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THE EFFECT OF MIXTURES OF PARTICLE SIZES ON THE MINIMUM IGNITION TEMPERATURE OF A DUST CLOUD

F.K. SWEIS

Department of Chemical Engineering, Faculty of Engineering and Technology, University of Jordan, Amman (Jordan)

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Summary

The ignition temperature in the air atmosphere at the separating line between an explosion and no explosion in a dust cloud, T_i^b, has been investigated for mixtures of fine and coarse dusts of the same material. The minimum ignition temperature, T_i^m, which is the lowest temperature at which an explosion is obtained has also been determined. Measurements were made in a Godbert-Greenwald Furnace apparatus. The results obtained indicated that the ignition temperature is dependent on the particle size, and an admixture of fine dust of 30% to coarse dust is sufficient to reduce the T_i^m values significantly.

Introduction

A dust cloud explosion occurs when a finely divided flammable solid material is dispersed into the atmosphere over an ignition source. A suspension of dust will explode when the dust concentration falls within the explosible limits, the combustible particles reach their ignition temperature, and the particle size distribution is capable of propagating flame [1,2].

Previously, the minimum ignition temperature, T_i^m, has been found to depend on the particle size of the combustible material [3,4]. Using cornstarch, the T_i^m values for low sample weight were found to decrease sharply as the particle size decreased, for high sample weight the T_i^m values were not significantly affected.

The experimental work presented in this paper was undertaken to extend the range of industrial dusts studied and to determine the effect of mixtures of particle sizes.

Materials

The industrial dusts which were used in this work are Jordanian oil shale and sugar. For each material, samples of a range particle size d ($212\mu m < d < 250\ \mu m$ and $63\ \mu m < d < 75\ \mu m$) were prepared. The particle sizes of

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230 μm and 68.7 μm were determined as the geometric mean of the coarse and fine particles, respectively. Mixtures of different weight percentages of both particle sizes were made. All the dust samples were dried at 75°C.

Equipment and procedure

A Godbert-Greenwald Furnace apparatus was used to determine T_i^m for mixtures of different particle sizes of the same material in air. The general layout of the apparatus is shown in Fig. 1 and full specifications of the furnace are given by Raftery [5].

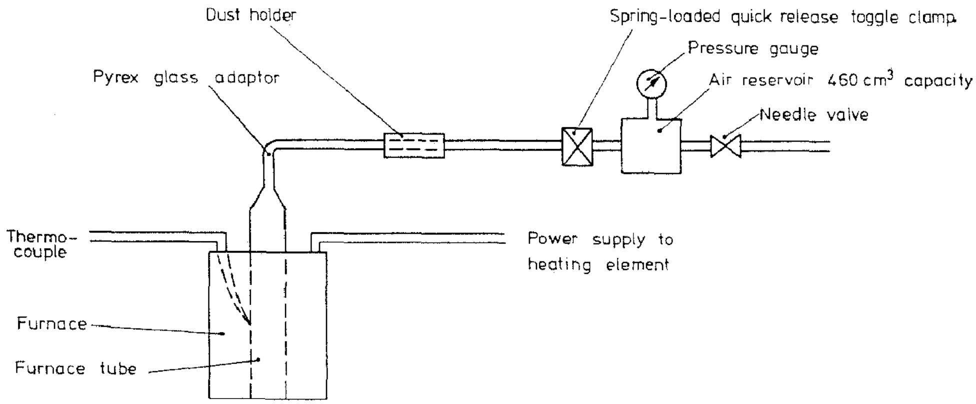

Fig. 1. The Godbert-Greenwald Furnace apparatus.

The experimental procedure adopted was as follows:

1. The furnace tube was heated and fixed at the desired temperature.
2. A weighed amount of the material was placed in the dust holder. This weight was divided by the volume of the furnace tube (0.232 l) to give the concentration of the dust.
3. The reservoir was filled with air up to the desired dispersion pressure.
4. The dust sample was dispersed through the furnace tube by a blast of pressurised air.

The criterion for indicating an explosion was the observation of flame at the bottom open mouth of the furnace. If explosion occurred, the furnace temperature was lowered and testing continued with different dispersing pressures (6—13 lb/in^2), until no flame was observed in ten tests at the same dust concentration. The difference in temperature between explosion and no explosion was 10°C. The lowest temperature at which ignition with flame occurred was taken as the ignition temperature T_i^b.

Results and discussion

Figures 2 and 3 show the variation of the ignition temperature T_i^b (°C) with dust concentration (g/l) for oil shale (230 μm) and sugar (68.7 μm).

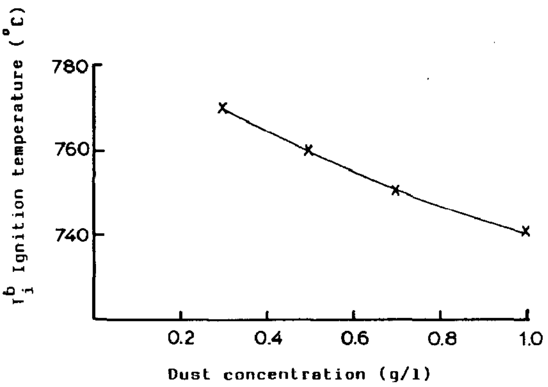

Fig. 2. The variation of the ignition temperature, T_i^b , with dust concentration of oil shale (mean particle size 230 μm).

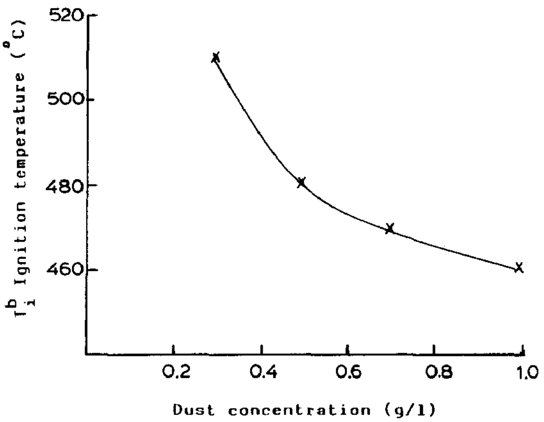

Fig. 3. The variation of the ignition temperature, T_i^b , with dust concentration of sugar (mean particle size 68.7 μm).

They are representative of the results obtained. Many trials were carried out at each dust concentration, and each point on the graphs represents the lowest temperature at which each material at the corresponding concentration was ignited with flame.

It can be seen, that as the dust concentration increased from 0.3 g/l to 0.5 g/l, the ignition temperature, T_i^b , decreased slightly from 770°C to 760°C for oil shale and sharply from 510°C to 480°C for sugar. With a further increase in the dust concentration, T_i^b decreased but with little effect for both materials. Values for the minimum ignition temperature, T_i^m , defined as the value of T_i^b at a dust concentration of 1 g/l, of 740°C and 460°C were obtained for oil shale and sugar, respectively.

In industrial processes, dusts are not usually of uniform particle size and it is important to know the effect of the particle size distribution of the same material on the T_i^m value. For earch material, several percentages of the coarse (230 μm) and fine (68.7 μm) dusts were mixed together, and the T_i^m values of the mixtures determined as those for different particle sizes. The results for all the mixtures of oil shale and sugar are shown in Figs. 4 and 5, respectively. Curves obtained with 100% of coarse and fine dusts of each material are also plotted.

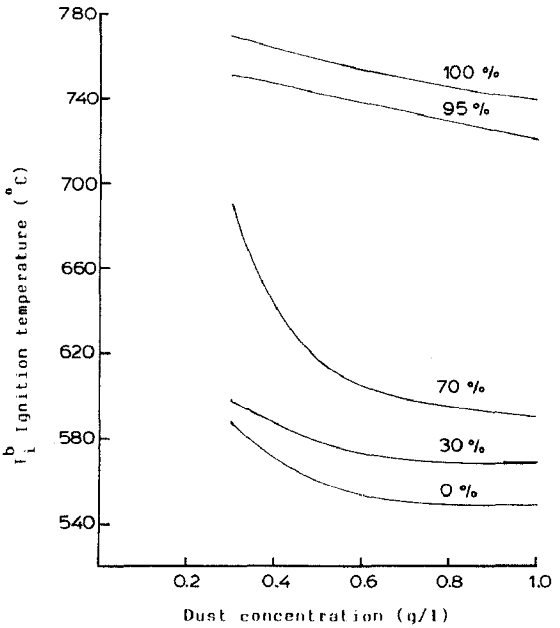

Fig. 4. The variation of the ignition temperature, T_i^b, with dust concentration for all the mixtures of oil shale. Figures on the curves refer to the percentage of coarse dust in the mixture.

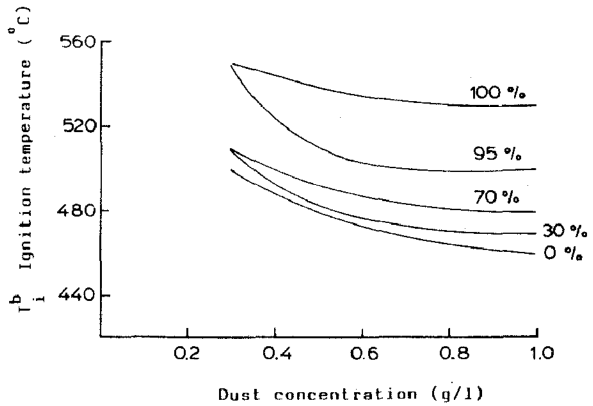

Fig. 5. The variation of the ignition temperature, T_i^b, with dust concentration for all the mixtures of sugar. Figures on the curves refer to the percentage of coarse dust in the mixture.

The general pattern for the variation of the ignition temperature with dust concentration for mixtures of both materials are the same as for different particle sizes. In general, the curves divide the plot into two regions, in the region above the curve ignition with flame is possible, and in the region below the curve ignition with flame is not possible.

The most important result of these tests is the nonlinear relationship between the composition of the dust mixture (percent by weight of large particles) and the T_i^m values obtained at 1 g/l for both materials. This is shown in Fig. 6. It can be seen that an admixture of 5, 30, and 70 percent by weight of fine particles with coarse reduces the T_i^m for oil shale by 11, 79 and 90 percent, respectively, of the difference between the pure coarse and pure fine values. The corresponding reduction for sugar are 43, 72 and 86 percent. For both materials, the ratio of particle diameters of coarse to fine was of the order of 3.4 to 1.

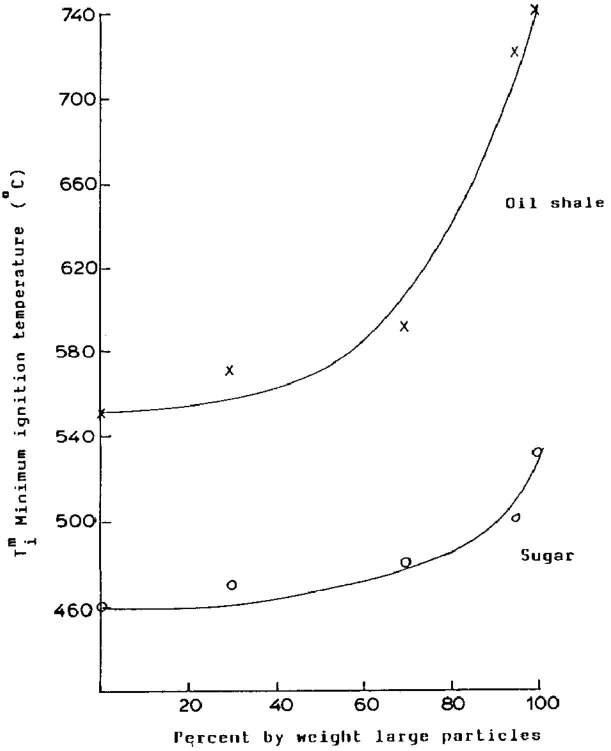

Fig. 6. The variation of the minimum ignition temperature, T_i^m, with percent weight of coarse dusts in the mixtures for oil shale and sugar.

Conclusions

The minimum ignition temperature, T_i^m, which is the minimum value of T_i^b at a dust concentration of 1 g/l provide an information for assessing the hazards of combustible dusts and help in the design of protective measures.

The parameter T_i^m , was found to depend on the type of the material, its concentration and its particle size. It was also found that where fine particles were mixed with coarse particles, the value of T_i^m for the fine particles most influenced the value of T_i^m for the mixture, and that an admixture of 30% by weight of fine particles would reduce the T_i^m value of the mixture by 70 to 80% of the total possible reduction.

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