Further investigations of temperatures and adsorption / desorption of volatile compounds in carbon filters under different smoking regimes

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Abstract

Previous work reported in Coresta in 2010 on "7 mg ISO tar" cigarettes containing an activated carbon filter had shown a significant removal of volatiles in mainstream smoke under ISO smoking. This work had also shown that high filter temperatures associated with the Canadian intense (CI) regime lead to a significant desorption of volatiles from carbon leading to an increase of mainstream smoke yield.

This study investigated filter temperatures and volatile retention under the ISO, Massachusetts, WG9 option B (WG9B) and CI smoking regimes. Temperatures were measured in the middle of the carbon section. Smoke temperatures passing through the filter, were highest for the CI and lowest for the ISO smoking regime.

Thermal desorption / gas chromatography / mass spectrometry analysis was used to monitor the relative distribution of volatiles between those adsorbed on the filter and those in the mainstream vapour phase according to the smoking regime. The experimental set-up was designed to evaluate the temperature effect on this relative distribution. A first experiment analysed the volatiles during smoking when placing the carbon section within the cigarette filter. A second experiment excluded the increase of temperature by placing the carbon section external to the filter and maintained at ambient temperature. The comparison of the resulting volatile distribution between those adsorbed in the filter and those delivered to mainstream smoke vapour phase allowed an estimation of the impact of temperature on the retention of volatiles.

In comparison with ISO and CI regimes, the other regimes induce intermediate filter temperatures and intermediate reduction of carbon filter efficiency even though puff volumes are higher in the case of the WG9B than the CI regime, showing that partial ventilation blocking still allows filter cooling. Additionally, carbon filters are a well known technology to reduce vapour phase yield under ISO smoking but for the most volatile compounds this tends to decrease during more intensive smoking especially under the CI regime.

Introduction

Background : Previous work on carbon filter adsorption/desorption had shown a loss of carbon efficiency under Canadian Intense (CI) smoking regime versus ISO smoking regime : increase of filter temperature had been pointed out as a major contributing factor. Experimental set-ups with and without temperature effect have been validated to depict the filter temperature impact on carbon filter efficiency.

Aim : This study investigates the **impact of filter temperature on carbon filter efficiency under Massachusetts (MASS) and WG9 option B (WG9B) smoking regimes** (Table I).

Additionally, the comparison with ISO and CI is also discussed

	ISO	MASS	WG9B	CI
Puff volume *(ml)*	35	45	60	55
Puff duration *(sec)*	2	2	2	2
Puff frequency *(sec)*	60	30	30	30
Vent blocking	No	Yes at 50%	Yes at 50%	Yes at 100%

Table I : Smoking parameters : ISO, MASS, WG9B and CI

Filter Temperature Measurements

Experimental conditions : *A 7 mg ISO tar commercial cigarette (filter vent 38%) was modified by addition of 50 mg of carbon after the filter ventilation holes. Three replicates were smoked on a smoking machine (D87 DFC Sodim instrument). A resistor based temperature sensor wire Type K was introduced into the axial and longitudinal middle of the carbon section of the filter and the temperatures recorded every 50ms.*

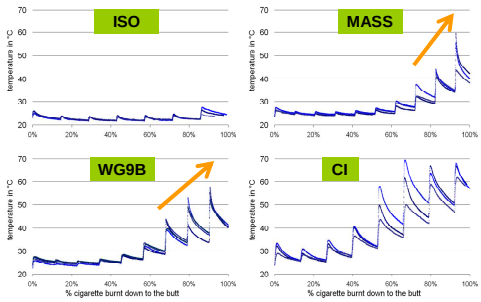

Figure 1: Filter temperatures under ISO, MASS, WG9B and CI

Figure 1 shows temperature graph obtained under MASS and WG9B in comparison with ISO and CI.

➔ **MASS and WG9B** smoking regimes: filter temperatures **significantly increase during the last 3 puffs** with a **maximum temperature achieved at 60°C** .

Both regimes induce low temperature, like ISO, during 70% of the smoking period.

Filter heating is restricted to the last 3 puffs, the partial ventilation blocking still allowed significant filter cooling even with higher puff volume (WG9B).

Temperature effect on carbon filter efficiency

Experimental

Three replicates*, using one carbon modified cigarette per replicate, were smoked on a KC Automation 5-port smoker (KC-SM5-B, Richmond) under each smoking regime and each experiment.*

Two experiments were carried out*. The first experiment was described as the condition* ***"With-temperature effect"*** *(Figure 2). The second experiment was described as the condition* ***"Without-temperature effect"*** *(Figure 3).*

13 volatiles compounds were monitored *in the carbon section and vapour phase : 1,3-butadiene, Isoprene, Acrylonitrile, Benzene, Acetaldehyde, Propionaldehyde, Acetone, Isobutyraldehyde, Butyraldehyde, Methyl Ethyl Ketone (MEK), Crotonaldehyde, Toluene and Styrene.*
Acrolein (lack of specificity), Formaldehyde (highly reactive compound) and lower molecular weight compounds (not detectable) were excluded due to method limitations.

Analysis were performed by Thermal desorption Gas Chromatography Analysis *(Gerstel/Agilent system). The sample tube was heated for total desorption at 350°C for 5 min. Separation was achieved using a RTX VMS column. Detection was in multi ion monitoring acquisition.*

Results *gave the area response for each compound from the total desorption of the filter or the vapour phase trap. For each compound and each replicate,* ***the relative distribution filter/vapour phase*** *was calculated (100% corresponding to the sum of filter + vapour phase allowing comparison of different smoking regimes). Compounds have been ranked by their volatility in decreasing order from the left to the right side on the X axis.*

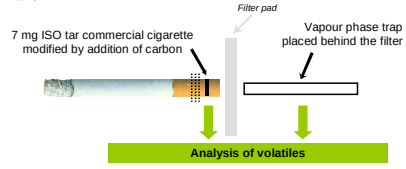

Figure 2 : Set-up With Temperature Effect

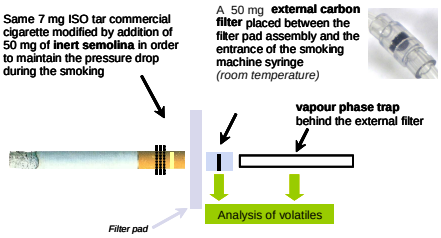

Figure 3 : Set-up Without Temperature Effect

Relative distribution of volatiles between carbon filter and vapour phase
Comparison with and without the temperature effect

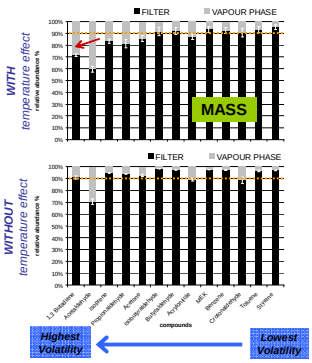

Figure 4 : Massachusetts smoking regime

Massachusetts smoking regime (Fig 4): Slight decrease of carbon filter adsorption, around 20% for the highest volatile 1,3-butadiene and lower than 10% for the other compounds

WG9 option B smoking regime (Fig 5): Temperature effect was more marked 30% for 1,3-butadiene, 20% for isoprene and propionaldehyde, 15% for acetaldehyde and acetone, less than 10% for the other compounds.

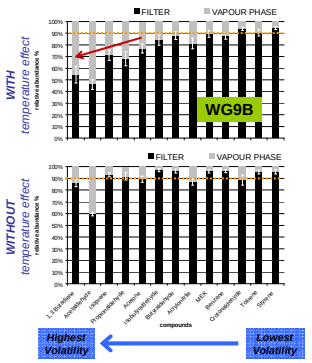

Figure 5: WG9 option B smoking regime

ISO, MASS, WG9B and CI
Comparison with the temperature effect

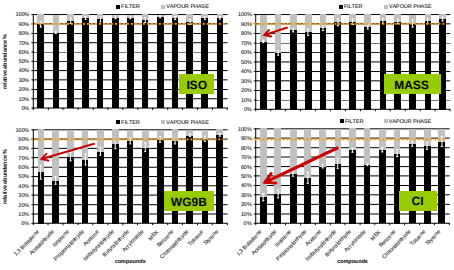

Figure 6: volatiles distribution ***with*** *the temperature effect: ISO, Massachusetts, WG9 Option B and Canadian Intense smoking regimes.*

Conclusion

Carbon filter temperatures are **less critical under Massachusetts and WG9 Option B** smoking regime than Canadian Intense. **Partial ventilation blocking still allows filter cooling.**

Carbon filter **maintains at least 50% of its efficiency under these two regimes** even with higher puff volume : it is less than ISO but more than Canadian Intense.

If regulators focus on 1,3-butadiene and if the Canadian Intense smoking regime is used, carbon filter may not be an effective solution to reduce its level.

The **efficiency of carbon to remove the compounds with the highest volatility is smoking regime dependent due to temperature effect. Canadian Intense reduces drastically its efficiency by modifying the cigarette design with full ventilation blocking.**