EFFECT OF SMOKING PARAMETERS ON THE TEMPERATURE IN CIGARETTE FILTERS DURING SMOKING

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SUMMARY

In this study, the filter temperature was measured for cellulose acetate and carbon filtered cigarettes during smoking using a thermocouple probe. The probe tip was inserted 5 and 20 mm from the filter end and cigarettes were smoked under the following regimes: ISO (35 mL/60 sec/0 % vent block), Massachusetts (45 mL/30 sec/50 % vent block), WG9 Option B (60 mL/30 sec/50 % vent block), and Canadian Intense (55 mL/30 sec/100 % vent block). Under ISO smoking, temperature rises were only detected for the last two puffs (last 15 % of the cigarette burnt), while much higher filter temperatures (up to 95 °C) were measured when cigarettes were smoked under more intense conditions over a greater percentage of the cigarette burnt, particularly the Canadian intense regime. This significant temperature rise was observed for low tar products in particular when smoked under intense conditions.

INTRODUCTION

Filter design is a major tool to modify the filtration efficiency for cigarette smoke. Adsorption of smoke constituents in carbon containing filters is likely to be influenced by the temperature generated in the filter during smoking. Our work with carbon filtered cigarettes smoked under more intense conditions than ISO has shown that vapour phase compounds were not only adsorbed but also partly desorbed from the carbon filter. This behaviour was probably due to the high temperatures these filters experienced during both puffing and smouldering under intense smoking conditions.

For this study, the temperature inside the filter was measured for cellulose acetate and carbon filtered cigarettes during smoking using a thermocouple probe inserted into the filter. The maximum temperatures during smoking under different regimes were recorded in order to estimate the likeliness of thermal desorption of vapour phase compounds.

EXPERIMENTAL

1. Temperature Measurement during Smoking

Test cigarettes were conditioned according to ISO and smoked on a one-port smoking machine (Borgwaldt RM 1). Prior to smoking, the tip of a thermocouple probe (ALMEMO® 2290-4 with NiCr-Ni sensor ZA 9020 FS) was inserted 5 and 20 mm from the mouth end into the centre of the filter. During smoking, the minimum and maximum temperature was

recorded for each puff (just before and about 2 seconds after the respective puff). Two independent replicate measurements were performed for each sample.

2. Studied Material

The following American blended test cigarettes were investigated:

- Cellulose acetate (CA) mono filter – 83.7 % filter ventilation, 1 mg tar/cig (ISO). Filter length: 25 mm, rod length 58 mm.
- 'Dalmatian'/CA double filter – cigarette with active carbon granules; 83.8 % filter ventilation, 1 mg tar/cig (ISO). Filter length: 25 mm, rod length 58 mm.
- Activated carbon paper/CA double filter – filter cigarette with carbon containing paper; 79.9 % filter ventilation, 1 mg tar/cig (ISO). Filter length: 25 mm, rod length 68 mm.
- CA/'Dalmatian'/CA triple filter – cigarette with active carbon granules; 40.1 % filter ventilation, 6.3 mg tar/cig (ISO). Filter length: 25 mm, rod length 58 mm.

More detailed information on the filter construction is given in Figure 1.

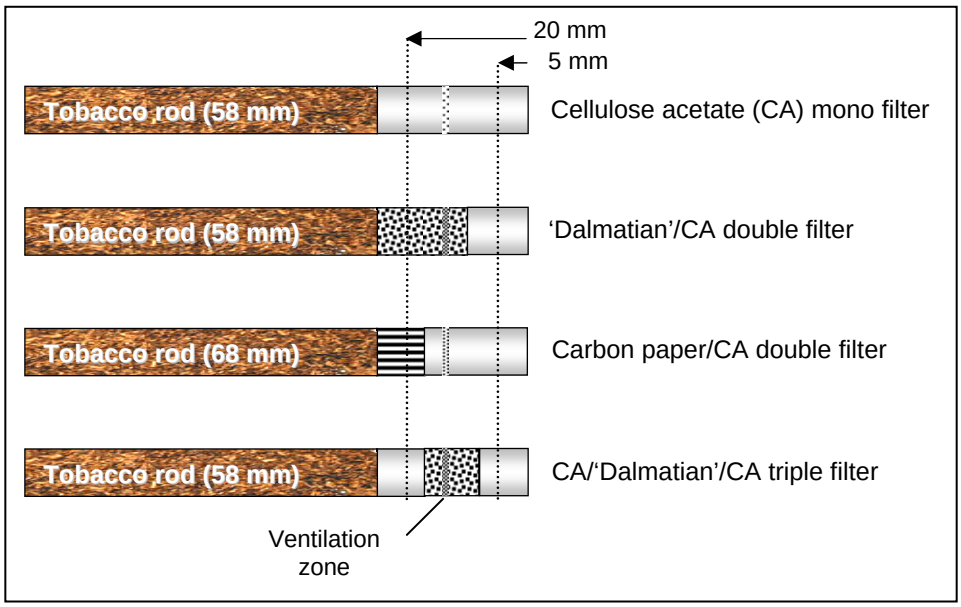

Figure 1: Design of test cigarettes. Temperature measurements were performed 5 and 20 mm from the mouth end of cigarettes.

3. Smoking Regimes

Test cigarettes were smoked according to ISO, Massachusetts, WG9 Option B, and Canadian Intense regime. Smoking parameters are summarised in Table 1.

Table 1: Smoking regimes applied for temperature measurements.

Smoking regime	Puff volume [mL]	Puff frequency [sec]	Puff duration [sec]	Vent blocking [%]
ISO	35	60	2	0
Massachusetts (MASS)	45	30	2	50
WG9 Option B	60	30	2	50
Canadian Intense (CI)	55	30	2	100

RESULTS AND DISCUSSION

Cellulose acetate (CA) mono filter

Results of temperature measurements in CA mono filter during the course of puffing are shown in Figure 2 and 3. Puff numbers were normalised to the percent of cigarette burnt down to the butt length so that data from all replicates could be plotted in the same figure.

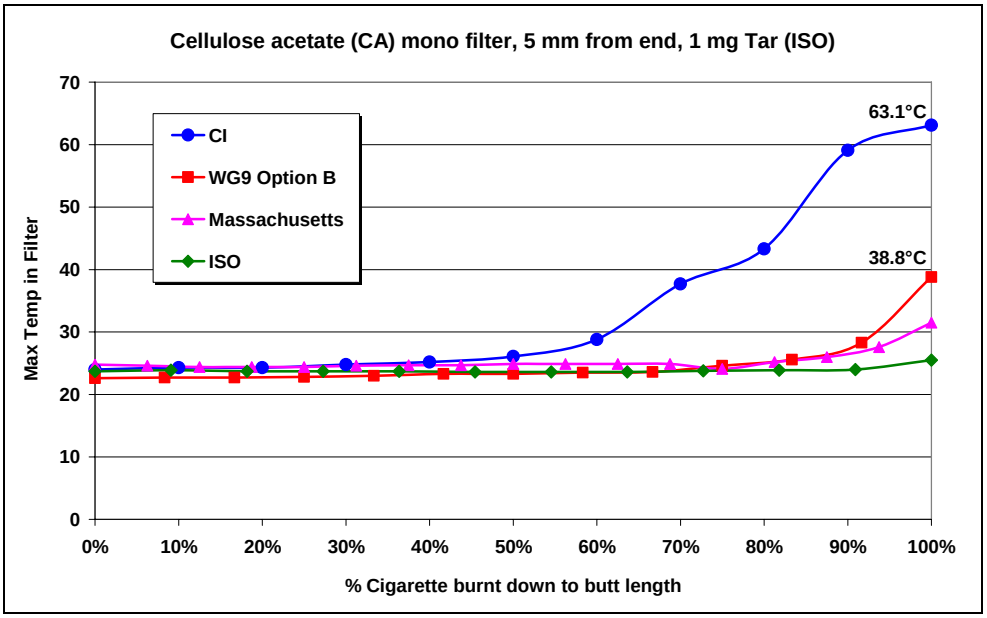

Figure 2: Maximum temperature measured in CA filter, 5 mm from mouth end.

Figure 2 shows the maximum temperature during smoking with the thermocouple situated 5 mm from the mouth end. For the CI regime, significant temperature increase was observed when 50 % of the cigarette was burnt resulting in a final temperature of 63 °C. For the other smoking regimes, temperature increase was observed for the last two puffs when 90 % of cigarette was burnt. The results of this work indicate a lower temperature profile and a lower final temperature (39 °C) for WG9 Option B than for CI regime even with the larger 60 mL puff volume. This is due to the diluting air through the ventilation holes that cools the smoke even at 50 % vent blocking. Even though the two most intense regimes produce similar tar yields, there are distinct temperature differences during smoking.

Figure 3 shows that the temperature profiles measured 20 mm from the mouth end are generally higher than in Figure 2. For the CI regime, temperature increase was observed from the second puff on resulting in a final temperature of 95 °C. For ISO, temperature effects were only observed for the last puff (final temperature 50 °C).

Measurements in Figure 3 were performed nearer to the tobacco rod before the ventilation holes and thus, a cooling effect by diluting air is not observed.

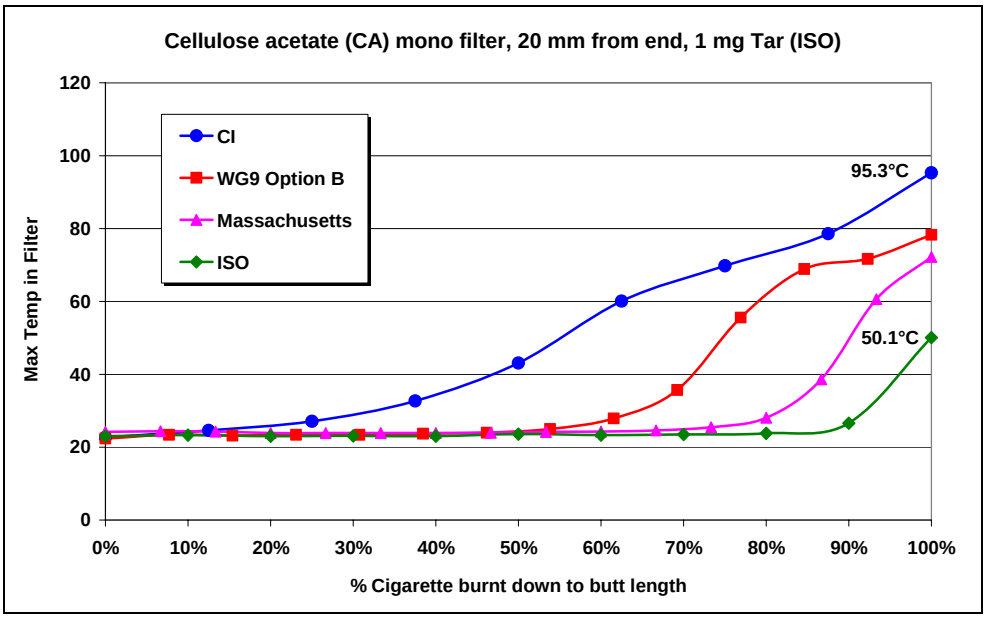

Figure 3: Maximum temperature measured in CA filter, 20 mm from mouth end.

'Dalmatian' active carbon/CA double filter

For the 'Dalmatian' type filter containing activated carbon, temperatures were recorded inside the carbon section (20 mm from mouth end) during smoking according to ISO and CI regime (Figure 4).

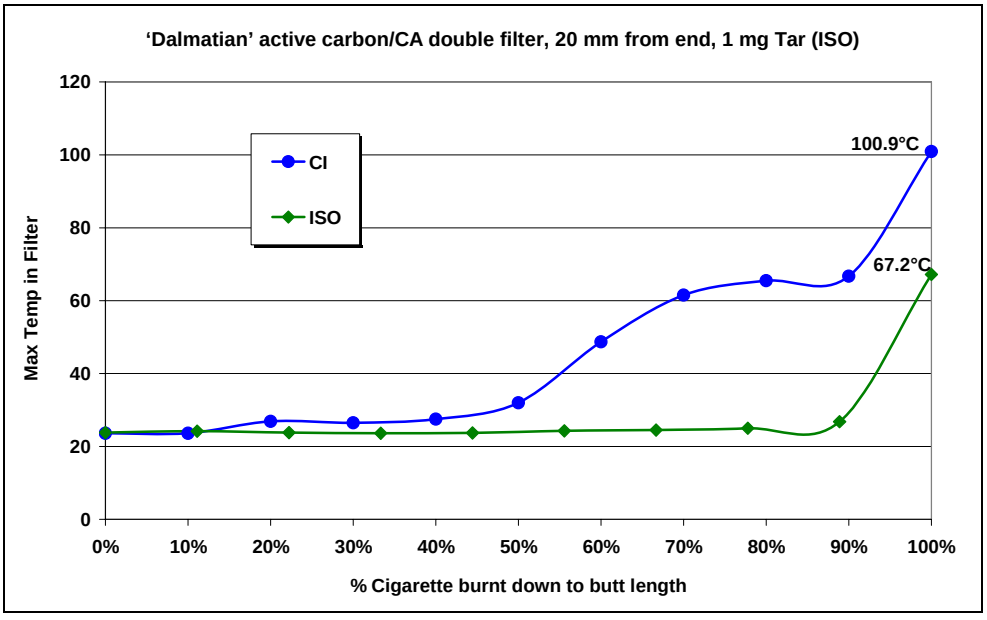

Figure 4: Maximum temperature measured in 'Dalmatian' type carbon filter, 20 mm from mouth end.

Temperature profiles look similar to CA mono filter (Figure 3) but final temperatures tend to be significantly higher for carbon filtered cigarettes (67 °C for ISO, 101 °C for CI regime).

Higher temperatures for carbon filters compared to CA were also observed by other authors. The temperature increase observed for carbon filters might be explained by the lower heat capacity of carbon compared to CA [1].
This work shows that inordinately high filter temperatures are observed for the CI regime with 100 % vent blocking during puffing and smouldering. Such observations have previously been made by other workers [1].

Carbon paper/CA double filter

For the carbon paper/CA double filter, temperatures were recorded in the CA part (5 mm from mouth end, Figure 5) and inside the carbon paper section (20 mm, Figure 6).

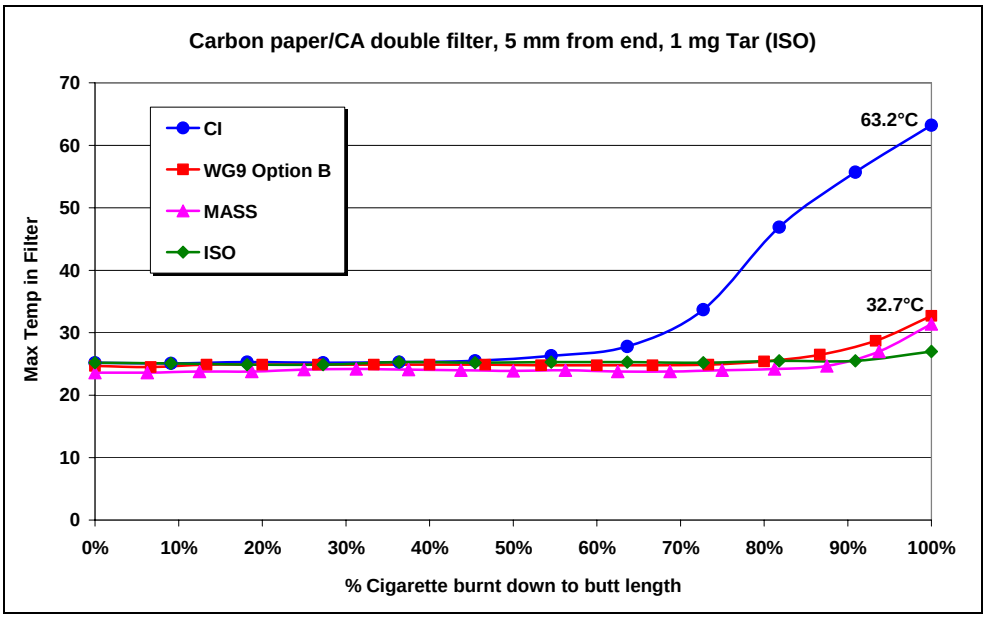

Figure 5: Maximum temp. measured in carbon paper/CA filter, 5 mm from mouth end.

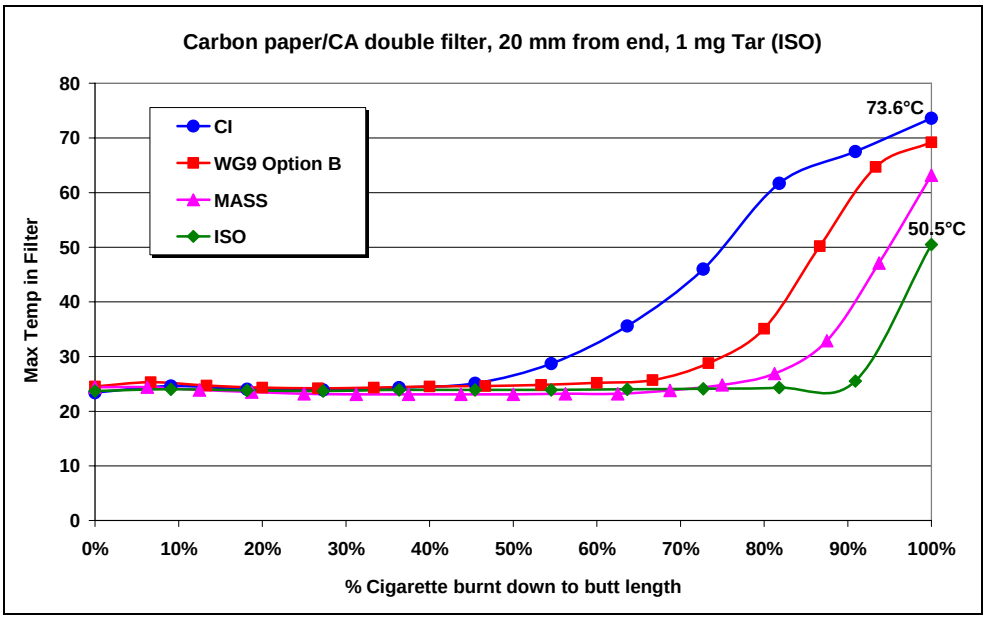

Figure 6: Maximum temp. measured in carbon paper/CA filter, 20 mm from mouth end.

For the CA part (5 mm from mouth end), temperature profiles and final temperatures (63 °C for CI, 33 °C for WG9 Option B) are very similar to the CA mono filter (Figure 2). This observation also applies to the carbon paper section (20 mm from end) which could be an indication for comparable heat capacities of CA and the carbon paper used in this cigarette filter.

CA/'Dalmatian' carbon/CA triple filter

The CA/'Dalmatian'/CA triple filtered cigarette with active carbon granules yields 6.3 mg tar/cig under ISO conditions. Compared to the low tar products described before (filter ventilation around 80 %), the filter ventilation of this test cigarette is only 40.1 % to reach the 6.3 mg tar level. In case of 50 % vent blocking (WG9 Option B, Massachusetts regime), the amount of diluting air through the ventilation holes is lower compared to low tar products and the cooling effect is less distinct during smoking. This effect is reflected by the temperatures measured in the CA sections of the carbon filter (Figure 7, 8).

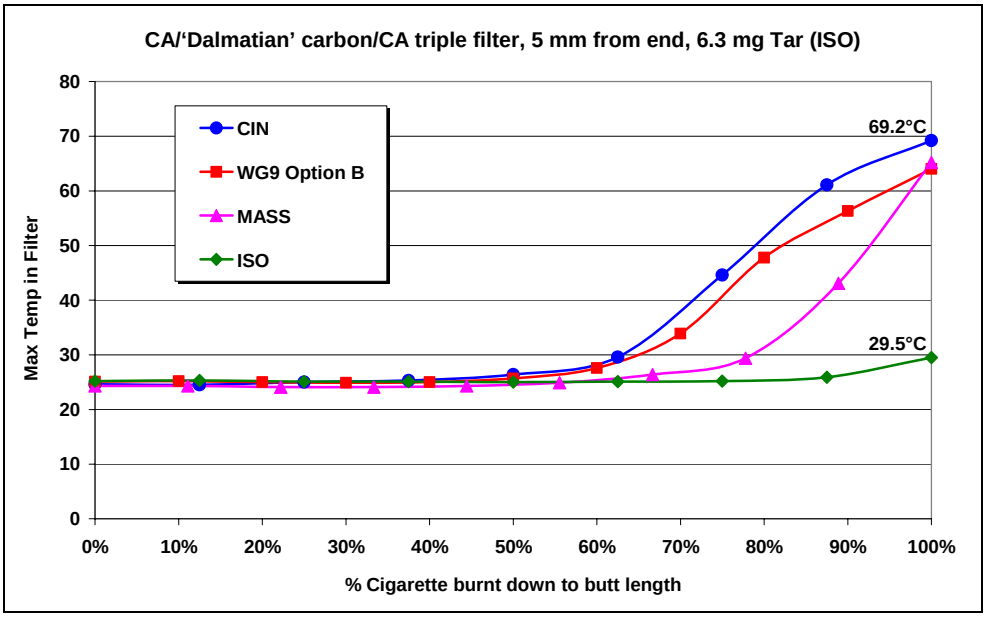

Figure 7: Maximum temperature measured in CA/'Dalmatian' carbon/CA triple filter, 5 mm from mouth end.

For ISO and CI regime, the temperature profiles and final temperatures are similar to those of the CA mono filter described before for either measuring position (5 mm and 20 mm from mouth end).

For WG9 Option B and Massachusetts regime (50 % vent blocking), temperature profiles at 5 mm from the end tend to be similar to CI regime which is due to the less distinct cooling effect compared to low tar products with higher filter ventilation (Figure 7).

Measurements in Figure 8 were performed close to the tobacco rod before the ventilation holes and a cooling effect by diluting air is not observed.

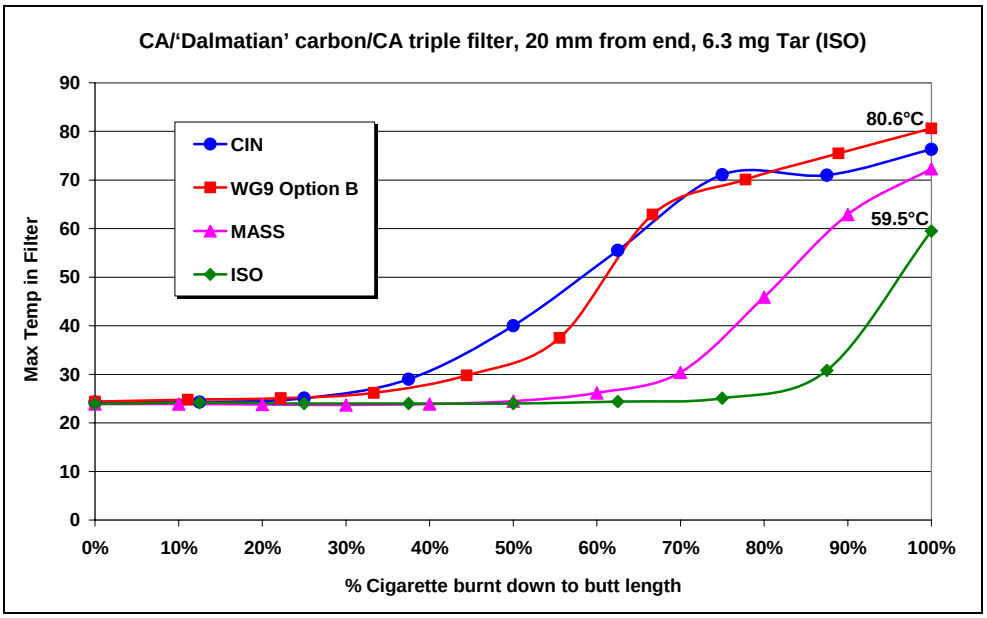

Figure 8: Maximum temperature measured in CA/'Dalmatian' carbon/CA triple filter, 20 mm from mouth end.

CONCLUSIONS

As shown in other studies [3], vapour phase compounds are not only adsorbed but also partly desorbed from cigarette filters containing activated carbon, particularly at elevated temperature. The results of this study clearly demonstrate that carbon filters might experience temperatures as high as 100 °C during smoking under Canadian Intense conditions, and thermal desorption of vapour phase compounds seems to be very likely to occur at these inordinately high temperatures.

Temperatures observed under Canadian Intense conditions with 100 % vent blocking seem to be unrealistic high to describe real "in use" smoking conditions.

REFERENCES

[1] C. Zha, R. Robertson, J. Lockhart, H. Coburn: „*Temperature Profile of Cigarette Filter with Different Designs*", Paper presented at 60th TSRC, Montréal, Canada (2006).

[2] H. Borowski, F. Seehofer: „*Temperaturverlauf des Hauptrauches im Cigaretten-stummel während des Rauchens*", Beiträge zur Tabakforschung 9, 329-333 (1962).

[3] B. Teillet, X. Cahours, S. Purkis: „*Investigation of filter temperatures and desorption of volatiles from carbon filters under different smoking regimes*", Paper SSPT02 presented at CORESTA Joint Study Groups Meeting, Aix-en-Provence, France (2009).