CONFIDENTIAL

F.R. Note No. 74/1953
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 VIII - JUTE CLOTH UNDER AIRFLOW CONDITIONS

by

K. N. Palmer

Summary

The effect of an air draught upon the smouldering of jute cloth has been investigated; the rate of propagation of smouldering is markedly increased by an airflow and smouldering may be converted into flaming by airflows travelling at less than 1½ m.p.h. The sequence of events from the initiation of smouldering by a cigarette end to the development of fire has been traced, thus demonstrating the fire hazard associated with the general industrial use of ordinary jute sacks, unless stringent precautions are taken to ensure the absence of sources of ignition.

August, 1953.

Fire Research Station,
Boreham Wood,
Herts.

SMOULDERING IN DUSTS AND FIBROUS MATERIALS
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Introduction

Experiments upon the smouldering of jute cloth in still air have been the subject of an earlier Note (1). It was shown that the rate of propagation of smouldering in still air depended upon several factors such as the weight and weave of the cloth, the condition of the material (new, worn or soiled), the direction of propagation of smouldering relative to the weave, whether the propagation was horizontal or vertical, and the number of layers in contact. Further, sustained smouldering was found to be easily initiated by a small source of ignition, such as a glowing cigarette end.

These results have a practical importance owing to the general industrial use of jute sacking and the possibility of a smouldering fire being started in this material by a dropped light. This process is of particular interest in the consideration of fires in stacks of bagged materials when there may be a long delay between the probable time of ignition and the visible outbreak. It was concluded from the experiments in still air that smouldering could easily continue within a large stack of bagged materials for several days.

The experiments described in the present Note were concerned with the estimation of the air draught required to convert smouldering into flaming, in addition to the effect of airflow upon the rate of propagation of smouldering. The cloth was investigated both in a new condition, as received from the manufacturers, and in "worn" conditions produced artificially. In all experiments the propagation of smouldering was in a horizontal direction.

Experiments and results

Materials The samples of cloth used in the present experiments were taken from the same specimens as in the earlier work under still air conditions. (1) The characteristics of the cloths are given again for reference.

Table 1

Details of the jute cloths, in the condition as received

Cloth	I	II	III
Weave	Twill	Twill	Scrim
Weight per unit area gm/cm^2	0·077	0·044	0·016
No. of warp threads (ends) per inch	38	27	10
No. of weft threads (picks) per inch	12	10	15
Thickness mm	1·20	0·67	0·66
Moisture content %	9·4	8·8	9·5

Cloth I, the heaviest, was very closely woven but was not as thick as some of the coarsest types of sacking in common use; cloth III had a very open weave and was typical of the lightest material. Cloth II was of intermediate weight and weave.

As with the earlier experiments the simulation of wearing of the new cloth was carried out either by washing the cloth in boiling water, to expand the threads and loosen the weave, or by stroking the cloth with a small wire brush to raise a nap. The detailed procedures have already been described. (1)

Smouldering rates The effect of airflow upon the rate of propagation of smouldering was investigated using Cloth I in its original state, without treatment; the material was cut into rectangular pieces and clamped in a metal support of width 13·5 cm (Plates 1 and 2). Six layers of cloth were used and were arranged so that smouldering propagated parallel to the weft threads. Smouldering was initiated by a small gas flame and the support and cloth were then placed in a wind tunnel 13 in. x 13 in. cross section and 29 ft. in length; the time for the smouldering zone to travel 1 cm (smouldering time) was then measured over a distance of 10 cm.

The results are given in Fig. 1 where smouldering time and air velocity are plotted on linear axes. Measurements of smouldering time could not be made for air velocities above 252 cm/sec as the smouldering was transformed into flaming on application of the draught.

Airflow for production of flaming Two series of experiments were carried out on the conversion of smouldering into flaming by the action of an air draught. In the first series the cloth specimens were clamped in the metal support as for the determination of smouldering rates and the air velocity was increased in steps of about 50 cm/sec until flaming occurred; this series enabled direct comparisons to be made of the effects of weight and condition of the cloths. By this method the air velocity for the transition from smouldering to flaming was thus estimated to within a range of about 50 cm/sec; the results are given in Table 2.

Table 2

The transition from smouldering to flaming. Cloth specimens in metal support.

Cloth	Condition	Air velocities between which flaming first occurred cm/sec	
		2 layers cloth	6 layers cloth
I	As received	160 - 205	195 - 250
	Washed	105 - 170	165 - 200
	Brushed	200 - 290	160 - 200
II	As received	62 - 105	155 - 200
III	As received	---	62 - 105
	Washed	---	62 - 105
	Brushed	---	62 - 105

44·7 cm/sec = 1 m.p.h.

In no case did only one layer of cloth sustain smouldering.

The second series of experiments upon the transition from smouldering to flaming was carried out with the cloth rolled into a small bundle within which a glowing cigarette end was placed. Smouldering could thus be initiated within the bundle and the transition to flaming then occurred with lower air velocities than in the first series of experiments. The procedure was to take several strips of cloth, each about 25 cm x 75 cm, and form them into a loose cylindrical roll, about 10 cm in diameter, which was laid in the wind tunnel; a glowing cigarette end was then placed within the roll. Photographs from a demonstration experiment, upon untreated cloth III, are shown in Plate 3. The time was measured from the moment of insertion of the igniting source to the first appearance of flame; the results are given below.

Table 3

The transition from smouldering to flaming. Cloth specimens rolled.

Cloth	Condition	Approximate air velocity cm/sec	Time required for flaming min
I	As received	100 60	19 n.s.
	Washed	160 100 60	23 18 s.n.f.
	Brushed	160 100	14 31
III	As received Washed Brushed	60 60 60	11 20 16

44·7 cm/sec = 1 m.p.h.

NOTES: n.s. smouldering not sustained.
s.n.f. smouldering sustained but did not develop into flaming.

Discussion

The results given in Fig. 1 for the relation between air velocity and smouldering time show that the effect of airflow upon the smouldering is very marked even at low velocities. At air velocities above 252 cm/sec the combustion rate was so increased that the smouldering developed into flaming, thus limiting the air velocity range to be investigated. Some scatter of the results was to be expected owing to non-uniformity in the cloth and also to separation of the cloth layers caused by the air flow, particularly at the higher velocities, and a detailed investigation of the effect of airflow upon the rate of smouldering was therefore not undertaken.

The first series of experiments upon the transition from smouldering to flaming, carried out with the cloth clamped in the metal support, showed that the air velocity required was only slightly affected by variation in the condition of the cloth but decreased with the weight and number of layers of the cloth in contact. However, in no case did only one layer of cloth sustain smouldering; this may not be of great importance from the practical viewpoint since increased thickness of cloth is present in folds and seams and two layers of material are in contact when bags are stacked together.

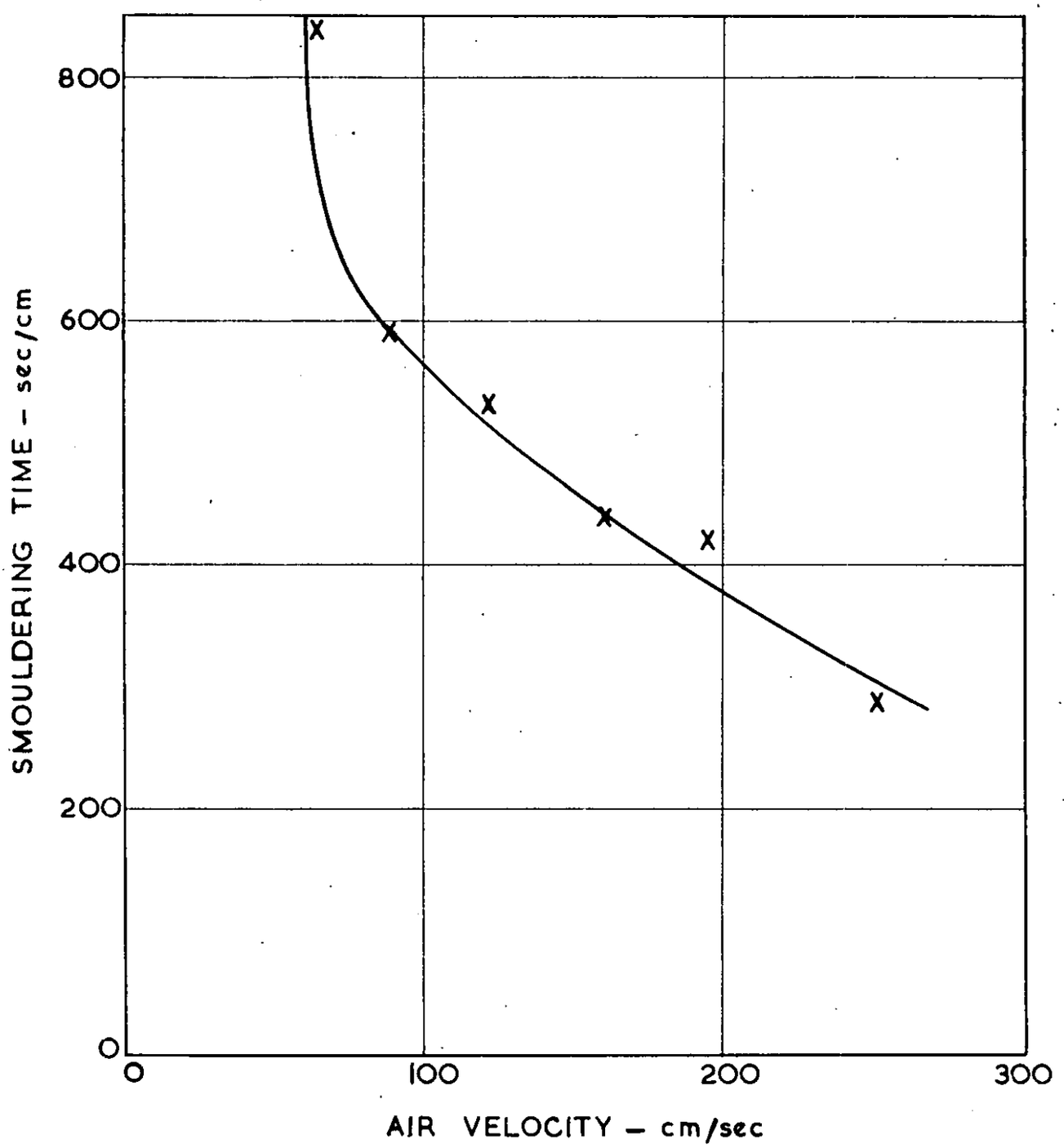
When the cloth was formed into a roll and smouldering initiated internally, as in the second series of experiments, the air velocity required for flaming was reduced appreciably with the heavy cloth (Cloth I). The variations in the times required for flaming to develop, Table 3, are not significant but the values given indicate an appreciable delay between the burning-out of the cigarette end (about 5 minutes) and the appearance of flame. These experiments show the complete sequence of events from the cigarette end coming into contact with the sacking to the production of flame, a sequence which may easily occur in industrial premises. In particular, the air velocity needed to convert smouldering into flaming is shown to be remarkably small, less than $1\frac{1}{2}$ m.p.h., and this emphasizes the fire hazard associated with the use of ordinary jute sacks unless particular care is taken to exclude all possible sources of ignition.

Acknowledgment

Mr. M. D. Perry assisted with the experimental work.

Reference

1. F.R. Note No. 27/1952.



Cloth I-6 layers in contact

Support C - smouldering parallel to weft

FIG.1. EFFECT OF AIRFLOW UPON THE SMOULDERING TIME OF JUTE CLOTH

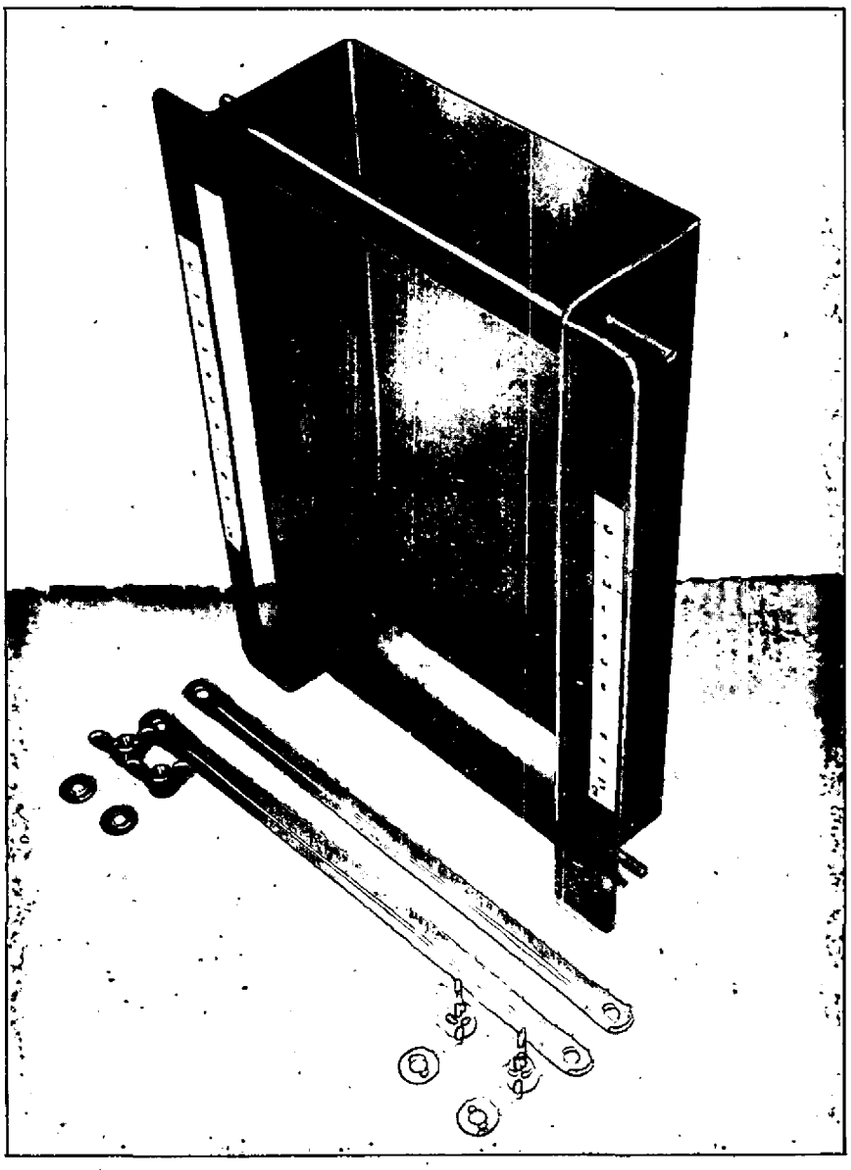


PLATE. I. SUPPORT FOR JUTE CLOTH
SHOWING CLAMPING BARS

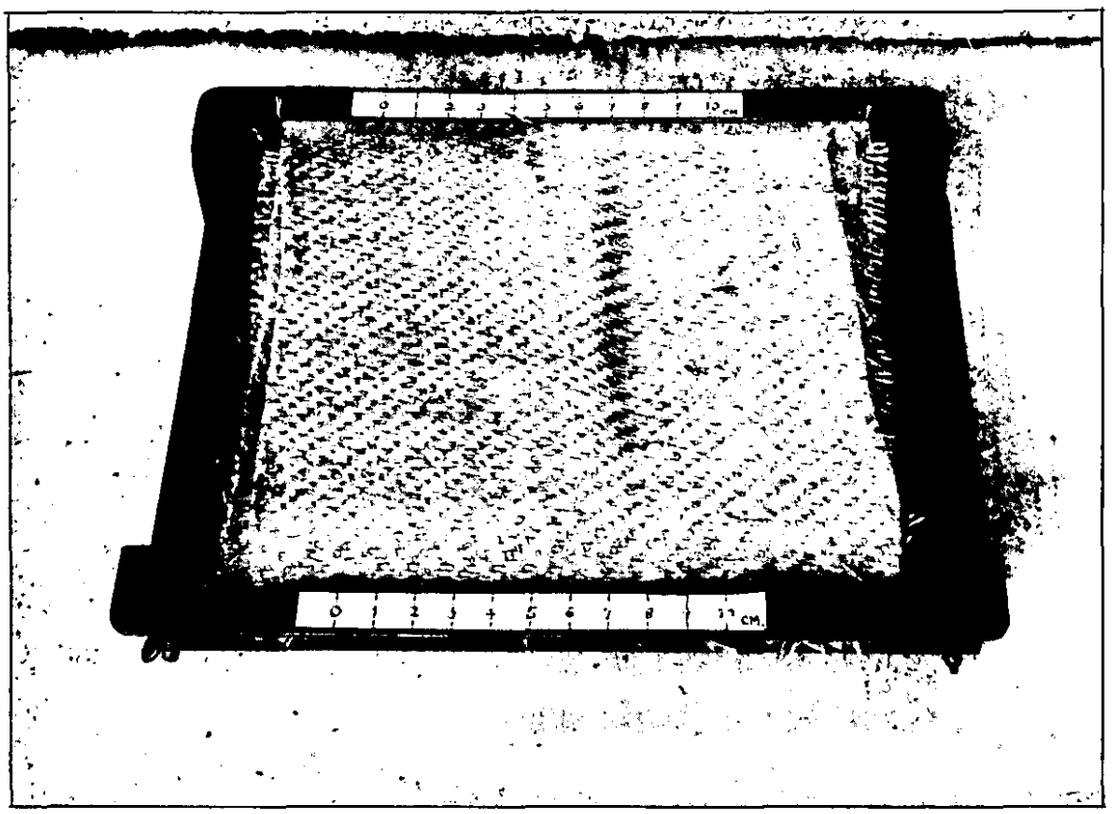
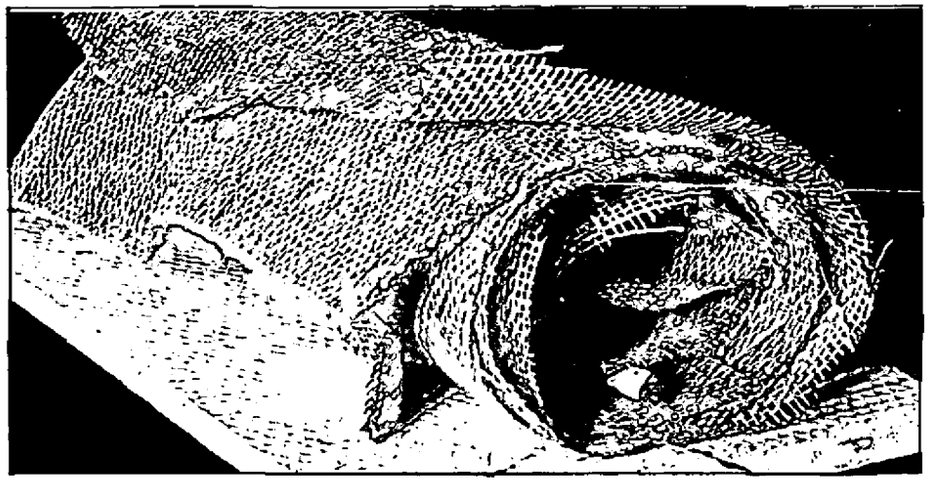


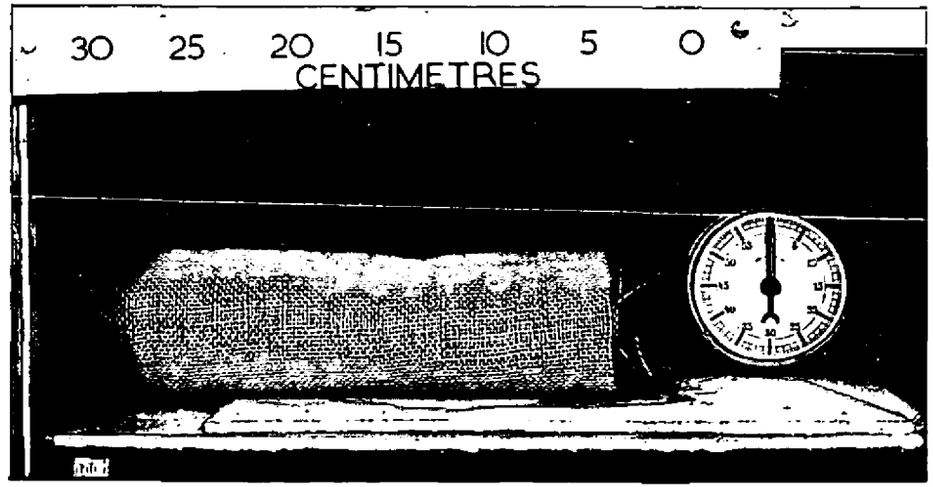
PLATE.2. SUPPORT WITH CLOTH IN POSITION

DS 7656/1/86 60 10/53 CL

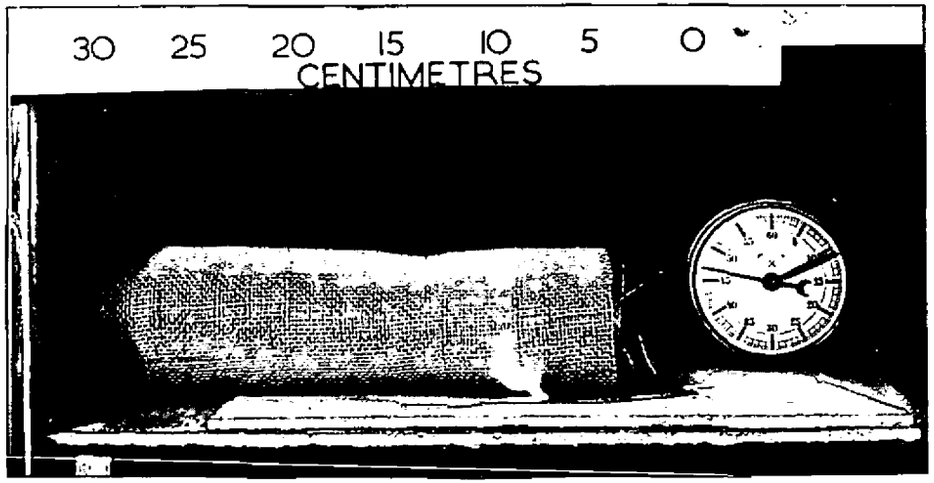
B 7656/2/86 60 10/53 CL



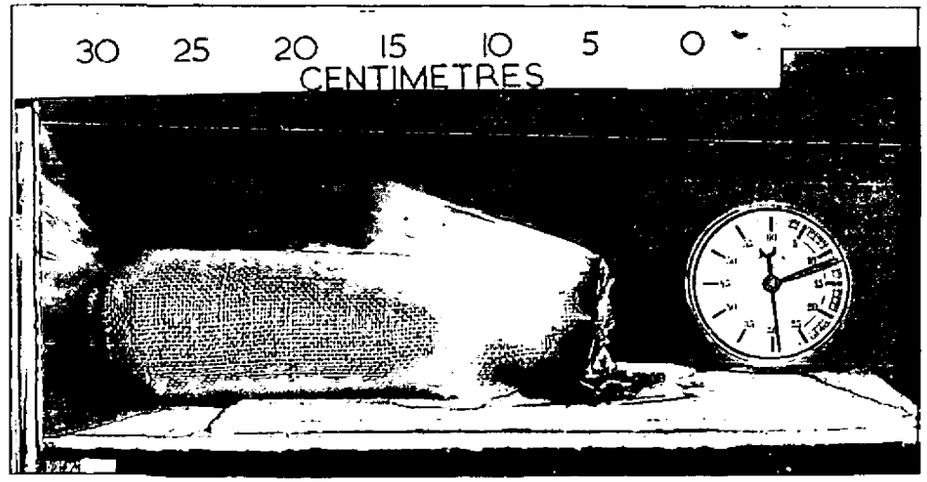
Position of glowing cigarette end



Omin Cigarette end placed on sacking



10min 47sec Smoke evolution increasing



11min 29sec Flame appears

PLATE.3. SMOULDERING IN JUTE CLOTH INITIATED BY A CIGARETTE END AND DEVELOPING INTO FLAMING UNDER A 2m.p.h. DRAUGHT