Contribution of Gasoline Particulate Filter (GPF) and Lubricant to the TGDi System Solution

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Outline

- GPFs: The need for change
- What is a GPF?
- Engine Oil: Part of the solution
- Lubricant impact on GPF function
- Summary

Gasoline Particulate Filters: The Need and the Challenge

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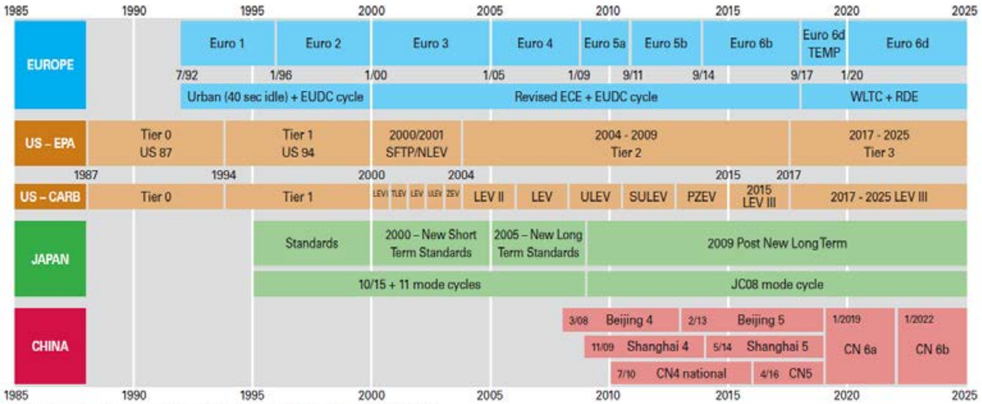
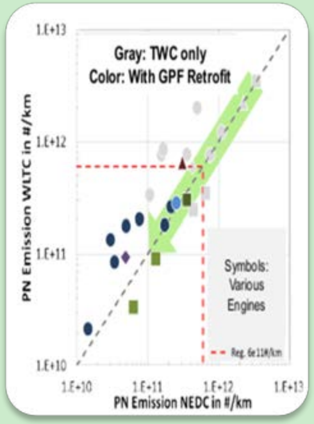
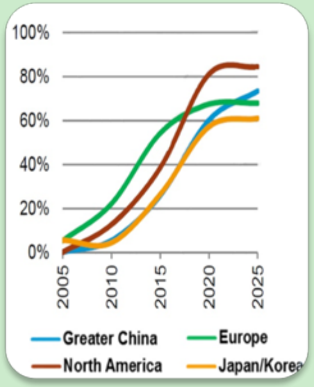
Emission Targets Driving Fundamental Shift

in Gasoline Vehicle Technology

Timeline – Toxic Emissions Standards Passenger Cars







1970/90s

Control of priority pollutants

- Adoption of catalysts and engine control
- Reduce HC, CO, NOx

Mid 2010s

Fuel Efficiency

- Improve FE/CO2 emissions
- Engine downsizing and power enhancement

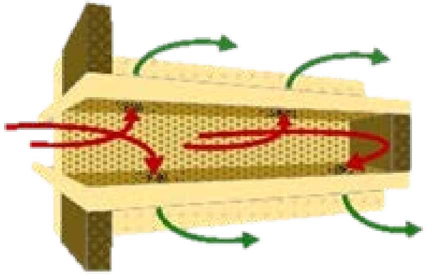
Late 2010s

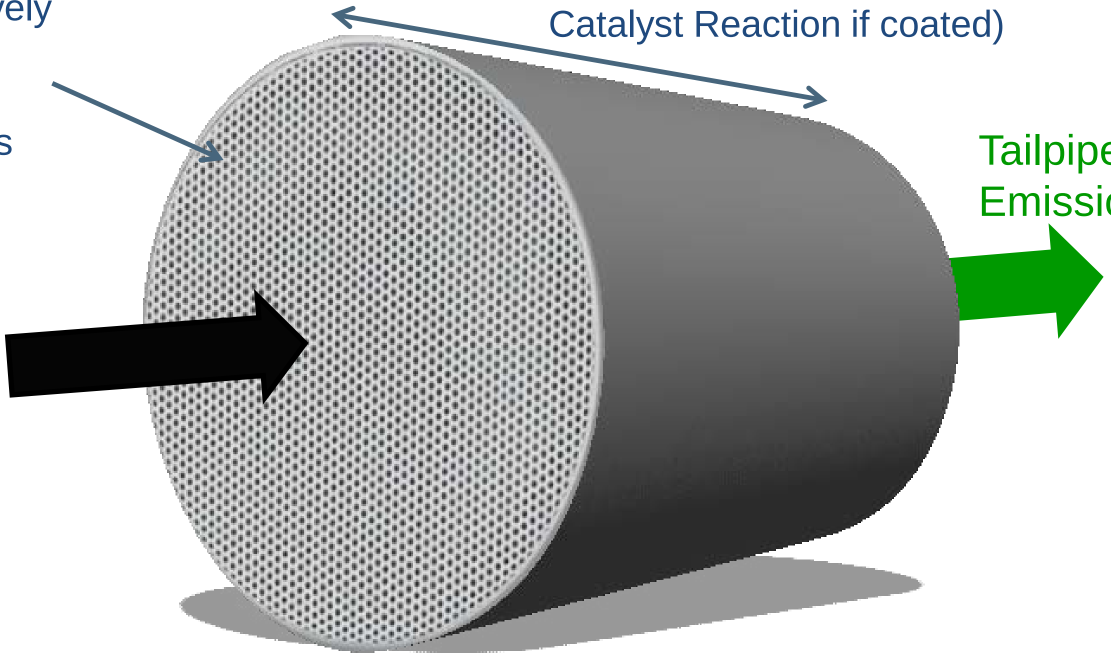
More stringent emission regulations

- Particulates
- RDE

References L to R: Delphi - Worldwide Emissions Standards, Passenger Cars and Light Duty Vehicles 2017-2018; IHS 2015 report, Corning, Gasoline Particulate Filter: A Overview, 2017 LD Emission Control Symposium

What is a Gasoline Particulate Filter?





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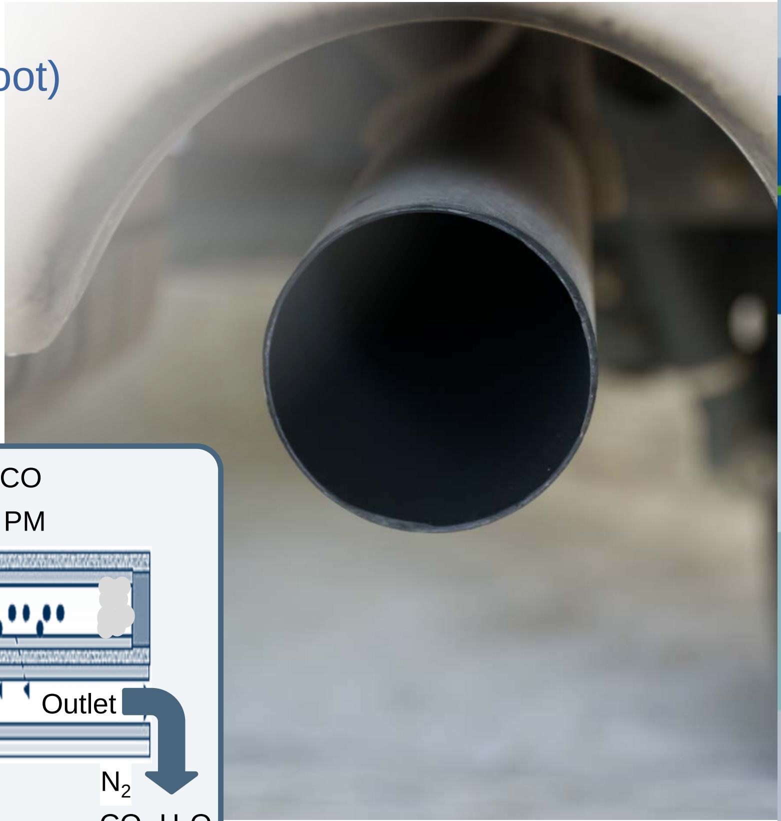
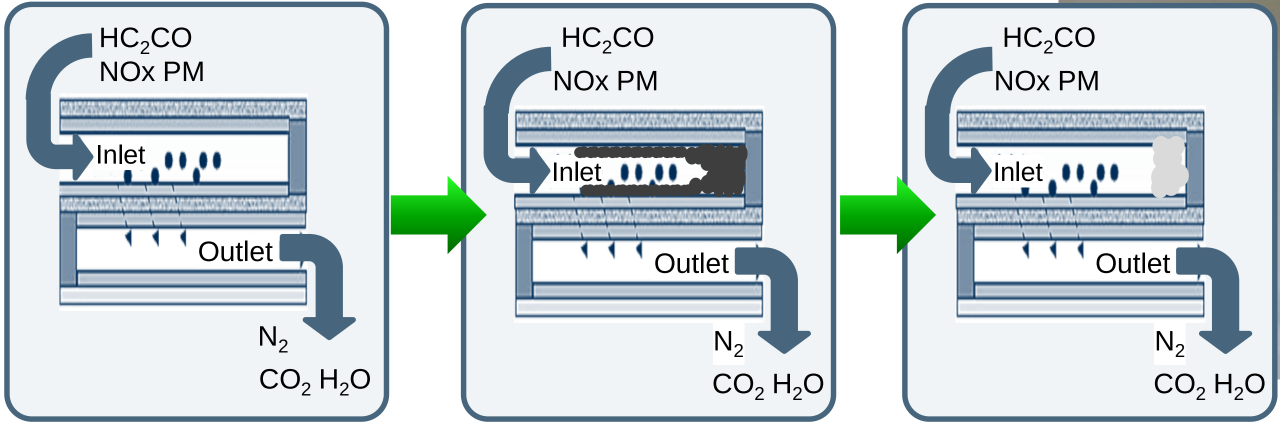
What is a Gasoline Particulate Filter?
continued

- Gasoline engines generate particulate emission (soot)
- GPFs are filters, or ‘traps’, fitted within the exhaust system of vehicles to catch particulate matter
- GPFs are not DPFs!





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GPF: System Optimization for Performance

- Packaging
- Particulate Filtration Efficiency
- Gaseous emission
- Calibration
- OBD Requirement
- Backpressure/Regeneration
- Total cost

Successful deployment of GPF technology needs system optimization for various performance requirements

…Including the engine lubricant

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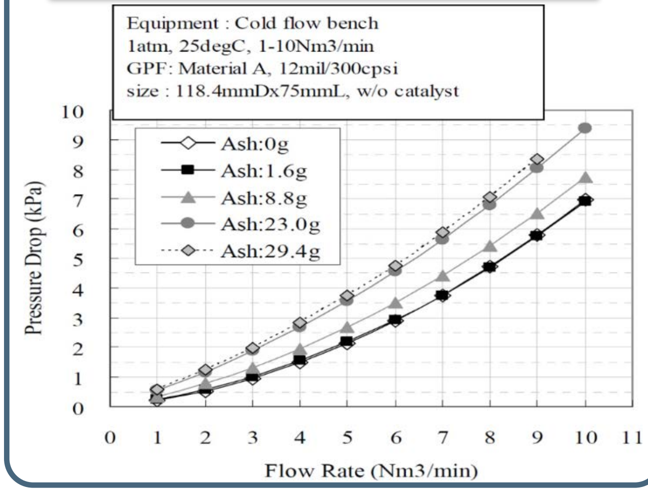
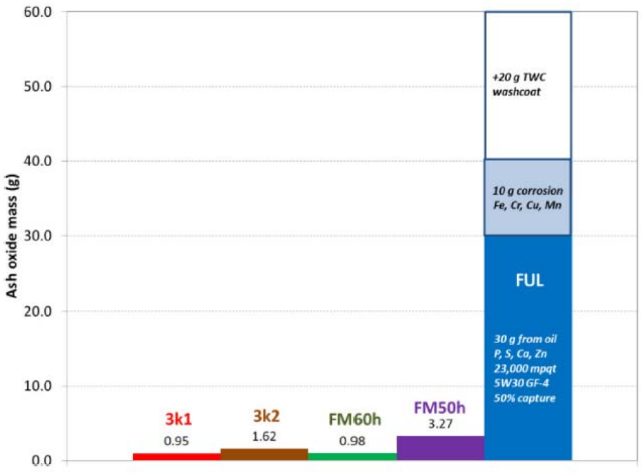
Effect of Ash on Backpressure

Effect of Ash - (Cold Flow Bench)



Ref.: SAE 2012-01-1241 (Shimoda et al)

XRF Analysis of Ash in GPFs



Ref.: SAE 2017-01-0930 (Lambert et al)

How Soot and Ash accumulate and are managed can have a marked impact on GPF performance and ultimately vehicle fuel economy

- Backpressure increases with soot and ash accumulation amount
- Low mileage and dyno aged filters contained far less fully oxidized ash mass than the full useful life (FUL) filter
- Approximately 50 wt% of the collected ash was not directly related to the oil consumption

Initial Insights

- Global emission legislation is driving towards more TGDi engines fitted with GPFs
  - Physical removal and oxidation of carbonaceous particulates
- Ash (and soot) loading rates / levels are one of several critical factors in GPF efficiency
- Lubricant formulation characteristics impact GPF filtration efficiency
  - Additive ash contribution

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Lubricants: Part of the System Solution

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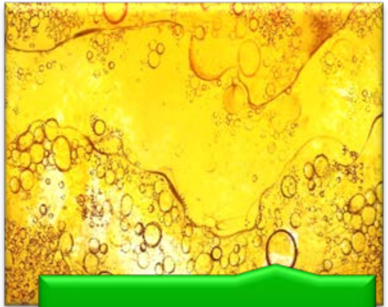
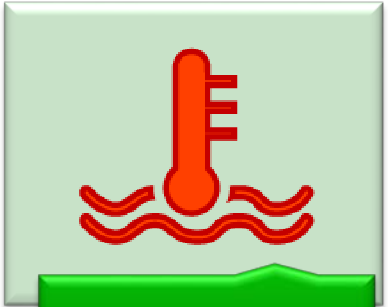
Roles of a Lubricant & Lubricant Additives



Lubricate

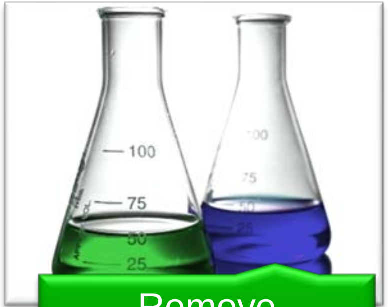


Cool

Pressurize

Prevent Wear

Reduce Friction



Remove Contaminants

Protect the oil

Enhance Performance

Modify Oil Properties

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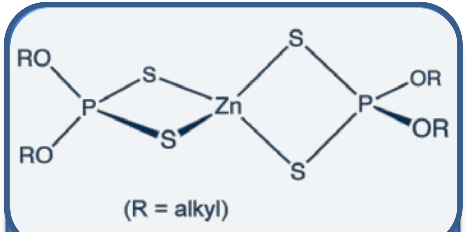
Key Lubricant Additives Adding Ash

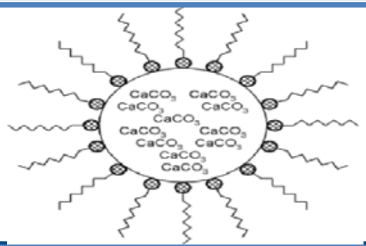


ZDDP
(zinc dialkyldithiophosphate)

Primary, and most effective anti-wear agent (durability)

Used for over 80 years

Also most cost-effective anti-oxidant

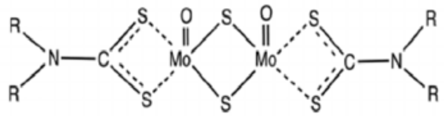


Metal Detergents
(sulfonate, phenate, salicylate)

Keeps engines clean, and neutralises combustion-acids.

Most chemically efficient way to add base to the lube

Range of surface impacts



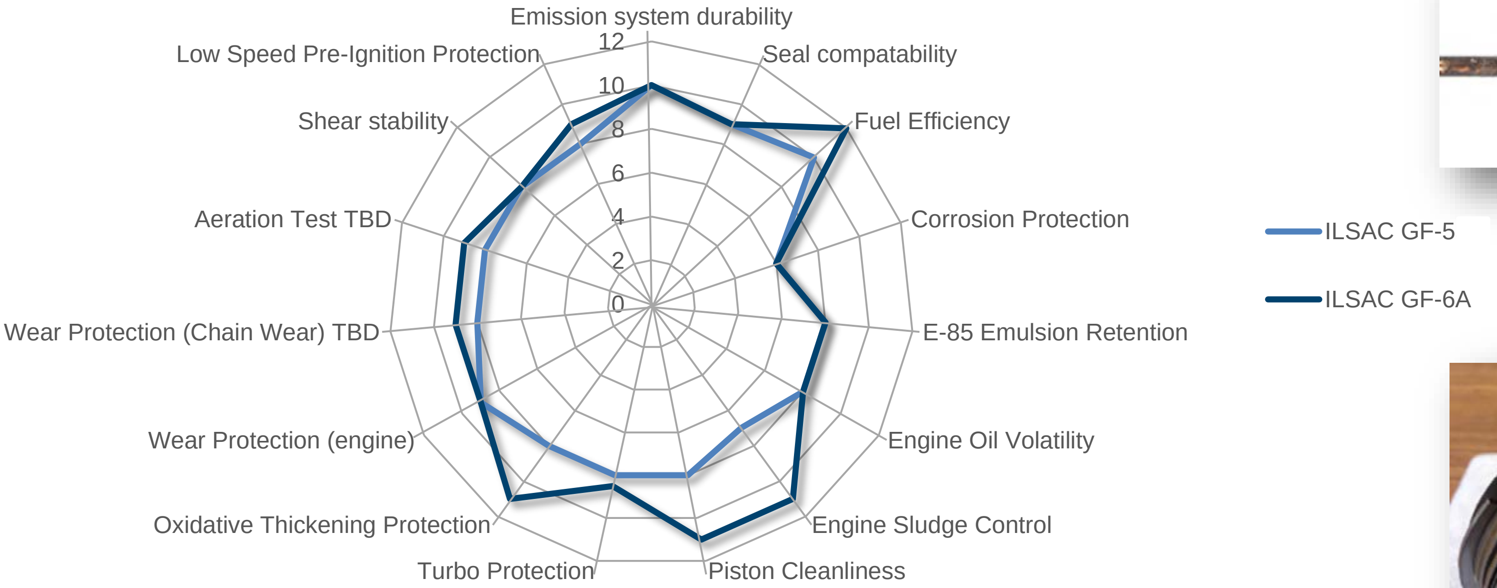
MoDTC
(molybdenum dithiiocarbamate)

Inorganic friction modifier

Increased use since mid-’90s

Particularly effective in motored-friction tests (fuel economy)

Lubricant Formulation Balance



Zero ash lubes are theoretically possible, but practically prohibitive
Thankfully, our research evaluations show we don't need to be so drastic
We must maintain a holistic approach to lubricant formulating

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Initial Insights

- Certain lubricant additives do add ash to the system
- These additives perform several roles that are critical to the effective operation of the engine
- The overall vehicle performance and protection is a complex system
  - Lubricant impacts both the engine and GPF operations
  - We need to consider the best overall solution

Lubricant Impact on GPF: Afton Testing

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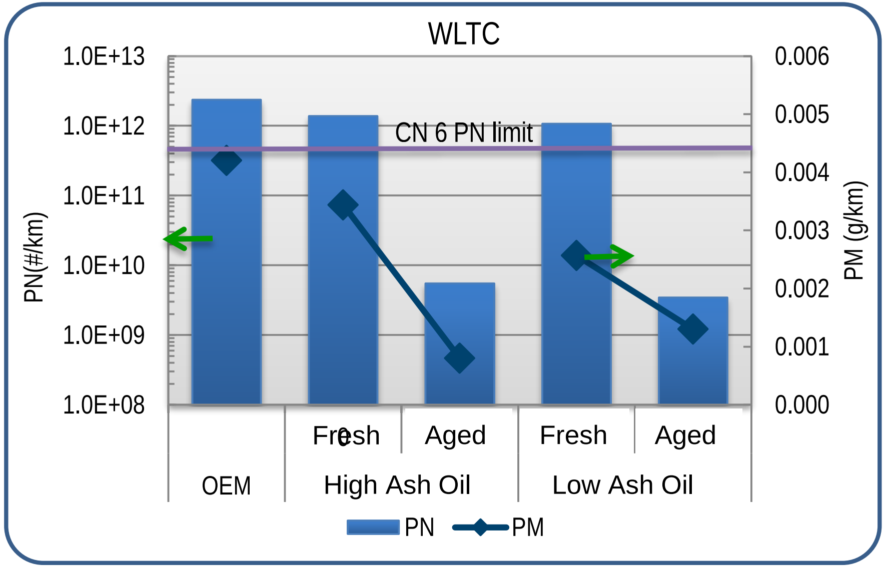
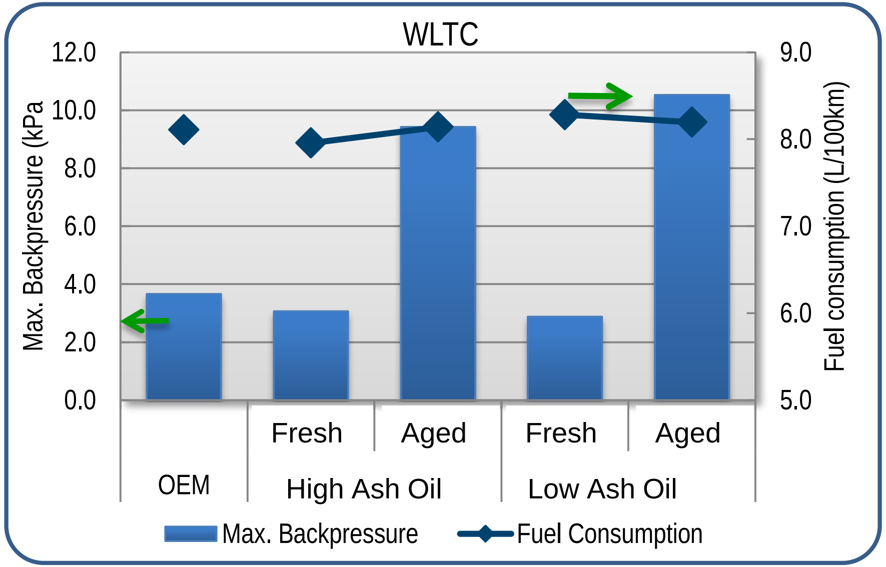
Lubricant Ash Impact on GPF Function





No significant difference in PM/PN emission, backpressure and fuel consumption between two lube ash levels in end-of-life performance

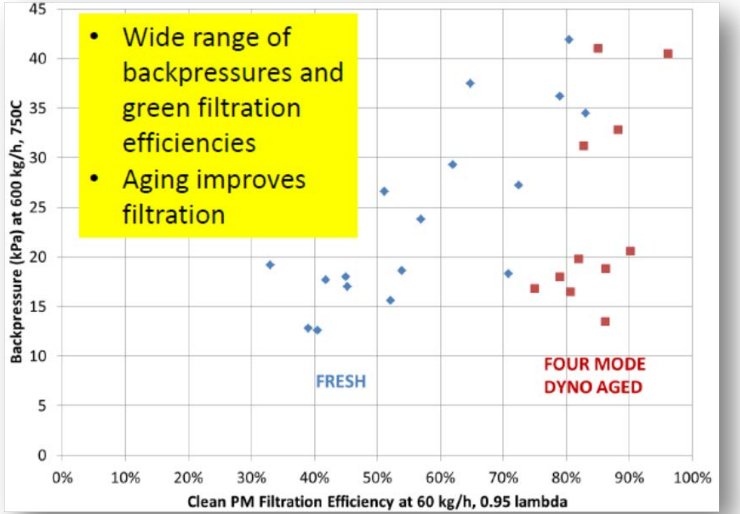
Poorer particulate filtration rate for unconditioned GPF

Clear impact of ash-loading on GPF backpressure

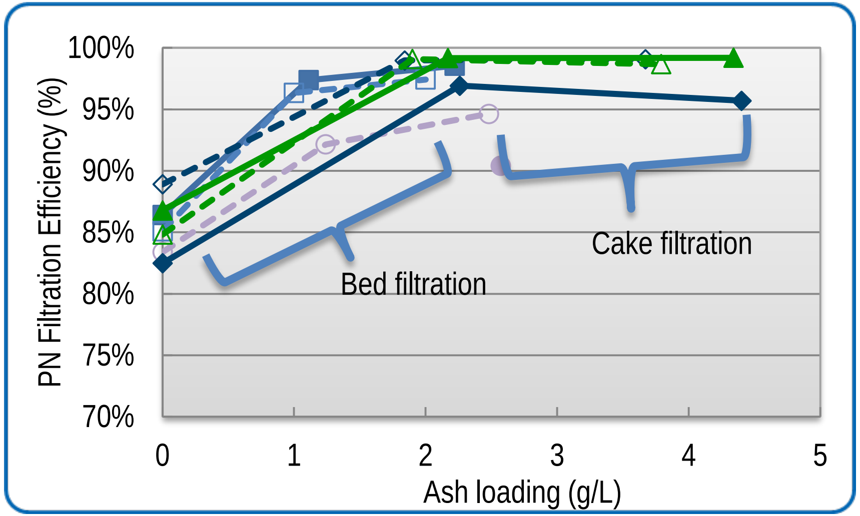
Note: Full Scale Engine/Vehicle Ash Loading/System Durability Studies

Source: Afton data 2017

Reality Check on Green Filtration Efficiency



Source: API DAP 12/12/17 (Lambert et al)



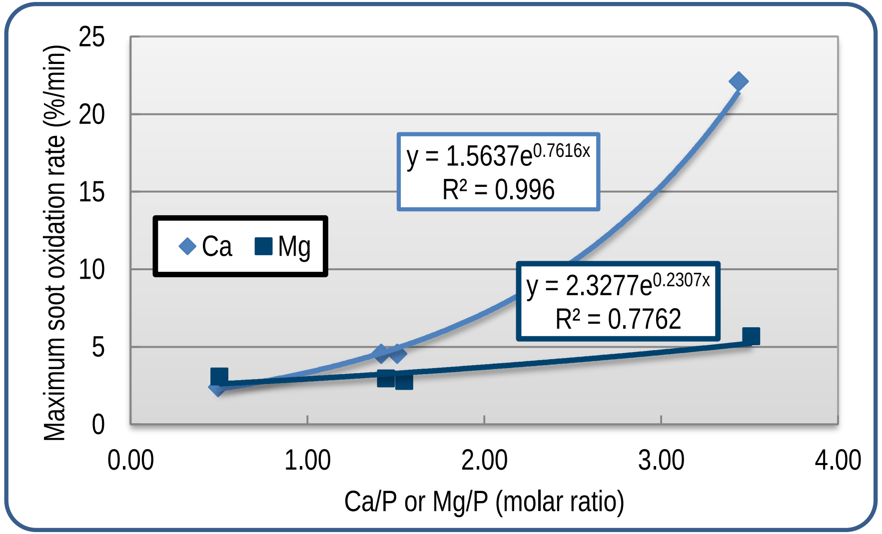
Source: Afton data 2017

Green filtration efficiency needs improvement to meet legislation requirements

Filtration efficiency improves greatly from bed filtration to cake filtration

Ensuring the vehicular emissions for new vehicles with "green" particulate filters may be a significant challenge

Model Engine Studies on GPF Cores: Formulation Affects Oxidation

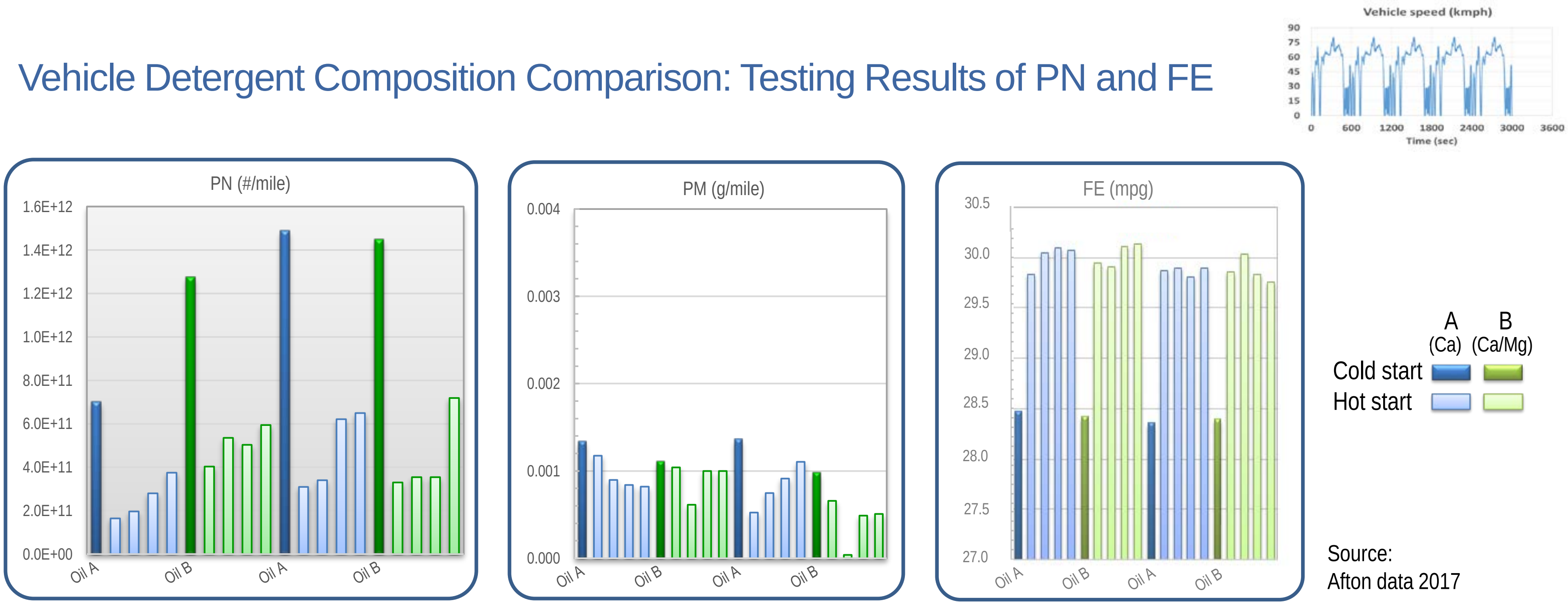


Source: Afton data 2017

- PM (soot) oxidation is affected by its composition, temperature, catalyst etc.
- Increased soot burn-off rate can equate to fuel economy savings
- Lubricant oil formulation can change oxidation rate

Lubricant oil formulation can impact GPF regeneration rate and hence benefit fuel economy

Vehicle Detergent Composition Comparison: Testing Results of PN and FE



Test Protocol: Cold Start US06-soak (1h)-US06-soak (1h)-US06 -soak (1h)-US06-soak (1h)-US06

Driving condition (cold start vs. hot start) has significant impact on both PN and FE

Source: Afton data 2017

Summary

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Summary

- Global emission legislation is driving towards more TGDi engines fitted with GPFs
- Lubricant formulation characteristics impact GPF filtration efficiency
- The overall vehicle performance and protection is a complex system
  - Lubricant impacts both the engine and GPF operations
- Generally the industry is gravitating to 0.8% Ash lubricants
  - Balancing engine durability and GPF efficiency requirements
- Green filtration sees a potential challenge in attaining low PN targets

Acknowledgments

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Thank you

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