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NATURAL RESOURCES CANADA - INVENTIVE BY NATURE

Evaluation of the CanmetENERGY Prototype Catalyzed Diesel Particulate Filter: Determination of the Balance Point Temperature

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Current Diesel PM Control

- Filtration of particulate matter (PM): Diesel particulate filter (**DPF)**
- Active Regeneration
  - Reduces DPF life and increases fuel consumption
- Passive Regeneration: **Catalyzed DPF**
  - commercial NO_2-based technologies
    - Continuously Regenerating Trap (CRT)
    - Catalyzed CRT (CCRT)
    - Catalyzed Soot Filter (CSF)
- Limitations of NO_2-based technologies:
  - Pt catalyst – expensive and sensitive to sulfur
  - High concentration of NO (high NO/PM ratio)
- Challenges for catalyst development:
  - Non PGM catalyst with high sulfur resistance and durability
  - Lower light-off temperatures for PM/soot oxidation
  - High activity without NO/NO_2

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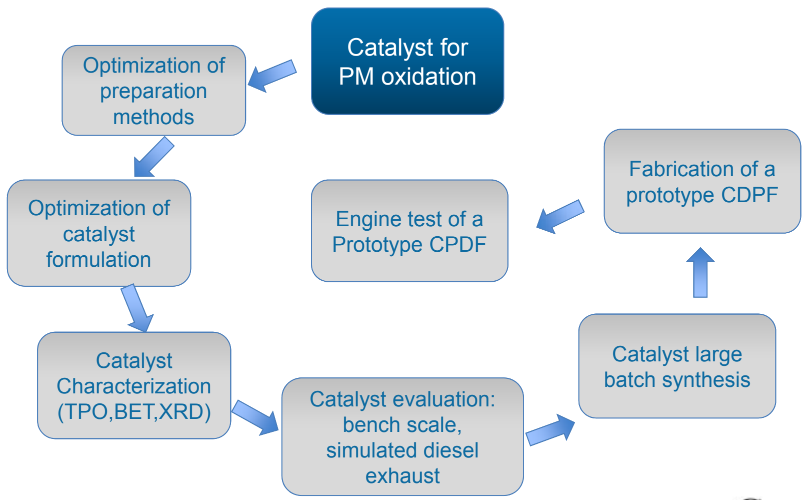
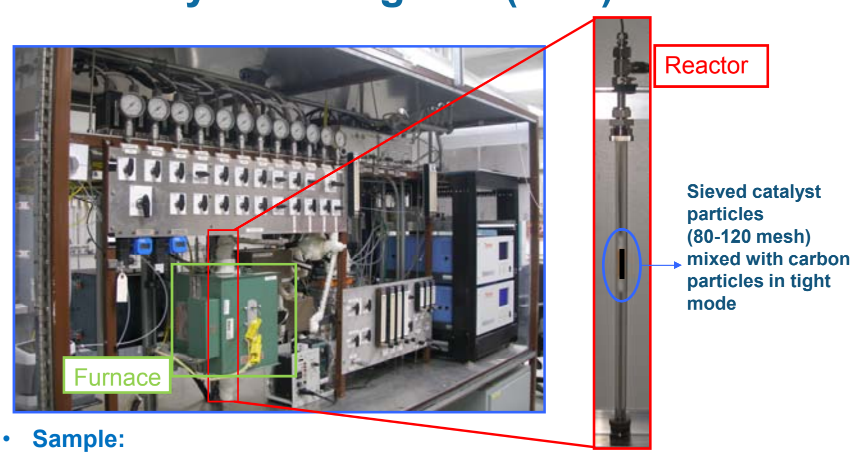
Catalyst Development

Objective: Development of a low cost catalyst to reduce PM emissions from heavy duty diesel vehicles at temperatures of diesel exhaust



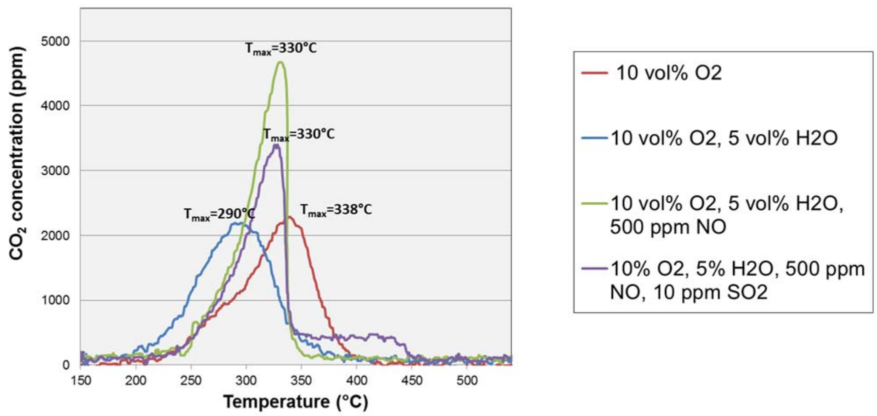
Catalytic Testing Unit (CTU)



- **Sample:**
  Catalyst : Carbon Black = 30:1, tight contact, 500 mg, 250 mg cordierite
- **Feed composition:**
  10 vol% O_2, 5 vol% H_2O, 500 ppm NO (10 ppm SO_2 optional)
- **GHSV:** 60k-80k h^{-1}
- **Temperature:** 150°C-600°C @ 3°C/min

CTU Test Results: Simulated Diesel Exhaust

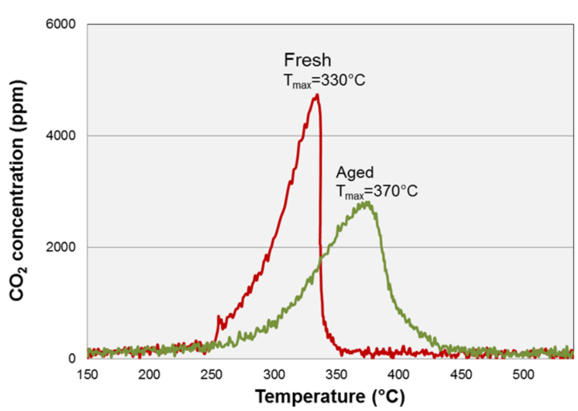
500 mg mixture diluted with 250 mg of cordierite, 3°C/min from 150 to 600˚C,



- T_{max} is selected as an activity indicator
- High activity for carbon oxidation and sulfur resistance

CTU Test Results: Hydrothermal Stability

- Aging protocol: 10 vol%O_2, 5 vol% H_2O, 750˚C, 15 h
- Testing feed gas: 10 vol%O_2, 5 vol% H_2O, 500 ppm NO



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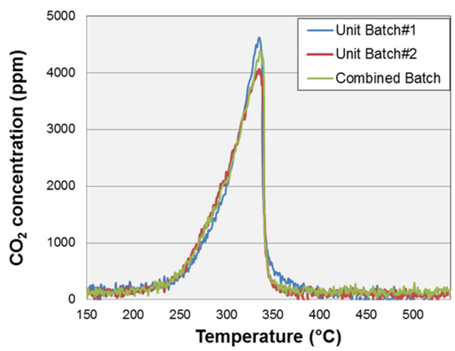
CanmetENERGY Prototype CDPF

- Unit batches: ~100 g
- Large batch catalyst: 1.3 Kg
- Activity of small and final batches were confirmed by CTU testing



- Cordierite core (400 cpsi)
- Stainless steel can
- 12.5 L
- CanmetENERGY catalyst
- Catalyst loading: 38 g/L
- Manufactured by DCL International Inc.

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Engine Test of CDPFs

Experimental Approach

- CanmetMINING accredited testing laboratory (ISO/IEC 17025)
- Comparison of the CanmetENERGY CDPF with the commercial base metal-palladium CPDF “Cattrap” produced by CDTi for mining operations
- Split flow and no DOC
- Low sulfur mining diesel fuel
- Pre-loading of diesel particulate on each CDPF to a predetermined level
- Determination of Balance Point Temperature (BPT) of each CDPF according to DECSE program[1]

[1] Diesel Emissions Control Sulfur Effects (DECSE) Program, Phase 1, Interim Report 1, US Department of Energy, Washington DC, August 1999.

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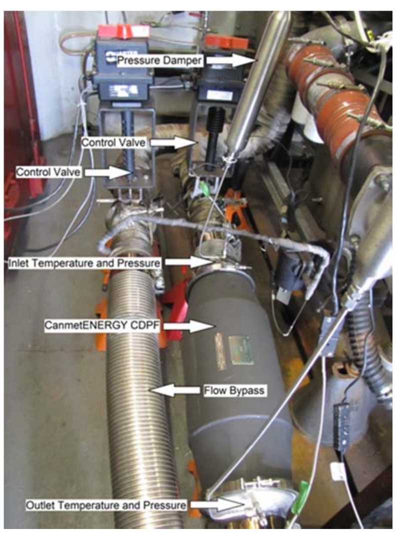
Engine Specification Data

Make	Detroit Diesel
Model	6063-WK32, Series 60
Serial number	06R0442911
Displacement	11.1 Liter
Rated power	242 kW @ 2100 rpm
Peak torque	1539 N.m @1200 rpm
Intermediate speed	1260 rpm
Aspiration	Turbocharged, charged air cooled
Fuel system	DI, Electronically controlled fuel injection
Max exhaust backpressure	10.1 kPa
Low idle speed	600 rpm
High idle speed	2225 rpm

CanmetMINING Engine Test Unit

CanmetENERGY CDPF set up



"Cattrap" CDPF set up

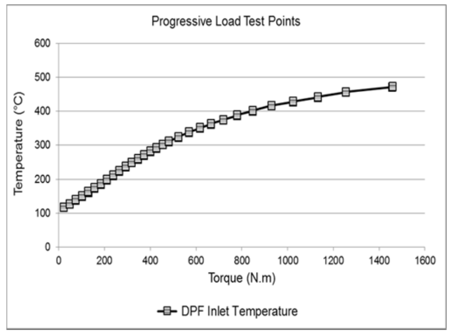
Test Procedure

Pre-loading of diesel particulate matter (PM)

- Engine speed of 2100 rpm and 10% load
- Temperature below the catalyst light-off temperature
- Duration about 30 h
- CDPF weight before and after loading

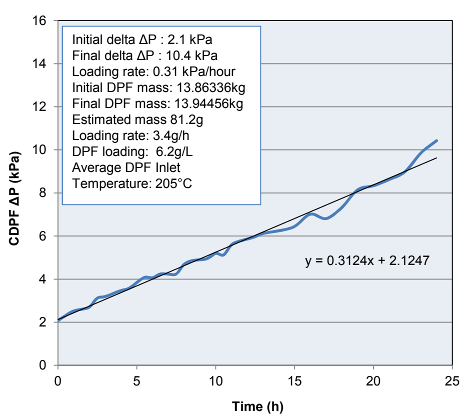
BPT determination

- Progressive engine load at 10 min intervals
- Stepwise change of CDPF inlet temperature (T)
- CDPF pressure drop (ΔP) recording
- Relationship between Δ P and T to determine Δ P=0

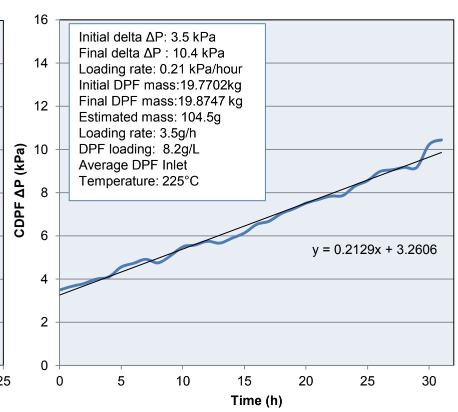


Results: PM Pre-loading

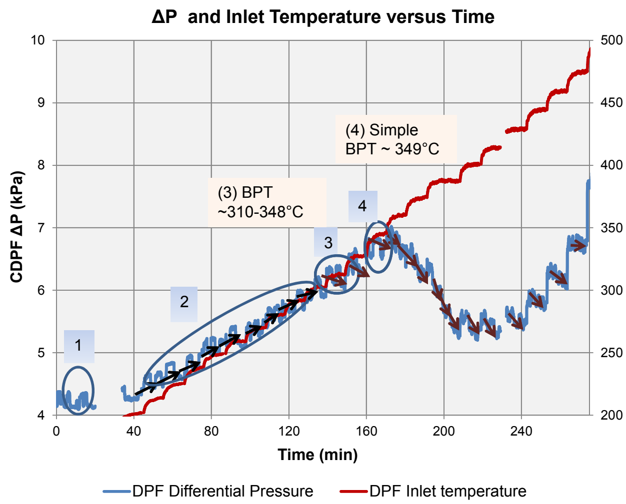
CanmetENERGY CDPF



“Cattrap” CDPF

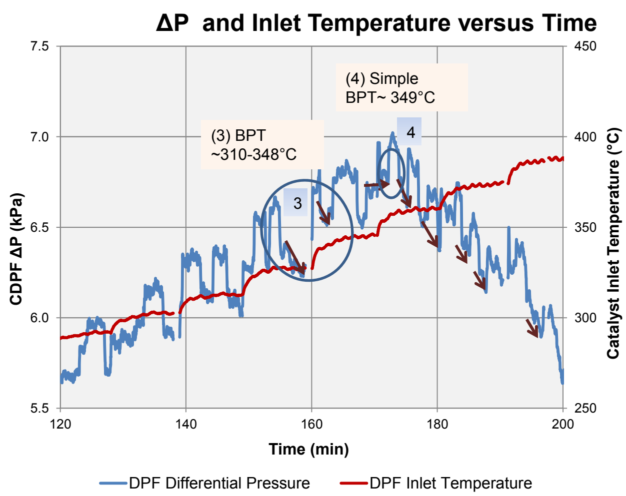


BPT of CanmetENERGY CDPF



- Characteristic pressure pulsations
- ΔP increase as a result of CDPF loading
- BPT range indicated by decreasing ΔP
- Simple BPT indicated by rapid decreasing ΔP

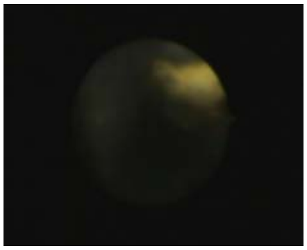
BPT of CanmetENERGY CDPF(Cont'd)



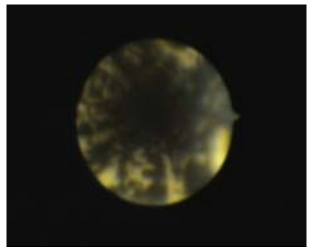
- Due to pressure pulsations the ΔP slope is difficult to model
- BPT range was selected where an obvious decrease in ΔP occurred
- Simple BPT was selected near the point where rapid decrease in ΔP was observed

Extent of Regeneration by Borescope in CanmetENERGY CDPF

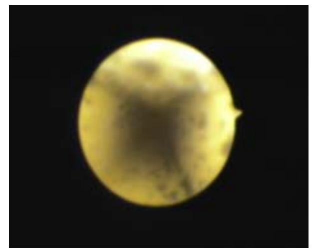
CDPF channel in the fully loaded state



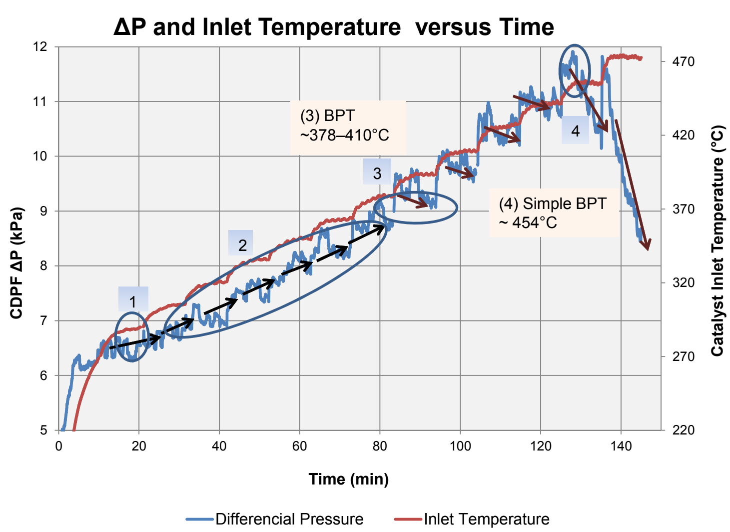
CDPF channel in the partially loaded state



CDPF channel in the fully regenerated state



BPT of "Cattrap" CDPF



Results: BPT of two tested CDPFs

Type of filter	BPT range (°C)	Simple BPT (°C)
CanmetENERGY p-CDPF	310 - 348	349
Cattrap CDPF	379 - 410	454

- The CanmetENERGY CDPF demonstrated ability for starting passive regeneration at 310°C
- The characteristic simple BPT and balance point temperature range for the “Cattrap” DPF agrees with the manufacturer’s balance point temperature range of 380 to 420°C

Conclusions

- A highly effective catalyst for soot oxidation was developed
- A prototype catalyzed diesel particulate filter (CanmetENERGY CDPF) with the developed catalyst was manufactured and tested on a diesel engine
- The CanmetENERGY CDPF was found to have a significantly lower balance point than a commercially available base metal – palladium CDPF (“Cattrap”)
- This measured improvement in DPF regeneration performance suggests the potential for the CanmetENERGY CDPF to oxidize PM during normal engine operation (passive regeneration)

Future work

- The performance of the CanmetENERGY CDPF could be compared to the conventional platinum-based CRT system
- Long-term stability of the developed CDPF needs to be tested
- Additionally, effectiveness in control of gaseous emissions such as CO, hydrocarbons and NO_x compared to noble metal-based CDPFs needs to be evaluated

Acknowledgements

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