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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
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THE IGNITION OF DUSTS IN CONTACT WITH HOT SURFACES

by

K. N. Palmer and P. S. Tonkin

Summary

The minimum surface temperatures for the ignition of several dusts, including tea fluff, have been determined for layers on a thermostatically controlled boiling plate.

It has been ascertained that increase in the depth of the dust layer and decrease in the particle size of the dust lower the surface temperature required for ignition.

Preheating tea fluff at 93·3°C (200°F) for 32 days lowered the surface temperature required for ignition. After the initial lowering of the temperature there was no tendency for further reduction as the preheating period increased.

Tea fluff which had not been preheated was ignited by friction sparks from an ordinary flint gas lighter.

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Introduction

Increased availability of electricity for tea factories in Ceylon has encouraged the use of electrical heater units to supply hot air for drying tea in withering lofts. During this operation a dust, known as tea fluff, is released into the atmosphere. The possibility that this dust might constitute a fire hazard when in contact with hot surfaces has been examined experimentally at the request of the Fire Offices' Committee.

Other dusts namely cork dust, mixed hardwood sawdust and coal dust were also examined in order that tea fluff could be compared with them under the same conditions and also, being available in larger quantities, they allowed a more comprehensive investigation than could have been carried out with the fluff alone. In addition it was considered that the inclusion of sawdust was of special interest in view of the decomposition and alleged consequent ignition of wood when in contact with surfaces at moderate temperatures, such as steam pipes, for prolonged periods(1).

The enquiry requested that the following three determinations be made:-

(a) the ignition temperature of tea fluff;

(b) the maximum safe temperature to which tea fluff can be heated for a prolonged period without risk of ignition;

(c) the effect on the ignition temperature of prolonged heating of fluff at a temperature of 93·3°C (200°F).

As ignition temperatures determined by experiment depend, to a large extent, upon the apparatus used it has not yet been possible to define ignition temperature solely in terms of physical properties. In the present investigation two distinct methods were used, one of which involved contact of the dust with a hot surface maintained at a constant temperature and the other was a rising temperature method originally described by Brown(2).

Experimental

Materials

The materials used in the experiments are listed in Table I together with relevant physical properties.

Table I

Materials used in the experiments

Dust	Particle size (cm)	Packing Density g/ml*	Moisture content per cent by weight of original material
Cork (0·48 cm - 0·24 cm)	0·38	0·07	4·2
" (25 - 60 B.S.S.)	0·043	0·08	6·7
" ("Through" 240 B.S.S.)	0·0065	0·17	8·8
Mixed hardwood sawdust	Unsieved	0·20	-
Carbonised hardwood sawdust	Unsieved	0·20	-
Coal dust, Dalton Main ("Through" 200 I.M.M.)	0·0063	0·47	-
Tea fluff	Unsieved	0·18	8·3

* Packing density of the undried material

The moisture content of the dusts was determined by heating a known weight at 105°C until a constant weight was obtained.

The mixed hardwood sawdust was taken from the same consignment as that used for earlier experiments on smouldering. A sizing analysis has been carried out and recorded elsewhere (4). The carbonised hardwood sawdust was obtained from smouldering tests (4).

The small tea fluff particles agglomerated to form larger particles, spherical in shape, and these tended to form clusters. Consequently, sieving was not possible.

Apparatus

The apparatus used for the determination of the ignition temperature of tea fluff by the "rising temperature" method is described elsewhere (3).

The experiments for determining ignition temperatures of the dusts in contact with a hot surface were carried out using a one kilowatt electric boiling plate, the temperature of which was thermostatically controlled and with which temperatures up to 394 °C could be obtained. The plate was of cast iron 19•1 cm in diameter and 1•27 cm thick. The circuit for the control of the plate temperature is shown in Figure 1. With this circuit it was possible to maintain the temperature of the plate within a narrow range about a chosen value irrespective of whether the plate was covered or not. This range did not exceed ± 4°C and its magnitude was mainly determined by the thermal lag in the operation of the relay switch.

The layers were formed from metal moulds and were of the following shapes and dimensions:-

(1) a frustrum of a cone, small diameter 3•5 cm, large diameter 9 cm, height 2•5 cm

(2) a frustrum of a cone, small diameter 7•5 cm, large diameter 17•8 cm, height 5•0 cm

(3) a cylinder, diameter 17•9 cm, for experiments involving changes in layer depth over a wide range.

Distribution of temperature over the surface of the boiling plate

Preliminary experiments were carried out with the heater connected directly to the mains electricity supply to determine the temperature distribution over the surface of the plate.

When the plate had reached thermal equilibrium with the atmosphere the surface temperature was measured by means of a thermocouple probe. This consisted of a 36 S.W.G. chromel-alumel thermocouple to which a small square of copper foil had been soldered. The copper foil ensured good thermal contact.

The temperature distribution over the surface of the plate was as shown in Figure 2, and was considered satisfactory for the series of experiments carried out. The low value at the plate centre was due to the plate being secured to the body of the appliance at that point.

Procedure

The plate was heated to the temperature required for the experiment and the calculated amount of dust required for a given packing density was weighed out and then placed on the plate using the appropriate mould to form a layer having the required depth. Except in cases where the cylinder was used, the shape of the layers permitted the moulds to be withdrawn after formation on the plate.

The time between depositing the layer on the plate and the appearance of smouldering at its outer surface was recorded. For each dust and after each ignition the temperature of the hotplate was lowered by 10°C until a temperature was reached at which ignition did not take place when the layer was heated for a prolonged period, usually of several hours.

The effect of particle size was investigated using three sieve fractions of cork dust and the effect of thickness of layer upon the minimum surface temperature for ignition was studied using mixed hardwood sawdust. The layers of sawdust were formed by means of the cylindrical mould. These tests were often of long duration, some continuing through the night. In those cases a 26 S.W.G. chromel-alumel thermocouple was placed in contact with the centre of the top surface of the layer and connected to a temperature recorder. The time taken for smouldering to emerge was then measured automatically.

The effect of preheating on the ignition temperature of tea fluff was investigated using fluff that had been heated at 93•3°C (200°F) in a thermostatically controlled oven (± 0•5°C).

The action of friction sparks upon the original tea fluff was ascertained. The sparks were made using an ordinary flint gas lighter.

Results

The ignition temperature of tea fluff obtained by the rising temperature method was 237°C. The temperature of the specimen overtook that of the furnace at 268•5°C (crossing point), and the temperature at which exothermic reaction first occurred was 173°C (Brown's point).

The results obtained from the experiments with the hotplate are given in Tables II, III and IV.

The original tea fluff could be ignited with sparks and smouldering was sustained.

Table II

Minimum temperatures for the ignition of dusts

Dust	Minimum surface temperature for ignition °C. Depth of layer 2•5 cm	Minimum surface temperature for ignition °C. Depth of layer 5•0 cm
Tea fluff	260	230
Mixed hardwood sawdust	270	240
Carbonised sawdust	240	-
Cork dust 0•38 cm diameter	320	260
" " 0•043 cm "	280	-
" " 0•0065 cm "	260	-
Coal dust (Dalton Main)	210	-

Table III

The effect of variation in depth of layer on the ignition temperature of mixed hardwood sawdust

Depth of layer cm	Minimum surface temperature for ignition °C	Time for emergence of smouldering	
		Hours	Minutes
2·5	270	-	51
5·0	240	3	37
7·5	230	6	57
10·0	230	7	30
12·5	*220 or less	13	46

*The sawdust layer 12·5 cm in depth was not tested at plate temperatures below 220°C.

Table IV

The effect of preheating on the ignition temperature of tea fluff. Depth of layer 2·5 cm

Duration of preheating at 93·3°C Days	Minimum surface temperature for ignition °C
0	260
32	250
60	250
91	250

Discussion

When applying values obtained for the ignition temperatures of dusts both the method of determination and the conditions of the particular problem, to which they are applied must be considered.

The significance of results obtained by the "rising temperature" method has been previously investigated and discussed (3). In the case of tea fluff the "rising temperature" method was used to ascertain the type of material with which the fluff could be compared. The apparatus produced none of the conditions associated with the problem from which the present investigation arose. It was shown, however, that the ignition temperature of tea fluff was similar to that of other dusts of vegetable origin such as beech sawdust (243°C) and grass dust (233°C).

The hot surface method, however, embodied a source of heat similar to that which had been contemplated for use in the drying of tea in Ceylon. The results obtained by this method may be applied to problems arising from such installations. It should be borne in mind, however, that the ignition temperatures obtained from such a series of experiments do not necessarily represent the lowest values possible under factory conditions.

The values obtained for minimum surface temperatures for ignition showed that although the temperatures varied among the dusts used, tea fluff could be classed with these dusts as a fire hazard when in contact with hot surfaces.

Variation in particle size, using cork dusts, showed that the surface temperature for ignition decreased with decrease in particle size.

The investigation of the effect of depth of dust layer upon the minimum surface temperature for the ignition of mixed hardwood sawdust, showed that the temperature decreased with increased depth and the time for smouldering to emerge from the layers was correspondingly longer. These results were similar in trend to those obtained at the Safety in Mines Research Establishment, Buxton, during a study of surface temperatures necessary to start smouldering in layers of coal dust, except that ignition was obtained at lower temperatures and only layers up to 6 cm in depth were reported(5).

Compared with previous smouldering experiments (4) on similar dusts the time taken for burning to emerge from the layers, after placing them on a hotplate was longer than when the dusts were ignited and allowed to smoulder without the application of an external heat supply. This difference in time would depend on the period between deposition on the plate and actual ignition of the dust.

The times, for comparison, listed in Table V are the approximate times for smouldering to emerge from layers of mixed hardwood sawdust after deposition on a boiling plate, and also after initial ignition with a gas flame with no further application of heat. The values for the layers ignited with a gas flame were taken from the graph obtained from the previous work on smouldering (4).

Table V

Comparison of times for smouldering to emerge from layers of mixed hardwood sawdust

Depth of layer	Approximate time for emergence of smouldering (h)	
cm	On boiling plate	After ignition with gas flame
5·0	3·5	1·3
7·5	7·0	2·8
10·0	7·5	4·8
12·5	13·8	7·5

When the layer depth of mixed hardwood sawdust was increased and when the mixed hardwood sawdust had been carbonised the consequent decreases in the surface temperature for ignition were not considered great enough to support the suggestion that wood in contact with surfaces at moderate temperatures, for long periods, would ignite(1). That possibility, however, is a matter for further investigation.

Preheating of tea fluff for 32 days lowered the minimum surface temperature for ignition. A similar effect had been obtained with wood sawdust preheated at 130°C (6). Preheating of tea fluff for an additional period of 59 days did not, however, cause a further reduction in the minimum surface temperature required for its ignition.

The results indicated that conditions could be obtained by which the surface temperature for the ignition of tea fluff would be reduced. Separation of fine dust particles, which may be expected to occur naturally when the fluff was disturbed, and the effect of preheating could cause the reduction. The surface temperature for ignition, however, would probably not be reduced below 200°C provided that the dust deposit did not exceed 12·5 cm in depth. The temperature of the hot surfaces used should never exceed 200°C. The insulating effect of layers on hot surfaces must be considered and the normal working temperature should be considerably below 200°C to ensure an adequate safety margin. This, together with a good standard of cleanliness in the withering lofts would considerably reduce the risk of fire.

The fact that tea fluff in the undried state was ignited by sparks emphasized the need for care in the installation of machinery which could, under factory conditions, produce sparks or friction heating.

Conclusions

(1) The ignition temperature of tea fluff was not abnormally low and this material could be classed with certain other dusts of vegetable origin as a fire hazard when in contact with hot surfaces.

(2) Increased depth of dust layers and decreases in particle size caused reductions in the surface temperatures for ignition.

(3) Preheating of tea fluff reduced the surface temperature required for its ignition. Continued preheating did not cause further lowering of this temperature.

(4) Electrical heater units could be used for supplying hot air for the drying of tea, providing a working temperature somewhat below 200°C were used and a good standard of factory cleanliness maintained.

(5) Tea fluff in its original state was ignited by friction sparks.

Acknowledgments

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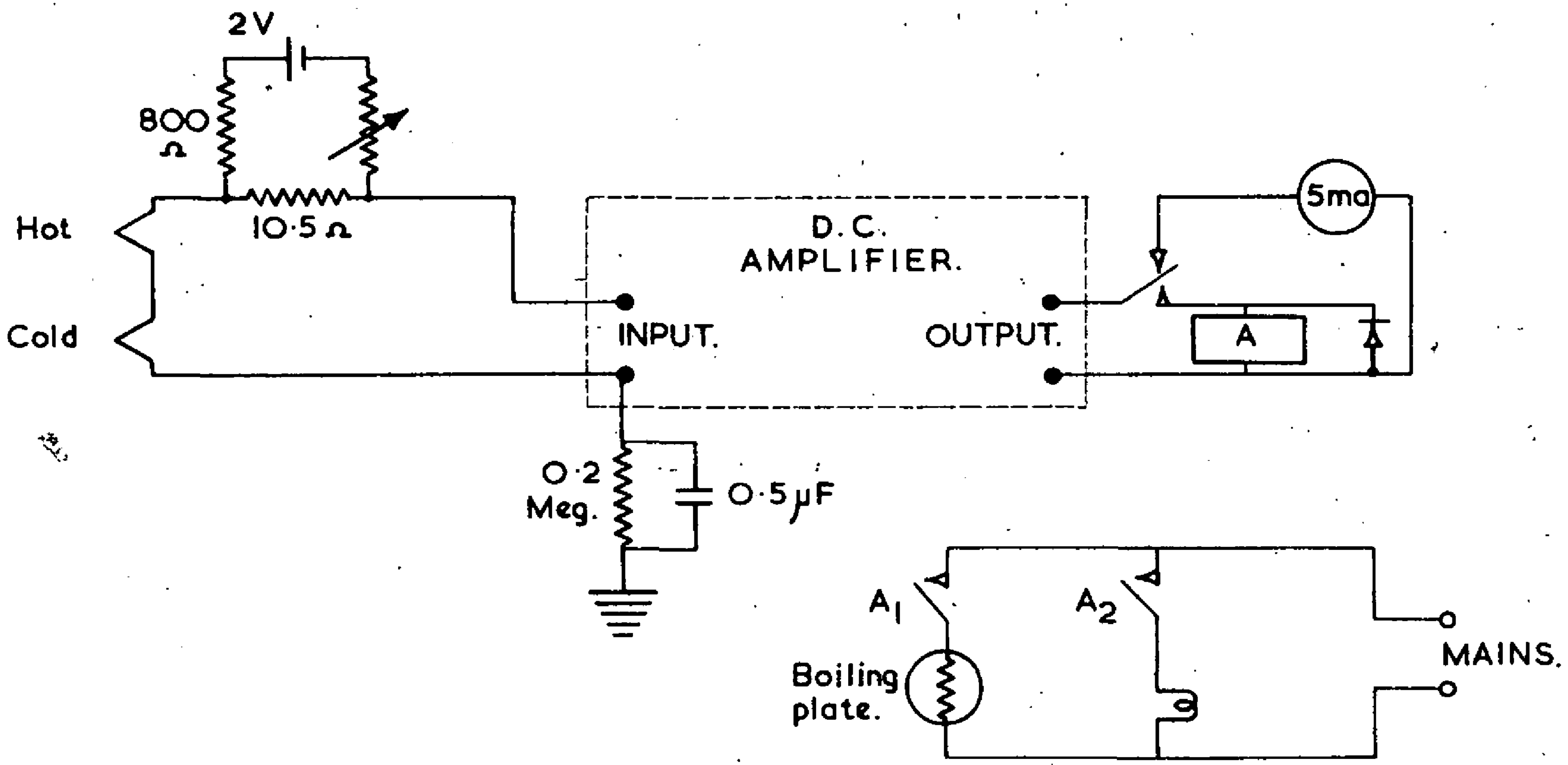

FIG. 1. CIRCUIT OF TEMPERATURE CONTROL UNIT FOR BOILING PLATE.

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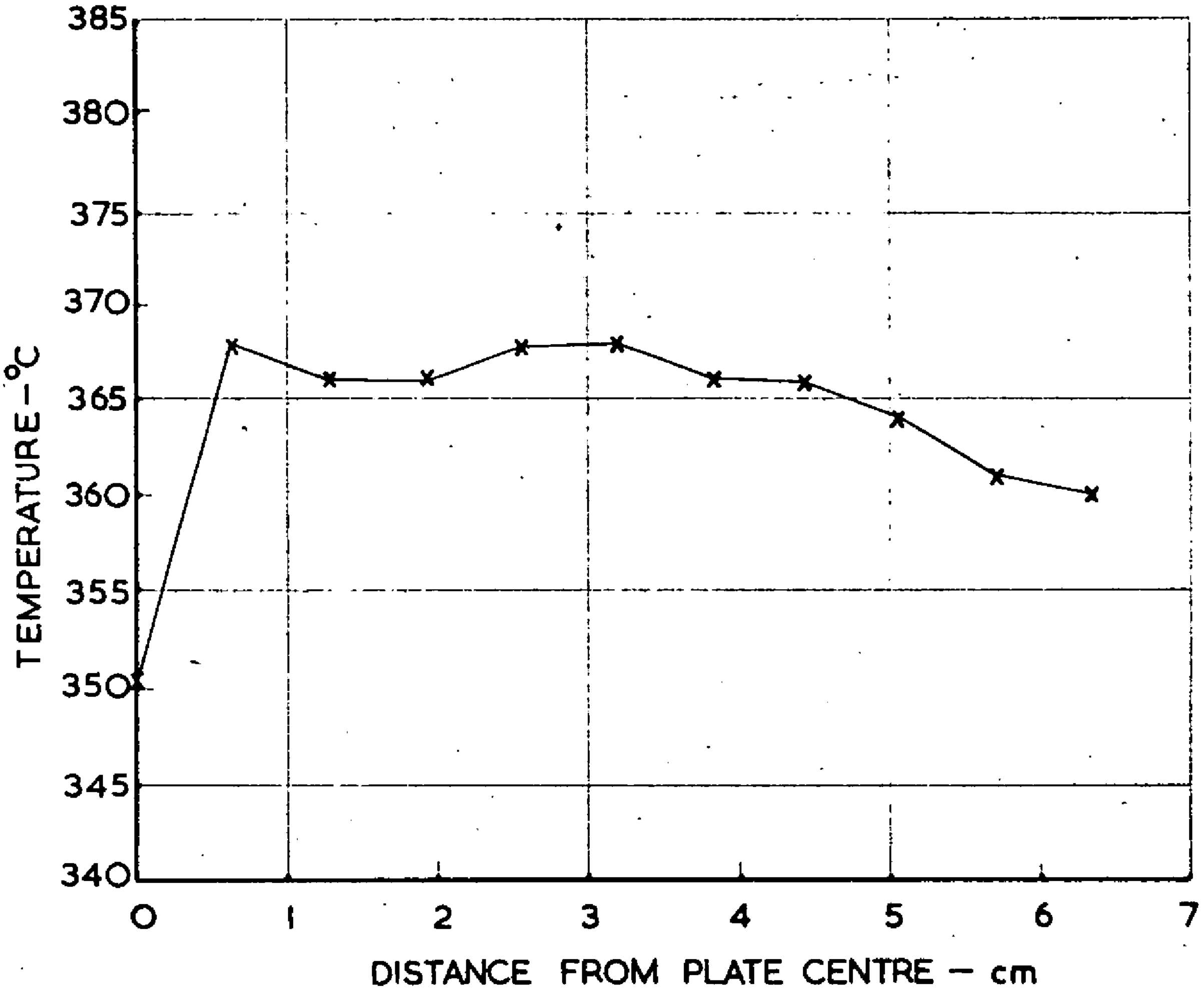

FIG. 2. TEMPERATURE DISTRIBUTION OVER THE SURFACE OF THE BOILING PLATE.