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BUTT RETENTION OF TARS AND NICOTINE [JAPANESE]

Tomohike Yamaoto

SUMMARY

The filtration coefficients of the butt for dry and wet TPM, and nicotine were investigated in relation to the physical variables of the butt, the burnning length (distance from the butt), and the burnning rate. Results obtained were summarized as follows ;

1) With increasing the packing density and the fractional volume of butt, the filtration coefficients for dry and wet TPM linearly increased. At the same fractional volume, the filtration coefficient was the highest for Buriey cigarette, intermadiate for Domestic (Matsukawa) cigarette, and the lowest for Flue-cured cigarette.

2) In the cellulose model cigarette, a linear relationship was found between the filtration coefficient for dry TPM and the total surface area of the shreds in the butt.

3) The filtration coefficient of butt for dry TPM was nearly constant regarless of the burnning length, while the values for wet TPM and nicotine increased with decreasing the burnning length.

4) Each filtration coefficient for dry and wet TPM, and nicotine increased with increasing the burnning rate of cigarettes.

According to a West German survey (Ref. 1), the average length of cigarette butt attached to the filter discarded by smokers is about 30 mm. In the survey of Jukura et al. (Ref. 2), a value average of approximately 45 mm was obtained. Since the tobacco shred contained in this butt is closer to the smoke than the filter is, it is expected to retain a fair amount of the particulate matter generated by burning.

A logarithmic permeability equation has been established for the particulate matter between the filter retention fraction E and filter length L: $\mu = -1/L \ln(1-E/100)$ (Refs. 3-6). Here, μ is the filtration coefficient which is a value indicating the retentive capacity per unit length of filter. There are fewer practical examples of tobacco shred retention than there are of filters, but filtration coefficients for particulate matter can often be determined by uniform quantity methods (Refs. 7-9). However, the correlations of the type of shred and packing fraction with the tar filtration coefficient of the butt shred have not yet been studied. On the other hand, Lipp has reported on the effect of the type of raw material on filtration coefficients for filter and shred nicotine and phenol as an effect of burning on the retentive action (Refs. 10, 11). The correlation between the butt tar filtration coefficients and burning length and burning velocity of the raw material has not yet been clarified.

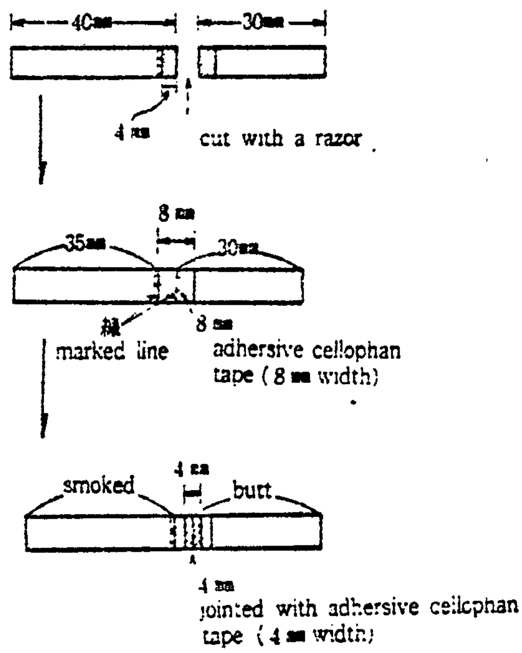

Fig. 1 Procedure to make a joint cigarette

Table 1 Sample cigarettes for the experiment on the relation of physical variables of cigarette to the filtration coefficient

Materials	Range of packing density (g/ml)	Range of cigarette weight (g/cig.)	Apparent density of the shred (g/ml)
Flue-cured cutter-1	0.244~0.373	0.55~1.30	0.786
Burley cutter-1	0.158~0.287	0.55~1.00	0.644
Matsukawa cutter-1	0.144~0.287	0.50~1.00	0.623

Length of cigarette ; 70mm Circumference ; 25mm

The authors previously reported a method of simple, rapid quantification of the water content in the tobacco shred by gas chromatography, which makes possible direct measurement of the amount of tars retained in the butt shred (Ref. 12). This direct method was used in this experiment to study the correlation between physical parameters such as shred surface area and tar filtration constants and, then, the effects of burned length and burning velocity of the raw material tobacco on the filtration coefficients of tar and nicotine in the butt shred.

The quantities of tar and nicotine retained in the butt shred were measured using joined cigarettes produced by the method shown in Figure 1. Specifically, a mark was made 30 mm from one end of the 70 mm cigarettes shown in Table 1 and Table 2. A strip of 8 mm wide cellophane tape was wrapped around on top of this so that the center of it was even with the 30 mm line. Next, the cigarette was separated by cutting the 30 mm line with a razor.

Table 2 Sample cigarette for the experiment to examine the effect of total surface area of shreds, burnning length and rate

Materials	Cigarette weight (mg/cig)	Pressure drop (mmH_2O)
Filter paper (thickness. 0.16mm)	560±10	31.6
	670±10	52.3
	710±10	64.4
Filter paper (thickness. 0.25mm)	580±10	11.3
	670±10	16.0
	730±10	17.7
Flue-cured cutter-1	1000±10	61.7
Burley cutter-1	800±10	49.2

Length of cigarette ; 70mm Circumference ; 25mm

These two separated parts were again joined as originally and the junction wrapped with 44 mm wide cellophane tape to produce a joined cigarette. This 4 mm wide cellphane tape was wrapped around once and a length of several mm was left hanging down so that it would be easy to remove after smoking. In addition to the fact that the weight of the 30 mm long butt (including cellophane tape) is easily measured using this method, it is also possible to test cigarettes in which the burning portion and butt portion are of different raw materials. The samples were kept at a temperature of 22°C and a relative humidity of 60%; they were then smoked intermittently by a constant flow automatic smoking device at one puff/min, 35 ml/2 sec, until the burning length had reached 35 mm. The weight difference of the 30 mm butt before and after smoking was taken as the crude tar retention. The amount of tar retained was found by subtracting the water content weight gain of the butt shred due to smoking from this value. The water content of the butt shred was found by the previously reported GC method (Ref. 12). The tar in the primary smoke was found by the official method and the nicotine in the butt and primary smoke by the official distillation methods. The cigarette packing fraction ($1-\varepsilon$) was calculated from the $1-\varepsilon = W/V\rho$ equation. Here, W and V are the weight and volume of the cigarette, respectively. Therefore, W/V is the packing density. ρ is the shred apparent density measured by the oil immersion method (Ref. 13) of Masuo et al.

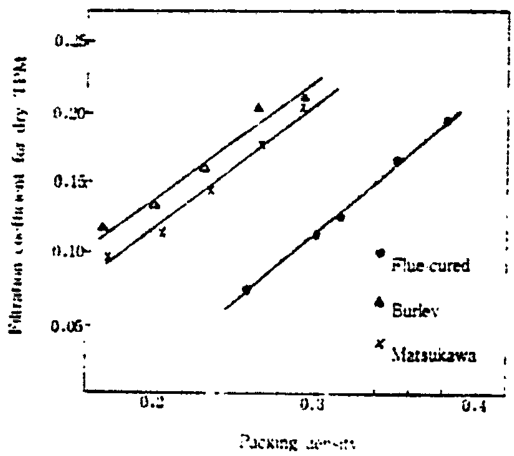

Fig. 2 Relationship between the filtration coefficients of the butt for dry TPM and the packing density

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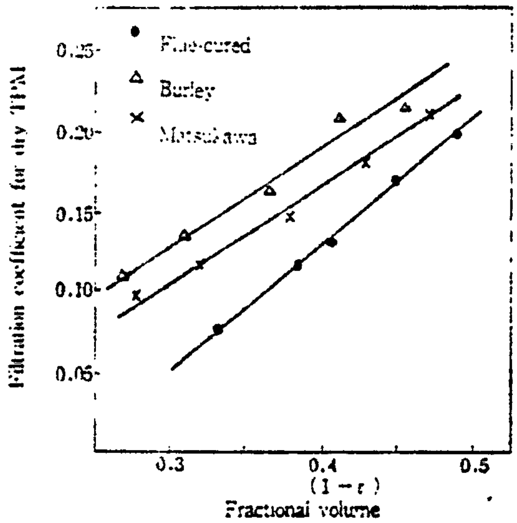

Fig. 3 Relationship between the fractional volume and the filtration coefficients for dry TPM

As shown in Figures 2 and 3, the tar filtration coefficient of the butt increased linearly with the packing density and packing fraction magnitudes. When the filtration coefficients of three different raw material shreds were compared at the same packing fraction, Burley gave the highest value, followed by Matsukawa for the flue-cured. The correlation between the crude tar filtration coefficient and packing fraction is shown in Figure 4. The values for the filtration coefficients of different raw materials compared at the same packing fraction were on the same order as those of tars when plotted on straight lines passing thorugh the origin.

However, even at the same packing fraction, the total surface area of the shred in the butt differs according to the shape of the shred. Generally, the filtration phenomenon is held to be controlled by condensation of the vapor phase or dispersion and direct obstruction of the particulate phase or adsorption of particles on the shred surface by inertial impact, etc. (Refs. 14-16). Therefore, the following experiment was conducted, believing that the filtration coefficient of the butt shred is directly correlated with the total surface area of the shred in the butt. Using filter paper as shred since its surface area can be determined more accurately than that of tobacco shred, model filter paper cigarettes were prepared in uniform length (1 cm) and width (0.8 mm) with shred of differing thickness as the base. The number of shreds was determined from the unit area weight of the filter paper and the weight of the filter paper shred in the butt. The total surface area of the shred contained in the butt was calculated taking each individual shred as a rectangle.

The tar filtration coefficient of the butt shred (filter paper), as shown in Figure 5, correlated directly with the packing fraction and depended on the thickness of the shred. When we examined the correlation between this filtration coefficient and the total shred surface area in the butt, a linear correlation was obtained between them, as shown in Figure 6. From the above results, the dependence of the butt tar filtration coefficient

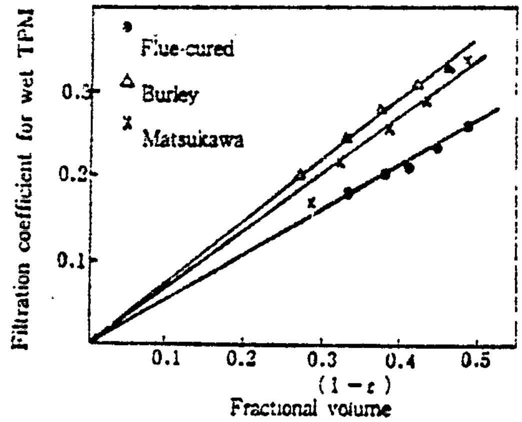

Fig. 4 Relationship between the fractional volume and the filtration coefficients for wet TPM

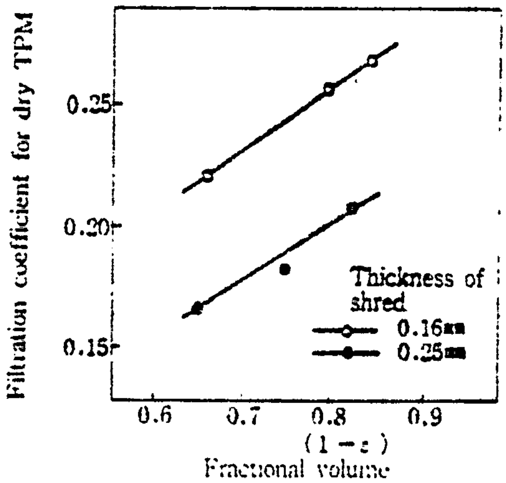

Fig. 5 Relationship between the fractional volume and the filtration coefficents for dry TPM in the celluiose model cigarette

on the type of shred and packing fraction (Figs. 2, 3) is an analogy for the differences in total shred surface area in the butt which originate in the thickness of the raw material tobacco and packing quantity.

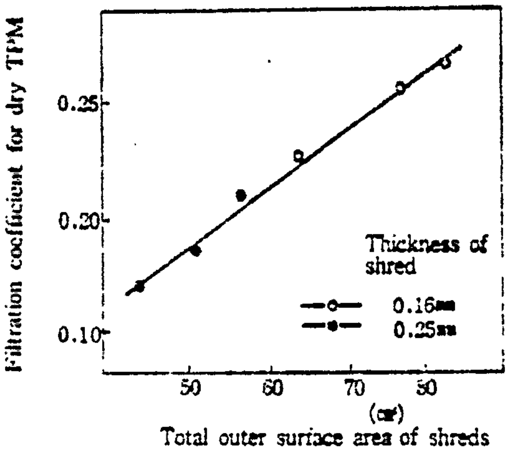

Fig. 6 Relationship between the total outer surface area of shreds and the filtration coefficient for dry TPM in the cellulose model cigarette

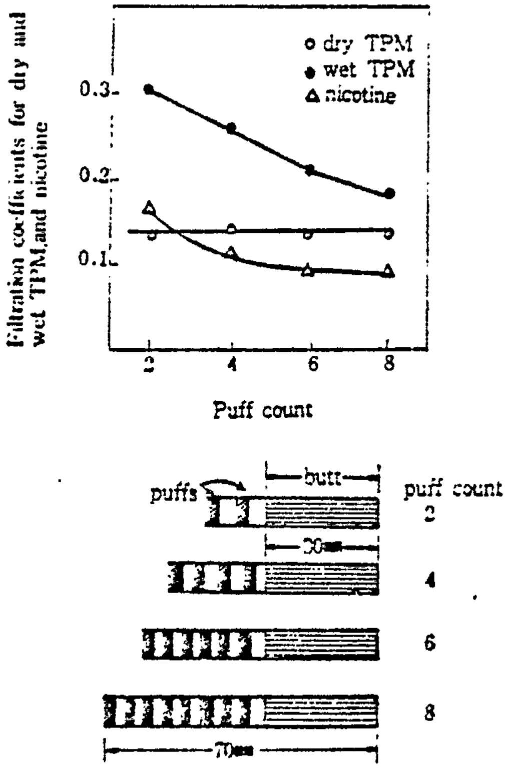

Fig. 7 The effect of burnning length on the filtration coefficients of butt for dry and wet TPM, and nicotine in the Flue-cured cigarette

Figure 7 shows the changes in butt shred filtration coefficients for tar, crude tar and nicotine when the burning length during intermittent puffing of a flue-cured cigarette was varied. According to this, the tar filtration coefficient of the butt shred is basically constant, even when the burning length changes. On the other hand, the filtration coefficients of crude tar and nicotine increase as the burning length drops. The nicotine filtration coefficient of the portion close to the butt became larger than the tar filtration coefficient when puffed twice. The nicotine which migrates to the smoke during puffing combustion is a so-called semivolatile substance which is present in both the vapor and particulate phases (Ref. 15). Also, during puffing, the gas temperature of the inside of the cigarette drops to less than 100°C 10-20 mm from the burning cone (Refs. 17, 18). Therefore, part of the water content and nicotine in vapor form in the smoke generated during puffing combustion is condensed rapidly on the shred, with the result that the nicotine and crude tar filtration coefficients near the butt during puffing are high. In contrast to this, since tar retention is believed to be due to filtration of smoke particles, the filtration coefficient arrived at by the previously discussed logarithmic permeation equation is uniform, regardless of the burning length.

The number of puffs shown in Table 3 is the number of intermittent smoking puffs required to burn a 35 mm length of cigarette under the above combustion conditions. This represents the burning velocity of the raw material. As can be seen in this table, the filtration coefficients of flue-cured and filter paper shred butts for tar, crude tar and nicotine all increased as the cigarette puff count decreased, i.e., as the raw material burning velocity

Table 3 The effects of burning rate on the retention and filtration coefficients for dry and wet TPM, and nicotine

Shreds of butts (30mm)	Shreds of burning rods (40mm)	Puff count	Retention (%) wet TPM	Retention (%) dry TPM	Retention (%) nicotine	Filtration coefficient wet TPM	Filtration coefficient dry TPM	Filtration coefficient nicotine
Flue-cured	Flue-cured	8.0	48.5	33.5	23.8	0.221	0.136	0.091
	Buley	5.0	52.6	43.5	38.7	0.249	0.190	0.163
	Filter paper A	4.8	54.3	48.4	—	0.261	0.221	—
	Filter paper B	3.0	59.8	51.3	—	0.303	0.240	—
Filter paper	Flue-cured	8.0	45.3	39.5	38.5	0.201	0.167	0.162
	Burley	5.0	48.7	44.7	43.9	0.222	0.197	0.192
	Filter paper C	4.0	53.4	53.7	—	0.253	0.256	—
	Filtes paper B	3.0	61.6	55.3	—	0.319	0.268	—

		Thickness	Amount of potasium added
Filter paper	A	0.25mm	0.2%
	B	0.16mm	1.0%
	C	0.16mm	0.2%

Potassium nitrate was added to the filter paper as burn additive by the method reported previously[19]

increased. Jenkins recently reported that the retention of TPM (crude tars) derived from Burley raw material in the leaf composition on the butt shred was larger than that of flue-cured raw material of the same leaf composition (Ref. 19). This does not contradict the results of the present experiment.

The reason that the tar retention rate increases under identical butt shred physical properties is believed to be that comparatively many readily condensed components are contained in the smoke. The properties of the smoke thus derive from differences in the components of the raw material tobacco. However, as shown in Table 3, tar retention increased as the burning velocity increased even in filter paper shred, the components of which differ greatly from those of tobacco. Therefore, the raw material burning velocity under uniform puffing conditions can be regarded as one controlling factor for the smoke properties related to tar retention.

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