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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
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SMOULDERING IN DUSTS AND FIBROUS MATERIALS
PART X. CORK DUST UNDER AIRFLOW CONDITIONS

by

K. N. Palmer and M. D. Perry

Summary

The smouldering of cork dust in an air draught has been investigated with dust fractions whose mean particle sizes ranged from 0.0065 cm to 0·48 cm. Over this wide range the relation between the rate of smouldering of dust trains and the velocity of the applied air was shown to vary markedly; and it is probable that differences in the relations obtained previously with other dusts were due, at least in part, to the differences in the particle sizes of those dusts. With the finer cork fractions the appearance of the smouldering did not differ markedly from that of other dusts, but with the coarser cork fractions the smouldering became more vigorous with copious evolution of smoke and intense glowing which led to the development of flaming under an air draught. Vigorous smouldering developed in the very coarse fractions, even in still air.

The effect of airflow upon the smouldering rate was less marked when the airflow and the propagation of smouldering were in opposing directions, thus preventing the air from impinging directly upon the smouldering zone, and it therefore seems probable that the vigorous smouldering noted above resulted from the ease with which air could penetrate between the particles of coarse dusts.

The minimum depth of dust layer for sustained smouldering in still air increased with particle size for the finer fractions, reached a peak value, and then decreased again with coarse fractions when the smouldering became more vigorous. There was no indication that cork dust might be too coarse to smoulder.

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Fire Research Station,
Boreham Wood,
Herts.

SMOULDERING IN DUSTS AND FIBROUS MATERIALS
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Introduction

The experimental programme on the smouldering of various dusts and fibre insulation boards has been reported in previous notes in this series (1-7). The experiments described have shown that smouldering combustion may present a considerable fire hazard, particularly in industrial premises, warehouses, etc. where combustible dust deposits may accumulate. If the dust then becomes ignited, it may smoulder for a lengthy period before flaming and a rapid spread of fire develop. Thus, it has been shown that smouldering may often be initiated by a small source of ignition, such as a glowing cigarette end, and will then propagate slowly through the combustible. The smouldering can then lead to open flaming on coming into contact with material such as wood shavings, newspaper, sacking, etc. under conditions of a slight air draught.

Smouldering rates in still air are usually slow and are speeded up considerably on applying an air draught in the same direction as the propagation of smouldering. The relations between the applied air velocity and the smouldering time (the time required for the smouldering to travel 1 cm) have been studied with several dusts and fibre boards; the results obtained may be divided into two groups as follows:

Group I: those for fibre insulation boards (6), powdered grass dusts and cocoa dust (7) in which the relation between the smouldering time S (sec/cm) and the air velocity V (cm/sec) over the velocity range investigated is approximately of the form

$$SV^n = a \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

where a is a constant and n is in the range 0·38-0·78.

This equation is similar in form to that derived theoretically and confirmed experimentally by Hottel and his co-workers (8) for the combustion rate of a carbon sphere suspended in a furnace and exposed to a measured current of air; in the derivation of the equation the diffusion of oxygen onto the surface of the combustible was assumed to be the rate determining process. The relationship of this result to those obtained in the previous experiments on smouldering has already been discussed (4, 6).

If the rate of smouldering is governed solely by the mass rate of transport of oxygen to the surface then the smouldering time might be affected by the distribution of the combustible (i.e. to the ratio of the mass of the combustible to the area of it exposed to the air). Experiments upon strips of fibre insulation board and trains of grass dust under still air conditions (2, 3, 7) have shown that the smouldering time does depend on the size of the specimen strip or train with these materials.

It should be noted that the grass and cocoa dusts used were of very small particle size, a considerable proportion passing a 240 B.S. (or 200 I.M.M.) mesh.

Group II: those for beech and deal sawdusts (4) in which the relation between the smouldering time S and the air velocity V, over the velocity range tested, is approximately of the form

$$\log (S/S_o) = -mV \ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

where m is a positive constant and S_o is the value of the smouldering time at zero incident air velocity (i.e. $S \ngtr S_o$).

When the dependence of smouldering time (S) upon air velocity (V) may be expressed as in Equation (ii), the sensitivity of S to changes in V is appreciably greater than when the dependence may be expressed as in Equation (i), particularly at higher air velocities. Thus the effect of airflow upon the smouldering time of the sawdusts was in general greater, relative to the still air value, than for fibreboard or grass and cocoa dusts. A further point of difference with the sawdusts is that the smouldering times of the trains in still air were independent of train size (1, 4), within the limits of experimental error. This behaviour is again different from that of grass and cocoa dust.

It should be noted that the sawdusts were coarser than the grass or cocoa, the finest fraction used being 100-120 I.M.M.

The possibility existed that the difference in behaviour of the smouldering of the sawdusts and other dusts were only of degree and that they were due principally to the differences in mean particle size of the two sets of dusts. The inference was that with the coarser dusts (sawdusts) the air current impinging upon the smouldering zones was more easily able to penetrate between individual dust particles, instead of being deflected by a comparatively solid front of combustible as with fibre board or trains of very fine dust. The smouldering of coarse dusts might then be more rapid owing to the increased supply of air to the smouldering zone. This was supported by previous observations on the beech and deal sawdusts (4, 5) showing that the effect of airflow on the rate of smouldering was proportionately greatest with the coarsest fractions of dust. When there is a rapid increase in smouldering rate with airflow greater concentrations of inflammable vapour, smoke, etc. distilled from the combustible are produced near the smouldering zone and may ignite to produce flames. Flaming had already developed on a few occasions with the coarsest fraction of deal sawdust (12-25 B.S.) (5).

The work described in the present note was undertaken with cork as a combustible because it was readily available in a wide range of particle sizes and it was also one of the more rapidly smouldering materials (in fine fractions). A disadvantage of this dust was that its composition might change with particle size to some extent, so that detailed comparisons of the behaviour of the sieve fractions should be made with caution. In the main series of experiments a study was made of the general form of the relationship between smouldering time and air velocity and its dependence upon the particle size of the dust, using the entire range of sieve fractions. With the coarsest fractions further consideration was given to the important transition from smouldering to flaming, in greater detail than in previous experiments.

In addition to the above experiments, in which the propagation of smouldering and the airflow were in the same direction, a brief investigation was also made of trains with the airflow opposing the smouldering (reverse flow). Under these conditions the smouldering zone was protected from the airflow directly, by the unburned dust, except on the surface of the train, and so any bulk movement of air into the smouldering zone was reduced. The behaviour of several dust fractions was investigated in these experiments.

A determination of the effect of train size upon the smouldering time of a fine cork dust was made under still air conditions, for comparison with the results obtained previously with grass dust (7), mentioned above.

Determinations were also made of the minimum depth of dust layer required for sustained smouldering in still air, and its reduction under an air draught.

Materials and Apparatus

The cork dust used in the experiments came from two different sources. Cork A, a fine industrial dust very similar in character to that used in the earlier still air work (2), was obtained through Safety in Mines Research Establishment, Buxton, and was sieved into the fractions listed below (Table 1). Cork B was a commercial granulated material, specified as having a particle size of $\frac{1}{4}$ in. and after either sieving or milling followed by sieving the 25-60 B.S. and coarser fractions listed below (Table 1) were separated. After collection, each fraction was thoroughly mixed and its moisture content determined by the method described previously (1). The mean particle diameters and moisture contents of the fractions and the dry weight packing densities used in the experiments are also tabulated below:

Table 1

Characteristics of the various dust fractions

Dust		Mean particle diameter cm	Moisture content %	Dry weight packing density gm/ml
Cork A	through 240 B.S.	<0·0065	8·8	0·18
	120-240 B.S.	0·0095	8·6	0·13
	72-120 B.S.	0·017	8·3	0·11
	60-72 B.S.	0·023	8·3	0·11
	25-60 B.S.	0·043	6·7	0·09
Cork B	25-60 B.S.	0·043	3·4	0·06
	12-25 B.S.	0.10	2·2	0·07
	7-12 B.S.	0·19	2·4	0·07
	0·48-0·24 cm	0·36	4·2	0·07
	>0·48 cm	>0·48	4·2	0·07

In the determinations of smouldering rates the trains of cork dust were formed either from the small metal moulds A-E used in earlier experiments (1) or from some new larger ones (EE-GG). The new moulds had sides of smaller slope to enable trains formed from them to withstand higher air velocities without erosion. Some dimensions of these moulds are tabulated below.

Table 2

Mould dimensions

Mould	A	B	C	D	E	EE	FF	GG
Top width cm	1·35	2·35	3·55	5·10	7·25	11·3	17·6	26·1
Vertical depth along centre cm	0·30	0·80	1·00	1·65	2·40	2·40	3·70	5·70

An additional mould (ZZ) was also made for the determinations of the minimum depth of dust layer required for sustained smouldering; details of this and other moulds are given below.

Table 3

Dimensions of wedge moulds

Mould	Y	Z	ZZ
Top width cm	5·7	5·7	5·7
Vertical depth at ends cm	1·70 and 0·00	3·40 and 1·40	5·20 and 2·80

The two wind tunnels used in the experiments under airflow conditions were of 5 in. x 5 in. and 13 in. x 13 in. cross-section respectively; some details of the construction of these tunnels have already been given (4, 9).

Experiments and results

Procedure. The experimental procedure in the formation of the cork dust trains was the same as that previously employed with other dusts and described earlier (1). As before, smouldering was initiated at one end of the dust train, across the whole width, by a small gas flame. With some of the coarse fractions smouldering was initiated first in a train of finer dust which led into the coarser material; in this way a more regular smouldering zone was obtained.

Effect of airflow upon smouldering time. The main series of experiments was concerned with the effect of an incident air draught upon the smouldering time of cork dust, the airflow and propagation of smouldering being in the same direction, and was carried out using all the ten sieve fractions described in Table 1. The results for three of the finer fractions, from cork sample A, are given in Figures 1-3, the smouldering time being plotted on a logarithmic scale; the results obtained with the remaining fractions from this sample (120-240 B.S. and 60-72 B.S.) were intermediate in character between those of the adjacent fractions. Further results are given in Figures 3 and 4 for all the fractions obtained from the granulated cork sample B; the details of the moulds used are given in the Figures in each case.

Appearance of the trains. The appearance of the smouldering produced in the finer fractions, from cork sample A, exhibited slight variation with particle size. In still air the finest fraction (through 240 B.S.) burned away to a small amount of grey ash, whereas the residue from the 25-60 B.S. fraction was black and friable and of about the same volume as the dust initially. This carbonised residue, however, burned away with visible glowing under airflows in excess of about 150 cm/sec.

Much more marked variation was obtained with the coarser fractions, from sample B. Thus the 12-25 and 7-12 B.S. fractions smouldered very slowly in still air (Figure 4), the surface of the trains being unmarked except for a slight darkening along the centre. The smoke evolution was less than with the finer fractions, although the trains were larger. Carbonisation of the surface of the trains occurred with the 12-25 B.S. fraction at air velocities above 120 cm/sec, and this burned away completely, with visible glowing, under an airflow of 196 cm/sec.

With an airflow of 130 cm/sec the 12-25 B.S. fraction smouldered irregularly, short spurts of rapid glowing combustion being interrupted by long periods of slow carbonisation, and no significant value for the smouldering time could be measured at this velocity (Figure 4). Visible glowing was also obtained with the 7-12 B.S. fraction at airflows of 53 cm/sec and above. The very coarse fractions, 0·48-0·24 cm and > 0·48 cm, smouldered with visible glowing in still air, more rapidly than the 7-12 and 12-25 B.S. fractions. There was very little residue.

Development of flaming. The visible glowing of the coarse fractions was accompanied by a marked increase in the volume of smoke evolved, and the transition from smouldering to flaming occurred frequently under airflow conditions with the 7-12 B.S. and coarser fractions. In some cases flaming did not develop until sufficient of the trains had burned for a determination of the smouldering rate to be made; such values of smouldering time are marked "f" in Figure 4. At higher air velocities flaming developed soon after the exposure of the trains to the draught and no value of smouldering time could be measured. Each of the results given in Figure 4 is based on one experimental determination only. Flaming was also obtained with the 12-25 B.S. fraction, but only with a train from the largest mould (GG), the result being given as a separate point on Figure 4. The manner in which flaming appeared did not vary noticeably with particle size of the dust and the transition from smouldering usually came about in one of two ways: either from the ignition of the smoke in the centre of the smouldering zone or from the ignition of apparently unburnt material left behind by the smouldering zone at the side of the train. It was not clear whether the actual ignition was due to radiation from the glowing combustion zone or to stray sparks.

A series of photographs is given in Plate 1, showing the initiation of smouldering by a glowing cigarette end in a train of the 72-120 B.S. fraction; the smouldering then led to flaming in a larger train of 0·48-0·24 cm dust, under an airflow of about 2 m.p.h.

Airflow and smouldering in opposing directions. The experiments under reverse airflow conditions were carried out with trains of the through 240, 72-120, and 25-60 B.S. fractions of cork sample A formed from mould D. The results are given in Figure 5, where the smouldering time is again plotted on a logarithmic scale against the incident air velocity. The air velocity ranges investigated were limited by erosion of the dust and particular care was taken to make observations only on undisturbed trains.

Effect of train size on smouldering time in still air. Determinations were made in duplicate of the still air smouldering time of the through 240 B.S. fraction of cork A, using moulds A-E, to provide a measure of this effect. The results are given in Figure 6 where the ratio of the area to the perimeter of the cross-section of the train is plotted against smouldering time; some results obtained earlier for a sample of powdered grass (7) are also included for comparison. The reason for expressing the results in this manner is discussed later.

Minimum depth for sustained smouldering. The variation of minimum depth in still air with particle size is shown in Figure 7 and the effect of an airflow on the minimum depth of two fractions of cork A in Figure 8. The particle diameters of the extreme fractions of cork samples A and B (through 240 B.S. and > 0·48 cm respectively) are, as an approximation, taken in Figure 7 to be equal to the corresponding sieve apertures. The two coarsest fractions again gave visible glowing in still air, and as the smouldering was more vigorous than with finer fractions the results are joined by a broken line in Figure 7.

Discussion

Smouldering time - air velocity relation. The dependence of the smouldering rate of cork dust upon the incident air velocity may be seen from the results given in Figures 1-4 to change markedly with particle size if this is varied over a sufficiently wide range.

Thus as the particle size is increased the smouldering time at high air velocities is progressively reduced until flaming develops. The behaviour of the finest fraction (Figure 1) may be represented approximately by the relation

$$SV^n = a \qquad \text{(a is a constant)}$$

over the velocity range investigated (50-695 cm/sec). It has been mentioned in the Introduction that results obtained earlier for grass dust, cocoa dust, and fibre board strips may also be represented by an equation of this type (Equation (i)). The values of the quantities n and a in Equation (i) are, however, subject to variation both between materials and train or strip sizes (6, 7).

Table 4

Range of values of the constants n and a in the Equation $SV^n = a$

Material	n	a
Cork dust (through 240 B.S.)	0.41	780
Powdered grass	0.53-0.78	1,340-5,520
" cocoa	0.69	14,400
Fibre board strips	0.38-0.48	1,250-2,410

The values of the constant a in the above Table differ widely, being dependent upon the still air smouldering rate, but n is always fractional and its value for the cork dust is within the range of those for other materials. Equation (i) is an approximation and cannot hold for smouldering in still air (V = 0), a correction should therefore be applied at low air velocities. The effect of this correction is small at higher velocities and has already been discussed in relation to fibre insulation boards (6).

The smouldering time-air velocity relation obtained for the next fraction, 72-120 B.S. (Figure 2), is of a different form from that given as Equation (i). Thus the smouldering time decreases more rapidly than previously at airflows above 250 cm/sec, so that the results fall on a slightly sigmoid curve; this curve is the nearest approach obtained with the cork dusts to the logarithmic relationship for wood sawdusts (Equation (ii) in the Introduction) which would be drawn as a straight line. This change in the smouldering time-air velocity relation with particle size indicates that the division of the previous results into two groups, as given in the Introduction, may be artificial and that intermediate types of relation could be obtained.

The two 25-60 B.S. fractions were from different sources and did not give identical results (Figure 3) although both sets followed similar patterns, falling on curves of pronounced sigmoid shape. At airflows above 200 cm/sec the smouldering rate increased rapidly with airflow and so the results for the air velocity range investigated cannot be represented by either Equation (i) or (ii).

The results given for the 12-25 B.S. fraction (Figure 4) show a further difference in that at low air velocities (up to 120 cm/sec) the slow smouldering was little affected by the draught but at velocities above 150 cm/sec the smouldering was rapid and sensitive to changes in airflow. It seems probable from the irregular character of the smouldering at intermediate air velocities that the alternations between slow and rapid smouldering are abrupt and that the two processes may be distinct and do not merge gradually. Similar behaviour was observed with the 7-12 B.S. fraction, but the more rapid combustion was obtained with a smaller airflow than previously. With coarser fractions only the rapid type of smouldering was obtained, even in still air. No abrupt changes in the smouldering rate with air velocity had been observed in previous experiments with wood dusts, although flaming developed on a few occasions. However, none of the sawdusts was coarser than 12 B.S.

With the cork dusts the transition to flaming only occurred in trains undergoing rapid smouldering and the ease of transition increased with particle size; flaming was obtained with the 12-25 B.S. fraction, but only with large trains (mould GG), and so the dimensions of the train also probably affect the ease of transition to flaming. As flaming developed frequently in trains of the coarsest fractions and limited the number of smouldering rate determinations, no definite relationship could be established between the smouldering time and incident air velocity. It is possible that with even coarser fractions the smouldering time in still air would decrease further and thus under these conditions the transition from smouldering to flaming might occur in still air; for such materials smouldering combustion would then be unstable.

Smouldering and airflow in opposing directions. The results for the three series of experiments, given in Figure 5, show that airflow causes only a slight increase in the rate of smouldering. The similarity between the results for different fractions is particularly noticeable when it is compared with the differences in corresponding results when the airflow and smouldering were in the same direction (Figures 1-3). It has been found that the results in Figure 5 for smouldering time (S) and air velocity (V) may be represented approximately by an empirical equation of the type

$$SV^n = a + bV \quad \text{......................} \quad \text{(iii)}$$

a and b being constants and n having the value 0·8.

In Figure 9 values of $SV^{0.8}$ are plotted against V for the three fractions and a single line can be drawn for all the points; the corresponding results for a powdered grass fraction are also included, for comparison. Curves calculated from Equation (iii) are also indicated in Figure 5 by broken lines. Equation (iii) thus holds for both the powdered grass and the three cork fractions; a similar relation was obtained previously with fibre board strips suspended in an airflow (6), the value of n in this case being 0·5. The value of smouldering time given by Equation (iii) can be shown to pass through a minimum; for the three cork fractions S_{min} = 117 sec/cm at an airflow of 216 cm/sec, and for the grass dust S_{min} = 170 sec/cm at an airflow of 420 cm/sec. A minimum value of the smouldering time was also obtained with fibre board and the effect is more marked with this material.

The similarity between the results for the three cork fractions in Figures 5 and 9 indicates that the marked differences in the behaviour of these fractions in the main series of experiments were not due solely to variations in the dust. In the present experiments, with reverse airflow, the smouldering was protected directly from impinging airflow by the unburnt part of the train and this probably hindered penetration of the zone by the air draught. The rapid increase in smouldering rate at higher air velocities, noted previously with the 25-60 B.S. fraction, does not then take place.

Effect of train size on smouldering time in still air. In earlier experiments with fibre board upon the effect of strip size on the rate of smouldering it was found that the smouldering time was approximately proportional to the ratio of the area to the perimeter of the cross-section of the strips (3). Although the smouldering time of the fine fractions of cork and grass dusts does vary with train size (Figure 6) the effect is complicated by the presence of the asbestos base and by curvature of the smouldering zone in larger trains. Hence no simple relation between the train cross-section and the smouldering time was obtained.

Minimum depth for sustained smouldering. The results for the variation of minimum depth in still air with particle size, given in Figure 7, show that the minimum depth increases with particle size up to the 7-12 B.S. fraction (0·191 cm), but with the very coarse fractions the values obtained were rather lower. This decrease is clearly associated with the more vigorous nature of the smouldering, accompanied by visible glowing, obtained with these fractions in still air. The general variation of minimum depth with particle size is clearly defined, except for the very coarse fractions but closer examination should be made with caution as there may be some variation of composition through the fractions.

The experiments upon the minimum depth in still air give no indication that cork dust could be too coarse to smoulder, although the smouldering dust might, as discussed above, inflame in still air.

Practical considerations. The fire hazard involved in the smouldering of cork dust is obvious, both from the above remarks and also from the photographs in Plate 1. It can be seen that a small source of ignition can initiate smouldering which will then develop into flaming in coarse material under a 2 m.p.h. draught. It has been found possible for smouldering to be initiated by a cigarette end and for flaming to develop in the one material. The ease with which the smouldering of the cork is converted into flaming is particularly noteworthy and may be compared to that of the wood shavings or newspaper used previously with beech sawdust trains (4).

Conclusion

The experiments above have shown that the relation between the smouldering time of cork dust trains and the incident air velocity can vary considerably with particle size. It seems probable that the differences in the relation observed previously with other dusts were mainly due to the different particle sizes of those dusts and also that the behaviour of the smouldering of fibre board strips is comparable to that of fine dust trains. In addition, the development of flaming observed with coarse cork fractions may then be obtained with other coarse dusts, so that the transition from smouldering to flaming may occur if the particle size of the dust is sufficiently large. The ease of transition with cork was shown to be dependent on the size of the train and probably increases with particle size.

The results indicate that increase in particle size permits greater movement of air into the smouldering zone and hence more rapid combustion may be sustained. Thus, when the airflow and the propagation of smouldering were in opposing directions, the smouldering zone being partly shielded from the airflow, there was no marked increase in the smouldering rate and several fractions gave similar results. In the main series of experiments with these fractions, marked differences in the smouldering rate were apparent at high airflows.

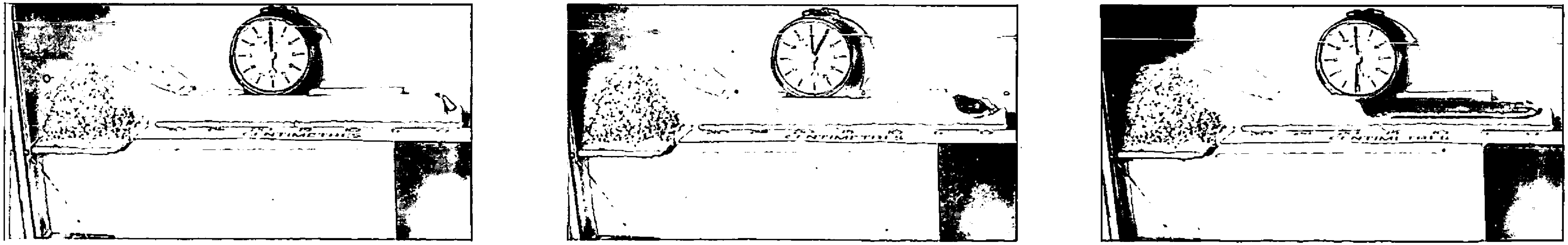
The minimum depth of dust layer for sustained smouldering in still air was shown not to increase continually with particle size. With coarse fractions the smouldering became more vigorous, with glowing and copious smoke evolution, and the observed minimum depth was reduced from a maximum of 4·7 cm to about 3·6 cm.

The experiments on cork dust have demonstrated the fire hazard involved in the smouldering of the dust. Thus initiation in shallow layers of fine dust by a small source of ignition can lead to the development of flaming in coarser fractions of the same material. These facts emphasize the need for good house-keeping in premises in which this type of material may accumulate.

References

(1) F.R. Note No. 6/1952.
(2) " " " 11/1952.
(3) " " " 24/1952.
(4) " " " 48/1952.
(5) " " " 50/1953.
(6) " " " 73/1953.
(7) " " " 89/1953.
(8) Tu, Davis, Hottel. Ind. Eng. Chem. 1934, <u>26</u>, 749.
(9) F.R. Note No. 74/1953.

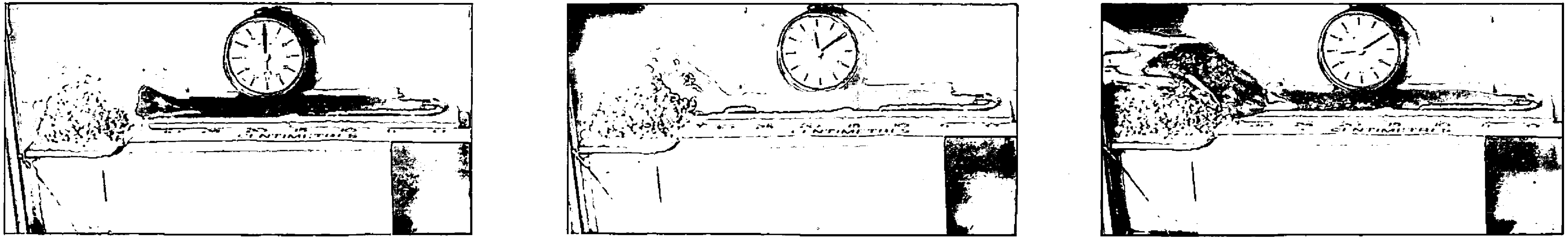
PC.



0 min Cigarette end put on cork dust. (72 - 120 B.S.).

5 min Spread of smouldering into dust train.

31 min Smouldering zone advancing along train

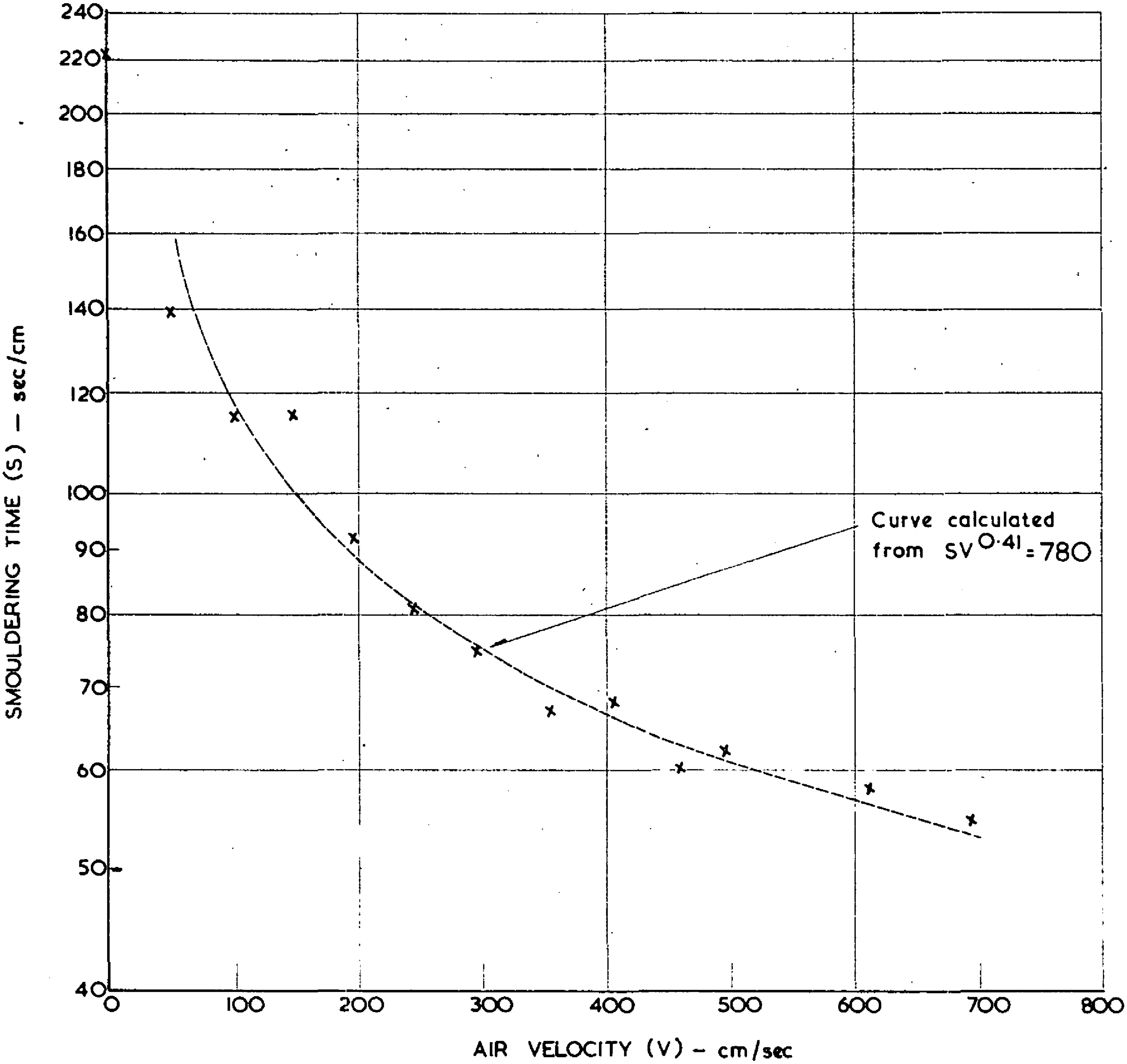


60 min Smouldering zone reaches coarse cork. (0·48 - 0·24 cm fraction).

69 min Sudden build - up of smoke.

70 min 44 sec Flaming develops.

PLATE. I. THE TRANSITION FROM SMOULDERING TO FLAMING IN CORK DUST. UNDER AN AIR DRAUGHT OF 2 M.P.H.



Cork A.

Mould D.

THE EFFECT OF AIRFLOW ON THE SMOULDERING TIME OF THE THRO' 240 B.S. FRACTION.

Fig. 1

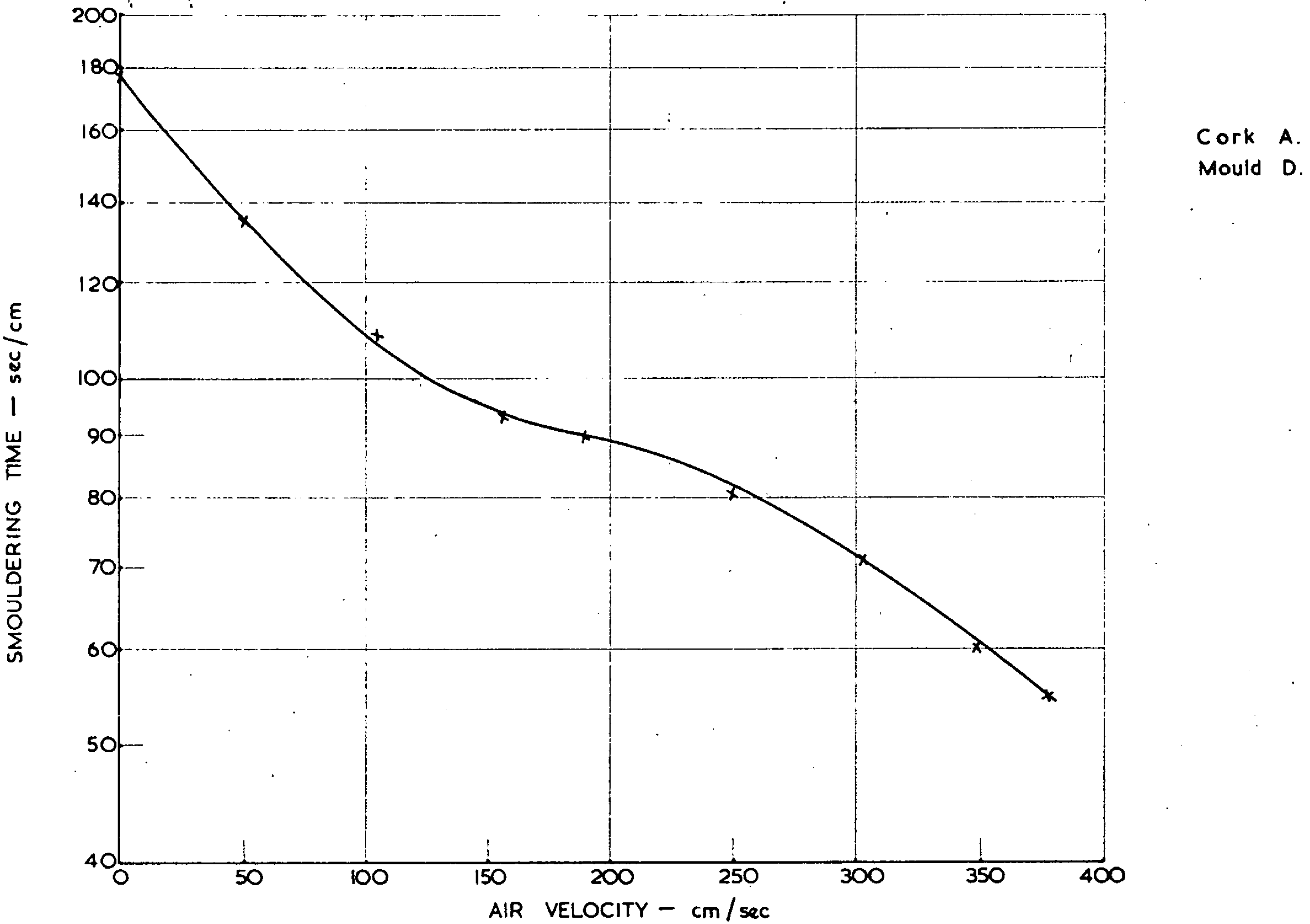


FIG. 2. THE RELATION BETWEEN AIRFLOW AND SMOULDERING TIME FOR THE 72 - 120 B.S. FRACTION

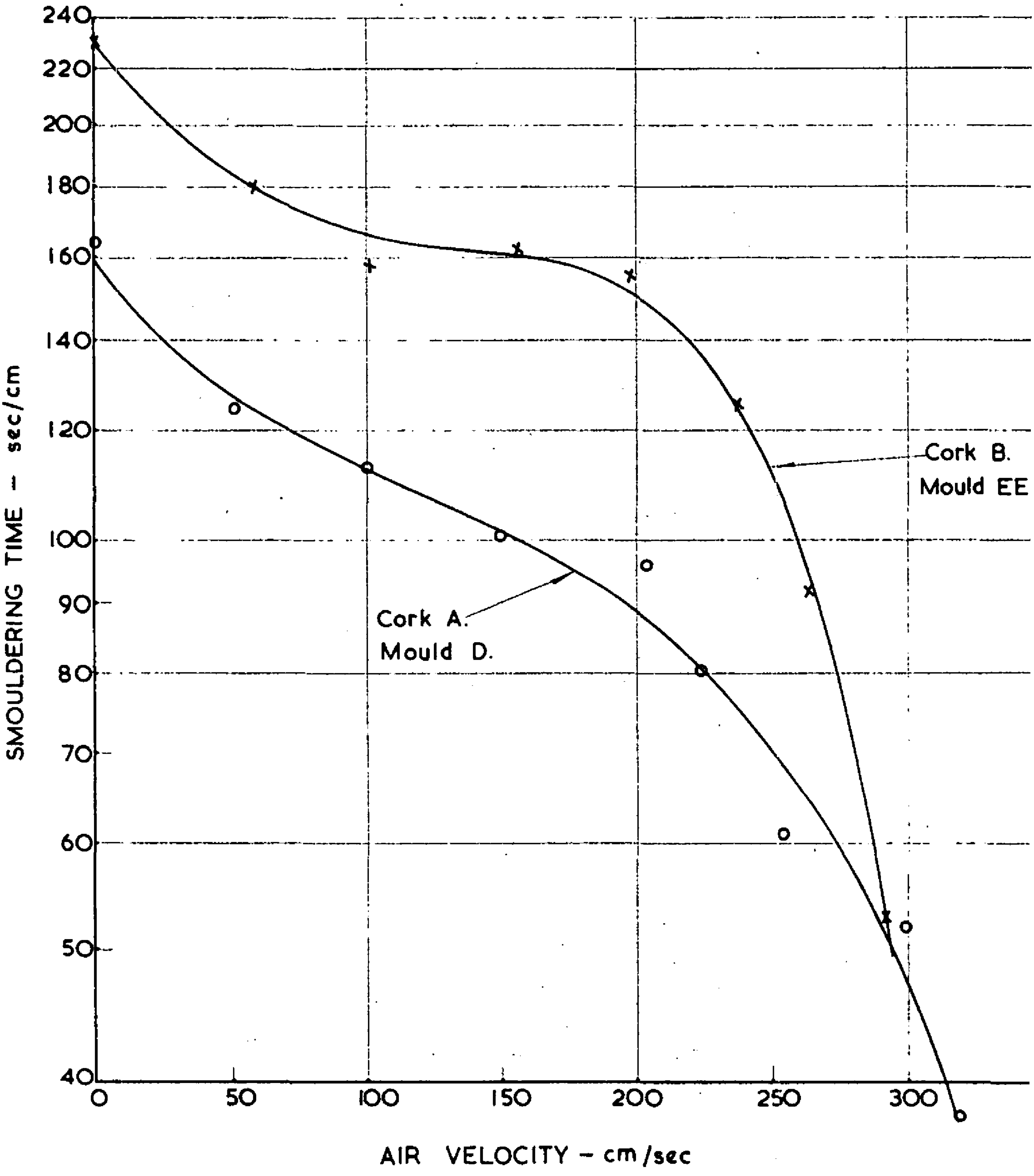


FIG. 3. THE EFFECT OF AIRFLOW ON THE SMOULDERING TIME OF THE 25-60 B.S. FRACTION.

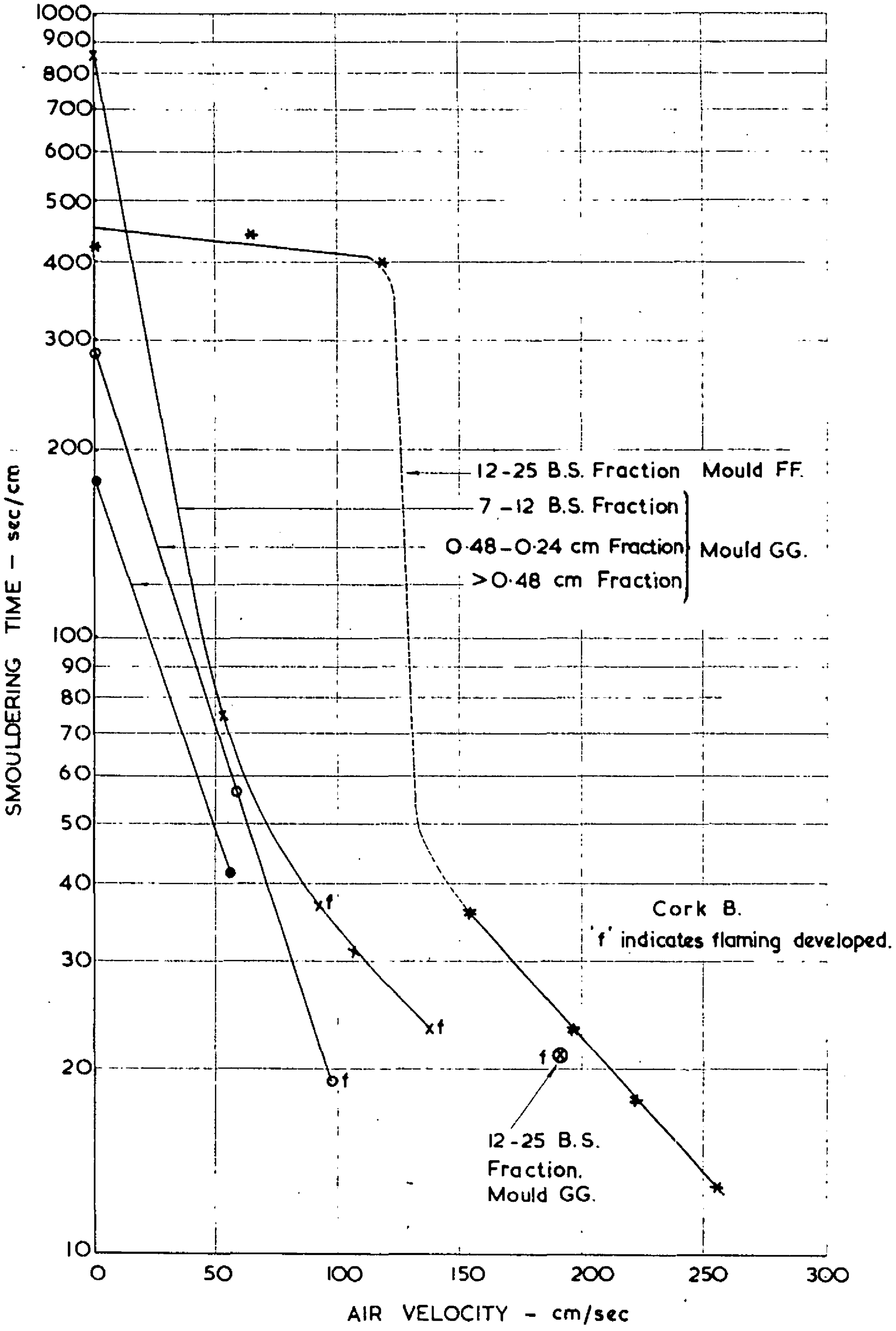
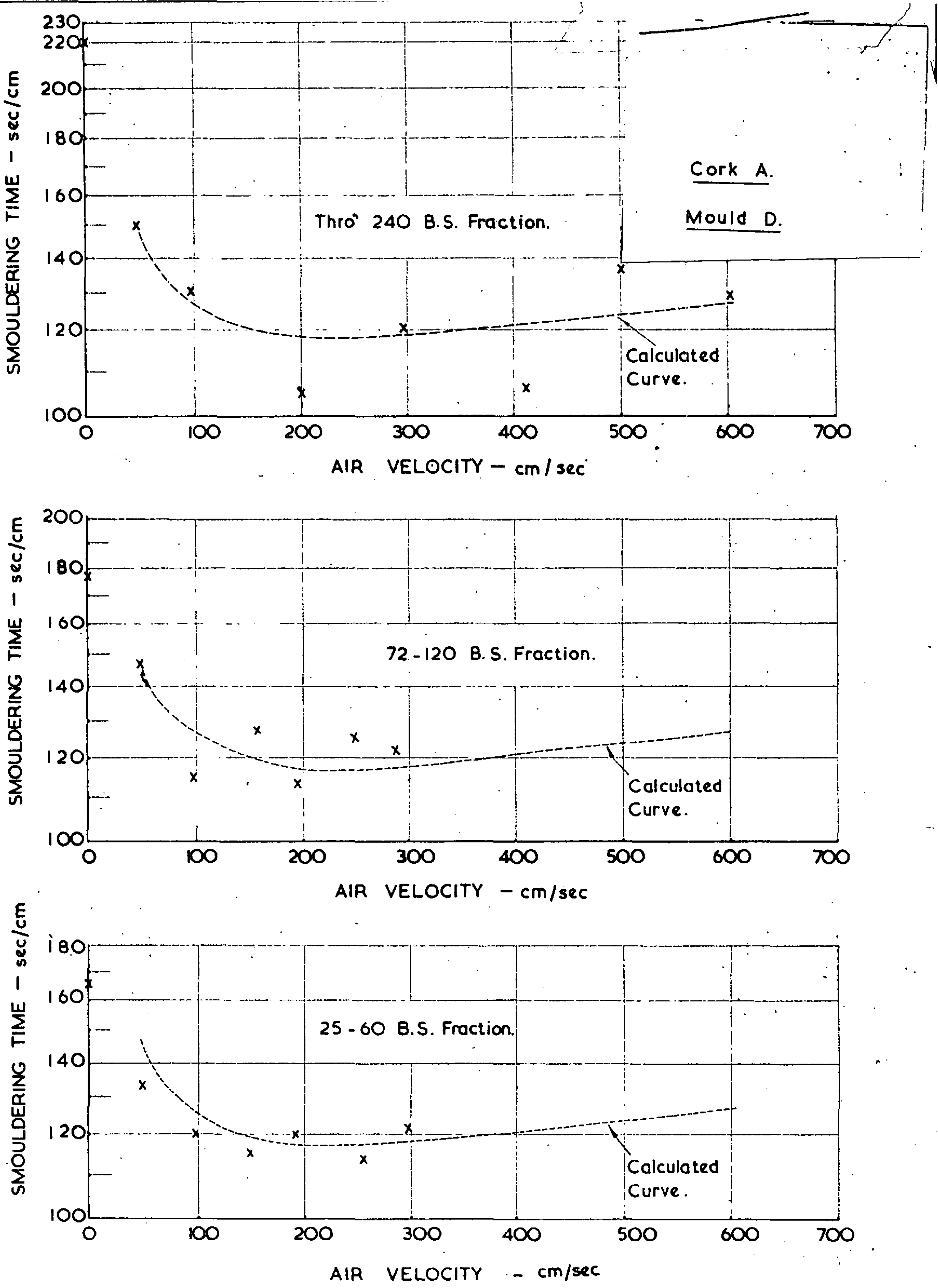


FIG. 4. THE EFFECT OF AIRFLOW ON THE SMOULDERING TIME OF FRACTIONS COARSER THAN 25 B.S.



THE VARIATION OF SMOULDERING TIME WITH INCIDENT AIR VELOCITY. AIRFLOW AND PROPAGATION OF SMOULDERING IN OPPOSING DIRECTIONS.

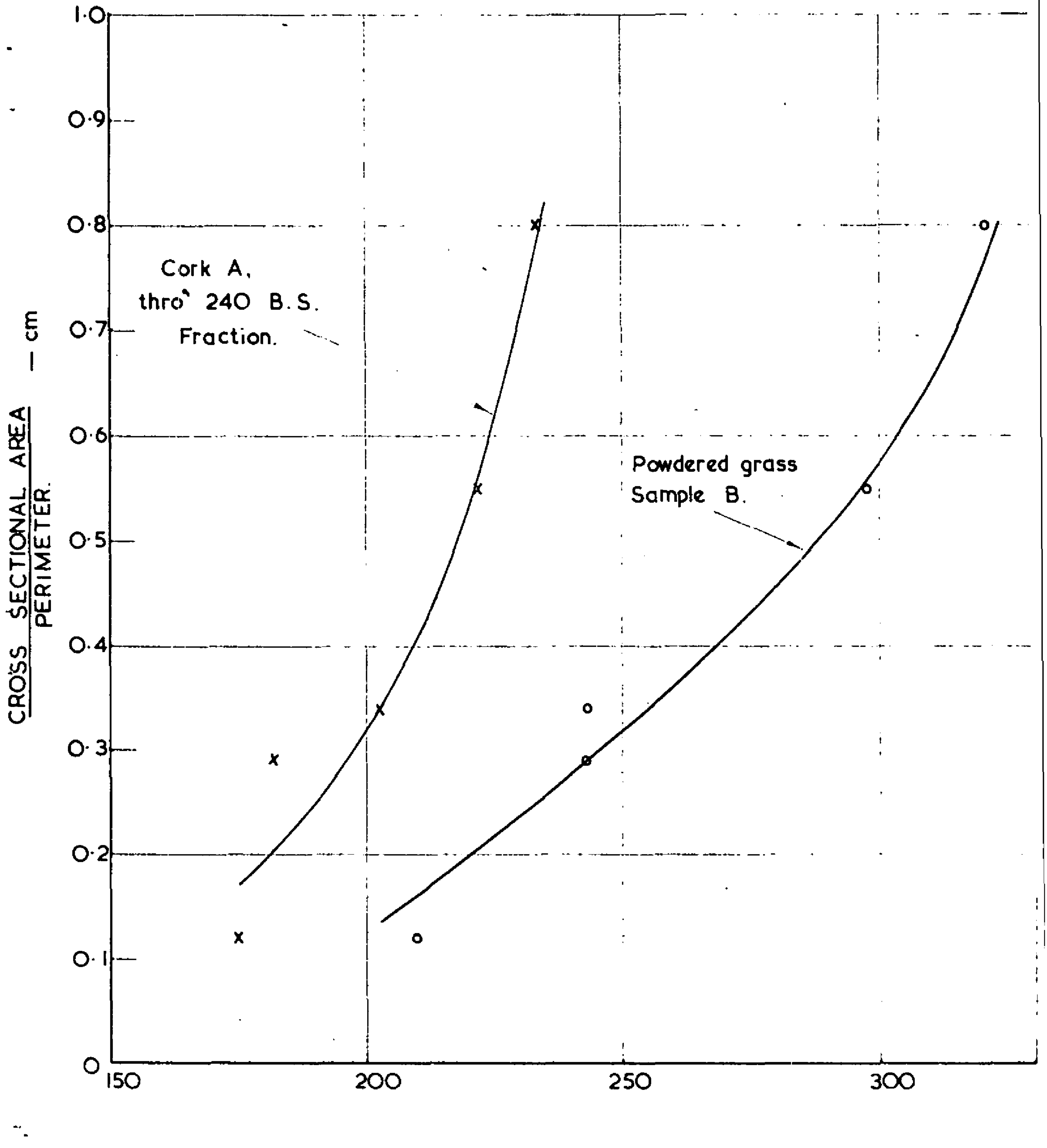


FIG. 6. THE RELATION BETWEEN SMOULDERING TIME IN STILL AIR AND MOULD DIMENSIONS FOR CORK AND GRASS DUSTS.

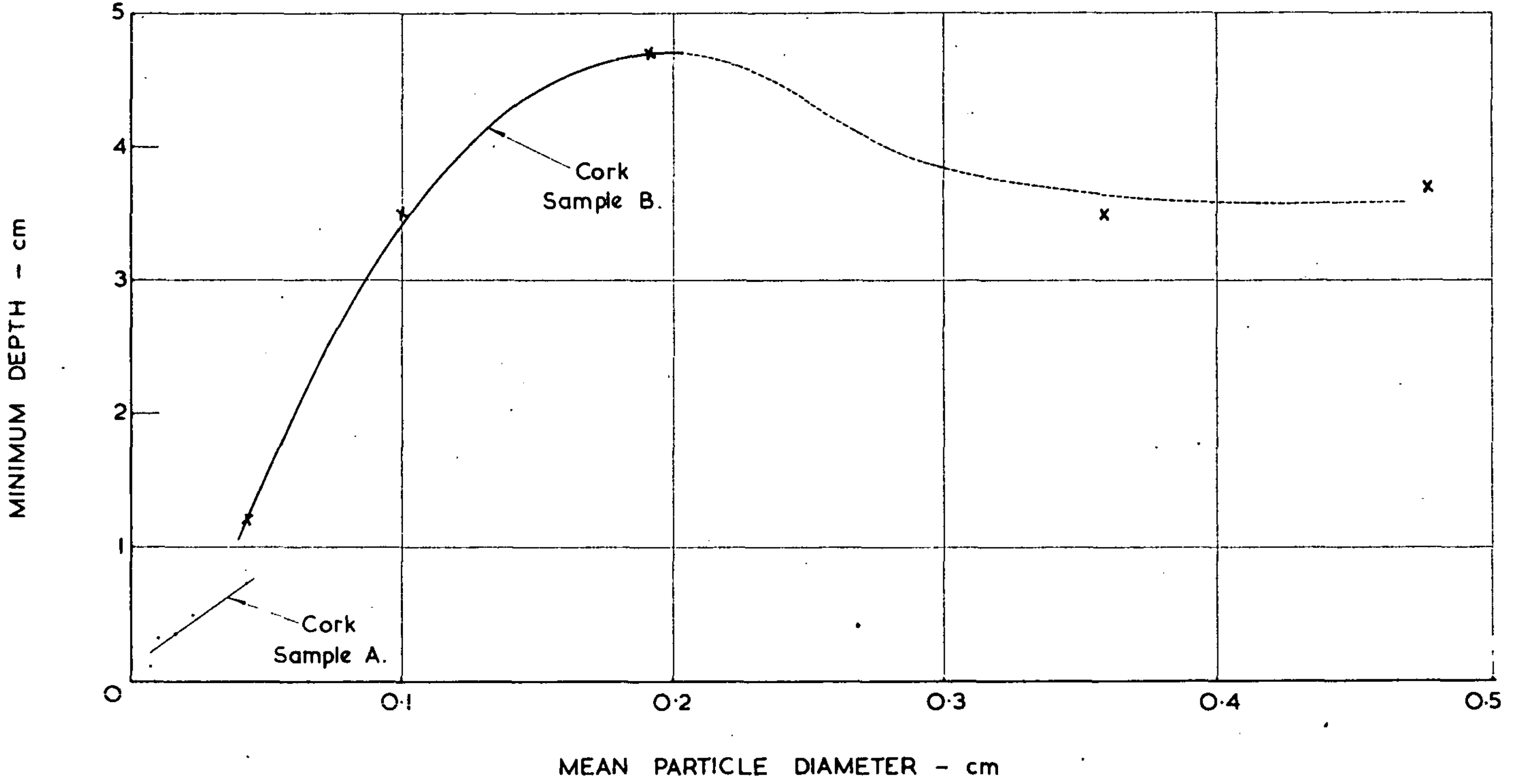


FIG. 7. RELATION BETWEEN PARTICLE DIAMETER AND MINIMUM DEPTH OF TRAIN FOR SUSTAINED SMOULDERING IN STILL AIR.

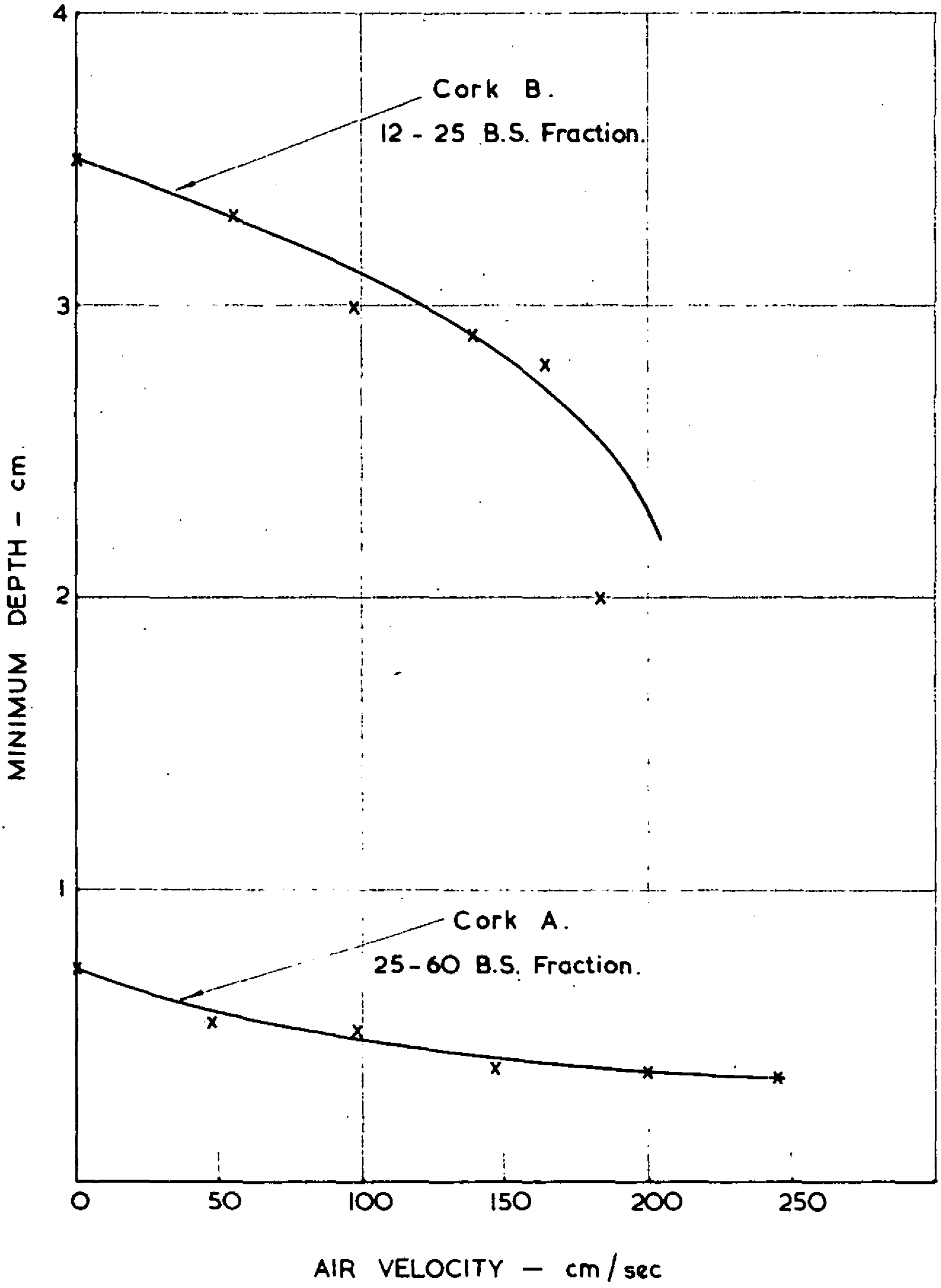


FIG. 8. EFFECT OF AIRFLOW ON THE MINIMUM DEPTH FOR SUSTAINED SMOULDERING.

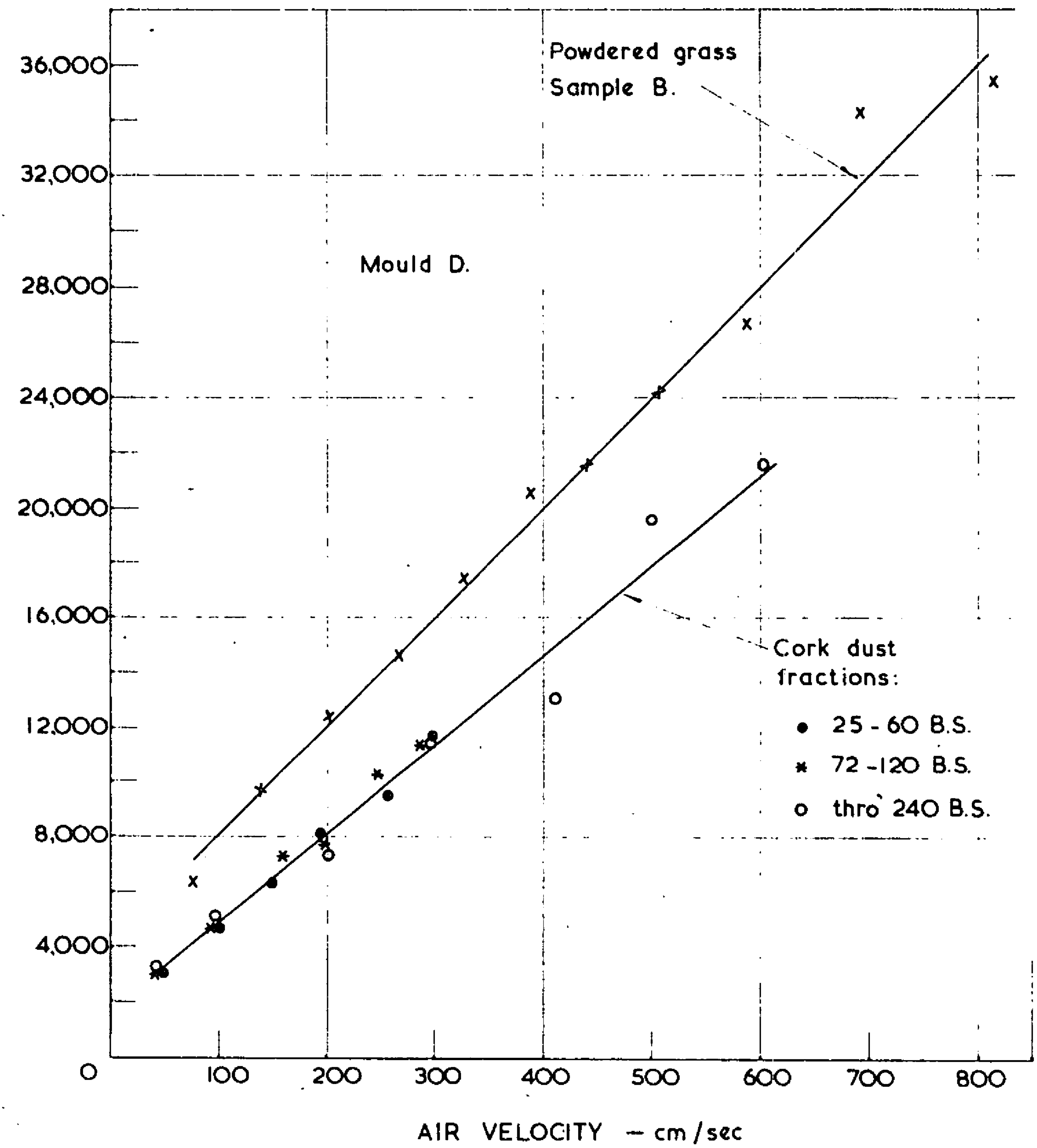


FIG. 9. COMPARISON OF THE RELATION BETWEEN SMOULDERING TIME AND AIR VELOCITY (REVERSE AIR FLOW) FOR CORK DUST FRACTIONS AND POWDERED GRASS.