Investigation of filter temperatures and desorption of volatiles from carbon filters under different smoking regimes.

B. Teillet, X. Cahours and S. Purkis
Background

- Previous work carried out by C. Mueller
  
  *Poster SSPT21*
  
  - Loss of efficiency of carbon filter for the retention of volatiles in the last puffs during Canadian Intense (CI) smoking regime
  - Higher filter temperature in the last puffs

  ➔ Hypothesis: thermal desorption from the carbon filter might occur during CI and may not in ISO
From ISO to CI Smoking regimes

- Smoking parameters CI versus ISO

<table>
<thead>
<tr>
<th></th>
<th>ISO</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puff volume</td>
<td>35 ml</td>
<td>55 ml</td>
</tr>
<tr>
<td>Puff duration</td>
<td>2 sec</td>
<td>2 sec</td>
</tr>
<tr>
<td>Puff flow rate</td>
<td>1,05 L/min</td>
<td>1,65 L/min</td>
</tr>
<tr>
<td>Puff frequency</td>
<td>60 sec</td>
<td>30 sec</td>
</tr>
<tr>
<td>Vent blocking</td>
<td>No</td>
<td>Yes 100%</td>
</tr>
</tbody>
</table>

Higher filter load
Higher flow rate
Higher filter temperature

Experimental design focused on temperature effects but additional phenomena to be taken into consideration
1. Evaluation of filter temperature

2. Volatiles distribution between filter and vapour phase with the filter temperature effect

3. Volatiles distribution between filter and vapour phase without the filter temperature effect

4. Impact of filter temperature effect on the filter/vapour phase distribution
Evaluation of filter temperature: experimental

A 7 mg ISO tar commercial cigarette (filter vent 38%) modified by addition of 50 mg of carbon after the filter ventilation holes

Temperature measurement

Experimental conditions
Probe in the middle of carbon section (axial and longitudinal)
Linear smoking machine equipped with a digital recorder (Sodim)
acquisition period 50 msec
3 replicates
Evaluation of filter temperature: ISO smoking

ISO Smoking regime:
- Slight increase during each puff
- Maximum temperature 27°C in the last puff
Evaluation of filter temperature: Canadian Intense smoking

CI Smoking regime
High increase during whole smoking period
Maximum temperature: 70°C in the last puffs
Evaluation of filter temperature: Summary

Differences in filter temperature according to the smoking regimes

- **ISO**
  - Constant
  - Slight increase only in the last puff
  - Maximum temperature $\Rightarrow 27^\circ$C

- **Canadian Intense**
  - High increase during the whole smoking period
  - Maximum temperature $\Rightarrow 70^\circ$C
Filter/vapour phase volatiles distribution with the filter temperature effect

Experimental

7 mg ISO tar commercial cigarette modified by addition of carbon

Vapour phase trap placed behind the filter pad

Analysis focus on 13 volatiles compounds

**VOC** : 1,3-butadiene; Isoprene; Acrylonitrile; Benzene.

**Carbonyls** : Acetaldehyde, Propionaldehyde, Acetone, Isobutyraldehyde, Butyraldehyde, Methyl Ethyl Ketone (MEK), Crotonaldehyde.

**Semi-volatiles** : Toluene, Styrene.

**Method limitation**: *Acrolein* excluded (lack of specificity), *Formaldehyde* excluded (highly reactive compound), *Lower molecular weight* compounds excluded (not detectable)
Filter/vapour phase volatiles distribution with the filter temperature effect

Volatile analysis

Thermal desorption Gas Chromatography Analysis (TDS-GC/MS)

**Experimental conditions**: TDS-GC/MS Gerstel/Agilent system, RTX VMS column - multi ion monitoring acquisition -
**Total desorption**: 350°C for 5 min - 3 replicates
Filter/vapour phase volatiles distribution with the filter temperature effect

Results expression

Thermal desorption Gas Chromatography Analysis (TDS-GC/MS)

**Results**: Area response for each compound from the total desorption of the filter or the vapour phase trap

**Expression**: 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.
Filter/vapour phase volatiles distribution with the filter temperature effect

ISO smoking regime
Filter/vapour phase volatiles distribution with the filter temperature effect

CI smoking regime

![Bar chart showing relative abundance of various compounds in filter and vapour phase with highest and lowest volatility indicated.](chart.png)
Filter/vapour phase volatiles distribution without the filter temperature effect

Experimental

Same 7 mg ISO tar commercial cigarette modified by addition of 50 mg of inert semolina in order to maintain the pressure drop during the smoking.

An 50 mg external carbon filter placed between the filter pad assembly and the entrance of the smoking machine syringe (temperature checked: room temperature).

Filter pad

vapour phase trap behind the external filter

Analysis of volatiles
Filter/vapour phase volatiles distribution with the filter temperature effect

ISO smoking regime

![Graph showing filter/vapour phase volatiles distribution with the filter temperature effect.](image-url)
Filter/vapour phase volatiles distribution without the filter temperature effect

CI smoking regime

Relative abundance %

compounds

1,3 Butadiene Acetaldehyde Isoprene Propionaldehyde Acetone Isobutyraldehyde Butyraldehyde Acrylonitrile MEK Benzenetetraldehyde Toluene Styrene
ISO smoking with/without filter temperature effect: summary

No major difference among volatiles distribution between filter and vapour phase with or without temperature effect in ISO.

Temperature profile showed low temperature during the whole smoking period.

→ No temperature effect on carbon filter efficiency in ISO.
Slight differences between the maximum filter relative abundance (Cambridge filter pad in front of the external filter: filter load difference)

Huge differences between the filter relative abundance for the highest volatility compounds.

Temperature profile showed high temperature during the whole smoking period.

Temperature effect on carbon filter efficiency suspected in CI.

Further investigations: Desorption estimation by TDS-GC/MS
Filter temperature effect on volatiles distribution: CI experimental

7 mg ISO tar commercial cigarette modified by addition of **semolina**

**TDS-GC/MS Analysis in 2 steps**

1. **Vapour phase trap**  
   **Analysis**

2. **external carbon filter**

**TDS** until maximum occurring temperature
60°C/min up to 70°C during 6 sec

**full desorption**
350°C 5 min
Impact of filter temperature effect on the filter/vapour phase distribution CI desorption simulation

- Desorption loss
- Filter: 45%
- Desorption: 15%
- Vapour phase: <10%

Compounds:
- 1,3 Butadiene
- Acetaldehyde
- Isoprene
- Propionaldehyde
- Acetone
- Isobutyraldehyde
- Butyraldehyde
- Acrylonitrile
- MEK
- Benzene
- Crotonaldehyde
- Toluene
- Styrene

Relative abundance %

Negligible desorption loss
CI smoking with filter temperature effect /TDS simulation: summary

Relative abundance of volatiles in the filter after desorption simulation in a good agreement with CI including temperature effect

Hypothesis:

Thermal desorption of volatiles from the filter to the vapour phase due to temperature effect

Higher temperature involved thermal desorption for the highest volatility compounds
Investigation of filter temperatures and desorption of volatiles from carbon filters under different smoking regimes.

Summary

Canadian intense regime involves higher temperatures than the ISO.

In comparison with ISO an additional phenomena occurs related to temperature effect. It could drastically reduce carbon filtration power for the highest volatility compounds.

Thermal desorption estimation shows reduction in carbon filter efficiency depending of the compounds from 45% to more than less 10%.

Hypothetically, it might be a combination of both desorption and loss of adsorption due to filter temperature.

Blocking 100% filter ventilation does not allow the smoke cooling effect during the Canadian intense smoking period. However, the Canadian regime may not well represent human smoking conditions.
Thank you for your attention