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Afton Catalyst Test (ACT)
Researching the Effect of PEI on Phosphorus-Related Catalyst Poisoning

A report given to the GF-5
Emission System Compatibility Improvement Team

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Purpose of Test

- Determine the relevance of PEI on phosphorus-related automotive catalyst poisoning

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Why is Afton developing this test?

- Afton has a wealth of experience in testing and understanding automotive catalyst performance issues
- We believe that catalyst poisoning associated with engine oils can be better-controlled through lubricant chemistry rather than through chemical and/or physical limitations

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Brief Catalyst Deactivation Primer Catalyst Deactivation

- Thermal -- Irreversible
  - Extended operation above a critical temperature causes loss of surface area
    - Sintering of precious metal
    - Sintering of wash Chemical
- Chemical – Reversible
  - Chemical deposition inhibits mass transfer of exhaust into catalyst.
  - Masking of precious-metal atoms

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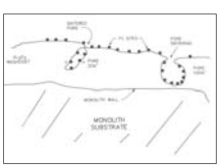
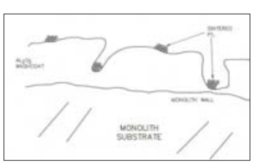
Thermal deactivation

Loss of surface area due to wash coat “flowing”



Loss of surface area due to Platinum sintering.



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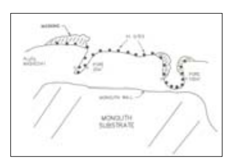
Chemical Deactivation

- Phosphorus from engine oil forms a glaze that covers or “masks” the platinum catalyst sites and Cerium Oxide wash coat.



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Afton Test Precepts

- Avoidance of accelerated aging regimes
  - Experience has taught us that this can introduce effects not seen in field service
- Avoidance of thermal aging conditions
  - Catalyst deactivation is a combination of thermal and chemical effects
  - Afton wishes to focus on oil chemistry effects
- Maximization of volatility-related effects / minimization of bulk oil consumption
  - OPEST I and II were bulk-oil tests

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Test Details and Installation

- Engine and controls
  - Ford 4.6L V8 built to Sequence VG configuration
    - Control oil, coolant and rocker cover temperatures and flows
    - Precise control of Lambda (air-to-fuel ratio)
  - Single light-off catalyst, relocated to reduce inlet temperature
  - Full emissions measurement capability
  - Full control over exhaust gas temperature

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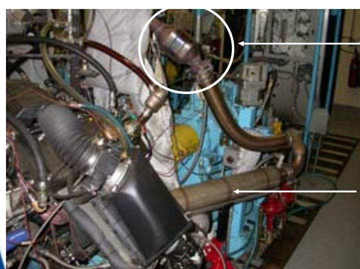
Test Cell Photos



Catalyst position

The catalyst position facilitates using a single catalyst for both banks and lowers the maximum inlet temperature by over 200 °C.

Conversion efficiencies are performed using the left-bank only. Exhaust is cooled via an air-air heat exchanger shown in the photo.

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Test Cell Photos

Modified Light-off Catalyst

900 CPI Ford 2004MY

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Test Cell Photos

Heat Exchanger for controlling EGT

This heat exchanger allows testing between 145 °C and 360 °C EGT in 10 °C increments. Ramping interval is 10-minutes between set points with no overshoot. Lambda is controlled.

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Test Development Oils

- From SAE 2002-01-2680
  - Ethyl/Delphi/Ford field test
    - Oils 32, 33, 35
      - Oil 32 - Low PEI (15), ILSAC GF-2
      - Oil 33 - High PEI (46) , Zero Detergent
      - Oil 35 - Zero-Phosphorus, PEI=0
    - Other oils
      - GF-4 formulation style, PEI 11
      - GF-4 formulation style, PEI 90

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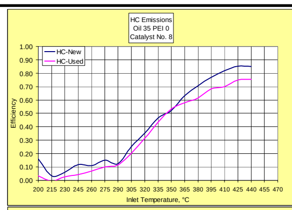
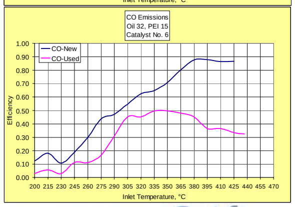
Operating Cycle

- De-green catalyst
- Determine baseline conversion efficiency (CE)
- Age catalyst for 10 days
- Re-measure CE
- Calculate loss of CE, loss of T-50

Operating Conditions

- 120°C Oil
- 115°C Coolant
- 24-hour oil change
- 1800 rpm
- 58.5 MAP
- 8 kg/hr fuel (EEE)

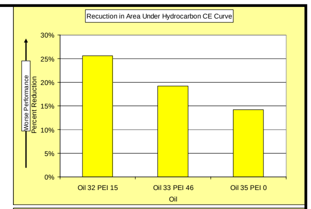


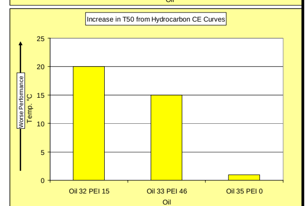


Result Interpretation

Area under the CE curve is calculated and difference between new and used is determined. A larger change in area means more emission breakthrough (less conversion).

T50 is the temperature where 50% of the inlet emissions are oxidized for CO and HC. An increase in T50 is detrimental since vehicles produce most of their emissions when starting from a cold-soak. A higher T50 value means a longer time before the catslyst reaches optimum CE temp, and therefore more emissions breakthrough.

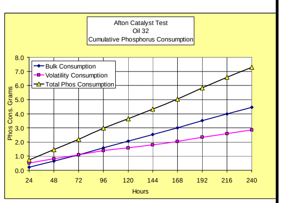


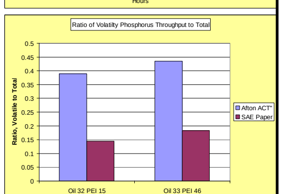


Phosphorus Throughput

Phosphorus throughput is determined by measuring reduction in P concentration for each 24-hour oil add and accounting for normal additive concentration due to bulk-oil volatility losses.

Oil 33 with a higher PEI value has a higher ratio of volatility-related phosphorus consumption to the total consumed. This was also observed in the Ford/Delphi/Afton Field Test.





Where we're at today

- Limited testing suggests the ACT is responsive to phosphorus concentration and volatility and work is underway to increase contribution of phosphorus throughput due to volatility.

Future Test Plans

- Phosphorus determination on catalyst face
  - XRF
  - SEM-EDX
- Phosphorus chemical speciation
  - Proprietary Afton tests
- SAE paper in 2007

References

- SAE 2004-01-2986 "How Much ZDP is Enough?"
- SAE 2002-01-2680 "Effects of Engine Oil Formulation Variables on Exhaust Emissions in Taxi Fleet Service"
- SAE 940746 "Engine Oil Additive Effects on Deactivation of Monolithic Three-Way Catalysts and Oxygen Sensors"
- SAE 920654 "Effects of Phosphorus and Ash Contents of Engine Oils on Deactivation of Monolithic Three-Way Catalysts and Oxygen Sensors"
- SAE 872080 "Use of a Novel Non-Phosphorus Antiwear Additive for Engine Oils"
- SAE 841406 "Catalyst Deactivation Due to Glaze Formation from Oil-Derived Phosphorus and Zinc"
- "Catalytic Air Pollution Control", Heck and Farrauto