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THE RELATIVE FIRE HAZARD OF PLAIN AND TIPPED CIGARETTES

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Summary

The suggestion that the increasing number of fires in buildings attributed to "smoking materials" was associated with the rapidly increasing consumption of filter-tipped cigarettes was examined statistically in a previous report[1] with somewhat inconclusive results and it was therefore decided to make a laboratory comparison between plain and tipped cigarettes. In the first situation examined, with the cigarettes smouldering on wood shavings in a draught, it appears that plain cigarettes can be more hazardous than tipped cigarettes. It is concluded that any further consideration of the relative fire hazard of different types of cigarettes must include some assessment of the actual circumstances in which fires are caused by them.

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Introduction

The increase in the number of fires attributed to smoking materials has recently been the subject of a study by Mrs. J. M. Hogg.

After a slight decrease from 1947 to 1951, the number of fires in buildings rose from less than 4,000 to over 8,000 in 1961 but the amount of tobacco consumed had increased by only about 30 per cent in this period. However, the proportion of this tobacco smoked in the form of filter-tipped cigarettes had risen from about 0.5 per cent in 1947 to about 15 per cent of the total sales of tobacco in 1961, the last year considered in the report, and is expected to become half of the total in 1965. If the number of fires attributed to smoking materials was proportional to the amount of tobacco consumed, the above figures would imply that, if the unknown number of fires due to pipes and cigars (and the matches associated with them) is neglected, about one-sixth of the total tobacco consumption is responsible for half the building fires attributed to smoking materials, i.e. that filter-tipped cigarettes are about five times more likely to cause a fire than plain cigarettes. In only one of the four analyses - viz. that for fires in buildings from unknown causes - was both the consumption of tobacco in the form of tipped and of plain cigarettes significant, but the regression coefficients - which measure the extra number of fires associated with extra tobacco - were roughly the same.

The report concludes that "fires caused by tipped cigarettes appear to be more likely to be recorded as being caused by smoking materials than those caused by standard (i.e. plain) cigarettes" and that "tipped cigarettes .... could either be more intrinsically hazardous than standard cigarettes or they could be being smoked under conditions which are more likely to lead to a fire". The increased consumption by women and its possible association with tipped cigarettes is also mentioned.

The collection of fire statistics in the years prior to 1947 was less comprehensive than in 1947 and subsequently, and the data for 1946 were excluded from the statistical analysis. However, the figures available suggest that there was not a marked decrease in the number of fires attributed to smoking materials from 1946 to 1947 but the consumption of tobacco did indeed fall as a result of large price increases and only regained its pre-1947 value in 1959. Any weight given to these data tends to increase the doubt as to the significance of the statistical trends under examination.

Because of this, a laboratory study of ignition by cigarettes was undertaken. Up till then, the fire hazard of only plain cigarettes had been studied[2,3] and there was no information on the relative hazards of the two types. Yockers and Segal[2] found that the burning temperatures were the same in both types and thus assumed equal hazards for both, while the Japanese workers[3] used two brands of plain cigarette only. However, the difference between the construction of tipped and of plain cigarettes was thought to make the tipped butt either more prone to ignite materials than plain butts under identical conditions; more difficult to stub out or, by the burning dottle becoming detached from the tip, more likely to introduce an unnoticed source of ignition into flammable materials.

In the present paper, the relative fire hazard of plain and tipped cigarettes has been assessed in two ways. The first was to find their relative heat outputs, the second to measure their relative fire hazard under one set

of circumstances. Since there is, in practice, a very large number of situations in which cigarettes may cause a fire, and the chance of any one cigarette causing a fire is also very low[4,5], a situation was chosen which was found to give a greatly increased probability of ignition.

A. General.

A.1. Method of smoking experimental cigarettes

In order to produce a standard cigarette butt, all cigarettes were smoked using a simple smoking machine (Fig.1). This consisted of a suction pump connected via an aspirator valve to a cigarette holder in which the cigarette was placed. When the valve was open, air was drawn through it and not through the cigarette; when closed, the cigarette was drawn. The cigarette was drawn on for approximately 10 sec. per minute, the suction pressure being 1.0 in W.G. This consumed the cigarette at a similar rate to that found in practice.

A.2. Brands of cigarette tested

Several different brands of the two types of cigarette were used in these tests. Many of these had been in store for some years and had a lower moisture content than freshly-made cigarettes; this is known not to affect the burning temperature[6]. The dimensions of these cigarettes are given in Table 1a. Some freshly-purchased cigarettes were also used in the experiments and details of these are given in Table 1b. Over the period of the tests, the cigarettes listed in Table 1a were stored in the open laboratory but those in Table 1b were kept under controlled conditions of 65 per cent relative humidity at a temperature of 20°C.

B. The relative heat output of different types of cigarette.

B.1. Experimental details

The burning cigarette butts were laid on a horizontal copper disc of thickness 0.03 cm and diameter 2.5 cm (Fig.2), with a chromel/constantan thermocouple fixed to the underside. The output of this was continuously recorded. Most of the measurements were made in still air but a few were repeated with the disc in a wind of speed 1 m/s.

The length of butt was, in most cases, 2.5 cm (equal to the diameter of the disc) but in some tests other lengths were employed. In the case of tipped cigarettes, this butt length included the length of the filter.

Because of the unknown magnitude of the cooling effect of the disc on the butt and also of other heat losses, the values of peak thermocouple output obtained are not simply interpreted in terms of heat output. They do provide, however, a basis for comparisons between the different brands of cigarette.

B.2. Results

The thermocouple outputs for the two types of cigarette butt followed patterns similar to curves A and B in Fig.3. When tipped cigarettes had their filters removed, they also followed curve A. The main parameters of the curves for the various brands of cigarette in still air are given in Table 2. Each mean value in this table is based on five results, the measured values falling in the range ± 15 per cent of the mean.

Table 1a

Details of the brands of old cigarettes tested

Type	Brand	Length: (cm.)			Diameter (cm.)	Mass: (gm.)		Packing density of tobacco ($g.cm^{-3}$)
		Total	: of tip	:of cork paper		Total	: of tobacco	
Tipped	B	7.2	1.4	1.8	0.80	1.03	0.84	0.292
	C	8.5	1.5	1.8	0.78	1.19	0.94	0.283
	D	8.5	1.5	1.8	0.76	1.20	0.97	0.308
	E	7.5	1.1	1.5	0.77	1.04	0.86	0.293
	F	7.2	1.3	1.7	0.77	1.00	0.76	0.278
Plain	J	7.0	-	-	0.80	1.10	1.10	0.314
	K	7.0	-	-	0.80	1.10	1.10	0.316
	L	7.1	-	-	0.78	1.07	1.07	0.317
	N	7.0	-	-	0.80	1.11	1.11	0.315

Table 1b

Details of the brands of fresh cigarettes tested

Type	Brand	Length: (cm.)			Diameter (cm.)	Mass: (gm.)		Packing density of tobacco ($g.cm^{-3}$)
		Total	: of tip	:of cork paper		Total	: of tobacco	
Tipped	P	8.4	1.5	1.8	0.78	1.25	1.05	0.318
	Q	7.3	1.6	1.8	0.79	1.06	0.90	0.324
Plain	R	7.0	-	-	0.81	1.16	1.16	0.322
	S	6.9	-	-	0.81	1.13	1.13	0.318

Table 2

Mean results of tests on old cigarettes burning on a copper disc

Type	Brand	Mean time to reach peak (min.)	Mean total duration (min.)	Mean peak disc temperature (deg.C above ambient)
Tipped	B	3.0	7.6	60
	C	3.1	7.6	54
	D	3.8	8.3	51
	E	3.7	8.5	76
	F	3.4	7.9	62
Plain	J	9.0	12.9	138
	K	10.2	14.0	130
	L	7.2	11.0	159
	N	7.5	11.3	160

Table 3

Mean results of tests on fresh cigarettes burning on a copper disc

Type	Brand	Mean time to reach peak (min.)	Mean total duration (min.)	Mean peak disc temperature (deg.C above ambient)
Tipped	E	3.8	8.7	63
Plain	N	7.2	10.3	140
Tipped	P	2.5	7.4	39
	Q	3.2	8.6	44
Plain	R	9.0	12.0	121
	S	9.0	12.3	128

The chief parameters for the heat output curves of freshly-purchased cigarettes are shown in Table 3. Since these measurements were made at a later date than those in Table 2, two brands of old cigarettes were included as a control. The shapes of the heat output curves were similar to those in Fig.3.

Tipped butts having a tobacco length of 2.5 cm were also tested on the disc. This meant that the length of the butt was greater than the diameter of the disc and the tip was allowed to extend beyond the disc. For these tests, heat output curves similar to curve C of Fig.3 were obtained.

The results for those experiments where the butt was in a wind of speed 1.0 m/s tended to show lower peak outputs than previously but this was probably due to the increased heat loss from the disc rather than a decrease in the burning rate of the butt. The general shape of the heat output curve for plain butts was similar to that shown in Fig.3 but the final burst of energy was accentuated, sometimes representing as much as a 50 per cent increase over the steadily burning value.

B.3. Analysis and discussion of results

The differences between curves A and B of Fig.3 are not due to differences in the tobacco of the two cigarette types, since these have similar burning properties. The length of tobacco in the butt is the main reason for the differences, as may be seen by comparison of curves A and C of Fig.3. However, this does not explain the final burst of heat energy from the plain butt, which occurs very shortly before the butt is burnt out. Inspection of the cigarette at this time shows a greater glow and an increased output of smoke, i.e. an increased burning rate. Since the composition of the tobacco is not significantly different in this region of the butt, this increased rate is most probably due to increased availability of oxygen. With a comparatively long butt, most of the air required for combustion is drawn by natural convection from the surroundings of the burning zone and only a small proportion through the unburned tobacco, owing to the high resistance of this path. When the burning zone reaches the end of the butt, the resistance decreases and air will be drawn in at a higher rate. This will increase the burning rate considerably and the small butt remaining will be quickly consumed. Such a mechanism cannot occur with a tipped cigarette, since the filter-tip will maintain a high resistance to longitudinal air flow, even when all the tobacco has been burned.

The results for the peak outputs as given in Table 2 were statistically tested for significant differences by means of the Student's t test. Besides the obvious difference between the two types of cigarette, the much smaller differences between brands of the same type were found to be significant at the 1 per cent level.

The difference between the peak outputs for the two types of cigarettes in Table 3 was again obviously significant but there was no significant difference between brands of the same type.

C. The fire hazard of cigarettes.

C.1. Experimental procedure

The burning cigarette butts were laid on oven-dried wood shavings contained in a wire-mesh basket and placed in a wind tunnel; the butts lying across the direction of the wind. This situation was chosen to give a probability of ignition of the shavings of approximately 0.5 and, hence, to provide a comparison from a reasonable number of tests. This probability was achieved with a wind

speed of 0.75 m/s for the cigarettes detailed in Table 1a and a speed of 1.0 m/s for those in Table 1b. (A speed of 0.75 m/s gave only about a 0.3 probability of ignition for the cigarettes in Table 1b).

This experimental arrangement was first used with some of the cigarettes of Table 1a to establish the relative hazard of different butt lengths and of the different types of cigarette. The cigarettes of Table 1b were then employed to confirm the effect of the different types and to show the effect of various brands. Butts of length 3 cm were used in this second series.

C.2. Results

It was found that the burning cigarette butt could produce one of three distinct effects on the wood shavings during a wind tunnel test. Firstly, it could burn itself out causing only charring, or, occasionally, glowing, of the immediately adjacent shavings; secondly it could initiate smouldering which would eventually destroy the whole of the shavings; and, thirdly, it could cause flaming ignition of the shavings. The first effect was considered 'non-hazardous' and the others, 'hazardous'.

The results of the tests in the wind tunnel are given in Tables 4 and 5.

Table 4

Results of wind tunnel tests on different butt lengths

Type	Butt length (cm.)	Number of butts producing:-				Total number tested
		Smouldering ignition	Flaming ignition	Hazard	No hazard	
Tipped	6	1	6	7	21	28
	3	3	8	11	17	28
Plain	6	6	9	15	13	28
	3	6	12	18	10	28

Table 5

Results of wind tunnel tests on different brands

Type	Brand	Number of butts producing:-				Total number tested
		Smouldering ignition	Flaming ignition	Hazard	No hazard	
Tipped	P	5	15	20	30	50
	Q	5	12	17	33	50
Plain	R	12	25	37	13	50
	S	11	25	36	14	50

It was found that most of the hazardous conditions for both types of butt were initiated when the butt was first placed on the shavings. In addition, for plain butts, there were some ignitions immediately before the cigarettes burned out.

C.3. Analysis and discussion

Analysing the results in Table 4 by means of the χ^2 test showed that the difference in frequency of ignition between tipped and plain butts was significant at the 2 per cent level. However, the difference in this frequency due to different butt lengths was not significant. Hamada and Wakamatsu[3], using 2 cm and 3 cm butts; 0, 3 and 6 m/s wind speed and two brands of plain cigarette, found that butt length did affect the probability of ignition but not in a consistent manner.

The results in Table 5 were also analysed by means of the χ^2 test and the difference between tipped and plain cigarettes was again found significant, though in this case at the 0.1 per cent level. There was no significant difference between brands of the same type.

When the frequencies of flaming ignition and of smouldering ignition were considered individually, i.e. not lumped together as 'hazardous'; the same effects were obtained but at lower significance levels.

Conclusions

Two experimental comparisons between tipped and plain cigarettes have shown that plain cigarettes produced more heat in still air, and in a draught were more likely to ignite wood shavings. No study has yet been made of such factors as the likelihood of hot dottles falling from the butt; which factor has been suggested as a feature of some tipped cigarettes which might cause fires.

Since, on the basis of these experiments, there are situations where plain cigarettes could be more hazardous than tipped ones, no association between the increased number of fires and the increased consumption of tipped cigarettes could be demonstrated on physical grounds without some knowledge and analysis of the circumstances in which accidental fires are actually caused by cigarettes.

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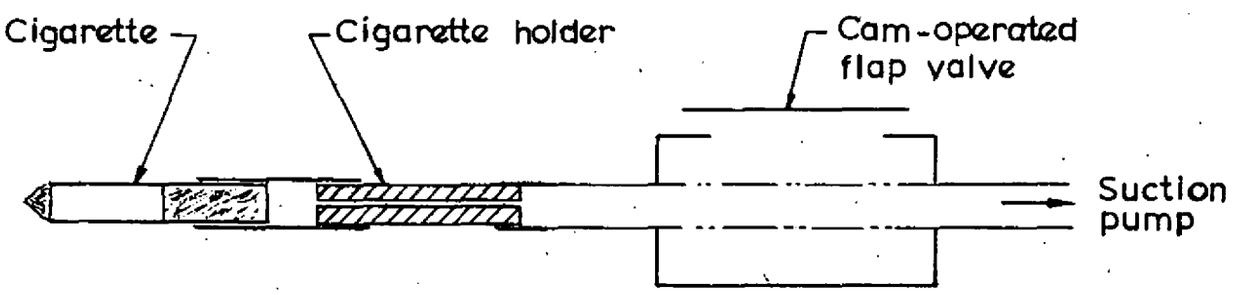


FIG.1. SECTION THROUGH SMOKING MACHINE

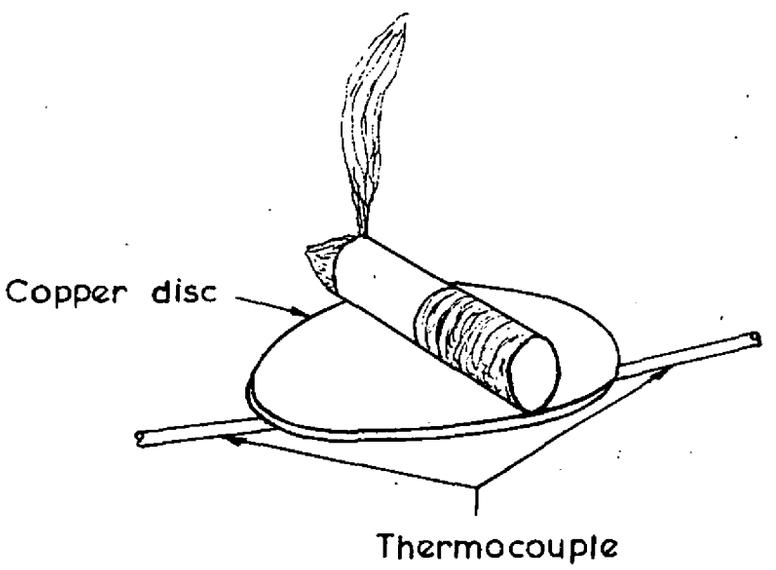
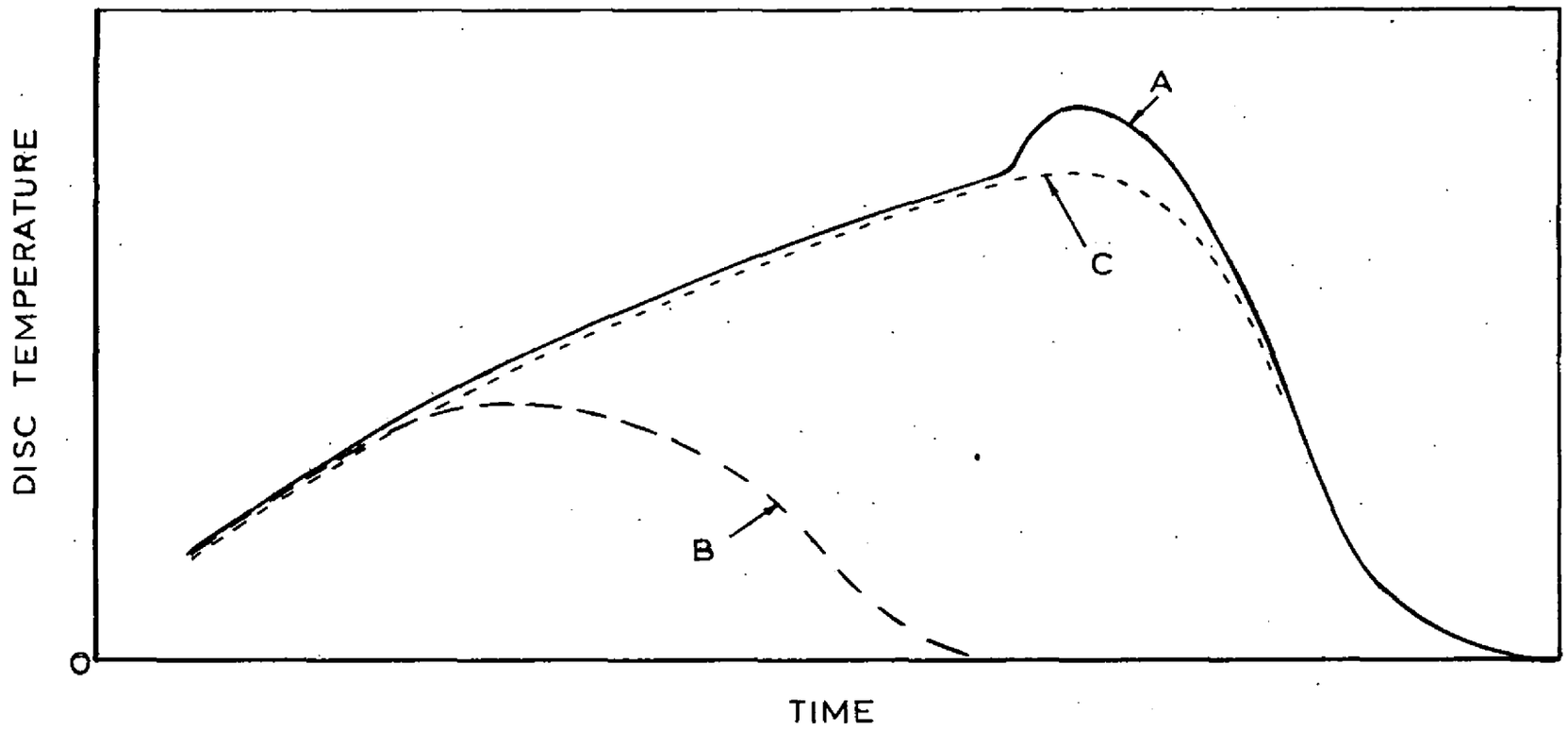


FIG.2. A CIGARETTE BUTT ON THE COPPER-DISC THERMOCOUPLE



Diagrammatic curves. See table 2 for details

——— A Plain } 2·5 cm butt length
— — — B Tipped }
------ C Tipped, 2·5 cm length of tobacco

FIG.3. HEATING OF COPPER DISC BY CIGARETTES