leads us to suppose that a large portion of the primary products of the decomposition of coal are high molecular weight paraffins. These decompose into olefines which in turn form the decomposition products for the formation of benzene and its homologues. The course of the reactions may be indicated as follows:

IV—Diminishing the duration of the carbonization reactions by recirculation tends to increase the actual yields of total, light and heavy oils as well as the yields of the total benzene, toluene and xylene fractions.

V—Recirculation tends to increase the percentage yields of the paraffins and to decrease the percentage yields of aromatics and unsaturated bodies thus offering further evidence that the aromatics are formed at the expense of the other two.

VI—Although the *percentage* yields of the individual aromatics, benzene, toluene and xylene, are favored by increasing the duration of the carbonizing reactions by non-circulation, in the zones of maximum aromatic formation—usually between 700 and 900° C.—the *actual* yields are favored by recirculation.

VII—Recirculation tends to increase both the *actual* and the *percentage* yields of tar acids in the light oil. This would tend to confirm the conclusions of other investigators that the tar acids are products of the primary decomposition of coal.

VIII—The results as a whole emphasize the necessity of temperature control in coal carbonization if the yields of the important aromatics are to be considered. Under the conditions usually maintained in standard practice, it is evident that for actual efficient combined yields of benzene, toluene and xylene, the carbonizing temperatures should not greatly exceed 800° C., nor should they lie much lower than 700° C. The fact that such good yields of the aromatics are obtained at the gas and coke works where very high temperatures are employed is, no doubt, due to the protection offered by the cooler central core of coal which does not reach the cracking temperatures, and to the cooling effect on the hotter gases due to dilution with the cooler gases emerging from the center of the charge.

IX—By the use of any device whereby the duration of the carbonizing reactions is shortened, it seems possible both to increase the yields of the paraffin oils at the lower temperatures and the yields of the aromatics at the higher temperatures. It is also possible to operate at higher carbonizing temperatures.

X—The similarity of the coal carbonizing reactions to those undergone during oil cracking suggests the possibilities of carbonization at low temperatures and a treatment of the low temperature tars by the cracking processes used on the petroleum oils. In this way the valuable tar acids could be conserved by removing them before the cracking treatment, and

more efficient yields of the aromatics (or possibly of the lower boiling paraffins) could be obtained. However, until the oil cracking processes prove more fully their industrial worth, this phase of by-product recovery will not be entitled to serious consideration.

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INFLAMMABILITY OF CARBONACEOUS DUSTS

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The fact that coal dust is explosive is very generally known to-day. The large loss of life that often accompanies a mine disaster has forcibly called attention to this. As early as 1844, Faraday recognized that coal dust was an important factor in explosions in mines. But only within the last thirty years has it been fully recognized that coal dust alone was explosive without the presence of gas. To-day nearly every large country has its experiment station to study causes and means of prevention of mine explosions.

It must not be concluded, however, that coal dust is the only dust that will explode, as experiments have clearly shown that many other carbonaceous dusts are at least as easily ignited and as capable of propagating an explosion as is coal dust. While most of the dust explosions reported in surface plants occur in mills and elevators handling wheat, oats and corn, and their products, it appears that no mill handling carbonaceous material is immune from the possibility of an explosion. The list of known explosions in other kinds of mills includes those handling dextrine, sugar, starch, malt, wood, linseed meal, cottonseed meal, paper, cork, fertilizer, sulfur, cocoa, and spice dusts.

That flour dust will explode was clearly demonstrated in 1878 by a tremendous explosion in the Washburn Flour Mills in Minneapolis. An investigation was made by Professors Peck and Peckham¹ in connection with which they tested the explosibility of a variety of dusts by blowing them as a cloud into a closed box containing a small flame. They concluded that practically all finely divided, highly carbonaceous material would explode under the conditions tried. More recently R. V. Wheeler,² chief chemist for the *Explosion in Mines* Committee, England, carried out some systematic tests for the purpose of discriminating between harmless and dangerous dusts, and to determine the temperatures at which inflammation of the dangerous dusts takes place readily. As a result of these tests he divided the dusts into three classes, *viz.*:

I—Dusts which ignite and propagate flame readily, the source of heat required for ignition being comparatively small, for example, a lighted match.

¹ *Mines and Minerals*, 29 (1908), 55.

² Report on the Inflammability and Capacity for Transmitting Explosions of Carbonaceous Dust Liable to be Generated on Premises, under the Factory and Workshop Acts, 1913. R. V. Wheeler, D.Sc.

II—Dusts which are readily ignited but which, for the propagation of flame, require a source of heat of large size and high temperature, such as an electric arc, or of long duration, such as the flame of a Bunsen burner.

III—Dusts which do not appear to be capable of propagating flame under any conditions likely to obtain in a factory, because (a) they do not readily form a cloud in air, or (b) they are contaminated with a large quantity of incombustible matter, or (c) the material of which they are composed does not burn rapidly enough.

Certain dusts of interest in the present investigation were classified by Wheeler as follows:

"CLASS I	Sugar	Grain (flour mill)
	Starch	Maize
	Rice meal and sugar refuse	Grain (grain storage)
	Wood flour	Rape seed
	Malt	Corn flour
CLASS II	Oat husk	Flour (flour mill)
	Rice milling	Grist milling
	Castor oil meal	Horn meal
	Offal grinding (bran)	Mustard
	Spice milling	Sack cleaning
CLASS III	Cottonseed	Rape seed (Russian)
	Cottonseed and soya bean	Grain cleaning ¹

The Minneapolis explosion aroused milling men to the danger of existing conditions and caused many to take precautions immediately to guard against repetition of similar occurrences. The impression was not lasting and although a large number of grain dust explosions occurred after that time, general interest was not awakened again until June 24, 1913, when an explosion occurred in a feed grinding plant at Buffalo in which 33 men lost their lives, and over 70 men were injured. This explosion, which occurred during the ordinary process of operation, completely destroyed the milling plant and did considerable damage to surrounding property. As a result of this disaster the millers in and around Buffalo were very desirous of obtaining any possible information relating to the inflammability of grain dust which would help them in taking effective safety precautions in addition to the measures already adopted. An agitation was started which resulted in a coöperation between the millers and the Bureau of Mines for the investigation of questions relating to explosions of grain dusts. This was later taken up by the Government and is being continued as a coöperation between the Bureau of Chemistry and the Bureau of Mines. The laboratory investigations, originally carried on in the laboratories of the Bureau of Mines at Pittsburgh, have recently been transferred to the laboratories of the Bureau of Chemistry at Washington.

SIMILARITY BETWEEN GAS AND DUST EXPLOSIONS

Although the investigations of dust explosions have not been as complete or conclusive as those made on gas explosions—probably because of the great difficulties encountered in maintaining or even obtaining a uniform dust cloud of any desired density—the available data show quite conclusively that the phenomena exhibited by the two types of explosions are very similar. A statement of a few pressures and flame velocities measured in explosions of coal dust and of gases will serve to indicate this fact.

The United States Bureau of Mines¹ reports having

¹ U. S. Bureau of Mines, *Bull.* 56 (1913).

measured in a coal dust explosion an average velocity of 2273 ft. per sec. over a distance of 100 ft. In experiments at the British Experiment Station,¹ Altofts, England, an average velocity of 2014 ft. per sec. has been obtained. Taffanel² obtained a velocity of 3300 ft. per sec.

A pressure of 103 lbs. per sq. in. is reported by the Bureau of Mines. The British authorities report pressure up to 100 lbs. per sq. in., with an estimated pressure in one test of 120 lbs. Taffanel reports having measured pressures of 227 to 270 lbs. per sq. in., while in one test the steel gallery, with an estimated breaking strength of 570 lbs. per sq. in., gave way, pieces of the sheet steel being thrown distances up to 150 meters (472 ft.).

The maximum velocities of propagation of flame in many gas mixtures have been determined with accuracy by Dixon,³ Berthelot,⁴ Emich,⁵ Nernst,⁶ and others.⁷ For certain of these mixtures the following results were obtained:

GASEOUS MIXTURES	VELOCITY PER SECOND	
	Meters	Feet
2H ₂ + O ₂	2820	9250
4 parts coal gas + 5 parts oxygen.....	2700	8876
C ₂ H ₄ + 3O ₂	2364	7724
CH ₄ + 2O ₂	2322	7616
2CO + O ₂	1680	5510

Mallard and LeChatelier⁸ obtained a pressure of 6.5 atmospheres (97.5 lbs. per sq. in.) for a mixture of 1 vol. CH₄ + 2 vol. O₂ + 9 vol. air. Leau and Bone⁹ found a pressure of 20.7 atmospheres (310.5 lbs. per sq. in.) developed in a mixture of 2H₂ + O₂.

It will be noted that as high pressures have been observed in coal dust explosions as in gas explosions. However, the extremely high velocities attained by the flame in certain gas mixtures have not been reported as observed in dust explosions. Such high velocities could not be expected, for even the finest dust particles are many times larger than gas molecules, and so, even in the most dense dust clouds the particles could not be as close together nor as intimately mixed with the oxygen as are gas molecules. Therefore, the heat of combustion of one dust particle cannot be as readily transmitted to the next particle as it can in a mixture of gases. But the finer the dust the more nearly will it approach the size of a gas molecule. Therefore, it might be expected that the velocity of the flame through a cloud of very fine dust would more nearly approach the velocity attained in gas explosions. As a matter of fact, this is true. Taffanel¹⁰ has brought this out in tests made at the French Experiment Station. Results obtained by the Bureau of Mines¹¹ lead to the same conclusion.

The rate at which inflammation travels through a

¹ Report of Committee on British Coal Dust Experiments. Record of first series, 1910.

² "Les expériences françaises sur les poussières de bouille." Internationaler Kongress, Düsseldorf, 1910. Berichte der Abteilung für Bergbau.

³ H. Dixon, *Phil. Trans.*, **184**, 97, 161; **200**, 328; *Chem. News*, **46**, 70.

⁴ M. Berthelot, "Sur la Force des Matières Explosives," **1** (1883), 159.

⁵ Emich, *Ber.*, **42**, 2462.

⁶ Nernst, "Theoretische Chemie," Dritte Auflage, p. 628.

⁷ Notably Vieille; Mallard and LeChatelier.

⁸ E. Mallard and H. LeChatelier, *Ann. Mines*, [8] **4** (1883), 379.

⁹ B. Leau and W. A. Bone, *Chem. News*, **66** (1882), 101.

¹⁰ Taffanel, Fourth Series of Tests.

¹¹ G. S. Rice, "Investigations of Coal-Dust Explosions," *Bull. Amer. Inst. Mining Eng.*, **1914**, p. 2476.

FIG. I

gas mixture is dependent upon at least two factors, the inflammability of the gas and the percentage of the gases in the mixture. The rate at which inflammation travels through a dust cloud seems to be dependent upon two similar factors, namely, the inflammability of the dust and the amount of dust in suspension. A third important factor is the fineness of the dust.

It will be seen, therefore, that gas and dust explosions are similar in many ways and that a gas explosion is only a limited case of a dust explosion.

A thorough knowledge of the nature of dust explosions and of the accompanying phenomena is necessary in order to devise means for the prevention of such explosions and for the stoppage of explosions if by mischance they should start. It is, therefore, necessary to know how dust ignites, the various means by which it may be ignited, or inflamed, and the chemical processes that take place. Another important factor to know is the ease with which the dust ignites and propagates a flame. This property we may call the "inflammability" of the dust. The term "explosibility" has also been applied in this connection.

DEVELOPMENT OF METHOD FOR TESTING INFLAMMABILITY OF DUSTS

When the present investigation was started to determine the causes and means of prevention of grain dust explosions, one of the first problems undertaken was to devise a method for testing the inflammability of the various dusts, or to adapt some method at present used for testing the same property of coal dusts. The method of Wheeler was tried, but the tests were unsatisfactory. A method for testing coal dusts had been developed by the United States

Bureau of Mines. Preliminary tests showed that it could be adapted. Several kinds of dusts were tested and the results published by the Millers' Committee of Buffalo, New York, as a "Preliminary Report on the Explosibility of Grain Dusts."¹

Further tests were made with the same and other dusts, at the same and at lower temperatures. The results are given in Fig. I. The temperatures were measured by a thermocouple with its hot junction on the inside of the igniting coil. The pressures given for temperatures from 1000 to 1200° C. are the average of all results given by each dust at these temperatures. But at the lower temperatures ignitions were not obtained in every test, so that the points given are the average of only those where the dust ignited. The results given at 1100 and 1200° C. were referred to Pittsburgh Coal Dust as a standard, but the results at all lower temperatures are those actually obtained. Also, as in the early tests, all the dusts except 61, 112, and malt, were dried at 105° C. in a current of dry air.

Tests were also made on a few other undried dusts at two temperatures only. The results at 1200° C. were referred to the coal dust standard.

No.	SAMPLE	Pressure at 1200° C.	Pressure at 800° C.
13 A	Wheat smut.....	21.4	0.6
4 A	White dextrin.....	15.5	7.6
7 A	Dark canary dextrin.....	15.1	7.3
6 A	Canary dextrin.....	14.9	7.9
11 A	Wheat starch.....	14.1	8.5
1 A	Sugar.....	13.0	7.5
3 A	Corn starch.....	12.6	6.7
12 A	Rice starch.....	12.3	5.3
9 A	Potato flour.....	10.4	6.2

These results are given as a basis of comparison of the dusts by the method used in testing them and the

¹ Abstract THIS JOURNAL, 6 (1914), 934.

method to be described. They are given also to show how low a temperature is required to ignite these dusts—a temperature of 700° C. on the inside of the igniting coil showing only a very dull redness at the surface that is scarcely visible in daylight.

VARIABLES AFFECTING RESULTS—The method as used at this time was not at all satisfactory for either coal or grain dusts, as the results were less uniform and reproducible than was desired. There were too many variables. The igniter, with its means of temperature measurement, was unsatisfactory since it did not give the actual temperature at the point of ignition, and did not compensate for the deposition of ash on the coil, or the wearing away of the alundum coating. Probably the most important variable was the manner in which the dust was inserted into the globe and against the coil. This, it appeared, was controlled not only by the amount of air used to force in the dust and by its rate of flow, but also by the size and shape of the funnel which holds the dust. Other variables were the amount of dust used, the temperature used to ignite the dust, and whether or not a screen was used over the funnel through which the dust would be forced.

MEASURING TEMPERATURE OF IGNITER—To overcome the variables in the igniter, a coil of similar construction was used, except that it had, outside the alundum coating, platinum foil fastened tightly around the coil. The temperature at the surface of the coil is measured by a thermocouple. The wires of the thermocouple are not fused together in the usual manner to form the hot junction, but are attached separately to the platinum foil. The platinum rhodium wire is fastened around the coil at the center and the platinum wire about 3 mm. to one side. These were fastened to the foil by means of heat and pressure. The hot junction is then at the immediate surface of the coil and the temperature registered is that of the point of contact between the small platinum rhodium wire and the platinum foil. To reduce to a minimum the loss of heat from the surface of the igniter by conduction along the wires, the ends in contact with the foil are drawn down to a diameter of 0.15 mm. With this arrangement the coil can always be kept clean and the actual temperature at the point of ignition known.

METHOD OF INSERTING DUST—It was early observed that by grading the releasing of the air used to force in the dust, that is, by opening the pinchcock at various rates, a great variation in results could be obtained with any dust. To obviate this a mechanical releasing device was made which would always release at the same rate and very rapidly. With certain dusts this rapid forcing of the dust against the igniting element was found to be too rapid to obtain the highest pressures possible. Therefore, the rate of flow of the air was controlled by a short piece of capillary tubing placed between the releasing device and the funnel.

This method gave much more satisfactory results than had previously been obtained. However, it was observed that the results could be varied by in-

serting the dust into the funnel in different ways, that is, whether it was compact or loose, partly around the bend in the funnel, or entirely in the upright portion, or partially in the bowl. Concordant results were very difficult to obtain with the original funnel. Therefore, an extensive series of tests was started to develop a funnel that would be suitable for all types of dusts, and also a size of capillary which would give consistent results.

In these series of tests seven different types of funnels were tested before one was obtained which was satisfactory. Tests with several different types of dusts were made with each funnel. Capillaries of from 1.0 to 2.5 mm. bore were used in the tests. The two extreme sizes were used in only a few tests as the one of 0.1 mm. bore was found to be too small to allow passage of sufficient air to raise the dust, and the one of 2.5 mm. bore gave results only slightly higher in some cases than were given with the next size smaller. Therefore, only the following sizes were used in most of the tests: 1.5, 2.05, and 2.35 mm. bore, respectively.

The pressure of the air used to force the dust into the globe also affected the results very appreciably. Tests were made with the air under 15 cm. and 20 cm. of mercury. The latter pressure was found the more satisfactory.

The manner in which the dust was inserted was also affected by a 14-mesh screen placed over the funnel. This served to break up the dust and make a more uniform cloud. However, some of the grain dusts were very fibrous, and so did not pass readily through the screen. This gave irregular and low results with some of these dusts so that tests were made using the screen and without it.

AMOUNT OF DUST—In all the early work 50 mg. of the dusts were used in each test except where curves were run with varying amounts of material. These results indicated that a larger amount of material would give more uniform results, therefore series of tests were run with both 50 and 75 mg. of the dusts. The results with 75 mg. were much higher in every case, fully as uniform, and in some cases more uniform than with 50 mg. As 75 mg. was a convenient amount to handle, giving sufficiently high results with the less inflammable materials, and not too high for safe handling of the apparatus with the more inflammable, this amount was used in all later experiments.

EFFECT OF LARGE AMOUNTS OF DUST—The tests with 75 mg. of dusts suggested a study of the effect of large amounts of material. Therefore, a short series of tests was made with four different dusts. That size capillary was used which previous tests had indicated would give highest results. The results of these tests are given in Fig. II. It will be observed that for Samples 47 and 33 the curve had nearly reached its maximum at 150 mg. of material, while the pressures for sugar and starch were still increasing at this point. Higher points were not run because pressures might be obtained beyond the safe working limits of the apparatus.

FIG. II

The results indicate that large amounts of the more inflammable materials could not be used in the present type of apparatus, and also that only a certain pressure will be developed even though more material is used. It is possible that these curves would behave as gas curves and begin to decrease if sufficiently large amounts of materials were used.

In running this series of tests it was observed that a slight amount of charring resulted in each test with 100 mg. of Sample 47, while with 150 mg. of material a considerable amount of charred material was found in the flask after ignition. Only very slight charring was noticed with the starch and flour. When 150 mg. of sugar were used, a perceptible odor of formaldehyde came from the flask, while with 200 mg. the odor was quite strong. These observations would indicate incomplete combustion with these amounts of material, and also that the heat of the reaction caused some decomposition of the dust.

INDICATIVE RESULTS—For comparison with previous and later results there is given in Fig. III the results obtained with a few typical dusts, using three different sized capillaries, with and without a screen over the funnel. These results were obtained with the funnel that was found to be most satisfactory. Seventy-five milligrams of material were used and ignited at a temperature of 1100°C ., a temperature approximately the same as 1200°C . on the inside of the coil, which had been used quite satisfactorily in the early work. The results are those actually given, and are not referred to any standard dust.

In these tests it will be observed that the results with dextrin, sugar, and Samples 13 and 47 are higher at certain or all points when no screen was used over the funnel. No reason can be assigned to the two former, but the latter two contained fibrous material which was held back by the screen. With the other dusts the screen served to break up the dust and form a more uniform cloud.

All these dusts except wheat flour (No. 33), and

Pittsburgh coal dust, gave higher results with the 2.05- and 2.35 mm.-bore capillaries, and in some cases with the 1.5 mm. capillary than were given at the highest temperature in the earlier tests. The 2.05 mm. capillary gave the most concordant results.

OTHER VARIABLES—However, the results at this point were not entirely satisfactory. The only other variables that had not been thoroughly tested were the effect of higher temperature and the action of the valve between the air reservoir and explosion flask. A slight change in capillary was also considered.

EFFECT OF VALVE—Tests were made to determine the effect of the valve. The results obtained without the valves were appreciably lower than when the valve was used. This was expected as the volume of air affected by the ignition was thereby increased by the volume of the air reservoir. However, the valve

FIG. III

was discarded, as it was shown that it did not always work, and the results without it, though lower, were more uniform.

TEMPERATURE OF IGNITION—To determine the effect of temperature under the new conditions, a series of tests was made at temperatures from 1000 to 1200°C . at 50° intervals. In these tests a capillary of 1.9 mm. bore was used as this was the size used by the Bureau of Mines at this time in testing coal dusts, and as it was only slightly smaller than the capillary (2.05 mm. bore) found to give the most satisfactory results with grain dusts.

As some of the dusts had not reached a maximum pressure at 1200° , tests were made at 1225°C . The results of these tests are given in Fig. IV.

It will be observed that the curves begin to become horizontal at 1150° , and that the results at 1200 and 1225° are only slightly higher in most cases. The

results at all these temperatures were quite uniform and concordant. On account of these facts, and because the results at 1200° C. were not much different from those obtained at 1150° C., which would mean that a slight variation of this temperature would not make any appreciable difference in the results, and since 1200° C. was more convenient to use than a higher temperature, it was taken as a standard temperature.

EFFECT OF CAPILLARY.—To determine the most satisfactory size of capillary for all types of dusts, a series of tests was made at 1200° C., using four different capillaries, 6 cm. long and varying in bore by 0.1 mm. from 1.9 mm. to 2.2 mm. These results are given in Fig. V.

It will be observed that in most cases the size of capillary had no marked effect upon the average results. This was due, probably, to the high igniting temperature, and to the fact that the differences in diameter of the capillaries were not large enough to affect greatly the rate of flow of the air. However, there was a difference in the uniformity of the results obtained. The 2.0 mm. capillary gave the more uniform and concordant results, and these were nearly as high or higher than the results given with other capillaries. So this capillary was chosen as the best for future work.

COMPARISON OF METHODS FOR COAL AND GRAIN DUSTS—During the development of this method, the Bureau of Mines was also perfecting their method for testing coal dusts. As the properties of the two dusts are very dissimilar, a duplication of tests could not be avoided. However, it was thought advisable

FIG. IV

FIG. V

Fig. VI

1200° C., capillary 6 cm. long and 2.0 mm. bore; air under 20 cm. pressure; no one-way valve between air reservoir and explosion flask, but a pinchcock back of the air reservoir; 75 mg. of material; a coarse screen over the funnel except when very fibrous dust is tested; and a funnel 4.0 mm. internal diameter, with a bowl $\frac{3}{4}$ in. deep and $\frac{5}{8}$ in. across at the top, and the bend in the funnel being a right-angle $\frac{5}{8}$ in. below the bowl and having a small wire screen inside and just back of the bend.

The same type of apparatus is used in testing the inflammability of both the coal and the grain dusts. It is shown in Figs. VI and VII. The only difference in construction is in the funnel. The methods of

FIG. VII

to have as few differences in the methods as possible. It was partly for this reason, to conform more closely to Bureau of Mines practices, that the valve was discarded, and that a temperature of 1200° C. and a 2.0 mm. capillary was adopted. These conditions gave the best results with coal dust, and practically the same results with grain dusts as slightly different conditions would give. The method as adopted for testing grain dusts is as follows: Temperature,

operation are different, however, in that 75 mg. of grain dust are used as against 100 mg. for the more inflammable coals, and 300 mg. for the less inflammable. The vital difference is that oxygen under 15 cm. of mercury pressure is used to insert the 100 mg. of coal dust, while air at 20 cm. of mercury pressure is used to insert the grain dusts.

RESULTS WITH CARBONACEOUS DUSTS—The method as developed and standardized has been used in test-

ing the inflammability of a large variety of dusts. The results are given in Table I in the order of inflammability:

TABLE I—INFLAMMABILITY OF CARBONACEOUS DUSTS

Sample No.	KIND OF DUST	Pressure Generated Lbs. per Sq. In.
51 A	Lycopodium.....	17.5
13 A	Stinking smut of wheat.....	15.9
61	Yellow corn dust from first break in dry milling.....	15.2
18 A	Dextrin dust from dextrin kiln.....	14.6
47 A	Stinking smut of wheat.....	14.3
20 A	Powdered wheat starch.....	14.0
46 A	Stinking smut of wheat with wheat dust.....	13.9
4 A	White dextrin.....	13.9
21 A	Starch dust (corn) from dry starch kilns.....	13.8
6 A	Canary dextrin.....	13.8
43 A (200 mesh)	Tan bark dust.....	13.3
5 A	Powdered corn starch.....	13.2
11 A	Wheat starch.....	13.1
17 A	Starch and dextrin dust from about tray filler.....	13.0
35 (200)	Wheat elevator dust, side wall.....	13.0
19 A	Dextrin dust from top of reels and mixer.....	12.8
36 A (200)	Wood dust from chipper room.....	12.8
3 A	Corn starch.....	12.7
37 (200)	Oat and corn dust from unloading station.....	12.6
2 A	Lump corn starch pulverized to pass 200 mesh.....	12.5
112	White corn dust, top of elevator.....	12.5
13 (200)	Wheat elevator dust.....	12.5
43	Oat and corn dust, top of elevator.....	12.4
57 (100)	Oat dust from ground oat hulls.....	12.3
1 A	Sugar, lump pulverized to pass 200 mesh.....	12.2
23 A	Gluten feed dust, from beams, etc., in curing room.....	12.1
47 (200)	Oat dust from feed oats.....	12.0
7 A	Dark canary dextrin.....	11.8
65 (200)	Feed dust from dust collector.....	11.8
9 A	Potato flour.....	11.7
31 A	Sugar dust from sugar pulverizer.....	11.7
12 A	Rice starch.....	11.3
33 (200)	Wheat flour from packing room.....	11.2
14 A	Powdered wheat starch.....	11.0
24 A (200)	Corn elevator dust.....	11.0
50 A	Malt dust from discharge of collecting system.....	10.6
103	Wheat flour dust, rolls and purifiers.....	10.5
48 A (200)	Fertilizer dust, from grinding dry tankage.....	10.5
26 A	Tapioca flour.....	10.4
34 A	Sugar dust, collector from powder mills.....	10.3
13 C	Pittsburgh Standard Coal Dust.....	10.1
43 A	Tan bark dust.....	10.0
29 A	Tapioca flour.....	9.9
32 A	Cocoa dust from cocoa bolters.....	9.9
97	Reduction middlings.....	9.4
33	Wheat flour from packing room.....	9.3
42 A	Cocoa dust from cocoa cooling room.....	9.1
8 A	Rice starch.....	9.0
41 A	Extra fine sulfur flour.....	8.8
44 A	Wheat smut and field dust.....	8.8
49 A	Ground cork dust.....	7.4
30 A	Rice flour.....	5.6
25 A (200)	Arrowroot powder.....	3.9
15 A	Potato starch.....	3.2
37 A	Gelatin dust from elevator.....	1.1

The results in Table I cannot be considered as absolute, as showing that the order as given here is the exact order of ease with which these will ignite. It is, however, the order of inflammability, as given under the conditions used in the tests. A change of any of the conditions might increase the pressure given by some, while it would decrease the pressure given by others. This fact is clearly shown in Fig. III, where increasing the size of capillary caused an increase in pressure with certain dusts, but a decrease with others. However, the results indicate that most of the dusts have a higher degree of inflammability than Pittsburgh coal dust, but in the light of present knowledge it is difficult to interpret the significance of this higher pressure, except that the dust is more easily ignited.

Although these results are only relative, they indicate that all the dusts tested have a high degree of inflammability, and that a dangerous condition exists where a cloud of any one of them is in suspension, or in a position where it can be easily thrown into suspension in the air. The relative degree of danger is approximately in the order of the foregoing results.

Tests on a larger scale are under way which will aid

in the interpretation of these results. These are designed to demonstrate under what conditions each dust will ignite, whether the source can be as small as a static spark, or whether it must be as large as a gas flame, or something between these limits.

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A STUDY OF COMMERCIAL BEECHWOOD CREOSOTE

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A sample of beechwood creosote, made by a commercial process and furnished by the manufacturer, has been analyzed at the Forest Products Laboratory, Madison, Wisconsin, as a part of the studies on hardwood tars, creosotes and other related substances.

The sample was found to have the characteristics indicated in Table I.

TABLE I—ANALYSIS OF SAMPLE

Fraction No.	Temp. ° C.	Per cent Observed	Per cent Cumulative	Sp. Gr. 60° C.	Ind. Ref. 60° C.	CHARACTER OF FRACTION
1	205	3.7	3.7	...	...	Yellow liquid
2	215	10.1	13.8	...	...	Golden yellow liquid
3	225	20.8	34.6	1.003	1.5074	Golden yellow liquid
4	235	8.1	42.7	1.009	1.5083	Golden yellow liquid
5	245	5.5	48.2	1.012	1.5111	Golden yellow liquid
6	255	8.4	56.6	1.019	1.5117	Golden yellow liquid
7	265	13.4	70.0	1.021	1.5123	Golden yellow liquid
8	275	2.7	72.7	1.022	1.5138	Golden brown liquid
9	285	4.8	77.5	...	1.5138	Red-brown paste
Residue	...	21.6	99.1	...	...	Black solid

In the present investigation it was desired especially to determine if any considerable portion of the phenolic constituents have boiling points around 205° C.—that of guaiacol. As the sample contained some tar and pitch it was thought best to remove these before further studies.

The distillation was carried on in an iron still holding about 5 liters. On account of frothing, only about 2 liters could be distilled at one time. There was an overflow attachment to the still so arranged that when frothing became so violent as to cause an overflow, the lead to the condenser could be closed and another passing out of the window opened to prevent the contamination of the distillate with the froth. In the first run there were about 2 liters in the still. This was heated slowly, about 1½ hours being required for the first drops to come over at 45 to 50° C. The temperature rose rapidly to about 85°, then slowly to 90°, where it was constant for a while. The liquid coming over at this temperature was light brown and a good deal of water was present. Finally, the temperature rose to 130° and the other fractions were

TABLE II—DISTILLATION OF BEECHWOOD CREOSOTE

No.	1	2	3	4
Amount Distilled	2 liters	2510 g.	2609 g.	2597 g.
130 to 200°.....	175 cc.	63	66	64
200 to 215°.....	160	140	288	286
215 to 230°.....	240	638	481	521
230 to 245°.....	450	390	485	459
245 to 250°.....	...	357	209	177
260°-up.....	...	192	267	...
Pitch.....	...	590	584	...

taken. Table II gives a summary of the fractions obtained in four distillations.