It is apparent that petrographic composition of different coal fractions varies through a considerable range, even for the Pittsburgh coal bed, which is well-known for its general uniformity. Doubtless there are many coals that show component segregation and concentration due to various causes that are more extreme than those tabulated.

One of the primary objectives of investigations by this method involves preparation of coal with a minimum concentration of organic inert matter for use in experimental hydrogenation. Both opaque matter and fusain are very difficult to liquify, and one of the desirable qualities for an ideal coal for hydrogenation is that it contains a minimum of such inert organic material.

Inert Organic Matter in Eastern Coals

It has been recognized for many years that certain of the organic constituents of coal differ in reactive properties and could, in certain instances, modify the behavior of coal. A concentration of these constituents beyond a certain limit influences the carbonization properties adversely, and these constituents contribute heavily to the unreacted residue in the carbonization process. Unless they are present in an unusually pure concentration, their effect upon combustion reactions is imperceptible, because reactions are influenced most by the most reactive of the materials present. The concentration of more inert organic materials is most desirable where agglomerating properties are deleterious, as in gasification processes or where coal with free-burning characteristics is essential.

In most, if not all, of the eastern American banded coal deposits, the more inert constituents occur in varying concentration through different layers of the coal beds. Some of the nonbanded, cannel, or boghead coals have substantially uniform composition with a high concentration of inert constituents. More significantly, an even greater proportion of these coals lacks agglomerating properties, because spore coats and other waxy components are reactive but do not form a viscous melt on heating. However, the nonbanded coals are local or sporodic in occurrence and usually are associated to some extent with the banded varieties. The important source of weakly caking eastern coal for gasification or allied uses is the beds of banded coal with splinty layers. Splint coal differs in important physical respects from associated bright bands and frequently is amenable to separation and concentration by preparation practices. The splinty bands generally are zones of opaque attritus concentration. Opaque attritus and fusain are inert organic constituents most conducive to weakly caking properties in bituminous rank coal.

As a guide in selecting coals most appropriately considered as potential sources of weakly caking coal, table 2 has been compiled from the many analyses made during the past 15 years. The analyses are arranged in the order of decreasing content of organic inert constituents and range from nearly 50 percent in the case of a cannel deposit in the Elkhorn coal bed to those containing 20 percent inert matter.

TABLE 2. - Petrologic analyses of coals, with noteworthy concentrations of organic inert materials (fusain and opaque attritus)

Coal bed, mine and mining company, locality (county and State), date of sampling and analysis	Anthraxylon, percent	Translucent attritus, percent	Opaque attritus, percent	Fusain, percent	Organic inert matter, percent	Remarks
Elkhorn coal bed Standard mine, Standard Elkhorn Colliery, Inc. Garrett, Floyd Co., Ky. Sampled 1938; anal. 1938	Nil	51	49	Nil	49	Cannel coal 42 inches thick.
Van Lear coal bed Piedmont mine, Kentucky Block, Cannel Coal Co. (?) Caney, Morgan Co., Ky. Sampled 1938; anal. 1939	Nil	55	45	Nil	45	Cannel-boghead; a 15-inch lump specimen was examined; coal is 32 to 26 inches thick below sandstone roof.
High-Splint coal bed Closplint mine, Clover Splint Coal Co. Closplint, Harlan Co., Ky. Sampled 1930; anal. 1941	25.5	37	30.5	7	37.5	Splinty 7-inch block specimen selected from banded coal.
Cedar Grove coal bed Island Creek mine, Island Creek Coal Co. Holden, Logan Co., W. Va. Sampled 1942; anal. 1942	Nil	64	36	Trace	36	Boghead-cannel 8-inch block specimen from upper part of coal bed
Winefrede (Dorothy) coal bed No. 10 mine, Carbon Fuel Co. Notomine, Kanawha Co., W. Va. Sampled 1936; anal. 1936	17	48	33	2	35	Splinty, banded coal 64¼ inches thick; coal No. 43, carbonization test series.
Elkhorn coal bed No. 204 mine, Consolidation Coal Co. Jenkins, Letcher Co., Ky. Sampled 1930; anal. 1938	17	50	31	2	33	Splinty, 5-inch block specimen selected from banded coal.

TABLE 2. - Petrologic analyses of coals, with noteworthy concentrations of organic inert materials (fusain and opaque attritus) (Cont'd.)

Coal bed, mine and mining company, locality (county and State), date of sampling and analysis	Anthraxylon, percent	Translucent attritus, percent	Opaque attritus, percent	Fusain percent	Organic inert matter, percent	Remarks
Cedar Grove coal bed Island Creek mine, Island Creek Coal Co. Holden, Logan Co., W. Va. Sampled 1938; anal. 1938	Nil	*70	30	Nil	30	Boghead cannel, 20-inch block specimen from upper part of coal bed.
Upper Cedar Grove coal bed Junior mine, Red Jacket Consolidation Coal & Coke Co. Red Jacket, Mingo Co., W. Va. Sampled 1935; anal. 1935	33	37	28	2	30	Splinty, banded coal 48¼ inches thick; coal No. 39 carbonization test series.
Eagle coal bed Mallory No. 3 mine, Mallory Coal Co. Mallory, Logan Co., W. Va. Sampled 1936; anal. 1936	42	30	26	2	28	Splinty, banded coal 32½ inches thick; coal No. 46, carbonization test series.
High Splint coal bed Closplint mine, Clover Splint Coal Co. Closplint, Harlan Co., Ky. Sampled 1937; anal. 1938	31	41	26	2	28	Splinty, banded coal 40 inches thick; coal No. 54, carbonization test series.
Elkhorn coal bed No. 204 mine, Consolidation Coal Co. Jenkins, Letcher Co., Ky. Sampled 1930; anal. 1930	36.6	35.5	24	3.9	27.9	Splinty, banded coal 90.6 inches thick; coal No. 2, carbonization test series.
Clintwood coal bed No. 1 and 2 mines, Buchanan County Coal Corp. Big Rock, Buchanan Co., Va. Sampled 1933; anal. 1935	41	33	24	2	26	Splinty, banded coal 53.5 inches thick; coal No. 31 carbonization test series.

*Includes 42 percent algae, 14 percent spore coats, and 14 percent humic and resinous matter.

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TABLE 2. - Petrologic analyses of coals, with noteworthy concentrations of organic inert materials (fusain and opaque attritus) (Cont'd.)

Coal bed, mine and mining company, locality (county and State), date of sampling and analysis	Anthraxylon, percent	Translucent attritus, percent	Opaque attritus, percent	Fusain, percent	Organic inert matter, percent	Remarks
Stockton (Lewiston) coal bed Sharon mine, Wyatt Coal Co. Sharon, Kanawha Co., W. Va. Sampled 1939; anal. 1939	35	39	24	2	26	Splinty, banded coal 46.4 inches thick.
Alma coal bed Red Jacket No. 6 mine, Red Jacket Coal & Coke Co. Red Jacket, Mingo Co., W. Va. Sampled 1935; anal. 1935	44	31	23	2	25	Splinty, banded coal 47½ inches thick; coal No. 36 carbonization test series.
Lower Banner coal bed Keen Mountain mine, Red Jacket Coal & Coke Co. Hanger, Buchanan Co., Va. Sampled 1938; anal. 1938	3	72	23	2	25	Cannel specimen, 4-inch block 39½ inches from floor of bed.
Sharon coal bed Jackson Iron & Steel Co. mine Jackson, Jackson Co., Ohio Sampled 1937; anal. 1937	55	21	18	6	24	Splinty, banded coal 32 inches thick.
Lower Cedar Grove coal bed Junior mine, Red Jacket Consolidation Coal & Coke Co. Red Jacket, Mingo Co., W. Va. Sampled 1935; anal. 1935	38	38	22	2	24	Splinty, banded coal 60¾ inches thick; coal No. 40, carbonization test series.
Eagle coal bed Prospect opening near No. 7 mine, Carbon Fuel Co. Carbon, Mingo Co., W. Va. Sampled 1943; anal. 1943	37	39	19	5	24	Splinty, banded coal 31½ inches thick; coal No. 82 carbonization test series.

TABLE 2. - Petrologic analyses of coals, with noteworthy concentrations of organic inert materials (fusain and opaque attritus) (Cont'd.)

Coal bed, mine and mining company, locality (county and State), date of sampling and analysis	Anthraxylon, percent	Translucent attritus, percent	Opaque attritus, percent	Fusain, percent	Organic inert matter, percent	Remarks
Van Lear (?) (Millers Creek No. 1) coal bed No. 155 mine, Consolidation Coal Co. Van Lear, Johnson Co., Ky. Sampled 1935; anal. 1935	49	27	21	3	24	Splinty, banded coal 48 inches thick; coal No. 33, carbonization test series.
Upper Banner coal bed No. 9 mine, Clinchfield Coal Corp. Clinchco, Dickenson Co., Va. Sampled 1936; anal. 1936	37	40	21	2	23	Splinty, banded coal 51½ inches thick; coal No. 42 carbonization test series.
Powellton coal bed Coal Mountain mine, Red Jacket Coal Co. Guyan, Wyoming Co., W. Va. Sampled 1943; anal. 1943	44	33	18	5	23	Banded coal 42 inches thick; coal No. 81 carbonization test series.
Taggart coal bed Dunbar mine, Stonega Coal & Coke Co. Dunbar, Wise Co., Va. Sampled 1930; anal. 1930	53	24	20	3	23	Banded coal 52 inches thick; coal No. 3, carbonization test series.
Straight Creek coal bed Hanby mine, Fox Ridge Fuel Co. Hanby, Bell Co., Ky. Sampled 1939; anal. 1939	6	71	23	Nil	23	Cannel coal layer.
Beckley coal bed Winding Gulf No. 1 mine, Smokeless Fuel Co. Winding Gulf, Raleigh Co., W. Va. Sampled 1935; anal. 1936	40	39	15	6	21	Banded coal 54¾ inches thick; coal No. 41, carbonization test series.

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TABLE 2. - Petrologic analyses of coals, with noteworthy concentrations of organic inert materials (fusain and opaque attritus) (Cont'd.)

Coal bed, mine and mining company, locality (county and State), date of sampling and analysis	Anthraxylon, percent	Translucent attritus, percent	Opaque attritus, percent	Fusain, percent	Organic inert matter, percent	Remarks
Lower Banner coal bed Keen Mountain mine, Red Jacket Coal Co. Hanger, Buchanan Co., Va. Sampled 1938; anal. 1938	30	49	19	2	21	Banded coal $54\frac{3}{4}$ inches thick; coal No. 58, carbonization test series.
Pocahontas No. 3 coal bed Buckeye No. 3 mine, Buckeye Coal & Coke Co. Stephenson, Wyoming Co., W. Va. Sampled 1938; anal. 1938	60	20	11	9	20	Banded coal 42-5/8 inches thick; coal No. 56, carbonization test series.
Alma coal bed No. 4 mine, Spruce River Coal Co. Ramage, Boone Co., W. Va. Sampled 1931; anal. 1931	31	49	14	6	20	Banded coal 66 inches thick; coal No. 16, carbonization test series.
No. 1 Bell ("Smith" or Owen) coal bed Bell No. 1 mine, Mid-continent Coal & Transportation Co. Near Sturgis, Crittenden Co., Ky. Sampled 1939; anal. 1939	54	26	13	7	20	Banded coal $40\frac{1}{2}$ inches thick; coal No. 61, carbonization test series.
Brookville coal bed Conifer No. 1 mine Near Conifer, Jefferson Co., Pa. Sampled 1933; anal. 1934	50	30	16	4	20	Banded coal 48 inches thick; C. K. Graeber sample No. 1.
Brookville coal bed McClellan coal mine (local bank) 3 miles east of Brookville, Jefferson Co., Pa. Sampled 1934; anal. 1934	43	37	17	3	20	Banded coal ca. 24 inches thick; C. K. Graeber sample No. 4 (?)

COAL MINING

Experimental Mine and Dust Explosions

Demonstrations and Lectures

Following cessation of hostilities, the restrictions against visitors to the Experimental Testing Station at Bruceton, Pa., were lifted. Numerous requests were received from miners, mine officials, and mining schools for educational demonstrations of the ignition of coal-dust clouds by various means that are commonly found in mines, of the dangers arising from the use of black powder, of the greater safety attained through the proper use of permissible explosives, and of recommended safeguards against explosions. Accordingly, seven large-scale mine-explosion demonstrations were held, which were attended by nearly 3,000 persons. In addition, many smaller demonstrations were given for small groups of visitors, among them field men of explosives companies that require them to visit the station as part of their preliminary training, and technical persons from Australia, Brazil, China, France, Great Britain, Holland, Peru, Russia, and this country.

Inflammability and Explosibility of Industrial Dusts and Powders

Continued investigation of the inflammability and explosibility of dusts produced in industrial plants is being carried out. Over 60 dust samples were submitted by industry for evaluation of the explosion hazard that might be encountered in their production and use. A number of the samples were received after actual explosions, flash fires, and fires of spontaneous origin had been caused by the products. These included peanut cracklings, a byproduct from the extraction of peanut oil, dehydrated, ground citrus peels used as cattle feed and fertilizer; soap powders; bituminous coal from a pulverizer; seacoal used as facing for foundry molds; and gilsonite dust from a mine in Utah in which a severe explosion occurred. Tests on several samples of gilsonite indicated that this dust is considerably more explosive than fine bituminous coal dust; the nature of the gilsonite deposit and the methods of mining are such that application of rock dust for preventing the propagation of explosions is most difficult, if not impossible.

Among the other dust samples tested were metal powders, plastics, drugs, insecticides, dehydrated rice, soybean, coffee, sulfur, activated carbon, coal, pitch, dust from exhaust system of an office building, D.D.T., cellucotton, tung hulls and kernels, starch, moss, kelp, rockweed, ingredients of explosives, and other products. Nearly all of these were found to present some degree of dust-explosion hazard under proper conditions. For all dusts investigated, recommendations were made concerning safeguards to be taken in the plants in order to reduce the hazard. In testing insecticides containing fine sulfur powder and noninflammable ingredients, it was found that even mixtures with as little as 10 percent sulfur can cause fairly severe explosions. Sulfur powder can be ground and mixed safely in an inert gas atmosphere containing 10 percent or less oxygen. In connection with the proposed use of mixtures of powdered coal-tar pitch and aluminum powder for foundry facings in steel plants, a study was made of the explosion hazards of mixtures containing various proportions of stamped and of atomized aluminum powders. This disclosed that mixtures containing atomized aluminum are not more explosive than the pulverized pitch along, but those containing flaked or stamped aluminum are more hazardous.

Research work was conducted on (1) accurate determinations of the lower explosive limits of dust clouds, (2) development of new types of ignition sources for dust clouds exploded in the laboratory bomb, and (3) studies of the effect of dust concentration upon the energy required to ignite dust clouds by static electrical sparks. Two publications were prepared relating to research work on metal-powder explosions.8/

Review of the present state of knowledge of dust-explosion phenomena has indicated that greater progress in prevention of explosions could be made if scientific knowledge were available as to the basic mechanism of the ignition of dust particles, the mechanism of propagation of heat and pressure waves and of flames through the dust cloud, and of the relation of these phenomena to the physical and chemical properties of the dusts.

Release of Dust-Explosion Pressures to Prevent Structural Damage

Few manufacturing structures can withstand the pressures developed by violent dust explosions in a confined space. Rapidly opening explosion-relieving devices or vents in the enclosing walls or roof afford means of dissipating pressure during an explosion. It becomes important to study the design requirements of such relief vents for reducing structural damage. The first phase in this study has been completed and is the subject of two reports.9/ A short motion picture of this work was made. A few of the more important findings of the study are:

1. Aside from the chemical and physical properties of the dust, the violence of a dust explosion in a given enclosure is affected by the method of formation of the cloud, particularly as it influences the uniformity of distribution of the dust particles, by the position and nature of the source of ignition, by the timing of the ignition relative to the formation of the cloud, and by the concentration of the dust in the cloud.

8/ Hartmann, Irving, and Greenwald, H. P., The Explosibility of Metal-Powder Dust Clouds: Min. and Met., vol. 26, 1945, pp. 331-335. Hartmann, Irving, The Explosion and Fire Hazard of Metal Powders: Metals Handbook, American Society of Metals. (In press.)

9/ Hartmann, Irving, and Nagy, John, Effect of Relief Vents on Reduction of Pressures Developed by Dust Explosions: Bureau of Mines Rept. of Investigations 3924, 1946, 22 pp.
Hartmann, Irving, Pressure Release in Dust Explosions: Nat. Fire Protec. Assoc. Quart., vol. 40, pt. 1, July 1946, pp. 47-53.

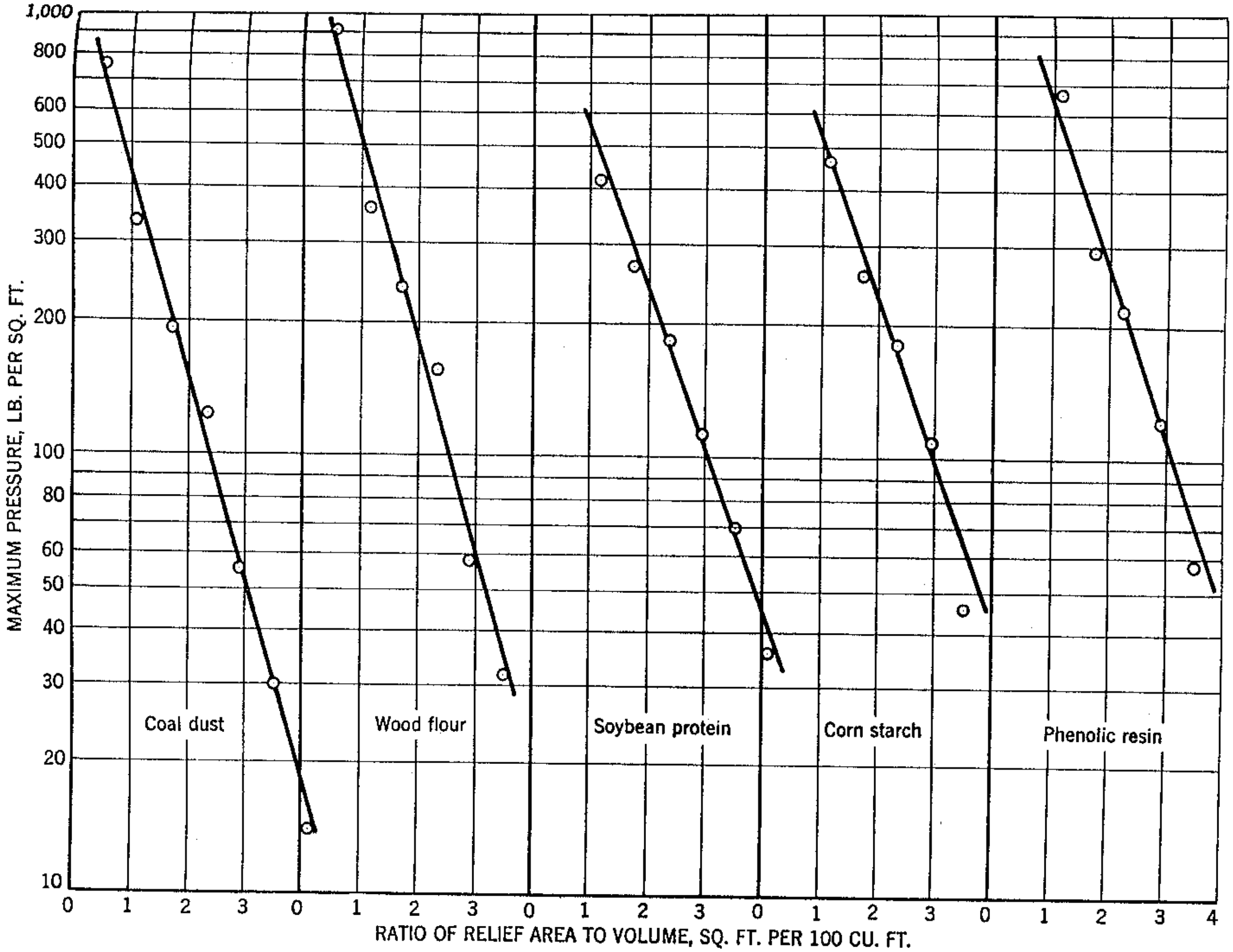

Figure 3. - Effect of unrestricted relief vents upon pressures produced by explosions of various dust clouds.

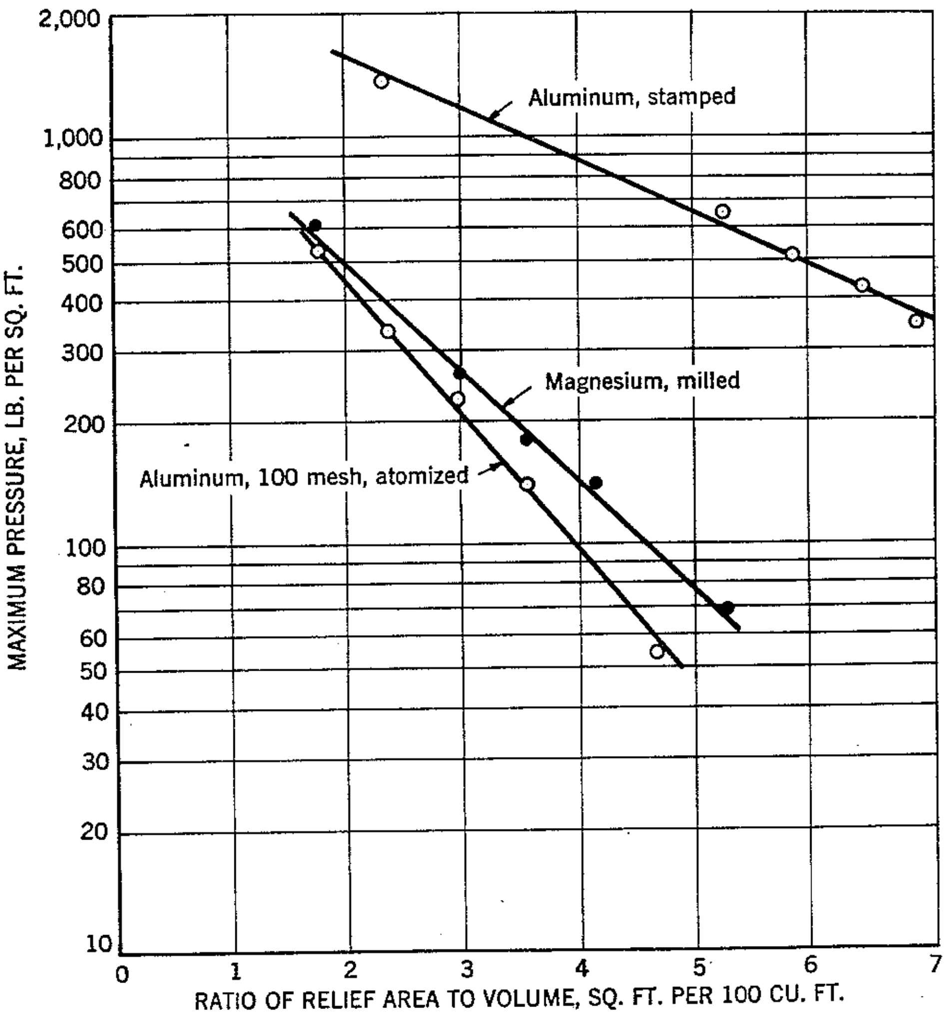

Figure 4. - Effect of unrestricted relief vents upon pressures produced by dust explosions of aluminum and magnesium powders.

2. Explosions initiated by short electrical sparks are not as violent as those initiated by the flame from a small quantity of guncotton or other ignition source of similar intensity. This is because flame initially raises the temperature of a greater proportion of the dust cloud to the ignition point.

3. Explosions initiated at the instant when all the dust is in suspension in the air produce higher pressures than explosions initiated either prematurely or after some of the dust has settled on the surrounding surfaces.

4. Under similar test conditions, the strongest explosions in the gallery were produced by clouds of stamped-aluminum powder dust. Next in approximately decreasing order of intensity were explosions produced by milled magnesium, atomized aluminum, phenol-formaldehyde resin, cornstarch, soybean protein, wood flour, and coal dust.

5. Data were obtained for all dusts tested, by aid of which the reduction of the maximum explosion pressures with increase in the area of unrestricted or free relief vents could be established. The relations are plotted on a semi-logarithmic scale in figures 3 and 4; they are expressible by an exponential equation of the form:

$$P = Ae^{-kr}$$

where P = maximum explosion pressure
r = ratio of relief vent area to volume of enclosure
A and k = empirical constants, whose values were computed from the test data for each dust

6. In this cubical gallery, explosions could be vented as effectively by several small, unrestricted vents as by a single vent having an area equal to the combined areas of the small vents. This will not necessarily be true of much larger structures or of those of different shapes.

7. To release explosions through vents closed off by heavy-paper or other diaphragms, larger vent areas must be provided than are necessary for unrestricted or free vents.

8. Saw-toothed cutters placed along the peripheries or near the centers of paper diaphragms on vents greatly facilitate their rupture when an explosion starts and permit the use of smaller relief vents than would otherwise be needed.

9. Unrestricted rectangular vents were found to be as effective as square vents of the same areas. Square vents closed by heavy-paper diaphragms proved to be somewhat more effective in releasing explosion pressures than rectangular vents with similar diaphragms.

10. For releasing relatively slow explosions, such as for coal dust, light, hinged, swinging panels are nearly as effective as unrestricted