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Novel Approach to Determine Oil Dilution

A Novel Approach in Determining Oil Dilution Level on a DPF Equipped Vehicle as a Result of Regeneration

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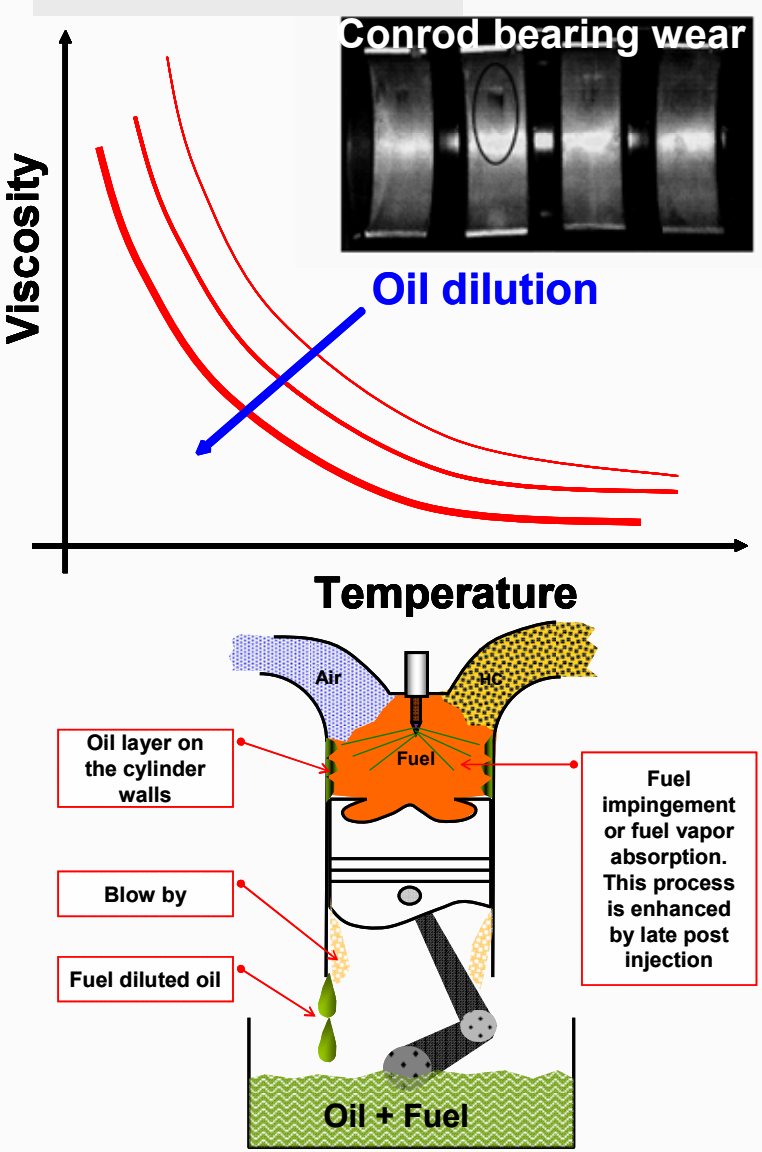
Introduction



- Oil dilution is detrimental to engine durability
- More DPF and NAC equipped medium and light duty vehicles
- In-cylinder late cycle diesel injection for regeneration and more
  - Critical for oil dilution
- Challenge on positioning post injection strategy vs. oil dilution
- Estimating in-use oil dilution not well understood other than expensive laboratory tests
- Lambda based in-use oil dilution estimation

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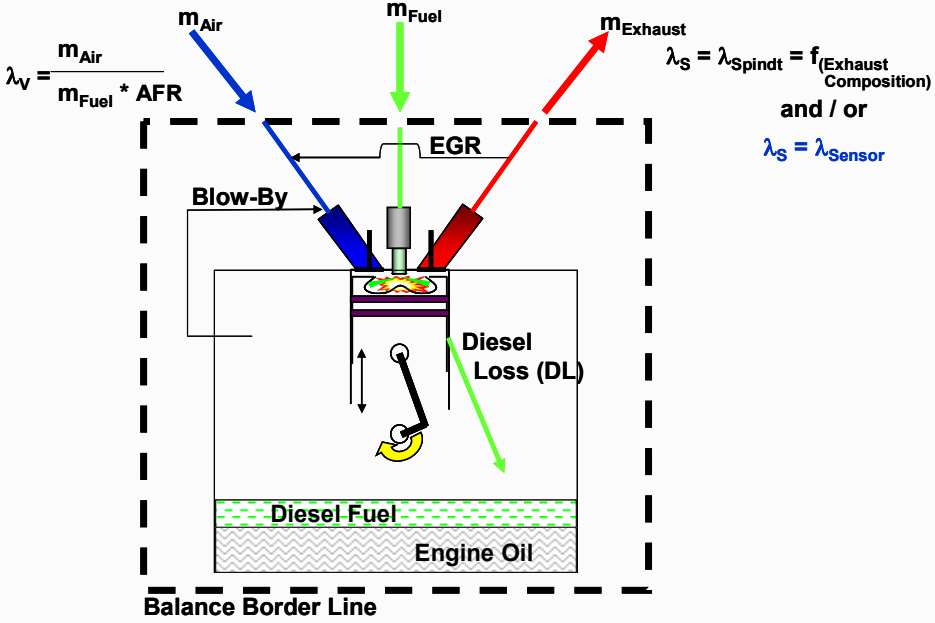
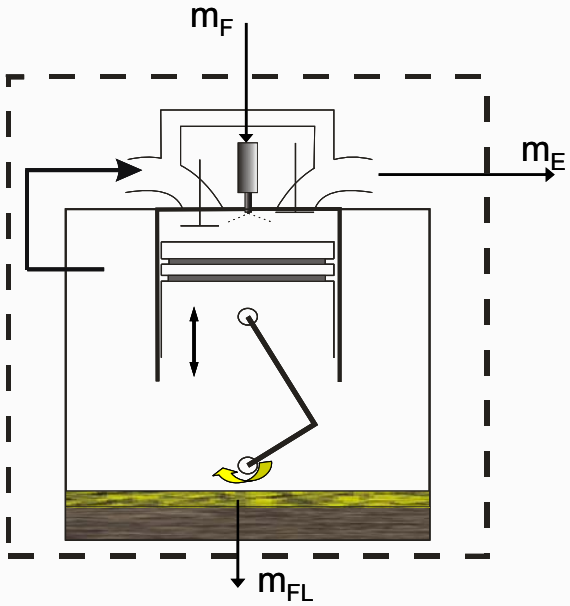
Fundamentals : Novel approach methodology

Lambda balance



Fuel balance



- Diesel-Loss [**DL**] is estimated as

$$DL = \frac{\lambda_S - \lambda_V}{\lambda_S} * 100\ \%$$

  - POSITIVE diesel loss = Oil dilution
  - NEGATIVE diesel loss = Fuel evaporation

- Mass of fuel loss to oil sump : $m_{FL} = m_F * DL$

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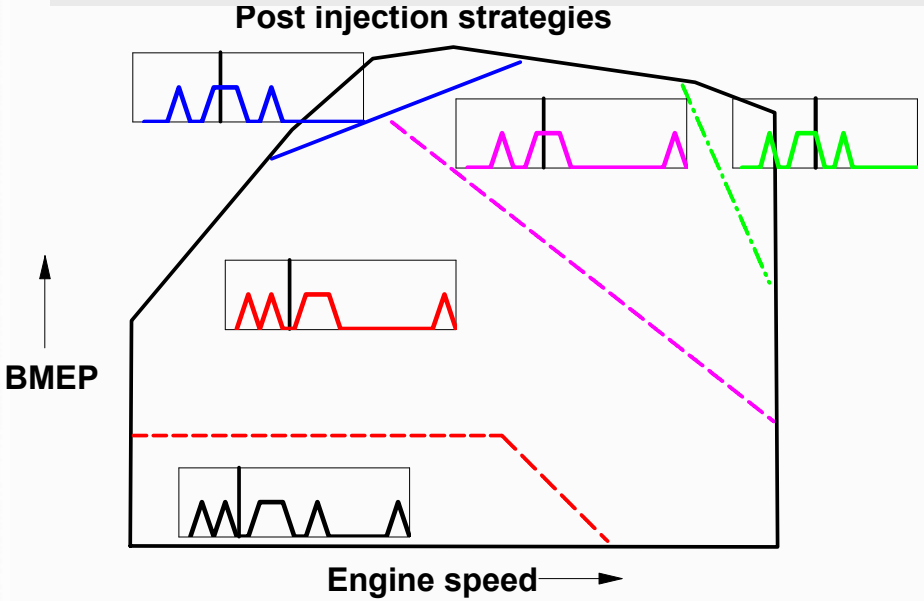
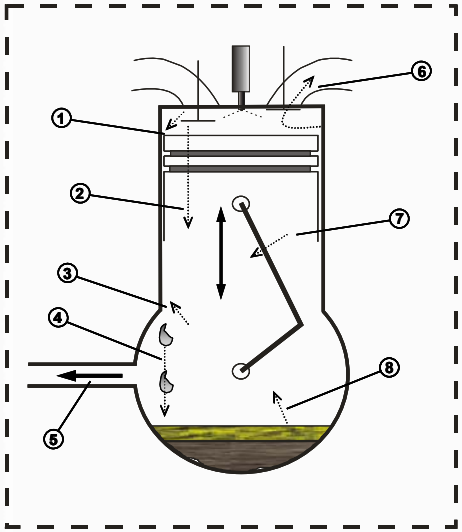
Fundamentals : Oil dilution phenomenon





1 Fuel absorption by oil film
2 Blow-by transports fuel
3 Oil feed from sump to liner film
4 Oil drain back into the crankcase carrying absorbed fuel
5 Breather gases leave the crankcase carrying vaporized fuel
6 Part of the liner film is burnt during combustion stroke
7 Desorbtion of fuel components
8 Fuel desorbtion into the breather gases

- **Post injection**
  - DPF regeneration
  - NAC regeneration
  - NAC desulfurization
  - In-cylinder soot reduction
- **Fuel in oil**
  - Fuel vapor absorption
  - Fuel injection wall wetting
    - Late cycle injection
  - Cylinder charge leak and condensation
- **Fuel evaporation**
  - Diffusion off the oil layer in cylinder
  - Blow by

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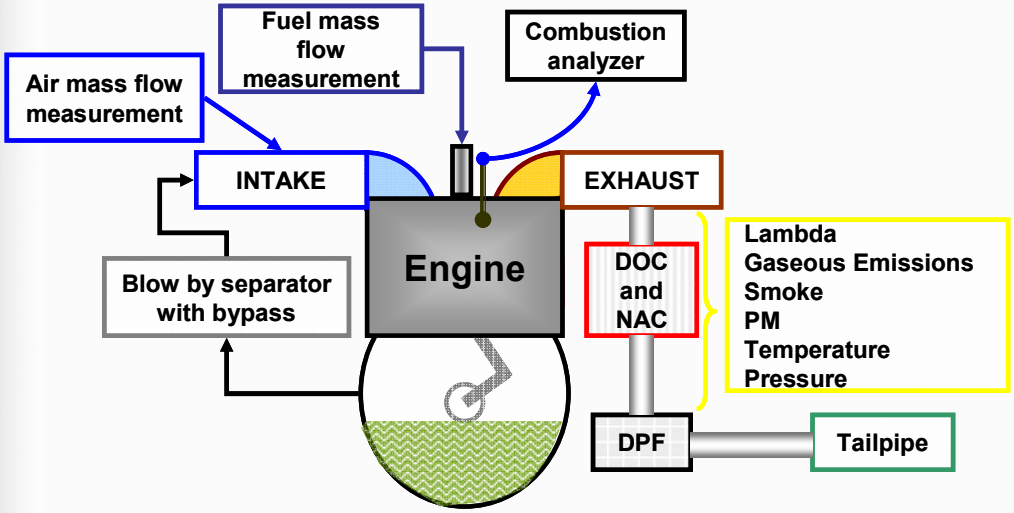
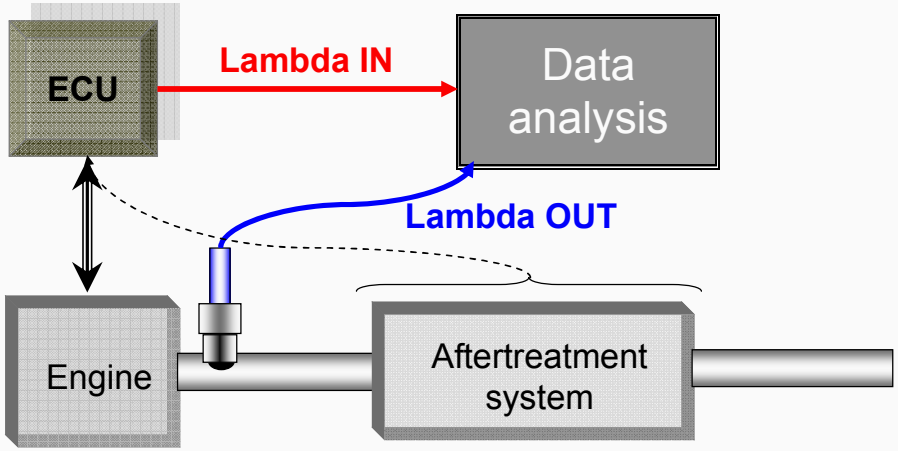
Results : Test setup

Test cell setup for oil dilution estimation



Vehicle setup for oil dilution estimation



TEST CELL

- Coriolis type fuel mass flow measurement
- Dynamic high accurate air mass flow measurement
- Blowby separator with bypass
- Complete exhaust instrumentation
  - Lambda sensor
  - Emissions measurement and Lambda exhaust
  - Smoke and PM measurement
  - Temperature and pressure

VEHICLE

- Air and fuel measurement through ECU
- Vehicle instrumentation to gather temperature and pressure signals
- Exhaust Lambda sensors

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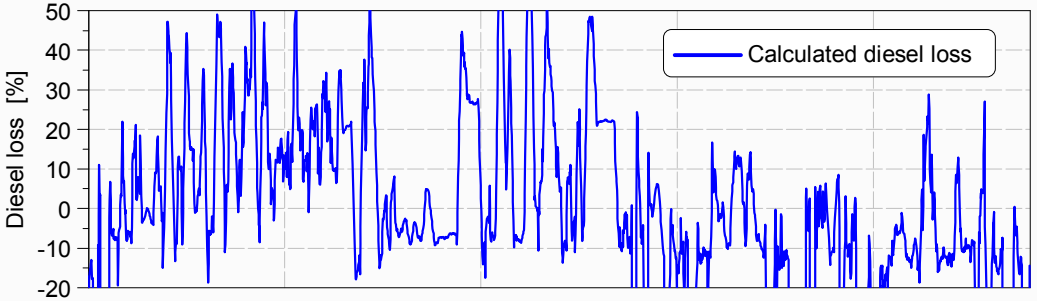
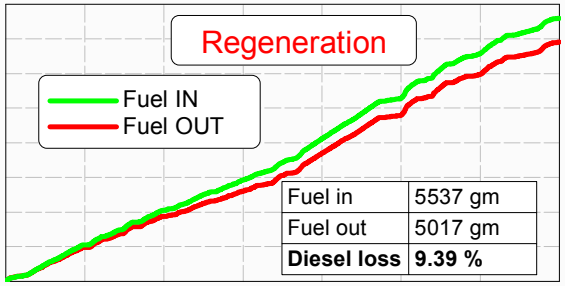
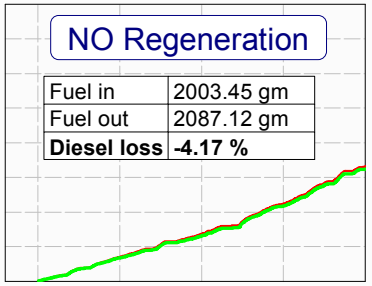
Results : Test plan

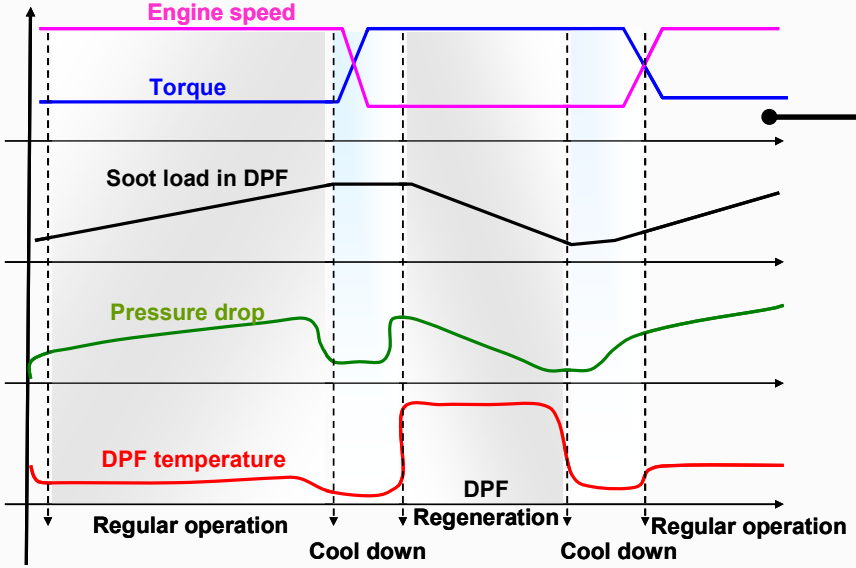
- **Vehicle tests** ⟵
  - Statistics of diesel loss for regeneration of DPF & NAC as well as normal engine operation in both city and highway driving
  - Correlation of the vehicle tests to test cell for controlled engine testing to study the diesel loss method







Time ⟶



Test cell

- **Oil dilution estimation**
  - Oil change interval simulation through vehicle test correlation
  - ECU executed in-cylinder post injection based regenerations
- **Extended study**
  - Extended oil change interval
  - Blow by effect
  - Oil ageing study over time

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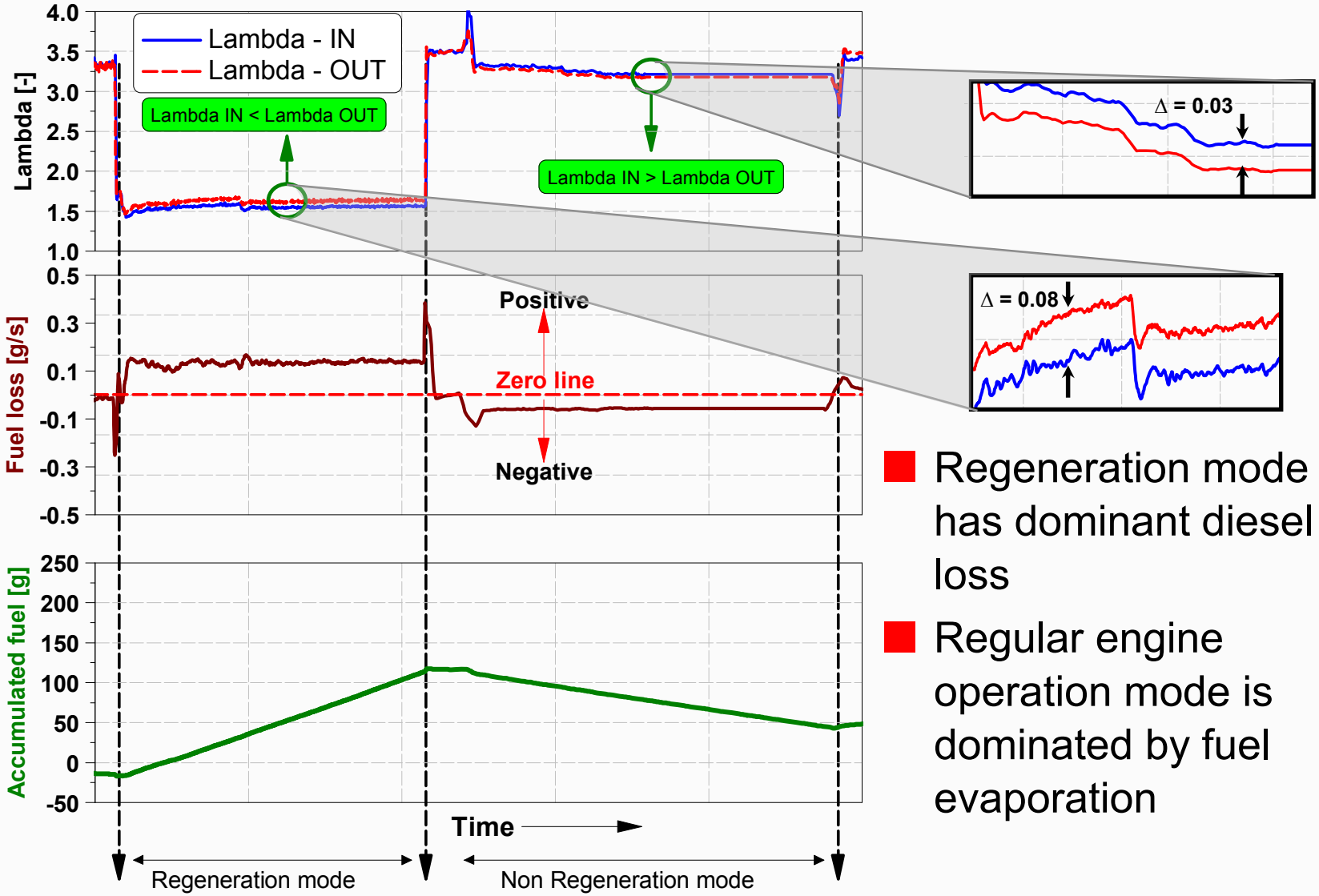
Results : Test data analysis



- Regeneration mode has dominant diesel loss
- Regular engine operation mode is dominated by fuel evaporation

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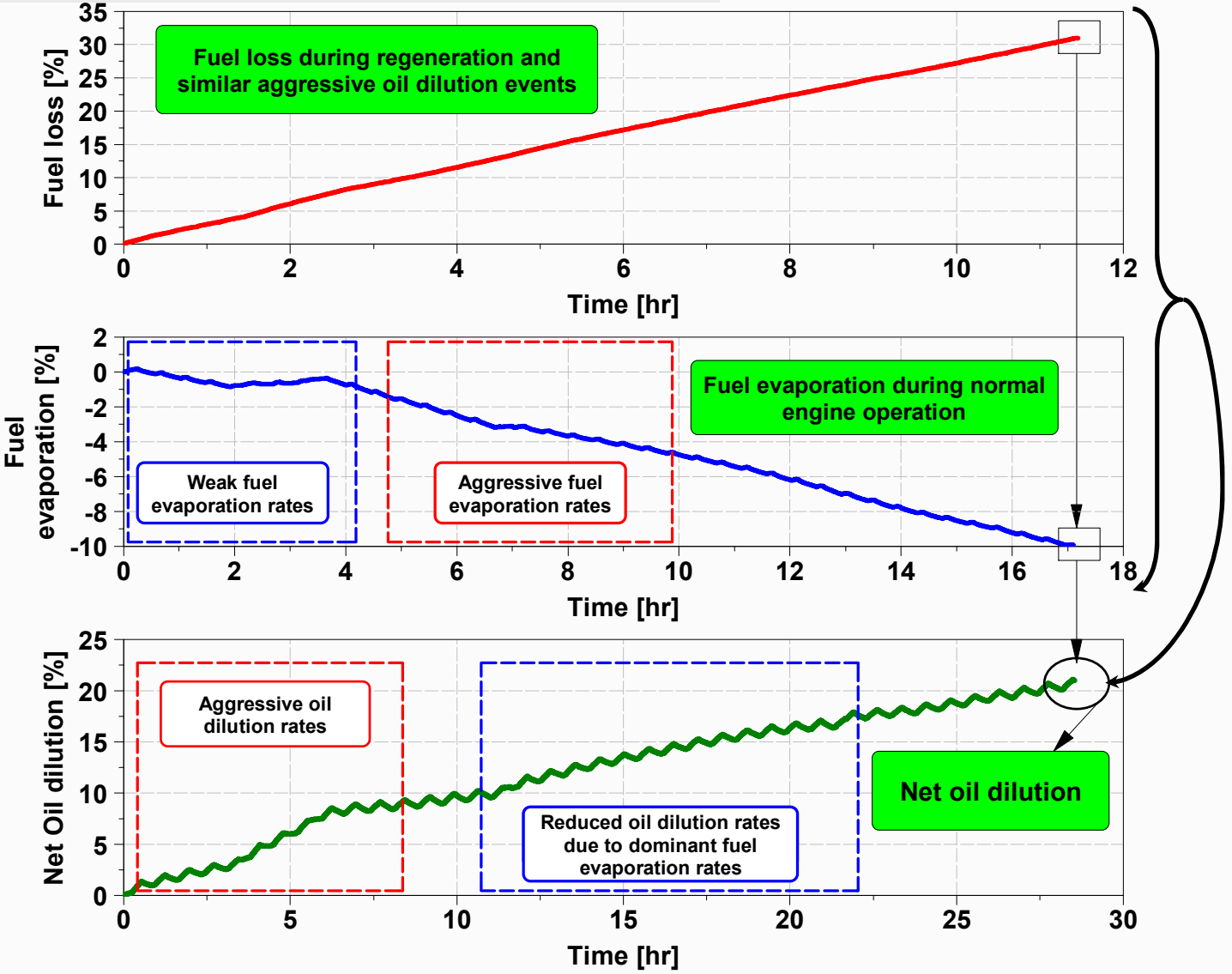
Results : Test data analysis



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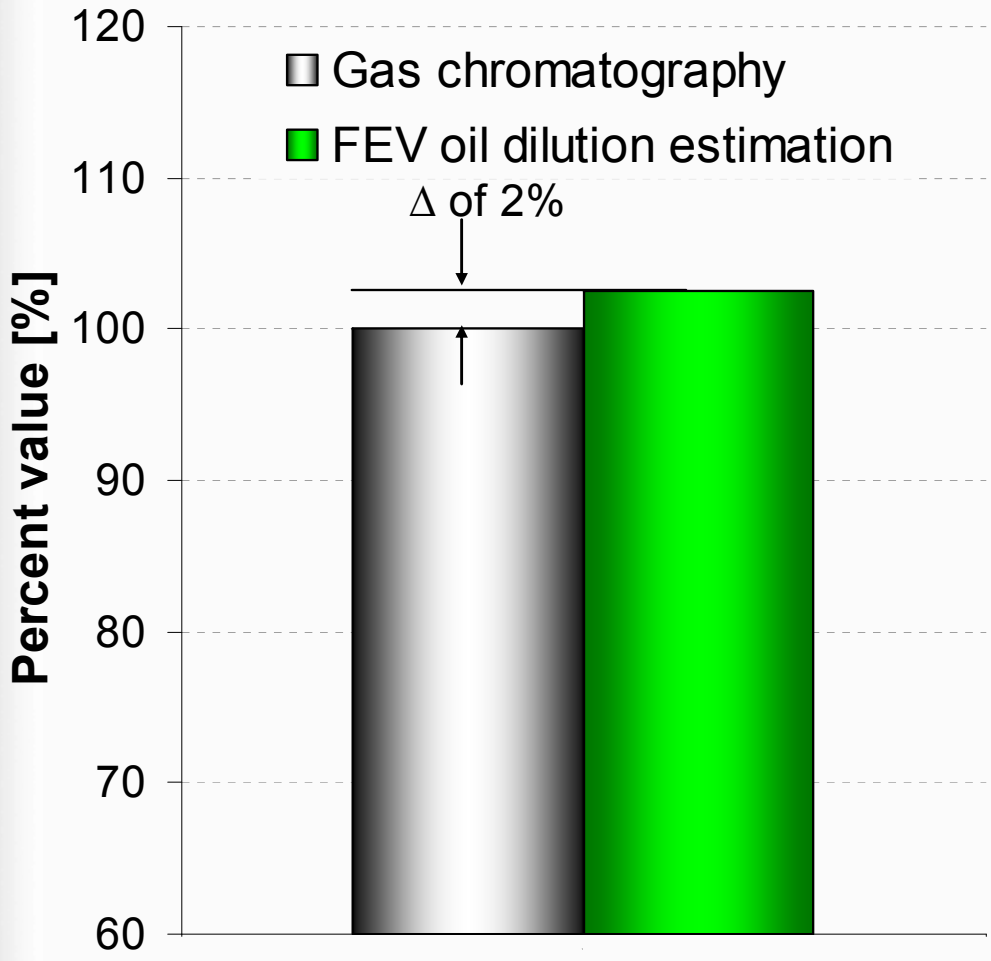
Results : Test data analysis



Test data analysis boundaries

- Tight control on evaluating oil and fuel consumptions
- Correlation between vehicle and test cell engine was established also on miles vs. fuel consumption
- Steady state engine operating points chosen based on vehicle test results to meet fuel evaporation rates
- Focus on worst case scenario
- Actual analysis of the oil done through gas chromatography

Good correlation between estimation vs. actual

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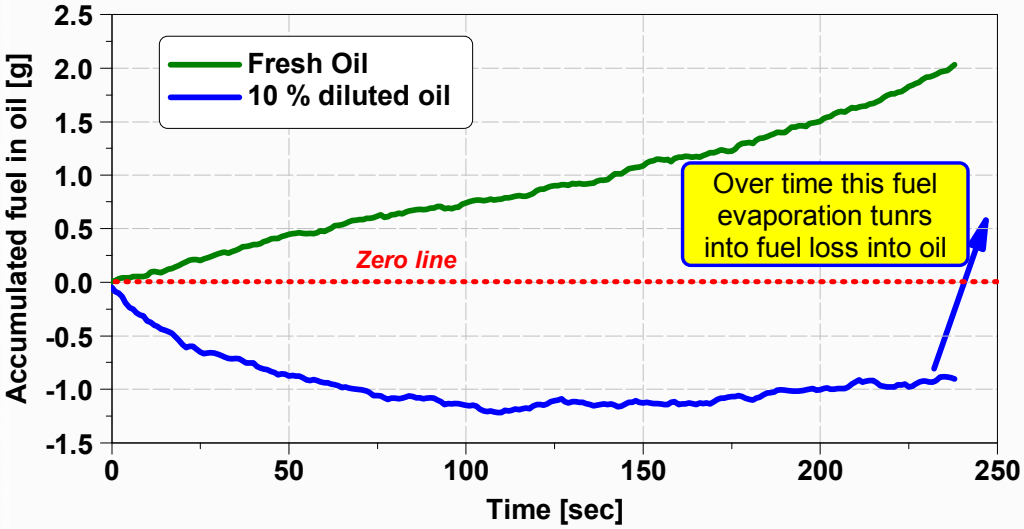
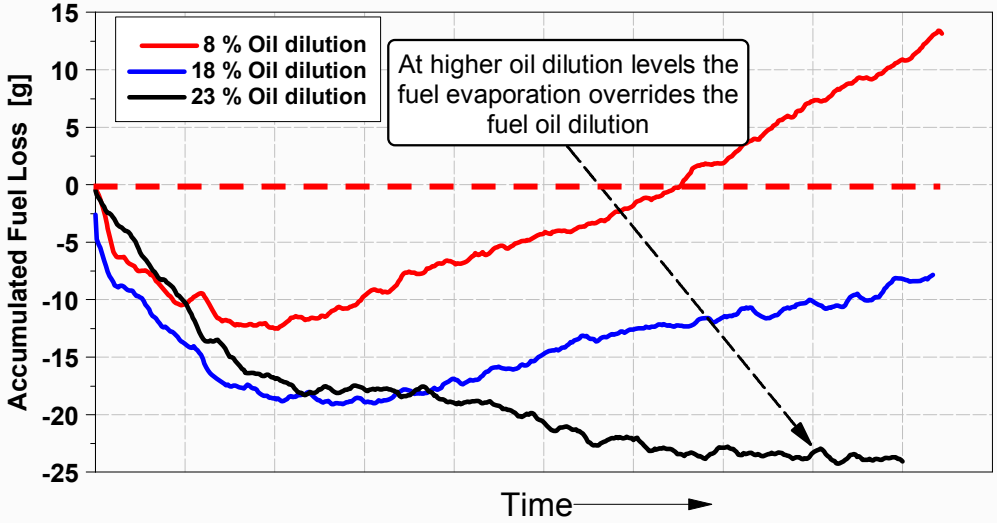
Results : Test data analysis - Study findings





- More aggressive oil dilution is seen with fresh oil
- As the oil dilution increases so does the fuel evaporation rates
- As the dilution progress the negative fuel loss or fuel evaporation balances the dilution levels
- Blowby plays a role in fuel evaporation

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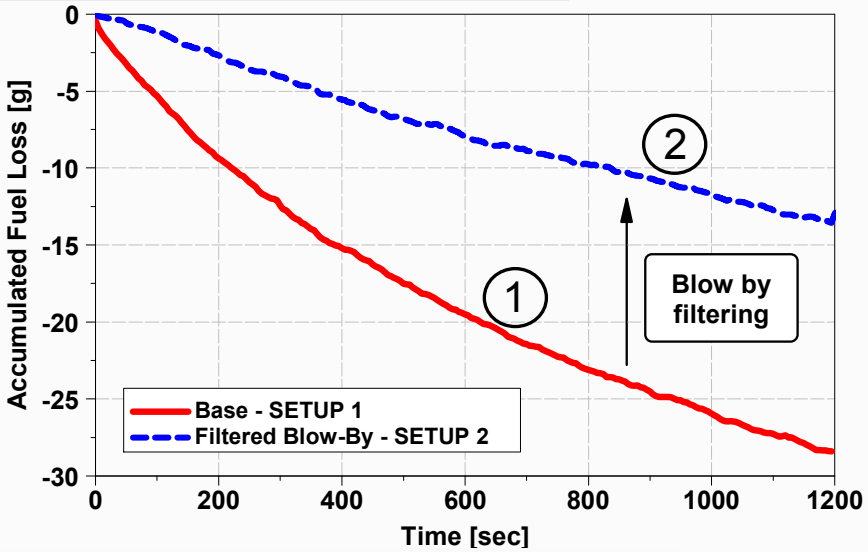
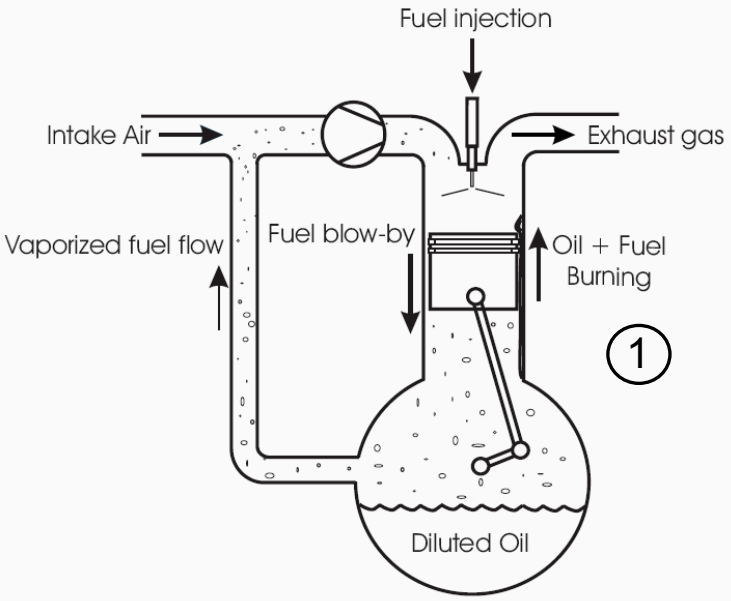
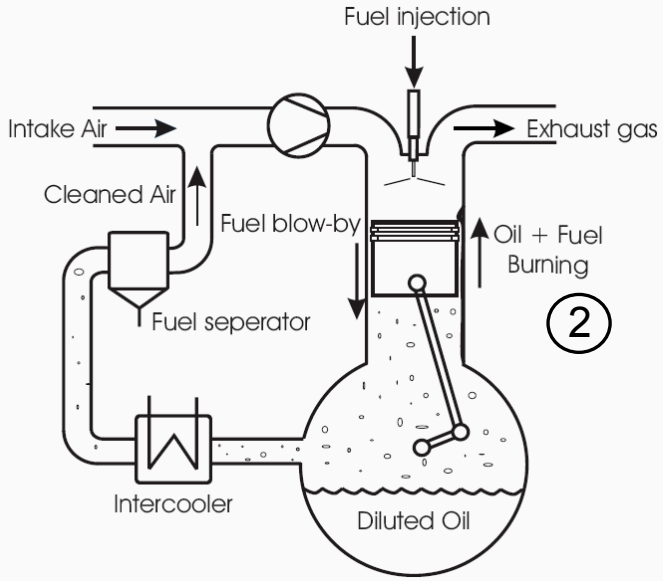
Results : Test data analysis - Study findings

- With blowby and no fuel fume separation [1] it is clear that there is more fuel evaporation is observed
- With blowby with fuel fumes separation the net fuel evaporation is greatly reduced
- This proves the fact that fuel evaporation from oil is present and greatly influenced by blowby







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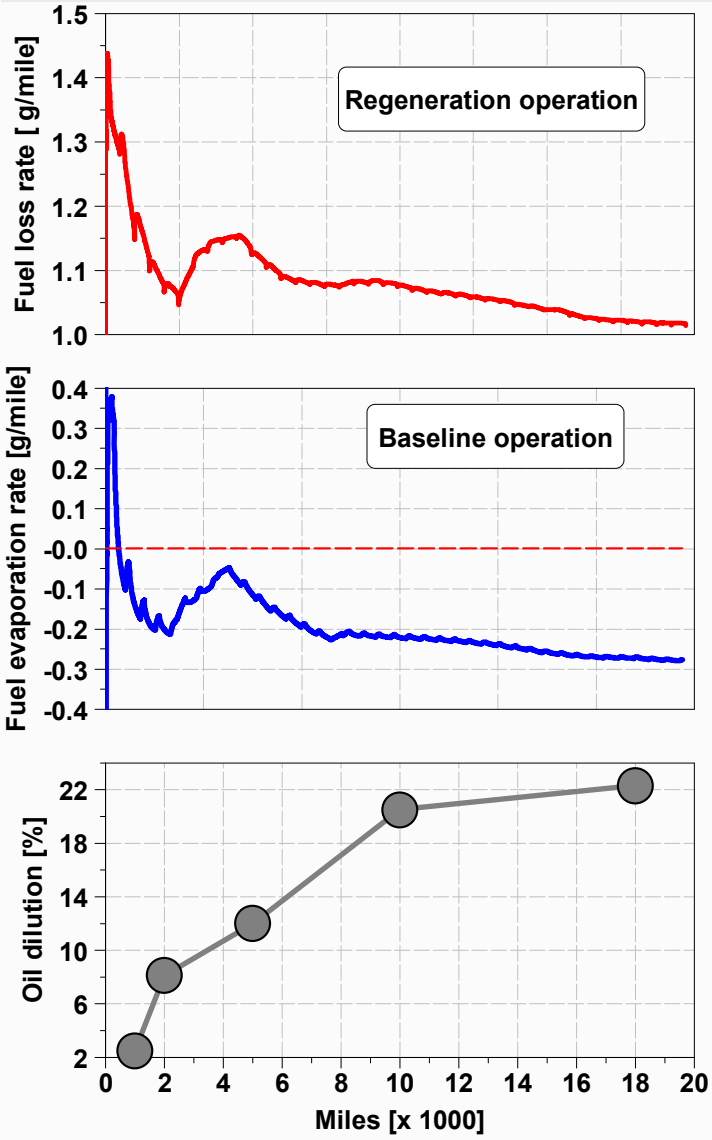
Results : Test data analysis - Study findings



- With increase in oil dilution the fuel loss rate also reduces due to saturation effects
- As observed earlier the fuel evaporation rates dominate with increase in oil dilution
- Over certain oil dilution level there was no significant increase in oil dilution as the fuel evaporation rates balance out the dilution levels
- However these trends are subject to engine operation and thermodynamic boundaries in which it operates

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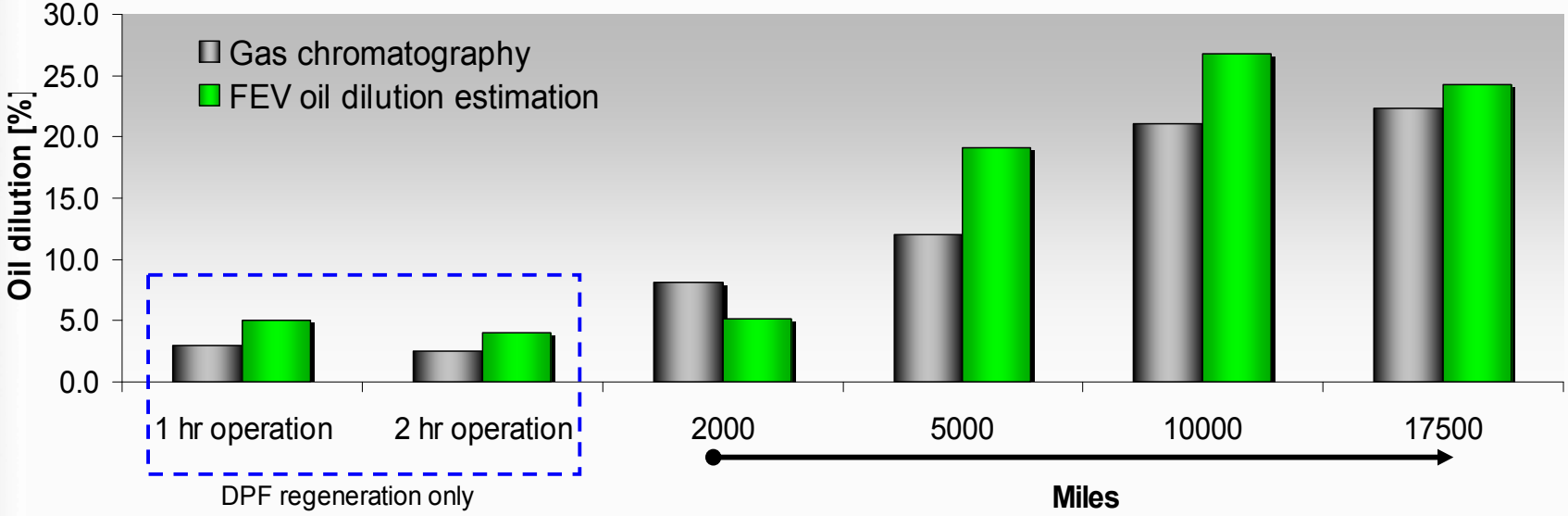
Results : Test data analysis - Statistics



Findings

- Oil dilution rate is a function of dilution effects such as late post injection and evaporation rates during regular operation
- Fuel evaporation of the oil layer is subject to blowby rates and oil temperatures
- The oil dilution rate varies with respect to dilution level, so does the evaporation rates
- Oil dilution estimation is subject to accuracy of the measurement

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Conclusion

- The novel approach determines the oil dilution within 2 – 20% accuracy
- This approach can be easily adopted for developing optimum engine calibration meeting performance, emissions and oil dilution
- This novel approach of oil dilution estimation would help avoid issues that may arise with fixed oil change intervals
  - Oil dilution degradation as a result of varying drive cycle
  - Avoid severe degradation of oil quality before specified oil change interval
  - At many instances increase the oil change interval beyond specific miles limit
- Implementation of this methodology does not demand new sensors but a new strategy
- Accuracy of the measurement signals and noise elimination is crucial for the quality of estimation