(see Figure 2), and lower minimum explosive concentration. Furthermore, since in a fine dust cloud there are more particles with a greater total surface area and the particles are spaced more closely than the particles in a coarse cloud of equal weight concentration, the rate of flame propagation is greater and the heat losses are smaller; therefore in a fine dust cloud higher maximum pressures and higher rates are developed in explosions. These effects are illustrated in several papers by Hartmann and co-workers for coal[8], for metal powders,[5] for synthetic resins and molding compositions,[6] and for cornstarch.[7] An extreme example of the effect

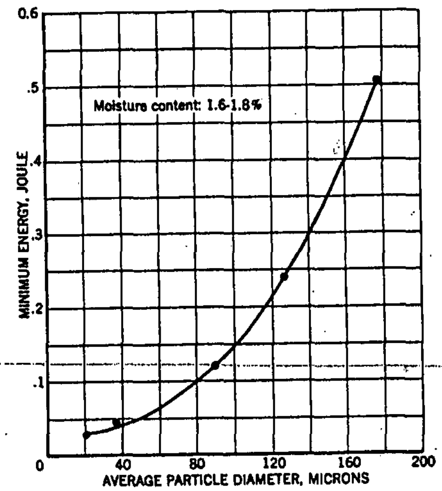

Figure 2. Effect of particle size on the minimum energy required to ignite dust clouds of cornstarch in air by electrical sparks. (Courtesy Bureau of Mines, U. S. Department of the Interior.)

of fineness on flammability is manifested by the pyrophoric behavior of certain magnesium, lead, iron, uranium, and other metal powders. When of very small particle size, these powders oxidize so rapidly upon exposure in air that they ignite spontaneously.

Dusts of a given material produced by different manufacturing processes often have different shapes and surface characteristics that affect their flammability. This may result from differences in surface area, density, the amount of adsorbed gas, or the formation of protective surface layers. It is known, for example, that aluminum and magnesium powders produced by stamping, which yields flat, thin particles, have higher flammabilities than approximately spherical particles of the same mesh size produced by atomization or by milling.

[8] I. Hartmann, J. Nagy, and H. Brown, *U. S. Bur. Mines Rept. Invest.* No. **3722**, 1943.

[6] I. Hartmann and J. Nagy, *U. S. Bur. Mines Rept. Invest.* No. **3751**, 1944.

[7] I. Hartmann, A. R. Cooper, and M. Jacobson, *U. S. Bur. Mines Rept. Invest.* No. 4725, 1950.

3. *Concentration of Dust Cloud*

In a dust cloud, just as in a gas-air mixture, ignition of one part of the cloud will be propagated throughout the entire mixture and develop into an explosion only when the concentration of the dust in the air is between certain lower and upper limits. The minimum explosive concentration, or lower limit of explosibility, is that concentration at which there is just barely enough dust in the air to propagate flame throughout the cloud after ignition at a localized point. The upper explosive limit is theoretically that dust concentration at which the heat generated through complete combustion of a portion of the dust in the available oxygen is insufficient to raise the entire dust cloud to the ignition temperature.

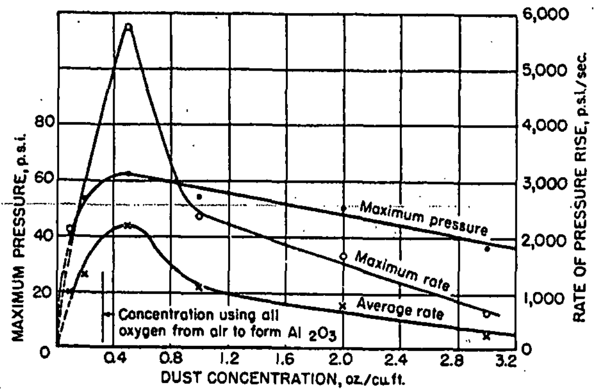

Figure 3. Maximum pressure and rates of pressure rise developed during explosions of aluminum powder at various concentrations.

Between these two limits there is an "optimum" concentration at which there is just enough dust in the cloud for complete combustion in the available oxygen. Neglecting dissociation, in a dust cloud of uniform concentration this optimum value should correspond to the stoichiometric mixture; actually it is always somewhat higher. The pressure developed and the speed of the explosion at the optimum dust concentration under most favorable conditions are greater than at lower or higher concentrations. The effect of concentration on the maximum pressures developed and on the rates of pressure rise in explosions of dust clouds of stamped aluminum powder can be seen in Figure 3. Similar data have been illustrated for other metal powders and metallic hydrides,[8] for bituminous coal,[8]