CONFIDENTIAL

F.R. Note No. 89/1953
Research Programme
Objective B3/(1)

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

SMOULDERING IN DUSTS AND FIBROUS MATERIALS
PART IX COCOA AND GRASS DUSTS UNDER AIRFLOW CONDITIONS

by

K. N. Palmer and M. D. Perry

Summary

The smouldering of cocoa and grass dusts under airflow conditions has been compared with that of beech and deal sawdusts described earlier. The dusts were formed into small trains and placed in a wind tunnel, and measurements were made of the effects of airflow and train size upon the rate of smouldering and of the effect of airflow on the minimum depth of dust layer necessary for sustained smouldering. Certain aspects of the behaviour of cocoa and grass dusts smouldering under airflow conditions are similar to the behaviour of beech and deal sawdusts. In the presence of slight draughts, trains of grass dust only 3 mm deep can initiate smouldering in covering layers of wood shavings and newspaper, with the subsequent production of flame, thus showing that grass dust is particularly hazardous.

December, 1953.
December, 1953.

File No. F.1020/4/1

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Boreham Wood,
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Introduction

This note describes further investigations that have been made on the smouldering of dusts and fibrous materials. Earlier work in this series (1,2) has shown that in still air smouldering could be initiated in trains of certain common industrial dusts by a small source of ignition, such as a glowing cigarette end, and that slow, but sustained, smouldering would ensue providing the depth of dust layer was above a certain critical value, which in any given dust depended chiefly upon the mean particle size. The linear rate of smouldering was found to be little affected by changes in size of train, mean particle size, packing density and moisture content of the dust. Subsequent experiments carried out on the smouldering of beech and deal sawdusts in a forced draught (3,4) have shown that the rate of smouldering increases rapidly and the minimum depth of dust layer necessary for sustained smouldering decreases rapidly with increasing incident air velocity (V). Approximate logarithmic relationships of the form $\log(S/So) = aV$ where So is the value of the smouldering time (i.e. the reciprocal of the linear rate) at zero air velocity and a is an empirical constant for any given train, were found to exist between the smouldering time and the incident air velocity. Similar logarithmic relationships were found to exist between minimum depth and incident air velocity.

The investigations described in this note include the effect of airflow upon the smouldering time of powdered cocoa and grass dust, the effect of train size upon the smouldering time of grass dust, and the variation of minimum depth with airflow for powdered cocoa. This work was done to find out whether the behaviour of these two dusts smouldering under airflow conditions was similar to that observed previously for beech and deal sawdusts (3,4) despite the differences in properties and behaviour tabulated below.

TABLE 1

Dust	20-40 I.M.M. Beech sawdust	Cocoa	Grass
Dry weight packing density g/ml	0.28	0.5	0.23
Still-air smouldering time min/cm	11.1	18.9	4.2
Still-air minimum depth mm	13	9	< 2

In the appendix to this note an account is given of some experiments which were carried out on the spread of smouldering from trains of grass dust to wood shavings and newspaper and the subsequent production of flame.

Experimental

Materials

The experiments were carried out on one sample of powdered cocoa and three samples of grass dust (A-C). The powdered cocoa and grass dust A were taken from the same samples as those used in the earlier still-air work; moisture contents and dry weight packing densities of these two dusts and of the other samples of grass dust are given in Table 2.

TABLE 2

Characteristics of the various dusts

Dust	Cocoa	Grass A	Grass B	Grass C
Moisture content as per cent wet weight.	6.1	8.2	7.5	8.5
Dry weight packing density g/ml.	0.50	0.28	0.28	0.28
Per cent wt. of particles passing 200 I.M.M. screen.	58 *	70	99	36

* passing 240 B.S. screen.

Procedure

The experimental procedure was similar to that used in the airflow experiments on beech sawdust. Dust trains, which had previously been formed on strips of asbestos from small metal moulds, were supported centrally in the combustion chamber of a windtunnel, and smouldering was then initiated by a small gas flame. Some dimensions of the moulds used in the determination of smouldering times are given in Table 3 for reference; details of the wedge mould Y used for finding minimum depths are given in an earlier report (1).

TABLE 3

Dimensions of moulds used in the determination of smouldering times

Mould	A	B	C	D	E
Top width cm.	1.35	2.35	3.55	5.10	7.25
Vertical depth along centre cm.	0.30	0.80	1.00	1.65	2.40

Results

Appearance of the trains

Unlike trains of beech and deal sawdusts smouldering in an airflow, the ash formed in the smouldering of trains of powdered cocoa and grass was not carried away in the forced draught except at high velocities. It was also noticed that in trains of grass dust the glowing smouldering zone extended several centimetres along the train; such trains sustained higher air velocities without disturbance.

Effect of train size upon smouldering time in still-air

Still-air values of the smouldering time for various size trains of grass B and grass C were determined and are given in Table 4.

TABLE 4.

Smouldering times in still-air (sec/cm)

Mould	A	B	C	D	E
Grass B	210	243	243	297	320
Grass C	188	240	252	297	315

Effect of airflow and train size upon smouldering time

The variation of smouldering time with airflow for powdered cocoa was investigated using trains formed from mould D. The results obtained are shown in Fig. 1 where the smouldering time and applied air velocity are plotted on logarithmic scales.

The experiments above were repeated with trains of the three grass dust samples, and to provide a measure of the effect of train size under airflow conditions, trains of grass B formed from moulds A and B and trains of grass C formed from mould A were also investigated. Fig. 2, 3 and 4 show the results obtained with grasses A, B and C respectively, where both smouldering time and air velocity are plotted on logarithmic scales. A series of experiments in which the airflow and propagation of smouldering were in opposing directions was conducted upon trains of grass B formed from mould D. The results obtained are given in Fig. 5 where the smouldering time is plotted on a logarithmic scale against the applied air velocity.

Variation of minimum depth with airflow

This series of experiments was carried out upon cocoa only since the minimum depth of grass dust is in the order of 2 mm in still-air and any reduction would be unimportant. In Fig. 6, which gives the results of this investigation, minimum depth is plotted on a logarithmic scale and air velocity on a linear one.

The effect of particle size upon smouldering time was not investigated since although the three grass dust samples were of different mean particle size, the compositions of the samples were probably not the same.

Discussion

Cocoa

Effect of airflow

The results in Fig. 1 show that the smouldering time of cocoa trains decreased with increasing incident air velocity; moreover there is an approximate linear relationship between the logarithms of the smouldering time (S) and the air velocity (V) within the velocity range investigated. The relationship between smouldering time (sec/cm) and air velocity (cm/sec) within this range of velocities is thus of the form $S = aV^{-n}$, where a and n are positive constants. In this particular case n = 0.69 and a = 1440. This equation, however, cannot hold at very low velocities for smouldering time is known to have a finite value at zero applied velocity (i.e. in still-air).

Variation of minimum depth with airflow

The minimum depth necessary for sustained smouldering in a layer of cocoa dust decreases considerably with increase in airflow, and an approximate logarithmic relationship exists between the two quantities (Fig. 6). It was found earlier that beech and deal sawdusts behave in a similar manner. A further point of resemblance is that the scatter of results is again greater than would be expected from the accuracy of the method of measuring minimum depth.

Grass

Effect of train size under still-air conditions

The results for trains of grass B and grass C smouldering in still-air (Table 4) indicate a noticeable increase in smouldering time with increase in train size; a comparable effect was obtained in the experiments on the smouldering of fibreboard strips (5). With the grass, however, no simple relationship was obtained between smouldering time and train size. It was found earlier (1) that the rate of smouldering of trains of beech and deal sawdusts is not appreciably affected by variations in train size for the sieve fractions investigated.

Effect of airflow and train size

Fig. 2, 3 and 4 show the results obtained with the grass dust samples A, B and C respectively for the applied airflow and propagation of smouldering acting in the same direction. It will be seen that again there is an approximate linear relationship between the logarithms of the smouldering time (S) and the air velocity (V) within the velocity range investigated, viz., $S = aV^{-n}$, where a and n are constants for any given train (Table 5). The separation of the lines in Fig. 3 and 4 caused by variation in train size is small and is comparable with the scatter of individual results, thus although the lines fall in order of train size, no relationship between the separation and the size of train could be obtained.

TABLE 5

Values of a and n in the equation $S = aV^{-n}$ for various grass trains

Mould	Grass A		Grass B		Grass C	
	a	n	a	n	a	n
D	2800	0.68	5520	0.78	2820	0.66
B	-	-	2870	0.65	-	-
A	-	-	1810	0.55	1340	0.53

When the propagation of smouldering in powdered grass and the applied airflow were in opposing directions (Fig. 6), the smouldering time at low velocities decreased rapidly with increase in air velocity; at higher airflows smouldering time appeared to become independent of air velocity. With fibre insulation board smouldering under similar airflow conditions (6) similar behaviour occurred at low air velocities but at high velocities the smouldering time increased with air velocity. The smouldering of beech sawdust trains differed in that the rate of decrease in smouldering time with air velocity steadily increased up to the velocity at which the train became disturbed (3).

Practical aspects

The work described in the appendix to this note has shown that in the presence of slight air draughts flaming combustion in wood shavings and newspaper can result from the spread of smouldering in trains of grass dust three millimetres deep to covering layers of these materials. In addition it was found earlier that smouldering may easily be initiated in trains of grass dust by a glowing cigarette end. It can thus be seen that the fire hazard presented by powdered grass are particularly severe.

Conclusions

The main points arising from this work are:

1. Certain aspects of the behaviour of cocoa and grass dusts smouldering under airflow conditions are similar to the behaviour of beech and deal sawdusts.

2. The effect of airflow upon smouldering time is greater than other factors investigated. Within the velocity range investigated, the smouldering time of cocoa and grass dusts appeared to be inversely proportional to a fractional power of the air velocity, the relationship being only slightly affected by variations in train size.

3. The minimum depth of cocoa layer necessary for sustained smouldering decreases rapidly with increasing air velocity, this behaviour is similar to that observed for beech and deal sawdusts.

4. Experiments detailed in the appendix have shown that flaming may be produced in materials such as wood shavings and newspaper in contact with trains of grass dust only 3 mm deep when smouldering in a slight draught. This demonstrates the fire hazard of even slight deposits of this dust.

Acknowledgement

The supply of dusts was arranged by Mr. K. C. Brown, H.M. Inspector of Factories, Safety in Mines Research Establishment, Harpur Hill, Buxton.

References

1. F. R. Note No. 6/1952.

2. F. R. Note No.11/1952.

3. F. R. Note No.48/1952.

4. F. R. Note No.50/1953.

5. F. R. Note No.24/1952.

6. F. R. Note No.73/1953.

APPENDIX

In these preliminary experiments various sized trains of grass dust were covered to a height of about three inches by layers of wood shavings or newspaper, leaving about two inches of the trains exposed. Smouldering was then initiated at the exposed end and the lowest air velocity (to within 50 cm/sec in most instances) required to produce flaming in the layer material was recorded.

Since finely powdered grass dust has a very low minimum depth ($<$ 2 mm in still-air), it was of interest to find out whether grass trains of a depth of a few millimetres could lead to flaming in a covering layer of combustible material. From the table of results (Table 6) it will be seen that, although grass trains formed from mould A (3 mm in height and 1.35 cm wide) would not lead to flaming at an air velocity of 250 cm/sec, by using trains of the same height but of greater width (10.1 cm) formed from mould W this could be achieved. A series of photographs from a demonstration experiment, in which smouldering was initiated in a grass train 5 mm in height by means of a cigarette end, is given in Plate 1.

The results of other experiments indicate that the minimum applied airflow required for flaming probably decreases with increase in train size, but, since only single experiments were carried out at any particular velocity, any apparent differences between the hazards of grass A and grass C and between coverings of wood shavings and newspaper are not significant.

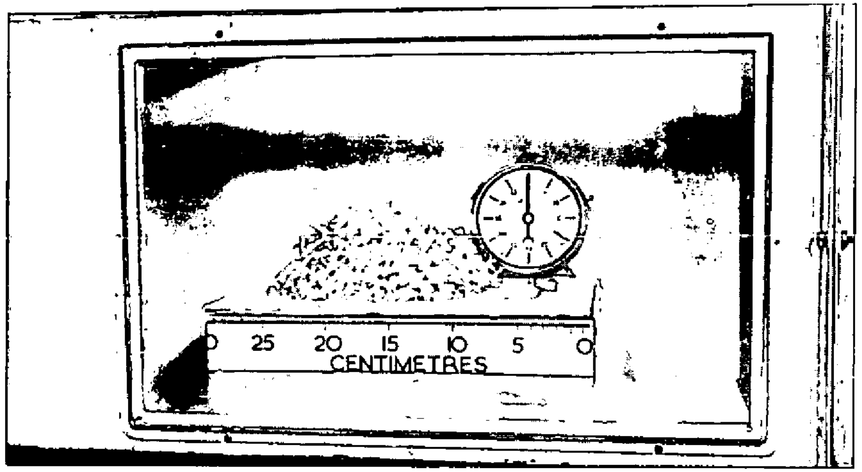
TABLE 6

Experiments on the production of flame

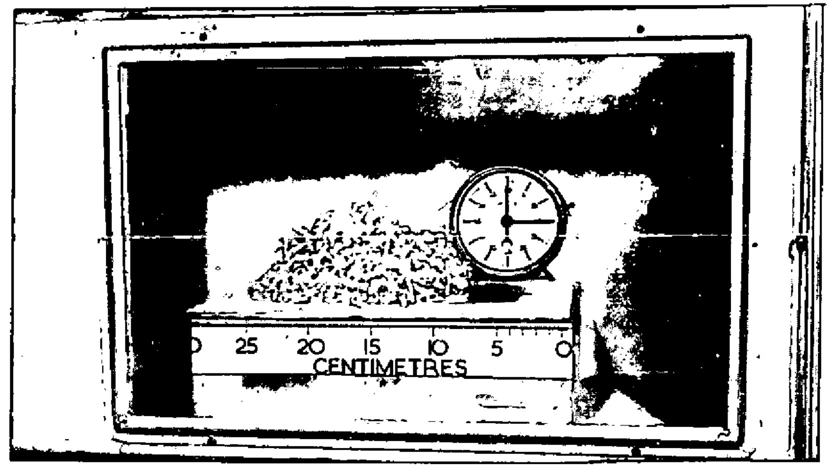
Train material	Mould	Layer material	Minimum applied airflow for flaming cm/sec
Grass A	B	Deal wood shavings	200-250
" A	B	Crumpled newspaper	150-200
" A	A	Deal wood shavings	No flaming at 250
" A	A	Crumpled newspaper	" " " 250
" A	A	Shredded newspaper	" " " 250
" A	W	Deal wood shavings	No flaming at 250
" A	W	Crumpled newspaper	$<$ 250
Grass C	D	Deal wood shavings	100-150
" C	W	Deal wood shavings	200-250
" C	W	Crumpled newspaper	200-250

1 m.p.h. = 44.7 cm/sec

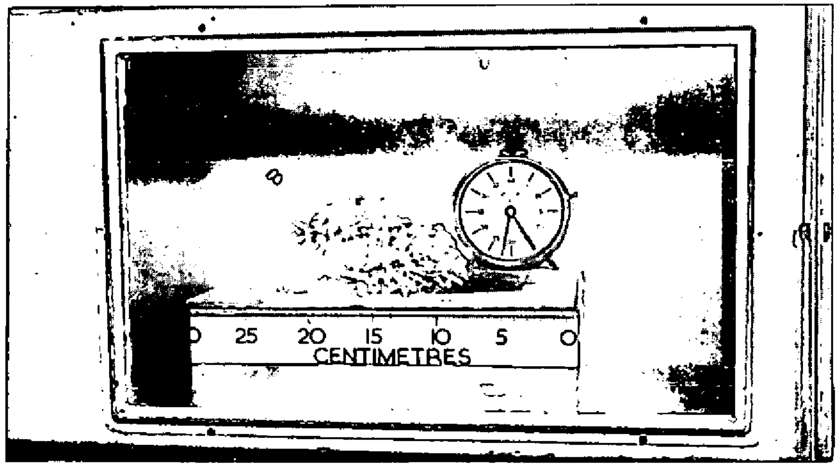
VHM



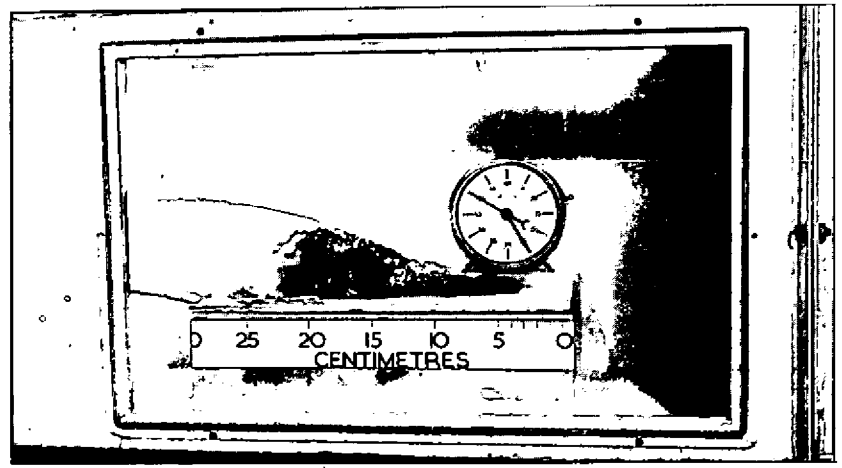
Glowing cigarette end dropped on grass dust train (0 min)



Smouldering initiated and advancing along the grass dust train (15 min)



Smoke evolution increased as shavings are about to catch fire (25 min 32 sec)



Shavings well alight (25 min 50 sec)

PLATE. 1. THE SPREAD OF SMOULDERING, IN PRESENCE OF 250 CM/SEC DRAUGHT, FROM 3 MM DEEP TRAIN OF GRASS DUST TO COVERING LAYER OF WOOD SHAVINGS WITH SUBSEQUENT PRODUCTION OF FLAME

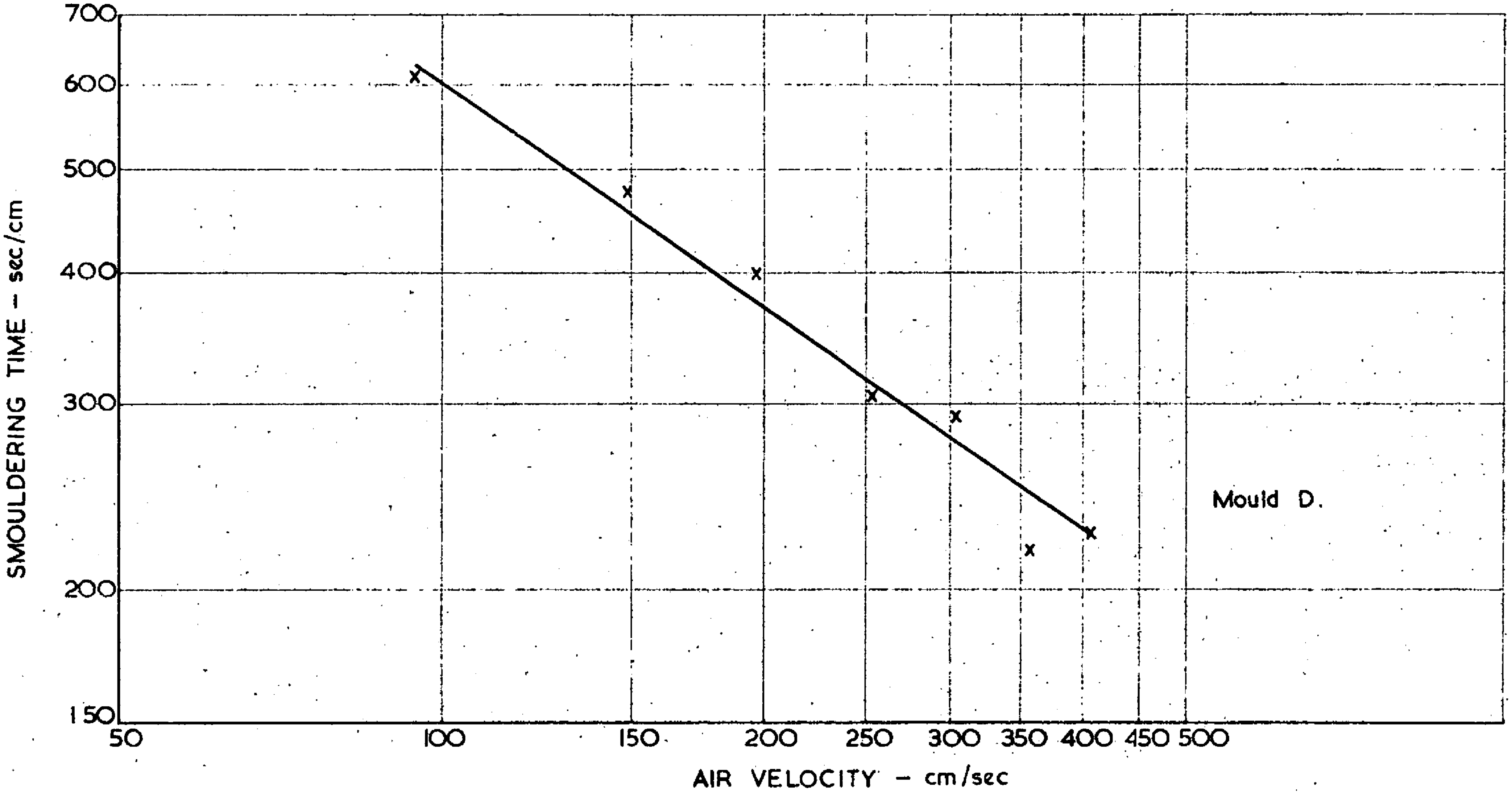


FIG. I. THE EFFECT OF AIRFLOW UPON THE SMOULDERING TIME OF COCOA.

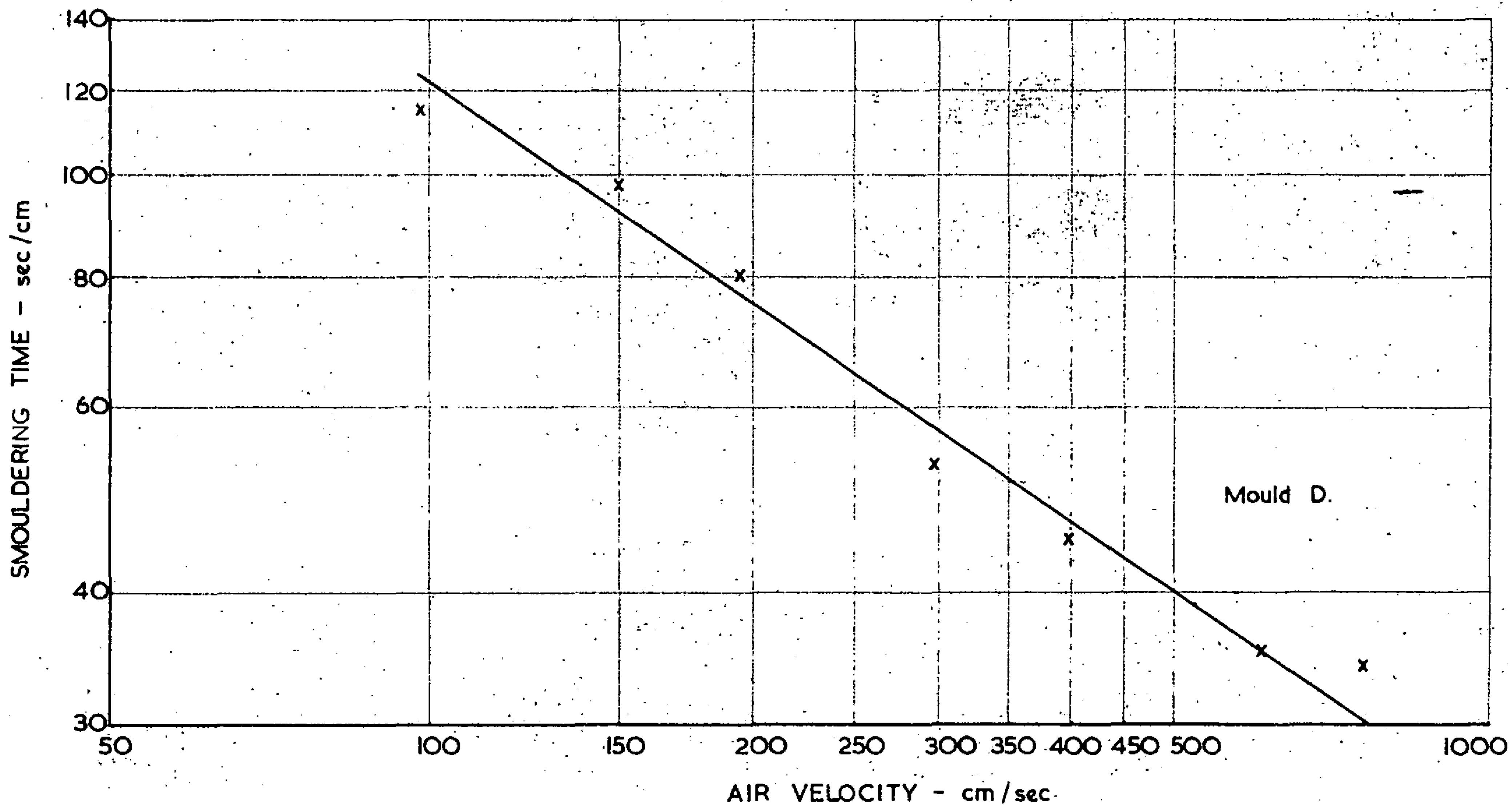


FIG. 2. THE EFFECT OF AIRFLOW UPON THE SMOULDERING TIME OF GRASS DUST. SAMPLE A.

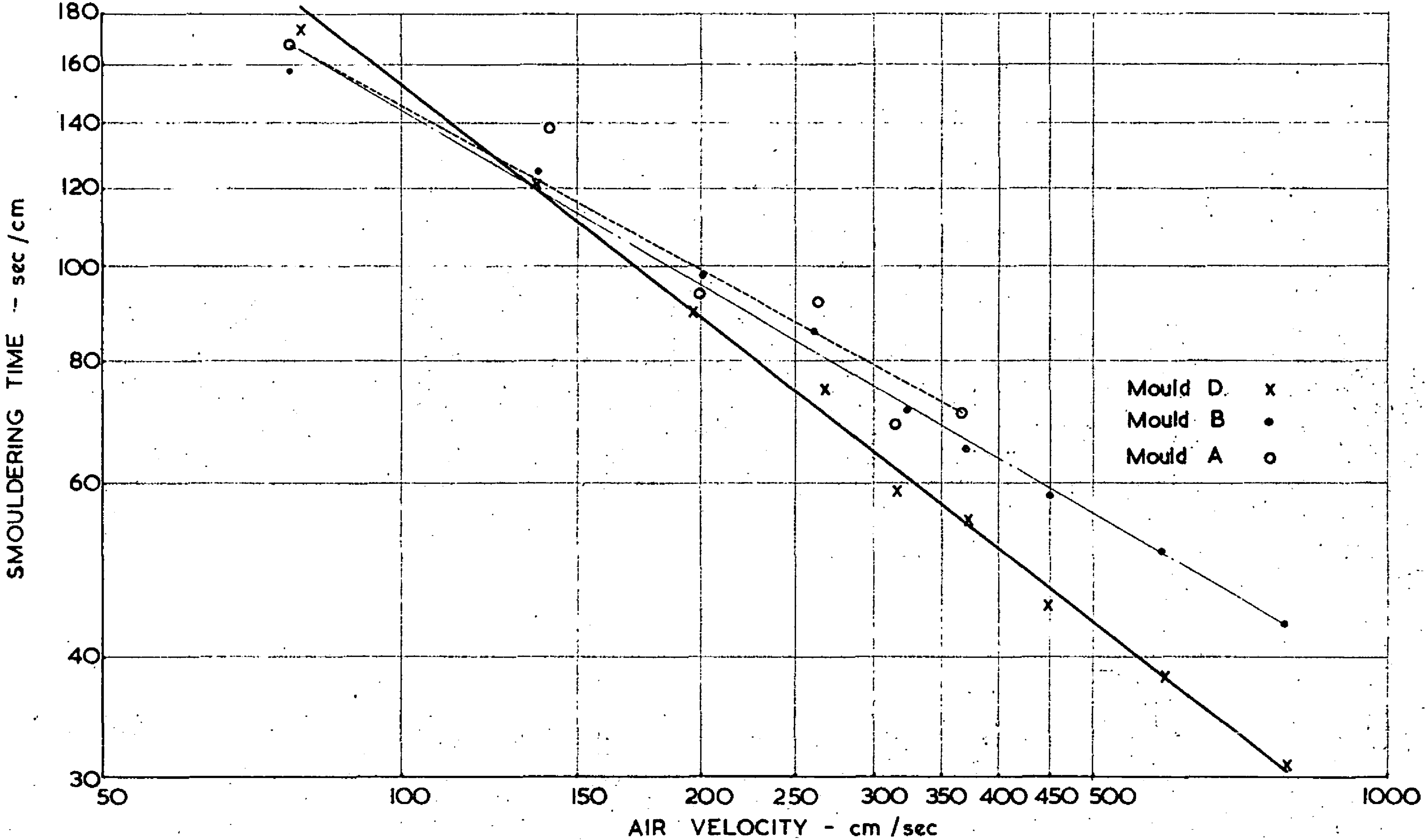


FIG. 3. THE EFFECTS OF AIRFLOW AND TRAIN SIZE UPON THE SMOULDERING TIME OF GRASS DUST SAMPLE B.

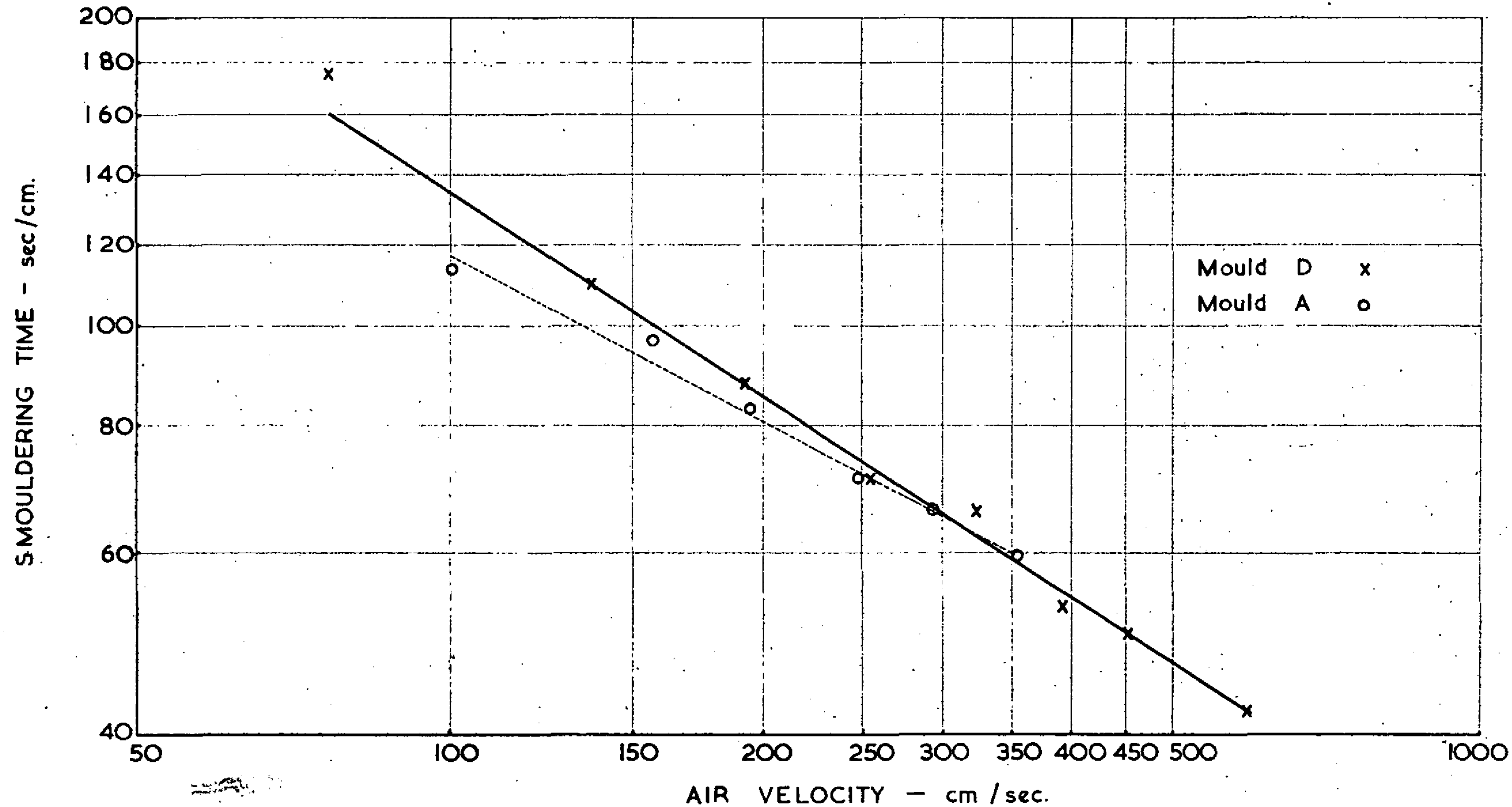


FIG. 4. THE EFFECTS OF AIRFLOW AND TRAIN SIZE UPON THE SMOULDERING TIME OF GRASS DUST SAMPLE C.

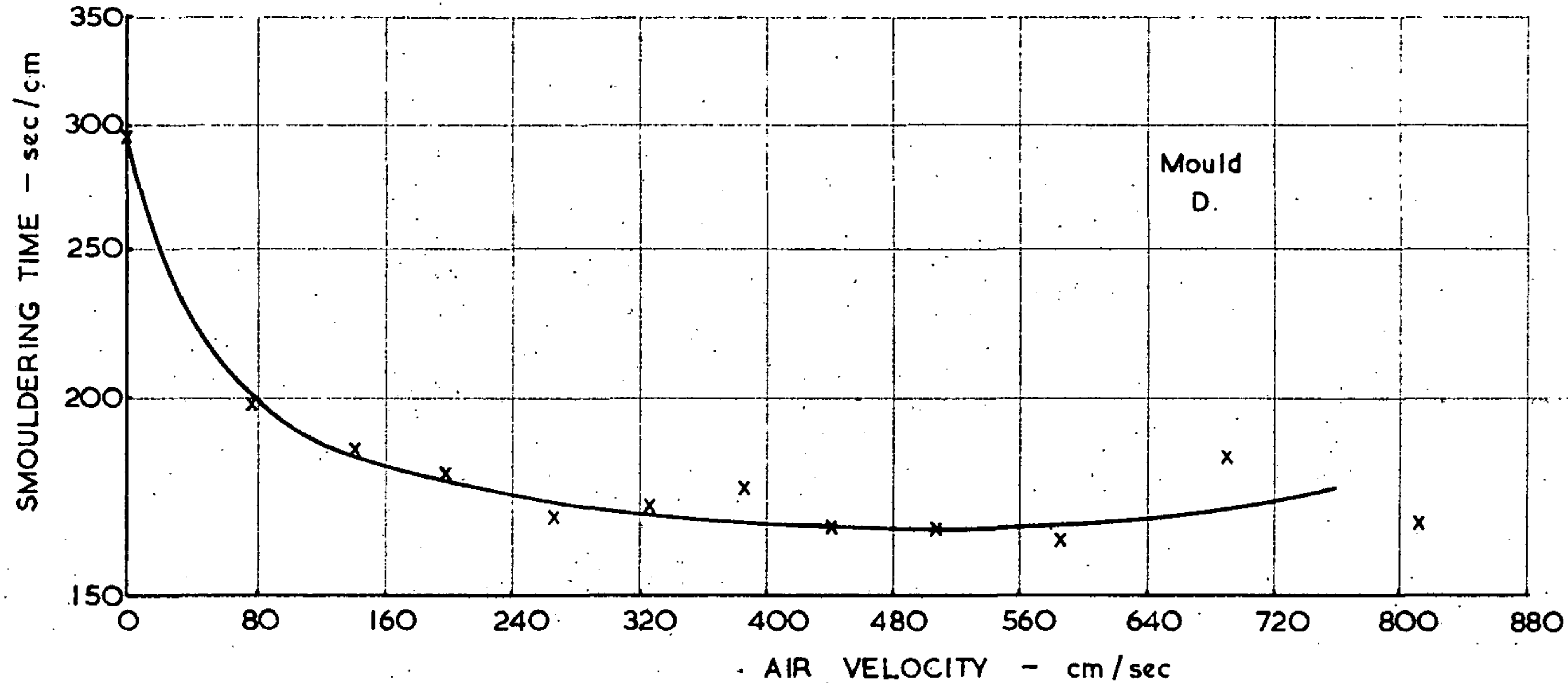


FIG. 5. THE EFFECT OF AIRFLOW UPON THE SMOULDERING TIME OF GRASS DUST.
SAMPLE B.
AIRFLOW OPPOSING THE DIRECTION OF PROPAGATION OF SMOULDERING.

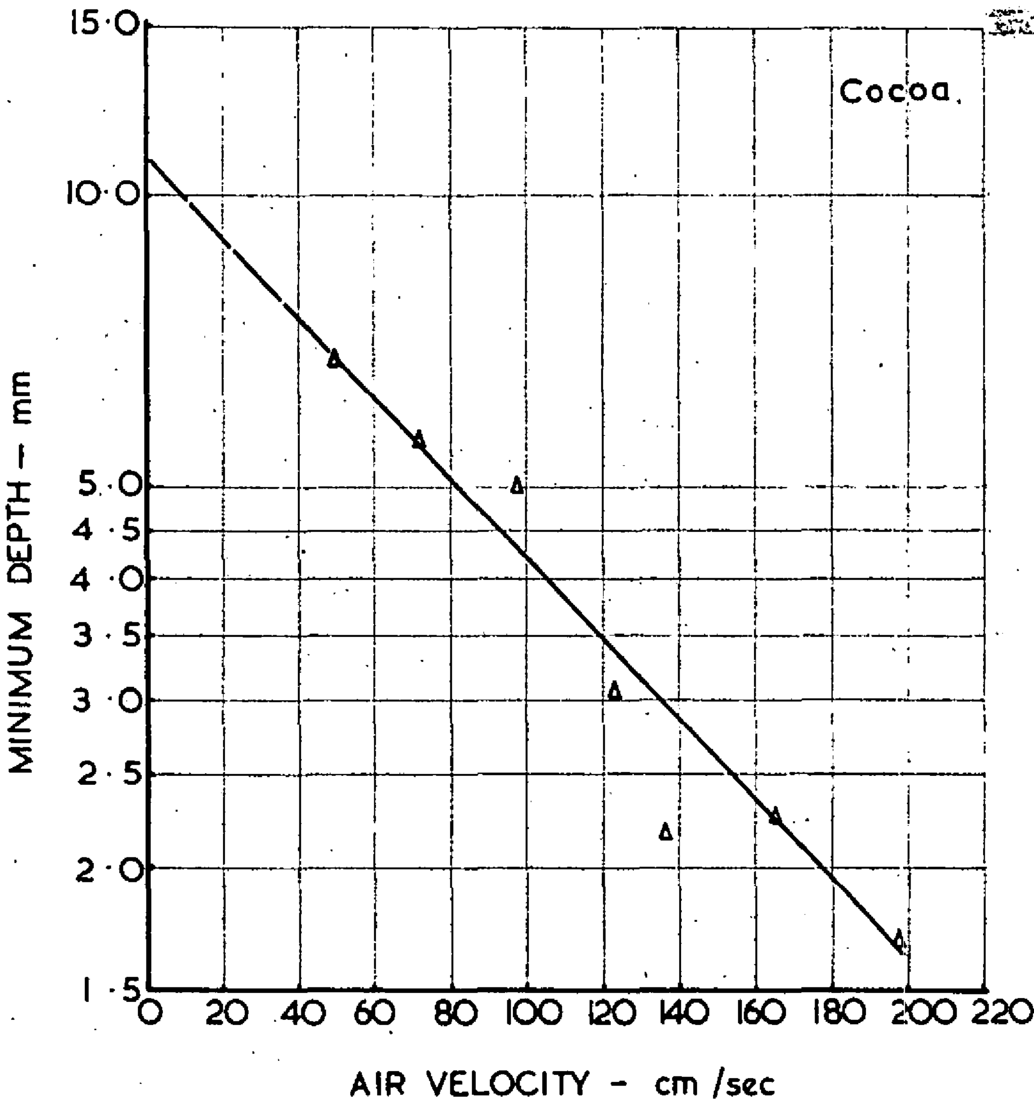


FIG. 6. THE VARIATION OF MINIMUM DEPTH FOR SUSTAINED SMOULDERING WITH INCIDENT AIR VELOCITY.