INFLAMMATION OF ALUMINIUM POWDER.

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1. Introduction.

Powder of combustible solid matter can inflame explosively in dispersed state in the air. That is the so called "Dust Explosion". Powders of sulfur, charcoal, wheat flour or cane sugar are known as dangerous source of damage in the milling industry. Powder of aluminium or magnesium can also react in the same manner, though the evolution of gas is not accompanied. In such a type of reaction as this, dust explosion is considered to be analogous to gaseous explosive reaction.

According to the authors' opinion[1], an explosive reaction can be induced through two steps; (1) excitation process and (2) propagation process. In the first step, the activation energy must be given from out side of the reaction system in condensed state locally. In the second step, the reaction energy emitted from the reaction zone can activate its adjacent zone. Thus propagation can be carried on. In other words, propagation is a continuous process of activation held in the reaction system itself.

In order to initiate an explosive reaction, both conditions for the first and second process must be fulfilled. Accordingly, the limiting conditions for inflammation or explosion may be given by combination of two experimental conditions as follows.

(I) Conditions for excitation.

Kinds of energy, intensity and procedure of excitation.

(II) Conditions for the reaction system.

Size, form, or composition of the powder and method of dispersion.

However, we must bear in mind that such limiting conditions for explosion necessarily contain a dynamic factor which is difficult to measure quantitatively and depends for the most part upon the procedure of excitation. And this difficulty comes from the essential property of inflammation or explosion itself which is *dynamic* and *non-stationary*. For the above reasons, the limiting conditions though expressed numerically has the only qualitative meaning.

2. Experimental Procedure.

(i) **Sample.** Kinds of aluminium powder used for experiments were as follows;

1) R. Goto, *Rev. Phys. Chem. Japan*, **16**, 152 (1942).

Kind	Lustre	Size mesh	% of Al_2O_3
Fukuda "AA12"	lustrous	<325	2.6
" "G500"	non	<325	5.2
" "No. 10"	non	100~325	2.1
Hayashi "SS76"	lustrous		15.0
Merck	non		7.6
Takeda	lustrous		1.9
Shimada	lustrous		8.6

(ii) Method of dispersion. Powder placed in a glass vessel or an evaporating dish was blown up with compressed air (Fig. 1).

(iii) Excitation. Aluminium powder can be inflamed by various energies as follows.

(a) Electrically heated wire.

(b) Electric spark discharge.

(c) Flame of a coal gas burner.

(d) Radiation of the photo-flash lamp.

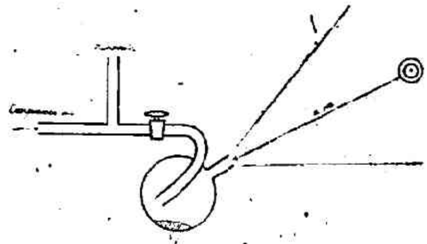


Fig. 1.

For the sake of convenience, the limiting condition was observed in the case of excitation by flame. Excitation by radiation was investigated specially from the stand point of reaction kinetics.

3. Experimental Results.

(i) Limiting curve of inflammability. Limits of inflammability of various kinds of aluminium powder are plotted on Fig. 2, which shows the relation between the weight of aluminium powder a and the distancial d from the energy source.

(ii) Influence of additionals. Fig. 3. shows the influence of various kinds of additionals, where the distance between the flame and the jet is 12cm and v means the minimum volume

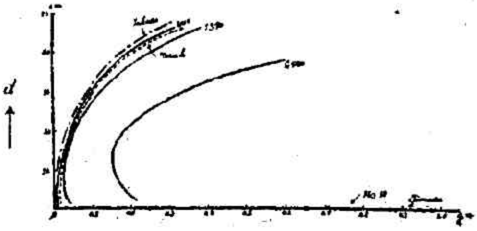


Fig. 2.

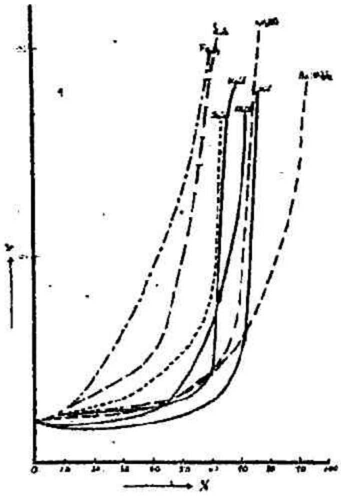
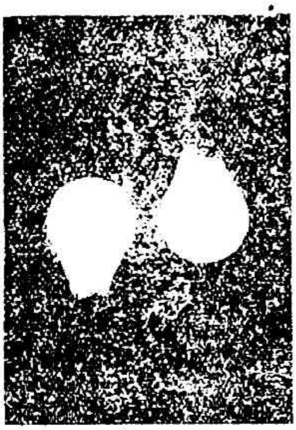


Fig. 3.

to inflame the powder. It was found that almost the additionals used suppressed the inflammability of aluminium powder.

(iii) Inflammation by radiation. It was found that aluminium smoke can be inflamed by the radiation of the photo-flash lamp which is composed of aluminium foil and oxygen sealed in a glass bulb and can be ignited electrically. Reversely, the flash lamp can be ignited by radiation from the flame of aluminium smoke. It is a well-known fact that a flash lamp can be ignited also by ignition of another lamp which is placed about 3cm apart (Fig. 4).



The left: flashed electrically. The right: propagated by radiation through three plate-glasses.

Fig. 4.

These phenomena suggest that the inflammation and its propagation can proceed through emission and absorption of the radiation energy in the reaction zone of aluminium. Further, it is indicated that there is an analogical relation between the propagating inflammation of aluminium smoke and that of flash lamp. Indeed we can consider that the inflammation of aluminium powder is the infinitesimal case of propagating inflammation of the flash lamps.

According to the investigation[2] of emission spectrum of the flash lamp, predominant emission is localized in the infra-red zone. From this fact it is induced that the radiation which activates the reaction system is principally thermal. This conclusion is proved by the following experiment illustrated with Fig. 5. *A* is an aluminium foil which is the same as that sealed in the photo-flash lamp and is hung in vacuum. *B* is a photo-flash lamp. When the lamp is flashed, the foil *A* melts and is blown off to the opposite side to the lamp on the spot. This fact indicates that the aluminium foil is heated up at least to its melting point by thermal radiation of the lamp, inspite of the extraordinarily reflective power of alminium surface.

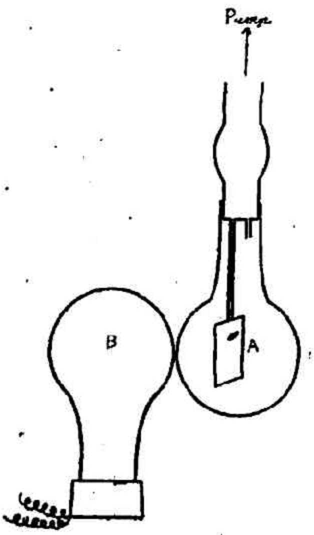


Fig. 5.

4. Discussion.

Assuming that the aluminium powder spreads radially

2) W. E. Forsythe and M. A. Easley, *J. Opt. Soc.*, 24, 195 (1934).

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in the air, the concentration C at d cm from the jet may be given as follows,

$$C=k\frac{a}{d^2} \qquad (1)$$

where k is a proportional constant and a is the quantity of alminium taken in the vessel. Let the limiting concentration of inflammation take some definite quantity C_0. Then, from the relation (1),

$$a=\frac{C_0}{k}d^2 \qquad (2)$$

or

$$\log a=\log K+2\log d \qquad (3)$$

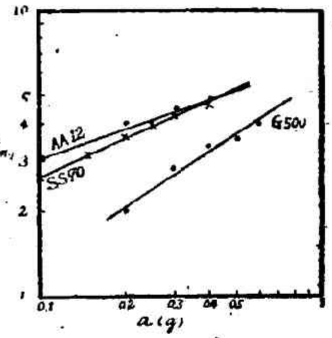

Fig. 6.

where K is equal to $\frac{C_0}{k}$ and is a constant. For the experimental results shown in Fig. 2, plotting $\log d$ against $\log a$, we obtain Fig. 6. Thus, in actual case, the relation (2) takes next form:

$$a=Kd^n \qquad (4)$$

and n depends upon the kind of the sample.

In the theory of explosive reaction of gases[3], it is considered that the reaction proceeds through chain mechanism in which ordinary molecules are activated by collision of another active molecules or atoms. It has not been considered that radiation can take part in the reaction chain as activating energy, except the primary process of photo-chemical reaction. Nevertheless, in the experiment above stated, it was confirmed that inflammation of alminium smoke can be induced and propagated by radiation energy given from outside or inside of the reaction system.

In conclusion, the explosion or inflammation of alminium powder proceeds through chain mechanism in which radiation participates at least partly. This type of reaction chain we name "*radiation chain*".

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3) N. Semenoff, *Chemical Kinetics and Chain Reactions* (1934). Oxford.
C. N. Hinshelwood, *The Kinetics of Chemical Change* (1940). Oxford.