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Minimum Explosible Dust Concentrations Measured in 20-L and 1-M³ Chambers

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Abstract—Minimum explosible concentrations (MEC) of dusts were measured in the Bureau of Mines 20-L chamber and in the Fike 1-m³ (1000-L) chamber. The MEC values for gilsonite dust and bituminous coal dust were measured in each chamber at several ignition energies. The explosibility of anthracite coal was also studied in the two chambers. Strong chemical ignitors with energies of 500 to 10 000 J were used in the tests. The uniformity of the dust dispersions in each of the chambers was studied by using optical dust probes. One purpose of the research was to determine if the 20-L chamber was "overdriven" at high ignition energies. The MEC-values measured in the 20-L chamber with 2500-J ignitors were comparable to those measured in the 1-m³ chamber with 10 000 J ignitors. At higher ignition energies in the 20-L chamber, there was evidence of overdriving.

INTRODUCTION

An accurate knowledge of the explosibility behavior of materials is essential for a realistic safety evaluation of their use in manufacturing and processing. One explosibility characteristic that can be measured is the minimum explosible concentration (MEC) or lean flammable limit (LFL) of a dust cloud; this is the lowest concentration of the dust dispersed in air that can propagate an explosion. The MEC has been measured in different types of laboratory chambers for many years (Hertzberg *et al.*, 1979). The two most common sizes of dust explosibility test chambers in use throughout the world today are those with volumes of 20 L and 1 m³ (1000 L). Tests can be made more easily and quickly in the 20-L chambers, but the larger 1-m³ chambers are expected to produce data that are more realistic in terms of industrial hazards.

One question about laboratory data, and in particular the 20-L data, is whether a strong ignition source can "overdrive" the system. Dust clouds are intrinsically more difficult to ignite than gases and therefore require stronger ignition energies to measure the MEC or LFL. A "true" MEC is one that is independent of ignition energy. If too weak an ignition source is used, one measures an apparent MEC that is higher than the true value. This is an ignitability limit rather than a flammability limit, and the test could be described as "underdriven". Ideally, one increases the ignition energy until the MEC-value becomes independent of ignition energy . This would be represented by a vertical asymptote on a graph of ignition energy versus apparent or measured MEC. However, at some point the ignition energy becomes too strong for the size of the test chamber, and the system becomes "overdriven". This would be represented by an outward recurvature of the data at higher energy on the ignition energy vs. apparent MEC graph. When the ignitor flame becomes too large relative to the chamber volume, a test could appear to result in an explosion, while it is actually just dust burning in the ignitor flame with no real propagation beyond the ignitor. Alternatively, too strong of an ignitor energy could sufficiently change the initial test conditions, such as raising the initial temperature of the dust cloud, so that a nonexplosible mixture becomes explosible. If the vertical asymptote can be clearly distinguished on the ignition energy vs. apparent MEC graph, then the "true" MEC is known. However, for most dusts, there is no clear vertical asymptote when using a 20-L chamber.

To evaluate the effect of overdriving in a 20-L chamber, comparison tests must be made in a larger chamber such as a 1-m^3 chamber. A given ignitor that overdrives a 20-L chamber would not overdrive the much larger 1-m^3 chamber. Therefore, it is easier in principle to determine an ignition energy independent MEC-value in a 1-m^3 chamber. The extent to which strong chemical ignitors overdrive the 20-L chamber for LFL measurements of gases was discussed in a previous paper by Hertzberg *et al.* (1988a) in which 20-L data were compared to data from a 120-L chamber. Bartknecht (1989) also reported some data on the overdriving of the 20-L chamber with 10 000-J ignitors when measuring the minimum oxygen concentration for a dust explosion.

The data in this paper were obtained in the Bureau of Mines 20-L chamber (Cashdollar and Hertzberg, 1985) located near Pittsburgh, PA and in the Fike Corporation 1-m^3 chamber located at Blue Springs, MO. The 20-L chamber is the standard laboratory test chamber used at the Bureau for studying the explosibility and inerting of fuel dusts and gases. Some data on the explosibility of coals and other carbonaceous dusts as measured in the Bureau 20-L chamber have been reported previously. Those previous papers have discussed the ignition energy requirements for accurate measurements of flammability limits of dusts and gases (Hertzberg *et al.*, 1988a), a volatility model for coal dust flame propagation (Hertzberg *et al.*, 1988b), a comparison of laboratory and mine research on lean explosibility limits and rock dust inerting of various coals (Cashdollar *et al.*, 1987), and the effect of volatility on the explosibility limits of coals and other carbonaceous dusts (Cashdollar and Hertzberg, 1989a; Cashdollar *et al.*, 1989b). The Fike Corporation also has a 20-L chamber of somewhat different design, but it was not used as part of the current test program. There is a third 20-L design (Siwek, 1977; Siwek, 1985) that is in wide use in Europe. Bartknecht (1989) designed a 1-m^3 chamber that has been used for explosibility testing in Europe for over twenty years. There is also a third 1-m^3 chamber design with a unique recirculating dust dispersion system (Kauffman, 1985).

An important test condition that can affect the accuracy of the MEC measurements is the uniformity of the dust concentrations in the chambers. Therefore, optical dust probes were used to evaluate the uniformity of the dust dispersions in both the 20-L and 1-m^3 chambers.

The measurements described in this paper include minimum explosible concentrations as a function of ignition energy for gilsonite, bituminous coal, and anthracite coal as measured in the Bureau 20-L chamber and in the Fike 1-m^3 chamber. One purpose of these tests was to determine an appropriate ignition energy to use in the 20-L chamber by comparing 20-L and 1-m^3 data. In this paper, the terms "flammability" and "explosibility" are used interchangeably to refer to the ability of an airborne dust cloud to propagate a flame after it has been initiated by a sufficiently strong ignition source. The terms refer to a rapid deflagration and not a detonation.

EXPERIMENTAL APPARATUS AND DUST ANALYSES

Some of the dust explosibility data in this paper were obtained in the Bureau of Mines 20-L laboratory chamber (Cashdollar and Hertzberg, 1985) shown in Figures 1 and 2. The near-spherical chamber is made of stainless steel and has a gauge pressure rating of 21 bar, g. The hinged top is attached with six 19-mm-diameter bolts which are not shown on the drawings. Two optical dust probes (Liebman *et al.*, 1977;

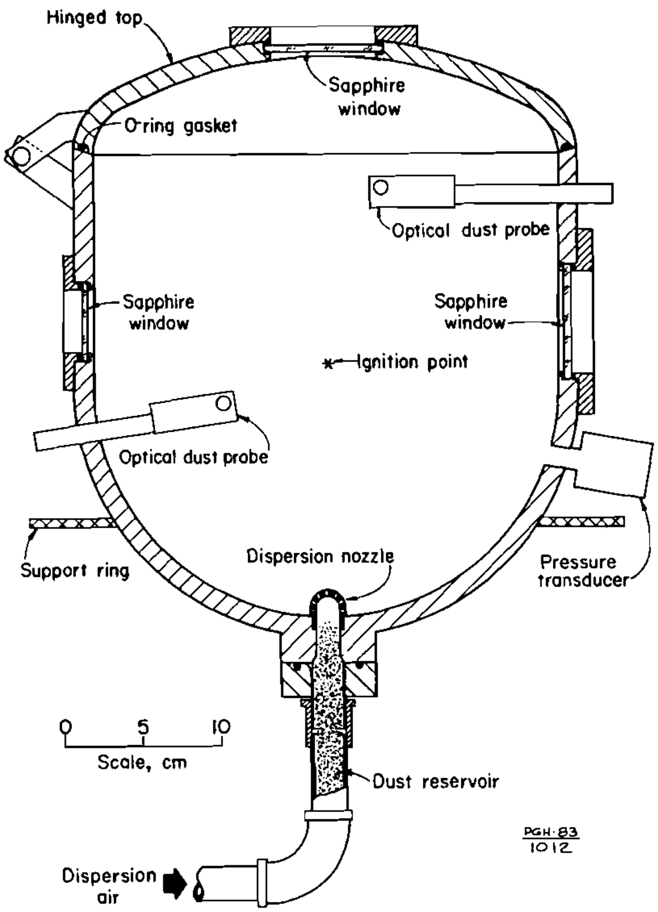

FIGURE 1 Vertical cross section of Bureau of Mines 20-L explosibility test chamber.

Cashdollar *et al.*, 1981; Conti *et al.*, 1982) were used to measure the uniformity of the dust dispersion at the positions shown in the drawings. The optical probes measure the transmission over a 38-mm path length through the dust cloud. Thin jets of air keep the windows of the probes clean. Examples of previous dust probe transmission measurements in the 20-L chamber are in Cashdollar and Hertzberg (1985) and in Cashdollar *et al.* (1987). The strain gauge pressure transducer measured the explosion pressure. Multichannel infrared pyrometers (Cashdollar and Hertzberg, 1982) can be used to measure the explosion temperature. The data from the various instruments were collected by a high speed personal computer (PC) based data acquisition system. It can sample data from 16 channels at a maximum rate of 9 kHz if all channels are used or at faster rates if fewer channels are used. Data were displayed on a color monitor immediately after each test. The dust to be tested can be placed either in the dust reservoir or on top of the dispersion nozzle at the bottom of the chamber (Figure 1). After the dust and ignitor have been placed in the chamber, the top is bolted on and the chamber is partially evacuated to an absolute pressure of 0.14 bar, a. Then a short blast of dry air (0.3 s duration at 9 bar, g from a 16-L reserve tank) disperses the dust and raises the chamber pressure to about 1 bar, a. The ignitor is

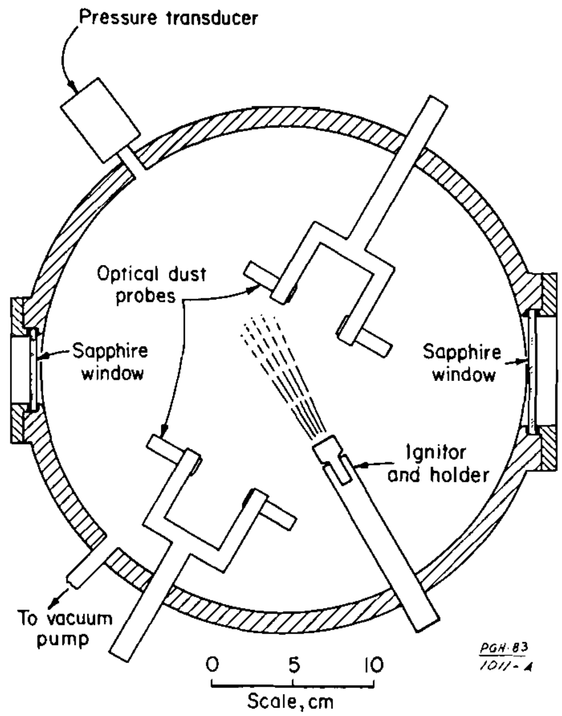

FIGURE 2 Horizontal cross section of Bureau of Mines 20-L explosibility test chamber.

activated after an additional delay of 0.1 s. This results in a total ignition delay of 0.4 s from the start of dispersion until ignition. The experimental dust concentration reported in this paper is the mass of dust divided by the chamber volume.

The Fike Corporation 1-m^3 chamber (Figures 3 and 4) was also used to measure the MEC-values of the dusts. The 1-m^3 chamber is spherical with an internal diameter of 122 cm and a wall thickness of 0.95 cm. It has a pressure rating of 21 bar, g. The

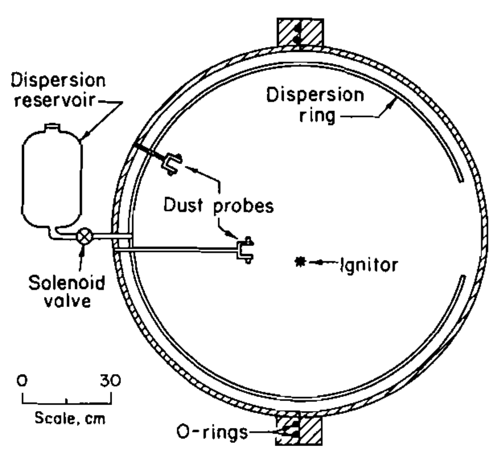

FIGURE 3 Vertical cross section schematic of Fike 1-m^3 explosibility test sphere.

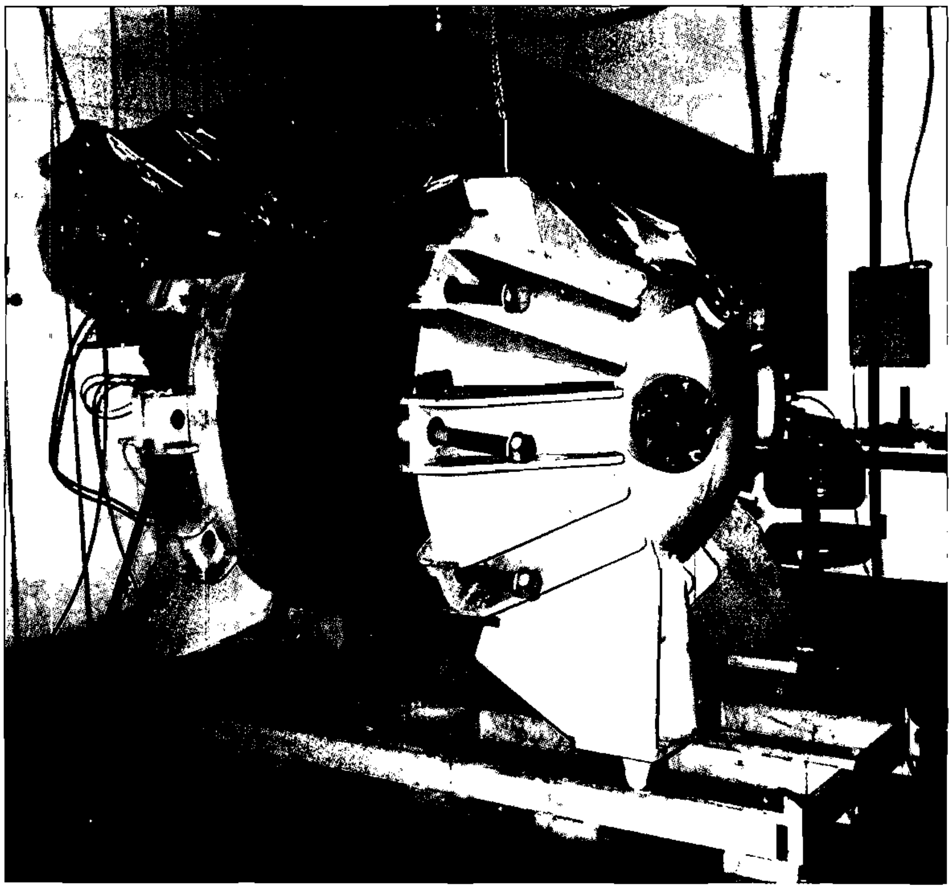

FIGURE 4 Fike 1-m^3 explosibility test sphere with the two halves open for cleaning.

two halves of the sphere are connected by twelve 51-mm-diameter bolts (Figure 4). Two variable-reluctance pressure transducers were used to measure the explosion pressure. For the tests described in this paper, two Bureau of Mines optical dust probes were installed in the Fike 1-m^3 chamber to monitor the dust dispersion uniformity at the positions shown in the drawing (Figure 3). Data from the instruments were collected by a high speed PC based data acquisition system.

The dust injection system for the 1-m^3 chamber consists of a 5-L dispersion reservoir, a 19-mm pneumatically activated ball valve, and a circular dispersion ring (Figure 3). To create a dust cloud, a weighed sample of dust is placed in the dispersion reservoir. The reservoir is pressurized with dry air to 32 bar, g and the 1-m^3 chamber is partially evacuated to 0.88 bar, a. Activation of the ball valve disperses the dust and air into the 1-m^3 chamber through the dispersion ring and raises the chamber pressure to about 1 bar, a. The ignitor is activated 0.55 s after activation of the ball valve.

The dispersion time and turbulence level in the Fike 1-m^3 chamber are comparable to those in the European 1-m^3 chambers (Bartknecht, 1989). This is the turbulence level in VDI Standard 3673, ISO Standard 6184/1, and ASTM Standard E1226 to determine the maximum rate of pressure rise of a dust explosion. The turbulence level in the Bureau of Mines 20-L chamber is lower, but this should mainly affect the rates

TABLE I
Physical and chemical analyses of the dusts

	Gilsonite	Bituminous coal	Anthracite coal
Surface mean diameter, $\bar{D}_s$, μm	19	30	24
Mass mean diameter, $\bar{D}_w$, μm	37	50	45
Mass median diameter, D_{med}, μm	28	44	40
Weight < 75 μm, %	91	81	85
Weight < 20 μm, %	36	16	23
Moisture, %	1	1	2
Volatile matter, %	84	37	8
Fixed carbon, %	15	56	79
Ash, %	0	6	11
Heating value, cal/g	9900	7700	7100

of pressure rise (at high concentrations) and should not affect measurements of the minimum explosible concentration. The main effect of increased turbulence at low dust concentrations is to make the dust cloud more difficult to ignite (Amyotte *et al.*, 1989). With the strong ignitors used for the tests, the somewhat higher turbulence level in the 1-m^3 chamber should have little effect on the MEC measurements. This was confirmed by limited measurements (for one dust at one ignitor energy) in the Bureau of Mines 20-L chamber at a higher turbulence level, comparable to that in the Fike 1-m^3 chamber.

The ignition sources used for the 20-L and 1-m^3 tests were electrically activated, chemical ignitors manufactured by Fr. Sobbe* of Germany. These ignitors are composed of 40% zirconium, 30% barium nitrate, and 30% barium peroxide. They are activated electrically with an internal fuse wire and deliver their energy in about 10 ms. The Sobbe ignitors are available in energies of 250, 500, 1000, 2500, 5000 and 10 000 J. These are nominal calorimetric energies based on the mass of pyrotechnic powder in each ignitor. The 5000 J ignitor by itself produces a pressure rise of about 540 mbar in the 20-L chamber but only 11 mbar in the 1-m^3 chamber. The pressure rises from the other ignitors in the two chambers can be estimated based on their relative energies. The Sobbe ignitors for these tests are the new type that are sealed with plastic end caps. The older type were sealed with paper end caps and tended to lose some of the powder, resulting in lower effective energies. Additional information on the Sobbe ignitors (older type) is in Hertzberg *et al.*, (1988a).

The physical and chemical analyses of the three dusts are listed in Table I. The gilsonite is a mined asphaltic material from Utah. The bituminous coal is from the Pittsburgh seam; this dust has been used for decades as a standard test dust at the Bureau of Mines (Rice and Greenwald, 1929; Nagy, 1981; Cashdollar *et al.*, 1987). The anthracite coal is from eastern Pennsylvania. The size distributions were determined from a combination of sonic sieving data and Coulter counter data. In the first and second rows, $\bar{D}_s$ is the arithmetic surface mean diameter and $\bar{D}_w$ is the arithmetic volume or mass mean diameter. The mass median particle diameter D_{med} is listed in the third row. The fourth and fifth rows list the weight percent of each dust that is less than 75 or 20 μm, respectively. The data show that all three dusts have similar size distributions. The proximate analyses (ASTM standard D3172) and heating values (ASTM standard D2015) of the three dusts are also listed in Table I. Note that the gilsonite has a high volatility, the bituminous coal has an intermediate volatility, and

*Reference to trade names does not imply endorsement by the Bureau of Mines.

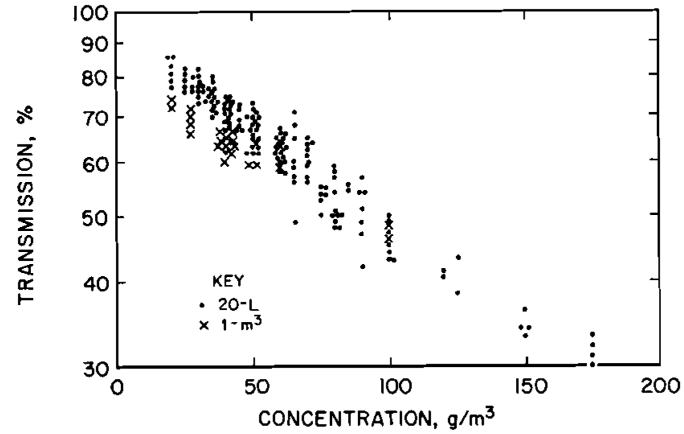

FIGURE 5 Dust probe transmission data from the 20-L and 1-m³ chambers for gilsonite.

the anthracite has a low volatility. As discussed in Hertzberg *et al.* (1988b), the volatility of a carbonaceous dust is expected to have a major effect on its explosibility.

EXPERIMENTAL DATA AND DISCUSSION

The effectiveness of the dust dispersion in the 20-L and 1-m³ chambers was studied by using the optical dust probes to measure the transmission through the dust cloud at various positions in the two chambers. As described in Cashdollar *et al.* (1981), the transmission T is related to the mass concentration C_m by Bouguer's law: $T = \exp(-3QC_m l/2\rho\bar{D}_s)$, where Q is a dimensionless extinction coefficient, l is the path length, ρ is the density of a particle, and $\bar{D}_s$ is the surface mean particle diameter. The dust probe data are plotted as the logarithm of the transmission vs. the concentration in Figures 5, 6, and 7. The gilsonite data in Figure 5 generally follow the expected linear relationship. Due to agglomeration, the $\bar{D}_s$ mean particle size in the dust cloud is usually larger than that listed in Table I. The scatter in the data in Figure

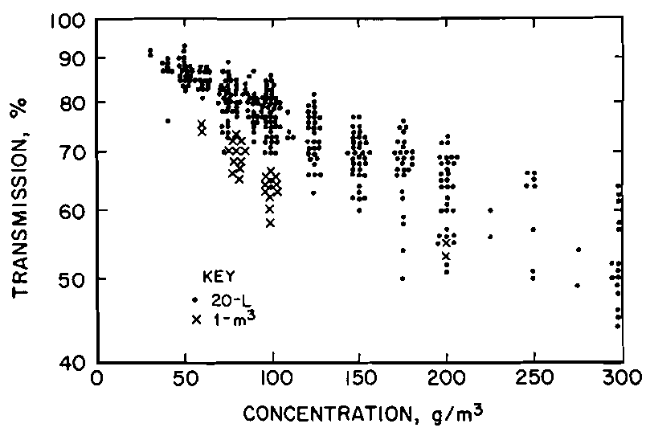

FIGURE 6 Dust probe transmission data from the 20-L and 1-m³ chambers for Pittsburgh bituminous coal.

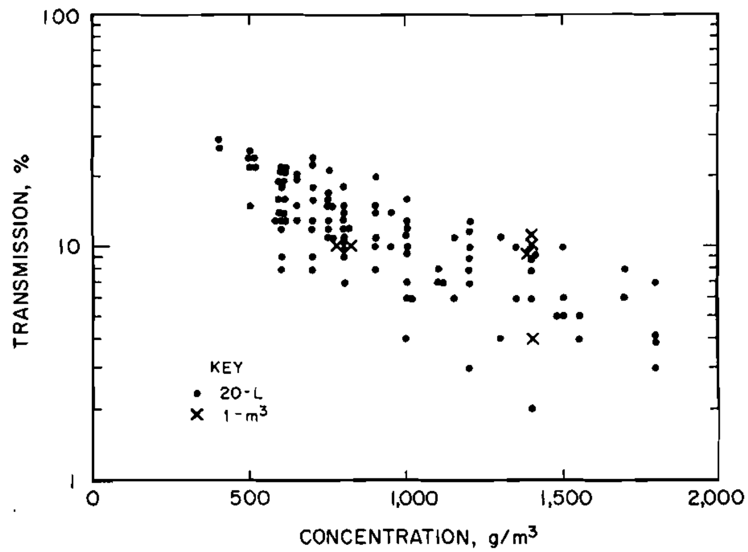

FIGURE 7 Dust probe transmission data from the 20-L and 1-m^3 chambers for anthracite coal.

5 is probably due to variations in the agglomerated particle size of the air dispersed dust. At the lower concentrations, the 1-m^3 transmission data are slightly lower than the 20-L data, possibly because there is more agglomeration of the dust in the 20-L chamber. Similar results for the bituminous coal are shown in Figure 6. The anthracite coal in Figure 7 show no systematic differences between the 20-L and 1-m^3 data. The optical dust probe data for the three dusts show that the dispersion in the Fike 1-m^3 chamber is at least as good as that in the Bureau of Mines 20-L chamber.

The majority of the explosibility tests for the gilsonite and bituminous coal dusts in the Fike 1-m^3 chamber were made with an ignitor energy of 10000 J. Additional tests were made to also determine the MEC-values of 2500- or 5000-J ignitors. Explosibility data for the gilsonite dust in the 1-m^3 chamber are shown in Figure 8. In the bottom part of the figure, the maximum absolute explosion pressure for each test is plotted versus the dust concentration. In the top part of the figure, $(dP/dt)V^{1/3}$ is the maximum rate of pressure rise for each explosion test, normalized by the cube root of the chamber volume, V. In a 1-m^3 chamber, this value is identical to dP/dt. The value $(dP/dt)V^{1/3}$ is proportional to the maximum flame speed (Amyotte *et al.*, 1989; Hertzberg and Cashdollar, 1987). In determining the MEC-value from the data, the criterion used for significant flame propagation in the 1-m^3 chamber is an absolute pressure of $\geqslant 2$ bar or, equivalently, a pressure rise of $\geqslant 1$ bar. Using this criterion, the MEC for this gilsonite dust is about 36 g/m^3, using the 10000-J ignitor energy. At lower dust concentrations, there is no significant pressure rise. At higher dust concentrations, the pressure continues to increase with concentration. At concentrations of several hundred grams per cubic meter, the explosion pressure data would level off as all the oxygen in the chamber is consumed (Hertzberg and Cashdollar, 1987). Using the 5000-J ignitors, the MEC is somewhat higher—about 40 g/m^3. The data for the 2500-J ignitors are not shown, but they are comparable to the 5000-J data.

The explosibility data for the gilsonite dust with 2500-J ignitors in the Bureau 20-L chamber are shown in Figure 9. In the bottom part of the figure, the pressure ratio (PR) is the maximum absolute explosion pressure (with the pressure rise of the ignitor

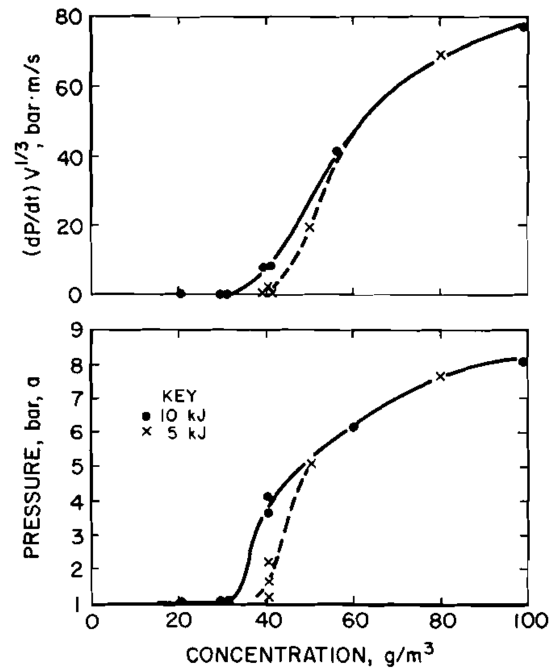

FIGURE 8 Explosibility data for gilsonite dust from the 1-m^3 chamber at two ignitor energies.

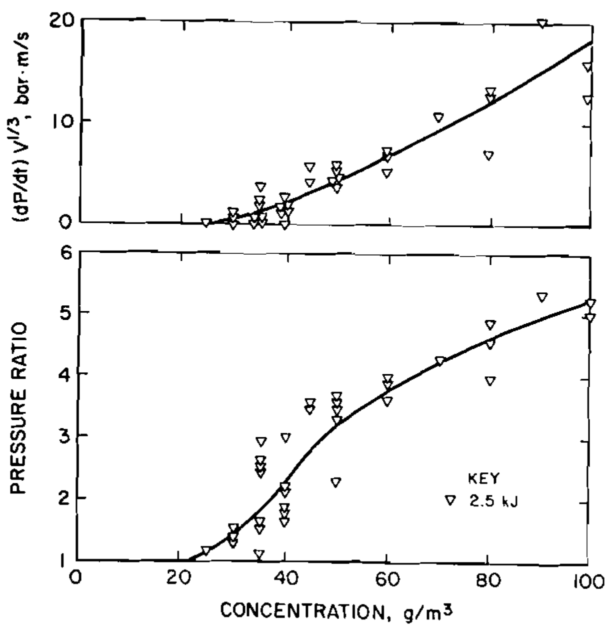

FIGURE 9 Explosibility data for gilsonite dust from the 20-L chamber, using 2.5 kJ ignitors.

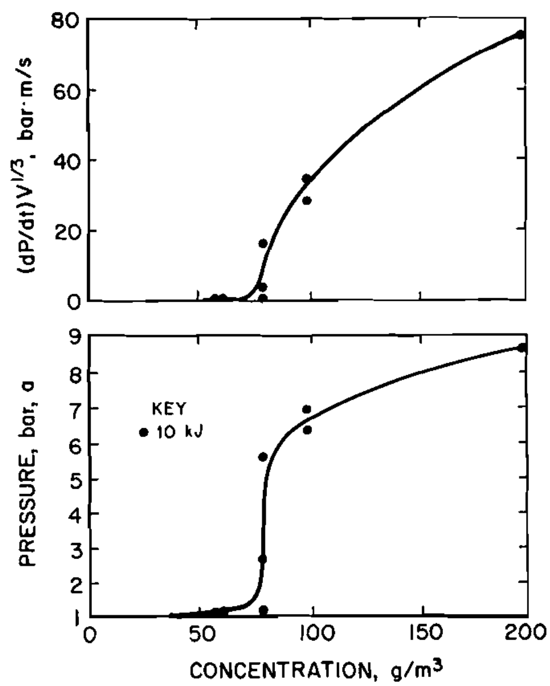

FIGURE 10 Explosibility data for Pittsburgh bituminous coal dust from the 1-m^3 chamber, using 10 kJ ignitors.

subtracted) divided by the pressure at ignition (about 1 bar, a). Therefore, the pressure ratio corresponds approximately to the absolute explosion pressure in atmospheres or bars. For the 1-m^3 chamber, the pressure rise of the ignitor itself was very small and no correction was made to the measured dust explosion pressure. In Figure 9, there is more scatter in the 20-L data than in the 1-m^3 data shown in Figure 8. The discontinuity at the lean limit is less well defined, and the MEC-value would have more uncertainty even though there are many more data points than in Figure 8. The criterion used for significant flame propagation in the 20-L chamber is PR $\geqslant$ 2 and $(dP/dt)V^{1/3} \geqslant 1.5$ bar · m/s (Hertzberg *et al.*, 1988a). The second part of the criterion was added to require that there be some real propagation of the dust flame and not just a pressure rise due to dust burning within the ignitor flame. The second part of the criterion partially corrects for the possible overdriving of the 20-L system by strong ignitors. Using this double criterion, the MEC for gilsonite in the 20-L chamber with 2500-J ignitors is about 35–40 g/m^3. Data were also obtained in the 20-L chamber with ignitors of other energies. A summary of these data will be shown later in the paper.

The explosibility data for the Pittsburgh bituminous coal with the 10 000-J ignitors in the 1-m^3 chamber are shown in Figure 10. The sharp discontinuity in the pressure data shows that the MEC is about 80 g/m^3. The MEC-values were slightly higher for the 2500 and 5000-J ignitors. Figure 11 shows the explosibility data for bituminous coal in the 20-L chamber with 2500-J ignitors. Again, there is more scatter in the data in the smaller chamber. The MEC is about 80 g/m^3, using the 2500-J ignitors.

Because of the standard turbulence level in the Bureau of Mines 20-L chamber was lower than that in the Fike 1-m^3 chamber, a limited series of tests was made in the 20-L

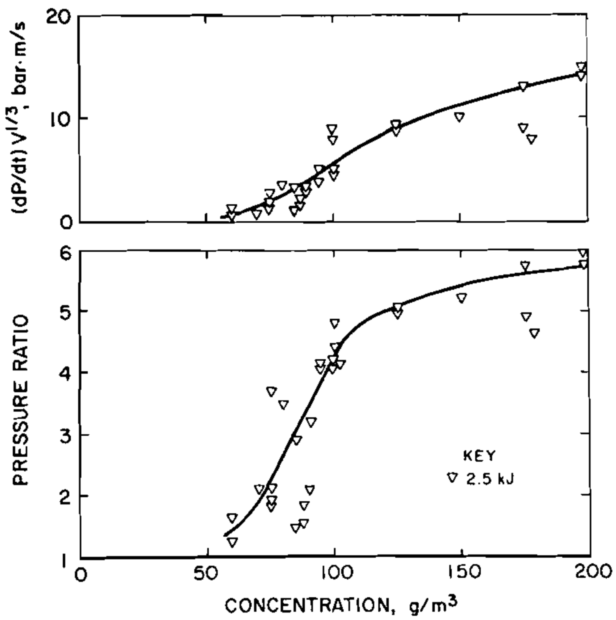

FIGURE 11 Explosibility data for Pittsburgh bituminous coal dust from the 20-L chamber, using 2.5 kJ ignitors.

chamber at a higher turbulence level. In the standard 20-L chamber procedure, the total dispersion-delay time was 0.4 s. In the higher turbulence tests, the total dispersion-delay time was 0.1 s, comparable to that in the Siwek (1977, 1985) 20-L chamber and ASTM standard E1226. Pittsburgh coal dust was used with 2500 J ignitors for the higher turbulence tests in the 20-L chamber. The measured dust transmission data for the higher turbulence dispersion of the coal dust were within the range of 20-L chamber data shown in Figure 6. The measured pressure data for the higher turbulence dispersion were within the range of data in Figure 11. The $(dP/dt)V^{1/3}$ data were comparable to those in Figure 11 at the lower concentrations, but were two to three times higher at concentrations above $100\,g/m^3$, as expected for higher turbulence dispersion. These measurements showed that the MEC for Pittsburgh coal dust was essentially the same at both turbulence levels in the 20-L chamber.

As discussed in the Introduction, the "true" minimum explosible concentration for a dust is that value that is independent of ignition energy. To evaluate this for the gilsonite and bituminous coal dusts, the 20-L and 1-m^3 data are plotted on a graph of ignition energy versus measured or apparent MEC in Figure 12. In the 1-m^3 chamber, the measured MEC data for the two dusts are relatively independent of ignition energy over the range studied. The vertical asymptotes for the 1-m^3 data yield a MEC of 35 to 40 g/m^3 for the gilsonite and a MEC of 80 $\pm$ 5 g/m^3 for the Pittsburgh bituminous coal. The 20-L MEC-values were measured over a wider range of ignition energies. Sobbe ignitors were used for all the data except for the lowest energy, which corresponds to two electric matches. The measured MEC-values increase at the lowest energies where the ignition energy is insufficient to measure a true limit. At the highest energies studied, the apparent MEC-values from the 20-L chamber are lower than those from the 1-m^3 chamber. This is evidence of overdriving in the 20-L chamber when the strongest ignitors are used. The measured MEC-values at 2500 J in the 20-L

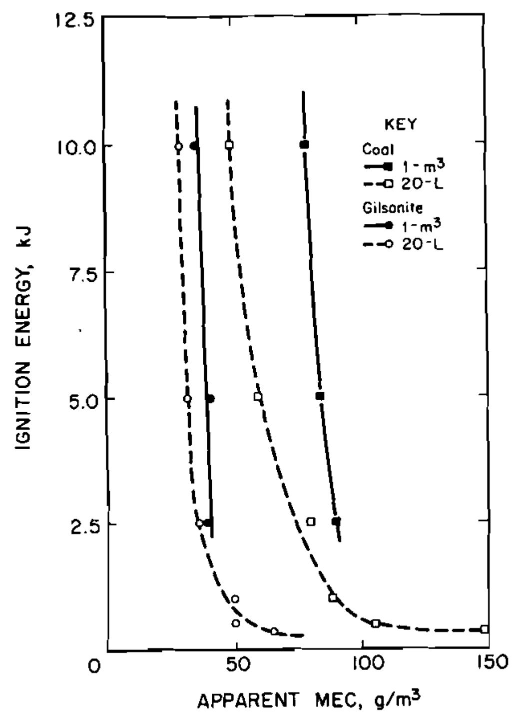

FIGURE 12 Effect of ignition energy on the apparent minimum explosible concentration (MEC) for gilsonite and Pittsburgh bituminous coal.

chamber are about 35–40 g/m^3 for the gilsonite and about 80 $\pm$ 10 g/m^3 for the bituminous coal. These values are comparable to the asymptotic values at high ignition energy in the 1-m^3 chamber. Therefore, for these dusts, the 2500-J ignitor appears to be appropriate for measuring the MEC in the 20-L chamber without overdriving the system.

The MEC data for gilsonite and Pittsburgh bituminous coal in the 20-L and 1-m^3 laboratory chambers can be also be compared to large-scale experimental mine tests (Greninger *et al.*, 1991). In the mine tests, there is a 12 m long methane–air ignition zone at the face (closed end) of the mine entry. The dust is placed on roof shelves. The methane–air explosion both entrains and ignites the dust. The dust concentration data reported are the nominal values, assuming uniform dispersion throughout the cross section. However, the dust does not necessarily disperse as uniformly in the mine entry as it does in the laboratory chambers. Using a long (152-m) dust test zone, the minimum nominal loading for an explosion of gilsonite dust was about 35 g/m^3. This is in good agreement with the value in the 1-m^3 chamber with 10 000 J ignitors. The mine value for Pittsburgh coal under the same test conditions was about 60 g/m^3. This value is somewhat lower than the 80-g/m^3 value measured in the 1-m^3 chamber with 10 000 J ignitors. However, the agreement may still be rather good when one considers the possibility of less uniform dispersion in the mine entry.

As another test of possible overdriving in the 20-L chamber, anthracite coal was tested in both laboratory chambers. Using 5000-J ignitors, the anthracite produced explosions at dust concentrations above 600 g/m^3 in the 20-L chamber as shown in Figure 13. Using 2500-J ignitors in the 20-L chamber, the anthracite produced only

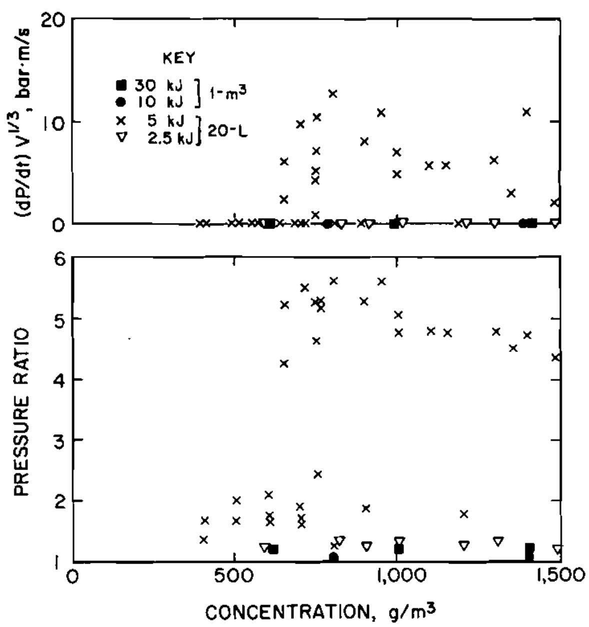

FIGURE 13 Explosibility data for anthracite coal dust from the 20-L and 1-m^3 chambers.

a slight pressure rise and no evidence of flame propagation. The anthracite was also tested in the 1-m^3 chamber with 10- and 30-kJ ignition sources, and no ignitions were observed. Since the anthracite did not ignite even with the 30-kJ ignitor in the 1-m^3 chamber, the apparent ignitions with 5 kJ in the 20-L chamber are evidence of overdriving. The 1-m^3 data are also consistent with those from full-scale experimental mine tests in which similar pulverized anthracite dusts did not produce explosions (Rice and Greenwald, 1929; Nagy, 1981). The pressures generated during the 20-L tests are larger than would be expected from anthracite dust burning within the 5 kJ ignitor flame. Therefore, it is likely, in this case, that the ignitor had changed the initial test conditions in the 20-L chamber sufficiently (such as raising the temperature) to allow the anthracite to deflagrate.

CONCLUSIONS

The data presented in this paper show that useful MEC data may be obtained in a 20-L chamber, but that more accurate data may be obtained in a 1-m^3 chamber. For the gilsonite, bituminous coal, and anthracite coal dusts tested here, the 2500-J ignitor appears to be the most appropriate energy for MEC-testing in the 20-L chamber in order to obtain data that are comparable to those obtained in the 1-m^3 chamber with 10 000 J. At higher ignitor energies, there is evidence of overdriving in the 20-L chamber. Ignitor energies below 2500 J are not recommended for dust explosion testing because they give MEC values that are larger than the "true" MEC values. The conclusions reached here apply to the particular dusts tested, and one must be cautious in generalizing or in extrapolating to other dusts or other sizes of these dusts.

For practical MEC testing in a 20-L chamber, the 2500 J ignitor is recommended for initial testing. If the dust does not ignite, further tests with a stronger (5000 or 10 000 J) ignitor would be appropriate if such strong ignition sources are a possible hazard in the industrial situation. However, the user should understand that these stronger ignitors may produce overly conservative data in a 20-L chamber, and that further tests in a 1-m^3 chamber would be necessary for a more realistic hazard determination. Even for dusts that do ignite with 2500 J in a 20-L chamber, a comparison of MEC data at 2500 and 5000 J would be useful in evaluating possible overdriving.

For other types of explosibility data from 20-L chambers, a different ignitor energy may be more appropriate. Siwek (1977, 1985) recommends a 10 kJ ignitor for measuring the size-normalized maximum rate of pressure rise in his 20-L chamber. For most of the dusts he studied, 10 kJ in the 20-L chamber gave the best agreement with 10 kJ in a 1-m^3 chamber. However, our data for anthracite dust show that 10 or even 5 kJ in a 20-L chamber is inappropriate for some dusts because they appear to deflagrate in the 20-L with 5 kJ but do not ignite in a 1-m^3 chamber even much stronger ignitors. The 20-L anthracite data are overly conservative for both MEC and $(dP/dt)V^{1/3}$. By testing with both 2500 J and stronger ignitors as recommended by the standard test method, the likelihood of overdriving in the 20-L tests can be evaluated. A general recommendation for dust testing [either MEC or $(dP/dt)V^{1/3}$] is that if a dust appears to deflagrate with a 5 or 10 kJ ignitor but does not ignite with a 2.5 kJ ignitor in a 20-L chamber, the final determination should be made in a larger system, such as a 1-m^3 chamber. For dusts that ignite with 2.5 kJ or lower energy, useful data may be obtained in 20-L chambers using the recommended standard test procedures for measuring the minimum explosible concentration or the maximum rate of pressure rise.

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