Fire Research Note

NO. 607

THE EXPLOSIBILITY OF SOME INDUSTRIAL DUSTS IN A LARGE SCALE VERTICAL TUBE APPARATUS

by

K. N. PALMER and P. S. TONKIN

FIRE
RESEARCH
STATION

F. R. Note No. 607

THE EXPLOSIBILITY OF SOME INDUSTRIAL DUSTS IN A LARGE SCALE VERTICAL TUBE APPARATUS

by

K. N. Palmer and P. S. Tonkin

SUMMARY

The explosibility of six industrial dusts has been investigated in a large scale vertical tube apparatus. All six dusts were classified for explosibility in the standard small scale test apparatus. Direct comparison is made between explosibility in both types of apparatus.

Flame propagation was obtained in the large scale apparatus with marginal Class I dusts but no flame propagation was obtained in that apparatus with the Class II dusts.

The behaviour of the dusts in the large scale vertical tube apparatus was similar to that obtained previously with phenol-formaldehyde resin/magnesium oxide mixtures with the same explosibility Classifications.

September, 1965.

MINISTRY OF TECHNOLOGY AND FIRE OFFICES' COMMITTEE

JOINT FIRE RESEARCH ORGANIZATION

THE EXPLOSIBILITY OF SOME INDUSTRIAL DUSTS IN A LARGE SCALE VERTICAL TUBE APPARATUS

by

K. N. Palmer and P. S. Tonkin

INTRODUCTION

In industry, explosible dusts constitute a hazard, the degree of which can be assessed by classifying the dusts according to the ease with which they explode. Dusts are tested for explosibility in laboratory scale apparatus, which has been described previously(1). The results of such tests are used to classify the dusts as follows:-

Class I. Dusts which ignite and propagate flame readily, the source of heat required for ignition being small.

Class II. Dusts which ignite readily with flame but require a larger source of ignition.

Class III. Dusts which do not ignite in the tests.

These tests do not, however, show whether or not marginal Class I dusts cause explosions in large scale plant or whether or not Class II dusts can propagate flame away from the influence of the igniting source. Dusts were considered to be marginally Class I when flame was obtained in only some of the small scale tests with small sources of ignition.

In order to investigate these two matters six industrial dusts have been classified for explosibility in the small scale apparatus and then investigated for explosibility in a large scale vertical tube apparatus of industrial dimensions. The dusts were:- methyl cellulose (Class I), manioc (marginal Class I), sodium carboxy methyl cellulose (marginal Class I), processed starch (marginal Class I), polyvinylidene chloride (Class II) and calcium citrate (Class II). The processed starch was a product derived from the processing of the normal carbohydrate which is a vigorous Class I dust.

The arrangement of the explosion tube, used in all the experiments, was that in which the top of the tube was open, the bottom closed and ignition was near the bottom of the tube.

EXPERIMENTAL

Materials

All the dusts used in the experiments were commercial grades as marketed by the manufacturers and used in industry. The dusts were sieved through a B.S. 60 mesh sieve before being classified in the standard apparatus and used in the large scale experiments. The usual procedure of drying and sieving during classification of the dusts was not used. Detailed sizing analyses are given in Table 1 and moisture content is given in Table 2.

Table 1

Sizing analyses of the dusts

Dust	Per cent weight			
	-60+72 mesh	-72+120 mesh	-120+240 mesh	-240 mesh
Methyl cellulose	8.0	20.8	21.8	49.4
Manioc	29.0	43.6	25.4	2.0
Sodium carboxy methyl cellulose	18.1	22.2	12.9	46.8
Processed starch	11.3	27.2	23.7	37.8
Polyvinylidene chloride	24.6	28.6	27.4	19.4
Calcium citrate	15.4	46.8	24.8	13.0

Table 2

Moisture content of the dusts

Dust	Moisture content per cent
Methyl cellulose	7.5
Manioc	14.1
Sodium carboxy methyl cellulose	11.2
Processed starch	11.3
Polyvinylidene chloride	4.5
Calcium citrate	11.2

Apparatus

The vertical explosion tube apparatus used in the experiments was the same as that described in detail previously[2] and is shown in Fig 1. The tube was 25.4 cm (10 in) internal diameter and its overall length was 5.2 m (17 ft). Incorporated in the tube were three 0.31 m (1 ft) long sections of good optical quality perspex.

These sections together with windows in the steel lengths of the tube permitted observation and photographing of flames propagating in the dust clouds.

Manually operated sliding trays were used to collect dust falling in the explosion tube. From the dust collected, data relating to the dust clouds, such as distribution, concentration and velocities of the falling particles were obtained.

The igniting source was a propane flame which was injected into the explosion tube horizontally to cover the cross section of the tube,[2] and was situated near the closed end of the tube.

The apparatus used to feed the dusts into the top of the explosion tube was the same as that used previously[2] and the screw conveyors delivered the dust into a lidless dispersing cylinder, the bottom of which was of perforated metal plate through which the dust passed into the explosion tube.

Flames were filmed using the cine camera and photographic materials as used in previous work[2].

Procedure

The general procedure adopted for determining the explosibility of a dust at a given dust concentration was firstly to measure the dust concentration in the explosion tube, then carry out a series of three explosion tests. The dust concentration was checked during the series. This procedure was repeated at various dust concentrations until either a flammable range was obtained for the dust or it was established that the dust would not propagate flame in the large scale tube. In all experiments the bottom slide valve was closed before the igniting flame was applied.

Dust concentrations were determined by collecting and weighing dust trapped in a known volume of the explosion tube and calculating the mass per unit volume.

Dust distribution, along two diameters of the explosion tube, was obtained by inserting small cylinders, equidistant and arranged in the form of a right angled cross, in the falling dust clouds. The contents of each cylinder were weighed and the values obtained plotted against the distance along the tube diameter at which it was collected.

Calculation of velocity of falling dust was based on dust concentration in the explosion tube, determined as outlined above, the amount of dust collected in a measured period of time, and the dimensions of the explosion tube.

The detailed procedures for determining dust concentration, dust distribution in the explosion tube and velocities of falling dust were as used in previous work and are described in detail elsewhere[2].

Results

The results of the dust explosion experiments carried out in the large scale vertical tube are given in Fig. 2 in which the extent of flame propagation is shown at various dust concentrations, distinction being made between flame propagation over the full length of the tube, propagation over part of the tube length in excess of 0.6 m (2 ft), and no propagation. The experimental procedure was such that each point on the graphs represented three tests; if the extent of flame propagation varied within a group of tests the result shown is that for the most extensive propagation. Results of the small scale standard tests are given in Table 3.

Table 3

Results of the small scale standard tests

Dust	Explosibility Class	Test apparatus in which ignition occurred	Minimum ignition temperature	
			°C	Apparatus
Methyl Cellulose	I	a - e	960	Horizontal tube
			350	Furnace test
Manioc	I	b - e	450	"
Sodium carboxy methyl cellulose	I	b, d and e	320	"
Processed starch	I	d and e	460	"
Polyvinylidene chloride	II	e	620	"
Calcium citrate	II	e	520	"

Apparatus a : Horizontal tube
b : Inflammator
c : Hartmann
d : Modified Hartmann
e : Furnace

Fig. 3 shows dust distribution curves for methyl cellulose along two diameters of the explosion tube. Similar curves were obtained for the other dusts.

Fig. 4 shows the variation in falling dust velocity with change in concentration for methyl cellulose. This type of curve was obtained for all the dusts used in the experiments.

Flame velocities, which varied between 100 cm/s and 940 cm/s, depending upon the dust concentration were obtained for propagations to the top of the tube in dust clouds of methyl cellulose.

DISCUSSION

Flammable concentration ranges were obtained for manioc and processed starch and the lowest concentration for flammability was obtained for methyl cellulose in the large scale explosion tube. The dust concentrations were the average concentrations in the volume of the explosion tube, determined as described above.

Since the values obtained did not take into account the falling velocity of the dust particles through the air in the tube or the flame velocities the concentrations were not those of the dust in the combustion zones of the flames[3]. There was no flame propagation in the dust clouds of sodium carboxy methyl cellulose, polyvinylidene chloride and calcium citrate in the large scale explosion tube.

Manioc, processed starch and sodium carboxy methyl cellulose were graded class I in the small scale test apparatus but were regarded as marginal class I dusts. In that respect they may be compared with phenol-formaldehyde resin/magnesium oxide mixtures in the proportions, 35/65 25/75, and 20/80 used in previous work[2]. Full tube length propagations were obtained with some concentrations of the 35/65 mixture, part tube length propagations were obtained with some concentrations of the 25/75 mixture while there was no flame propagation with the 20/80 mixture in the large scale vertical tube apparatus. The flame propagations obtained with processed starch were part tube length only and the maximum propagation obtained was about 1.2 m (4 ft) away from the igniting source. Concentrations at which flame propagations over part of the tube length occurred were regarded as explosible since it has been shown[2] that such flame propagations were independent of substantial changes in the size of the igniting source.

No flame propagation was obtained in the dust clouds of sodium carboxy methyl cellulose in the large scale tube although the minimum ignition temperature obtained, in the furnace test, for this compound was 320°C as compared with 480°C and 510°C for the 25/75 and 20/80 phenol-formaldehyde resin/magnesium oxide mixtures respectively. 320°C was, therefore, a low ignition temperature for a marginal class I dust. The result obtained with sodium carboxy methyl cellulose in the large scale tube shows that the ignition temperature of the furnace test is not necessarily a guide to the explosibility of dust in large scale equipment. The difference in the results obtained in the two types of apparatus is probably due to the design and mode of operation of the furnace test. In this test the temperature of the air into which the dust is dispersed is considerably above atmospheric temperature and dusts which require such higher temperatures for ignition are less likely to propagate flame in air at atmospheric temperature as in the large scale vertical tube.

CONCLUSIONS

1. Marginal class I dusts, i.e. those that propagated flame in some of the small scale tests with small sources of ignition, should be regarded as an industrial dust explosion hazard because some propagated explosions in the large scale vertical tube apparatus.

2. The marginal class I dusts had narrow ranges of flammable concentrations when ignited in the large scale vertical tube and in this respect were similar to the phenol-formaldehyde/magnesium oxide mixtures[2] which were in the same explosibility class.

3. The two dusts graded class II for explosibility in the small scale test apparatus, did not propagate flame in the large scale vertical tube apparatus.

4. The behaviour of the class II dusts in the large scale vertical tube was the same as that exhibited previously by the phenol-formaldehyde/magnesium oxide mixtures[2] with the same explosibility Classification.

ACKNOWLEDGEMENTS

Mr. T. M. Davies, Mr. C. A. Wright and Mrs. S. A. Morris assisted with the experimental work.

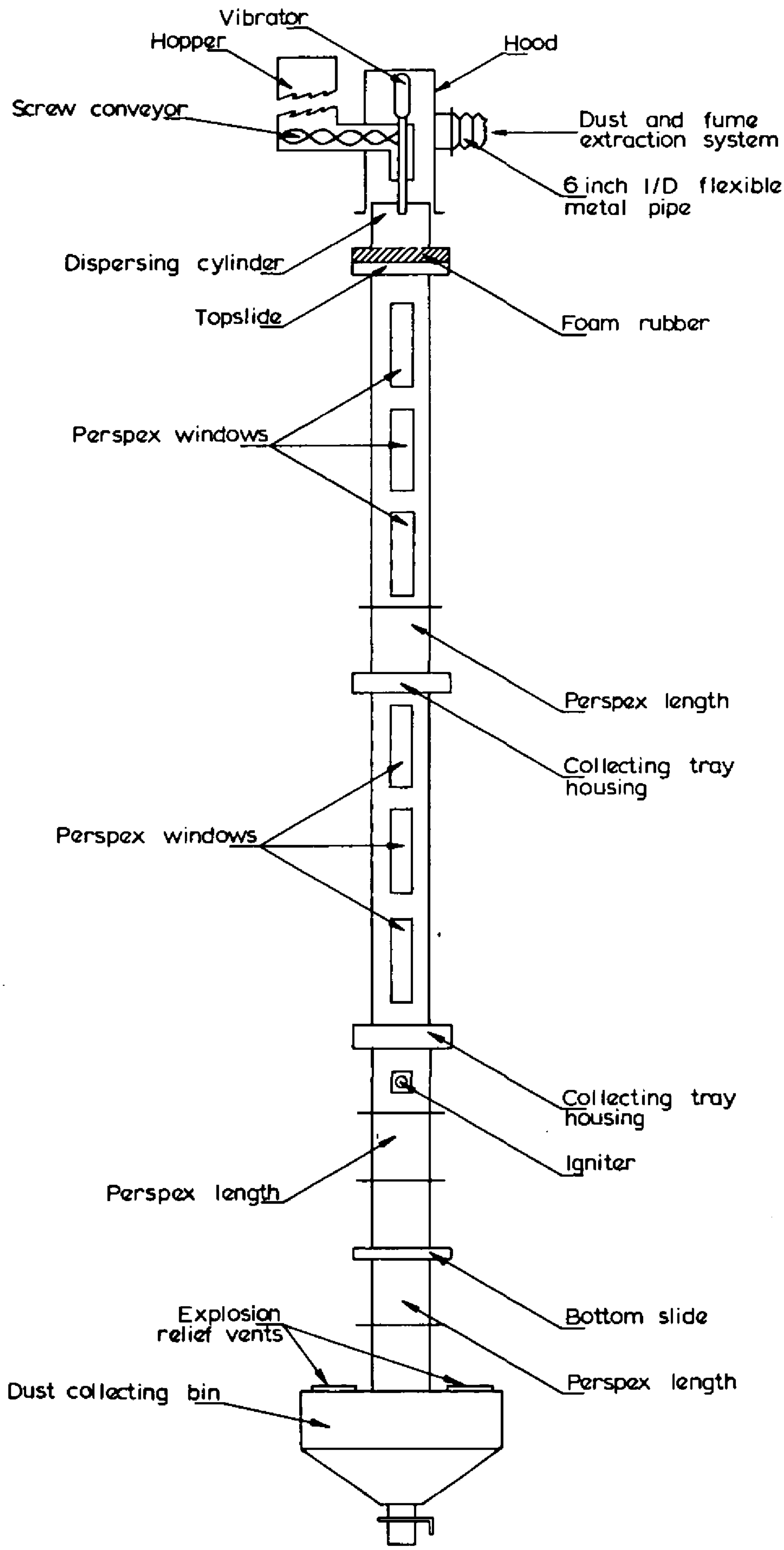
The small scale classification tests were carried out by Miss M. M. Raftery and Mrs. M. D. Harris.

REFERENCES

1. RAFTERY Miss M. M. Fire Research Note No. 557 July 1964.

2. PALMER, K. N. and TONKIN, P. S. Fire Research Note No. 605.

3. MAGUIRE, B. A., SLACK, C. and WILLIAMS, A. G. Combustion and Flame <u>6</u> (4) December 1962.



1/6376 F.R. 607

FIG. 1. VERTICAL 10 INCH I/D DUST EXPLOSION TUBE

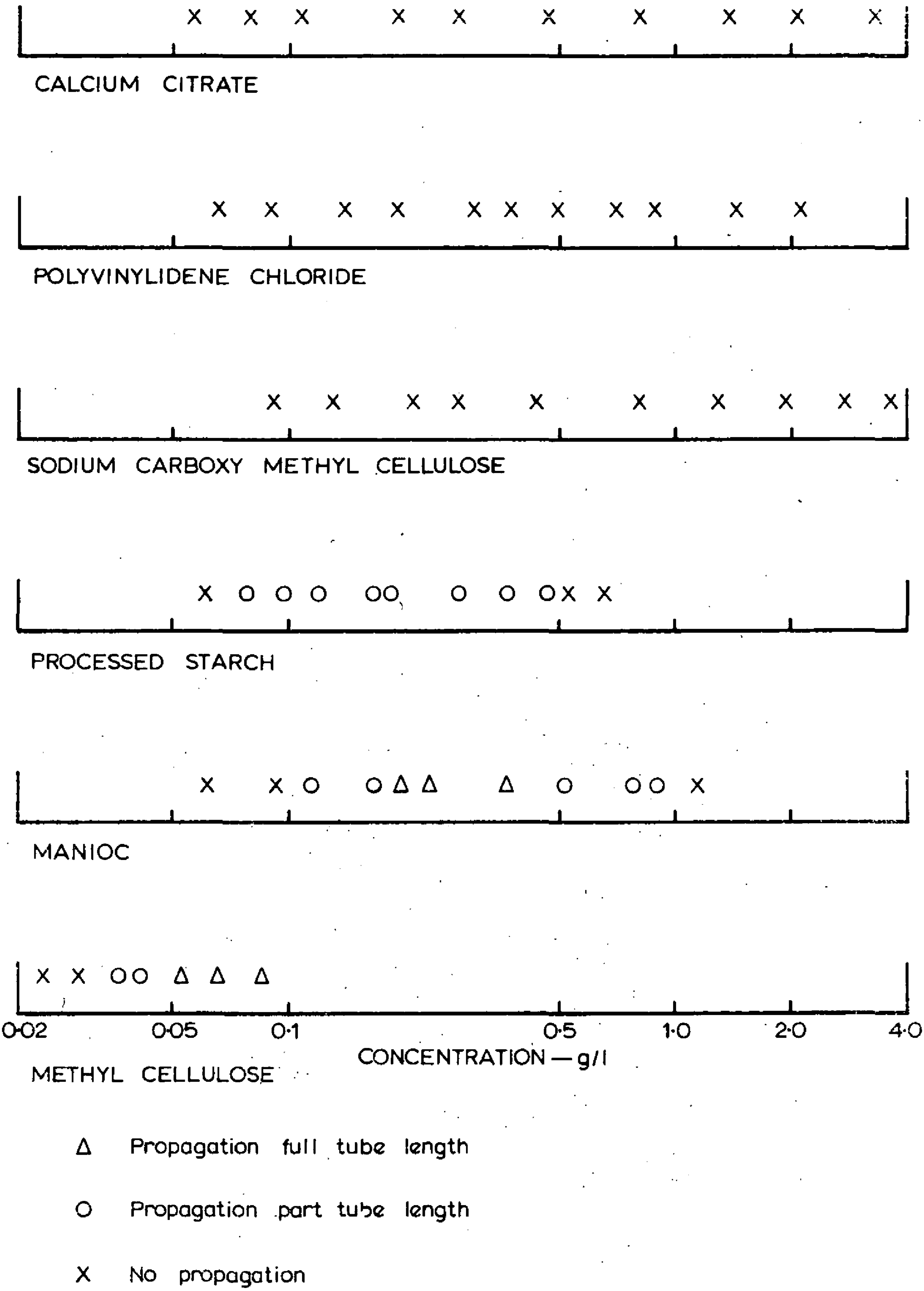


FIG. 2. RESULTS OF DUST EXPLOSION EXPERIMENTS IN LARGE SCALE VERTICAL TUBE APPARATUS

6377 F.R. 607

1/6878 F.R. 607

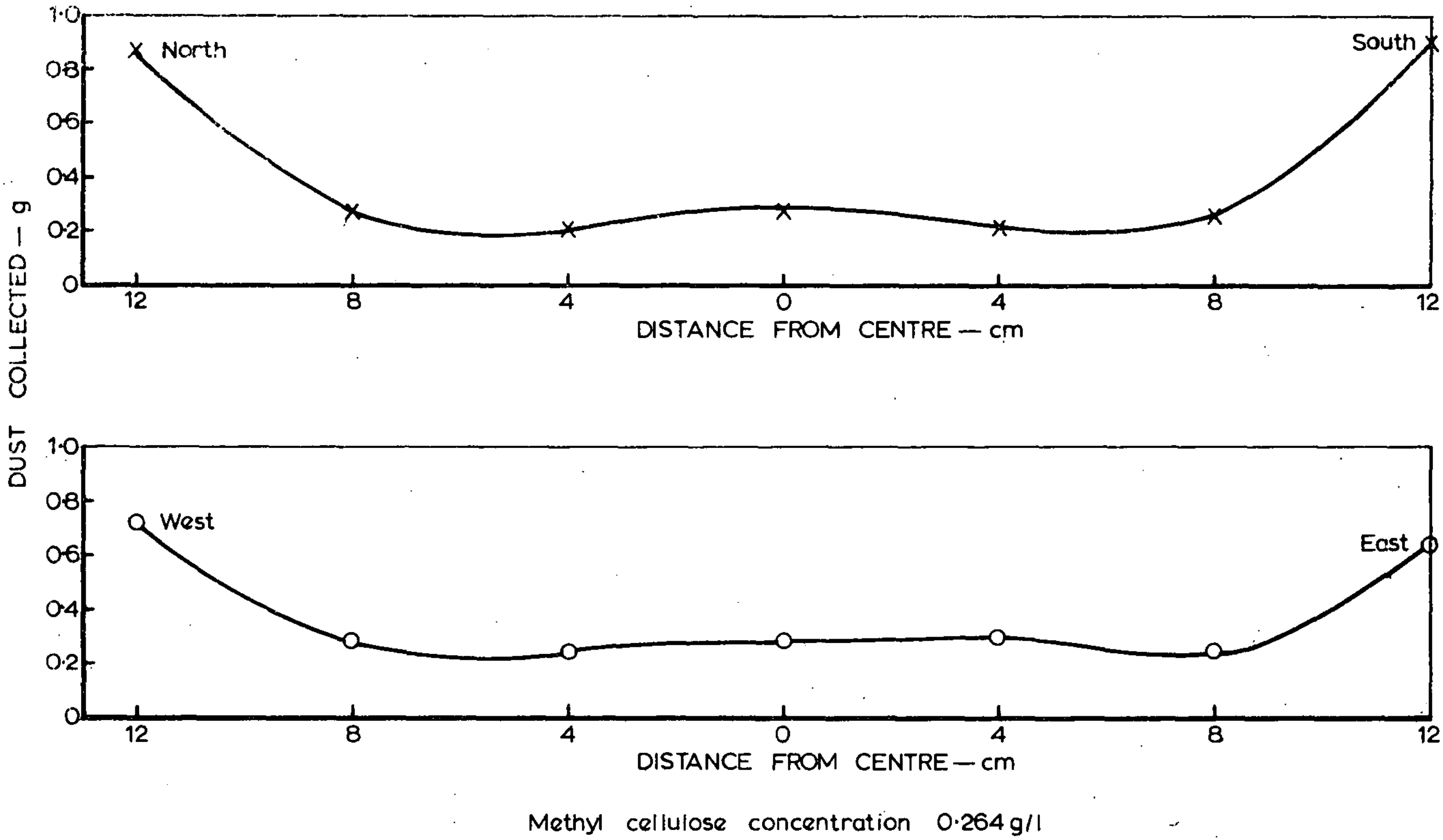


FIG. 3. DUST DISTRIBUTION ALONG TWO DIAMETERS OF THE EXPLOSION TUBE

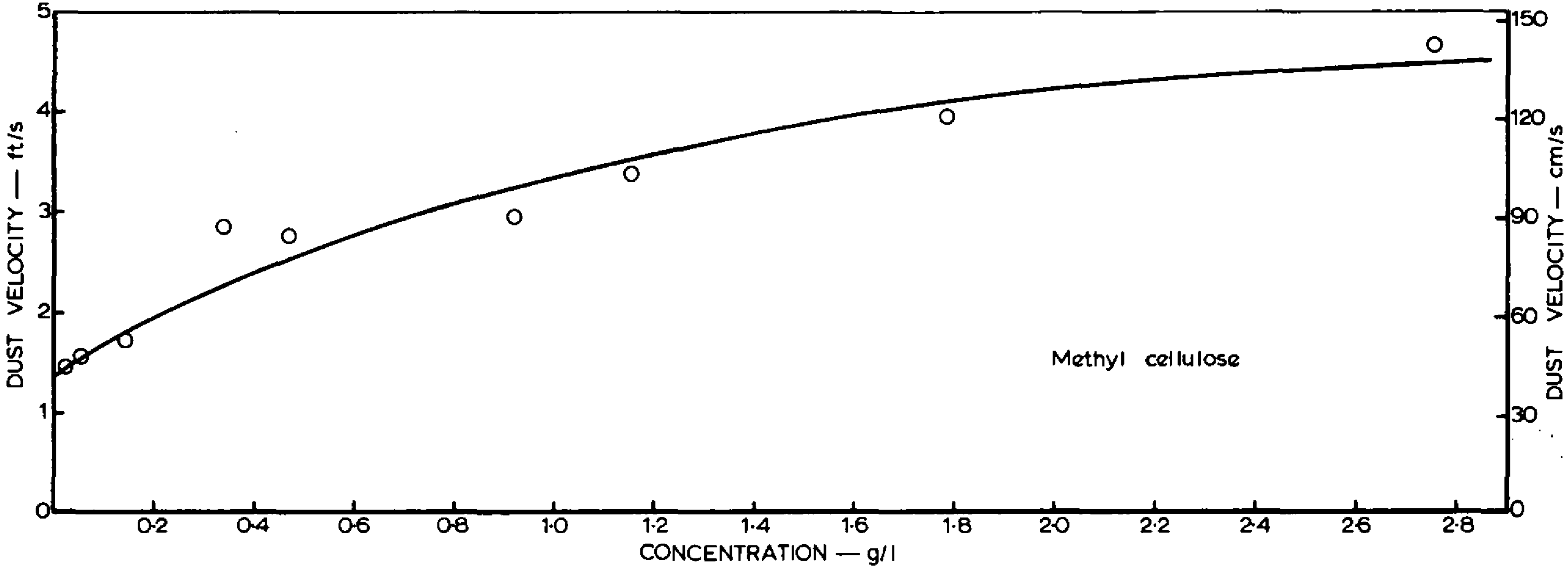


FIG. 4. FALLING DUST VELOCITIES AT VARIOUS DUST CONCENTRATIONS