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Effects of methane admixture, particle size and volatile content on the dolomite inerting requirements of coal dust

Paul R. Amyotte[a], Kenneth J. Mintz[b], Michael J. Pegg[a], Yu-Hong Sun[a] and Kenneth I. Wilkie[c]

Departments of [a]Chemical Engineering and [c]Agricultural Engineering, Technical University of Nova Scotia (TUNS) P.O. Box 1000, Halifax, N.S., B3J 2X4 Canada
[b]Canadian Explosive Atmospheres Laboratory, Mining Research Laboratories, CANMET Energy, Mines and Resources Canada, Ottawa, Ont. K1A 0G1 (Canada)

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Abstract

The dolomite inerting requirements of coal dust/air and methane/coal dust/air mixtures have been determined experimentally. All tests were conducted at initial pressures of nominally 1.0 bar in a 26-L spherical explosion bomb. Run-of-mine coal from the Prince, Lingan and Phalen seams of the Cape Breton Development Corporation was used. Two size fractions of each coal were tested at a single dust concentration of 0.5 kg/m^3, with dolomite concentrations ranging from 20% (on a weight basis) of the total solids mixture to the percentage required to suppress an explosion. It was observed that methane admixture brings about an increase in the dolomite percentage and the total incombustible content needed for suppression. The additional dolomite required in the presence of methane was predicted reasonably well by an empirical relationship developed by the U.S. Bureau of Mines. Coal particle size and volatility were also found to strongly affect the inerting level, with more dolomite being required for finer or higher volatility coals. The results from this work show that there is no rationale for relaxing the current rock dusting regulations in Canada.

Introduction

The scope of the present work is an investigation of small-scale, confined, deflagrative dust explosions. It is an experimental study, with the major piece of apparatus being a 26-L spherical explosion chamber. The material examined was coal dust produced from three run-of-mine coals. Two size fractions were generated for each of the three coals. The dolomite inerting requirements of each coal sample were investigated for the cases of coal dust alone and coal dust with admixed methane.

Of primary interest to the present authors is the prevention of dust explosions in coal handling facilities, particularly the underground coal mines of the Cape Breton Development Corporation (CBDC). Since 1968, CBDC, a Crown

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Corporation, has controlled coal mining operations on Cape Breton Island (located at the northeastern extremity of mainland Nova Scotia and linked to the mainland by a causeway since 1955). Coal mining in the area, however, dates back more than two centuries from the present time.

Since 1900 there have been 26 incidents involving fires and/or explosions in coal mines throughout the entire province of Nova Scotia. These incidents resulted in 294 fatalities, representing 15.9% of the total of 1,850 fatalities in mines throughout that time. The most serious explosion incident in a CBDC mine occurred in February, 1979 and resulted in 12 fatalities. A fire at the same location in April, 1984 led to one fatality and closure of the colliery (No. 26).

The term “inerting”, as applied to the mining of coal is a somewhat generic description of the practice of adding inhibitors to coal dust. This inhibitor addition can be carried out in a responsive manner to arrest flame propagation, as in the case of rock dust or water barriers, where the contents of the barriers are dispersed by the pressure wave from an explosion. Alternatively, premixing by hand or machine of rock dust with deposited coal dust is an example of inhibitor addition in a preventive manner. When added in the correct proportion, rock dust premixed with coal dust removes one of the conditions necessary for deflagration initiation, namely an explosible solids mixture.

Government regulations in Canada, the United States and many other countries require the use of rock dust (usually limestone or dolomite) as the chief inerting agent in coal mines. As with water, limestone and dolomite are generally viewed as thermal inhibitors by virtue of their heat-sink action. Additionally, rock dusts are effective as flame arrestors because of their ability to be simultaneously dispersed with coal dust [1]. Chemical inhibitors such as salt and ammonium phosphate have also been used in some countries; for example, both on an experimental basis in the United States, and salt, through an encrustation or binding technique, in West Germany. A good description of inerting requirements in coal mines, written from a practical point of view, has been given by Nagy [2]. He also describes rock dusting from an historical perspective by reviewing some of the early work in this field (such as, for example, Ref. [3]).

Experimental

Coal dust and dolomite

Coal samples from the Prince, Lingan and Phalen mines, and dolomite from the Kelly Cove (Cape Breton) deposit, were obtained from CBDC. The coal was run-of-mine and had not been processed prior to delivery to the Technical University of Nova Scotia (TUNS), where each coal was ground and sieved to produce two size fractions. There were thus six coal dust samples prepared for testing. They are referred to throughout this paper as Prince 1 and Prince 2, Lingan 1 and Lingan 2, and Phalen 1 and Phalen 2. Lingan is the oldest mine and is operated as a longwall advancing system; Phalen is the newest mine and is operated as a longwall retreat system. The Prince mine also is operated as a longwall retreat system. Unlike the coal samples, the dolomite was not processed in any manner after receipt at TUNS.

After grinding and sieving, each coal dust sample was thoroughly mixed and samples were withdrawn for particle size analysis and ultimate and proximate analyses. Particle size measurements were made using a Malvern Instruments (2600 Series) analyzer based on the principle of laser diffraction or ensemble light scattering. Particle size analysis results of all the coals, along with that of the dolomite, are shown in Table 1. It should be noted that the dolomite was relatively fine, and thus satisfied the conditions of being able to be dispersed with the coal dust and of having sufficient surface area to absorb thermal energy. The arithmetic volume or mass mean diameter, D_w, is the last entry in each row of Table 1. Equating the volume mean diameter with the mass mean diameter assumes a constant particle density; this assumption is valid for these coal samples. Proximate analyses of the coals are given in Table 2; the values

TABLE 1

Particle size analyses of coals and dolomite

Coal dust	Particle size distribution (wt.%)				D_w (μm)
	< 125 μm	< 75 μm	< 45 μm	< 20 μm	
Prince 1	100	95	76	44	23
Prince 2	100	100	88	53	19
Lingan 1	100	87	65	41	27
Lingan 2	100	98	83	53	18
Phalen 1	100	89	68	45	24
Phalen 2	100	100	89	60	15
Dolomite	94	76	56	32	37

TABLE 2

Proximate analyses of coals

Coal dust	Moisture (wt.%)	Ash (wt.%)	Volatiles (wt.%)	Fixed carbon (wt.%)
Prince 1	0.7	15.1	36.0	48.2
Prince 2	1.0	14.7	34.3	50.0
Lingan 1	0.2	18.4	31.9	49.5
Lingan 2	0.3	15.1	31.7	52.9
Phalen 1	0.3	35.2	26.3	38.2
Phalen 2	0.5	33.0	26.3	40.2

shown are the averages of three analyses done for each of the six dust samples. To prevent excessive loss of volatiles and surface oxidation, the coal dust was kept in an inert atmosphere over the duration of testing. A calcium/magnesium analysis of the dolomite indicated 55 wt.% $CaCO_3$ and 35 wt.% $MgCO_3$.

Explosion tests

Experiments were carried out on coal-dust/dolomite/air mixtures and methane/coal-dust/dolomite/air mixtures. A full set of tests was conducted for each coal type, particle size and methane concentration (0, 1 and 2%), with dolomite concentrations ranging from 20% (weight basis) of the total solids mixture to the percentage required to suppress an explosion. A single coal dust concentration of 0.5 kg/m^3 was used in all tests; the explosion characteristics of this concentration (without dolomite) were determined prior to the inerting experiments, and are described in the next section.

The explosion tests were conducted in a stainless steel, spherical vessel having a volume of 26 L (see Fig. 1). Prior to each run, the coal dust/dolomite mixture was placed in a curved tube located beneath a nozzle housed in the chamber bottom. Dust dispersion through the nozzle was achieved by an air blast from a 1-L reservoir pressurized to 13.8 bar (g). Also before each run, the explosion vessel was evacuated to 0.53 bar so that the dispersion pulse raised the vessel pressure to 1 bar at the time of ignition. This was done because variation in the initial pressure is known to affect the pressure history of a dust explosion [4]. Ignition was by a chemical ignitor having a stored energy of 5 kJ, centrally mounted in the chamber. A fixed time delay of 400 ms between commencement and ending of dust dispersion, followed by a 10-ms delay before ignition (i.e. a total ignition delay time of 410 ms), was used in all tests.

Pressure development during an explosion was measured by a piezoelectric transducer mounted flush with the interior of the vessel. An IBM PC was used to record the pressure–time data from which values of the maximum explosion pressure, $P_{\max}$, and the maximum rate of pressure rise, $(dP/dt)_{\max}$, were obtained. The PC was also used to control the dust dispersion and ignition sequence by opening and closing the solenoid valve shown in Fig. 1 and firing the chemical ignitor at the appropriate times.

For tests involving methane, the above procedure was modified slightly. Methane/air mixtures with the same concentration of methane were made up by the partial pressure method in both the dispersion reservoir and the explosion vessel prior to dust dispersion. The vessel pressure at the time of ignition was still 1 bar, but now the combustion atmosphere contained either 1% or 2% methane (by volume) depending on the test. These methane concentrations were chosen because in practice the cutting machinery in the mine automatically shuts down when the methane level reaches 1.25% by volume; at 2.25% methane, evacuation of personnel commences.

The above procedure was also modified at high dolomite loadings. For the

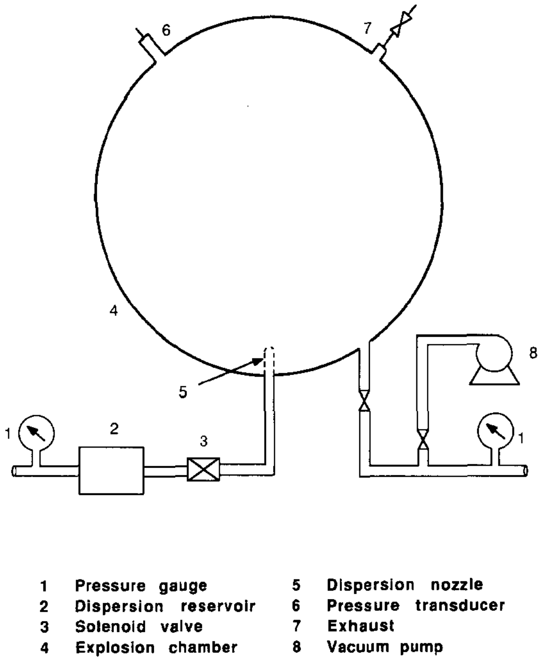

Fig. 1. Schematic of 26-L explosion vessel and auxiliary equipment.

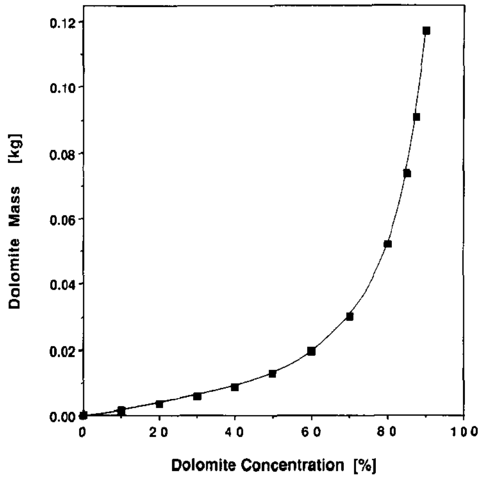

Fig. 2. Relationship between mass of dolomite and dolomite weight percentage.

apparatus and test conditions used here, approximately 30 g of dust is the maximum amount which can be dispersed through the nozzle and into the chamber. However, for a fixed coal dust concentration of 0.5 kg/m^3 (13 g in 26 L) and dolomite percentages greater than 60%, the total amount of solids (coal dust and dolomite) to be dispersed can be significantly greater than 30 g. Figure 2 gives a plot of the mass of dolomite required for various dolomite percentages. It was necessary, therefore, to adopt the procedure recommended by Cashdollar and Hertzberg [5]. Only that amount of dust which could easily be dispersed through the nozzle was placed in the curved-tube reservoir. The remainder was placed on top of the nozzle and was dispersed by the dust/air mixture flowing through the nozzle perforations.

The IBM PC used to record pressure–time data was interfaced with the piezoelectric transducer through an external analog-to-digital converter. The analog signal from the transducer was sampled at a rate of 10 kHz for dolomite concentrations less than 60% and at 5 kHz for concentrations greater than or equal to 60%. These sampling rates have previously been shown to be satisfactory by Swift [6].

A sample pressure–time trace recorded by the PC is given in Fig. 3. The solenoid valve shown in Fig. 1 is closed 400 ms after opening; by this time the pressure in the vessel has risen from its initial value of 0.53 bar to about 1 bar. The chemical ignitor is fired 10 ms after the solenoid valve closes, and there is a rapid increase in pressure. The initial shoulder in the pressure trace is due to the ignitor, while the remainder of the trace, including the main peak, is due to the coal dust.

The maximum explosion pressures given in this paper are absolute pressures which have been corrected for the contribution due to the ignitor. This was determined in preliminary testing to be 0.48 bar in the 26-L vessel. In calculating the maximum rate of pressure rise, the procedure recommended by Swift [6] was followed. The slope at each point was calculated from the slope of a

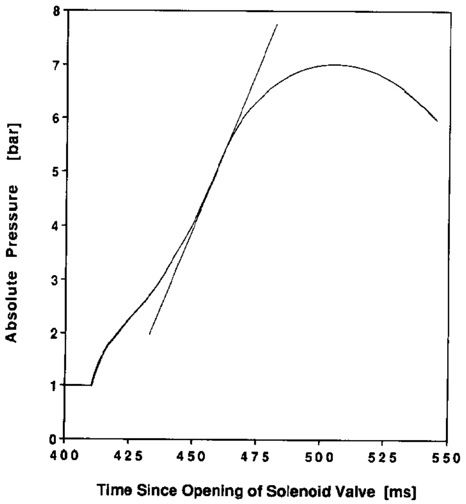

Fig. 3. Sample pressure–time trace.

line through three points before and three points after. Thus the slope at each point was a best fit of the data over six time intervals; this derivative calculation procedure was done by the computer software. The solid line in Fig. 3, drawn tangent to the steepest portion of the pressure–time curve, offers a quick visual check on the location where $(\mathrm{d}P/\mathrm{d}t)_{\max}$ occurs.

Results and discussion

A coal dust concentration of 0.5 kg/m^3 was chosen for the inerting tests because for this concentration and all conditions of coal type, particle size and methane percentage, the maximum explosion pressure had peaked and the maximum rate of pressure rise was at or very near to its peak value. This is illustrated by Fig. 4, which shows the variation of the explosion pressure parameters with coal dust concentration for the Prince 2 coal. These results were obtained from replicate tests carried out in a companion study [7] to the present work.

Typical results from the inerting tests are given in Fig. 5; the data shown are for the Lingan 1 coal with no methane present. The maximum explosion pressure undergoes only a slight decrease with an increase in dolomite percentage, up to near the inerting level (the percentage of dolomite required to inert the

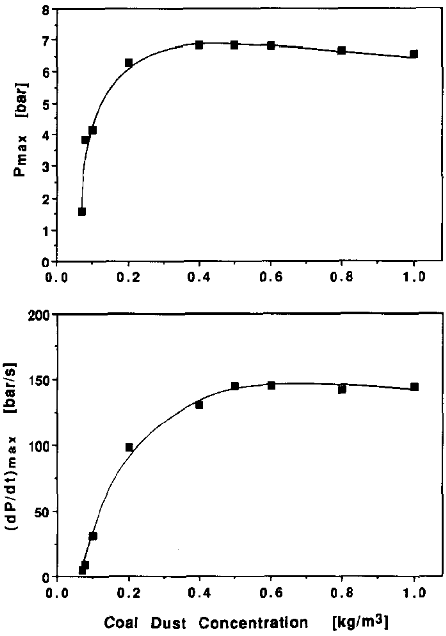

Fig. 4. Variation of $P_{\max}$ and $(\mathrm{d}P/\mathrm{d}t)_{\max}$ as a function of coal dust concentration (Prince 2, 0% methane).

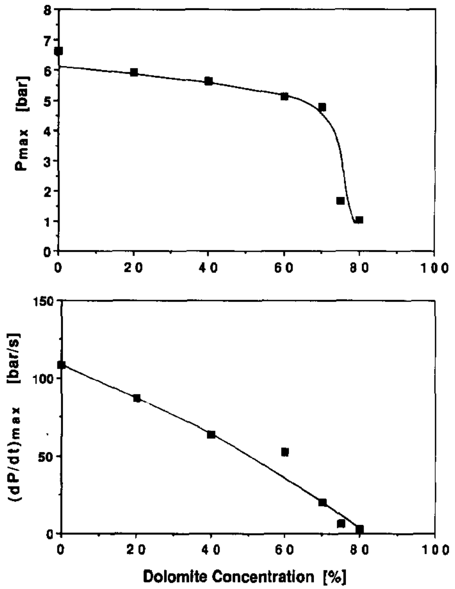

Fig. 5. P_{max} and $(dP/dt)_{max}$ at various dolomite concentrations (Lingan 1, 0.5 kg/m^3 coal dust, 0% methane).

explosive mixture). At this point, there is a sudden and rapid drop in P_{max}. The maximum rate of pressure rise, on the other hand, exhibits a fairly smooth and continuous decrease from the onset of dolomite addition. The general trends shown in Fig. 5 are consistent with those observed by Cashdollar and Hertzberg [8] in a recent laboratory study of limestone inerting requirements.

The inerting data were checked for trends with respect to methane admixture, coal particle size and coal volatile content, and were found to be consistent with previous results for coal dust alone [7]. For example, Fig. 6 shows the effect of methane admixture on P_{max} and $(dP/dt)_{max}$ for the Prince 2 coal. Adding methane to the oxidizing atmosphere has the expected effect of increasing $(dP/dt)_{max}$ at all dolomite percentages. The increase in P_{max} with methane addition is more pronounced near the inerting level; this is similar to the influence of methane admixture on P_{max} at concentrations of coal dust alone in the vicinity of another limiting condition, namely the lean flammability limit.

Of primary interest in this work was the inerting level; the criteria used here to specify this level were the same as those proposed by Hertzberg et al. [9] for the lean flammability limit. These are a pressure ratio (P_{max} divided by the initial vessel pressure) greater than or equal to 2 and a value of $(dP/dt)_{max} \cdot V^{1/3}$ greater than or equal to 1.5 bar·m/s, where V is the vessel volume.

In this work, the initial vessel pressure was 1 bar, so the pressure ratio is essentially equal to the absolute maximum explosion pressure. Also, the vol-

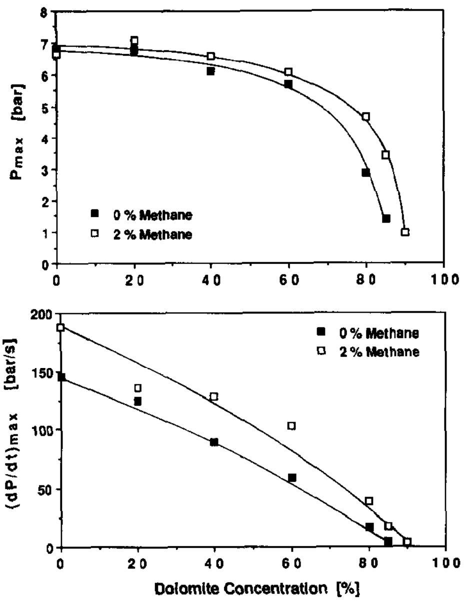

Fig. 6. Effect of methane admixture on dolomite inerting requirements of Prince 2 coal.

ume is 0.026 m^3, so to satisfy the requirement of $(dP/dt)_{max} \cdot V^{1/3} \geq 1.5$ bar·m/s, the maximum rate of pressure rise must be at least 5 bar/s in the vessel used in this study. The experimental procedure used was to first narrow the inerting range down to within 5% dolomite. For example, the Prince 2 coal shown in Fig. 6 (no methane) satisfied the P_{max} criterion at the 80% dolomite level, but not at 85% dolomite. A similar situation existed for the $(dP/dt)_{max}$ criterion, thus indicating that the inerting requirement was between 80% and 85% dolomite. The data were then interpolated between the "go" and "no go" dolomite percentages to give a value for the inerting level.

The inerting requirements thus obtained are shown in Table 3. The results are presented in two ways: as the percentage of dolomite in the total solids mixture (dolomite plus coal dust), and as the percentage of incombustibles in the total solids mixture. This last parameter, the total incombustible content or TIC, is composed of the dolomite and the ash and moisture in the coal.

Methane admixture

It is well-established that the effect of methane addition is to increase the amount of rock dust required for inerting (TIC is always affected in the same way as dolomite percentage). This is analogous to the extension of the lean flammability limit which is brought about by methane admixture, and is illustrated by Table 3. Alternatively, the effect is shown graphically by Fig. 7 for the selected example of the Prince coals. The inerting ratio, which is the ratio

TABLE 3

Dolomite inerting requirements for coal dust/air and methane/coal dust/air mixtures

Coal dust	Methane concentration (%)	Dolomite concentration (%)	Total incombustible content (%)
Prince 1	0	80	83
Prince 1	1	84	87
Prince 1	2	88	90
Prince 2	0	84	87
Prince 2	1	86	88
Prince 2	2	89	91
Lingan 1	0	74	79
Lingan 1	1	79	83
Lingan 1	2	84	87
Lingan 2	0	84	86
Lingan 2	1	87	89
Lingan 2	2	89	91
Phalen 1	0	64	77
Phalen 1	1	69	80
Phalen 1	2	74	83
Phalen 2	0	78	85
Phalen 2	1	84	89
Phalen 2	2	86	91

of dolomite to coal dust, is seen to substantially increase for each percentage of methane added.

As a result of full-scale mine tests, the U.S. Bureau of Mines has developed an empirical formula to predict the additional rock dust (limestone) required for each volume percent of methane: $A = (100 - I)/5$, where A is the additional limestone (in percent) and I is the total incombustible content (in percent) needed with no methane present. Table 4 gives the experimental values and predicted values (from the Bureau of Mines formula) of the additional dolomite required to inert for each extra percent of methane. The actual agreement between the two sets of data is reasonably good, particularly when the following points are considered. First, the Bureau of Mines formula was developed from large-scale tests using limestone as the inerting material, whereas the present study was carried out in a small-scale vessel with dolomite as the rock dust. Second, the experimental program followed in the current work was extensive and did not deal with only one type and size of coal. Rather, the coal dusts used were of various particle size, volatile content and ash content.

Coal particle size

The influence of coal particle size on the dolomite inerting requirements can be seen from Table 3. Decreasing the mass mean diameter by reducing particle

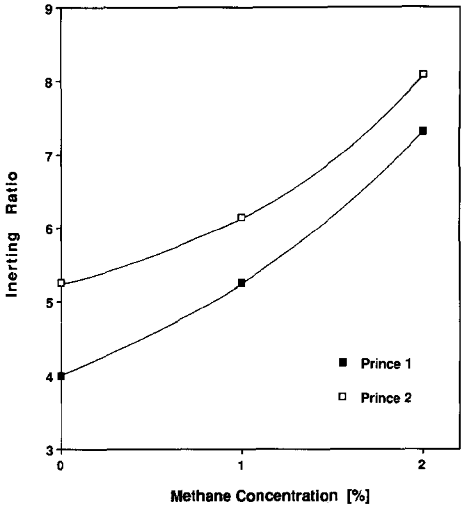

Fig. 7. Effect of methane addition and coal particle size on inerting ratio for Prince coals.

TABLE 4

Experimental and predicted values of additional dolomite due to methane addition

Coal dust	Methane concentration (%)	Experimental value of additional dolomite (%)	Predicted value of additional dolomite (%)
Prince 1	1	3	3
Prince 1	2	8	7
Prince 2	1	2	3
Prince 2	2	5	5
Lingan 1	1	5	4
Lingan 1	2	10	8
Lingan 2	1	3	3
Lingan 2	2	5	6
Phalen 1	1	5	5
Phalen 1	2	10	9
Phalen 2	1	6	3
Phalen 2	2	8	6

size throughout the entire size distribution substantially increases the inerting level for both the Lingan and the Phalen coals. This is especially apparent for the required dolomite percentage (or inerting ratio, as shown for the Lingan coals in Fig. 8), and, to a lesser degree, for the total incombustible content.

For the Prince coals, even with the decrease in volatile content from Prince 1 (36% volatiles) to Prince 2 (34% volatiles), there is still an increase in inerting requirements when the mass mean diameter is decreased from 23 μm

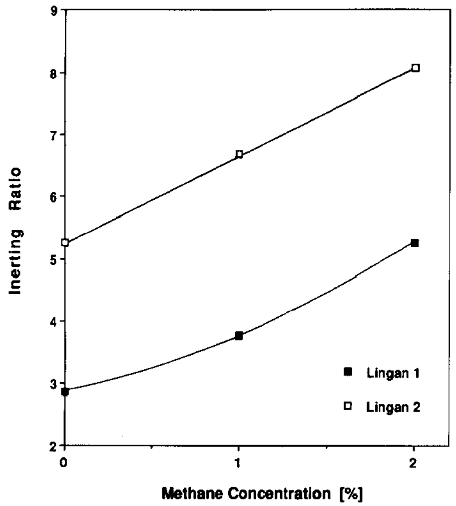

Fig. 8. Effect of methane addition and coal particle size on inerting ratio for Lingan coals.

(Prince 1) to 19 μm (Prince 2); this can be seen in terms of the inerting ratios depicted in Fig. 7. The implication here is that the particle size distribution of a coal can play a dominant role in establishing the level of dolomite concentration needed to suppress an explosion. It is pertinent to note that decreasing the mass mean diameter increases the number of fine particles, and that this is nearly equivalent to adding a combustible gas because of the rapid devolatilization of the fines. The increase in explosibility due to the increased volatiles yield and subsequent burning results in the need for higher inerting levels.

Coal volatile content

The effect of coal volatile content on the inerting level can be seen from the results for the Prince 1 (36% volatiles), Lingan 1 (32% volatiles) and Phalen 1 (26% volatiles) coals. Although not identical, the particle size distributions are approximately the same. In the absence of methane, the percentage dolomite required to inert decreases in direct proportion to decreasing volatile content, from 80% for Prince 1 to 74% for Lingan 1 to 64% for Phalen 1. It must be remembered, however, that the Phalen coals had ash contents which were about double those for the Prince and Lingan coals. It is not surprising, therefore, that when the inerting requirements are expressed on a total incombustible content basis, the difference between the Lingan 1 and Phalen 1 coals is greatly reduced.

Some measure of the effect of volatile content for smaller coal dusts can be gained by examining the Prince 2 and Phalen 2 results. There are slightly more fines (< 20 μm) in the Phalen 2 than in Prince 2, but the remainder of the size distributions are similar. Here, there is still a requirement for a greater dolomite percentage at the 34% volatile level than at the 26% level. The values are 84% dolomite for Prince 2 with no methane and 78% dolomite for Phalen 2 with no methane. Clearly though, the difference in inerting requirements for the two coals is now much less than for the larger sizes of the same two coals. This observation is consistent with the work of Cashdollar and Hertzberg [8] and was explained by them in terms of an increased rate of devolatilization from the smaller dusts, particularly for the lower volatile coal.

Inerting mechanism

As mentioned in the introduction to this paper, rock dusts such as limestone and dolomite are generally viewed as thermal inhibitors. Nagy [2] comments that although the quenching mechanism of rock dust is not fully understood, it is believed to arrest flame propagation by absorption of thermal energy from the heated gases and by absorption of radiant energy, thus reducing the preheating of unburnt particles. There is substantial evidence (gathered by various workers over a number of years) to support this contention that rock dust is a thermal, and not a chemical, inhibitor. The purpose of this section is to briefly review the relevant supporting data.

There is first the consideration that the average dolomite concentration for inerting of the six coals (with no methane present) is between 75 and 80%. Practically, this means that complete inerting does not occur until the mass of dolomite is quite high (refer back to Fig. 2); in fact, the inerting ratio is always greater than unity. This may be contrasted with the action of chemical inhibitors such as sodium chloride and ammonium phosphate, both of which are more effective than rock dust in that lesser amounts of each are required. Nagy [2] reports that in tests conducted at the U.S. Bureau of Mines, salt (sodium chloride) was found to be two to six times more effective on a weight basis than limestone (unfortunately, salt is also highly corrosive and hygroscopic). Also, ammonium phosphate is attractive as an inerting agent for methane/air mixtures, whereas rock dust is nearly totally ineffective against such gaseous hazards.

The data shown in Figs. 5 and 6 can thus be interpreted in the following manner. The reduction in $(\mathrm{d}P/\mathrm{d}t)_{\max}$ is a direct consequence of the lowering of the burning velocity, and hence the flame speed, of the dust/air mixture. This is caused by absorption of heat by the inert dolomite particles. Although the instantaneous rate of reaction (i.e. $(\mathrm{d}P/\mathrm{d}t)_{\max}$) is affected from the onset of dolomite addition, the overall reaction yield (i.e. $P_{\max}$) does not respond in a similar manner. The maximum explosion pressure remains largely unaffected over a wide range of dolomite concentrations. This is consistent with the general pattern in which $(\mathrm{d}P/\mathrm{d}t)_{\max}$ is more sensitive than $P_{\max}$ to other external influences, such as, for example, the turbulence intensity in the dust cloud. In the case of dolomite inerting, $P_{\max}$ is reduced dramatically only when

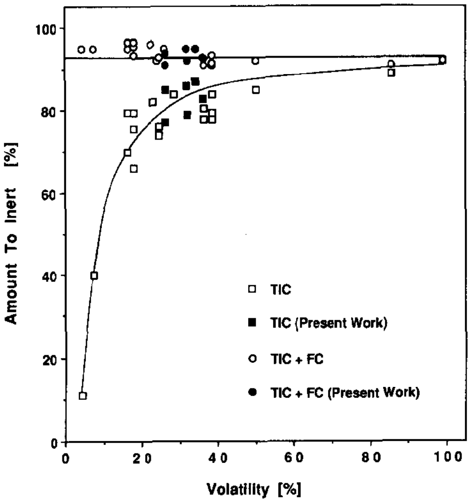

Fig. 9. Inerting requirements for dusts of various volatilities.

there is sufficient dolomite present to ensure massive heat losses from the reacting system (fuel particles) to the nonreacting system (inert particles).

Figure 9 has been redrawn from Cashdollar and Hertzberg [8] to include pertinent data from the present work. The amount needed to inert carbonaceous dusts covering a wide range of coal dust volatilities is shown in two ways: as the total incombustible content (TIC) and as the total incombustible content plus fixed carbon (TIC+FC). Most of the data are for anthracitic and bituminous coals; the three exceptions are the higher volatile dusts: a polyethylene–graphite mixture, gilsonite and polyethylene containing 50%, 85% and 100% volatiles, respectively. The data from Cashdollar and Hertzberg [8] were obtained with limestone as the inerting agent in a vessel only slightly smaller (20 L) than that used by the present authors (26 L), and with the same stored ignition energy as used here (5 kJ).

The main factor contributing to the close fit of the twelve datum points from the current study with the overall trends shown in Fig. 9 is the similar effectiveness of limestone and dolomite for inerting of coal dust explosions. This again supports the notion that the inerting mechanism of these rock dusts is thermal, not chemical. If the decomposition temperature, and hence possible chemical inhibition played a role, one would expect dolomite to be more effective than limestone (the decomposition temperatures are 750°C for dolomite and 825°C for limestone).

Figure 9 also illustrates that when the fixed carbon in the coal is included with the total incombustible content, a relatively constant amount of inert material is required. Justification for the inclusion of fixed carbon with inerts may be found in the short time scale of a dust explosion (typically of the order of a hundred milliseconds in this study). Over this short time period it is generally accepted that subsequent to devolatilization, the flame characteristics are dominated by the volatiles with combustion taking place primarily in the gas phase; see, for example, Hertzberg et al. [10] and Dixon-Lewis et al. [11]. As noted by Cashdollar and Hertzberg [8], the physical significance of the horizontal line drawn through 93% inerts is that the moisture, ash and fixed carbon in the coal are similar in inerting effectiveness to the added rock dust (limestone or dolomite). Ash and moisture are clearly thermal inhibitors and fixed carbon may reasonably be assumed to have a heat-sink effect over the short duration of combustion. Further credence is thus given to the role of rock dusts as thermal inerting agents.

Relevance to large-scale environments

As discussed previously by Amyotte and Pegg [12] and Amyotte et al. [13], turbulence plays a large role in determining the explosion characteristics of a dust, particularly $(dP/dt)_{max}$, and, to a lesser degree, P_{max}. In the present work, the choice of several test parameters which influence the turbulence level in a dust cloud, most notably the dispersing air pressure and the ignition delay time, was governed by the desire to obtain measurements of P_{max} and $(dP/dt)_{max}$ comparable to those determined at the U.S. Bureau of Mines in a 20-L test vessel for Pittsburgh seam bituminous coal dust. The U.S. Bureau of Mines small-scale results have been consistently shown to compare favourably with the data from large-scale testing at the Bureau's Bruceton and Lake Lynn Experimental Mines (Cashdollar and Hertzberg [8] and Cashdollar et al. [14]). Thus, the rationale for setting the turbulence level in the current study was to give the test results some relevance to what would be expected in an actual industrial setting. It is felt that this relevance was achieved throughout the investigation; a case in point is the data shown in Table 4, where the experimental values are from the present small-scale work and the predicted values are calculated via the formula developed from large-scale tests.

Coal particle size has as significant an effect on the dolomite inerting level as does coal volatility. A matter which must be addressed, therefore, is the relationship between the particle sizes used in this work and those of actual mine dust. This was done by comparison of Table 1 with the particle size analyses for several dust samples collected from various locations in the Prince, Lingan and Phalen mines; the colliery samples were collected and analyzed by CBDC. The larger size fractions in the current work (Prince 1, Lingan 1 and Phalen 1) were found to be representative of the finer mine sizes. The usefulness of the smaller size fractions (Prince 2, Lingan 2 and Phalen 2) lies in showing some of the effects of generating even finer coal dusts. Further support for the use of fine size fractions in laboratory testing is given by Sapko et al. [1]. Their review paper on prevention and suppression of coal mine explosions indicates that the coal dust being generated at present is finer than in earlier years, and that float coal dust is the most dangerous in terms of explosibility.

The final point to be discussed here is how the experimentally determined inerting levels compare with those required by government regulation. Canada is among the strictest countries in the world in this respect; the inerting requirements listed for Nova Scotia by Sapko et al. [1] are 75% total incombustible content for methane concentrations less than 1% and 80% total incombustible content for methane concentrations greater than 1%. The inerting requirements for coal dust/air mixtures shown in Table 3 are in all cases greater than 75% TIC, and the 75% level is therefore inadequate for explosion suppression of these dusts. It must be remembered, however, that these requirements are for fine size fractions, and that inerting levels are strongly dependent on coal particle size. Coarser mine sizes, such as found in the CBDC colliery samples referred to previously, would have lower inerting levels than those in Table 3. Laboratory-scale inerting requirements are, therefore, more appropriately viewed as relative indicators rather than absolute values. What is clear from the present work, though, is that there is no apparent rationale for relaxing the current Canadian rock dusting regulations.

Conclusions

An experimental investigation of the dolomite inerting requirements of coal dust/air and methane/coal dust/air mixtures has been conducted in a 26-L spherical chamber. Relatively fine size fractions of Canadian run-of-mine coals were used. Methane admixture, decreases in coal particle size, and increases in coal volatile content were all observed to increase the percentage of dolomite needed to suppress an explosion; these trends are consistent with findings of other workers. The additional amount of dolomite required in the presence of methane was predicted with reasonable accuracy by an empirical formula developed by the U.S. Bureau of Mines. The present work has demonstrated that there is no rationale for relaxing the current requirements for rock dusting operations in Canada.

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Notation

D_w	arithmetic volume or mass mean diameter, μm
$(dP/dt)_{max}$	maximum rate of pressure rise, bar/s
P_{max}	maximum explosion pressure, bar (a)
V	vessel volume, m^3

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