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The Control of Cigarette Smoke Deliveries Using Heat-Shrinkable Films*

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1. INTRODUCTION

In recent years, in many countries, the delivery of total particulate matter (TPM) and nicotine from cigarettes has been steadily reduced. This change has been achieved by improved degrees of smoke filtration and by the introduction of ventilation. If the total delivery per cigarette of TPM and nicotine is measured by the standard methods in which puff deliveries are combined, the effect of improved filtration and addition of ventilation on individual puffs cannot, of course, be judged. When smoke yields are determined on a puff by puff basis (Figure 1), the delivery of TPM and nicotine from plain cigarettes is shown to increase very rapidly during the final two to three puffs. The yield from the final puff is normally three or four times greater than the yield from the first puff. When a high efficiency filter and/or a ventilation zone localized near the mouth end of the cigarette is introduced, the delivery from each puff is reduced but a marked increase in delivery still occurs during the final two to three puffs. Under these conditions smoke deliveries from the first few puffs have been reduced to a very low level and the resulting smoke is perceived as too "mild" in character for many smokers. Alternatively, if smoke deliveries

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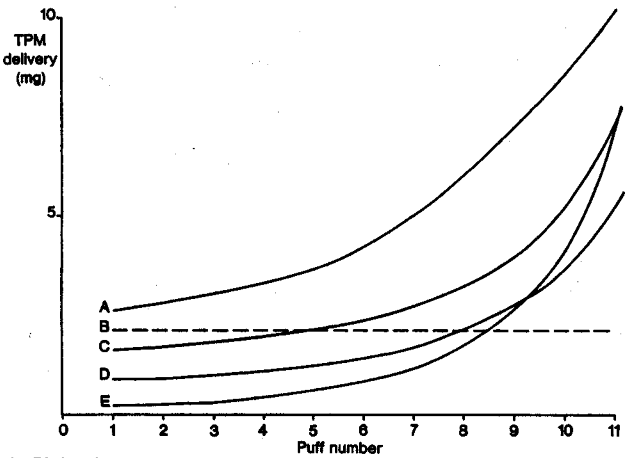
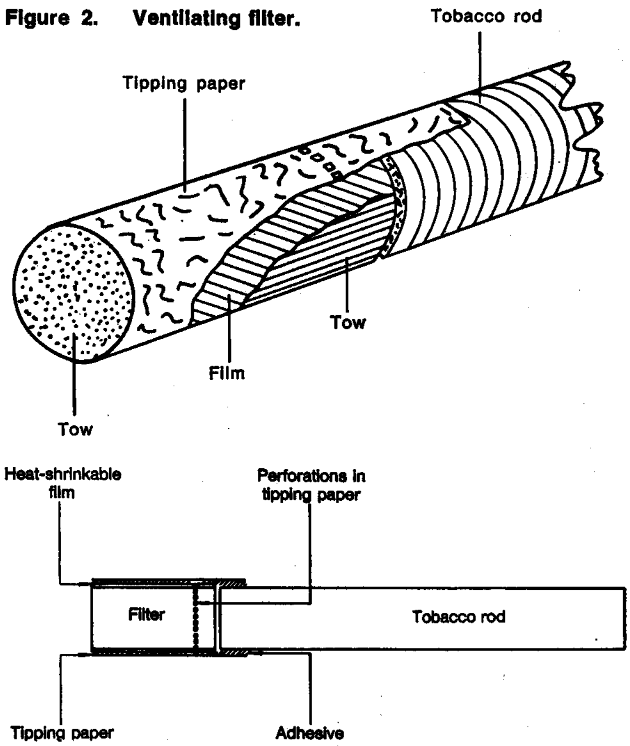
Figure 1. Typical puff by puff TPM deliveries.



A: Plain cigarette.
B: Constant delivery cigarette.
C: Filter cigarette.
D: Filter cigarette (with filter ventilation zone).
E: Filter cigarette (with porous/perforated cigarette paper).

Figure 2. Ventilating filter.



are reduced by ventilating the whole cigarette (by incorporating perforated or highly porous cigarette paper) the difference in deliveries between first and last puffs is increased, since the ventilated cigarette paper is consumed during smoking. When this approach is adopted, the resulting smoke is again perceived as too "mild" for many smokers.

If a constant quantity of TPM and nicotine could be delivered from each smoke puff (Figure 1) a fuller flavour cigarette with a relatively low delivery would be possible, which could appeal more to some smokers. This could be achieved by reducing selectively the smoke deliveries from the last few puffs. The earlier puffs would not be excessively dilute, and a more uniform smoking experience would be produced.

Two cigarettes have been marketed in the U.S.A. in which these concepts have been used. In one brand, a burn accelerator was applied in a checkerboard pattern to the cigarette paper (1). The pattern was designed to accelerate the burn rate during later puffs; this permitted a greater degree of ventilation behind the coal and thus a more marked delivery reduction for these puffs. In another brand, a polymeric film which covered ventilation areas in the cigarette paper was progressively melted by the heat from the approaching cigarette coal (2). Control over the puff delivery was exercised by variations in the film position. In the approach which is discussed here, control of ventilation is exercised through modification of the filter plug wrapping rather than the cigarette paper. The cellulose acetate filter section is wrapped in a heat-shrinkable film and attached to the tobacco rods using perforated tipping paper (Figure 2). When the cigarette is lit and puffed, air cannot enter through the perforations, since these are closed to airflow by the impervious heat-shrinkable film which is adhered to the tipping paper (except in the immediate vicinity of the perforations). When the burning zone reaches a point approximately 20—25 mm from the filter, transfer of heat from the cigarette coal to the film (via the smoke) becomes sufficient to raise the film temperature and cause the film to shrink. At the same time, the transfer of heat and deposited smoke to the cellulose acetate tow produces a softening or collapse of the filter. The combination of these effects permits compression of the tow by the shrinking film, reducing the circumference of the filter near the junction with the tobacco rod where shrinkage is greatest. This allows air into the cigarette through the perforations, reducing the delivery of particulate and vapour phase constituents from the remaining puffs. Smoke deliveries are reduced, then, by ventilation which is delayed to a point when smoke deliveries would normally be high. The profile indicated by the solid line in Figure 3 is typical of this approach.

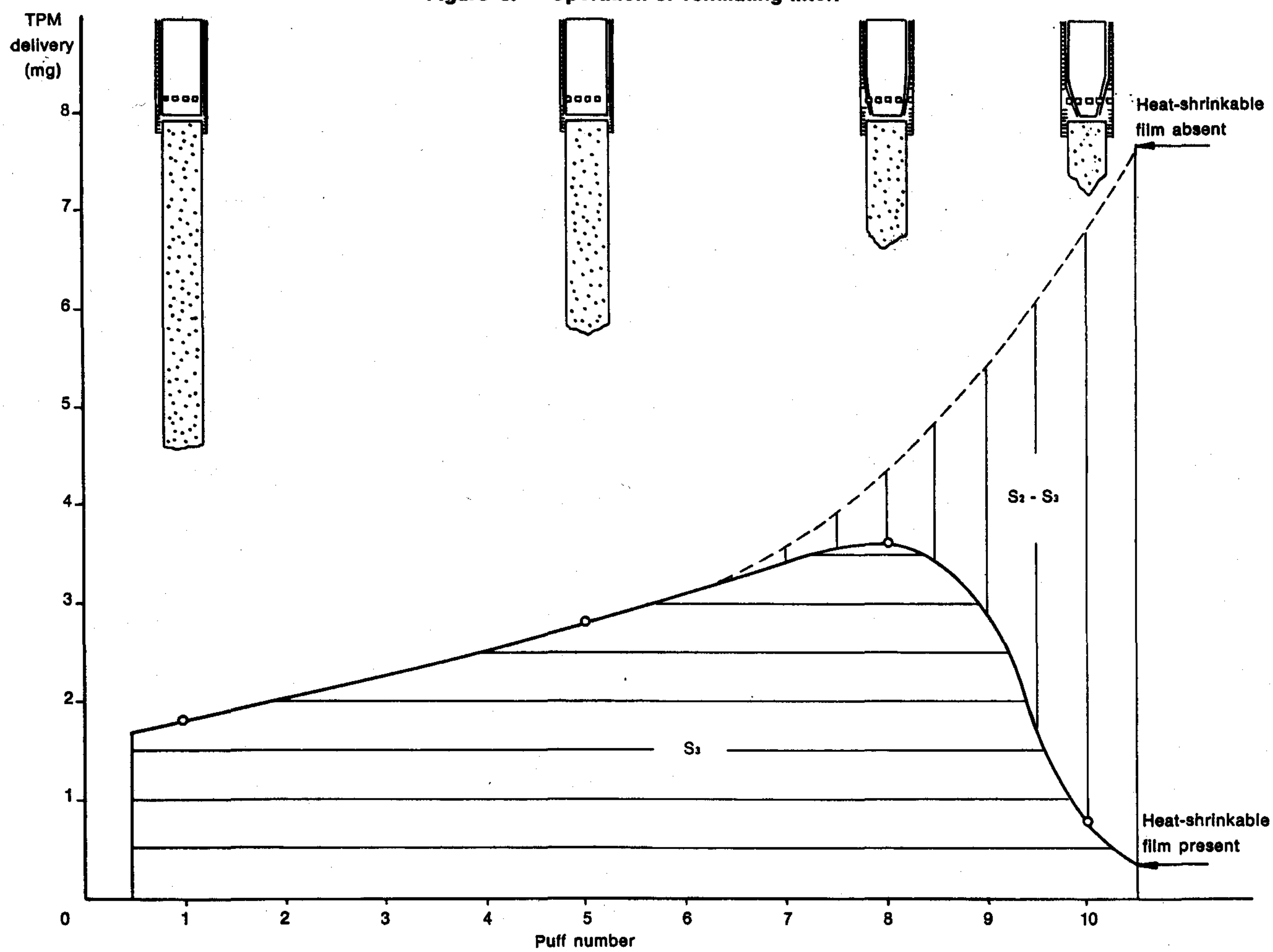
One important feature of this approach is that only slight modification of existing production methods is required.

2. EXPERIMENTAL DETAILS

2.1 *Cigarettes*

To investigate the effect of cigarette design and smoking variables on the effectiveness of this ventilating filter, samples were prepared by hand, using plain flue-cured tobacco rods, film-wrapped cellulose acetate filter rods (containing 10 % triacetin plasticiser, based on net tow weight), perforated tipping paper and polyvinyl acetate (PVA) adhesive. The quality of manufacture of cigarettes prepared in this way was checked by measuring the draw resistance of the cigarette when inserted into the machine holder so that a) the perforations were *not* covered by the holder and b) the perforations *were* covered by the holder. If a difference in draw resistance indicated that air was leaking through the perforations due to inadequate glue application, the cigarette was rejected.

Figure 3. Operation of ventilating filter.

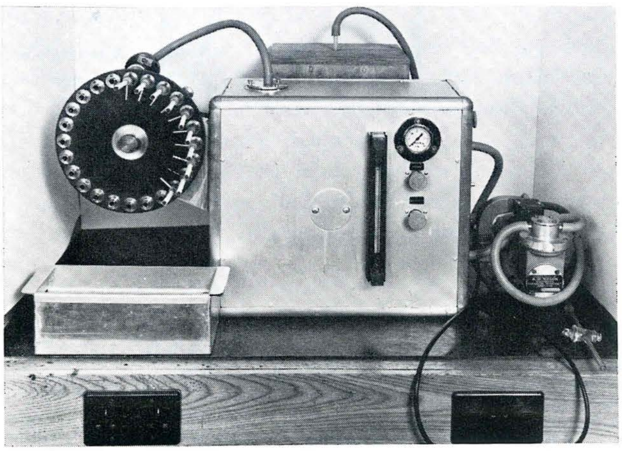


In addition, control cigarettes were prepared by using non-perforated tipping paper and conventional filter rods of the same tow specification.
Prior to assembly, tobacco rods were selected to constant weight ($\pm$ 2.5 % of mean) and draw resistance ($\pm$ 2.5 % of mean) while filter rods were selected to constant circumference ($\pm$ 0.5 % of mean) and draw resistance ($\pm$ 2.5 % of mean). Draw resistance values were measured at a flow rate of 17.5 cm^3/s and expressed in cm water gauge (WG).

2.2 *Smoking Machine*

The puff by puff delivery of smoke constituents was measured using a Mason Rotary Smoking Machine (Figure 4). Ten cigarettes were smoked through adjacent ports of the twenty-four-port machine. The TPM was collected on a Cambridge filter pad. The Cambridge filter assembly was repeatedly replaced after the puff on the tenth cigarette had been taken and whilst the vacant ports were passing the suction orifice. In this way, the quantity of TPM and nicotine produced by each puff could be determined.
The machine was adjusted to take a 35 cm^3 puff of 2 s duration, one puff being taken each minute. The puff volume was shown to be almost independent of the cigarette draw resistance within the range 3—20 cm WG. Draw resistance values outside this range were not encountered in this work.

Figure 4. Mason rotary smoking machine.



2.3 *Evaluation of Results*

The effectiveness in reducing smoke yields, E, of the ventilating filter (with respect to a conventional control filter) was assessed. The delivery in the presence of the film and perforations (S_3) and the delivery of the normal filter cigarette without these features (S_2) were measured.

$$\text{Effectiveness, E (ventilating filter)} = \frac{S_2 - S_3}{S_2} \times 100\,\%.$$

E values were determined for each puff (to chart progressively the effectiveness of the ventilating filter as the cigarette is smoked) or for the whole cigarette (to determine the total effectiveness of the ventilating filter in terms of smoke delivery reduction).

2.4 *Methods*

To determine the shrinkage of films at different temperatures, standard areas of the film (normally 100 mm $\times$ 100 mm) were kept at accurately known temperatures for two hours prior to remeasuring the area.
The shrink force (tension) of the films at different temperatures was measured using an Instron gauge by heating the sample in ethylene glycol to 100° C at 3 deg C/min. The procedure is similar to the American Society for Testing and Materials procedure number D 2838.
The degree of collapse of the filter was measured using 30 mm filter sections (wrapped in normal plugwrap paper). The whole assembly was rigidly clamped. A fine wire (0.1 mm diameter), linked to the core of a displacement transducer (9 g weight), was looped around the filter, 10 mm from the tobacco end. Resultant movement of the wire, due to softening of the filter during smoking, could therefore be determined electrically.

3. RESULTS AND DISCUSSION

To maximize the performance of the ventilating filter, experiments were carried out to establish the important parameters. A detailed assessment was carried out of the effect of variations in design parameters (film type, degree of perforation, tobacco packing density, etc.) and smoking parameters (butt length and puff volume) on the effectiveness of the ventilating filter.

3.1 *Effect of Design Parameters*

3.1.1 Film: A preliminary survey revealed that a number of types of heat-shrinkable film are available.
In Table 1, the properties of different types of heat-shrinkable film are summarized (3). It was assumed that the required film should possess the following properties:

a) Shrinkage should be maximized, so that a clear passageway for diluting airflow would be produced.
b) The tension generated in the film during shrinkage should be maximized, so that resistance of the tow to compression by the film would be overcome.
c) The shrink temperature of the film should be optimized, so that effects due to shrinkage of the film could occur during as many smoke puffs as possible. However, shrinkage should not occur at temperatures which are likely to be reached in warm weather.

The shrink properties must be located in the direction transverse to film manufacture, which is the direction applied circumferentially to the filter.
These requirements are met most closely by polyvinylchloride (PVC) films. To a lesser extent, high density polyethylene, vinylidenechloride copolymer and rubber hydrochloride films meet the requirements listed.

Table 1. Properties of different types of heat-shrinkable films.

Type	Density (g/cm³)	Shrinkage (%)	Shrink tension (kg/cm²)	Shrink temperature (° C)
Polyester	1.15 –1.39	25–45	50 –100	70–120
Polyethylene				
(low density)	0.90 –0.925	15–40	<5	105–120
(high density)	0.925–0.94	70–80	15 – 75	95–140
Polypropylene	0.90	70–80	20 – 40	105–165
Polystyrene	1.05	40–60	5 – 40	100–130
Polyvinylchloride	1.23 –1.39	50–70	10 – 20	65–150
Vinylidenechloride copolymer	1.64	30–60	2 – 10	65–100
Rubber hydrochloride	1.11	40–50	10 – 20	65–110

Data is taken from (3).

In the first stage of this investigation, nine grades of PVC films, four grades of polyethylene films and one grade of vinylidenechloride/vinylchloride copolymer film were obtained for evaluation. In addition, an ethylene/vinyl acetate copolymer film was examined. The evaluation revealed that PVC films are markedly superior to other film types, but also that the performance of PVC films varies considerably from grade to grade. The performance of the three most promising PVC grades can be judged from the data in Table 2.
The grades shown in Table 2 shrink biaxially when heated. Some of the other grades examined undergo monoaxial shrinkage only, but these are ineffective since the orientation of shrinkage produces only longitudinal (and not circumferential) contraction when used to wrap filter rods by the normal filter rod making process.

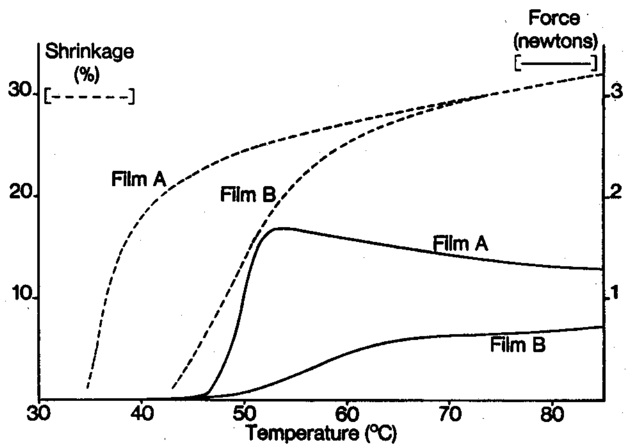
Table 2. Effect of film grade on deliveries and E values.

Puff number	Total particulate matter delivery (mg)			
	Film A	Film B	Film C	–
	S_3	S_3	S_3	S_2
1, 2, 3 (average)	1.7	1.7	1.7	1.9
7	3.0	2.9	2.8	2.7
8	2.9	3.5	3.6	3.2
9	2.0	2.6	2.5	3.0
10	0.6	1.5	2.1	3.7
Total	21	23	23	25
E (%)	17	9	7	–

Tobacco rod: 67 mm length, 25 mm circumference.
Cigarette paper porosity: 140 cm³/min/10 cm²/10 cm WG.
Filter length: 17 mm.
Film: 15 microns thickness.
Tipping perforation: 6.5 mm² (1 row), 4 mm from tobacco/filter junction.
Butt length: 13 mm tobacco + filter length.
Smoking:
Puff volume : 35 cm³.
Puff duration : 2 s.
Puff frequency : 1 min⁻¹.
S_3 : Delivery from cigarette with ventilating filter.
S_2 : Delivery from cigarette with control filter.

One of the three preferred films was obtained in two different gauges (thicknesses). No variation in performance could be detected over this range of gauges (15—20 microns). A greater range of thicknesses would be required to confirm that performance is independent of film thickness. However, in a related experiment, little change in performance was observed when an increased number of turns (or layers) of film were used. It is possible, therefore, that increased film tension (due to increased film thickness) would be counter-acted by increased film heat capacity.
The shrinkage (%) and shrink force versus temperature curves for two films, A and B, are shown in Figure 5. Film A, which is more effective on the ventilating filter than film B, begins to shrink at a lower temperature and generates greater tension, in the cross direction (circumferential to the filter).

Figure 5. Film properties.



3.1.2 Filter: The level of plasticiser incorporated into the filter tow determines the effectiveness of the ventilating filter (Table 3). Incorporation of triacetin plasticiser in the filter leads to a marked increase in the effectiveness. Examination of these filters revealed that the extent of filter collapse occurring increases as the level of plasticiser is increased. Marked collapse of the filter is therefore an integral part of the mechanism of the ventilating filter.

Table 3. Effect of plasticiser level on deliveries and E values.

Triacetin level (%)	Total particulate matter delivery (mg)		
	S_2	S_3	E (%)
0.0	37	33	12
1.9	38	31	19
4.2	40	31	23
4.6	38	29	23
6.4	41	29	29

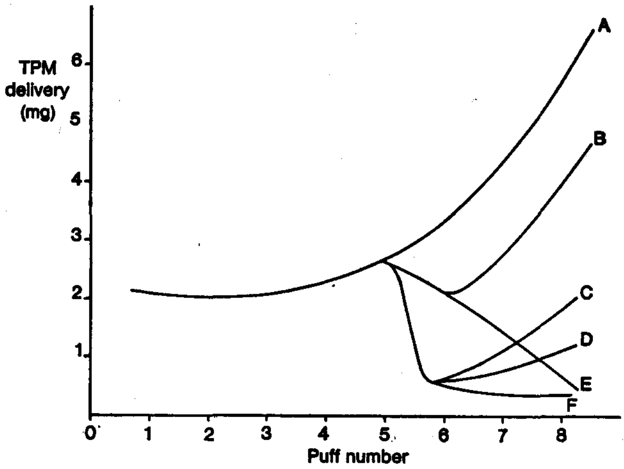
Tobacco rod: 70 mm length, 25 mm circumference.
Cigarette paper porosity: 80 cm^3/min/10 cm^2/10 cm WG.
Filter length: 15 mm, triacetin content based on net tow weight.
Film: A, 15 microns thickness.
Tipping perforation: 4.5 mm^2 (2 rows), 3 mm from tobacco/filter junction.
Butt length: 8 mm tobacco + filter length.
Smoking: as in Table 2.

3.1.3 Ventilation: Different amounts of ventilation or perforation in the tipping paper were introduced by varying:

a) the area of the individual perforations,
b) the number of perforations per row,
c) the number of rows.

The results presented in Table 4 and Figure 6 indicate that, as expected, an increase in the degree of perforation generally increases the effectiveness of the filter during the final three puffs, but does not influence the point during smoking when the effect commences. However, when film shrinkage starts, the ventilation can be implemented suddenly by using one row of perforations, or gradually by using several rows of smaller perforations. When several rows are present, each row is uncovered successively during smoking since the film "peels" slowly from the tipping paper (indicated by a steadily increasing E value).
Related experiments were carried out with porous tipping paper; a selection of papers in the porosity range 2640–13600 cm^3/min/10 cm^2/10 cm WG was examined. The ventilation is introduced gradually since the area of porous tipping paper through which diluting air may pass increases as the film shrinks progressively. In general, a higher effectiveness is achieved if the paper porosity is raised.
Ventilation through the cigarette paper decreases the efficiency of the ventilating filter (Table 5). A progressive decline in the E value occurs when the

Figure 6. Effect of perforation area.



A: Control.
B: 1.25 mm^2 (1 row).
C: 2.50 mm^2 (2 rows).
D: 5.20 mm^2 (1 row).
E: 6.52 mm^2 (5 rows).
F: 5.45 mm^2 (2 rows).

Table 4. Effect of perforation area on deliveries and E values.

Puff number	Total particulate matter delivery (mg)					
	Area of perforations (mm^2) [number of rows]					
	–	1.25 [1]	5.20 [1]	2.50 [2]	5.45 [2]	6.52 [5]
	S_2	S_3	S_3	S_3	S_3	S_3
1	2.1	2.2	2.3	2.1	2.6	2.1
2	2.1	2.6	2.1	2.0	2.1	1.6
3	1.9	2.7	2.1	2.4	2.4	1.7
4	2.2	2.3	2.8	2.6	2.9	2.5
5	2.6	3.4	3.2	3.3	2.7	3.0
6	3.2	1.6 [50]	0.4 [88]	0.7 [78]	0.5 [85]	1.8 [44]
7	5.0	3.9 [22]	0.9 [82]	1.4 [72]	0.4 [92]	1.4 [72]
8	5.6	3.0 [46]	1.0 [82]	1.7 [70]	0.4 [93]	0.7 [88]
Total TPM	25	22	15	16	14	15
E (%)	–	12	40	36	44	40

Tobacco rod: 51 mm length, 23.5 mm circumference.
Cigarette paper porosity: 80 cm^3/min/10 cm^2/10 cm WG.
Filter length: 15 mm.
Film: A, 15 microns thickness.
Tipping perforation: variable.
Butt length: 8 mm tobacco + filter length.
Smoking: as in Table 2.
Individual puff E values (%) in square brackets (puffs 6–8).

Table 5. Effect of cigarette paper porosity on deliveries and E values.

Puff number	Total particulate matter delivery (mg)					
	Paper porosity (cm³/min/10 cm²/10 cm WG)					
	440		140		90	
	S_2	S_3	S_2	S_3	S_2	S_3
1, 2, 3 (average)	1.7	1.7	1.9	2.0	2.1	2.2
n–2	2.4	2.5	3.2	2.8	2.9	2.8
n–1	2.7	3.3	3.0	3.5	3.4	3.3
n	3.1	1.4	3.7	0.6	4.2	1.0
Total	20	19	21	19	23	20
E (%)	6		9		13	

Puff n is last puff.
(Puff number decreased with increasing porosity.)
Tobacco rod: 67 mm length, 25 mm circumference.
Cigarette paper porosity: variable.
Filter length: 17 mm.
Film: A, 15 microns thickness.
Tipping perforation: 6.5 mm² (1 row), 4 mm from tobacco/filter junction.
Butt length: 13 mm tobacco + filter length.
Smoking: as in Table 2.

porosity of the paper is increased through the range 90—440 cm³/min/10 cm²/10 cm WG. This is due to the greater volumes of diluting air drawn into the cigarette (hence the decline in smoke deliveries during the early puffs). A possible explanation is that the diluting air does not mix effectively with the smoke, but channels down the periphery of the tobacco rod impinging directly on the film and thus retarding heating of the film. Alternatively, this diluting air may mix with and cool the smoke, thus delaying film shrinkage and filter collapse.

3.1.4 Tobacco Packing Density: The tobacco packing density of flue-cured tobacco was varied over the range 268—375 mg/cm³ (Table 6). This parameter did not affect the E values. This is somewhat surprising, since thermocouple measurements at the mouth-end indicated that the temperature of the smoke is generally higher at lower tobacco packing densities. Nonetheless, measurement of the extent of filter collapse indicated only a slight increase on changing to lower packing density.
To determine whether changing the type of tobacco in the cigarette affects the E values, cigarettes were manufactured to the same dimensions using the same cigarette paper, from both flue-cured and air-cured tobacco. An evaluation of the puff by puff delivery of the cigarettes revealed that changes in tobacco type did not produce changes in E values.

3.2 Effect of Smoking Parameters

3.2.1 Tobacco Butt Length: The effect of a change in the tobacco butt length to which the cigarettes were

Table 6. Effect of tobacco packing density on deliveries and E values.

Puff number	Total particulate matter delivery (mg)					
	Packing density (mg/cm³)					
	268		318		375	
	S_2	S_3	S_2	S_3	S_2	S_3
1, 2, 3 (average)	2.7	2.6	1.9	1.9	1.4	1.3
n–3	3.8	3.6	3.6	3.1	3.2	3.1
n–2	4.2	3.8	3.9	3.8	3.5	3.6
n–1	5.0	3.5	4.4	2.8	4.7	2.1
n	6.3	1.6	6.0	0.8	5.9	1.5
Total	31	23	29	22	32	25
E (%)	24		26		23	

Puff n is last puff.
(n is 8 for density 268 mg/cm³,
n is 10 for density 318 mg/cm³,
n is 12 for density 375 mg/cm³.)
Tobacco rod: 70 mm length, 25 mm circumference.
Cigarette paper porosity: 200 cm³/min/10 cm²/10 cm WG.
Filter length: 20 mm.
Film: B, 15 microns thickness.
Tipping perforation: 6.5 mm² (1 row), 3 mm from tobacco/filter junction.
Butt length: 8 mm tobacco + filter length.
Smoking: as in Table 2.

smoked can be judged from an examination of the Tables. Clearly when the butt length is decreased, the extra puff(s) required become subject to the effects of the ventilating filter. This produces a marked increase in effectiveness because the delivery of TPM increases rapidly as extra puffs are taken on the control cigarette. For example, for one of the cigarettes studied, E values of 9%, 15% and 17% were found for tobacco butt lengths of 13 mm, 10 mm and 7 mm, respectively.

3.2.2 Puff Volume: When the puff volume was increased (without changing the puff duration) the effectiveness of the ventilating filter also increased (Table 7 and Figure 7). This is attributed to the greater

Figure 7. Effect of puff volume.

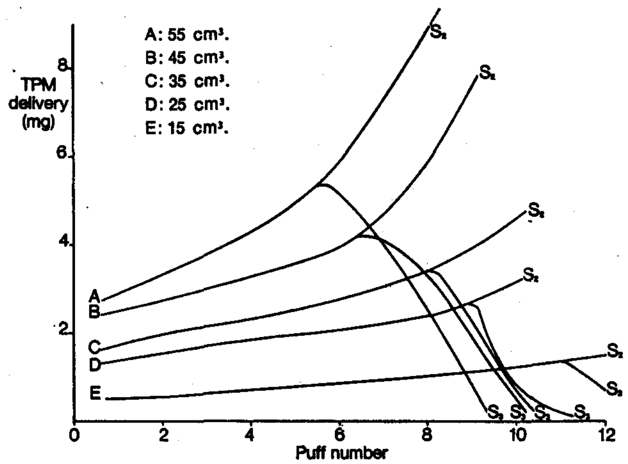


Table 7. Effect of puff volume on deliveries and E values.

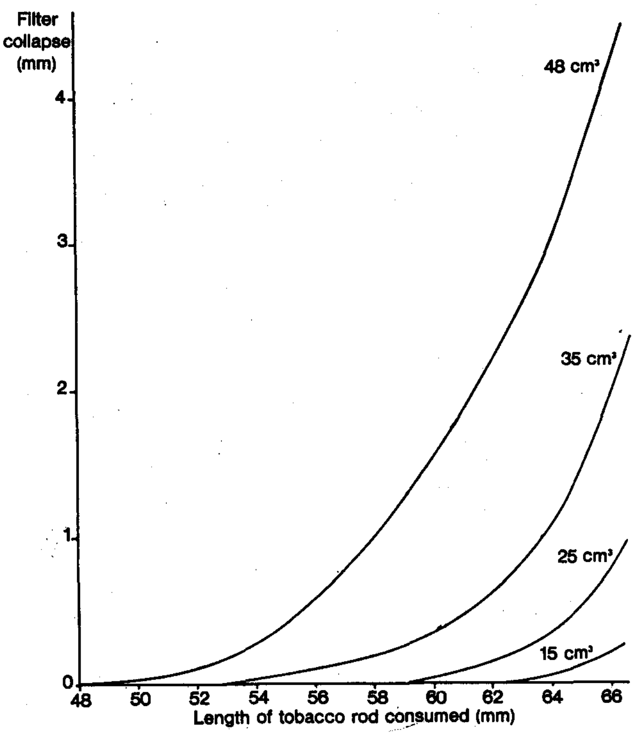
Puff number	Total particulate matter delivery (mg)									
	Puff volume (cm³)									
	15		25		35		45		55	
	S_2	S_3	S_2	S_3	S_2	S_3	S_2	S_3	S_2	S_3
1, 2, 3 (average)	0.7	0.5	1.6	1.5	1.9	1.9	2.8	2.6	3.3	3.2
n−4	1.2	1.0	2.0	2.1	3.0	2.7	3.9	3.8	4.4	4.6
n−3	1.2	1.0	2.3	2.2	3.2	2.8	4.0	4.1	5.2	5.3
n−2	1.4	1.2	2.6	2.6	3.5	3.3	4.7	3.3	5.5	3.7
n−1	1.5	1.4	2.7	0.8	4.4	2.3	6.1	2.2	7.1	3.0
n	1.4	0.7	3.1	0.2	4.5	0.8	7.5	0.7	8.2	1.0
Total puffs (n)	11.7	12.3	10.1	10.8	9.2	10.4	8.9	9.0	8.0	8.7
Total TPM	13	12	22	20	32	26	45	32	60	41
E (%)	8		8		20		29		32	

Tobacco rod: 64 mm length, 25 mm circumference.
Cigarette paper porosity: 200 cm³/min/10 cm²/10 cm WG.
Filter length: 20 mm.
Film: B, 15 microns thickness.
Tipping perforation: 6.5 mm² (1 row), 3 mm from tobacco/filter junction.

Butt length: 8 mm tobacco + filter length.
Smoking:
Puff volume : variable,
Puff duration : 2 s,
Puff frequency : 1 min⁻¹.

quantity of heat generated per puff and the increased flow of smoke through the filter. These changes result in an increase in the rate of transfer of heat from the cigarette coal to the film; consequently, the film shrinks at an earlier stage during smoking. In addition (Figure 8) the extent of filter collapse is increased markedly by puff volume increases.

Figure 8. Effect of puff volume on filter collapse.



3.3 Optimization of Shrink Effect

It has been shown that increases in film shrink tension and degree of shrinkage, filter plasticiser level, tipping paper perforation area and puff volume increased the effectiveness of the ventilating filter. In contrast, increases in film shrink temperature, cigarette paper porosity and tobacco butt length decreased effectiveness.

Samples were prepared, based on these findings, in which the effectiveness of the ventilating filter was optimized subject to the following constraints:

a) Puff volume was the commonly accepted standard (35 cm³).
b) Standard length tobacco rods were used (70 mm).

Table 8. Optimization of shrink effect.

	TPM delivery (mg)	Nicotine delivery (mg)	Carbon monoxide (mg)	Puff number
S_2	35	2.00	24	12.7
S_3	25	1.51	19	13.6
E (%)	30	25	21	–

Tobacco rod: 70 mm length, 25 mm circumference.
Cigarette paper porosity: 80 cm³/min/10 cm²/10 cm WG.
Filter length: 20 mm.
Film: B, 15 microns thickness.
Tipping perforation: 6.5 mm² (1 row), 3 mm from tobacco/filter junction.
Butt length: 4 mm tobacco + filter length.
Smoking: as in Table 2.

c) Films which are not stable at 35° C were excluded. It was found that filter rods prepared using film A decreased in circumference when prolonged exposure at 35° C was assessed. Films B and C were stable under these conditions.

Factors were optimized by choosing film B, high triacetin plasticiser content (10%), highly perforated tipping paper (6.5 mm²/cigarette), low porosity cigarette paper (80 cm³/min/10 cm²/10 cm WG) and short tobacco butt length (4 mm). Under these conditions, a high E value for TPM (30%) is achieved (Table 8). Slightly lower values are found for nicotine (25%) and carbon monoxide (21%). Other smoke constituents are expected to be affected to a similar extent.

SUMMARY

A ventilating filter for cigarettes has been developed which reduces the delivery of smoke constituents from the final two to three puffs. Since the normal delivery for these three puffs can account for up to half the total particulate matter and nicotine delivered by the whole cigarette, useful reductions per cigarette can be produced.

The ventilating filter consists of cellulose acetate tow wrapped in heat-shrinkable film and attached to a tobacco rod using perforated tipping paper. When the cigarette is smoked, the perforations remain closed by contact with the impermeable film until transfer of heat to the filter is sufficient to soften the filter tow and shrink the film. Ventilating air now enters the cigarette and reduces the smoke deliveries.

The effectiveness of the ventilating filter is increased by using films which have a low shrink temperature, high shrink tension and a high degree of biaxial shrinkage. Increases in filter plasticiser level, tipping perforation area and puff volume improve the effectiveness of the ventilating filter but increases in cigarette paper porosity and tobacco butt length reduce the effectiveness.

ZUSAMMENFASSUNG

Es wurde ein Ventilfilter für Cigaretten entwickelt, der die Ausbeute an Rauchinhaltsstoffen der letzten zwei bis drei Züge verringert. Da die Ausbeute dieser drei Züge normalerweise bis zur Hälfte der Gesamtausbeute an Partikelphase und Nikotin der ganzen Cigarette ausmachen kann, können durch den Filter je Cigarette nützliche Reduzierungen erzielt werden.

Der Ventilfilter besteht aus einem Celluloseacetatstrang, der von einer Folienschicht umhüllt ist, die unter Einwirkung von Wärme schrumpft. Mit dem Tabakstrang ist der Filter durch perforiertes Filterumhüllungspapier verbunden. Beim Verrauchen der Cigarette bleibt die Perforation durch die Verbindung mit dem undurchlässigen Film verschlossen, bis auf den Filter so viel Wärme übergegangen ist, daß der Strang weich wird und die Filmschicht schrumpft. Sodann dringt Ventilationsluft in die Cigarette ein und vermindert die Rauchausbeuten.

Die Wirksamkeit des Ventilfilters wird dadurch erhöht, daß Folien verwendet werden, die bei niedrigen Temperaturen schrumpfen, eine hohe Schrumpfspannung haben und bei denen die Schrumpfung in starkem Maße biaxial verläuft. Während eine Erhöhung der Menge an Weichmachern im Filter sowie eine Verstärkung der Perforation des Filterumhüllungspapiers und die Zunahme des Zugvolumens die Wirksamkeit des Filters verbessern, wird diese durch eine Erhöhung der Porosität des Cigarettenpapiers und durch eine Verlängerung des Tabakstummels vermindert.

RESUME

On a développé un filtre ventilé qui réduit la production des constituants de fumée durant les deux ou trois dernières bouffées de la cigarette. Comme la production normale de ces trois dernières bouffées contient jusqu'à la moitié de la matière particulaire totale et de la nicotine de la cigarette toute entière, d'utiles réductions par cigarette ont pu être obtenues.

Le filtre en question se compose d'un boudin en acétate de cellulose, enrobé d'un film thermo-rétrécissable, et attaché au boudin de tabac au moyen de papier d'enveloppement perforé. Quand la cigarette est fumée, les perforations restent fermées par contact avec le film imperméable, jusqu'au moment où le transfert de chaleur au filtre est suffisant pour amollir le bâtonnet-filtre et faire rétrécir le film. L'air entre maintenant par les perforations, et diminue les rendements de la fumée.

On peut augmenter l'efficacité du filtre ventilé en utilisant des films à basse température de rétrécissement et un haut degré de rétrécissement biaxial. Une haute teneur en plastifiant du filtre, une augmentation de la zone perforée et du volume de bouffée augmentent l'efficacité du filtre ventilé, tandis qu'une augmentation de la porosité du papier à cigarette et de la longueur du mégot de tabac en diminue l'efficacité.

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