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SMOULDERING IN DUSTS AND FIBROUS MATERIALS

Part VI Deal sawdust under airflow conditions

by

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Summary

The smouldering of deal sawdust under airflow conditions has been investigated in order to compare its behaviour with that of beech sawdust described earlier. The dust was formed into small trains, placed in a wind tunnel, and measurements made of the effect of variation of airflow upon the smouldering time (i.e. the reciprocal of the linear rate of smouldering) and on the minimum depth of dust layer necessary for sustained smouldering, and the effects of particle size and train size upon the smouldering time. Although these investigations were less extensive than those on beech sawdust, it was concluded that the behaviour of the two dusts was similar. The practical aspects of these results are discussed.

Introduction

This note describes further investigations that have been made on the properties of smouldering in common combustibles; details of earlier work in this series have already been given (1-5). It was found in these earlier experiments (1,2) 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 follow providing the depth of dust layer was above a certain critical value, which in a given dust depended chiefly upon the nature of the dust and its mean particle size. The linear rate at which the smouldering progressed was found to be affected to only a small extent by changes in the size of train, particle size, packing density and moisture content of the dust. Subsequent experiments carried out on the smouldering of beech sawdust under airflow conditions (5) have shown that the rate of smouldering increases rapidly with increasing incident air velocity, and the minimum depth of dust layer necessary for sustained smouldering decreases rapidly with increasing air velocity; approximate logarithmic relationships were found to exist between the smouldering time (i.e. the reciprocal of the linear rate of smouldering) and the air velocity incident upon the combustion zone, and between the minimum depth and the air velocity.

The investigations described in this present note, which included the effects of airflow, particle size and train size upon smouldering time, and the variation of minimum depth with airflow were made in order to find out whether the behaviour of deal sawdust smouldering under airflow conditions was similar to that observed previously for beech sawdust (5). The reasons why beech sawdust was chosen as a standard have already been given (1); the comparisons between beech and deal sawdust smouldering in still air and under airflow conditions have been made because of the differences in the hardness and resin content of the two woods.

In the appendix to this note an account is given of some experiments which were carried out on the spread of smouldering from deal sawdust to certain other common combustibles and the subsequent production of flame.

Experiments and results

Materials

The deal sawdust used in these experiments was taken from the same samples as those used in the earlier work carried out in still air; details of moisture contents and mean particle diameters of the two sieve fractions have already been given (1).

Procedure

The apparatus and experimental procedure were similar to that used in the earlier corresponding work on beech sawdust. Deal sawdust trains, which had previously been turned out onto thin strips of asbestos mill-board from small metal moulds, were supported centrally in the combustion chamber of a wind tunnel by a metal bridge, and smouldering was then initiated by a small gas flame. In all the experiments the trains were of medium packing density (0.19 - 0.21 g/ml). Some dimensions of the moulds used in the determination of smouldering times are given in Table 1 for reference, further details of these and the wedge moulds used for finding minimum depths are given in the earlier report (1).

TABLE 1

Dimensions of moulds used in the determination of smouldering times

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

Appearance of the trains

At air velocities below about 150 cm/sec the appearance of the trains was similar to that observed in still air; at higher velocities the division between burning and unburnt dust was rendered more distinct by the removal of ash and the exposure of a glowing surface. At air velocities above 350 cm/sec it became difficult to make measurements on the trains because some of the sawdust was blown away and the smouldering front became confined to the lower part of the train (burrowing) and was thus obscured. Burrowing also occurred before extinction when the air velocity was just below that at which smouldering was sustained. No appreciable wandering of the smouldering front was observed in experiments under airflow conditions.

Effect of airflow

The first investigation was concerned with the variation of smouldering time with airflow. For these experiments trains of 25-60 B.S.S. sawdust were formed from mould D. The results obtained are shown in Fig. 1 (upper line) where the smouldering time is plotted on a logarithmic scale against the air velocity. It will be seen that the extrapolation of this graph back to zero air velocity has been made with a dashed line, this convention is used throughout the following graphs to indicate that sustained smouldering occurred under still air conditions. When the smouldering was not sustained the extrapolation to zero air velocity has been made with a dotted line to indicate this difference.

Effect of particle size

The experiments above were repeated using trains of the coarser dust formed from the same mould; the results are shown in Fig. 1 (lower line), which thus provides a comparison of the effect of the two particle sizes. The transition from glowing to flaming occurred with the trains of the 12-25 B.S.S. sawdust fraction at an air velocity of 287 cm/sec and above, after the smouldering front has travelled almost the entire length of the train. A rapid increase in the volume of smoke evolved preceded the flaming, and as the flames were separated from the end of the train by a gap of several centimetres, little scorching of the surface layer of dust occurred.

Effect of train size

Experiments were carried out on trains of both the 12-25 B.S.S. sawdust (moulds D, E) and the 25-60 B.S.S. fraction (moulds B-D); the results obtained are shown in Fig. 2, those for mould D being taken from Fig. 1. The production of flames in trains of the coarser sawdust fraction formed from mould D has already been described, it was again observed in trains of the same dust formed from the larger mould E, but the extent of flaming and the air velocities required differed in the two cases. Thus the transition to flaming when the smouldering front had almost reached the end of the train occurred under a lower air velocity than for trains from mould D (222 cm/sec compared with 287 cm/sec); at higher air velocities in the range 264-340 cm/sec intermittent flaming occurred when the smouldering front had travelled only about half the length of the train. In these latter experiments the temperature of the central region of the smouldering front appeared to increase rapidly, and the extensive carbonization and increase in evolution of smoke produced were soon followed by flaming. When the air velocity was about 266 cm/sec the flames produced played upon the top surfaces of the trains, resulting in widespread surface carbonization and the initiation of smouldering in several new zones. This made further measurements after the flaming had ceased impracticable, thus the smouldering times corresponding to these air velocities were calculated from measurements made over 5 cm lengths of the trains only.

Variation of minimum depth with airflow

This series of experiments was conducted upon the 12-25 B.S.S. sawdust only, the wedge shaped moulds Y and Z being used in the formation of the trains. The results of this investigation are given in Fig. 3 where minimum depth is plotted on a logarithmic scale against air velocity; at air velocities above 260 cm/sec the minimum depth became very small and sufficiently accurate measurements could not be made.

Further investigations on the effects upon smouldering time of moisture content, packing density and airflows opposing the direction of propagation of smouldering were not carried out due to the limited supply of the deal sawdust samples.

Discussion

Effect of airflow

The results in Fig. 1 (upper line) show that the smouldering times of deal sawdust trains decreased with increasing air velocity incident upon them. Moreover there was an approximate logarithmic relationship between incident air velocity (v) and smouldering time (s), which has been found to hold not only for trains of deal sawdust but also for beech sawdust, viz. $\log \left(\frac{s}{s_0} \right) = kv$, where s_0 is the smouldering time at zero air velocity (the intercept on the smouldering time axis) and k is an empirical constant. There was reasonable agreement between the value of the smouldering time obtained experimentally for trains smouldering in still air and the corresponding value of s_0 obtained by extrapolation in Fig. 1 (e.g. 10.6 min/cm and 10.0 min/cm respectively for trains of 25-60 B.S.S. deal sawdust formed from mould D).

Effects of particle and train size

Fig. 1 shows that at any particular incident air velocity trains of the coarser sawdust fraction smouldered the more rapidly, and at any particular value of the smouldering time a greater rate of decrease of smouldering time with increase in air velocity occurred with the coarser fraction. The latter result was also obtained earlier with beech sawdust, but no simple relationships were obtained between particle size and smouldering time. Within the range investigated the effect of train size for deal sawdust was small (fig. 2). The apparent reversal of the effect of train size observed with the coarser dust, and the differences in the values of the intercepts obtained by extrapolation to zero air velocity, are probably not significant because of variations in the positions of the lines due to experimental error.

Transition from smouldering to flaming

It was found earlier (1) that in still air beech and deal sawdust trains would only support transient flaming. Under certain airflow conditions however, flaming occurred in trains of 12-25 B.S.S. deal sawdust; this phenomenon was not observed with beech sawdust. This difference in behaviour may be due to several factors such as the larger mean particle diameter of the deal sawdust (0.0992 cm) compared with that of the coarsest beech sawdust (0.0476 cm), the consequent greater opportunity for circulation of air into the train, and the greater smoke evolution of deal sawdust. Thus in smouldering trains of deal sawdust greater amounts of combustible distillation products would be brought into contact with the glowing combustion zone than with beech, and hence flaming could then be initiated and sustained. The transition from smouldering to flaming in trains of deal sawdust provides a definite fire hazard which is thus in addition to that of a smouldering sawdust train in contact with a covering layer of wood shavings (see appendix).

Variation of minimum depth with airflow

Experiments have shown that the minimum depth necessary for sustained smouldering in a layer of deal sawdust decreased considerably with increase in airflow, and that an approximate logarithmic relation existed between the two quantities (Fig. 3). It has been shown earlier that beech sawdust behaves in a similar manner, but the rate of decrease of minimum depth with increase in air velocity for the 12-25 B.S.S. deal sawdust was greater than that observed in any of the beech sawdust fractions investigated (Table 2).

TABLE 2

A comparison of the effect of airflow on the minimum depths of beech and deal sawdusts

Incident air velocity cm/sec	Minimum depth of 12-25 B.S.S. deal sawdust cm	Minimum depth of 20-40 I.M.M. beech sawdust cm
Still air	2.8	1.3
100	1.1	0.5
200	0.5	0.2

The scatter of results is greater than would be expected from the accuracy of the method used in determining minimum depth, this may be because the cessation of smouldering in a sawdust train is susceptible to chance local variations in the train.

Practical aspects

The work described in this report has shown that even under relatively slight airflows, as may easily be encountered in draughty buildings, the transition from glowing to flaming combustion can occur both in a layer of combustible material covering a smouldering train of deal sawdust and at slightly greater air velocities in such a train on its own. In addition, the minimum depth of deal sawdust is less than 1 cm under an airflow of 3 m.p.h. It can thus be seen that the fire hazard presented by deal sawdust are comparable with those of beech sawdust described previously.

Conclusions

The main points arising from the results are:

1. The behaviour of beech sawdust and deal sawdust smouldering under airflow conditions is similar.

2. The effect of airflow upon smouldering time is greater than other factors investigated. Smouldering time decreases approximately logarithmically with increasing air velocity.

3. The minimum depth of dust layer necessary to sustain smouldering is reduced with incident air velocity. The relation between minimum depth and air velocity is approximately logarithmic.

4. The fire hazards presented by the two dusts are comparable. Thus even under low air velocities flaming is produced in wood shavings which are in contact with a smouldering train of either dust. In addition, under certain conditions flaming may also be produced in trains of deal sawdust alone.

References

1. F. R. Note No. 6/1952
2. F. R. Note No. 11/1952
3. F. R. Note No. 24/1952
4. F. R. Note No. 27/1952
5. F. R. Note No. 48/1952

Appendix

Some preliminary experiments were carried out on the spread of smouldering under airflow conditions from deal sawdust to deal wood shavings and newspaper, and the subsequent production of flames. The experimental procedure was the same as that employed earlier (5), in which all but about 6 cm of a sawdust train was covered by a layer of combustible material. Smouldering was then initiated at the exposed end of the train and a stop watch started after the smouldering front had progressed about 2 cm, the times taken for a further 3 cm of the train to smoulder and for the first appearance of flames were recorded. The results are given below (Table 3).

TABLE 3

Details of experiments in which deal sawdust trains were partly covered by layers of other combustible materials.

Mould	Train material	Layer material	Air velocity cm/sec	Time for 3 cm of train to smoulder min	Time for flaming min
C	25-60 B.S.S. deal sawdust	Deal wood shavings	~~250~~ 218	12	22
D	" "	" "	~~83~~ 71	25	48
D	" "	Newspaper	~~82~~ 70	21	-
D	" "	" "	~~102~~ 88	not recorded	-

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

As with the corresponding experiments on beech sawdust flames were obtained with wood shavings at a low air velocity (< 2 m.p.h.). Although flames were not produced in the experiments with newspaper, a widespread glowing of the paper occurred with the evolution of large volumes of smoke; this in itself presents a fire hazard, and it is probable that flaming would have occurred if the amount or distribution of the paper had been changed, but further investigations are necessary.

NOTE

Since this report was produced a systematic error has been discovered in the measurement of the air velocity incident upon the trains. In consequence the values of air velocity shown in Figs 1-3 are too large by a constant factor; corrected values are given below.

Air velocity shown cm/sec	40	80	120	160	200	240	280	320	360	400	440	480
Corrected air velocity cm/sec	35	70	105	140	175	210	245	280	315	350	385	420

KNP/MDP/VHM

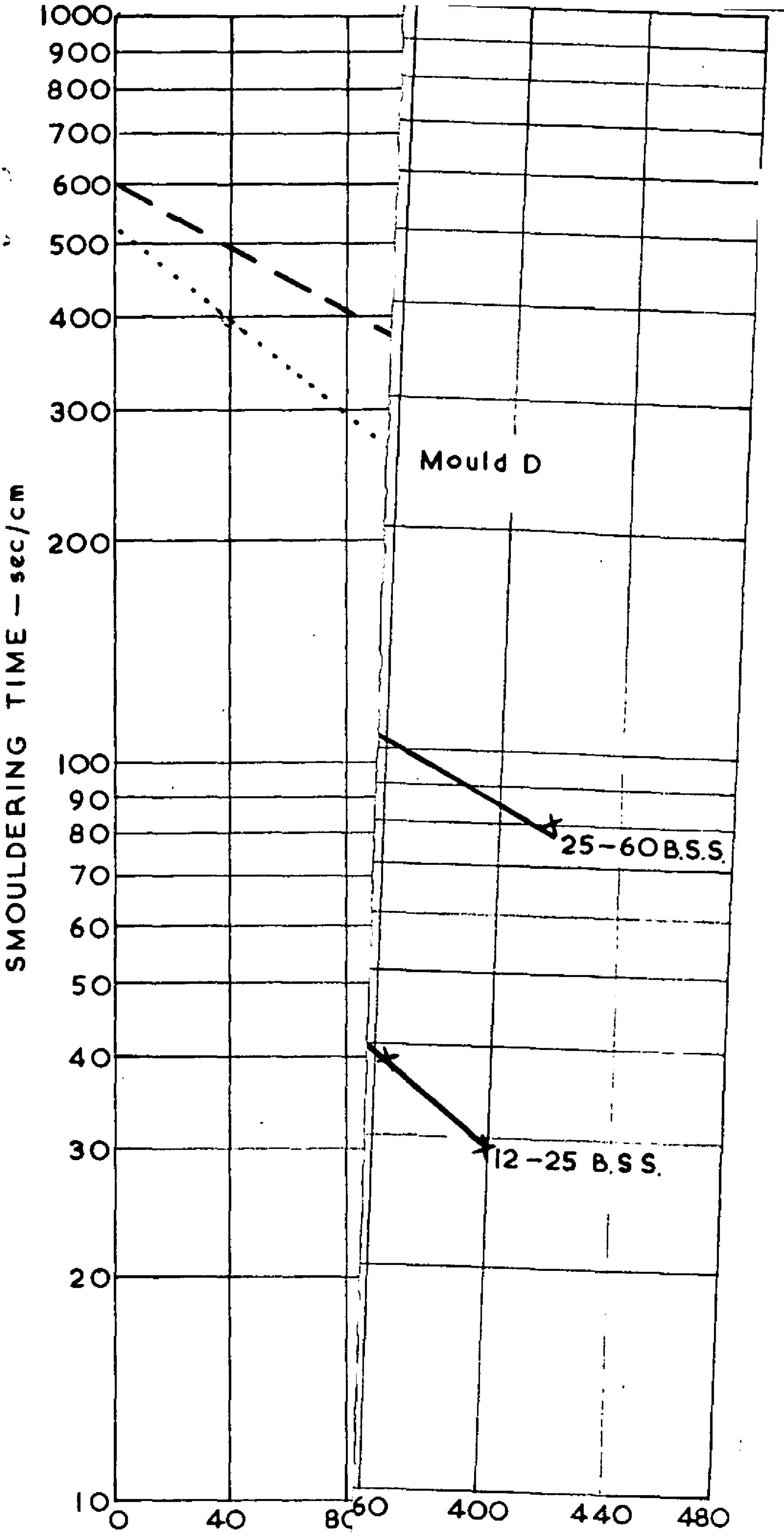

Fig. 2

THE EFFECT OF PA OULDERING TIME

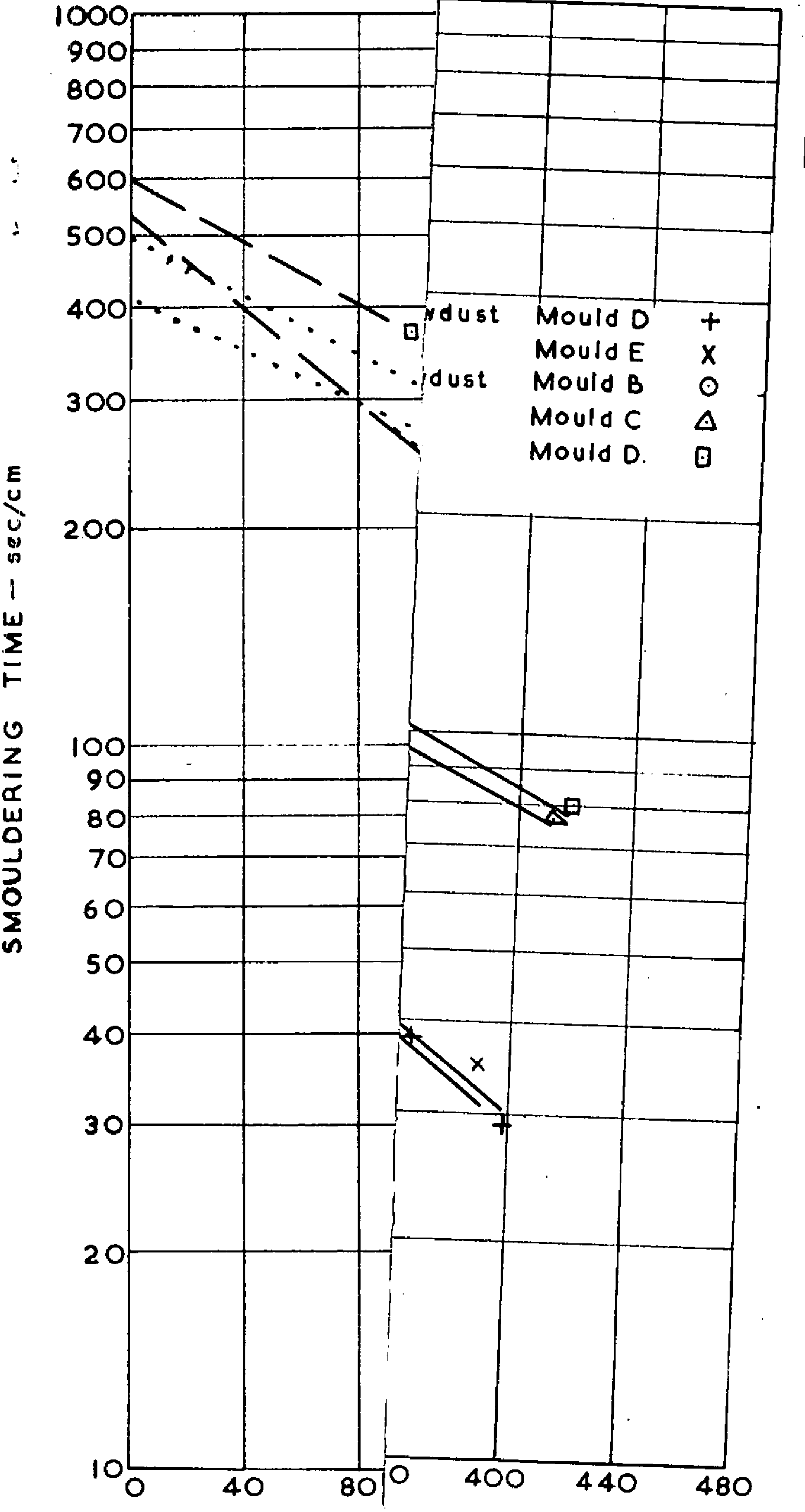

Fig. 1

THE EFFECT OF T OULDERING TIME

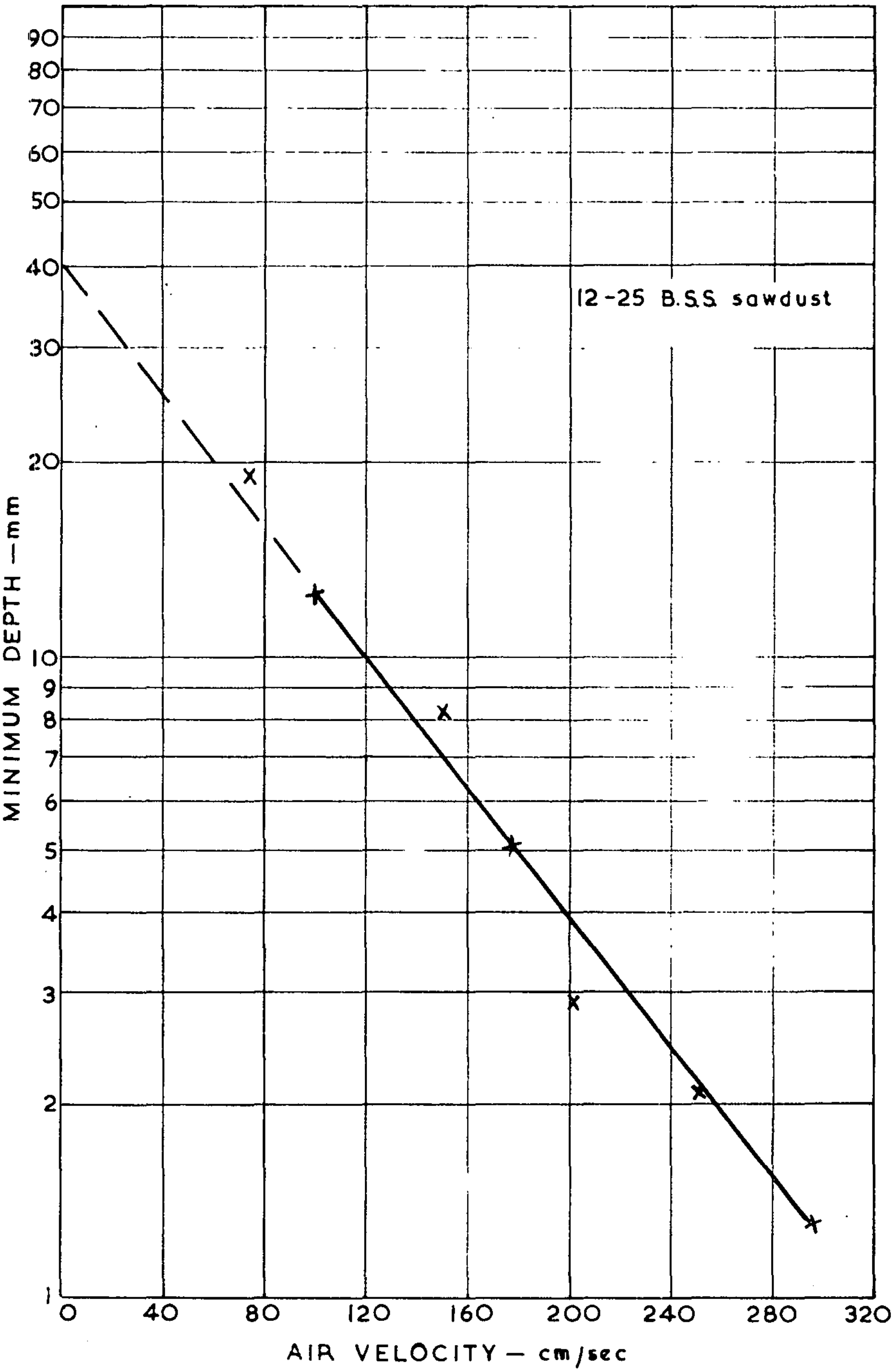

FIG. 3. THE VARIATION OF MINIMUM DEPTH FOR SUSTAINED SMOULDERING WITH INCIDENT AIR VELOCITY