Explosive Hazard of Arabinogalactan Dust

BRUCE V. ETTLING
Washington State University
Pullman, Washington

ARABINOGALACTAN (AG), a water-soluble vegetable gum found in Western larch and in several other species of trees, is a polysaccharide with two components of 16,000 and 100,000 molecular weight units (Mosimann and Svedberg, 1942). The polymer is composed of arabinose and galactose units in the ratio of 1:4 (Bouveng and Lindberg, 1958).

Neither the water solution of arabinogalactan nor the larch chips from which it is extracted constitutes a fire hazard. However, after the AG has been dried, it is a lightweight powdery substance including a fine dust (-325 mesh). By analogy with wood and starch dusts which are chemically related to AG, a suspension of AG dust in air should be a potential fire and explosion hazard.

Specifically, this study involved the following three points: 1. The minimum ignition temperature of AG dust; 2. The minimum ignitible concentration of AG dust in ounces per cubic foot; and 3. The maximum explosive pressure.

Data concerning these three points for only technical-grade AG are given in this study.

Experimental

Preparation of Dusts

In order to estimate the size of dust particles likely to be encountered in plant operations, some drum-dried, technical-grade AG from the pilot plant was classified in standard mesh sieves. Table 1 shows the distribution of particle sizes.

Table 1

Particle-Size Distribution for One Sample of Drum-Dried AG

Mesh Range	*Per Cent of Sample*
+20	4.7
—20+60	16.3
—60+150	32.8
—150+200	18.0
—200+325	24.0
—325	2.8
	98.6

The fractions of different particle size were used in tests on the fire hazard of AG. All dust samples used in the following experiments, except where noted, contained 6.0-6.5 per cent moisture based on oven-dried AG.

Minimum Ignition Temperature

The minimum ignition temperature or the least temperature at which a mixture of a combustible substance and air will burn spontaneously was determined for AG using the apparatus shown in Figure 1.

The combustion tube was a length of ½″ O.D. copper tubing. The temperature in the combustion tube was regulated with a variable transformer and determined with a thermocouple. Small quantities (1.5 to 8.0 mg.) of each AG dust fraction were blown into the combustion tube using the rubber bulb. Ignition of the dust was audible as a "pop" even if combustion was incomplete.

Any ignition at a given set of conditions was considered as a positive result. If no ignitions occurred in the first four trials, the result was considered negative.

The experiment was started at 772°C, and successive trials were made at decreasing temperatures to 497°C. Figure 3 shows the results of the experiment using AG dust of various particle-size ranges at different temperatures.

Another experiment was run similarly on 60-150 mesh AG at 0.75, 6.3, and 7.2 per cent moisture content.

Minimum Ignitible Concentration

The minimum ignitible concentration of AG dust in air was determined using the apparatus diagrammed in Figure 2. The combustion chamber was made from a 10″ length of 2″ diameter brass tubing. On each end of the cylinder was soldered a flange to which could be bolted an end plate sealed with a rubber gasket.

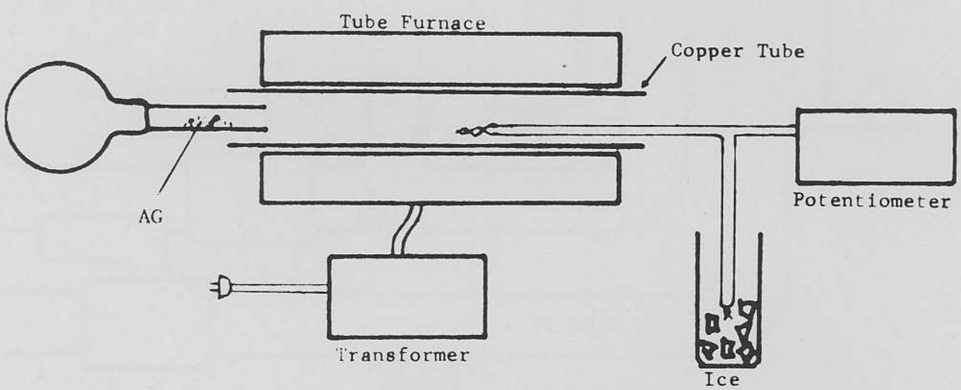

Figure 1. Schematic diagram of apparatus used on ignition temperature experiments.

Two lengths of copper tubing passed through the bottom plate. In one tube was a "tee" through which the AG powder was added. The apparatus was sealed and evacuated through tube #1. The #1 valve was closed, and then the valve on tube #2 was opened to allow the in-rushing air to draw the AG into the cylinder. Immediately after the dust entered the chamber, a high-voltage spark was set off across the gap between the electrodes. Ignition was accompanied by either a bang or by a hiss of gas escaping from the system.

The spark used was between 4500 to 5000 v. D.C. The energy of the spark could be adjusted by changing the capacitor across the output terminals of the power supply. The spark gap was approximately 0.1 in.

A weighed quantity of AG powder was poured into the "tee." The concentration of the dust in the known volume of the combustion chamber was calculated with the assumption that the AG was evenly dispersed in the chamber.

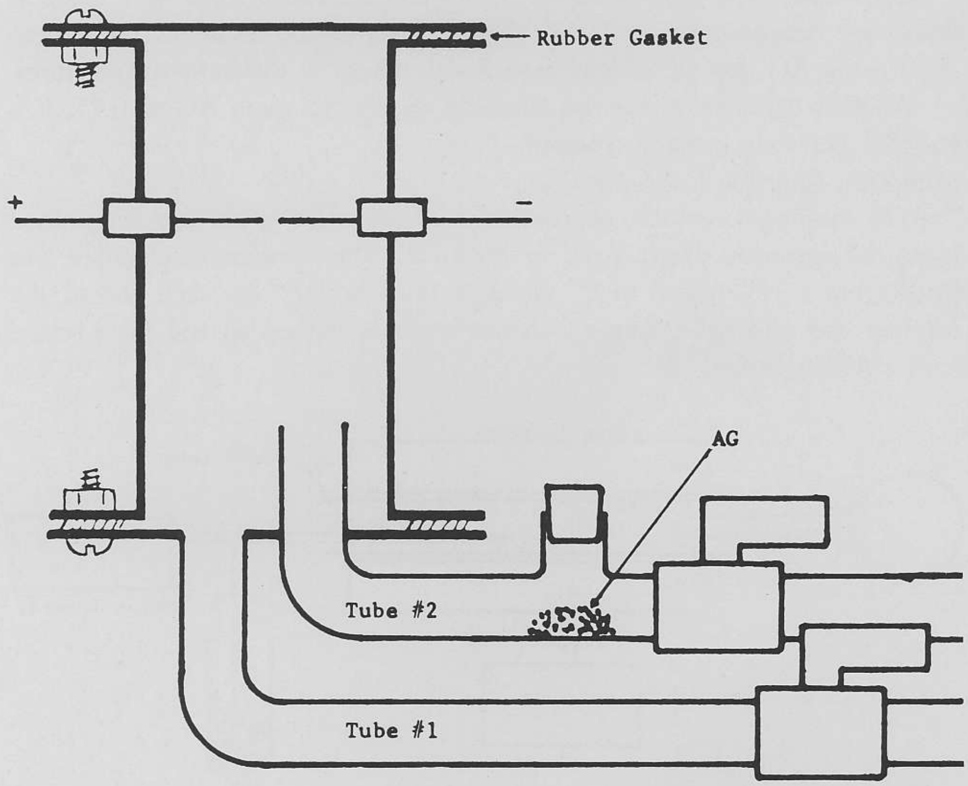

Figure 2. Diagram of apparatus used in experiments on minimum ignitible concentration and maximum explosive pressure.

Maximum Explosive Pressure

The maximum explosive pressure was determined using the same brass cylinder (Figure 2) used for the concentration measurements. In addition, two strain gages, attached to the outside surfaces, measured the elongation of the cylinder caused by the internal pressure. The procedure was essentially that used for the concentration measurements except that the valve on tube #2 was closed again immediately after the dust was drawn into the cylinder. The spark was discharged immediately after closing the valve. The pressure increase caused by combustion was detected by the strain gages and recorded with a Brush oscillograph. The detection system had been calibrated with static gas pressure in the cylinder.

Table 3 shows the results for several concentrations of -325 mesh AG using a 23 joule spark.

Discussion

Minimum Ignition Temperature

The minimum ignition temperature (MIT) of AG dust, illustrated in Figure 3, depends somewhat on the particle size.

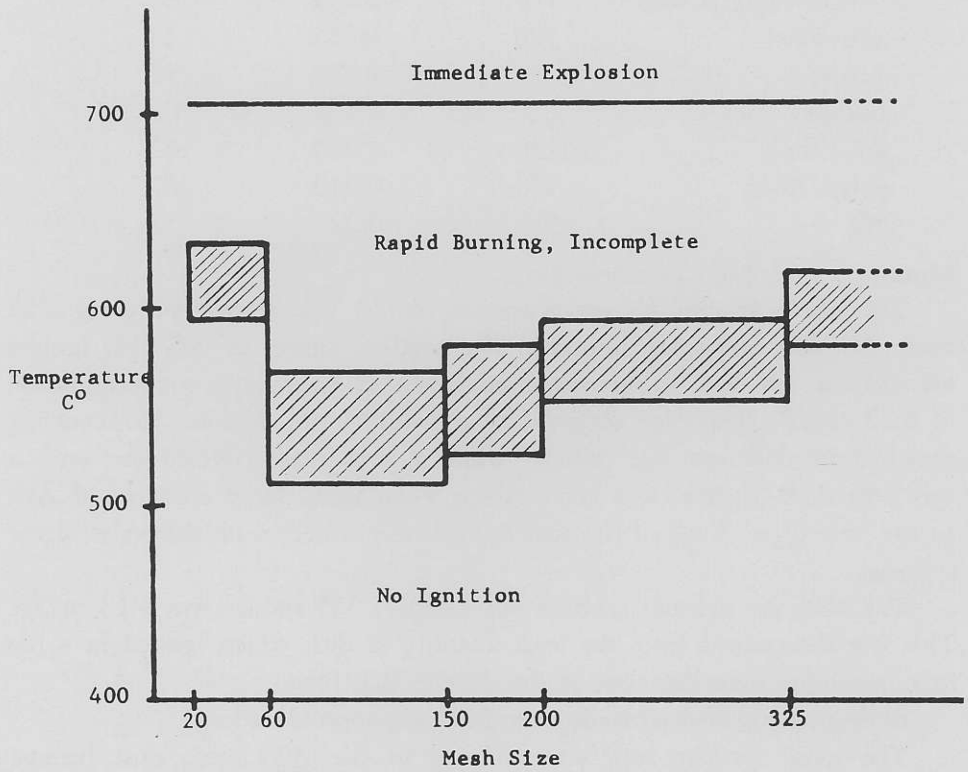

Figure 3. Minimum ignition temperatures of AG dust.

Shaded areas of Figure 3 indicate temperature ranges in which an individual sample of AG may or may not ignite. Between the shaded area and 705°C, combustion was certain, though possibly incomplete, for all sizes of dust. Above 705°C, combustion was explosive and apparently complete.

The moisture level of 60-150 mesh AG dust had no significant effect on the MIT. By comparison, a moisture content of 6-7 per cent lowered the MIT of several starch dusts by 10-30°C in one study (Hartmann and Nagy, 1949).

Surprisingly, the most easily ignited dust is the 60-150 mesh size. Other investigators (Hartmann and Nagy, 1944) found that with cellulose acetate, the finest dust (325 mesh) was the most sensitive. AG dust does not ignite at as low temperatures as do certain related dusts. Ignition properties of several dusts are compared in Table 2.

Table 2

Comparison of Published Properties of Several Substances to AG

Dust	*MIT (°C)*	*MIC (oz/ft³)*	*MEP (psig)*
cellulose acetate (molding powder)	410	0.035	62
corn starch	380	0.055	51
sucrose	------	0.120	56
glucose	------	0.110	68
wood flour	430	0.050	62
cotton flock	470	0.050	67
AG	511	0.22	52

Minimum Ignitible Concentration

The minimum ignitible concentration (MIC) was determined using -325 mesh AG dust and spark ignition. The smallest charge of AG that ignited was 0.10 g. which, if evenly dispersed in the cylinder, gave a concentration of 0.22 oz/ft^3. The even dispersal of the dust is not certain. However, by drawing the dust into the cylinder while a glass plate covered one end, it was seen that dispersal was good except when using large amounts of AG. In the latter case, much of the dust immediately collected on the walls of the cylinder.

The MIC for thermal ignition (of —200+325 mesh) was 0.13 oz/ft^3. This was determined from the least quantity of dust which ignited in a hot tube, assuming even dispersal of the dust in that tube.

Both methods of determining the MIC are approximations.

The spark ignition tests were limited to the -325 mesh dust because such high energy was needed to ignite the coarser dusts.

According to data on four dusts (Hartmann and Nagy, 1944; Meek and DallaValle, 1954), the MIC increased with average particle size. Thus, the data for AG, which are on the finest dust, are for the most hazardous size of dust. Dust encountered in actual operations would likely be larger and less easily ignited.

Maximum Explosive Pressure

The maximum explosive pressure (MEP) depends upon the concentration of dust as shown in Table 3.

Table 3

Explosive Pressure of AG Dust

Concentration (oz/ft^3)	*Pressure* (*psig*)
0.22	18.5
0.33	33.5±6.0
0.44	52.0±0.8
0.55	46.3±4.0
0.66	28.5±10.0
0.88	7.5

The optimum concentration is that in which the available oxygen will consume the dust. The MEP is greatest under that condition. Pressures vary considerably from one trial to another, as is indicated by the range of the standard deviations in Table 3 on three trials each. However, the deviation at the maximum was small (0.8%) indicating that the value is reliable. The 52 psig of pressure is three and one-half times atmospheric pressure or 7500 lbs/ft^2.

The tests used the finest AG dust (-325). According to two other studies (Hartmann and Nagy, 1944; Meek and DallaValle, 1954), finer dust gave greater maximum pressures. Hence, the data for the MEP of AG are for the most dangerous particle size.

For AG, the optimum concentration for explosive pressure is between 0.40 and 0.55 oz/ft^3. For three resins (Hartmann and Nagy, 1944) and three sugars (Meek and DallaValle, 1954) the optimum dust concentration ranges were 1.4-1.8 oz/ft^3 and 0.30-0.45 oz/ft^3, respectively.

The time interval between the spark discharge and the maximum pressure in the cylinder varied from 0.17 to 0.36 seconds. There is no correlation of time with dust concentration. However, the maximum pressure tends to increase as the time decreases. In other words, a more rapid (more explosion-like) burning produces higher pressure.

Spark Energy

A spark with an energy of 10 joules or more ignited the —325 mesh AG dust but not the coarser —200+325 mesh dust. The latter did ignite with a 23 joule spark. Hartmann and Nagy (1944) showed that the energy required to ignite cellulose acetate dust was less when the dust was finer. The energy needed to ignite cellulose acetate, ethyl cellulose, and starch dusts was less than that needed to ignite AG.

Summary

A drum drier produced arabinogalactan powder of 20 mesh to less than 325 mesh. The minimum ignition temperature (511°C) and the minimum ignitible concentration (0.13 oz/ft^3, thermal or 0.22 oz/ft^3, spark) are higher than those of starch, wood flour, cellulose acetate, and other similar substances. The spark energy required to ignite AG dust is greater than that required for starch, cellulose acetate, and similar substances. The maximum explosive pressure (52 psig) is slightly less than that for similar substances.

AG dust is slightly less explosive than wood flour, starch, cotton flock, or cellulose acetate. Nevertheless, if AG dust is ignited in a closed space, a pressure of 7500 lbs/ft^2 may be developed.

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