Measurement and Characterization of NOx Adsorber Regeneration and Desulfation

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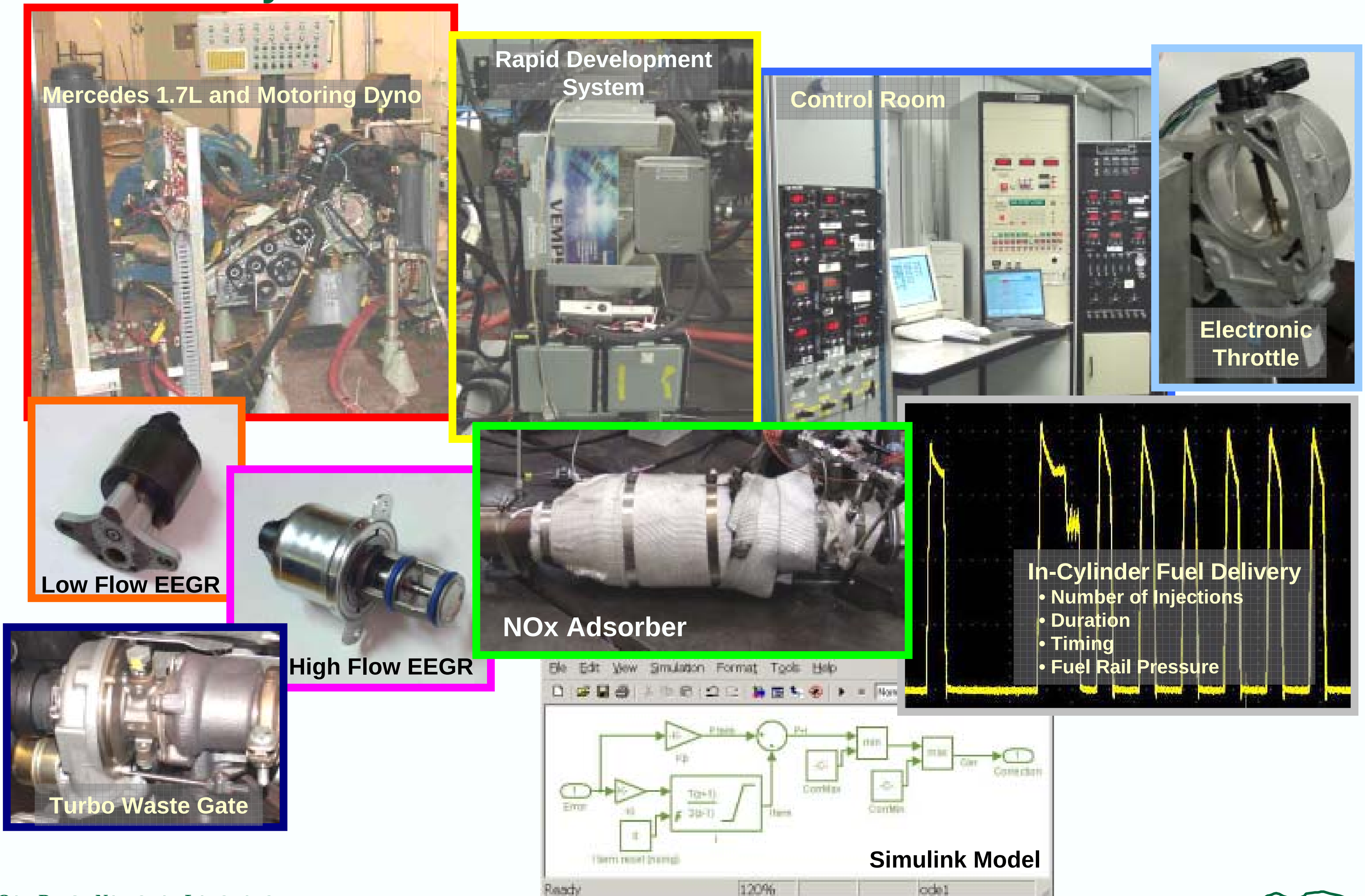
Objectives

- Characterize candidate NOx adsorbers for performance and degradation
- Quantify H_2, CO, and HC's generated and utilized
- Examine NOx adsorber materials in the DRIFTS and benchflow reactors
- Develop stronger link between bench and full-scale system evaluations

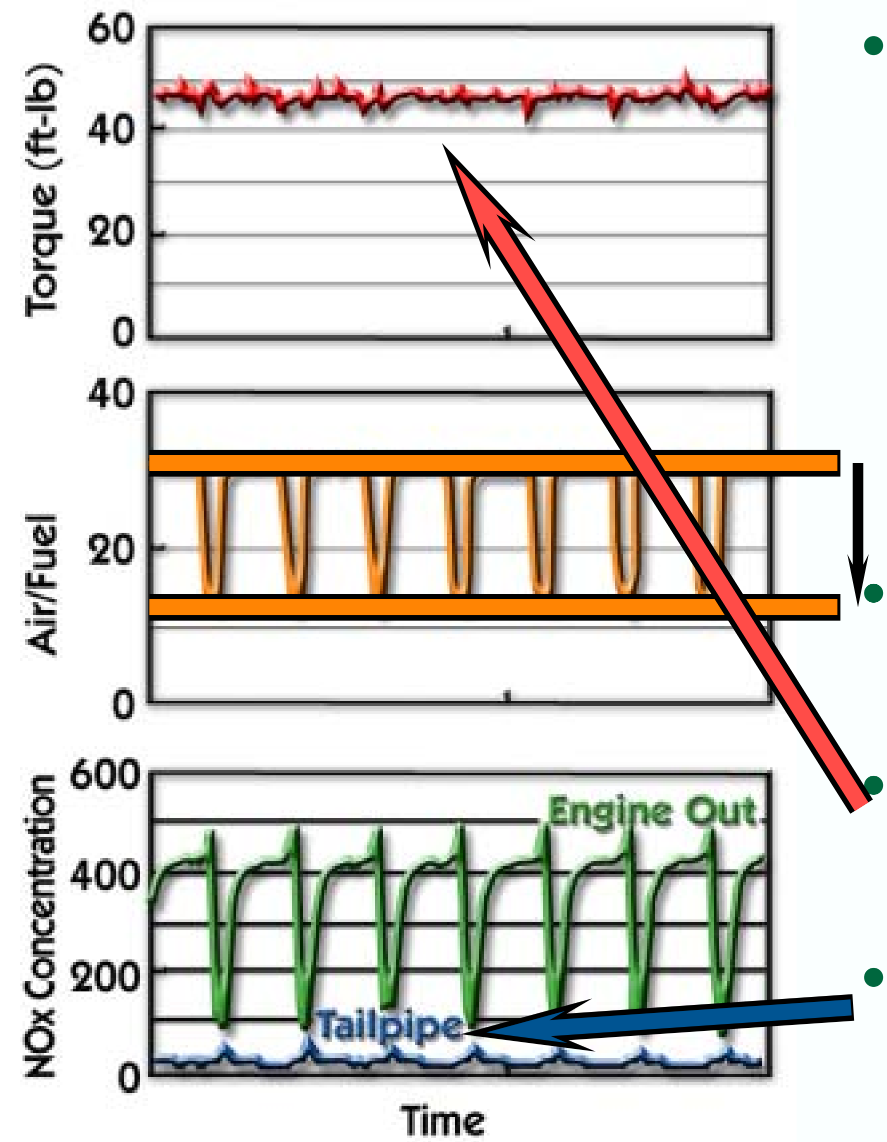
Approach

- Establish a relationship between exhaust species and various in-cylinder regeneration strategies
- Characterize effectiveness of each in-cylinder regeneration strategy
  - Examining potential strategies, will settle on 3 approaches with broadest pool of reductant species
  - Will mirror these strategies at 3 catalyst temperatures (200, 300, and 400°C)
  - Wide range of regeneration strategies will improve the understanding of catalyst mechanisms
- Develop and execute rapid sulfation/desulfation experiments
- Develop test plans for bench-scale work to further characterize adsorber monoliths, wafers, and/or powders

Common Rail Engine and Motoring Dynamometer dedicated to this activity



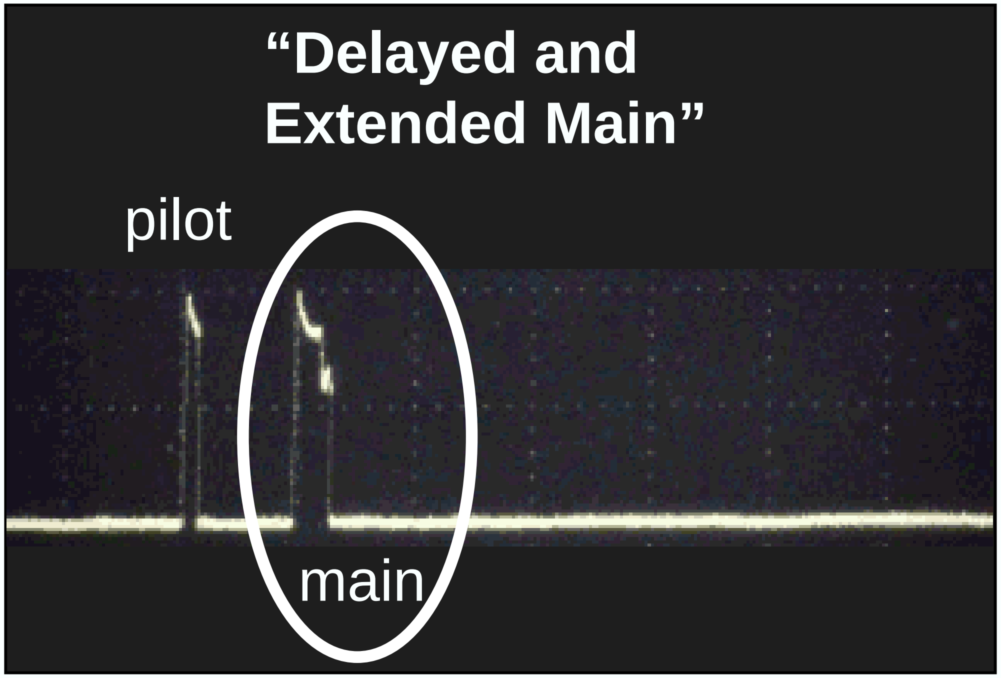
Research enabled by developing advanced engine control tools and algorithms

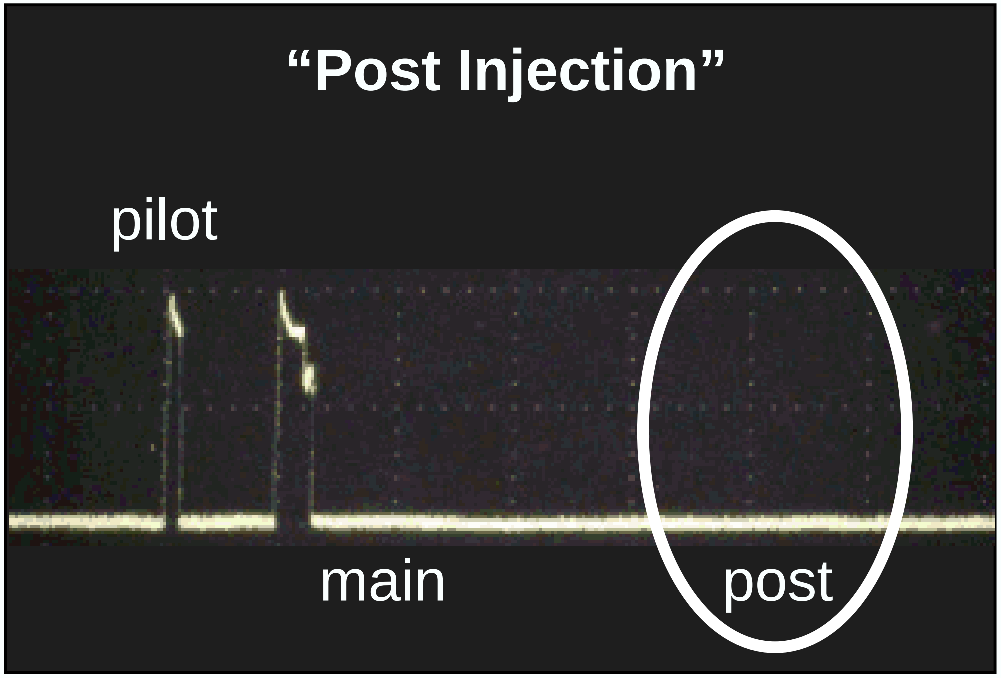


- Regeneration achieved when simultaneously:
  - Throttle closes to ~10% (reduce air flow)
  - Injection duration increases (decrease A/F ratio)
  - Timing retards (stabilize torque)
- Air: Fuel ratio dips from ~30 to ~12 during regeneration
- Smooth torque response during lean/rich transition
- Low levels of NOx escape to atmosphere

Three strategies are under development for achieving intermittent rich combustion

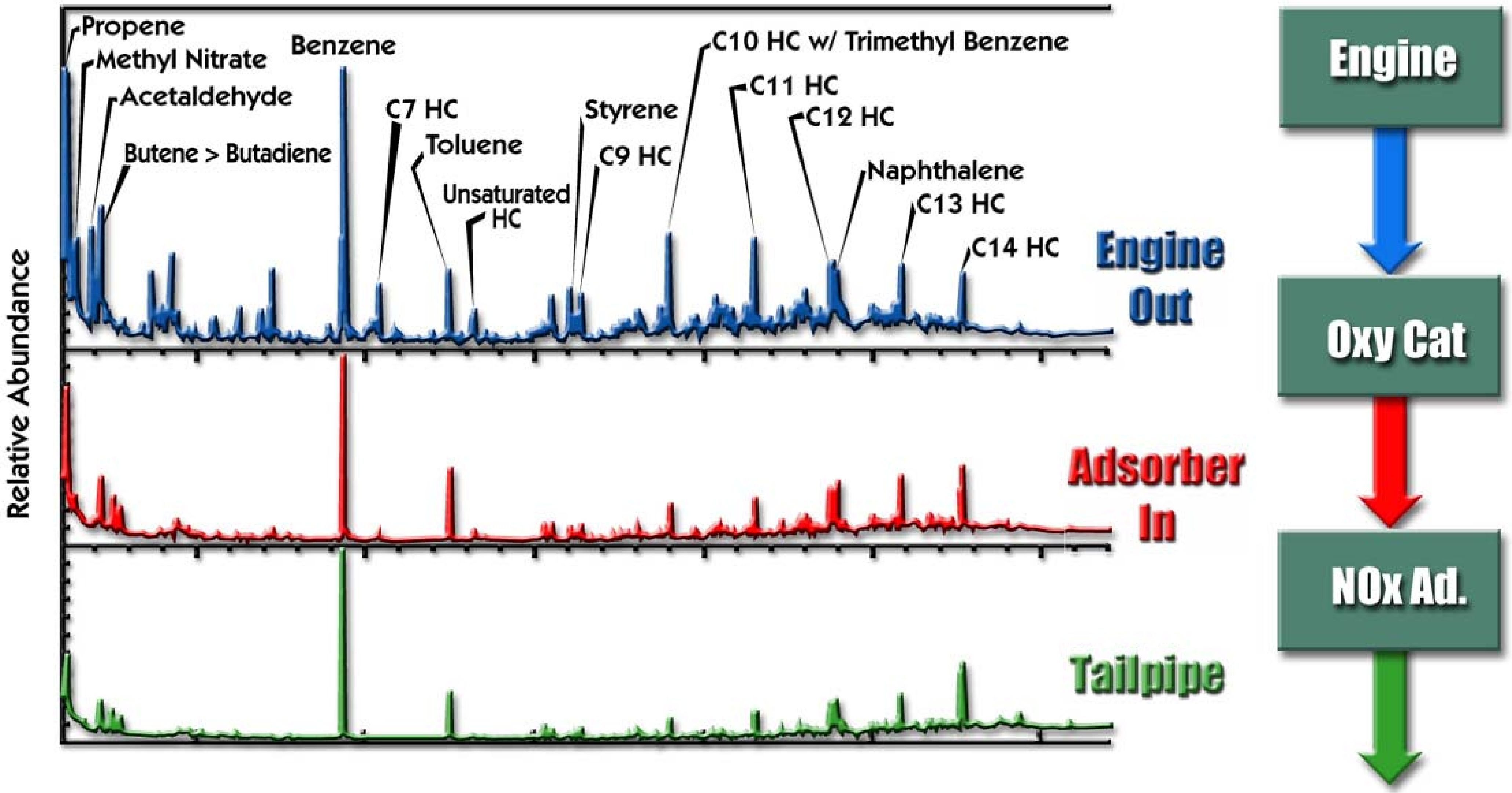
- All three strategies employ 15%-20% EGR during lean operation and intake throttling during the rich excursions





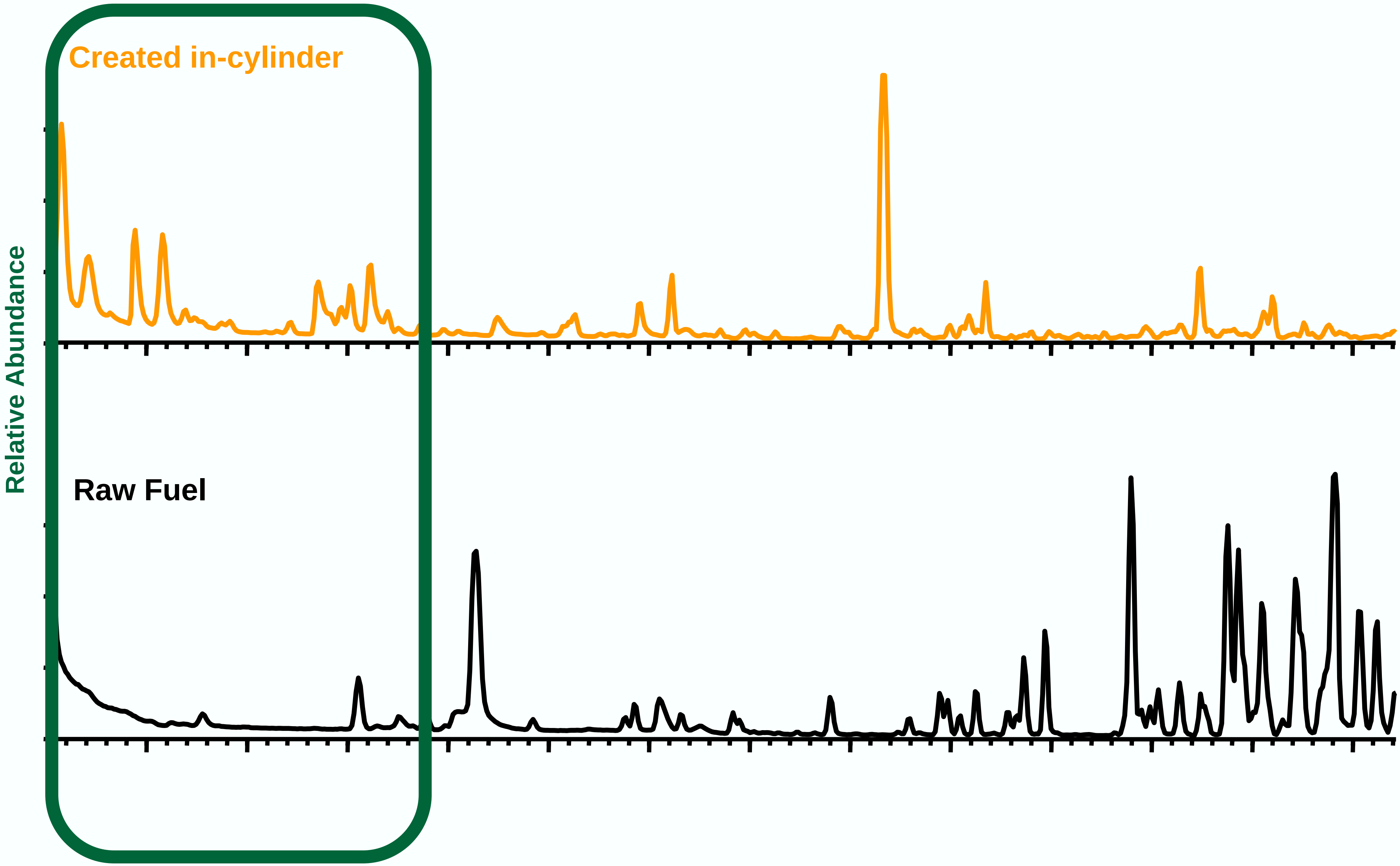
- 3rd strategy uses is an "Extended Main" with EGR during rich excursion
  - Timing unmodified
  - EGR rate is 30%-35% during rich excursion

GC/MS is used to identify the most effective HC compounds for NOx adsorber regeneration



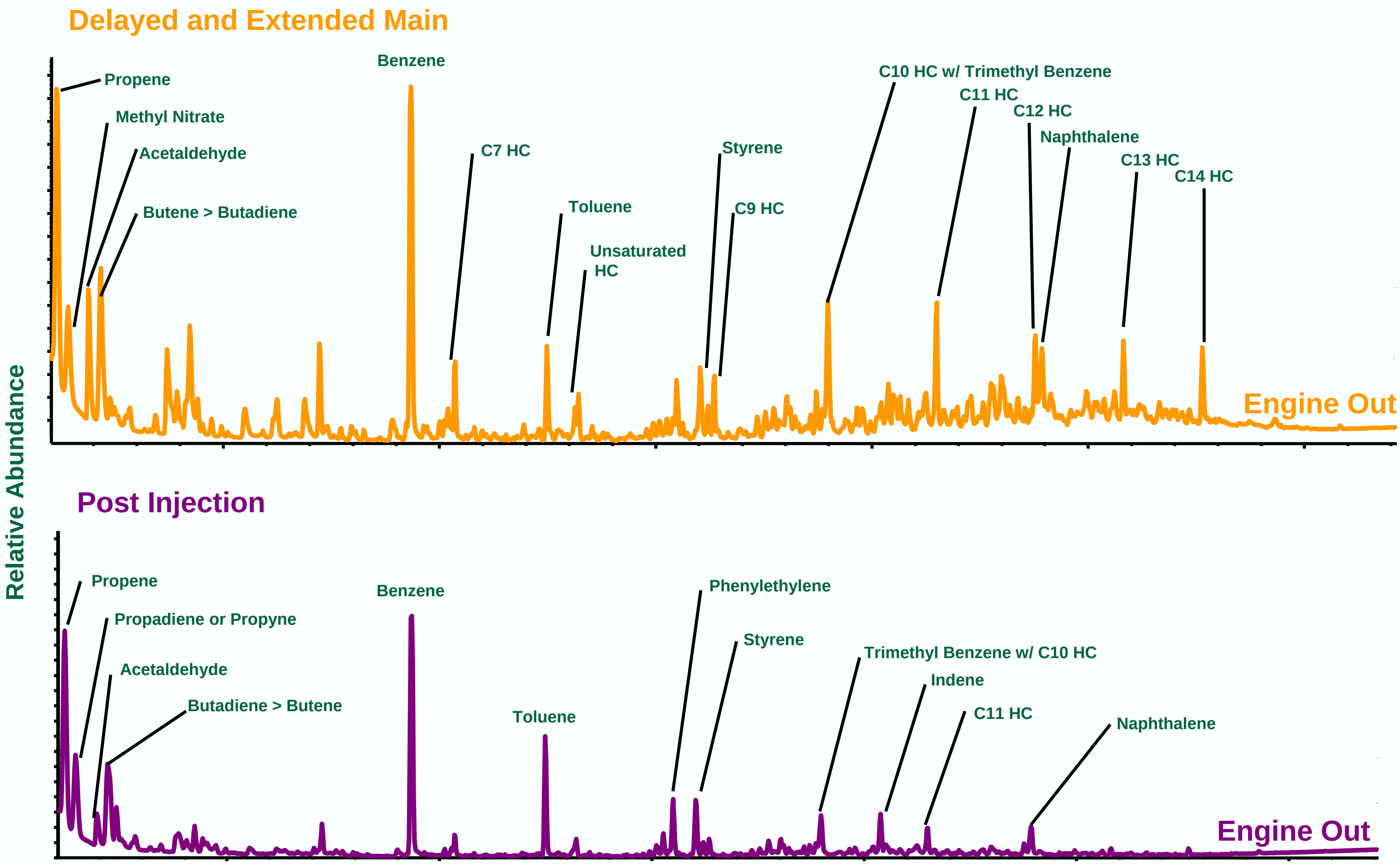
Note: Peaks represent individual compounds

“Delayed and Extended Main” produces lighter HC species that are not abundant in fuel



Note: Peaks represent individual compounds

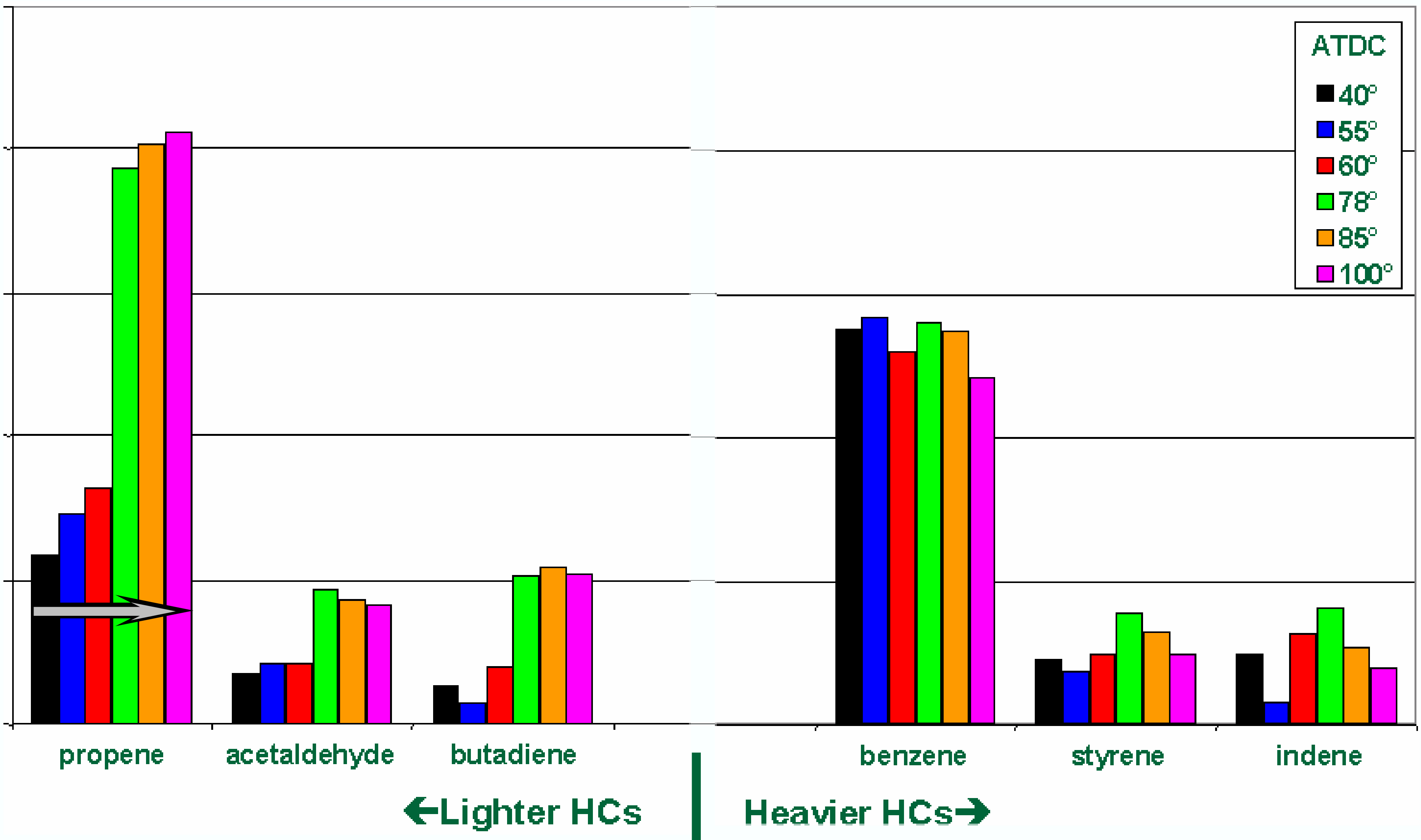
Unique HC pool produced by each strategy



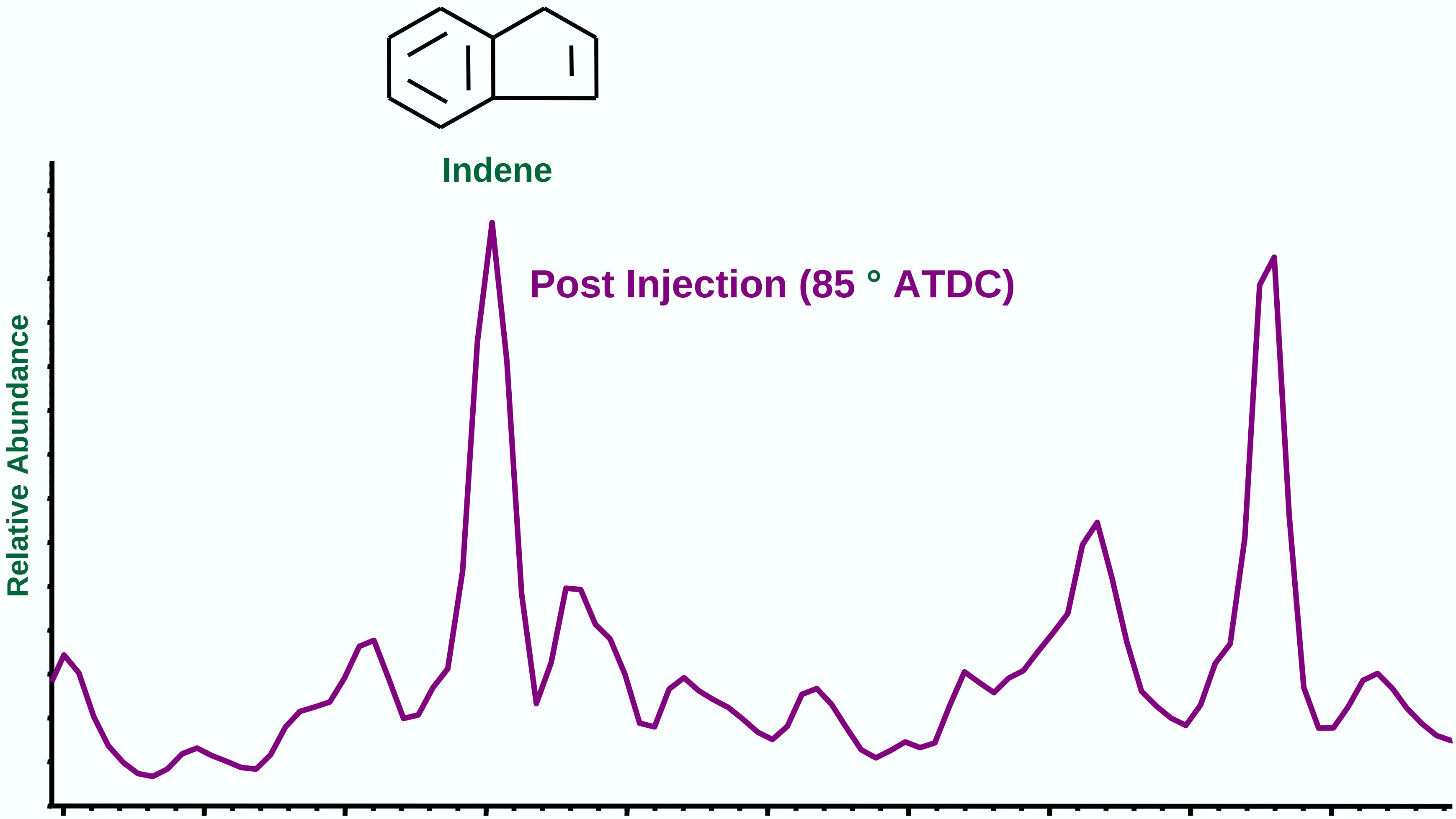
Note: Peaks represent individual compounds

Post injection timing affects species concentrations

- Lighter compounds increase between 70 & 80 deg
- Heavier compounds remain flat throughout timing sweep



In-cylinder strategies form unsaturated HCs, indicating abstraction of hydrogen and potential formation of H_2



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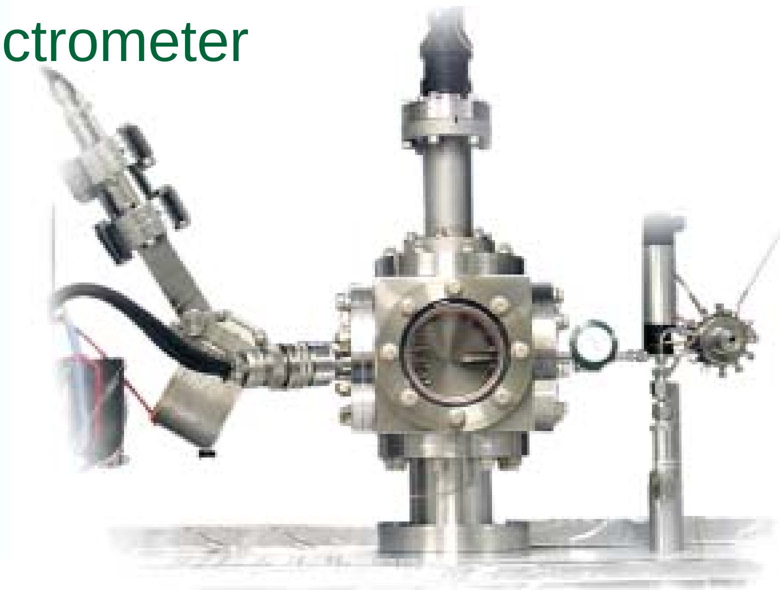
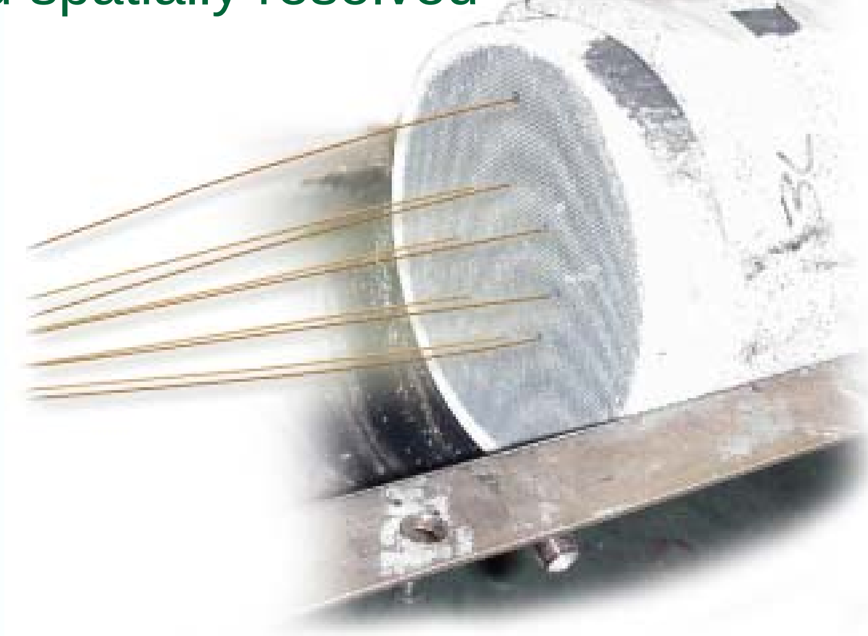
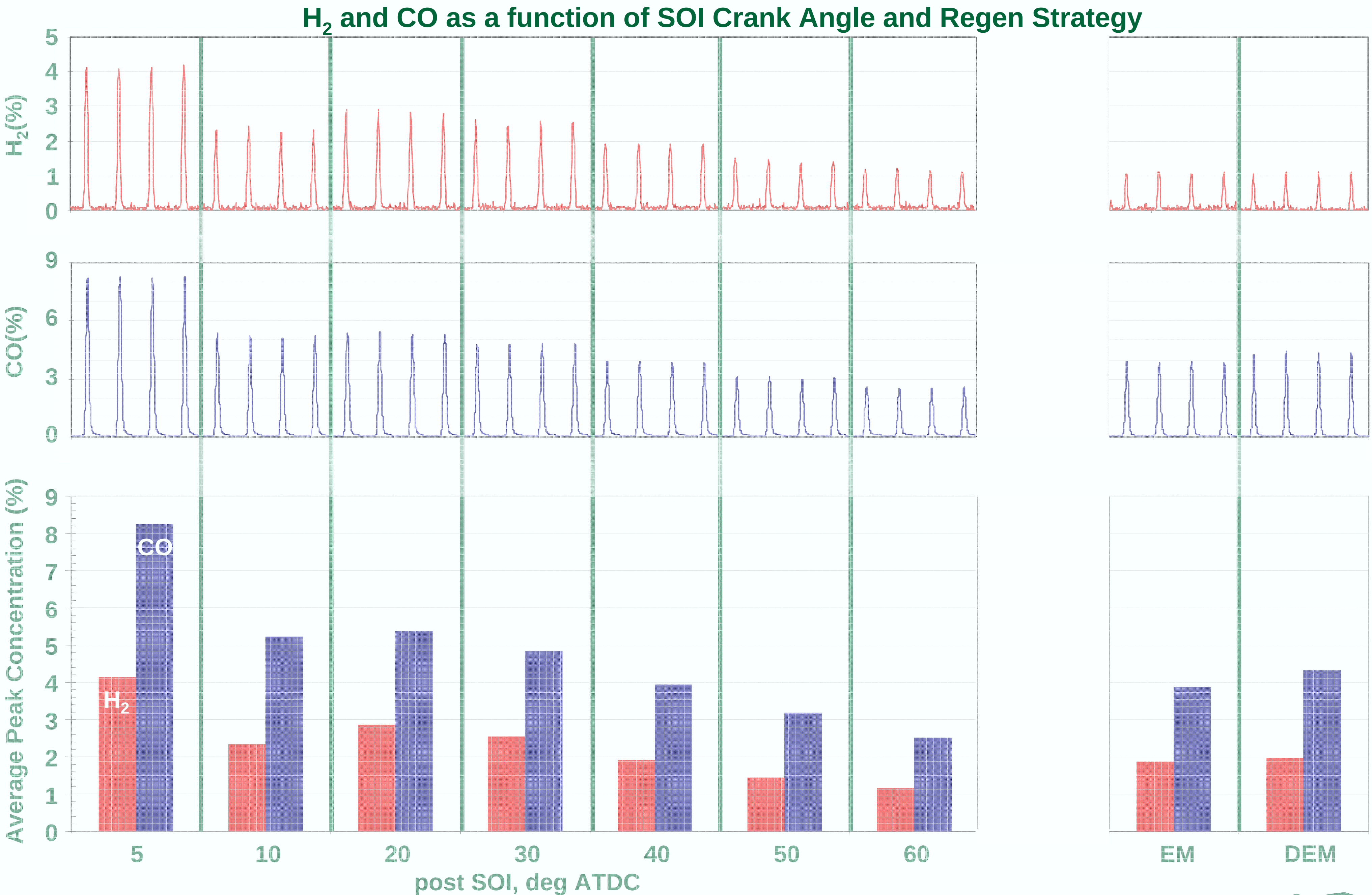
New H_2-SpaciMS instrument capable of in-situ hydrogen measurements

- Based on magnetic sector mass-spectrometer
- Capable of quantifying
  - H_2
  - H_2S
  - NOx
  - HC fragments
  - CO_2
  - SO_2
  - O_2
- Multiple capillaries allow in-situ spatially resolved measurements
- Minimally invasive
  - Sample rate ~10 μL/min
  - Probe diameter 200 μm





Regeneration strategies can be tuned to form H_2 and CO for the NOx Adsorber



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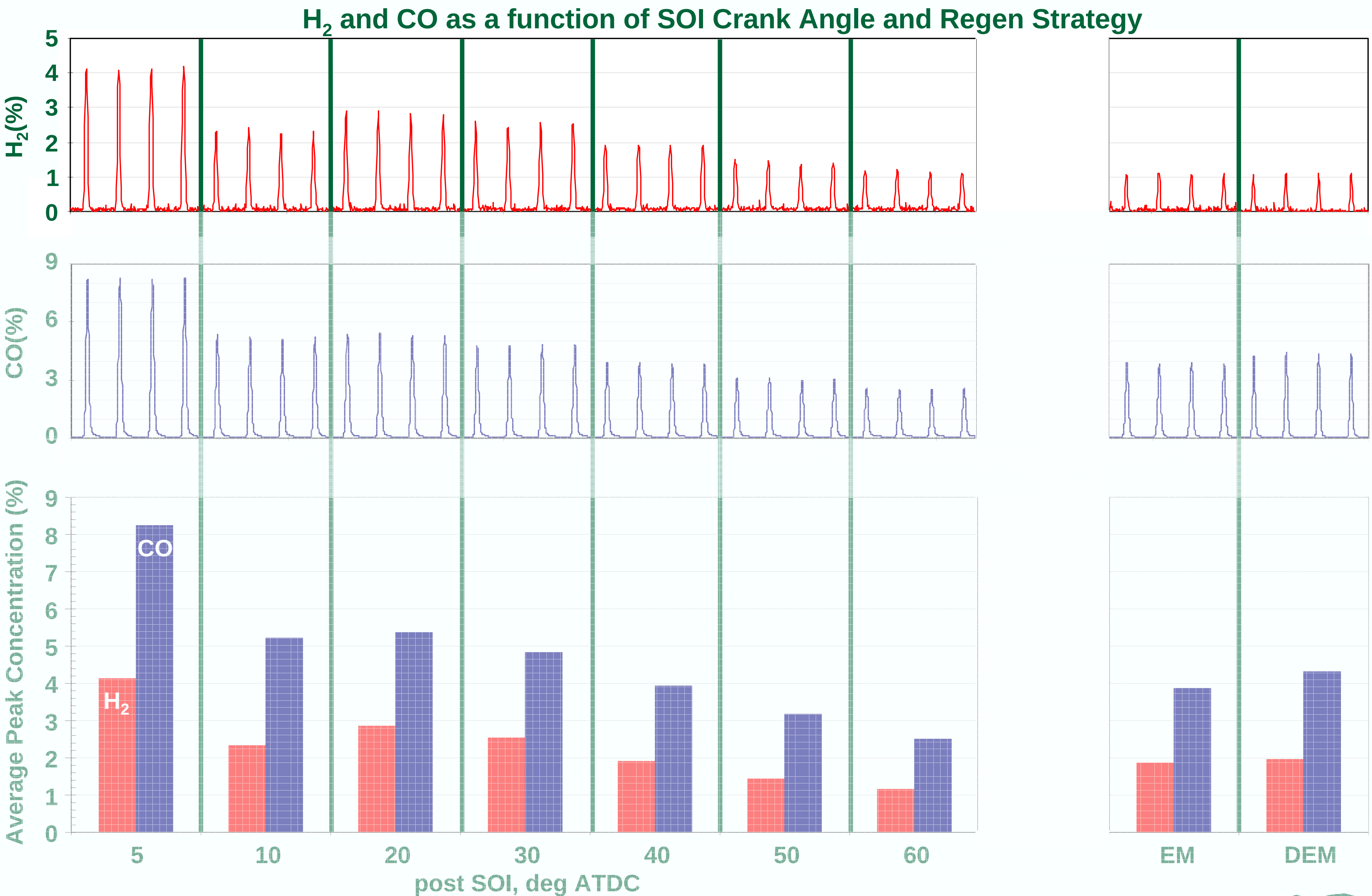

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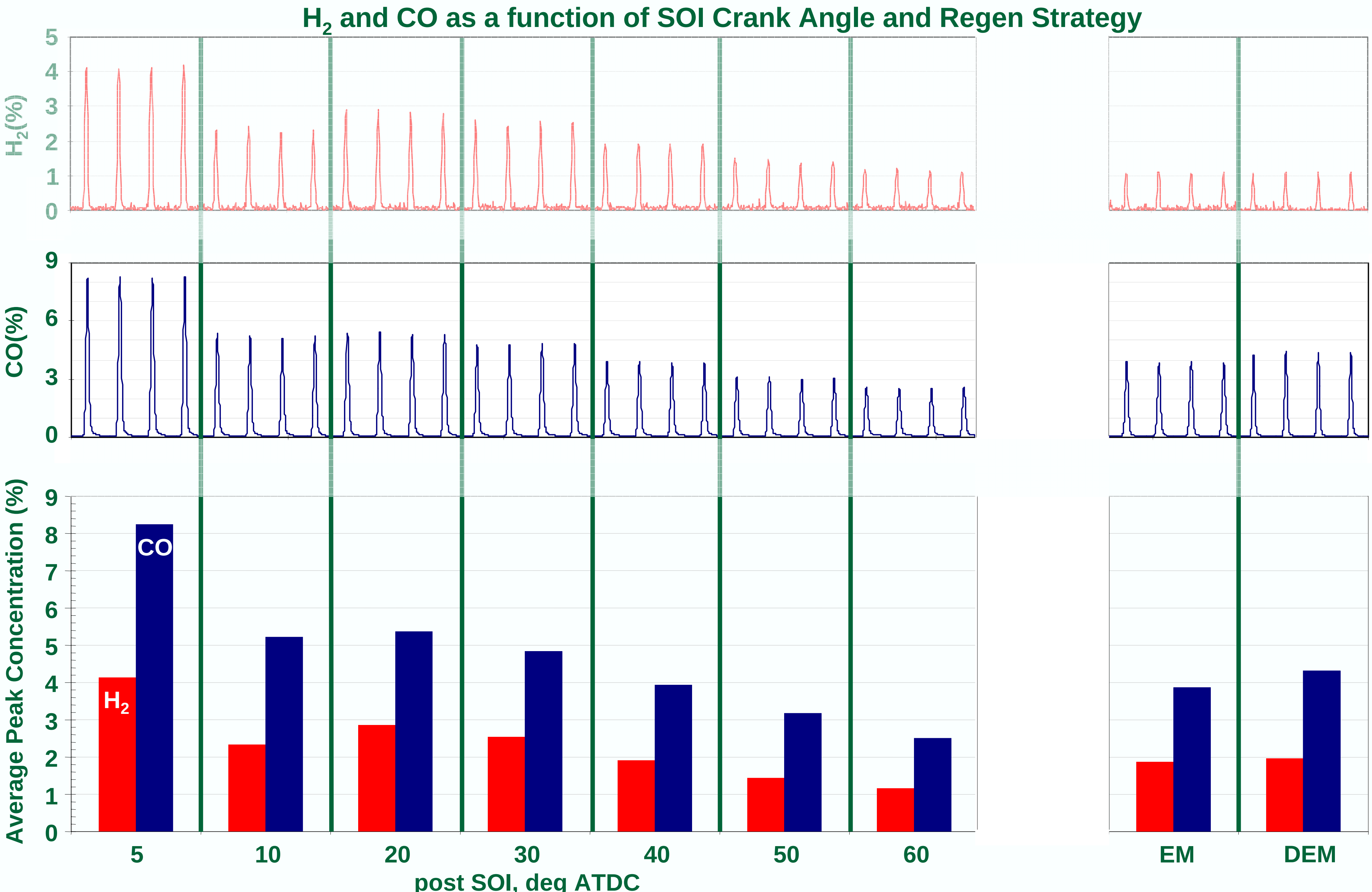

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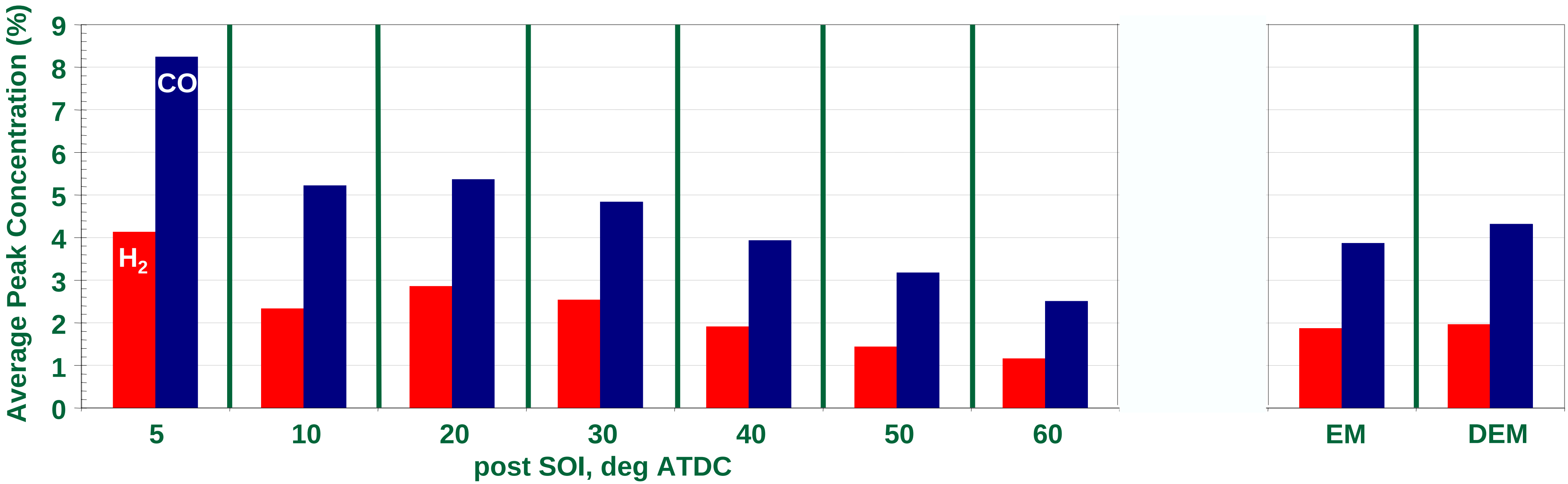

- H_2 and CO excellent reductants
- H_2 produced in-cylinder
- Can quantify H_2 and CO produced by different strategies
- 5° point produced >4% H_2 and >8% CO
- Downward trend in both CO and H_2
  ➔ increased HC
- CO to H_2 ratio = 2:1

Fuel Consumption

- 1500RPM / 5bmep with 60 sec cycle
- Fuel penalty compared with lean operation
  - ➢ Post: ≈ 5½%
  - ➢ DEM: ≈ 4%
  - ➢ EM: ≈ 2%

Regeneration strategies can be tuned to form H_2 and CO for the NOx Adsorber

- Plans for further engine work
- In-situ H2 measurements
  - Understand how H2 used
  - Measure if H2 generated within adsorber
- Correlate reductant pool with adsorber performance
- Study affect of EGR, during rich excursions, on species formation

Future Plans

- Complete development of regeneration strategies at 3 NOx adsorber temperatures
- Speciate HCs at adsorber inlet/outlet for each strategy and various catalysts
  - MECA units
  - Ford units
  - Model Catalyst
- In-situ H_2 measurements with H_2-SpaciMS
- Rapid sulfation/desulfation
- Examine samples on bench

Summary and Conclusions

- Tools assembled to evaluate NOx adsorber regeneration mechanisms
  - GC/MS is a valuable tool for identification of HC species
  - H_2-SpaciMS quantifies real-time production of H_2
- A wide range of species, including H_2, were measured during various NOx adsorber regeneration strategies
- This work will allow us to better understand the catalyst mechanisms
  - Help with both the development of improved catalyst formulations and in-cylinder regeneration strategies

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Internal Combustion Engines

International Textbook , Scanton, 1968, p 356.

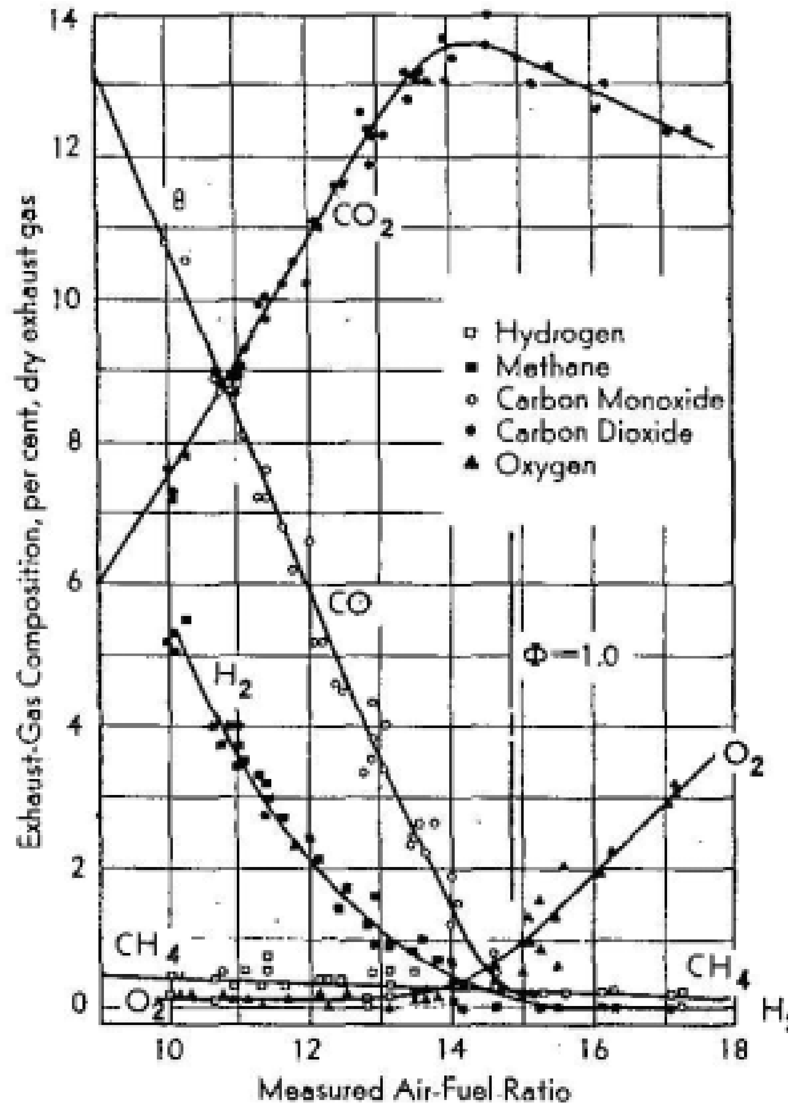
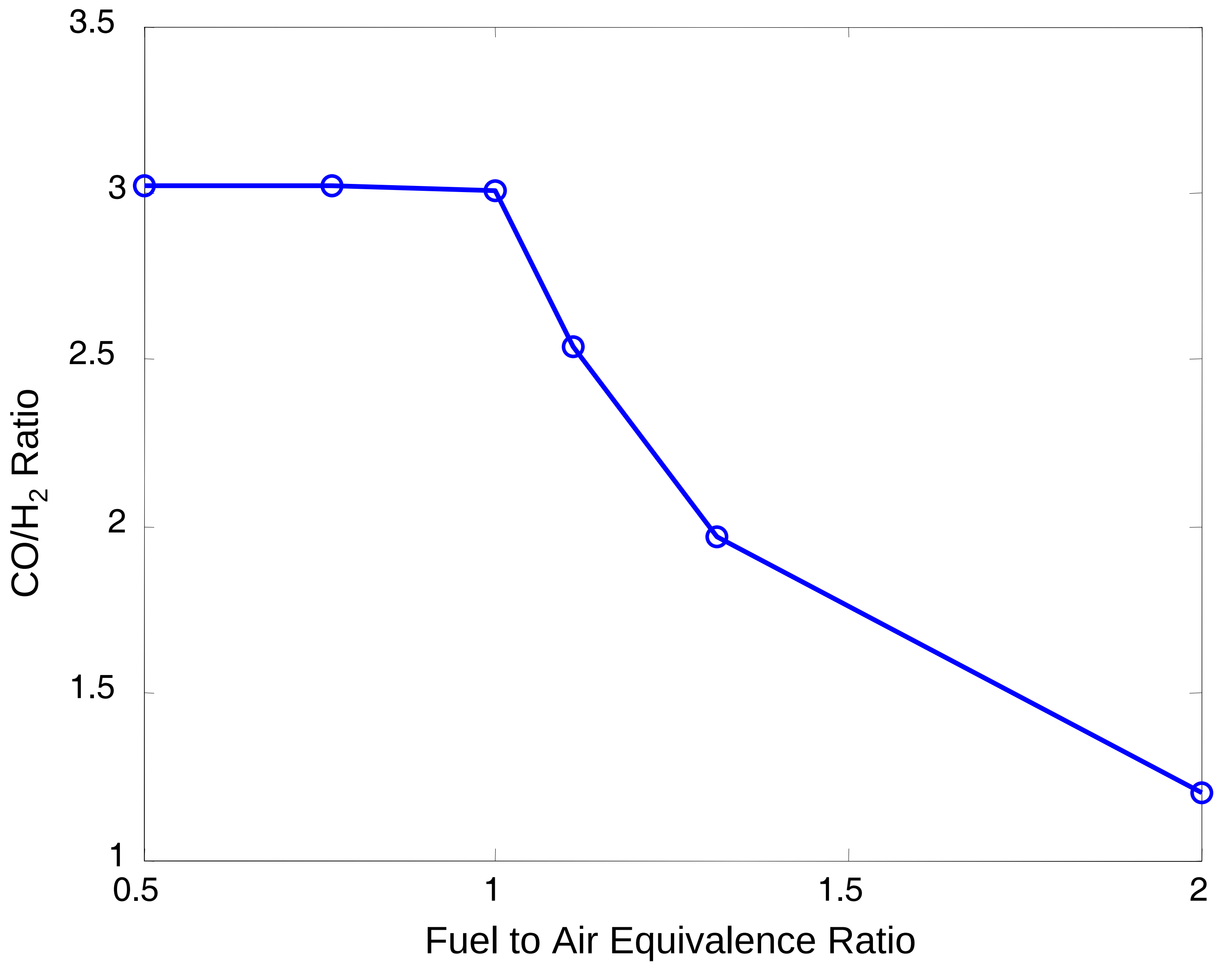


FIG. 10-7. Exhaust-gas composition vs. measured air-fuel ratio, for unsupercharged automotive-type engines. Fuel C_8H_{17}. (After D'Alleva and Lovell, Ref. 1.)

Equilibrium CO/H_2 for Iso-Octane in Air at 1700 K



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