

Diesel Exhaust Filters

For underground coal mining



Disposable Diesel Exhaust Filters

(Filter concepts for coal
mines, progress in Australia)



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Presented (in absentia for Freudenberg) By: Dr Andreas Mayer

Agenda



- Freudenberg Filtration Technologies (FFT)
- Why are disposable filters used?
- Coal Mine Legislation
-
- How do the filters work?
- Who uses them?
- Types of Filters
- Filter advancements
- Outcomes





Freudenberg Group

Freudenberg is a family-owned group of companies

- founded in 1849, comprises 16 Business Groups operating on various markets in 56 countries around the globe
- offers its customers technically challenging product solutions & services
- Products: seals, vibration control technology components, nonwovens, release agents and lubricants, household cleaning products, medical components, filtration solutions

Mircofresh (purchased by Freudenberg in 2010)

- Mircofresh Diesel Particulate filters are result of over 15 years of extensive testing
- 10 years of supplying Australian mines with zero reportable incidents
- Partners with most major coal vehicle OEMs
- Filters used at most mines in Australia (and some O/S)

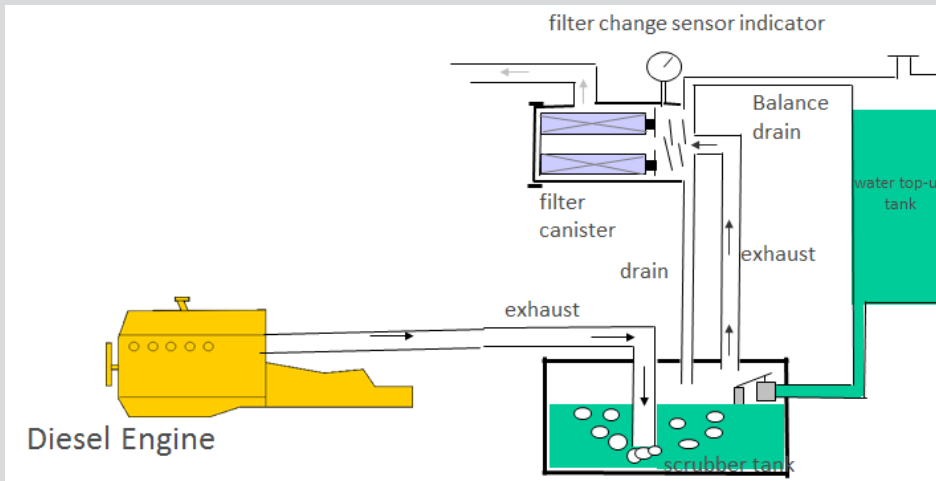


Why are Disposable filters used



- Diesel Particulate represents a significant health risk to underground coal miners
- Enclosed spaces
- Antiquated (Euro-0 – Euro-2) engine technologies
- All coal vehicle components must be flameproof (no sparks or temperatures above 150 degC)
 - Very difficult to use advanced catalytic / ceramic solutions in such confines effectively
 - High risk of premature plugging / maintenance or uncontrolled regeneration causing excessive temperature or spark and resulting explosion of atmospheric methane / coal dust
- Solution: Disposable filters

Typical coal mine exhaust / filter system



Close up of filter media cut from filter after 16 hours use



Typical Filter installations (light vehicles)



Filter / Housing

Typical pressure gauge



Typical Filter Installations (Heavy Vehicles)



Filter / Housing



FREUDENBERG FILTRATION TECHNOLOGIES

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Diesel Particulate Filters -Coal Mine Legislation



- Australian state governments do not mandate that filters must be used
- Atmospheric limit of 0.1 mg/m^3 elemental carbon is set as Maximum Exposure
- Whilst regular machine maintenance, fuel selection and ventilation can assist in meeting these guidelines, typically a filtration system will be needed also
- One major AUS mining state (New South Wales) makes vehicle OEMS prescribe a “**diesel particulate signature**” for their engines with / without filters
 - The minimum ventilation quantity required to disperse emissions to 0.1 mg/m^3
- Example from MDG-29 : GUIDELINE FOR THE MANAGEMENT OF DIESEL ENGINE POLLUTANTS IN UNDERGROUND ENVIRONMENTS
 - For a given 150 kW engine, The minimum ventilation quantity for:
 - (i) Gaseous emissions = $9 \text{ m}^3/\text{s}$
 - (ii) Particulate emission with no particulate filter installed = $28 \text{ m}^3/\text{s}$
 - (iii) Particulate emissions with a particulate filter installed = $4 \text{ m}^3/\text{s}$

“It takes 3x as much air to disperse particulate emissions”

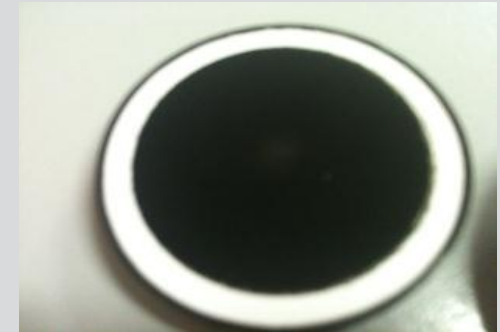
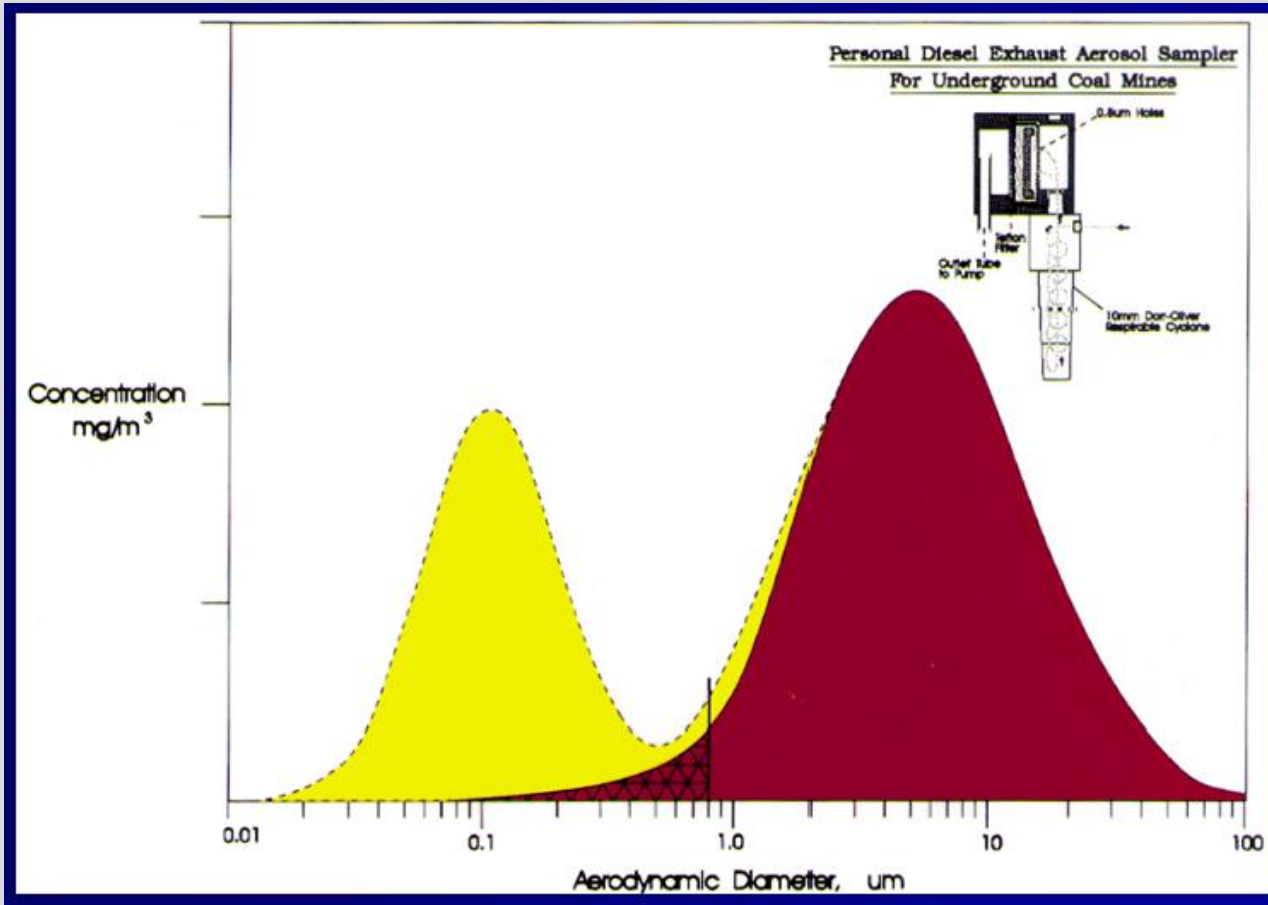
....much cheaper / more feasible to use filters than upgrade ventilation

Diesel Particulate Filters -Coal Mine Legislation

- DPM is Class 1 Carcinogen and must be controlled to:
AS LOW AS REASONABLY ACHIEVABLE / PRACTICABLE
- The vast majority of coal mines / mining groups are using filters to some degree
 - Some on all heavy and light equipment
 - Some only on heavy equipment in times of high diesel use / poor ventilation
 - Filter usage is increasing since WHO announcement
- USA is a little different with same 0.1 mg/m³ general exposure limit for non-coal mines and 2.5 g/hr maximum machine emission tailpipe limit set for coal mines
- No PN legislation for mines (atmospheric or tailpipe) in AUS or USA
- Certainly now an increased awareness of PN importance and growing support of PN limit

Size distribution of U/G coal mine Particulate matter

- Two peaks
 - Diesel soot below 1 micron (yellow)
 - Coal dust above 1 micron (red)



Where are the Filters used?

- Australian Mines by state
 - All types on mineral
 - Underground and Open Cut

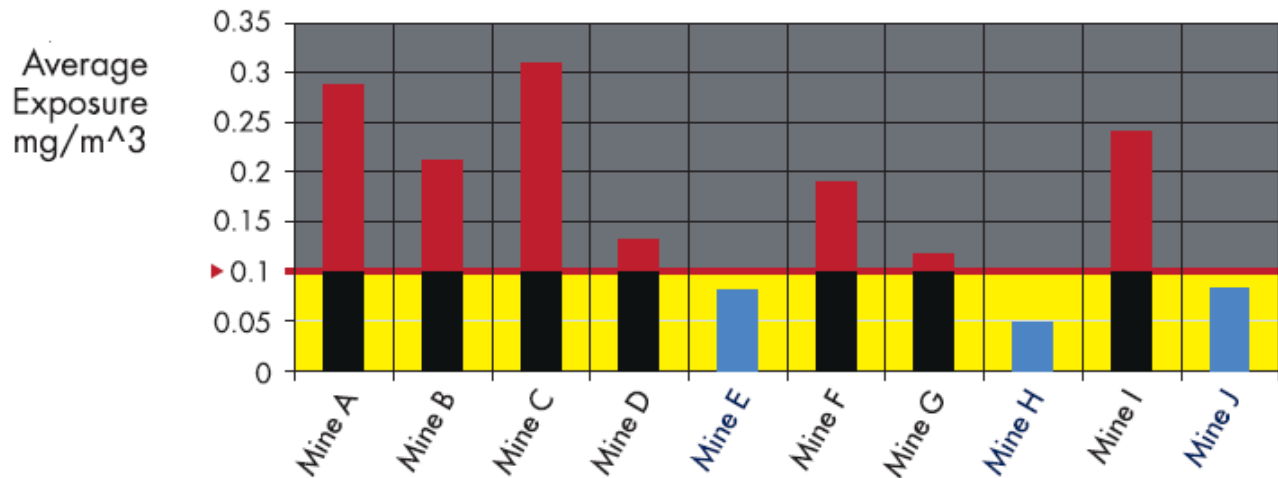


- All Underground coal mines are found in the states of
 - Queensland (Apprx. 10 mines)
 - New South Wales (Apprx. 20 mines)
- Approximately 1000 U/G vehicles across these mines
- Most of these vehicles are at least equipped with filter housings
- Around 50% of mines using filters on all equipment on a daily basis
- Remainder using filters selectively dependant on vehicle type and current mining processes

Underground DPM Emission Levels

- DPM mass as measured with SKC personal sampling pumps and tested via NIOSH 5040

Average Diesel Particulate exposure at 10 Australian Mines



Graph shows Average Site Exposures Only!
Maximum individual exposures at worst mines were up to 0.55 mg /m³
(Five and a half times over the limit!!)

Mines E, H and J use Micro Fresh Diesel Exhaust Filters on their Underground fleet*

Source: Diesel Particulate Exposure During Long-wall Moves, Gary Mace, Coal Services Health, 2006

Types of Filters



- Basically large air filters with pleated filter media for trapping particles
- Filters fall under 3 general types
 1. Cellulose / Paper, (sometimes with additional glass fibres and flame retardant)
 2. Fibre Glass
 3. Polymer
- Paper filters were first used in North American mines in the 90's
 - There were some instances of filter fires
 - Some paper filters still used in AUS today, not so much in USA
 - Moderate initial filtration efficiency
 - Short filter life (before pressure starts to rise)
- Fibre Glass filters have also been used in North American mines since 90's
 - Still the preferred solution for USA coal industry
 - Very low initial filtration efficiency
 - Long life (more particles passing through)

Types of Filters

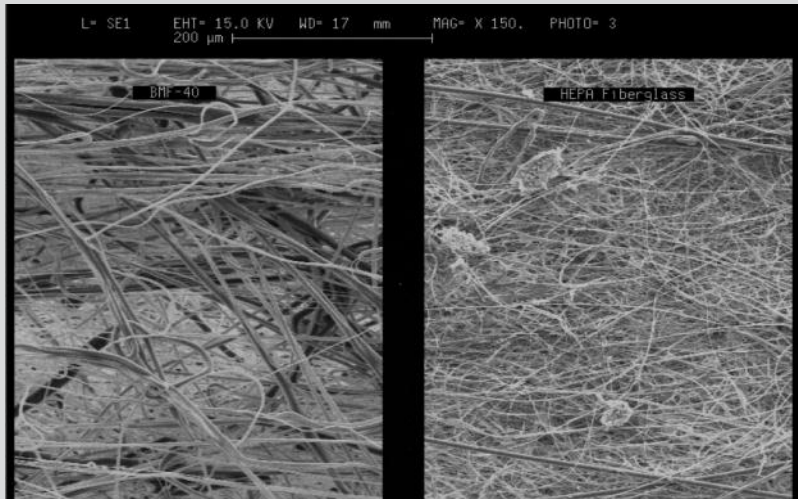


- Polymer filters have been used in Australian coal mines since late 90's
 - Recognized as industry leading solution and preferred choice of many AUS vehicle OEM's
 - Very high filtration efficiency (>95% @ 50 nanometers)
 - Moderate filter life
 - Developed by Freudenberg (formerly Microfresh) to overcome low efficiency and flammability / life concerns with alternate technologies
 - Suitable for exhaust temperatures <120 deg C (Coal Mine requirement – Methane)
 - Low Pressure Drop: 1 kPa(new) - 20 kPa(fully used)
 - High Auto-Ignition temperature (>960 deg C), melts at 140 deg C



Polymer Filter

Paper / Glass Filter



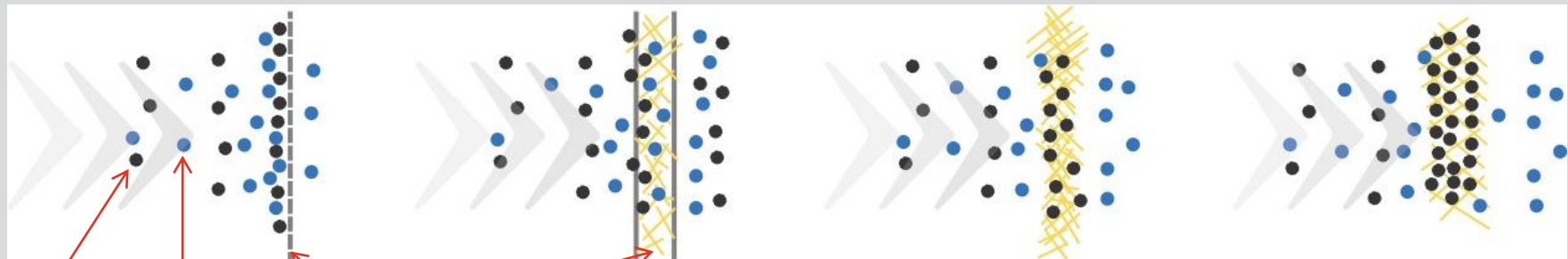
- Open fibre structure uses electrostatic charge for filtration
 - Water from temperature reduction scrubber can pass through
 - Nanoparticles are trapped
- A lot more open than paper/glass media
 - Polymer has Lower pressure drop
 - Polymer has Higher filtration

Filter Advancements



- FFT embarked on a new technology development program in 2012
- Major driver (other than remaining market leader):
Coal Price has dropped over 50% since 2012, all mines are seeking cost reductions
- Our target for a new **long life filter** was at least 50-100% increase in average filter life
- No reduction in filtration efficiency (Meet 0.1 mg EC maximum atmospheric exposure limit)

Paper Filters	Fibreglass Filters	Polymer Filters	Target Polymer Filter
Poor Efficiency	Very Poor Efficiency	Excellent Efficiency	Excellent Efficiency
Poor Water Pass Through	Excellent Water Pass Through	Good Water Pass Through	Excellent Water Pass Through
Good DPM Holding Capacity	Poor DPM Holding Capacity	Good DPM Holding Capacity	Excellent DPM Holding Capacity

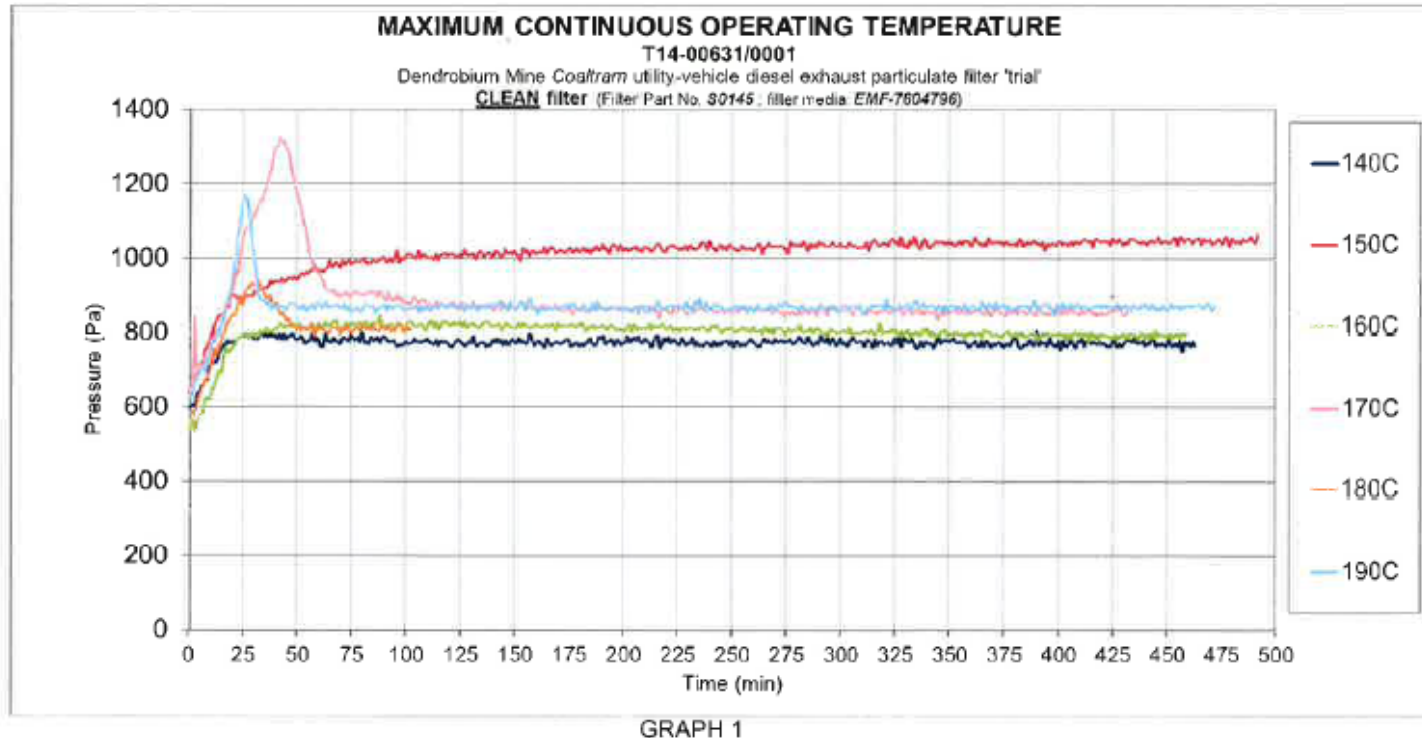


Diesel Particle Water Droplet Filter Media

Filter Advancements



- New Electrostatically charged polymer media developed by FFT
- Proprietary co-polymer design
- Maximum operating temperature increased from 120 degC to 160 degC



The Maximum Continuous Operating Temperature of the clean filter media, as determined by this method, was 160°C.

Disposable Diesel Particulate Filter Testing

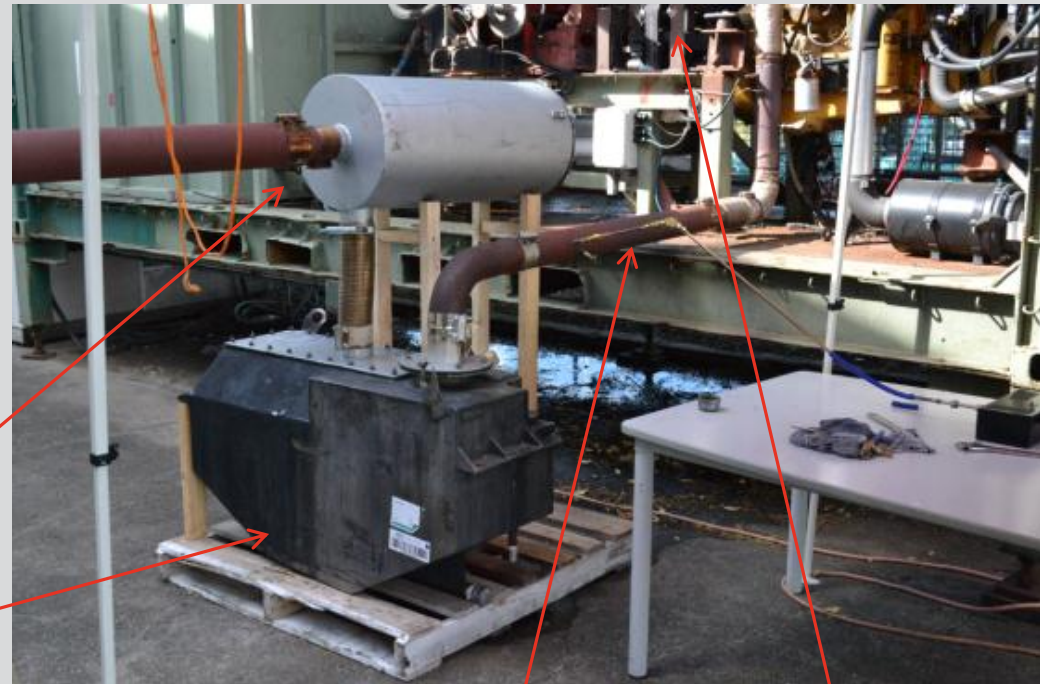
Test Engine / system: Caterpillar C7
fitted to water brake dynamometer

Apparatus

- EEPS particle count DPM meter for particle sizing /number
- MAHA MPM-4M Laser Light Scattering particulate mass measuring device

Filter Housing

Water Scrubber



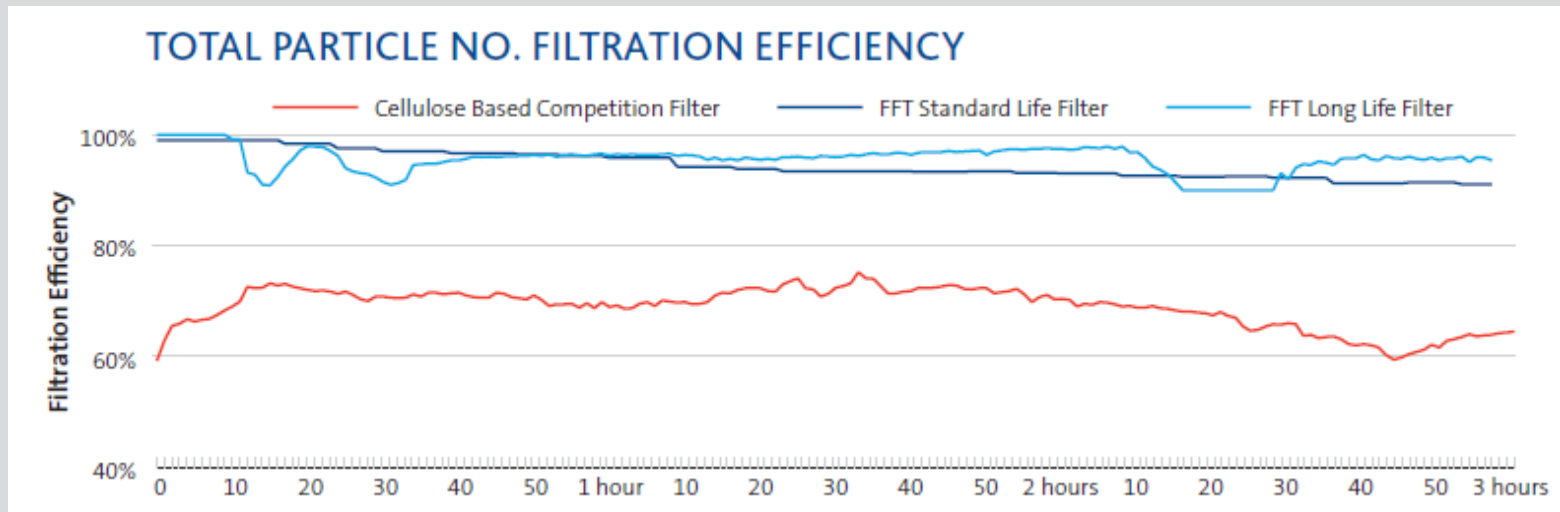
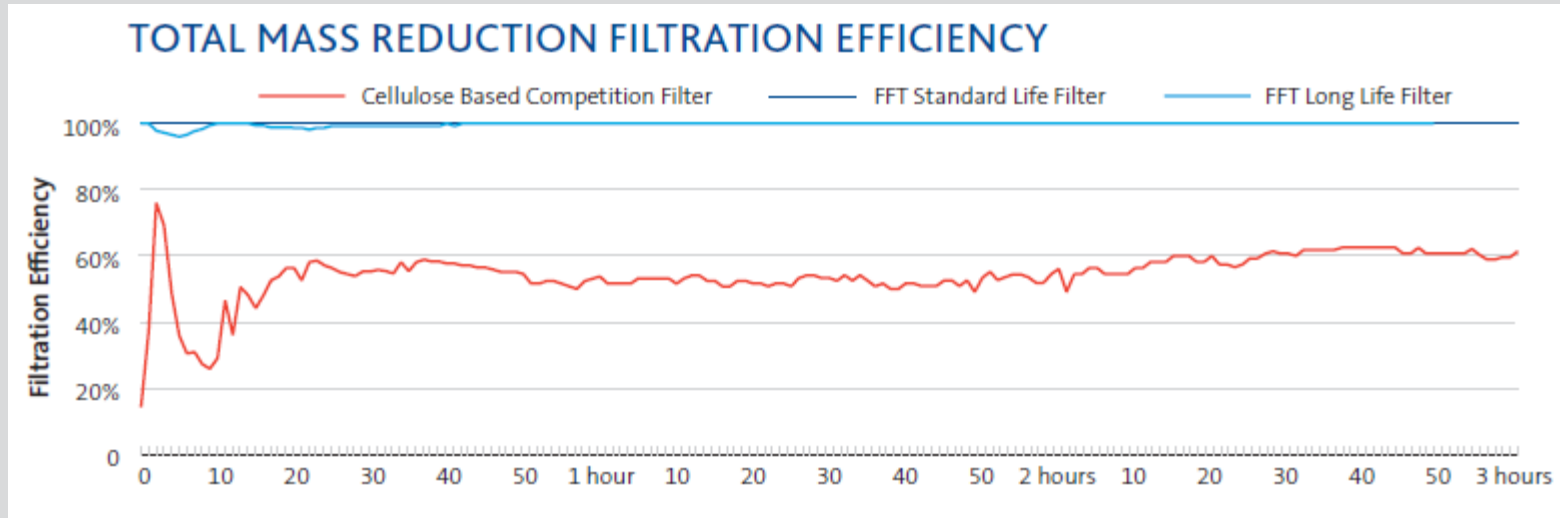
Exhaust Analysis Probe

Engine / Dyno

Test Protocol

- Dyno Load set to load / speed profile resulting in water challenge to filter and DPM emissions sufficiently high to mimic “in-use” condition
- Backpressure measured between filter housing and scrubber
- DPM measured pre and post filter housing

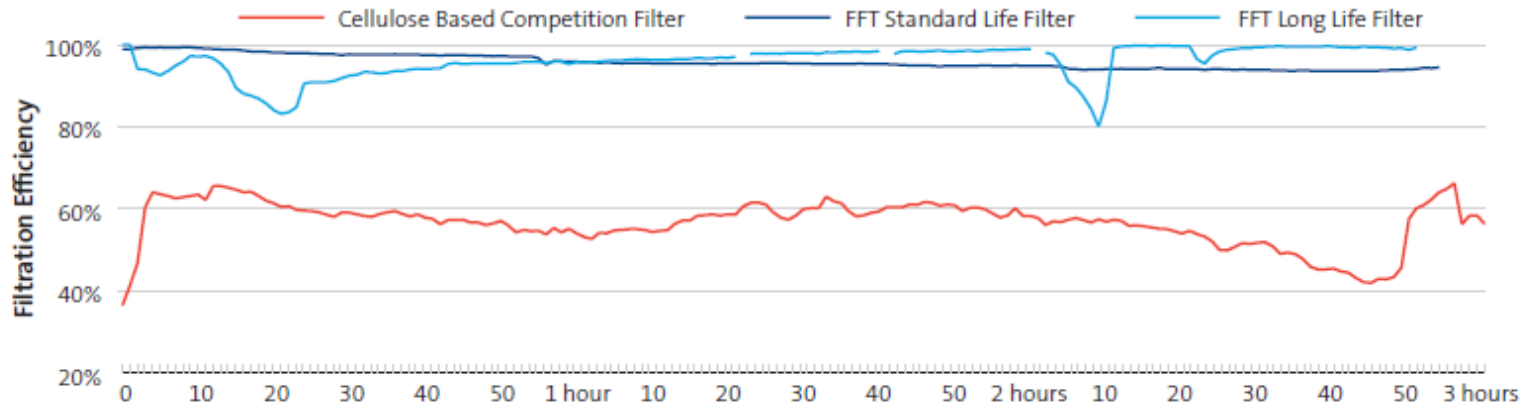
Disposable Diesel Particulate Filter Testing Results as compared to Cellulose / Paper Filter



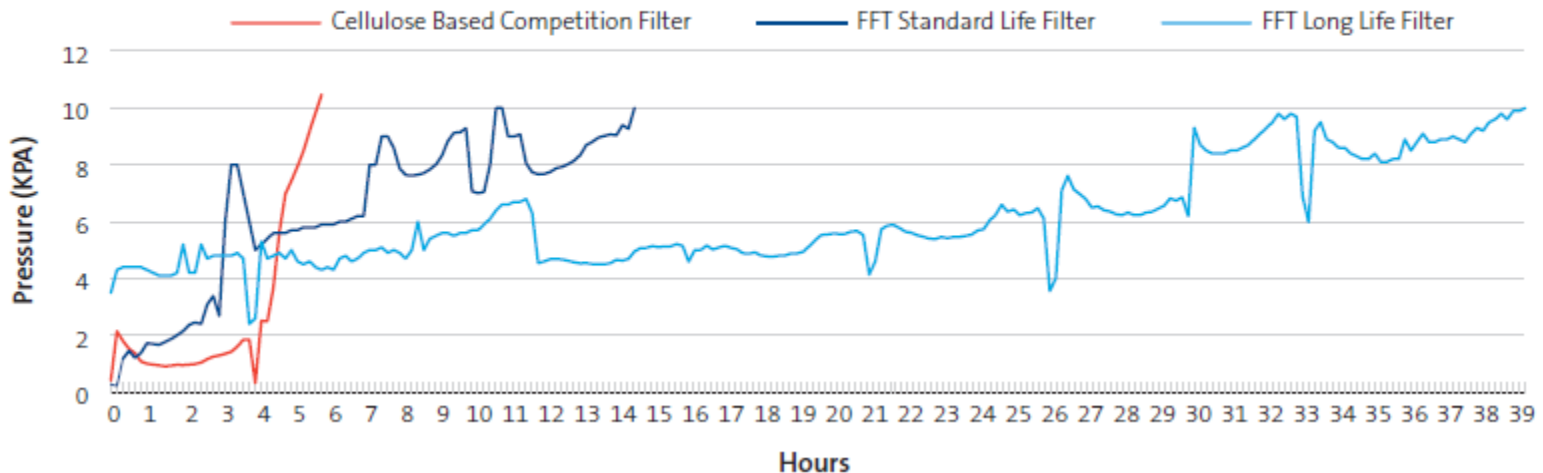
Disposable Diesel Particulate Filter Testing Results as compared to Cellulose / Paper Filter



FILTRATION EFFICIENCY OF 50 NANOMETRE SIZED PARTICLES



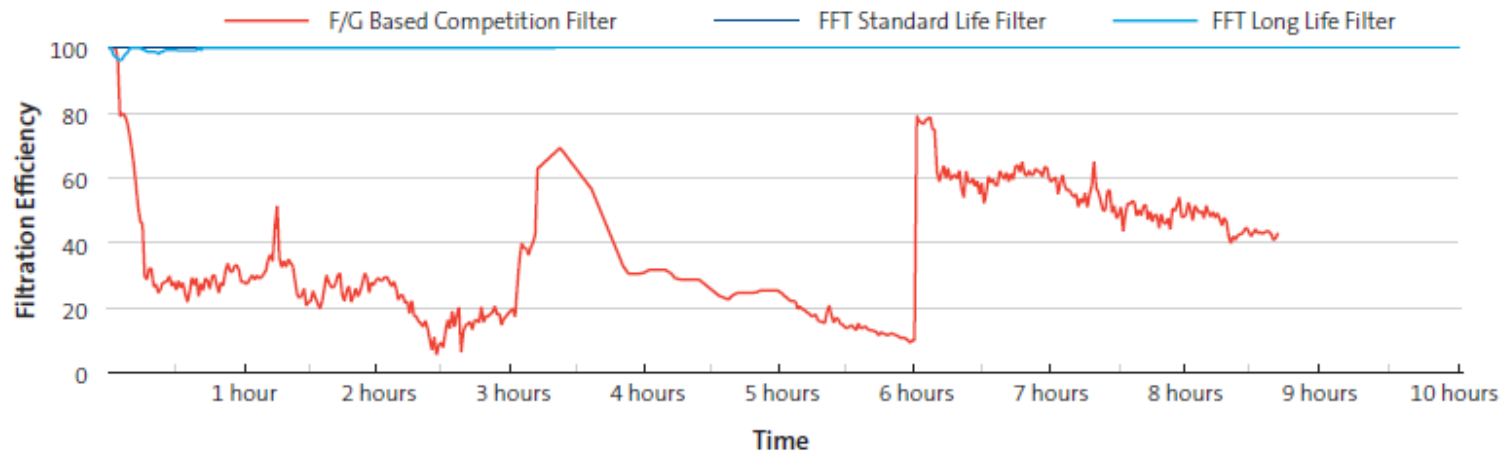
PRESSURE INCREASE OVER TIME



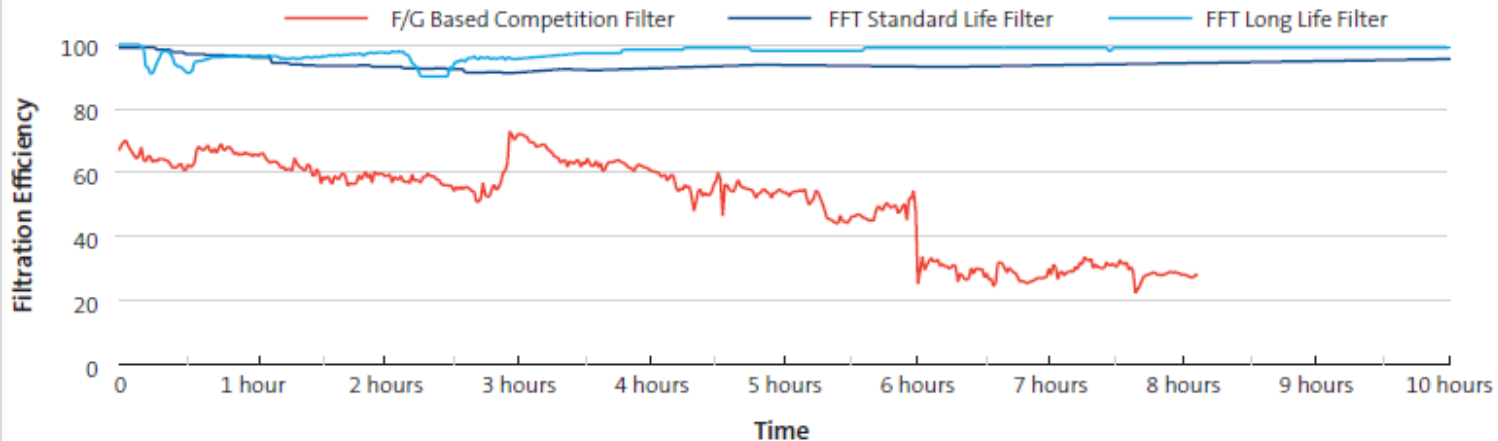
Disposable Diesel Particulate Filter Testing Results as compared to Fibreglass Filter



TOTAL MASS REDUCTION FILTRATION EFFICIENCY

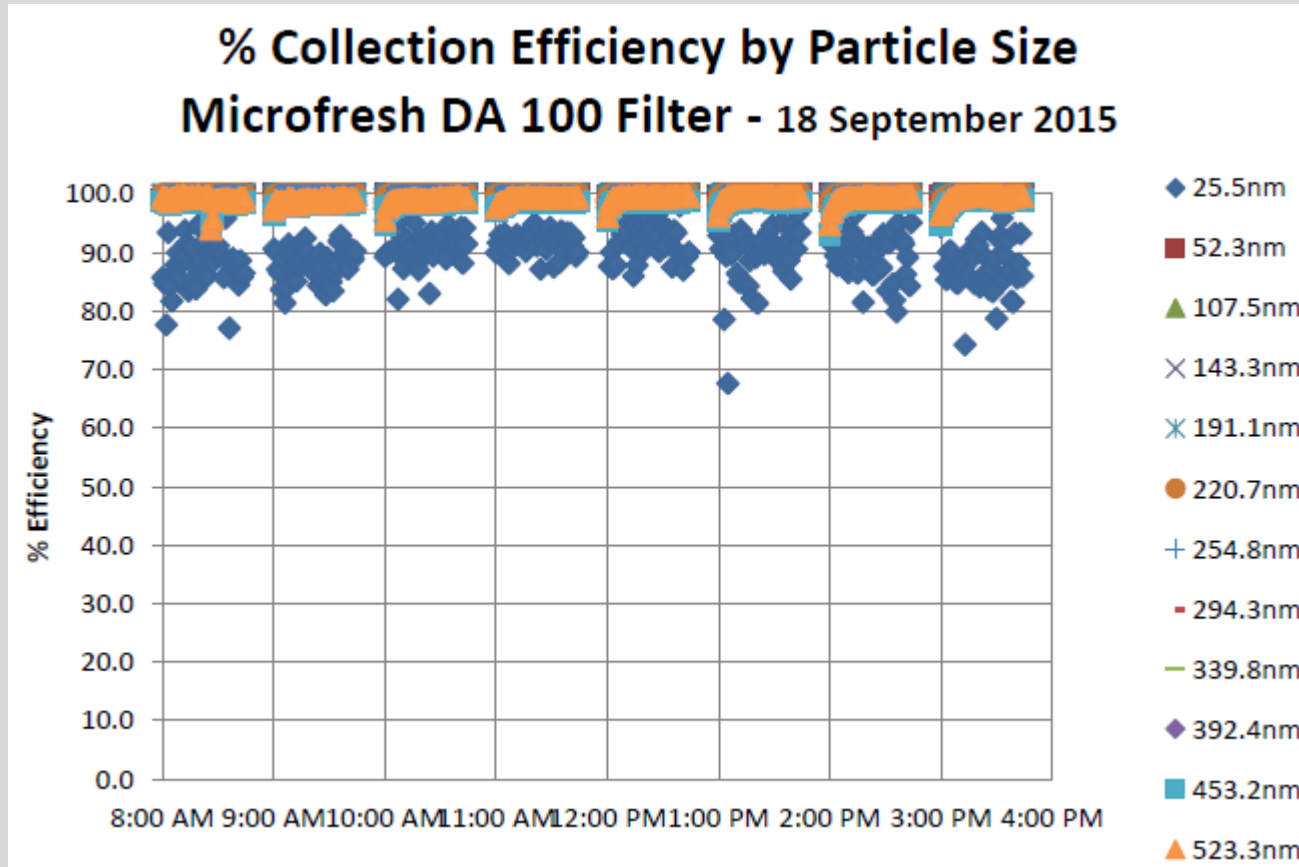


TOTAL PARTICLE NO. FILTRATION EFFICIENCY



Disposable Diesel Particulate Filter Testing

Results also broken down by particle size



Typical Polymer Filter filtration efficiency by size

- 97%+ reduction of particles over 50 nanometers
- 90% average reduction of particles around 25 nanometers (smaller than this falls in to noise of EEPS)

Outcomes



- The AUS coal mining industry is fast beginning to adopt the long life polymer Disposable DEF Technology to take advantage of:
 - Increased filter life (reduced costs)
 - Increased filtration efficiency (enhanced health)
- The technology is now approved for use on a large and expanding number of OEM vehicles in AUS
- The technology is also listed on the MSHA website (as of Feb 16) as approved for use in US mines
- Further enhancements are planned as part of FFT's continuous technology improvement process
- For further information or discussion around suitability for alternate applications please contact stephen.gledhill@freudenberg-filter.com

