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Performance of Special Filters

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Rhodia Cigarette Filter Colloquium
1st to 5th June 2008

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Overview

- Filter requirements
- Current filter usage
- Smoke composition
- Selective filtration
- Filter materials
- Performance of special filters
- Conclusions

The presentation gives a brief review of the current use of cigarette filters, the composition of cigarette smoke and some of the range of special filters that are currently available.

Ideal Filter Requirements

- Acceptable taste
- Low variability
- Acceptable appearance
- Reduces tar, nicotine and harmful compounds
- Acceptable pressure drop
- Reasonable firmness
- Dispersible or biodegradable and environmentally friendly

An ideal filter must give an acceptable taste to the consumer and be able to be produced to precise specifications of weight, circumference, pressure drop etc with low variability. The appearance must be acceptable to the consumer and the materials used capable of reducing some or all of the harmful compounds found in smoke. When used in the final cigarette the filter must give a product that has a draw resistance that is acceptable to the smoker. The filter must be firm enough so that the cigarette is comfortable to hold by the smoker. Finally the environmental impact of the filter should be as low as possible. That is it must disperse in the environment and preferable be biodegradable. Also the material used in the production of the filter materials should have minimal environmental impact say from the use of sustainable raw materials and minimal energy usage during production.

Functions of Specialty Filters

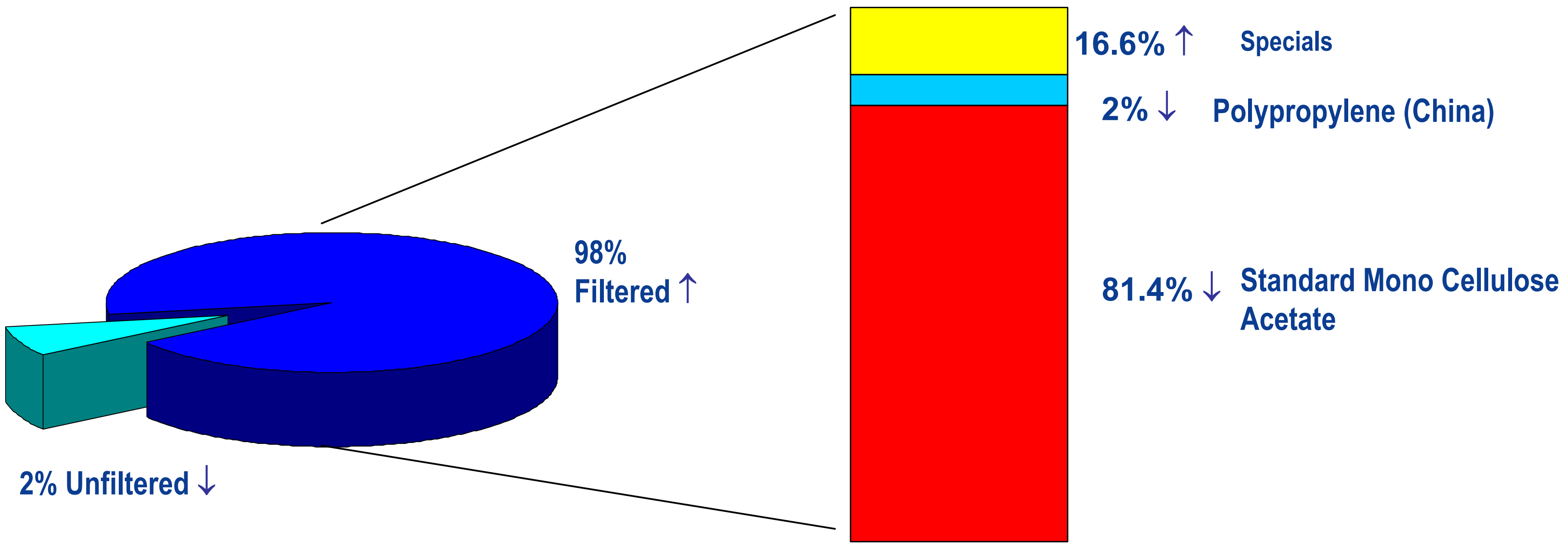
- Filtration performance
- Taste modification
- Selective filtration
- Brand differentiation

Filter as generally used for four major reasons on a cigarette

1. Filtration performance to give reduction of principally tar and nicotine deliveries and potentially other harmful smoke compounds
2. To modify the taste experienced by the consumer so that the cigarette is preferred by the consumer
3. If possible to give a high degree of selective filtration so that harmful smoke compounds are reduced to a much greater extent than say the compounds responsible for taste.
4. To give brand differentiation by novel appearance or superior filtration properties

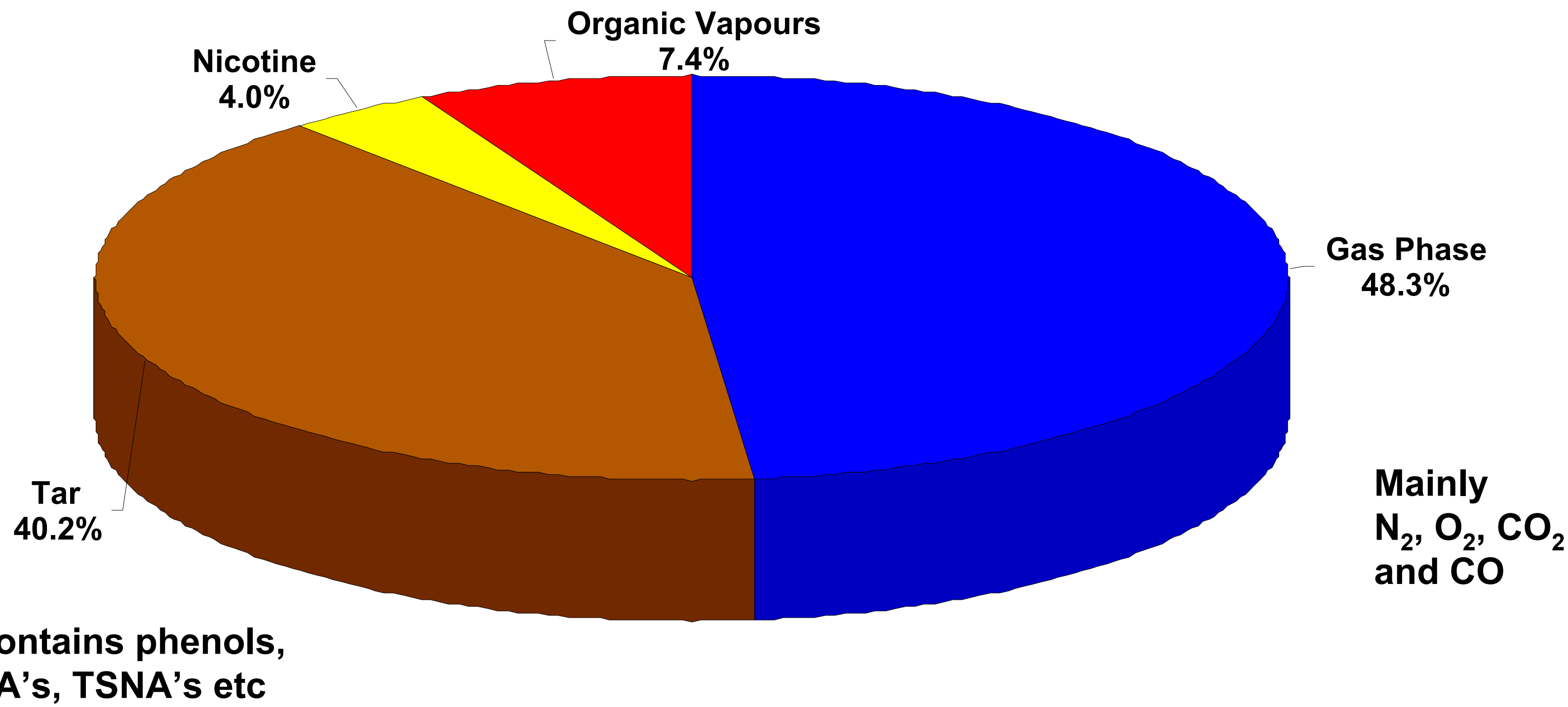
Global Filter Usage

Total Cigarette Market: 5.8 Trillion



The plot gives an approximate breakdown of global filter consumption. The general trends are a decline in unfiltered cigarettes and cigarettes using polypropylene filters. Specials are filters that are not standard monoacetate filters, for example filters containing carbon or flavours.

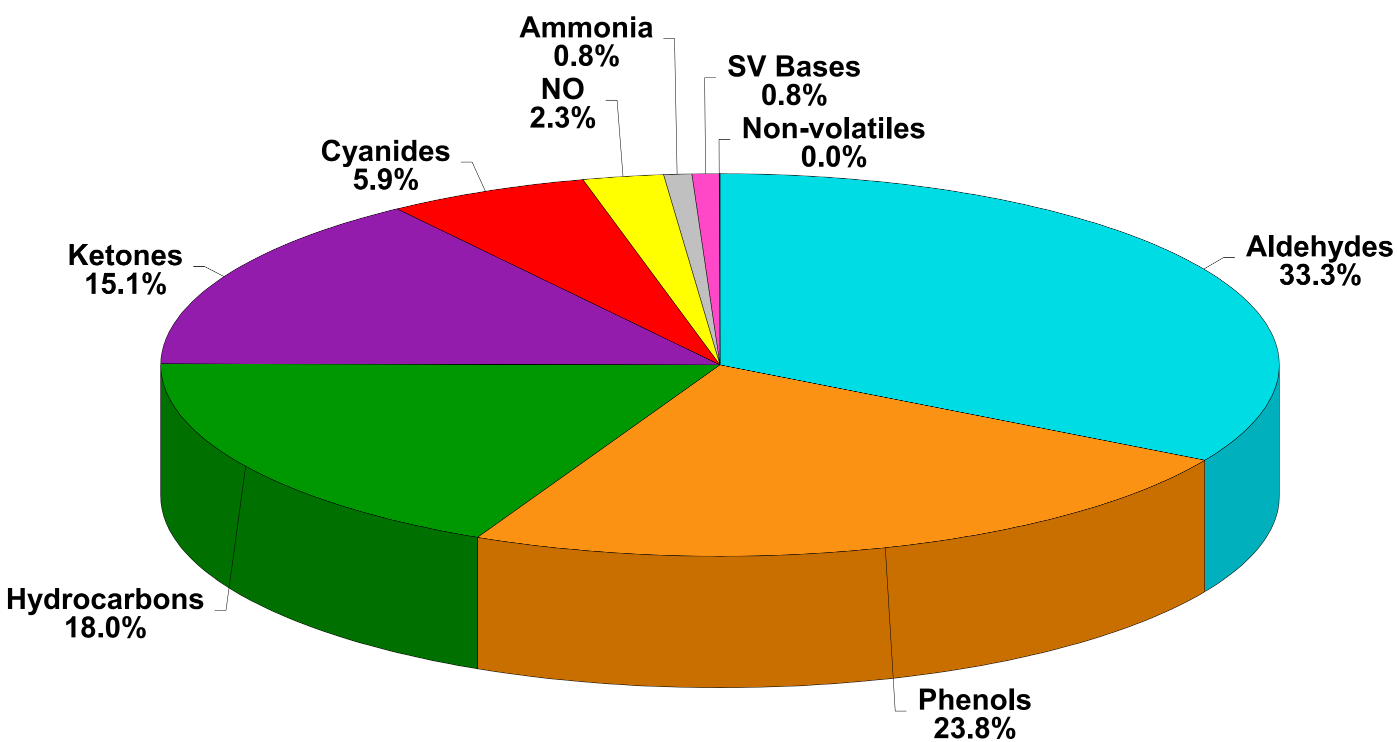
Smoke Composition



The plot shows the general composition of smoke from a filtered cigarette expressing the major compounds and those considered as harmful (Hoffmann compounds) as a percentage of the total. Note although mentioned as part of the gas phase nitrogen, oxygen and carbon dioxide are not used in the calculation as these are not considered as harmful compounds. The 48.3 % shown in the above plot is principally carbon monoxide and nitric oxide.

Potentially Harmful Smoke Compounds

The major smoke materials tar, nicotine and CO have been removed from the previous plot and the remaining Hoffmann list compounds plotted as a percentage of the total yield of Hoffmann compounds



Methods of Reducing Various Smoke Fractions

Smoke filtration usually depends on the physical form of the compounds as it passes through the filter. In general gas phase compounds (CO and NO) can only be reduced by ventilation. Vapour phase compounds such as aldehydes and hydrocarbons etc are reduced by ventilation and the use of carbon in a filter. Semi – volatile compounds are filtered effectively by acetate filters but can also be reduced by carbon and ventilation. Non – volatile compounds are reduced by ventilation and overall tar and nicotine filtration.

Smoke Compounds	Reduced by
Carbon Monoxide, Nitric Oxide	Ventilation
Volatile Aldehydes, Hydrocarbons and Cyanides	Ventilation Carbon
Semi-volatiles e.g. Phenols, Pyridine and Quinoline	Ventilation Carbon Filtration
Non- volatiles	Ventilation Filtration

Selective Filtration

- Most filters work by trapping smoke aerosol particles by direct interception and diffusional deposition with a minor contribution from inertial impaction but this is not a selective process
- The capture of particles by the fibres tends to be irreversible and all compounds in the particle are retained except for small quantities that may vaporise from the surface and be released into the smoke stream
- Another possible filtration mechanism is the removal of material at the surface of a fibre or granule by chemical reaction or adsorption
- Adsorption is the mechanism that occurs on porous solids such as activated carbon

In general a filter that shows a high degree of selective filtration towards harmful smoke compounds would be a highly desirable filter.

Selective Filtration

- To be selectively removed a compound must diffuse to the surface of the porous granule and then undergo adsorption or reaction to be removed from the smoke stream
- Once a compound is removed from the smoke then more will diffuse to the surface of the granule so that selective removal can be very efficient
- But diffusional mechanisms are critical for the occurrence of selective filtration
- Gases and vapours can diffuse quite readily
- Non-volatile compounds with no vapour pressure cannot diffuse

Irrespective of the make up of a filter only those smoke compounds that are available for selective filtration can be selectively removed by a filter

Selective Filtration

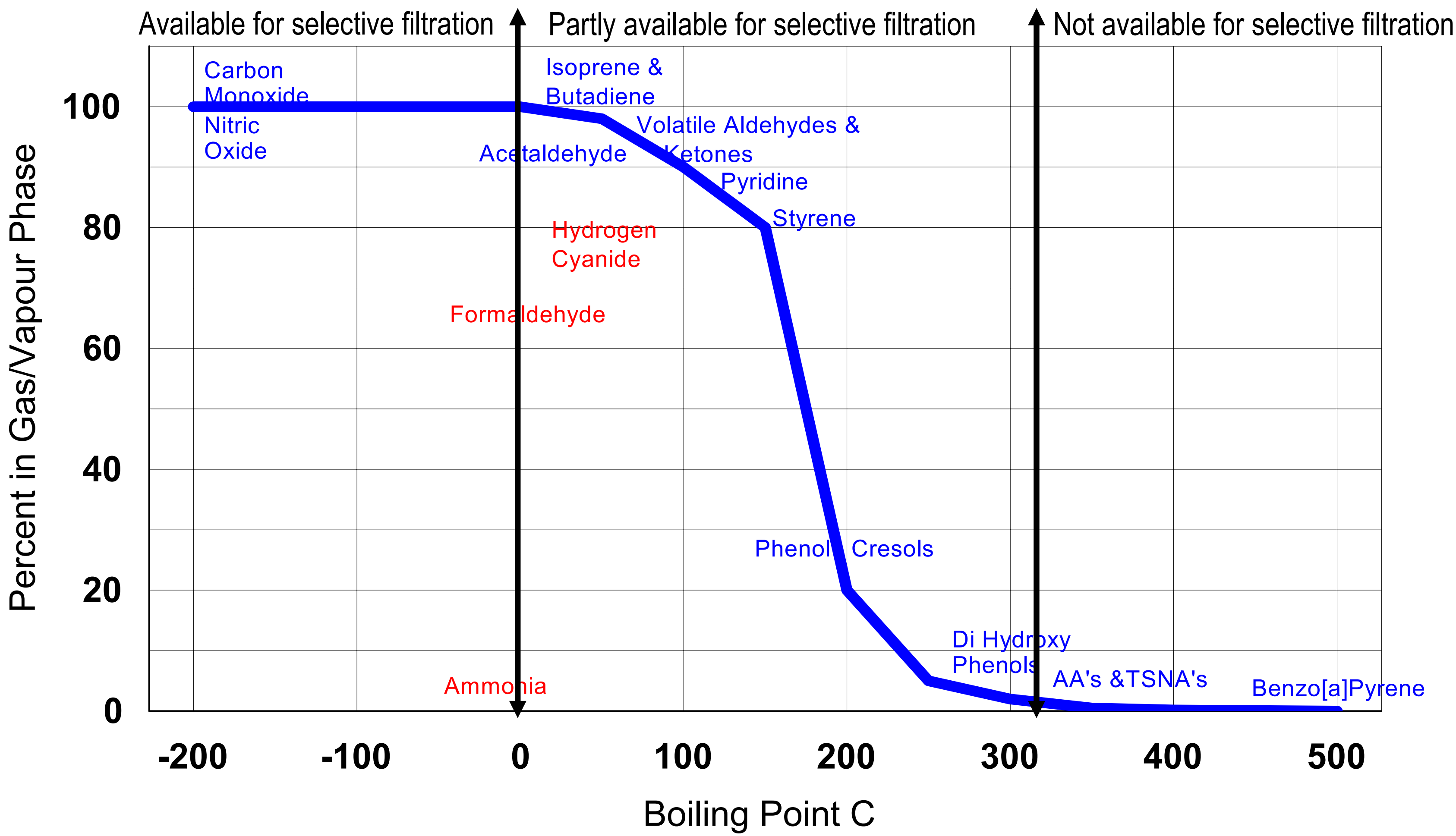
- The more volatile the compound the greater the chance of selective removal
- No volatility – no selectivity

Vapour compounds (e.g. Hydrogen Cyanide, volatile aldehydes etc) are readily available for selective filtration but non – volatile compounds such as Benzo [a] Pyrene are not.

Distribution of Harmful Smoke Compounds

The following plot shows the percentage of the major harmful smoke compounds available in the gas/vapour phase and shows the availability for selective filtration

Distribution of Harmful Smoke Compounds



Filter Materials

Material	Selectivity
Cellulose Acetate	Good tar and nicotine retention. Selective towards phenols and some other semi-volatile compounds
Paper	Higher overall tar and nicotine retention no selectivity
Granular Additives (Carbon)	Gives selective removal of organic volatiles and semi-volatiles

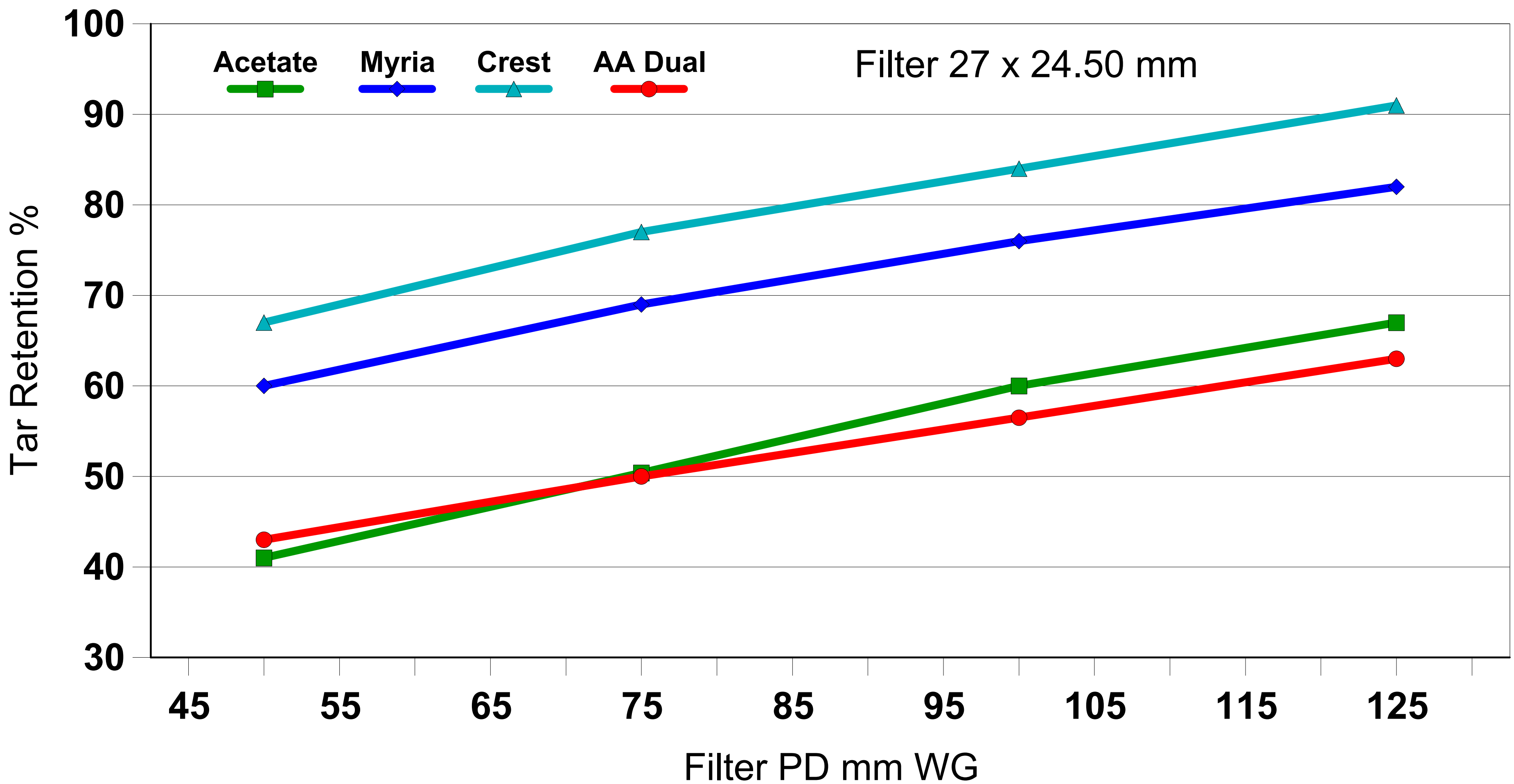
Only three major materials are use in filters in significant commercial quantities in the world today. Cellulose acetate, paper and carbon. The table above gives a comparison of the filtration properties of the three materials.

Filter Tar Retentions

The following plot compares tar retention of four different filter types, for a 27 mm length by 24.5 mm circumference filter at a range of filter pressure drops.

From the plot it can be seen that crest paper gives the highest tar retention followed by myria paper with the retention values for standard acetate filters and acetate filters containing carbon (an AA dual filter with a segment of acetate coupled with a segment on acetate and carbon combined) being about the same.

Filter Tar Retentions



Filtration of Smoke Compounds

The harmful compounds in smoke have been grouped into chemicals of the same type and a comparison of the filtration properties given by the main filter types for each class of chemical compounds are shown in the following plot.

In general gasses such as CO and NO are not retained by filters. Volatile compounds such as hydrogen cyanide, aldehydes, ketones and hydrocarbons are retained by carbon but not acetate or paper. Semi-volatile compounds and phenols are retained to a much greater degree by acetate than paper and the retention of non-volatile compounds tobacco specific nitrosamines (TSNA's) etc are similar for all filter types.

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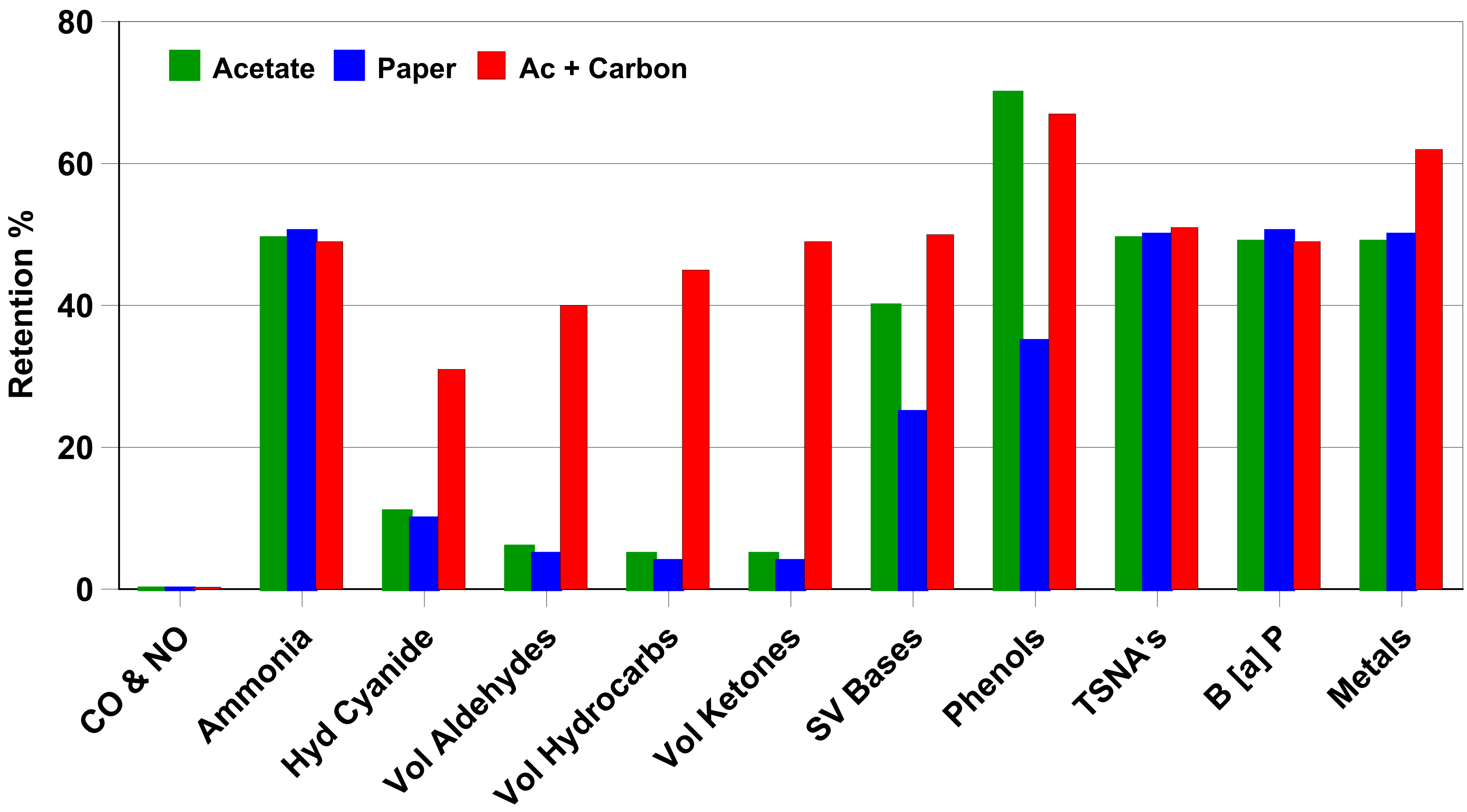
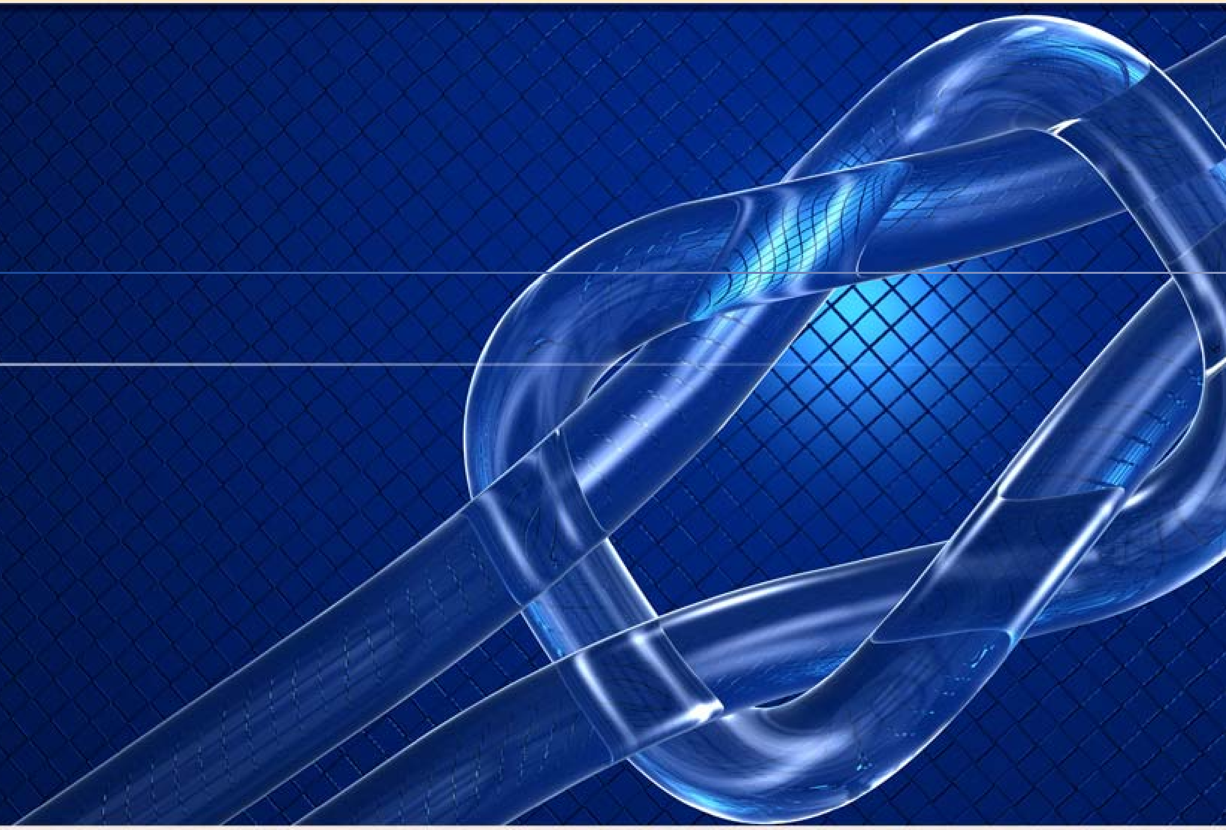
Filtration of Smoke Compounds



Special Filters



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Special Filters

On the following slides, a review is given of a range of filter types that have different filtration properties when compared to standard acetate filters.

These show either higher tar and nicotine retention or the higher removal of vapour phase compounds given by carbon.

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CPS Filter

The first of these filter types is the CPS filter (combined performance superior) which gives more tar and nicotine retention per unit pressure drop than an acetate filter combined with the potential for a special end appearance.

CPS End Appearance

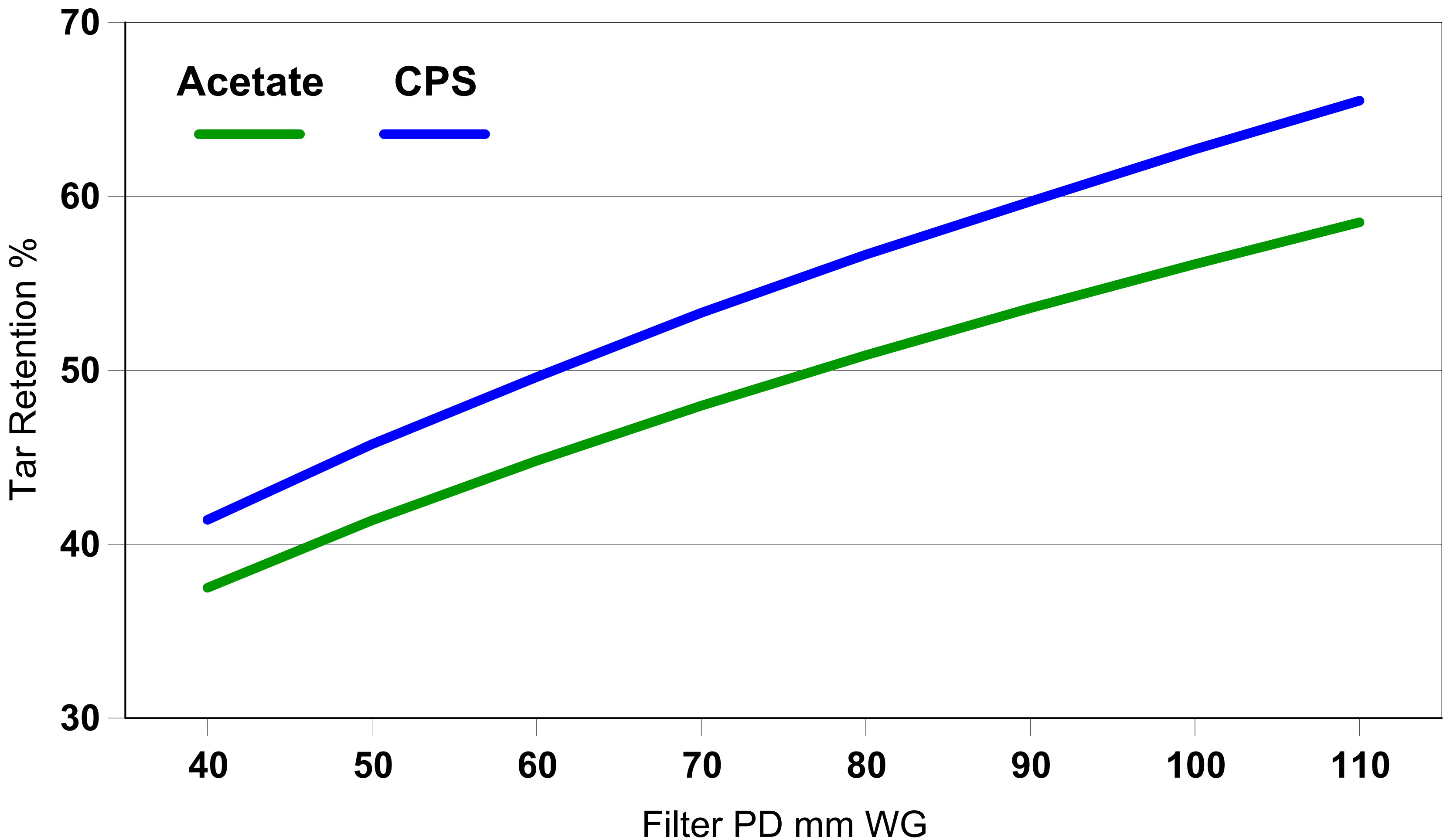
With the flutes of the filter orientated towards the mouth end of the cigarette the filter gives a unique end appearance which can be further enhanced by the use of a coloured inner wrap.

CPS Filter

- Cellulose acetate fiber with embossed inner wrap
- Gives higher tar and nicotine retention than mono-acetate
- Configured with flutes to mouth (FTM) or flutes to tobacco (FTT)
- Colored inner wrap can be used for anti-counterfeiting and brand identity
- Design flexibility - combined as a dual, have flavor added or possible other options
- Super Slim down to 16.7 mm circumference now available

The following plot shows a comparison of tar retention for the CPS and acetate filters. In general the CPS filter gives about 7% higher tar retention at any particular filter PD.

CPS Tar Retention



CPS Advanced Carbon Dual

A recently launched dual filter combination. The filter combines the reduction of harmful vapour phase compounds given by carbon with the higher tar and nicotine retention given by the CPS filter.

- Combines the extra tar and nicotine retention of CPS with the ability of carbon to reduce harmful compounds in smoke
- Cooler smoother smoke from the carbon
- Visual differentiation from the CPS

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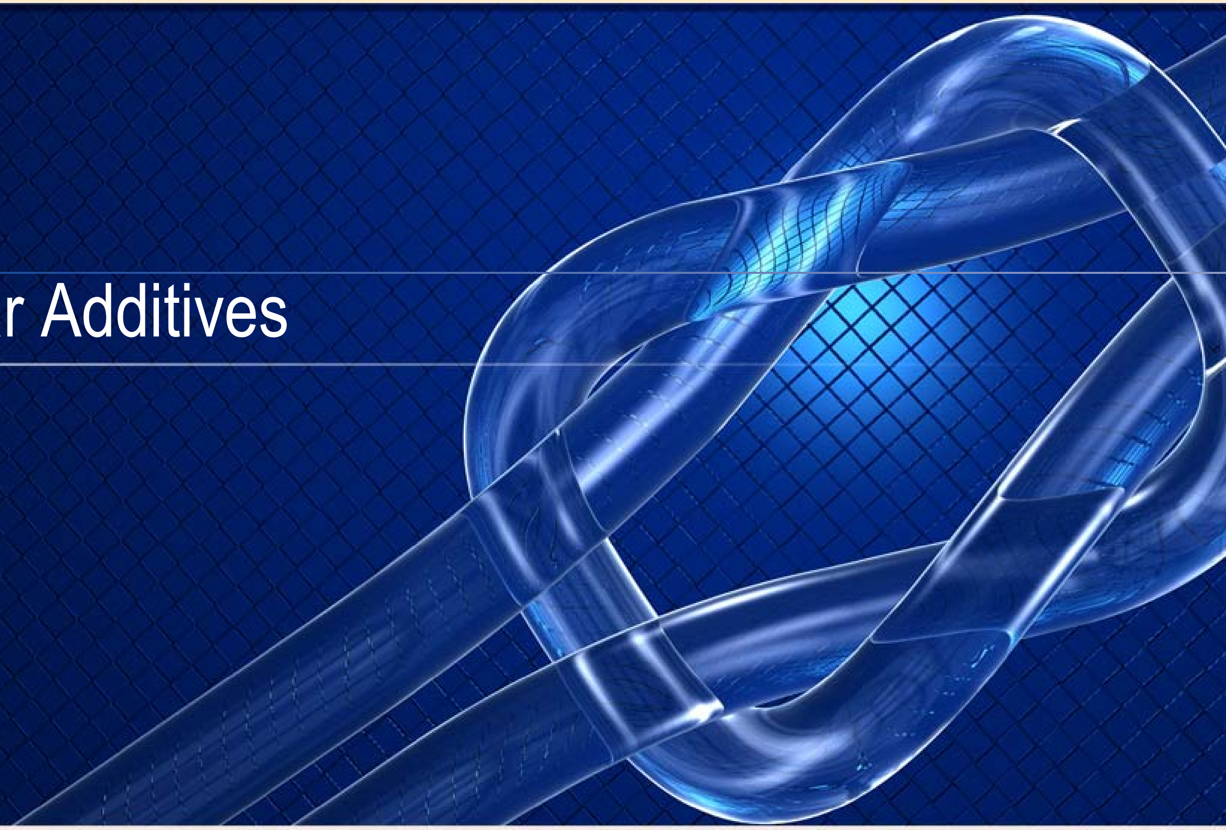
Filters with Granular Additives



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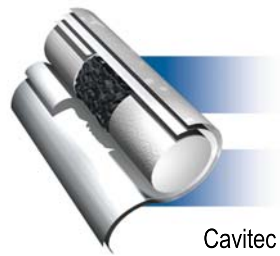
Filters with Granular Additives

Carbon is the major granular additive use in cigarette filter. It has an internal pore structure that gives it a high surface area and the ability to adsorb many harmful compounds from cigarette smoke that are not effectively filtered by acetate or paper filters.

A wide range of carbon filters are available and the main properties of these are shown in the next slides.

Filters with Granular Additives


WAAD


Cavitec


CPF (FTM) AAD


Recess AAD


HR-VPA


AMW


CPF (FTM) VPA


CPF (FTM) AMW


TRS


APF

Active Acetate Dual Filter

Active Acetate Dual Filter

- Most commonly used carbon filter
- Dual filter construction
- Wide range of carbon loading available from around 1mg/mm to 6 mg/mm
- Coloured tows and carbons can be used
- Mono-acetate end appearance
- Similar retention limitations to mono-acetate
- Possible contamination of Filtromats and makers
- Greater PD/Weight variability
- Carbon Filter as a marketing tool
- Smooth taste characteristics
- Reduces compounds in smoke not effected by standard filters
- May give a unique carbon taste

Recess Active Acetate Filter

- Gives active acetate dual filter a unique appearance for greater product differentiation

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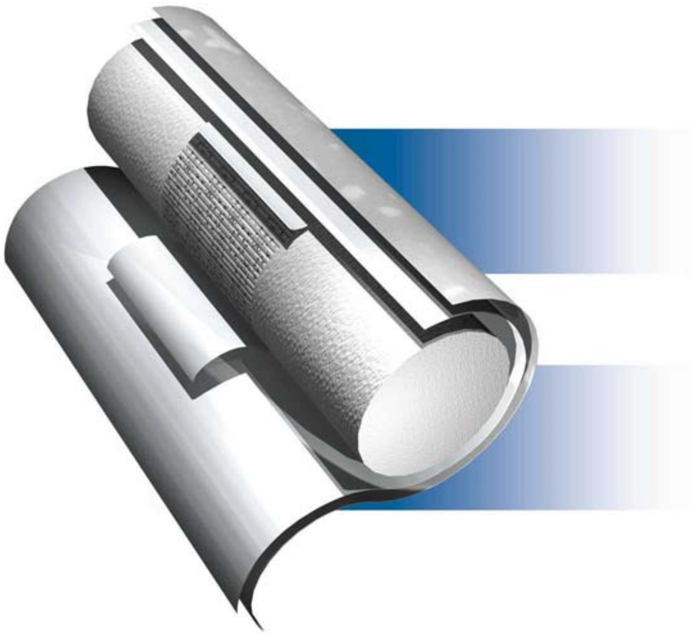
Triple Segment Filter



Triple Segment Filter

- Clean run version of active dual filter
- Triple filter construction with carbon segment in the centre
- Mono-acetate end appearance
- Carbon loading depends on centre segment type
- Using active paper as the centre segment would give higher tar/nicotine retention

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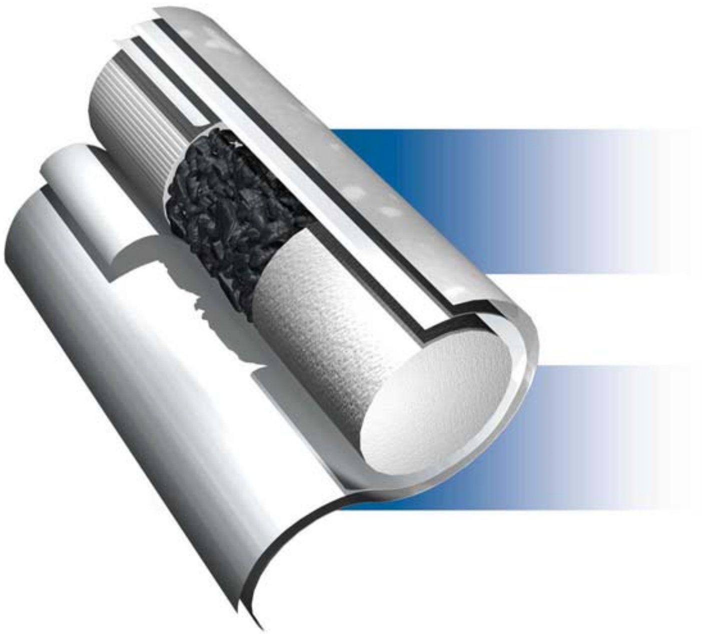
Complex Triple Segment Filter

Complex Triple Segment Filter

- Consists of three different filter segments in one filter
- Allows great flexibility both in terms of tar/nicotine retention and removal of vapour phase and other compounds by carbon or other adsorbents/selective filtration agents
- Can use two different granular materials in series in one filter
- Allows the use of paper and acetate segments in the same filter

Cavitec Filter



Cavitec Filter

- Triple filter construction
- Wide range of carbon loading from a low value up to 20 mg/mm of cavity length.
- Typically around 120 mg for a 7 mm long cavity with standard coconut shell carbon
- Versatile can mix materials in the cavity or use flavour carriers
- Acetate or paper tobacco end segment depending on tar/nicotine retention required
- No carbon segments cut during cigarette manufacture

Active Patch Filter

Until recently all carbon filters were multiple filters containing two or three different segments in the filter. Multiple filters are more complex to make as they require a number of different machine processes. For example, to make an acetate dual filter requires three machines, one to make the acetate mouth segment, one to make the active acetate segment with carbon and a dual machine to combine the two filter types. The active patch filter is the first commercial carbon filter made using one machine process.

- The first mono-process carbon filter.
- ‘Patch’ of activated carbon is ‘printed’ onto the inner surface of the plugwrap.
- Patch position is flexible, and can be either single patch, or split patch configuration.
- Porous plugwrap up to 12000 CORESTA units can be used
- Clean run filter concept - no machine contamination.
- Carbon loading up to 3mg per linear patch mm.
- Total loading controlled by the length of the patch.
- Similar VP and SV performance to other carbon filters but with less "carbon taste".

Active Patch Filter (APF)

The patch can be positioned anywhere along the length of the filter for example near the tobacco column end of the filter as shown here (ventilation would be just down stream of the patch if required).

Active Patch Filter Split Patch

For higher carbon loadings the patch can be split with ventilation achieved in the gap between the patches.

Active Patch Filter Maximum Carbon Loading

For maximum carbon loading the patch can be put along the majority of the filter with a small gap only at the mouth end of the filter. Ventilation if required would be with on line laser into the patch

Other Granular Additives

All of the filter types above can be made with a range of granular materials although at the moment carbon is the only one used commercially in large quantities. The standard carbon used currently has a surface area of about 1100 m^2/g but higher surface area coconut shell carbons are also available. An example of this is the HCNR carbon which is a high surface area carbon impregnated with an additive to selectively remove hydrogen cyanide from smoke. Materials such as silica gel, ion exchange resins and sepiolite have also been used in cigarette filters. The table compares the main physical properties of such materials.

Material	Bulk Density g/ml	Surface Area m^2/g	Particle Size mm	Cyclohexane Activity %
Coconut Carbon	0.51	1100	0.21 to 0.60	30
HCNR Coconut carbon	0.41	1600	0.21 to 0.60	49
Silica Gel	0.43	480	0.25 to 0.50	63
Ion Ex Resin	0.42	625	0.30 to 1.18	40
Sepiolite	0.68	325	0.25 to 0.60	35

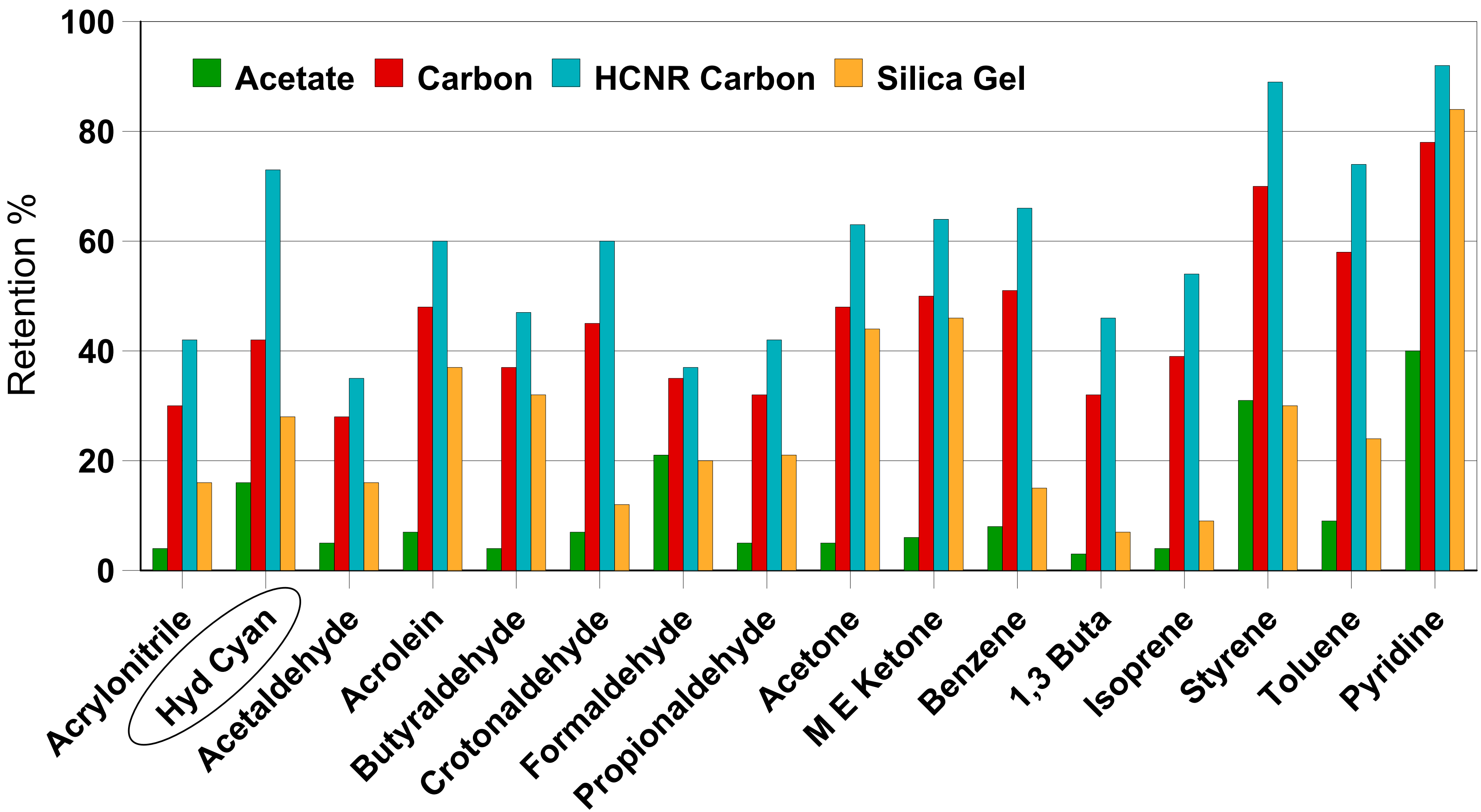
Effect of Granular Additives on Cigarette Smoke Compounds

The following plot shows the performance of three of the granular materials described in the previous slide compared to acetate for the retention of a range of harmful smoke compounds.

Carbon is seen to give the largest overall effect and increasing the surface area of the carbon increases its retention. Silica gel shows more selectivity towards smoke compounds in that it does effectively remove some compounds such as pyridine but has little effect on hydrocarbons such as benzene, 1,3 butadiene and isoprene.

The carbon with the impregnant is seen to give much higher retention than any of the other material for hydrogen cyanide.

Effect of Granular Additives on Cigarette Smoke Compounds



Conclusions

- Global trends will continue to be a reduction of the yields of all compounds in smoke
- Filters will continue to play a major role in product development and marketing
- Filters will continue to get longer and lower in circumference
- The trend in increased use of flavours will continue
- For the foreseeable future acetate and carbon will continue to be the major components of cigarette filters

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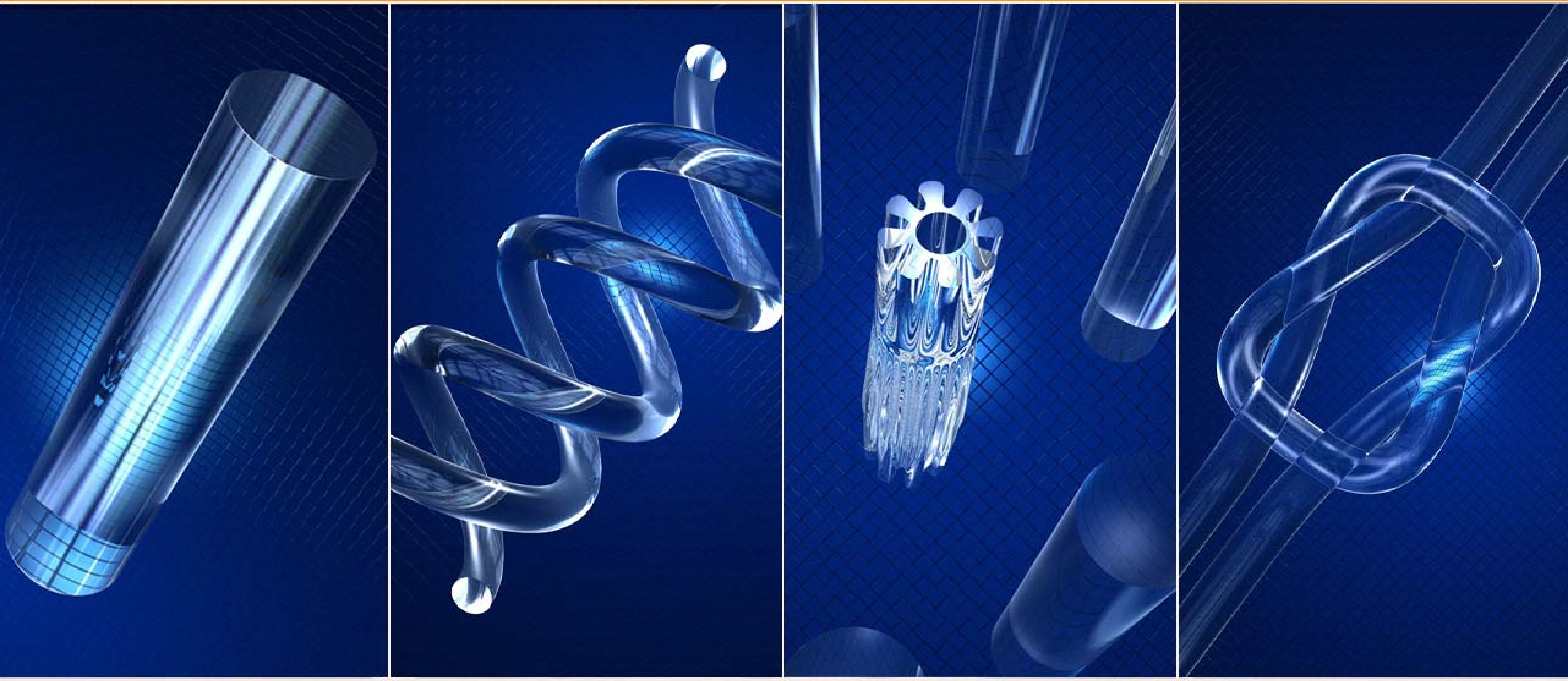

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