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MINES BRANCH INVESTIGATION REPORT IR 61-68

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**A COMPARISON OF THE EXPLOSIBILITY  
CHARACTERISTICS OF SOME CANADIAN COAL MINE,  
BASE METAL MINE AND INDUSTRIAL DUSTS**

by

W. J. MONTGOMERY

FUELS AND MINING PRACTICE DIVISION

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ABSTRACT

This report compares the relative explosibility hazards of a few dusts produced in both the mining and milling industries, and points out the possible dangers of each. Methods by which explosion hazards may be reduced or eliminated are also suggested.

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Direction des Mines

Rapport d'Investigation IR 61-68

COMPARAISON DES CARACTÉRISTIQUES D'EXPLOSIBILITÉ  
DE QUELQUES POUSSIÈRES PROVENANT DE HOUILLÈRES,  
DE MINES MÉTALLIQUES ET DE L'INDUSTRIE AU CANADA

par

W. J. Montgomery \*

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RÉSUMÉ

Ce rapport compare les dangers d'explosibilité de quelques poussières obtenues dans les industries d'extraction et de préparation minières, et indique les risques éventuels dans chaque cas. On suggère aussi des méthodes permettant de réduire ou d'éliminer les dangers d'explosion.

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## CONTENTS

	<u>Page</u>
Abstract . . . . .	i
Résumé . . . . .	ii
Introduction . . . . .	1
Materials Studied . . . . .	2
Ores, Tailings and Concentrates . . . . .	2
Coal and Other Carbonaceous (Organic) Materials . . . . .	3
Tests and Test Methods . . . . .	3
Proximate Analysis (ASTM D 271-58) . . . . .	3
Particle Size Distribution and Identification. . . . .	4
Minimum Ignition Temperature of a Dust Cloud . . . . .	4
Minimum Explosive Concentration . . . . .	7
Relative Flammability . . . . .	8
Pressure Developed . . . . .	8
Discussion of Test Results . . . . .	8
Minimum Ignition Temperature . . . . .	11
Relative Flammability . . . . .	13
Minimum Explosive Concentration . . . . .	14
Pressure Developed and Rate of Pressure Rise . . . . .	15
Acknowledgments . . . . .	18
References . . . . .	18

## TABLES

<u>No.</u>		<u>Page</u>
1.	Criteria of Dust Explosibility . . . . .	2
2.	Proximate Analysis of Dust Samples . . . . .	5
3.	Mineral Composition of Selected Sulphide Ore Dusts . . . . .	6
4.	Particle Size Distribution of Selected Samples of Sulphide Dusts . . . . .	6
5.	Explosibility Test Results . . . . .	12

## FIGURES

1.	Apparatus Used to Determine the Minimum Ignition Temperature of a Dust Cloud . . . . .	4
2.	Modified Hartmann Apparatus, Used to Determine Minimum Explosive Concentration . . . . .	7
3.	Modified Hartmann Apparatus with Bachrach Pressure-Measuring Device (Maihak-Indikator) . . . . .	9
4.	Explosion Pressure Curves for -325 Mesh (44 Micron) Dusts . . . . .	16

## INTRODUCTION

In recent years the Fuels and Mining Practice Division has carried out several investigations into the explosive characteristics of dusts from both coal and base metal mines. (1) (2) (3) (4) \*

This report presents a compilation of results previously reported, in order to show the relative explosibilities of the various materials investigated.

Only dusts which are readily oxidized present an explosion hazard and, of these, those containing reactive carbon ignite more readily than most inorganic materials. Two classes of dusts are involved in this study, namely organic materials--i. e. containing carbon, coal being a prime example-- and inorganic materials, such as metallic sulphide ores. Many dusts falling into these two classes may be inactive, from the explosive point of view, as a result of dilution by inert materials such as shale, sandstone, inorganic soil, and moisture.

The criteria of explosibility for the two above-mentioned classes of dusts vary considerably, and may be compared by referring to Table 1 below:

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\* References are listed at the end of the report in the order in which they are numbered in the text.

TABLE 1

Criteria of Dust Explosibility

Coal and other Carbonaceous Material	Metals and Sulphide Ores
1. Explosibility increases with increase of "volatile matter".	1. Explosibility increases with an increase of loss on ignition.
2. Particles of less than 20 mesh (840 $\mu$ ) may be airborne.	2. Particles of less than 200 mesh (74 $\mu$ ) may be airborne.
3. Specific gravity from 0.8 to 1.80. Large proportion of volatile or combustible.	3. Specific gravity from 3.0 to 6.5. Low proportion of combustible.
4. Readily dispersed by air currents of low intensity.	4. Not readily dispersed by air currents of low intensity.
5. Settles slowly.	5. Settles rapidly.

## MATERIALS STUDIED

Ores, Tailings and Concentrates

Samples of these materials were submitted for explosibility test purposes by three northern Quebec metal mines, namely Quemont Mining Corp. and Noranda Mines Ltd., Noranda, Quebec, and Normetal Mining Corp. Ltd., Normetal, Quebec. The bulk samples, 20 to 25 lb each, were in lump form in the case of ores, and fine powders for concentrates. Each sample was reduced in particle size by crushing and ball milling, and finally by screening to pass 325 mesh (44 $\mu$ ).

### Coal and Other Carbonaceous (Organic) Materials

In order to cover the range of coals mined in Canada, a typical sample representative of each of the four main ASTM ranks (as listed below) was taken from Division stores, crushed, screened to pass 325 mesh (44 $\mu$ ), and identified as follows:

Semi-Anthracite	-	Canmore Upper Marsh Seam, Canmore, Alberta.
High Volatile A Bituminous	-	Dominion No. 20, Sydney, Nova Scotia.
Subbituminous C	-	Diplomat, Forrestburg, Alberta.
Lignite	-	Klimax, Taylorton, Saskatchewan.

As examples of common industrial non-coal organic materials, the following two substances were used: (These samples were also crushed and screened to pass 325 mesh (44 $\mu$ ).)

Starch	-	Amer. Chem. Society grade (soluble)
Soap bark	-	A polishing material used by the Royal Canadian Mint to polish minted coins.

### TESTS AND TEST METHODS

#### Proximate Analysis (ASTM D 271-58)

This group of analyses are standard for coal and coke. They consist of the determination of moisture, ash and volatile matter, and the calculation of fixed carbon by difference. In the case of samples from metal mines and agricultural products, only moisture and ash



were determined, the remainder being considered "combustible".

See Table 2.

### Particle Size Distribution and Identification

These tests were carried out only on selected samples of ore, because of the time and techniques involved in making visual counts by microscopic means. See Tables 3 and 4. As yet, no suitable method is available in the Mines Branch for sizing opaque coal-like materials.

### Minimum Ignition Temperature of a Dust Cloud

This is defined as the lowest temperature at which a standard dust cloud will ignite. In order to determine the ease of ignition, a 1 gram sample of dust is dispersed downward by 15 psig oxygen pressure through an externally-heated tube furnace (see Figure 1) similar to that of Godbert and Greenwald. The temperature of the furnace is increased in 5°C steps until ignition occurs, followed by propagation of the flame.

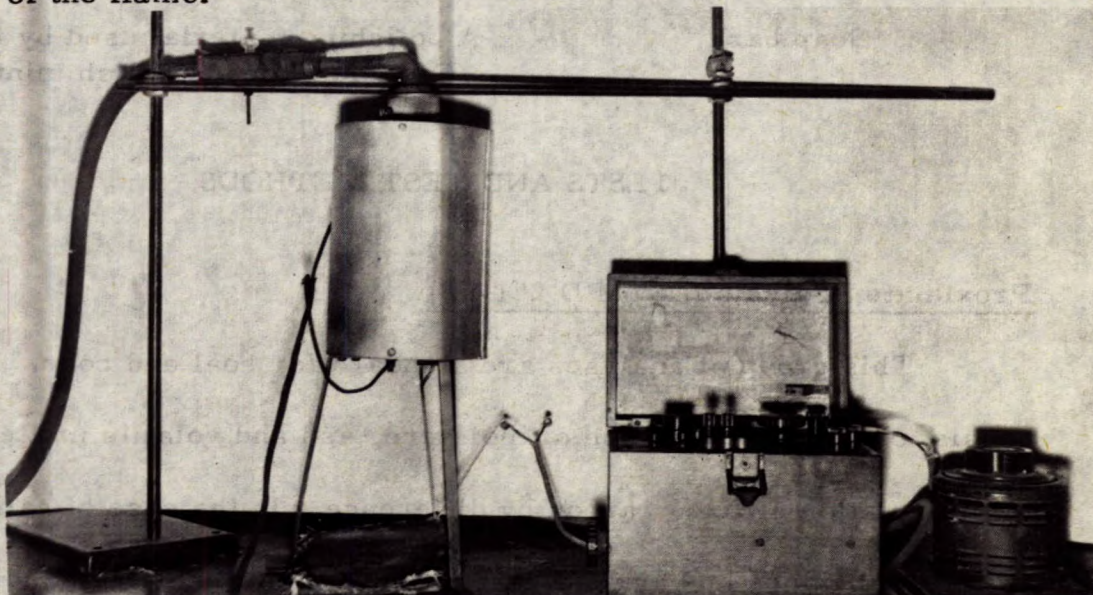


FIGURE 1 - Apparatus Used to Determine the Minimum Ignition Temperature of a Dust Cloud.

TABLE 2

Proximate Analysis of Dust Samples

Sample No.	Dust Type and Source	Moisture %	Ash %	Volatile Matter %	Combustible %	Fixed Carbon %
2617-60	Agricultural product, Soap Bark	7.90	8.13	--	83.97	--
2616-60	Agricultural product, Soluble Starch	11.05	0.25	--	88.70	--
2613-60	Coal, High Vol. A Bit., Dominion No. 20 Mine	1.35	9.73	34.56 38.86 <sup>3/</sup>	88.92 <sup>1/</sup>	54.36
2612-60	Coal, Semi-Anthracite, Canmore Upper Marsh	1.00	3.10	13.61 14.19 <sup>3/</sup>	95.90 <sup>1/</sup>	82.29
2614-60	Coal, Lignite, Klimax, Western Dominion	12.46	10.45	36.17 46.90 <sup>3/</sup>	77.09 <sup>1/</sup>	40.92
2615-60	Coal, Subbit. C, Diplomat, Forrest- burg Collieries	22.40	5.61	33.48 46.50 <sup>3/</sup>	71.99 <sup>1/</sup>	38.51
2216-60	Sulphide Ore, Noranda Pyrite 21-45N Stope	0.06	72.10	--	27.84 <sup>2/</sup>	--
2244-60	Sulphide Ore, Normetal Pyrite- Sphalerite	0.10	75.95	--	23.95 <sup>2/</sup>	--
2093-60	Sulphide Ore, Quemont Pyrite- Pyrrhotite	0.20	69.79	--	30.01 <sup>2/</sup>	--
2246-60	Sulphide Ore, Normetal Chalcopyrite- Pyrite-Sphalerite	0.10	88.37	--	11.53 <sup>2/</sup>	--
2215-60	Mill Concentrate, Noranda Pyrite Conc.	0.23	69.99	--	29.78 <sup>2/</sup>	--
2208-60	Mill Concentrate, Quemont Copper Conc.	0.13	83.12	--	16.75 <sup>2/</sup>	--
2243-60	Sulphide Ore, Normetal Massive Pyrite	0.10	71.80	--	28.10 <sup>2/</sup>	--

<sup>1/</sup> In coal samples, combustible is the total of volatile matter and fixed carbon.

<sup>2/</sup> More correctly defined as "Loss on Ignition".

<sup>3/</sup> Dry ash free.

TABLE 3\* (5)

Mineral Composition of Selected Sulphide Ore Dusts

Sample No.	% Pyrite	% Chalco-pyrite	% Sphalerite	% Gangue
2216-60	91.0	1.4	-	7.6
2093-60	90.3	2.6	5.3	1.8
2243-60	95.6	-	-	4.4

TABLE 4\*(5)

Particle Size Distribution of Selected Samples of Sulphide Dusts

Size in Microns	2216-60	2093-60	2243-60
110-80	-	-	-
80-65	-	4.9	-
65-50	-	3.9	-
50-40	2.5	5.9	-
40-32	5.9	9.5	-
32-26	13.0	7.9	3.2
26-19	17.0	7.9	5.2
19-15	12.8	8.2	7.7
15-13	10.6	9.9	6.5
13-10	10.3	9.5	9.0
10-6	8.8	8.9	11.6
6-3	10.8	12.1	13.0
3-1.5	6.0	7.5	12.9
1.5-0	2.3	3.9	30.9

\* These data are from Mineral Sciences Division Internal Report MS-60-67, prepared at the request of the Fuels and Mining Practice Division, April, 1960.

### Minimum Explosive Concentration

This is a measure of the minimum quantity of dust which, when dispersed, will ignite under standardized conditions. Increasing weights of dust are dispersed upwards in a modified Hartmann apparatus (Figure 2) through a spark gap passing a low-energy, high-voltage spark, in steps of 1/4 oz per cu ft, until ignition, followed by propagation, occurs.

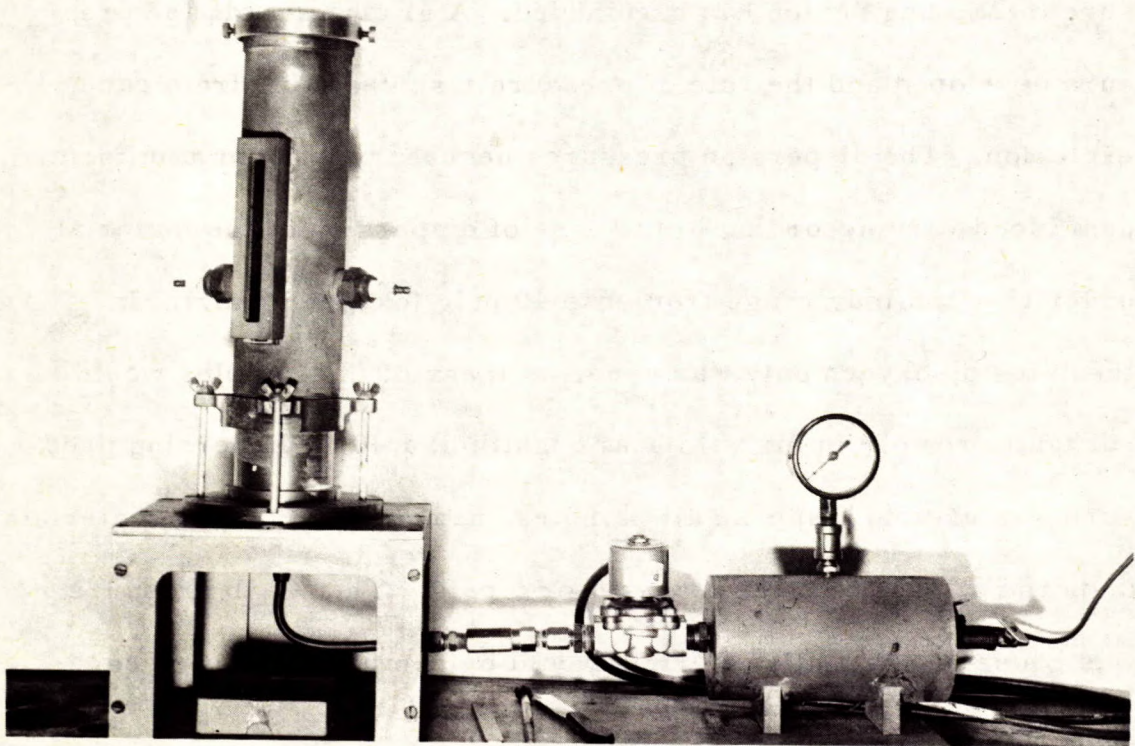


FIGURE 2 - Modified Hartmann Apparatus, Used to Determine Minimum Explosive Concentration.

### Relative Flammability

This is defined by Hartmann et al<sup>(6)</sup> as "the percentage of inert dust in a mixture with the combustible dust, required to prevent ignition of the mixture by a given igniting source", and is calculated to include the moisture and ash of the sample under test. In these tests, fuller's earth was used as the inert material because its apparent density is similar to that of coal dust.

### Pressure Developed

In this test a given concentration of dust is dispersed in the modified Hartmann apparatus (Figure 3), to which a Bachrach pressure-measuring device has been added. A graph records the pressure developed and the rate of pressure rise resulting from each explosion. The dispersion pressures necessary to form a uniform dust cloud vary according to the ease of dispersion of the material under test and may range from 4 to 40 psig (oxygen or air). In these tests, oxygen only was used, as many of the samples would not ignite readily in air with spark ignition; a 40 lb dispersing pressure was used to disperse all samples, although the lighter materials disperse at pressures as low as 4 or 5 psig. This 40 lb pressure was chosen so that all materials would be completely dispersed.

## DISCUSSION OF TEST RESULTS

By referring to Table 2, "Proximate Analysis of Dust Samples", a wide variation is noted in both the combustible and

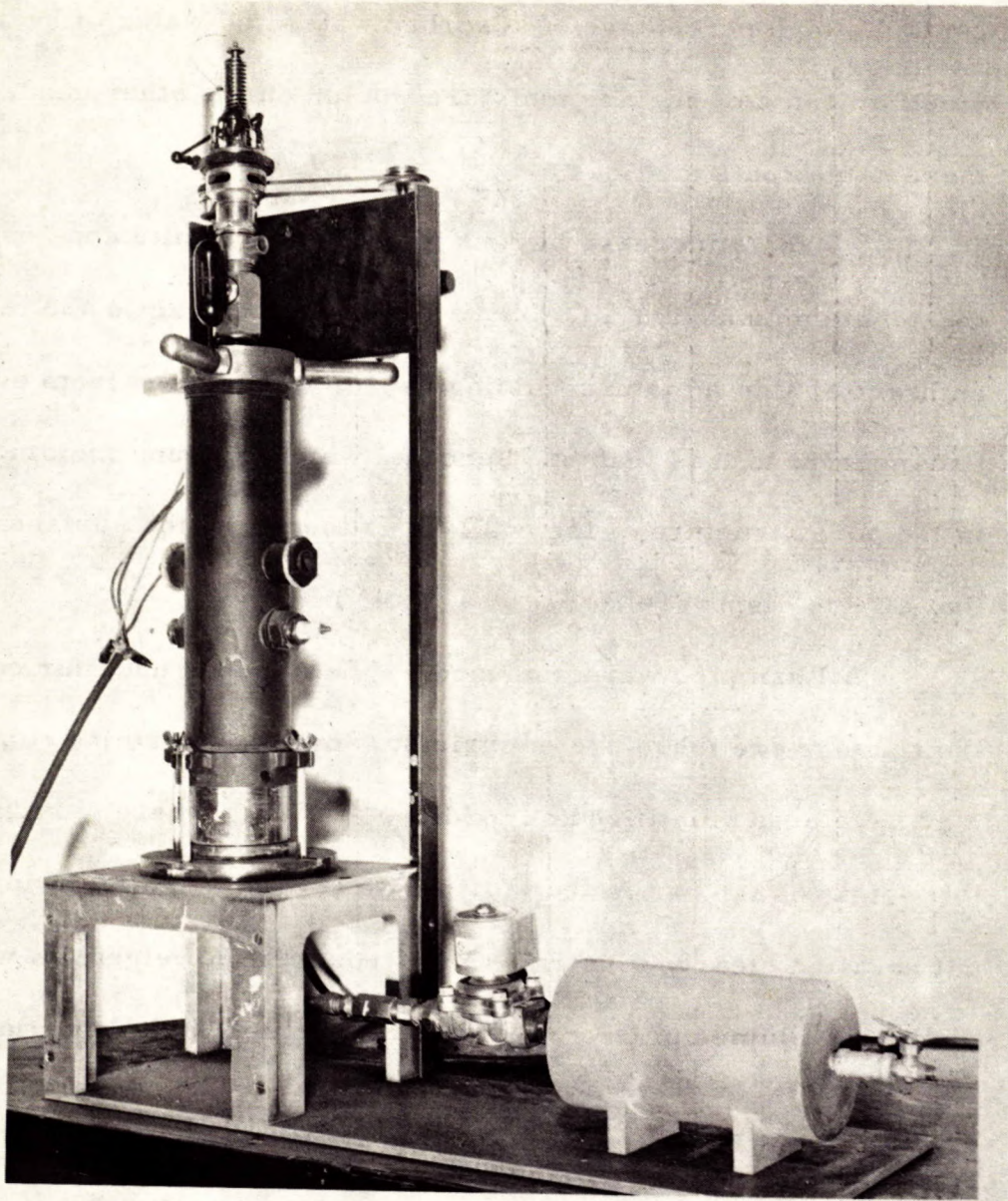


FIGURE 3 - Modified Hartmann Apparatus with Bachrach Pressure-Measuring Device (Maihak-Indikator).

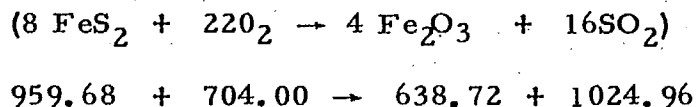
incombustible portions. Moisture contents vary from 0.1 to over 22 percent. Many materials--low rank coals, for example--are capable of holding large amounts of water retained within their cell structure and micropores. These coals may have a dry and dusty appearance yet

contain a high percentage of adsorbed water and water of hydration.

Small amounts of surface moisture would, on the other hand, render these same coals dustless.

As coals increase in rank from peat to lignite and, on through the subbituminous and bituminous levels, to anthracite and meta anthracite, this moisture-holding capacity decreases from over fifty percent to less than one percent, which is bound moisture held in the pore structure of the coal. It is therefore the surface moisture that affects dispersibility.

All samples were analyzed by the methods used for coal and the findings are therefore empirical. Some ash-forming constituents may have been volatilized or oxidized at 750°C, thereby reducing the weight of ash, as is true for pyrite (FeS<sub>2</sub>). The following chemical equation clearly illustrates this reduction in weight, as well as the large volumes of oxygen required to complete the reaction:



Metals or metal powders, on the other hand, would show an increase in weight.

Carbonaceous materials contain higher percentages of combustible matter, from which one may conclude that these materials are more readily ignited and present the greater explosion hazard. However, the reactivity of the combustible portion is

another factor to be considered. The ignition temperature of the combustible portion is dependent on the chemical composition, which in the case of the agricultural dusts could contain vegetable oils, or in the case of coals, methane; both of which are in themselves flammable, having a relatively low ignition temperature.

The sulphide ores studied, being inorganic, have no combustible volatile constituents, and therefore the explosive characteristics must be dependent on the ease of oxidation of the metallic sulphides. An explosion is, after all, an extremely rapid oxidation.

In naturally-occurring materials varying amounts of inert substances are present. These substances, such as moisture, ash, and incombustible gases, play an important part in the explosibility of a dust; in some cases their presence tends to increase explosibility by increasing dispersibility, or to decrease explosibility by acting as an absorber of heat or as a diluent.

#### Minimum Ignition Temperature

By reference to Table 5 it will be noted that the minimum ignition temperature increases for each group from top to bottom. For those who are familiar with ignition temperatures of some of these materials, it should be recalled that the dispersion medium is oxygen, resulting in values considerably lower than in air. Oxygen is used for comparative purposes only. Starch, for example, is reported by Hartmann and co-workers, of the U.S. Bureau of Mines, to have a minimum ignition temperature of 380 to 510°C,<sup>(7)</sup>



TABLE 5.

Explosibility Test Results

Sample No.	Mark		Minimum Ignition Temp., °C	Relative Flammability, % Inert		Minimum Explosive Conc., oz/cu ft	Pressure Developed (psig)		
							At Min. Expl. Conc.	At 1 oz per cu ft	At 2 oz per cu ft
2617-60	1	Soap Bark	150		75	0.3	54.1	109.5	139.4
2616-60	2	Soluble Starch	140		75	0.6	61.2	109.5	132.3
2613-60	3	Dominion No. 20 Mine Coal	160		80	0.3	113.8	51.2	31.3
2612-60	4	Canmore Upper Marsh Coal	200		50	0.9	109.5	99.6	92.5
2614-60	5	Klimax Lignite	160		85	0.3	66.9	125.2	139.4
2615-60	6	Diplomat Subbit. C	180		75	1.3	34.1	88.2	62.6
2216-60	7	Noranda Pyrite 21-45 N St.	375	<sup>1/</sup>	<sup>2/</sup> 39.4	1.3	34.1	18.5	35.6
2244-60	8	Normetal Pyrite-Sphalerite	400		84.6	1.1	17.1	17.1	32.7
2093-60	9	Quemont Pyrite-Pyrrhotite	520		81.8	1.0	Nil	38.4	45.5
2246-60	10	Normetal Chalcopyrite-Pyrite-Sphalerite	460		92.1	0.9	11.4	10.0	21.3
2215-60	11	Noranda Pyrite Conc.	410		82.5	1.1	39.8	Nil	44.1
2208-60	12	Quemont Copper Conc.	480		88.0	2.0	28.5	Nil	31.3
2243-60	13	Normetal Massive Pyrite	430		83.0	0.9	18.5	18.5	45.5

<sup>1/</sup> Relative flammability calculated to include moisture and ash of sample as for agricultural dusts and coal.

<sup>2/</sup> Calculated as an additional percentage; for example with Sample 2216-60, 0.394 g of inert was added to the 1 g test sample to prevent explosion.

bituminous coal dusts  $610^{\circ}\text{C}$ ,<sup>(8)</sup> and sulphur  $190^{\circ}\text{C}$ .<sup>(8)</sup> The ignition temperature may also be influenced by concentration.<sup>(9)</sup> Again these tests were carried out using one concentration only, i. e. the standard 1 g sample.

Ignition sources of low intensity may be encountered in many industrial plants, from overheated motors or bearings, frictional sparks, overloaded wiring, etc. These sources may be sufficiently strong to initiate an explosion in the first group of dusts.

Similarly, in coal mines frictional sparks could ignite methane, which in turn could raise enough dust and produce enough heat to propagate a dust explosion throughout the mine. However, ignition may be more frequently caused by blown-out shots or by the malfunction of electrical equipment damaged by rock falls or other underground accidents.

Ignition temperatures of the sulphide ore dusts are considerably higher than those of the other dusts, and may be in reality in excess of  $1000^{\circ}\text{C}$  in air. It is probable, then, that only sources of great heat, such as blown-out shots or exposed explosives uncovered by millisecond blasting, could ignite this type of material. Dust reduction during major blasting will undoubtedly lessen the probability of explosions, but only by reducing the sizes of blasts along with dust reduction will they be prevented.

#### Relative Flammability

By further reference to Table 5 it is found that the inert

material required to prevent propagation is 75% for the agricultural dusts, from 50 to 80% for the coals, and between 82 and 92% for the ores. In certain instances, the addition of inert material increases explosibility by increasing dispersibility, and this is probably the case for the ore samples which have a high specific gravity. By reference again to Table 2 it will be evident that the "combustible" portion of the base metal ores is not the characteristic responsible for their explosive qualities; it will also be evident that the use of rock dust or other inert material with them would be impractical because of the large quantities required and the difficulties ensuing when humid conditions present in base metal mines cause rock dust (limestone or gypsum) to cake. Present practices of using large volumes of water appear to be the most efficient.

#### Minimum Explosive Concentration

As previously stated, this is the minimum concentration of dust which, when completely dispersed, will initiate an explosion under the conditions of test, which in this case were -325 mesh samples dispersed in the modified Hartmann apparatus by a 40 psig oxygen pressure.

Again we refer to figures obtained by the U.S. Bureau of Mines (8) as differing greatly, as did the method of test. The minimum concentration for Pittsburgh coal dust is stated to be 0.035 oz per cu ft. In this case a much lower dispersing pressure was used and the particle size differed. Our figure of 0.3 oz for Dominion

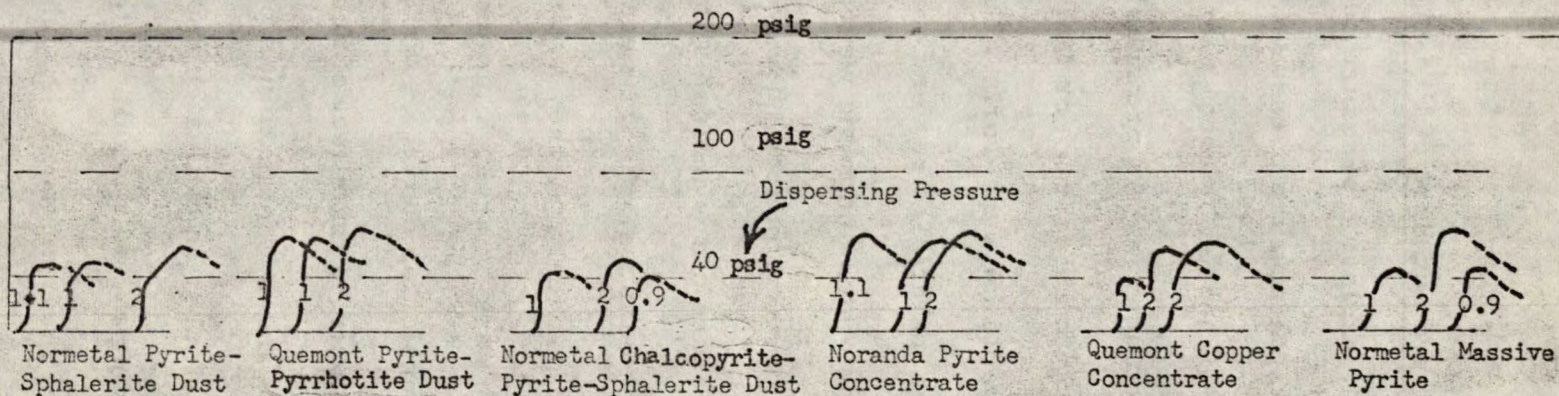
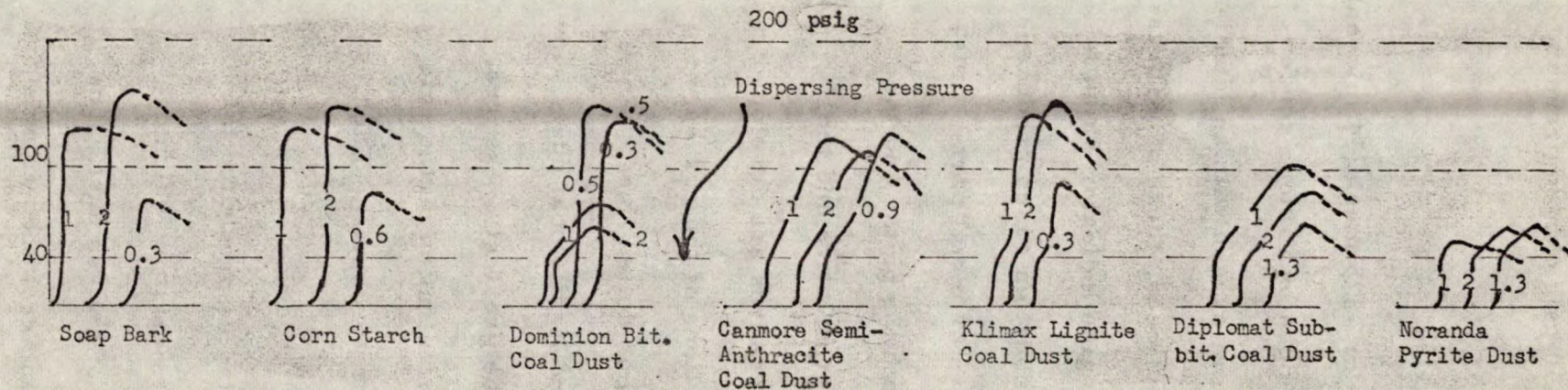
No. 20 dust is about 9 times as great, using 40 psig oxygen pressure and -325 mesh coal.

#### Pressure Developed and Rate of Pressure Rise

Figure 4, explosion pressure curves for -325 mesh (44 micron) dusts, shows graphically the pressures developed by various concentrations of dust dispersed by equal pressures of oxygen with an identical spark ignition source. As previously mentioned, these pressures were measured with a Bachrach or Maihak engine indicator which is not entirely suitable for such work. The combustion gases produced by many of these materials are very corrosive to metal parts, causing binding of the piston and rapid wear on both the piston and the cylinder. The graphs produced, however, are relative and the slope of the pressure curve indicates that pressures are developed rapidly in many instances. As the decay portions of the curves were uncertain due to gas leakage, they are shown as dotted lines.

The soap bark, starch, bituminous and lignite coal dusts show the most rapid explosion curve, as well as the greatest pressures. These curves illustrate the effect of dust concentration on the rate of pressure rise and on the maximum pressure produced. Each individual material must be evaluated separately.

On studying the test results of the samples presented in this report, it will be apparent that no simple rules exist by which one may predict accurately the possible dangers of a given dust. The factors affecting explosibility are many and interrelated; as one



NOTE: 0.5 = 0.5 oz per cu ft  
 1 = 1 oz per cu ft  
 2 = 2 oz per cu ft

--- Decay portion of curve uncertain, due to pressure leakage.  
 Horizontal scale, 60 mm = 1 second.

FIGURE 4 - EXPLOSION PRESSURE CURVES FOR -325 MESH (44 MICRON) DUSTS.

instance, a reduction or an increase in particle size may result in a better or a poorer distribution, by separating the particles to such an extent that ignition would not propagate from one particle to another, or cause extremely fine particles to form agglomerates by electrostatic attraction, thereby effectively increasing particle size and reducing the dispersibility. Dispersibility may also be affected by surface moisture which prevents the finer particles from becoming airborne.

The use of "rock dust" or other diluents in coal mines, or in industries such as flour milling or starch production, is effective if used in large enough quantities to prevent a secondary explosion. In metal mines it would appear that rock dusting would be of limited value, in that excessive quantities are required.

The present practice of wetting down the areas where scraping or blasting is to be carried out, is undoubtedly the most effective method of dust suppression. Fog-type nozzles, i. e. nozzles in which water is atomized by air pressure, as presently used, are effective in thoroughly wetting down working areas. In order to reduce explosion hazards to a minimum, air to the fog nozzle should be cut off during blasting, because excess air would only aid in producing conditions favourable to an explosion.

In coal mines, water infusion would appear to be the most effective means for dust reduction at a working face where efficient rock dusting is difficult and impractical.

## ACKNOWLEDGMENTS

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## REFERENCES

1. W. J. Montgomery, Preliminary Studies on Dust Explosibility of Canadian Coals. Trans. CIMM, Vol. LXIII (1960), pp. 484-486.
2. W. J. Montgomery and G. C. Behnke, Dust Explosibility Tests on Canmore No. 4 and Upper Marsh Seam Coals. Report TM 78/57-SF, Fuels and Mining Practice Division, Mines Branch, Dept. of Mines and Technical Surveys, Ottawa, Canada, January 1958.
3. W. J. Montgomery and G. C. Behnke, Explosibility Tests on Ores, Tailings and Concentrates from Three Quebec Metal Mines. Internal Report FMP 60/67-SF, Fuels and Mining Practice Division, Mines Branch, Dept. of Mines and Technical Surveys, Ottawa, Canada, May 1960.
4. W. J. Montgomery and G. C. Behnke, Preliminary Dust Explosibility Tests on Quemont Sulphide Ores. Internal Report FMP 60/21-SF, Fuels and Mining Practice Division, Mines Branch, Dept. of Mines and Technical Surveys, Ottawa, Canada, February 1960.
5. M. H. Haycock, Identification and Particle Size Distribution of the Constituents in Four Samples of Mine Dusts. Internal Report MS-60-67, Mineral Sciences Division, Mines Branch, Dept. of Mines and Technical Surveys, Ottawa, Canada, April 1960. (Restricted).

(References, concluded) -

6. Irving Hartmann, Murray Jacobson and R.P. Williams, Laboratory Explosibility Study of American Coals. RI 5052, U.S. Bureau of Mines, April 1954.
7. Irving Hartmann and John Nagy, The Explosibility of Starch Dust. Chem. and Eng. News (ACS) 27, 2071 (July 1949).
8. Irving Hartmann, Recent Research on the Explosibility of Dust Dispersions. Ind. and Eng. Chem. 40, 752 (April 1948).
9. Irving Hartmann, Austin R. Cooper and Murray Jacobson, Recent Studies on the Explosibility of Cornstarch. RI 4725, U.S. Bureau of Mines, August 1950.

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