ISO/TC 126/WG 10
Intense smoking regime
E-mail of Secretary: colinahill@aol.com
Secretariat: BSI

Presentation S Purkis - Influence of cigarette designs and smoking regimes on vapour phase yields

Date of document	2008-10-09
Expected action	Info

Background

Presentation from Mr Steve Purkis at the 3rd meeting of ISO/TC 126/WG 10 on 2008-10-08 in Berlin

Influence of Cigarette Designs and Smoking Regimes on Vapour Phase Yields

Steve Purkis
and
C. Mueller, M.Intorp and H.Seidel

Background

- Made matched carbon-filtered and cellulose acetate-filtered cigarettes
  - Designed as “1mg and 13mg tar” under ISO smoking
  - Smoked under ISO, Massachusetts and Canadian regimes
  - Measured per-cigarette and per-puff yields of 12 vapour phase components
  - Measured smoke temperatures passing through filter
- Estimated vapour phase yields generated at the coal
- Estimated yield reductions caused by
  - rod ventilation and rod diffusion
  - filter ventilation
  - (carbon) filter adsorption
- Used data to address issues relevant to WG10

Product Descriptions

- Details of product specifications are given in the paper
- 1mg and 13mg (ISO) tar yielding products were studied
  - Either with cellulose acetate filters or carbon filters
    - 85mg of carbon was incorporated within a section of cellulose acetate material within a dual filter
  - Other design features were similar
  - Main differences were that 1mg products had 84% filter ventilation and 13mg products were unventilated

Smoking regime parameters

Smoking Regime	Puff Volume (ml)	Puff Frequency (seconds)	Puff Duration (seconds)	Ventilation Blocking %
ISO	35	60	2	0
MA	45	30	2	50
CI	55	30	2	100

VP yields from the 2nd puff

Obtained under CI smoking regime

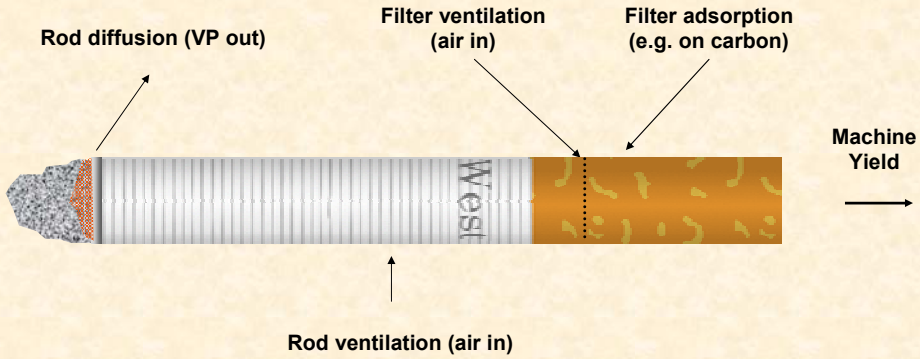
Vapour Phase Components µg / 2nd puff of per-puff profile	13mg – Cellulose Acetate (CA) filter	13mg – Carbon filter	% Reduction	1mg – Cellulose Acetate (CA) filter	1mg – Carbon filter	% Reduction
Butadiene	11.3	9.2	18	15.4	11.3	27
Isoprene	63. 8	37.5	41	111.5	39.3	65
Acetaldehyde	138.8	99.8	28	178.0	103.9	43
Acetone	52.1	23.1	55	62.5	21.3	66
Acrolein	11.9	5.4	55	17.2	5.4	69
Methanol	33.0	14.6	55	42.9	16.9	61
Benzene	8.76	3.2	64	11.8	3.2	73
Acrylonitrile	3.5	1.3	64	5.5	1.4	75
Acetonitrile	15.7	7.6	51	22.3	7.3	67
Hydrogen cyanide	22.3	15.1	32	44.4	15.9	64
Toluene	15.3	4.2	73	18.8	3.8	80
Styrene	1.5	0.4	73	1.5	0.1	96
Total Vapour Phase	377.7	221.5	41	531.8	229.6	57

Selective Reductions in Vapour Phase

Yields of smoke components are generally reduced by filter and rod ventilation, faster paper burn rate and lower tobacco density

Selective reduction of particulate phase is done by filtration in the filter

Reduction of vapour phase is limited to the following parameters and selective reduction (compared to the particulate phase) is limited to adsorption and diffusion



Reductions in Vapour Phase

- relative to those given by an unventilated cellulose acetate filtered product

Smoke generated at coal before reductions by filter and rod features - Yield reduction by rod ventilation & diffusion - Yield reduction by filter ventilation - Yield reduction by carbon filter adsorption = Machine Yield

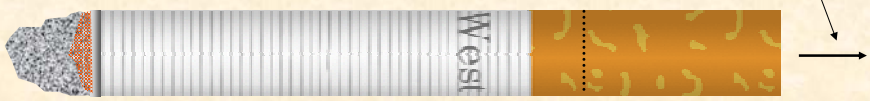
Reductions in Vapour Phase
General Approach

Cellulose acetate-filtered product made with matched design versus a carbon-filtered product in all other respects

Yield reduction by carbon filter adsorption

Machine Yield

measured



Yield reduction by carbon adsorption = Measured Yield of cellulose acetate filtered product – Measured Yield of carbon filtered product

Reductions in Vapour Phase General Approach

Filter ventilation levels were measured

Smoke yield reductions were estimated versus an unventilated product

Yield reduction by filter ventilation

Yield in an unventilated product	=	Machine Yield	X	100 / (100-FV)

FV = % Filter ventilation

Yield reduction by ventilation	=	Yield of unventilated product	–	Yield of ventilated product

Reductions in Vapour Phase General Approach

Smoke generated at coal before reductions by filter and rod features

The yield of the last "cut-off" puff yield is minimally affected by rod effects (rod ventilation and rod diffusion)

Smoke generated at the coal can be estimated from last puff adjusted to 0% ventilation

Smoke generated at the coal	=	Yield in last puff	X	Puff Number	X	100 / (100-FV)

FV = % Filter ventilation

Reductions in Vapour Phase General Approach

Yield reduction by rod effects = Yield generated at the coal – Yield reduction by filter effects

Yield reduction by rod ventilation & diffusion

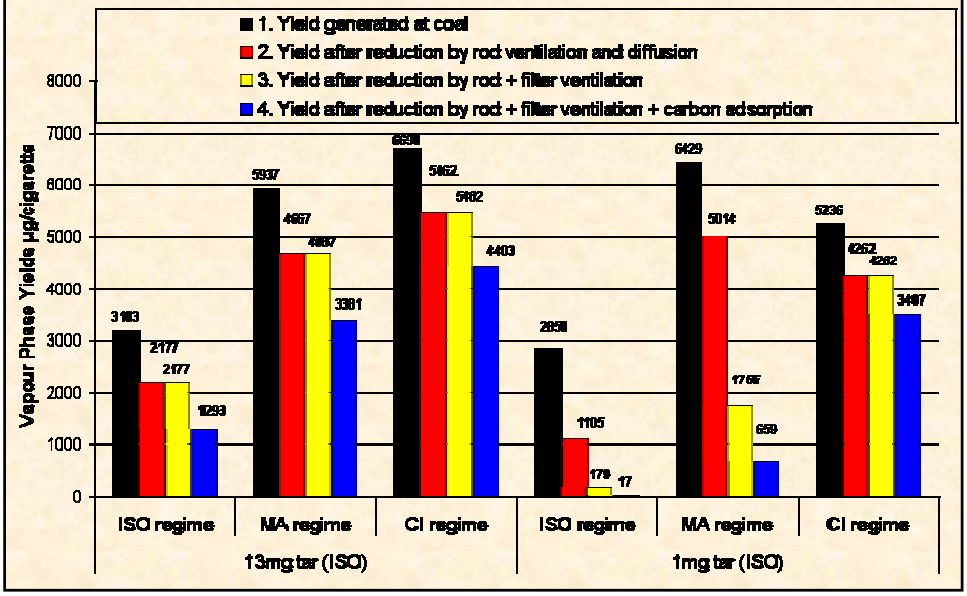
Rod Effects

- Rod Ventilation
- Rod Diffusion
- Pyrolysis of condensed tar in the rod

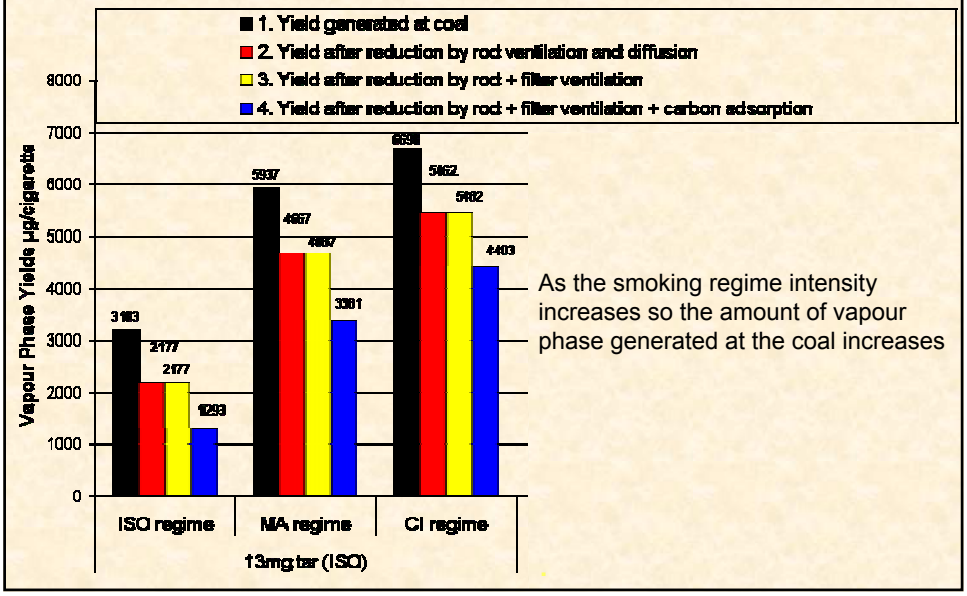
Condensation / re-pyrolysis does not appear to have a major effect on yields

Rod diffusion, in addition to rod ventilation, plays a significant role in vapour phase reduction especially when smoking at lower flow rates

Yield reductions by various cigarette design features



Yield reductions by various cigarette design features



As the smoking regime intensity increases so the amount of vapour phase generated at the coal increases

VP concentrations per ml smoke generated at the coal

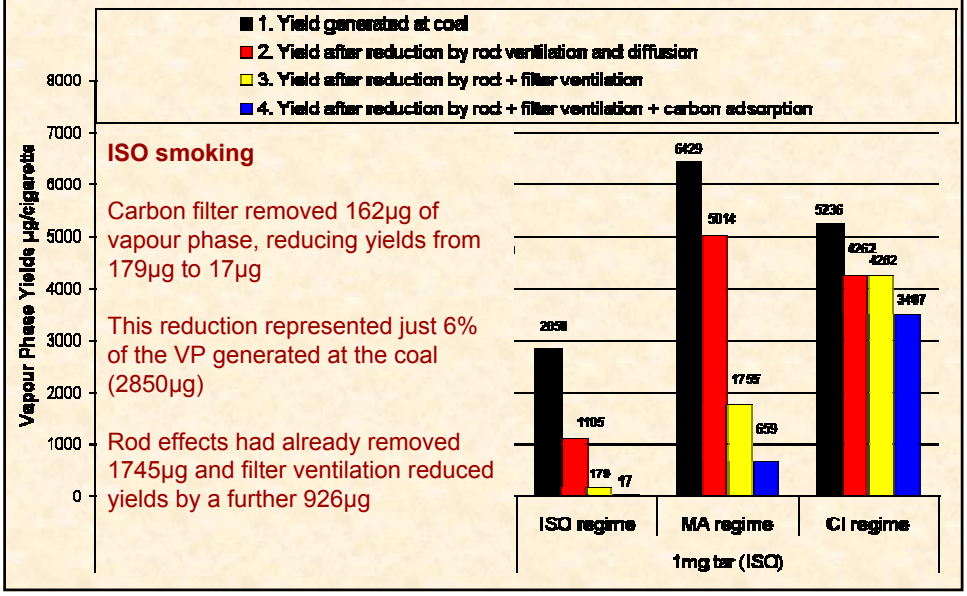
Regime	Puff Volume (ml)	Total VP from 13mg NFDPM CA-filtered products	
		VP yield for last "cut-off" puff (µg)	VP concentration at coal (µg/ml)
ISO	35	393	11.2
MA	45	519	11.5
CI	55	649	11.8

SIMILAR VALUES

VP concentration at coal = VP yield for last puff / (puff volume)

The volume of air passing over the coal is directly related to the generation and smoke concentration of these VP compounds.

Yield reductions by various cigarette design features



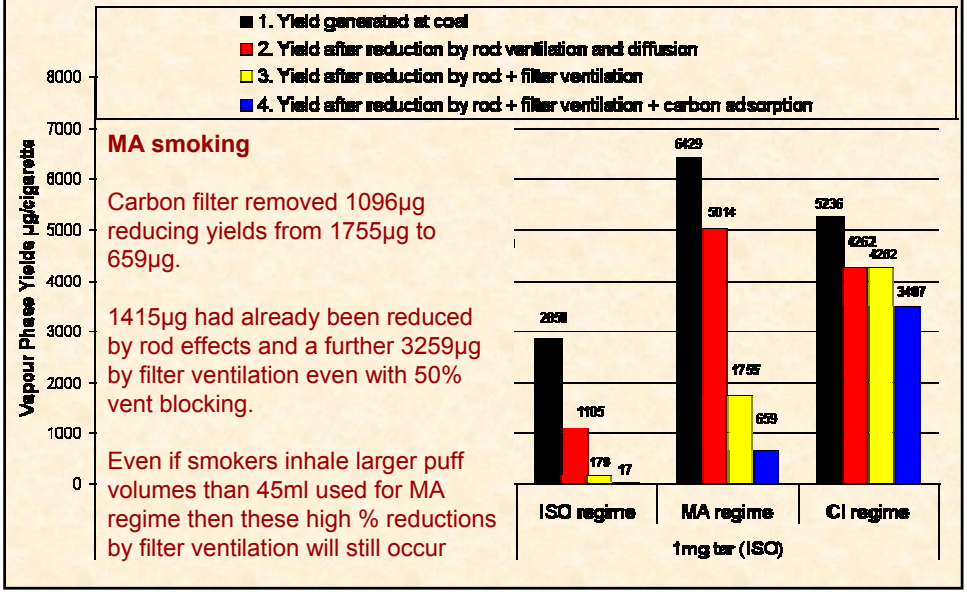
ISO smoking

Carbon filter removed 162µg of vapour phase, reducing yields from 179µg to 17µg

This reduction represented just 6% of the VP generated at the coal (2850µg)

Rod effects had already removed 1745µg and filter ventilation reduced yields by a further 926µg

Yield reductions by various cigarette design features



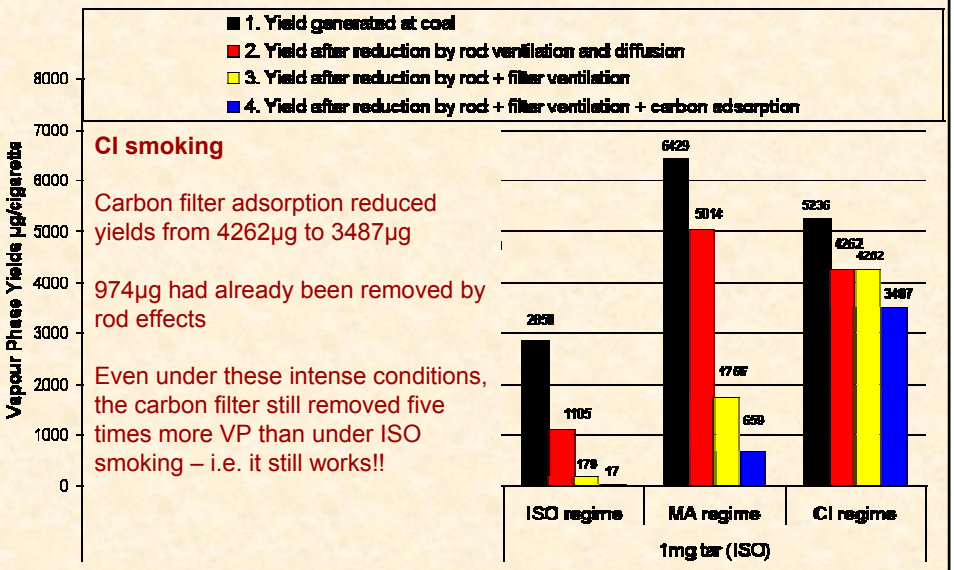
MA smoking

Carbon filter removed 1096µg reducing yields from 1755µg to 659µg.

1415µg had already been reduced by rod effects and a further 3259µg by filter ventilation even with 50% vent blocking.

Even if smokers inhale larger puff volumes than 45ml used for MA regime then these high % reductions by filter ventilation will still occur

Yield reductions by various cigarette design features



CI smoking

Carbon filter adsorption reduced yields from 4262µg to 3487µg

974µg had already been removed by rod effects

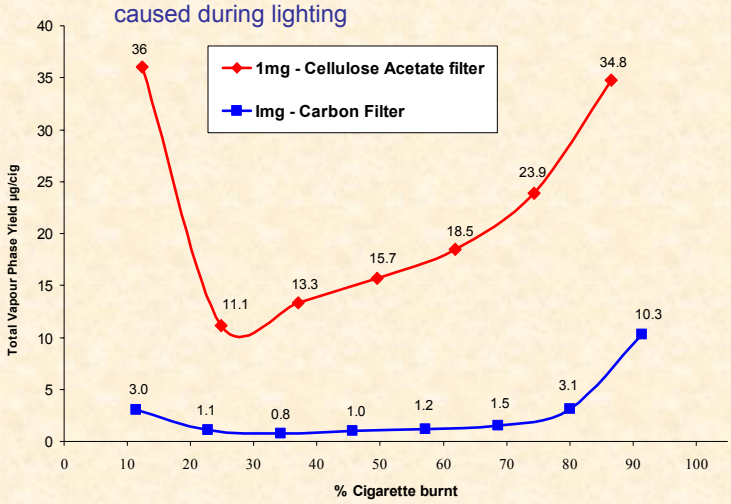
Even under these intense conditions, the carbon filter still removed five times more VP than under ISO smoking – i.e. it still works!!

Summary of yield reductions by various cigarette design features

- Main differences seen between 13mg and 1mg products caused by ventilation
- Copious amounts of VP are formed at the coal in 1mg and 13mg products
- Substantial reductions are made by ventilation – e.g. 51% under MA smoking
- Reductions by rod effects lessen in relative terms and remain at similar levels in absolute terms as the flow rate through the coal increases under intense smoking
- Carbon filters remove substantially more VP under intense smoking than under ISO smoking

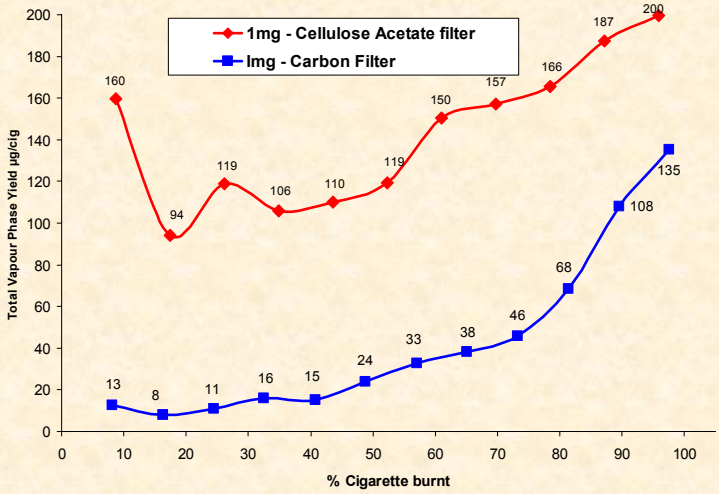
Per-puff ISO smoking

High yield in first puff
caused during lighting



For the 1mg carbon-filtered product, the carbon filter removed 164µg of VP in a very efficient manner during each puff.

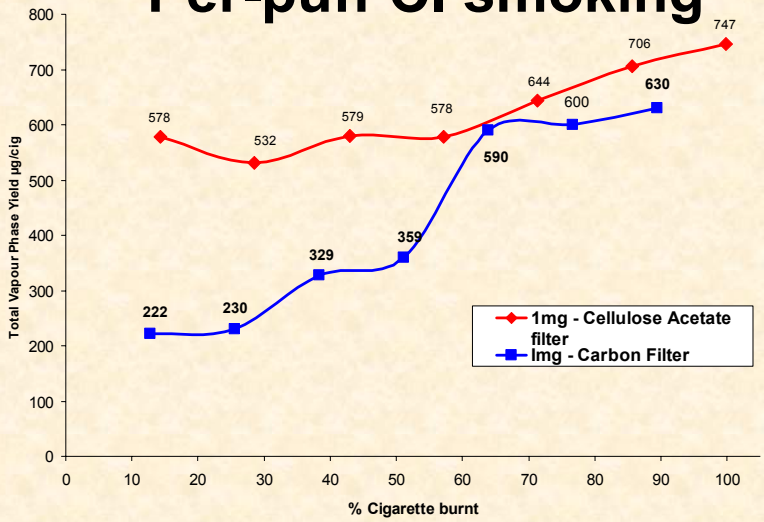
Per-puff MA smoking



The carbon filter removed 1096µg vapour phase with some convergence of the two per-puff profiles.

Note: The decline of carbon filter adsorption in the later puffs is indicated by convergence of the two yield profiles.

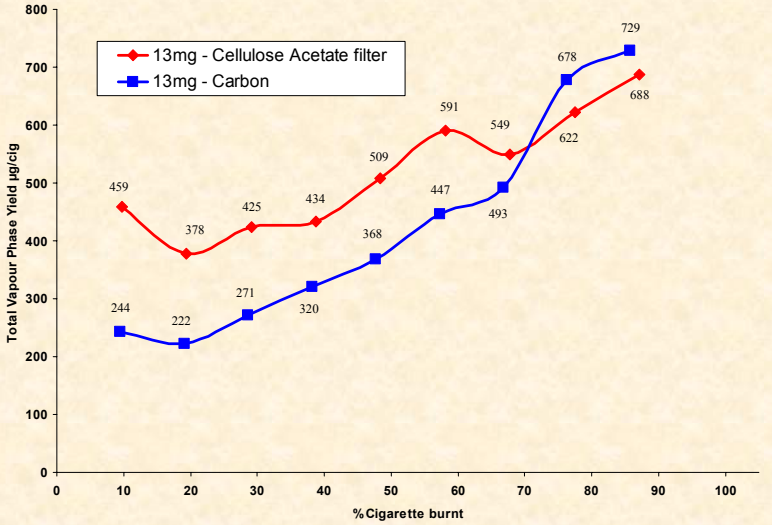
Per-puff CI smoking



The carbon filter removed 1129µg and a fairly constant amount of VP per-puff over the first 4 puffs (first 50%).

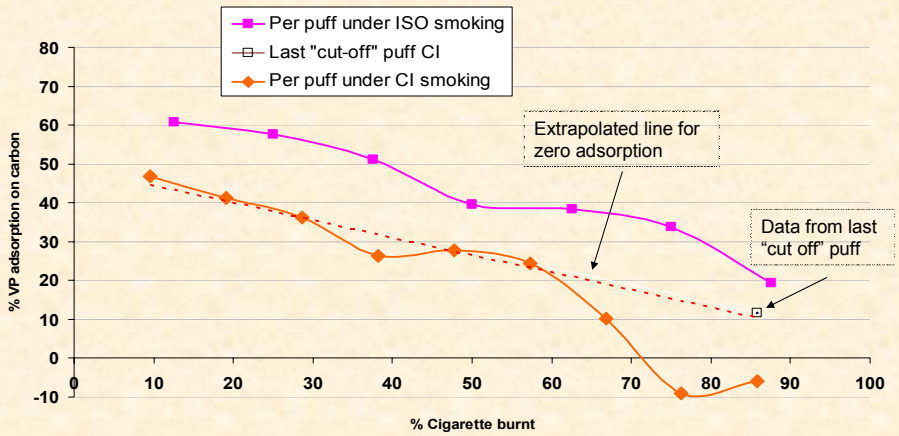
Then the two per-puff profiles tended to converge suggesting a loss of carbon activity …….. or some other reason?

Vapour Phase Desorption from Carbon in 13mg products



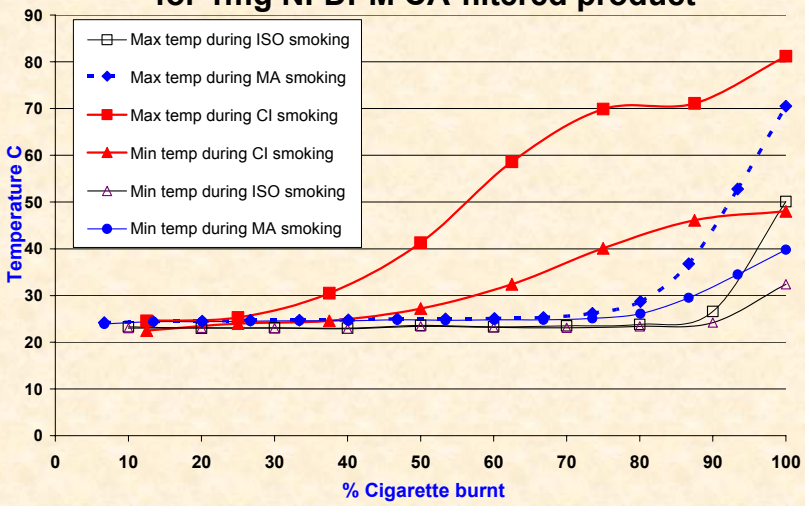
Per puff profiles crossed over for the 13mg product smoked under CI smoking

Vapour Phase Desorption from Carbon in 13mg products



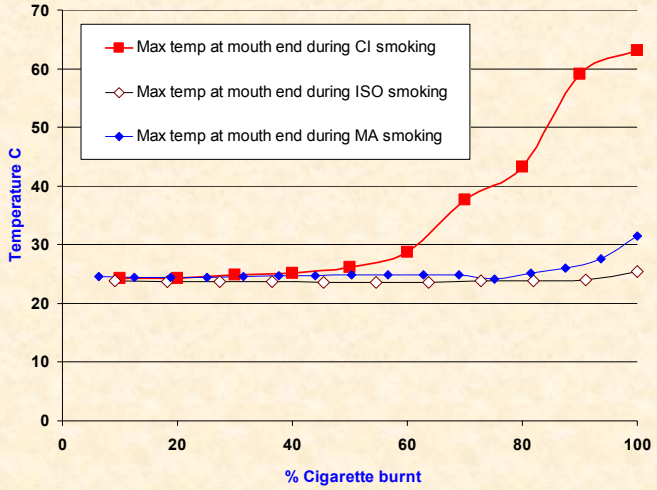
- The percentage of VP adsorbed within the carbon filters compared to VP machine yield of CA filtered products are shown
- It demonstrates carbon desorption in the later puffs.
- This desorption is in contrast to the VP adsorption in the last "cut off" puff where no VP had previously adsorbed on to the carbon.

Carbon Section Temperature Profile for 1mg NFDPM CA-filtered product



- High temperature of smoke passing through filter during CI versus ISO or MA smoking – during both puffing (max) and smoulder (min) period
- High temperature will decrease carbon filter adsorption efficiency (laws of physics)

Mouth End Temperature Profile for 1mg NFDPM CA-filtered product



If such high temperatures >60^{0}C in last few puffs were evident during human smoking then they would probably not be tolerated by smokers

... and human puffing behaviour would accordingly change!!

Comparison of total VP yields under CI smoking made from cigarettes with "used" filters attached

Product	Total VP yield (µg/cig)	Puff Number
1mg CA Filter	4498	7.25
1mg Carbon Filter	3468	7.55
1mg "used" Carbon Filter	3785	7.81

- 1mg NFDPM carbon-filtered cigarettes were smoked under CI conditions then the filters were detached from the remaining butt and re-attached onto fresh rods.
- Results suggested that carbon filters retained the capacity to remove further vapour phase (> 500µg) before again being exposed to the artificially high smoke temperatures in the later puffs.

VP concentrations per smoke nicotine

Regime	Measured Smoke component in 1mg NFDPM CA-filtered cigarettes	Machine yield	VP per smoke nicotine from machine yields (µg/mg)
ISO	Nicotine (mg)	0.14	1279
	VP (µg)	179	
CI	Nicotine (mg)	2.02	2110
	VP (µg)	4262	

Increase ↓

- VP components are not removed by filter retention whereas nicotine is efficiently removed by retention during both ISO and CI smoking
- VP components are not removed by filter ventilation during CI smoking
- Inevitably, yields expressed as VP concentrations per mg smoke nicotine increase under the CI regime compared to the ISO regime (from 1279 to 2110µg/mg) for highly ventilated products.
- Such increases would not be found using a smoking regime more associated with human smoking

Summary (1 of 4)

- High amounts of VP are produced during smoking. The volume of air passing the coal is directly related to the levels of VP components generated at the cigarette coal.
- A greater amount of VP is produced under the most intense CI regime but, due to the improbable 100% vent blocking, the measured VP yields are high and may be far removed from human smoking intake.
  - Vent blocking at 50% well exceeds most likely levels of human behaviour
  - Smokers increase intake by increasing their puff volume and puff frequency rather than by vent blocking (see WG9 review)
- Filter ventilation removed considerably more VP under the MA regime with 50% vent blocking compared to ISO smoking.
  - Reductions caused by filter ventilation, relative to the amount produced at the coal, were considerable (51% for MA and 32% for ISO)
  - These reductions well exceeded the measured machine smoking yields.

Q? Surely machine smoking data should be associated with smoking in humans to some extent .. to allow good correlation with biomarker studies?

Q? Surely any approach to characterise the smoke from a product after removing ventilation, one of its main design characteristics, is seriously misleading?

Summary (2 of 4)

- The particular carbon filter studied in this work removed around 1000µg VP and did not overload when smoking under ISO and MA regimes.
- Even when smoking the "1mg product" under the CI regime, the carbon filter removed five times more VP than under the ISO regime.
- The high artificial smoke temperature during CI smoking caused less VP adsorption onto and even desorption from the carbon in the later puffs.
- The temperature of the smoke passing through the filter is so significantly higher that it is unlikely to be tolerated by human smokers …. leading to change in human smoking behaviour
- Q? So surely cigarette characterisation that creates such high smoke temperatures is more misleading than the current ISO regime or one with partial vent blocking?

Summary (3 of 4)

- The design means available to bring CO yields down in parity with NFDPM to the 10mg yield ceilings are limited to
  - Rod Ventilation / Rod Diffusion
  - Filter Ventilation
  - Carbon Adsorption
- Reductions (up to 20%) are achieved by rod ventilation and diffusion during smoking.
  - However, requirements for Lower Ignition Propensity cigarettes, with low porosity bands on paper, may limit their effectiveness
- Filter Ventilation is the main design tool to provide products that enable manufacturers to meet regulatory ceilings on absolute yields of Tar, Nicotine and CO.
- If further reductions in VP yields were mandated then ventilation will inevitably be required

Q? Surely this requirement should also be reflected in a more intense smoking regime?

Summary (4 of 4)

- During CI smoking, VP components are not removed by filter retention or ventilation, whereas nicotine continues to be efficiently removed by retention.
  - Yields expressed as VP per mg smoke nicotine inevitably increase under the CI regime.
- Expressing yields per mg smoke nicotine after removing ventilation will
  - severely distort compliance with potential ceilings on VP concentrations per mg nicotine
  - bias against certain brand styles with lower than average smoke nicotine yields

Q?So surely it is more misleading to use a regime with 100% vent blocking for smoke concentration evaluation?

- Necessary to define well both the short-term and long-term objectives for using any new smoking regime
  - analyse the created distortions to human smoking - before undue regulatory reliance is placed upon the data