ESSENTRA

THE INFLUENCE OF CIGARETTE FILTER DESIGN ON THE YIELD AND COMPOSITION OF CIGARETTE SMOKE

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INTRODUCTION

- Cigarette Filters were first used to keep small pieces of tobacco from being drawn into the smokers mouth
- Filters are now an integral part of the final cigarette and are an important tool to allow cigarette designers meet a range of product parameters such as draw resistance and tar/nicotine yields
- Filters have been used for a long time and the first brands with paper filters appeared in the mid 1930's
- By early 1950's cigarettes with cellulose acetate filters began to appear and in the early 1960's filters containing carbon started to become more popular
- By 1964 over 50% of cigarettes worldwide were filtered
- Today over 99.5% of cigarettes are filtered

SMOKE CONSTITUENT YIELD REDUCTION

- In general, tar and harmful smoke compounds can be reduced by two methods
- Overall reduction of smoke compounds using a combination of
  - Greater filtration efficiency – overall tar and nicotine reduction
  - Higher levels of ventilation
  - Reduced tobacco weights or modified tobacco blends
  - Changes to cigarette paper porosity or additives
- Selective removal of targeted smoke toxicants
  - Granular adsorbents or modified granular materials for volatile compounds
  - Catalysts to oxidise gases such as CO
  - Adsorbent fibres or liquid additives

OVERALL REMOVAL EFFICIENCIES

- The main role of filter is overall reduction of the deliveries of tar and nicotine
- Filter retention is usually defined as the ratio, expressed as a percentage by weight of the material retained by the filter to those entering the filter
- Overall reduction is usually controlled by selection of material and filter pressure drop
- At a pressure drop of about 80 mm WG the overall retentions of the main filler materials used are

Material	Retention % TR	NR	Selectivity
Acetate	50	46	Yes phenol and cresols, pyridine and other polar compounds
Paper	60	63	No
Polypropylene	45	47	No

SMOKE VELOCITY

- Smoke velocity is an important parameter governing the performance of filters for both particulate retention and vapour adsorption. Particulate retention decreases as smoke velocity increases
- For adsorption processes the efficiency of adsorption depends upon the molecular weight and activity of the adsorbate, the contact time and the concentration of the molecules to be adsorbed
- Typically for activated carbon adsorption capacity increases as molecular weight increases and adsorption capacity is increased by higher concentrations. Longer contact times normally gives higher adsorption capacity but adsorption capacity decreases as temperature increases
- Contact times get shorter as smoke velocity increases and smoke velocities are higher for intense smoking regimes and slimline products

APPROXIMATE SMOKE VELOCITIES

- Smoke velocity for a fixed volume puff depends on the physical dimensions of the filter and the packing density of the filter material, either tow fibres or carbon granules

- Approximate smoke velocities are in the range 35 to 150 cm/second

Smoking Regime	Smoke Velocity cm/sec	
	Slimline Circumference	Standard Circumference
ISO	60 – 80	35 – 50
Intense	125 - 150	60 - 80

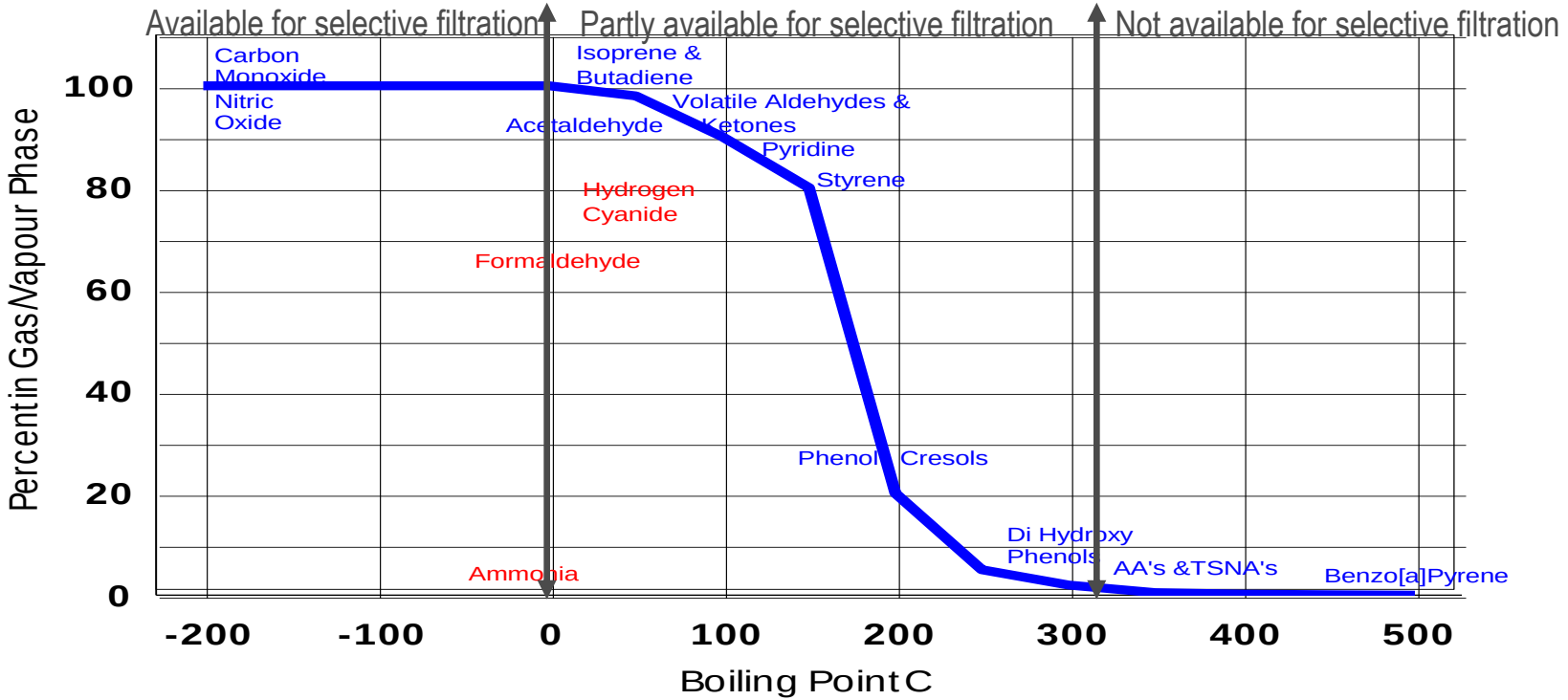
PARTICULATE RETENTIONS

Parameter	Slim Circumference		Standard Circumference	
	ISO	Intense	ISO	Intense
Tar Retention %	26.7	25.5	42.8	41.0
Nicotine Retention %	21.1	20.3	36.4	34.0

- For the majority of filter types acetate, paper, carbon on tow and triple granular etc. the measured filter retentions decrease by up to about 4% when puff volume increases from 35 to 55 ml.
- For slimline filters the change is smaller usually less than 2%
- Changes in the retention of non-volatile compounds such as BaP, TSNA's aromatic amines etc. generally follow the overall tar retention

COMPOUND DISTRIBUTION IN SMOKE

- Selectivity generally correlates to boiling points with some notable exceptions



SELECTIVE FILTRATION

There are a number of general rules concerning selective filtration:

- The more volatile the compound the greater the chance of selective removal
- No volatility - no selectivity
- Reactive or very soluble compounds often have lower than expected availability for selective removal

As more volatile compounds have lower boiling points, this can be summarised as:

- Boiling Point < 115°C - high availability for selective removal
- Boiling Point 115°C to 290°C - partial availability for selective removal
- Boiling Point > 290°C - no or very little selective removal

AVAILABILITY FOR SELECTIVE FILTRATION

Compound	Availability for Selective Filtration
Carbon Monoxide/Nitric Oxide	Fully Available
Volatile Aldehydes	> 90 %
Volatile Hydrocarbons	> 90 %
Hydrogen Cyanide/Formaldehyde	> 65 %
Phenol and Cresols	> 30 %
Ammonia	Slightly Available
TSNA's	Slightly Available
Benzo [a] Pyrene	< 1 %

CONTROL CIGARETTE YIELDS

Compounds	Slim Circumference		Std Circumference	
	ISO µg/cig	Int µg/cig	ISO µg/cig	Int µg/cig
Tar	9.7	25.6	13.3	26.3
Nicotine	0.55	1.24	0.97	1.83
CO	9.3	16.8	13.2	22.9
Aldehydes	634	1214	1036	1959
Ketones	250	485	428	853
Acrylonitrile	6	10	13	25
Hydrocarbons	398	725	526	1410

RETENTION OF VOLATILE COMPOUNDS

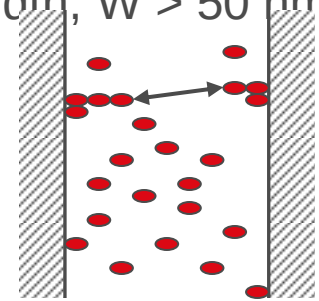
- The vapour phase of cigarette smoke contains around 600 different compounds
- Filters do not have any effect on permanent gasses such as carbon monoxide
- In general normal filter filler materials such as cellulose acetate, paper or polypropylene have retentions of less than 10% for vapour phase compounds
- The levels of vapour phase compounds in smoke are reduced by the use adsorbents with a high internal surface area
- Carbon is the preferred adsorbent in cigarette filters

COCONUT SHELL CARBON

Property	Standard	High Activity
BET Surface Area m2/g	1100	1600
Bulk Density g/ml	0.57	0.42
Activity CTC %	60	100
Macropore Volume %	22.5	18.6
Mesopore Volume %	16.8	18.3
Micropore Volume %	60.7	63.1

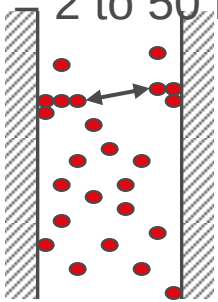
macropores

width, W > 50 nm



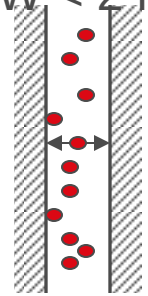
mesopores

W = 2 to 50 nm

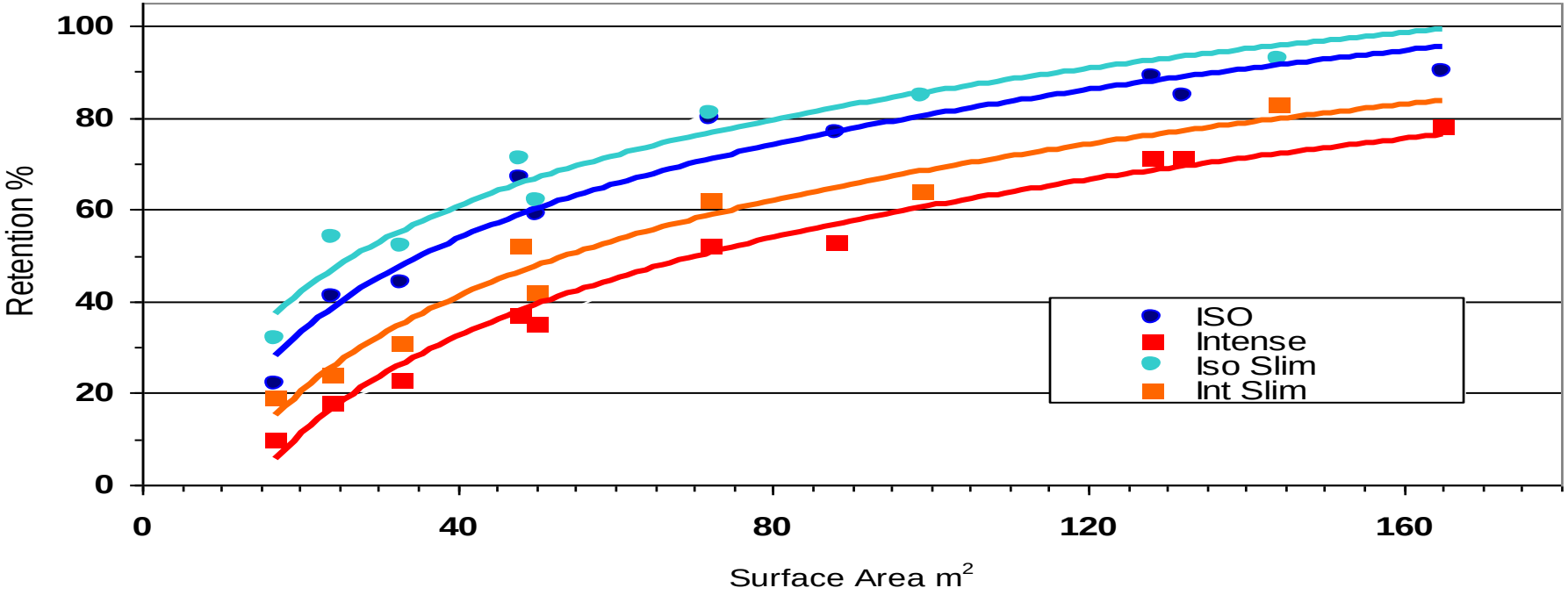


micropores

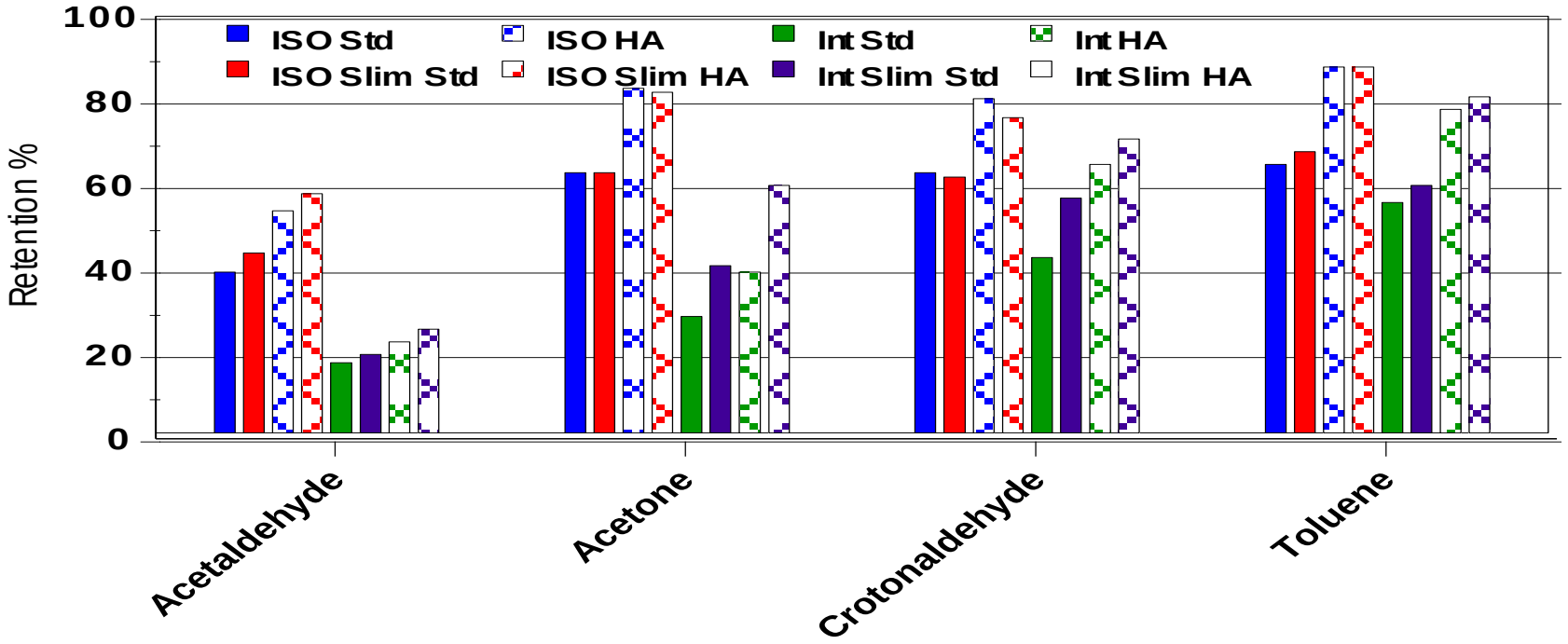
W < 2 nm



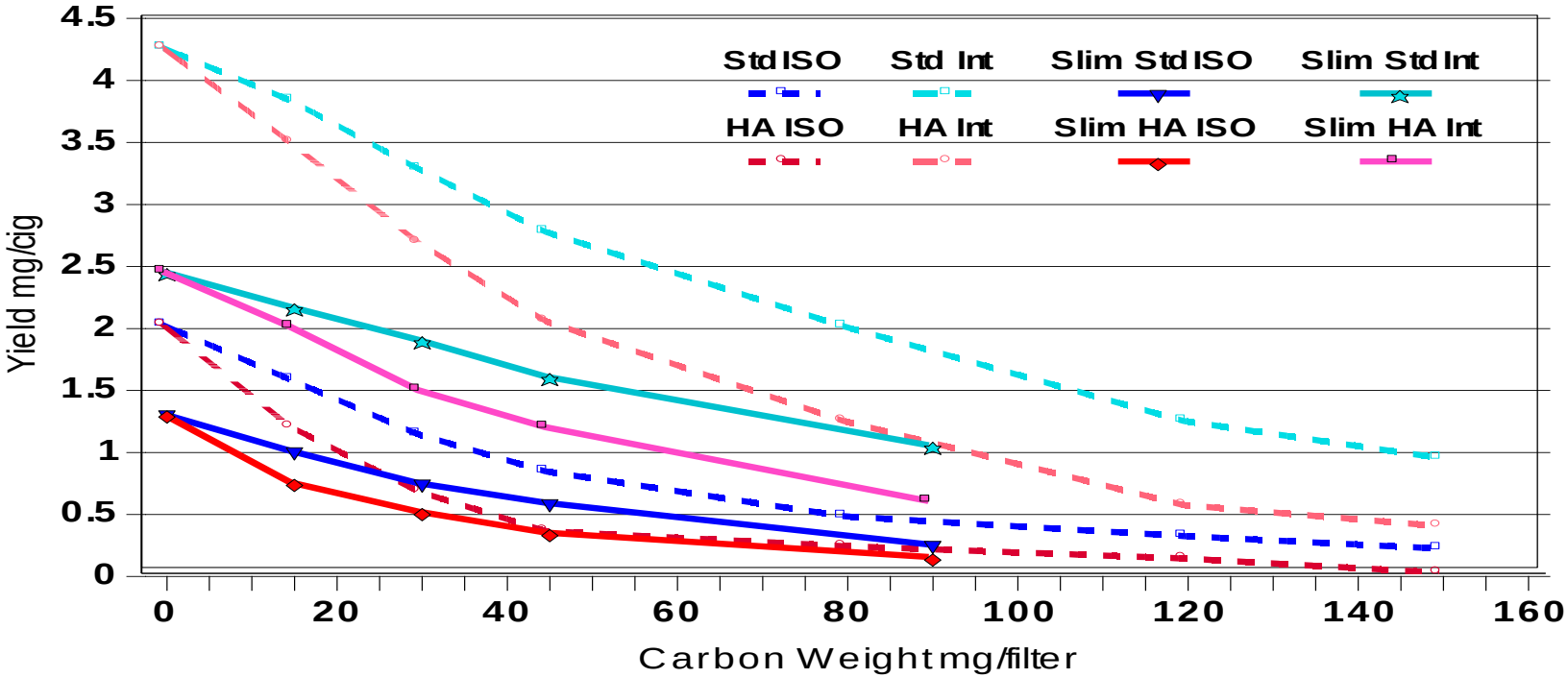
EFFECT OF CARBON SURFACE AREA ON MEAN VAPOUR PHASE RETENTION



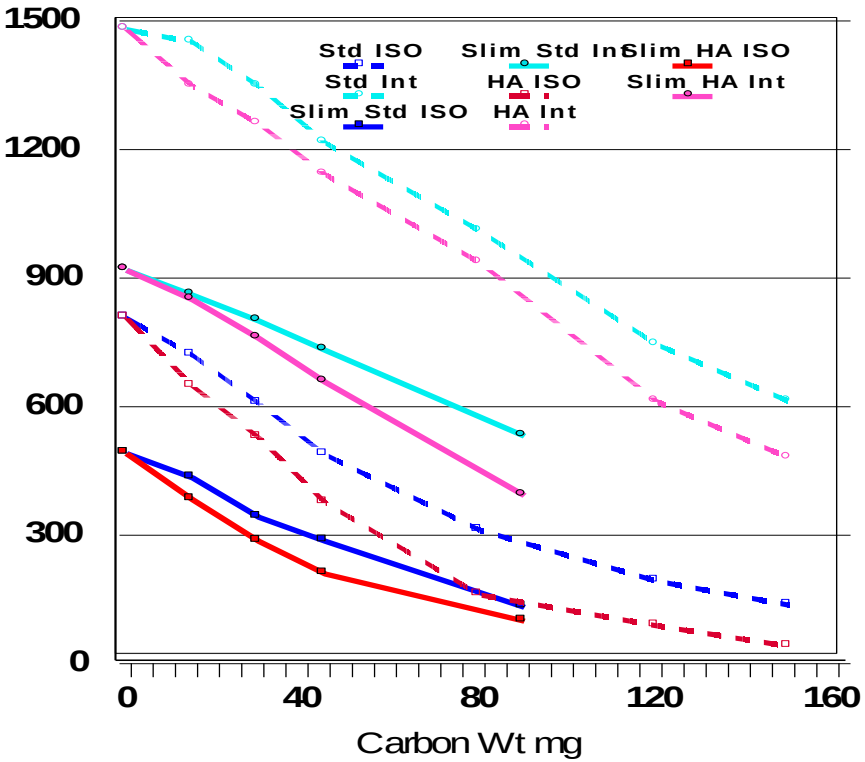
RETENTION OF SMOKE COMPOUNDS BY 45 MG CARBON

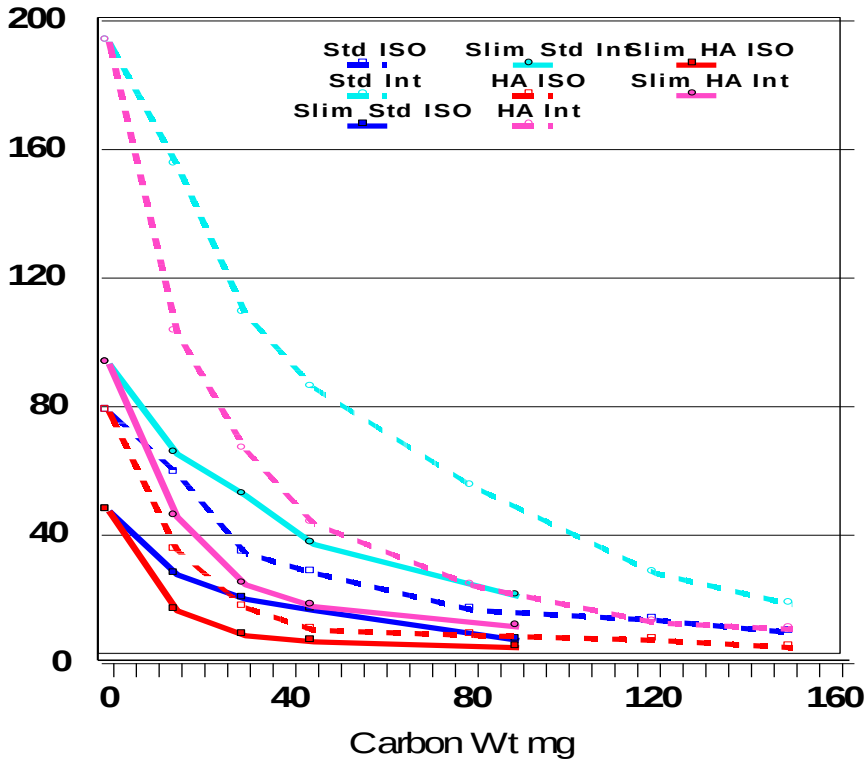


EFFECT OF CARBON WEIGHT ON TOTAL YIELD OF SELECTED VAPOUR PHASE COMPOUNDS



EFFECT OF TOTAL WEIGHT ON ACETALDEHYDE YIELD AND TOLUENE YIELD



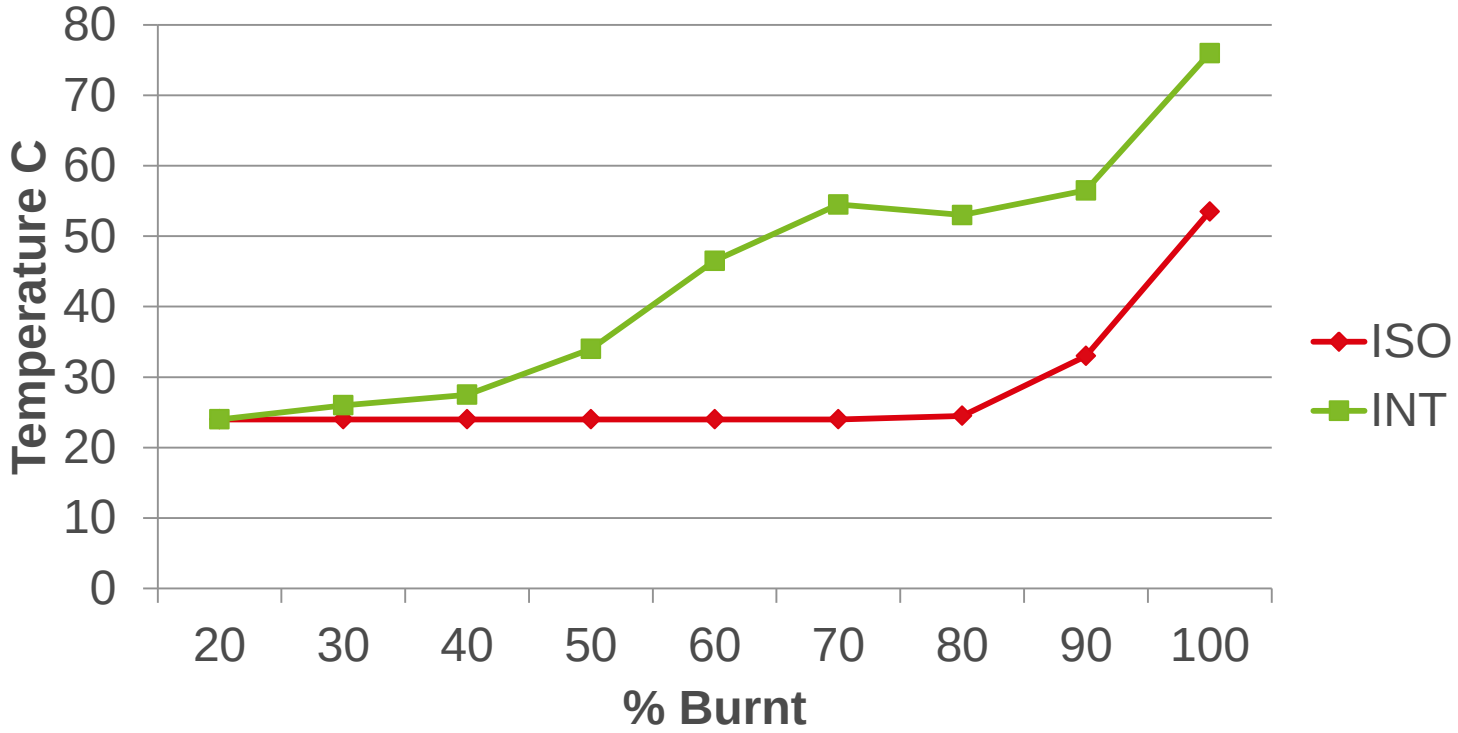


STANDARD CARBON WEIGHT TO ACHIEVE 50 % RETENTION OF VAPOUR PHASE COMPOUNDS

Compound	Slimline Circumference		Standard Circumference	
	ISO	Intense	ISO	Intense
Mean VP	28	60	38	75
Acetaldehyde	53	105	60	120
Acetone	28	60	38	82
Crotonaldehyde	25	46	32	60
Toluene	22	34	27	38

Weight of standard activity carbon in mg to achieve a 50 % retention of the compound of interest

FILTER TEMPERATURE



Purkis et al Beitrage Vol 24 No 1 April 2010

EFFECT OF TEMPERATURE

- Filter temperature increases as the burning coal approaches the filter
- The measured temperature approximately 20 mm from the mouth end of the filter increases by about 30 C for ISO smoking and 50 C for intense smoking
- The decrease in carbon adsorption capacity as temperature increases changes according to the compound considered
- For a hydrocarbons like benzene and trimethyl pentane the adsorption capacity decreases by about 0.1 to 0.3% per 1 C increase in temperature for concentrations in the ppm range
- Adsorption capacity from the first to last puff could decrease by up to 9 % for ISO smoking and up to 15 % for intense smoking .

OTHER FILTER ADDITIVES

- Catalysts mainly to reduce carbon monoxide by catalytic oxidation. These are generally poisoned very rapidly by cigarette smoke. The cost of the precious metal alone (Au or Pt) would add between $1 to 2 per pack of 20 cigarettes
- Carbon with Haemoglobin. Does not have any effect on CO but high carbon loading does reduce vapour phase compounds
- Plant extracts for example spinach
- Vitamins such as vitamin C to reduce formaldehyde. No evidence of significant reductions
- DNA to reduce harmful substances such as B a P.

CONCLUSIONS

- Filters play a vital role in enabling cigarette manufacturers to meet prescribed tar and nicotine ceilings
- Filters are available to enable selective reductions in the deliveries of specific smoke compounds especially those with significant vapour pressures in smoke
- Opportunities for new filter innovation may be limited by more widespread introduction of official lists of approved ingredients

CONCLUSIONS

- Surface area seems to be a good indicator of compound reduction for coconut shell carbon
- Smoking at more intense regimes does reduce the measured retention efficiency of carbon. But during more intense smoking carbon is retaining a smaller percentage of a much larger yield so it is actually adsorbing more material
- Carbon still acts as an effective adsorbent in slimline filters
- For slimline filters the percentage adsorbed is actually slightly higher than standard circumference products but this is a higher percentage of a lower amount so the amount adsorbed is less

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THANK YOU

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