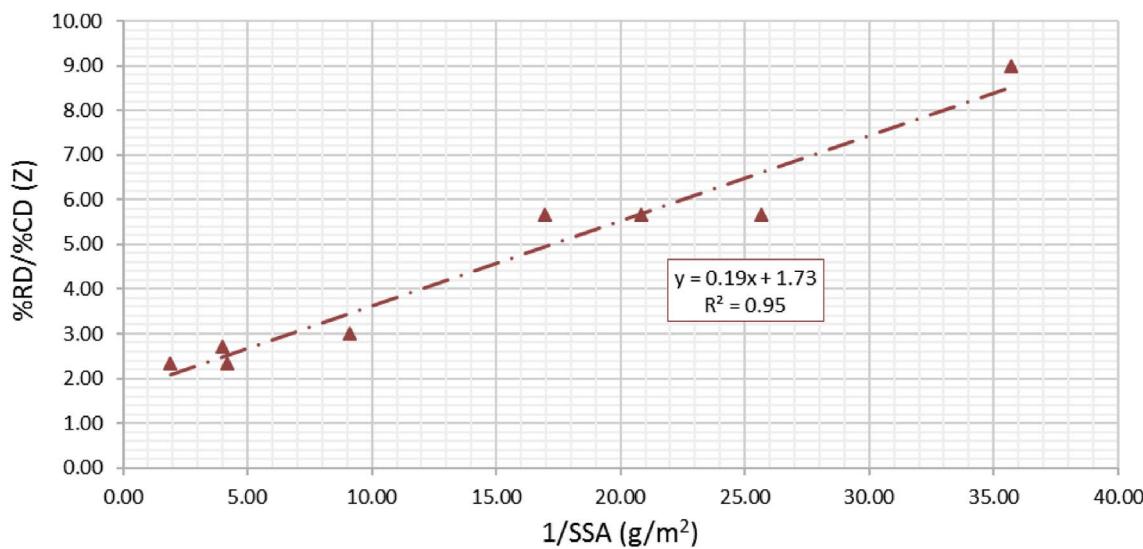


Fig. 6. %RD/%CD (Z) to inert PPC by the reference RD size fractions vs. 1/SSA of the rock dust.

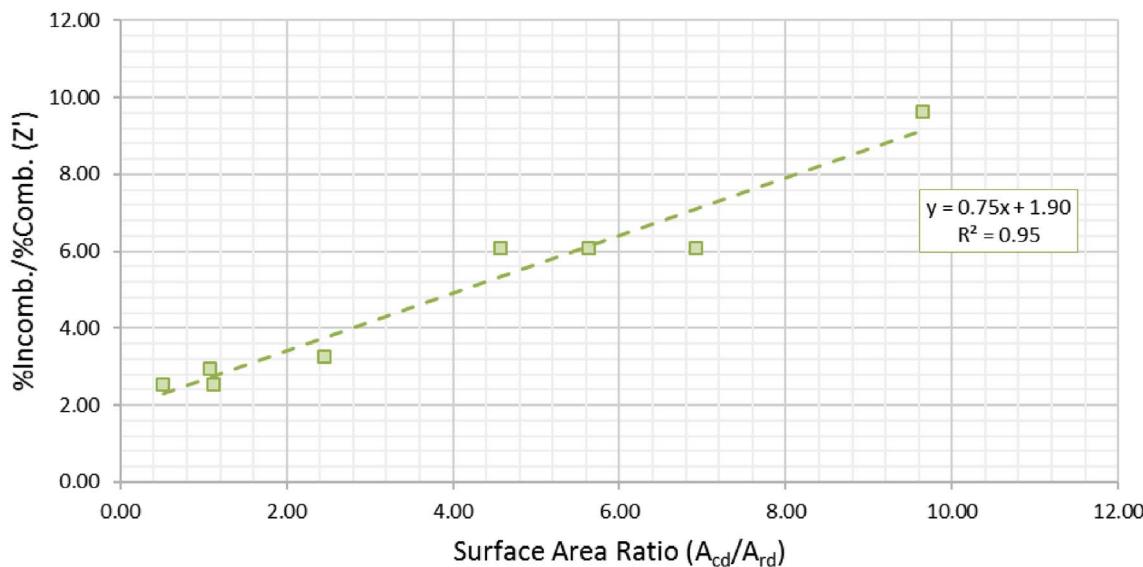


Fig. 7. %Incomb./%Comb. (Z') needed to inert PPC by the ref. RD fractions vs. the specific surface area ratios (Acd/Ard).

mentioned above. The results are not expected to be comparable to the laser scattering results reflected in the three Pittsburgh (Pgh) coal [PPC (100% < 250 µm, 67% < 75 µm), coarse coal (25% < 250 µm, 9% < 75 µm), and the –60-mesh fraction of the latter], the fractions (1) in Table 1, and the reference rock dust fractions (4) in Table 4. The latter values for D_{32} and the SSAs were obtained using the Beckman-Coulter laser scattering instrument with air dispersion. The absolute values for the SSAs of the same nominal dust in the two techniques are not expected to agree. In addition, there are variations inherent in the techniques and in sampling. Thus, the specific surface area (SSA) of PPC was calculated from Cashdollar data as $1400 \text{ cm}^2/\text{g}$, but was determined to be $2700 \text{ cm}^2/\text{g}$ in the laser scattering instrument. Similarly, the reference RD SSA was calculated as $1850 \text{ cm}^2/\text{g}$ from Cashdollar data, but as $3000 \text{ cm}^2/\text{g}$ with the scattering instrument. However, the ratios of the surface areas of the coals and rock dust as determined by the same technique should be more consistent. We will demonstrate that those ratios can be used to combine such data to give a general linear relationship of Z or Z' to area ratios (A_{cd}/A_{rd}).

We note that the rock dust concentration needed to inert coal dusts, when expressed as the ratio of the rock to coal dust in the mixture (Z) or incombustible to combustible (Z') ratio, is a linear function of the

specific coal surface areas (SSAs) for Polish coal fractions (Fig. 1). The linear dependence of Z' on the SSA of coal dust fractions was originally noted by Cybulski (1973, translated 1975). The percent incombustible needed to inert five Polish coal fractions was determined in the Barbara surface gallery (5 m² cross section and 140 m length) and correlated with the SSA of the Polish coals. While that plot required a polynomial fit, the corresponding plot of Z' was linear as shown in Fig. 1. The ratio of the coal surface areas to that of the same clay-slate dust used must also have the same relationship, as shown in Fig. 2. Large-scale determinations of explosion inerting are based on the suppression of explosion propagation in a mine entry/gallery by the rock dust content in a rock dust-coal dust mixture that was dispersed in the gallery, as was the case in the Polish study (Cybulski, 1973). The finding here, which reviews and reports the results obtained in a 20-L chamber, is that the same is true of American high- and low-volatile bituminous coals (Pittsburgh and Pocahontas, respectively), and for limestone rock dust as well as the clay-slate rock dust used in the Polish work (Figs. 3 and 4). This finding leads to the assumption of a general linear dependence of rock dust inerting (the Z and Z' ratios) on the SSA of coal dusts. The linear dependence of Z (Z') with the coal SSA and the surface area ratios is found whether a pressure criterion is used to determine non-

explosibility in a laboratory vessel, or whether the explosion propagation is curtailed in a large-scale test.

Figs. 1–4 show the good ($R^2 \geq 0.90$) linear relationship of Z and Z' to SSA and the surface area ratios (A_{cd}/A_{rd}) of the Pittsburgh, Pocahontas, and Polish coal dusts. Fig. 5 shows how the data by Cashdollar (1996) on Pittsburgh (Pgh) coal dust fractions inerted by the reference rock dust and such current data can be combined in a plot of Z vs. A_{cd}/A_{rd} , despite the differences in the method of surface area determination. Fig. 6 shows the same goodness of fit ($R^2 = 0.95$) for the Z values in PPC inerting by the reference limestone rock dust size fractions vs. $1/SSA$ of the latter. Fig. 7 shows the same relationship of Z' to the surface area ratios of coal to rock dust. The area ratios are thus a more likely candidate for combining data on a coal if the SSAs of the coal and rock dust are determined by the same method.

4. Conclusion

This study reports on the inerting of various high- and low-volatile bituminous coals (Pittsburgh, Pocahontas, and a Polish coal) by a reference limestone rock dust, a clay-slate dust (Polish study), and their size fractions. A good linear relationship is shown of the inerting ratio of rock to coal dust (Z) or incombustible to combustible content of the mixtures (Z') to the surface area ratios of coal to rock dust (treated as smooth spheres). As discussed, this relationship should hold true in general. However, the slopes and intercepts of these linear relationships will generally depend on the method and instrument used to determine the surface areas, as well as the explosibility chamber methodology, rock dust batch, and sampling. As shown here, in favorable cases, it is possible to combine data despite such differences.

The practical application of the above findings may lie primarily with the RD suppliers to coal mines in that it suggests that the calculated specific surface area (SSA) of their RD candidates is a key to meeting inerting performance requirements. Changes in particle size distribution as a result of equipment changes, or the deliberate exclusion of certain size fractions, will need to take the resulting SSA into consideration. Suppliers should insure that the SSA characterizing their acceptable RD candidates are not reduced when such changes are made.

Disclaimer

Mention of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health (NIOSH). 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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