UT-BATTELLE

Comparison of LNT catalyst performance with in-cylinder regeneration techniques

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OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

Three LNT Catalysts Characterized on Engine Platform

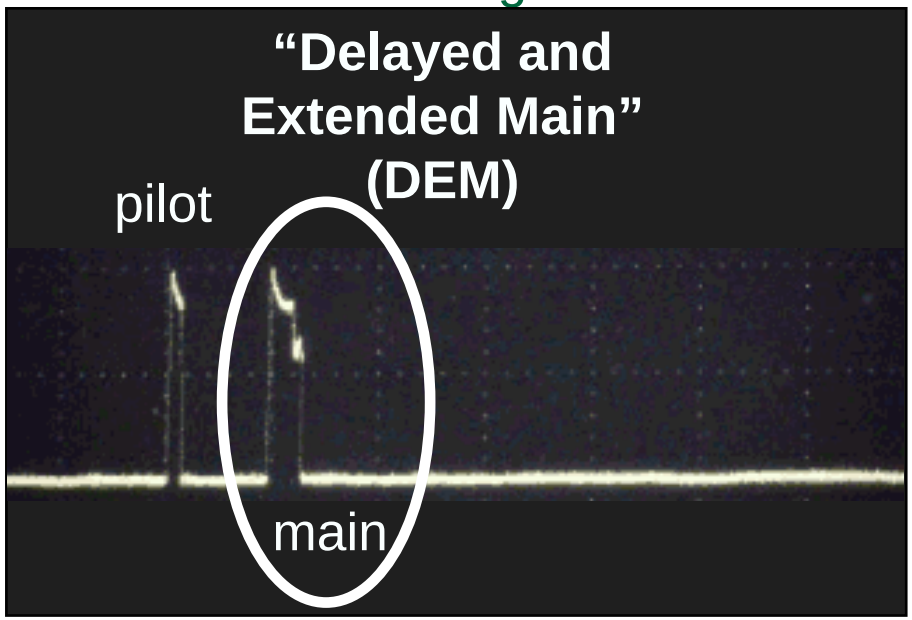
- **LNT Catalysts:**
  - **Umicore GDI LNT ("CLEERS" LNT)**
  - **Low Ba**
    - **γ-Al_2O_3/Pt/Ba LNT**
    - **Pt Loading is 100 g/ft3**
    - **BaO: 8% by weight on washcoat**
  - **Medium Ba**
    - **γ-Al_2O_3/Pt/Ba LNT**
    - **Pt Loading is 100 g/ft3**
    - **BaO: 20% by weight on washcoat**

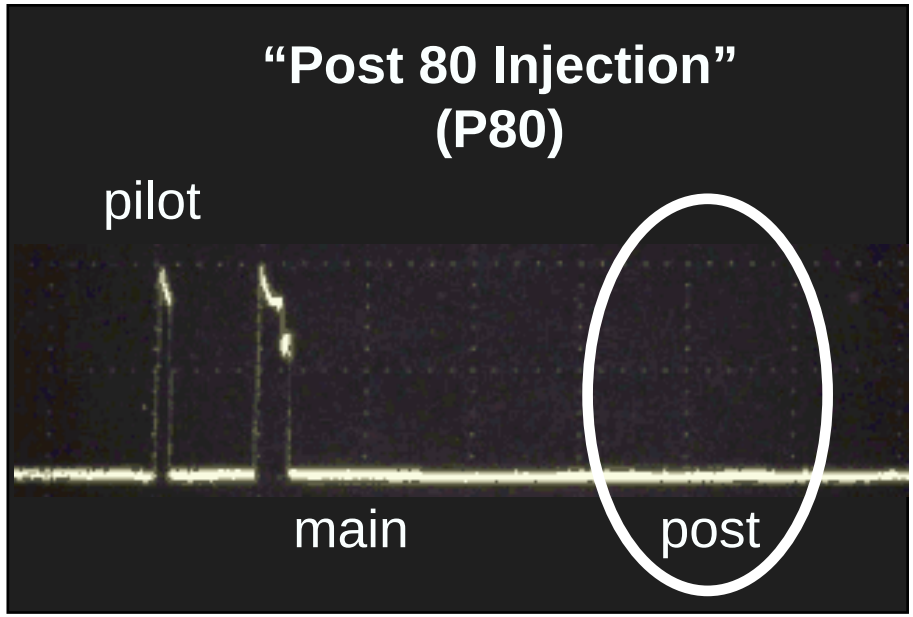
	Umicore*	Low Ba	Med Ba
BaO	29 g/l	~11 g/l	~27 g/l
Al_2O_3	160 g/l	~137 g/l	~137 g/l
CeO_2	98 g/l	---	---

- **Catalysts evaluated on ORNL Mercedes light-duty diesel engine platform**
  - **1.7-liter Mercedes A-class engine**
  - **BP15 fuel**
  - **Experiments conducted at 1500 RPM, 5 bar BMEP (~50 ft-lb), LNT inlet temperature of ~300°C**
- **DOC Catalyst Upstream of LNT (same DOC for all LNTs)**

*Rohr, et.al., *Applied Catalysis B: **Environmental** **56** (2004) 187–198

Two engine control strategies for achieving intermittent rich combustion for regeneration of LNT

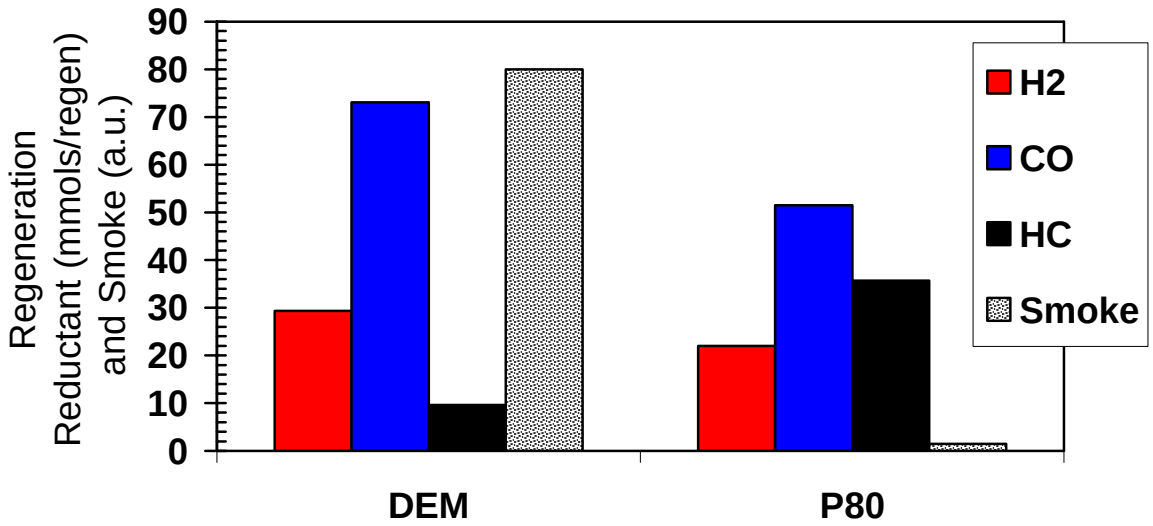




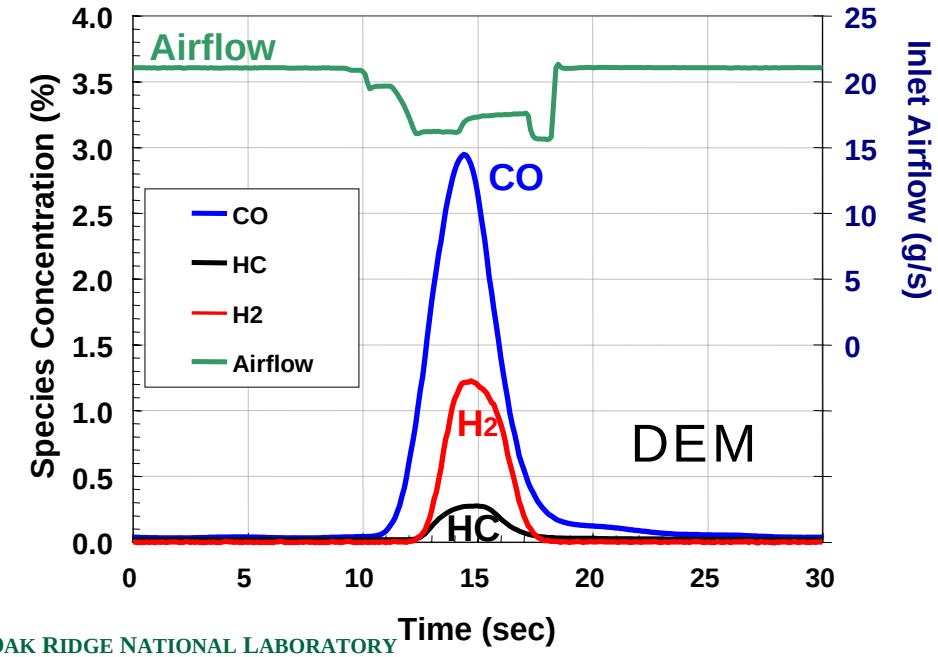
Two LNT Regeneration Strategies Chosen Based on Difference in Chemistry

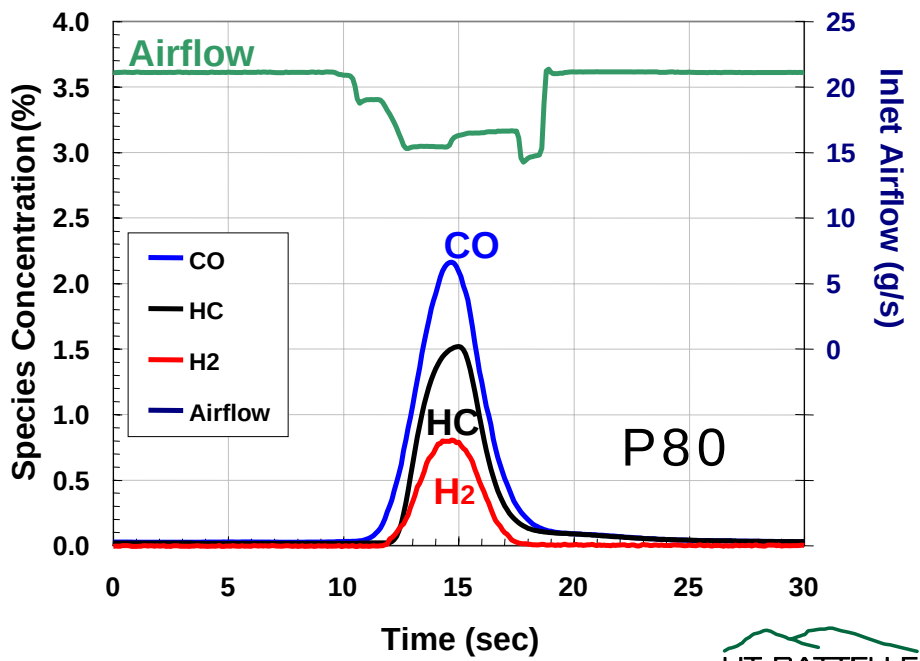
- **Delayed and Extended Main (DEM):**
  - **Throttle for reduced air flow**
  - **Extra fuel injected near main injection timing to achieve rich conditions**
- **Post 80 Injection (P80):**
  - **Throttle for reduced air flow**
  - **Extra fuel injected after main injection later in cycle to achieve rich conditions**

Two engine control strategies for achieving intermittent rich combustion for regeneration of LNT



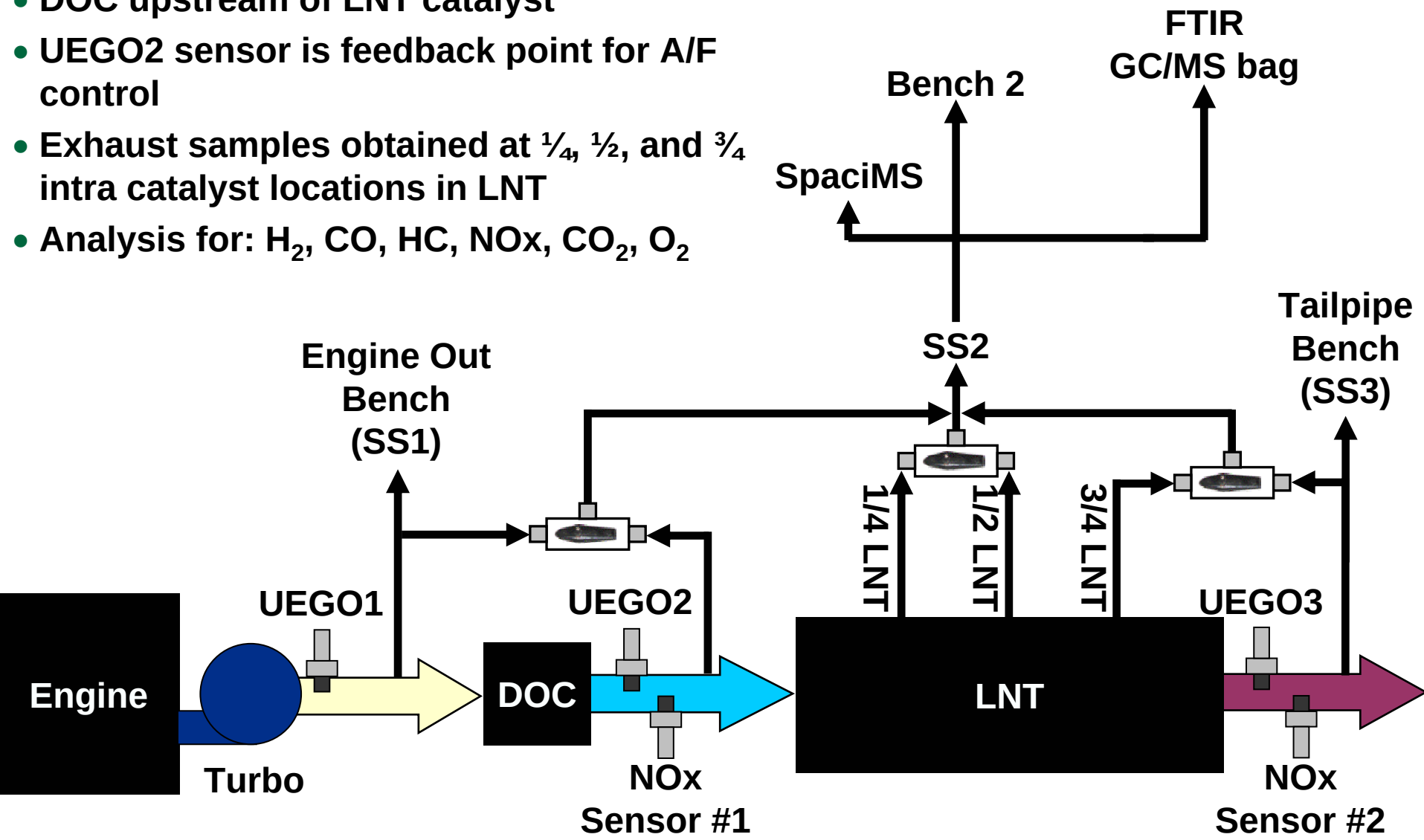
- **Delayed and Extended Main (DEM):**
  - **High H_2 and CO**
  - **Low HC**
  - **High PM**
- **Post 80 Injection (P80):**
  - **Moderate CO and H_2**
  - **High HC**
  - **Low PM**



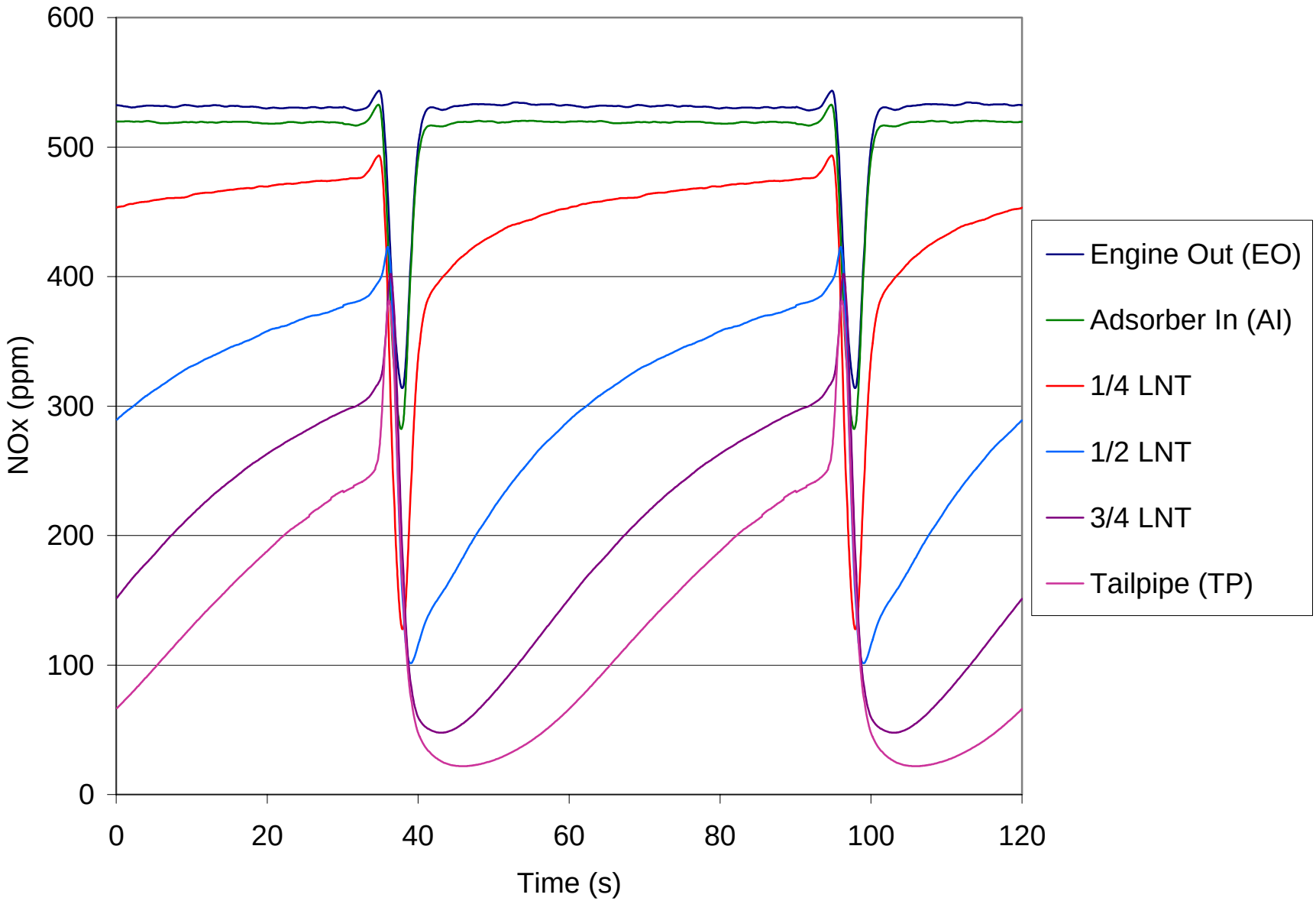


Experimental setup allows full exhaust species characterization throughout the catalyst system

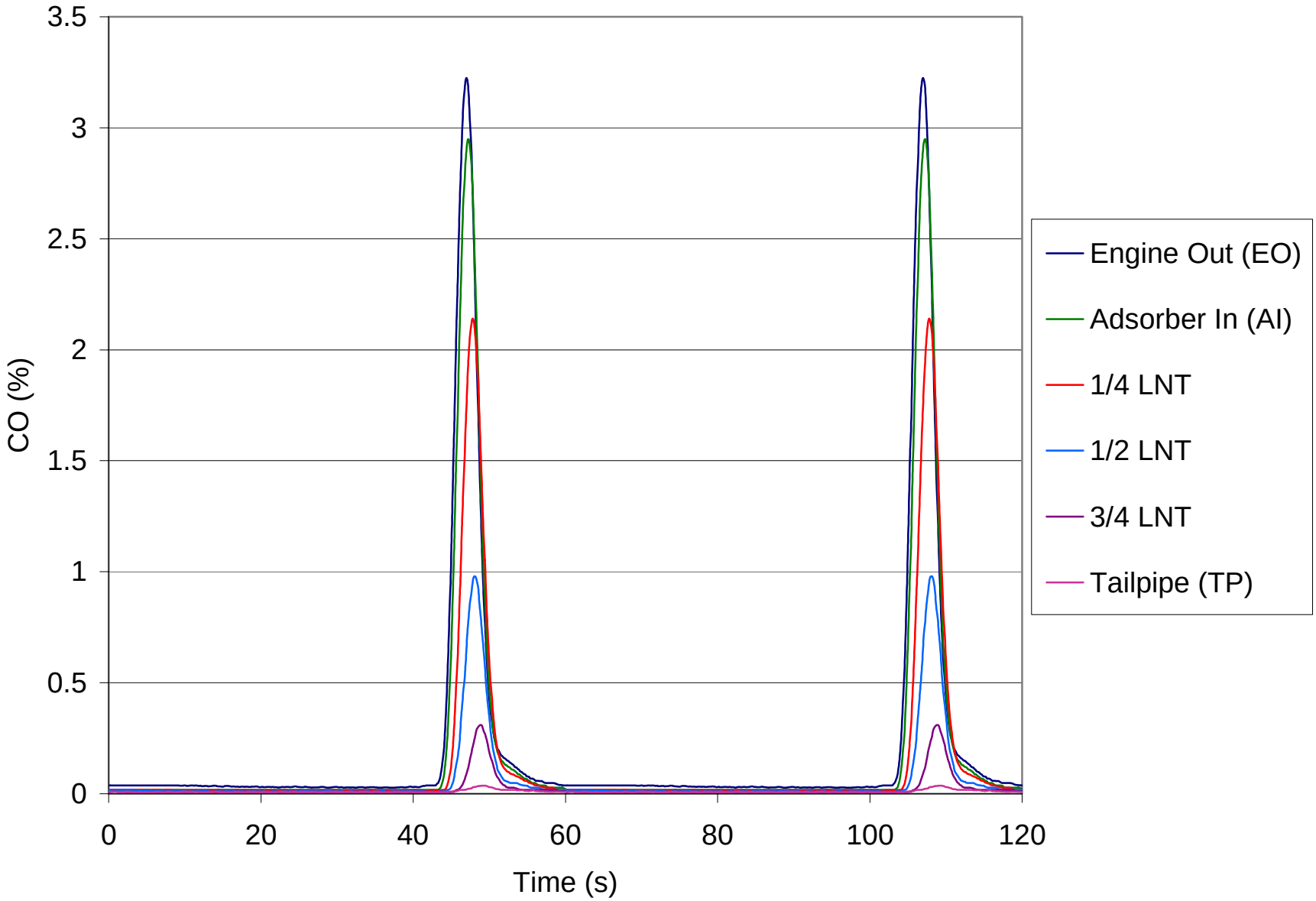
- DOC upstream of LNT catalyst
- UEGO2 sensor is feedback point for A/F control
- Exhaust samples obtained at ¼, ½, and ¾ intra catalyst locations in LNT
- Analysis for: H_2, CO, HC, NOx, CO_2, O_2



Umicore LNT: NOx vs. Time

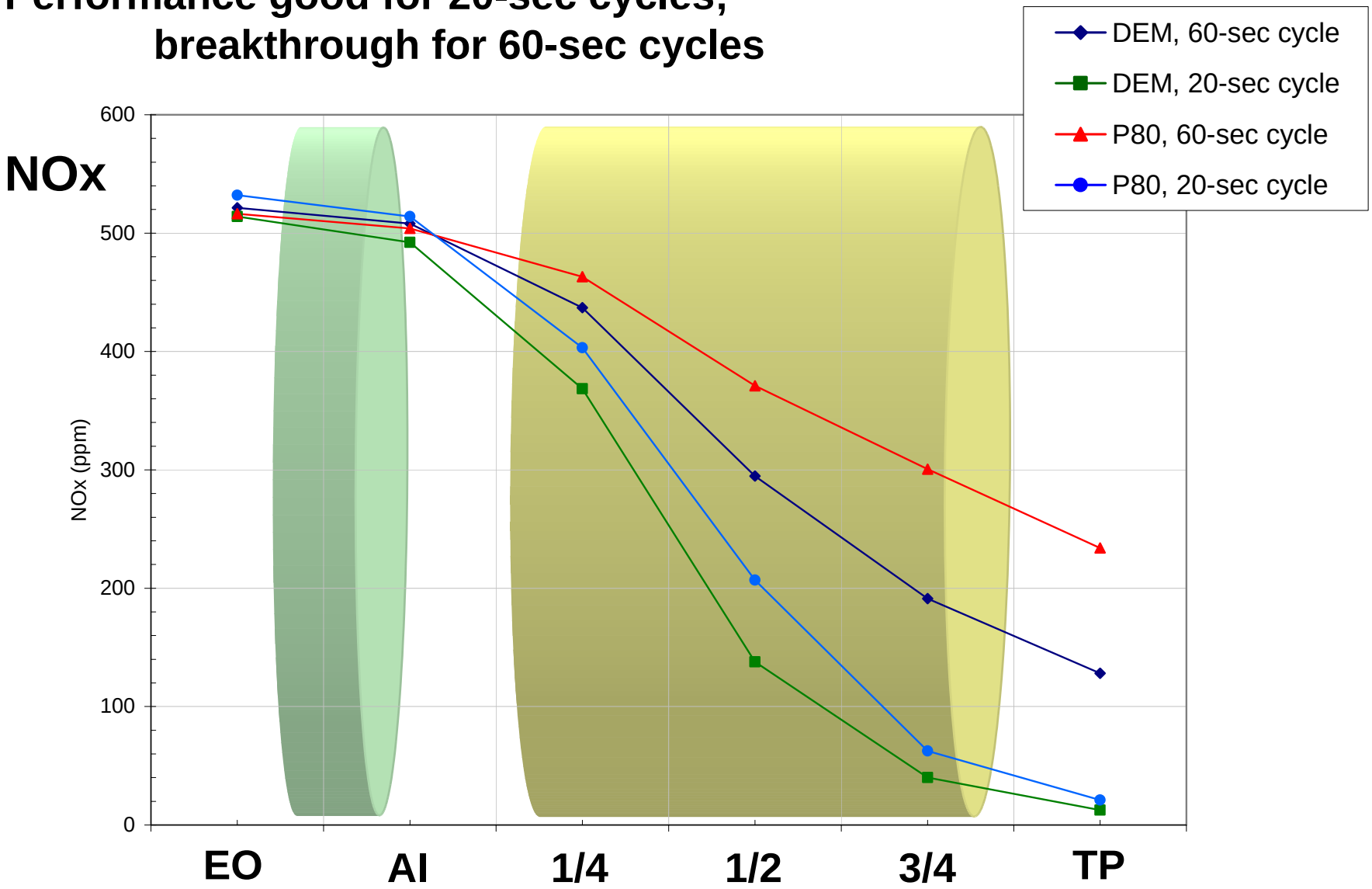


Umicore LNT: CO vs. Time



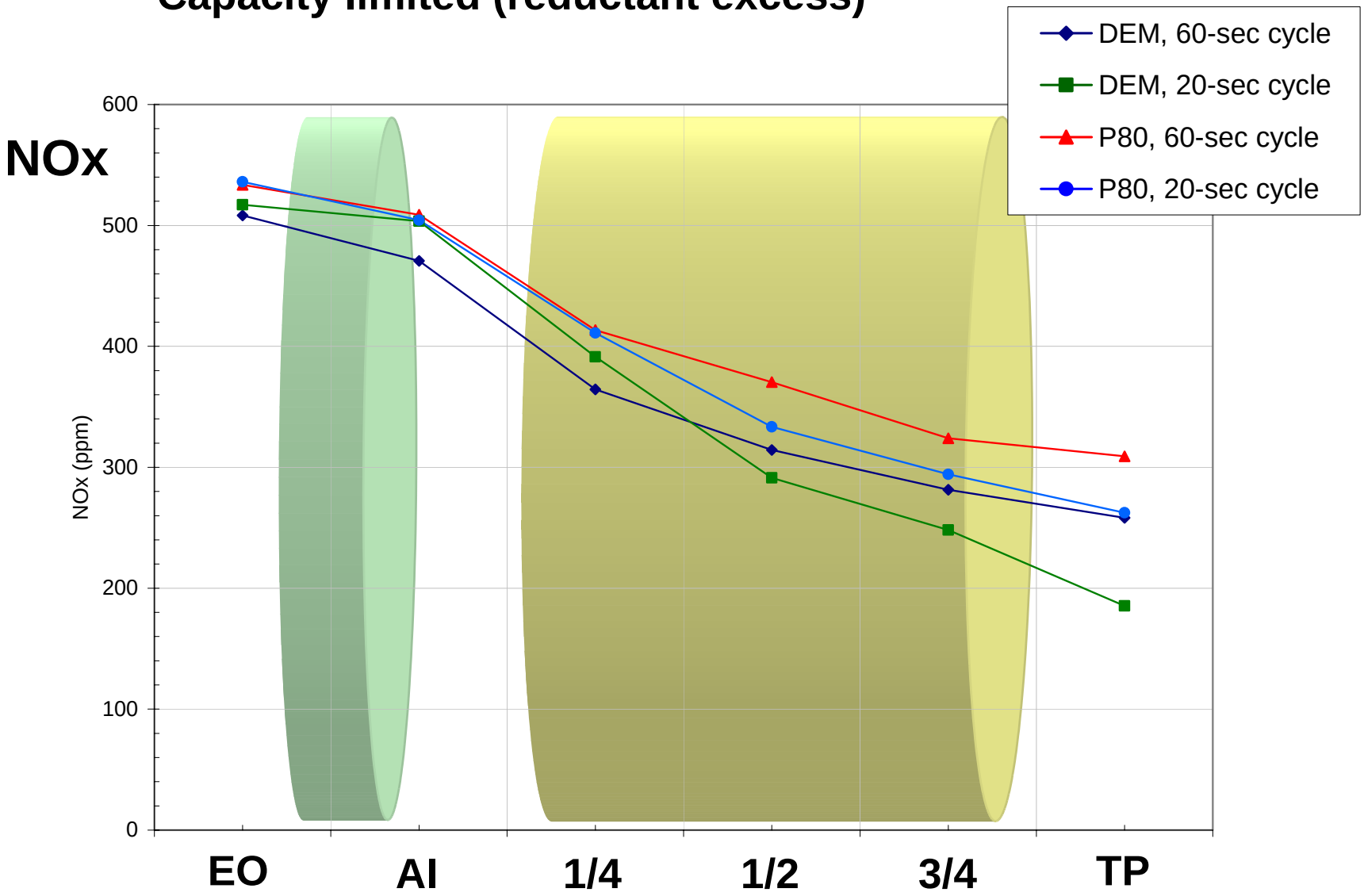
Umicore LNT: Cycle-Average NOx vs. Catalyst Position

Performance good for 20-sec cycles;
breakthrough for 60-sec cycles



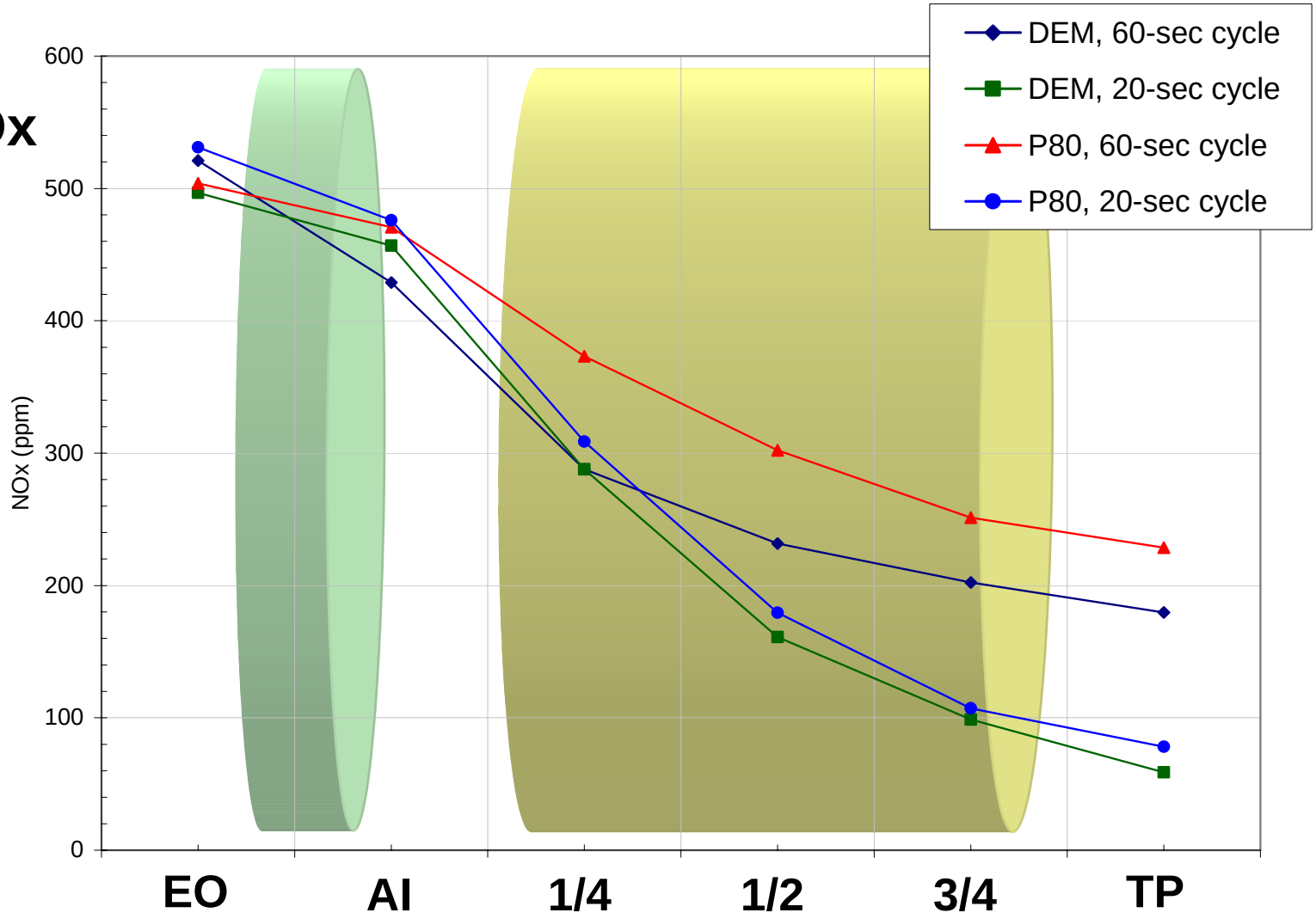
Low Ba LNT: Cycle-Average NOx vs. Catalyst Position

Low Ba LNT performance more similar for different strategies
Capacity limited (reductant excess)



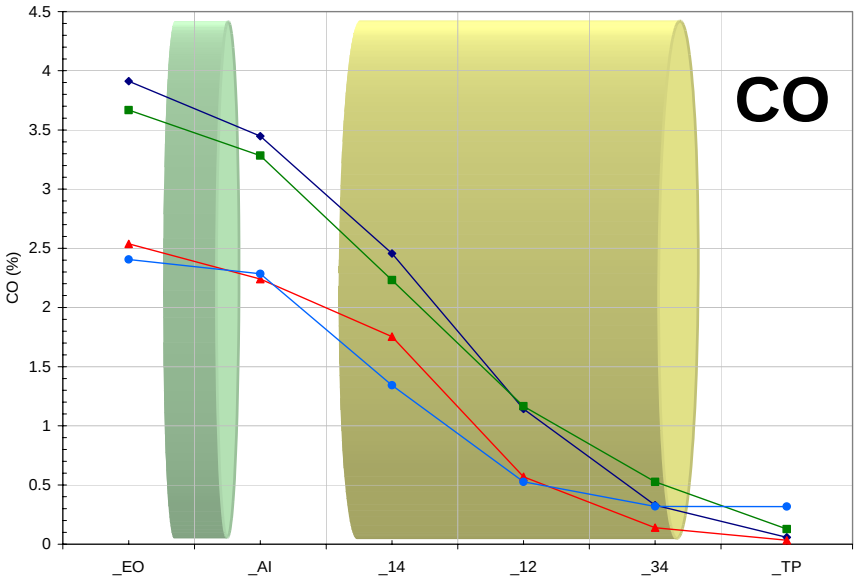
Medium Ba LNT: Cycle-Average NOx vs. Catalyst Position

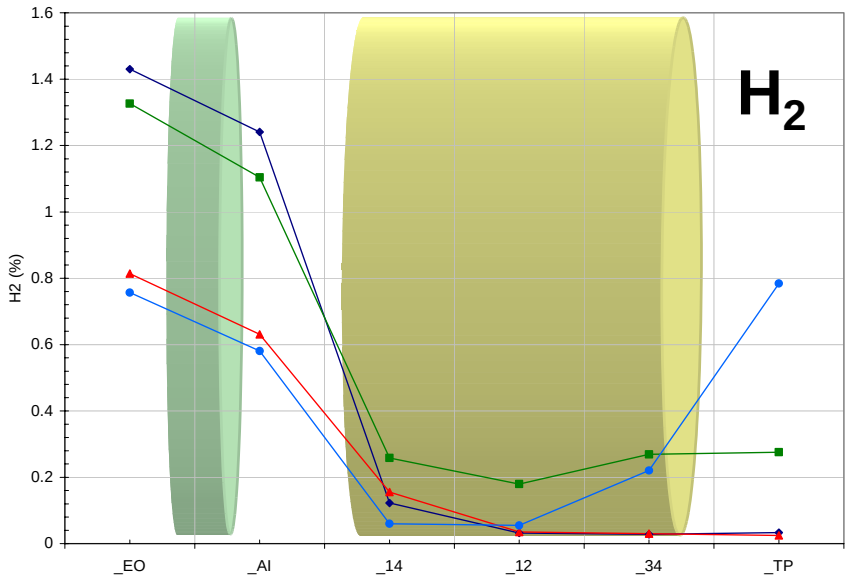
Medium Ba LNT performance similar to Umicore LNT

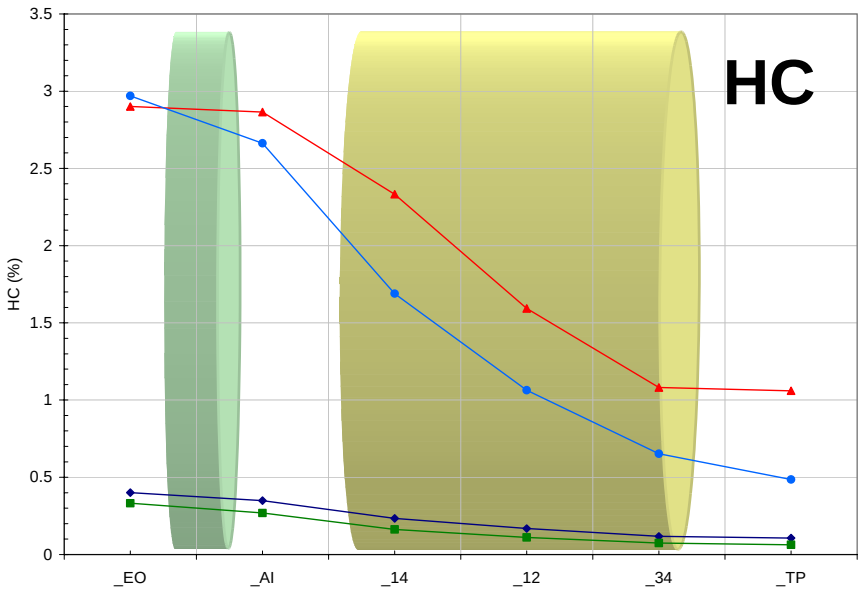


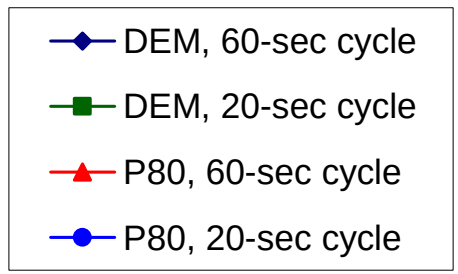
Umicore LNT: Reductants vs. Catalyst Position

Reductants → 3-sec Average During Regeneration



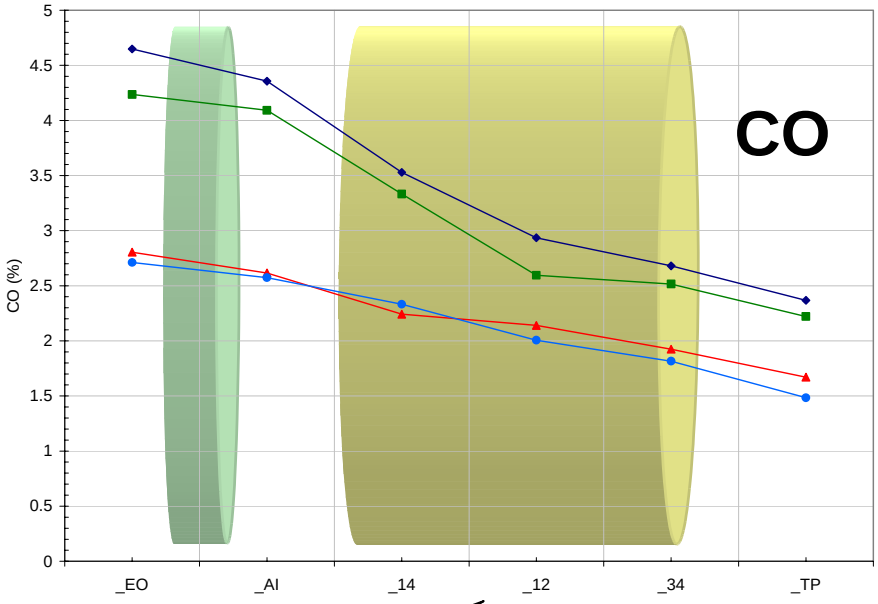


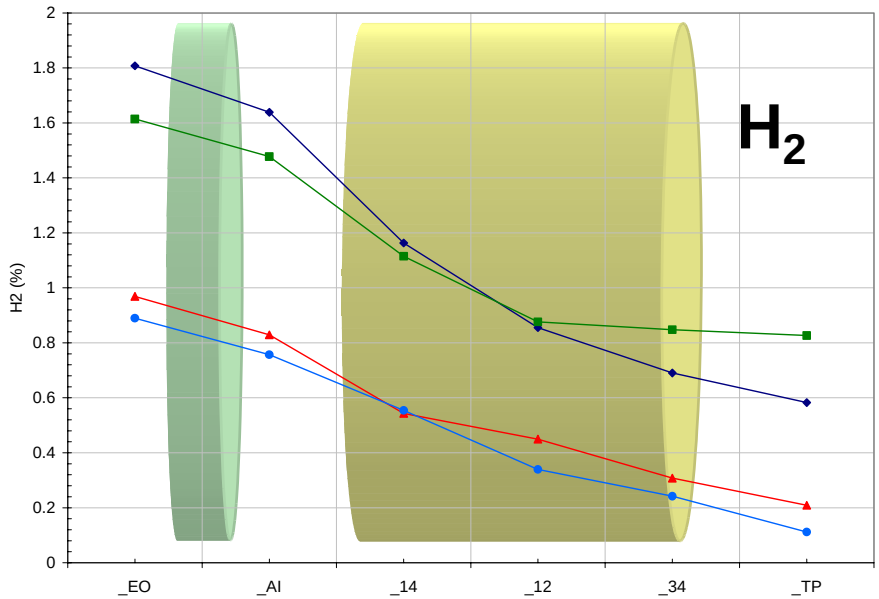




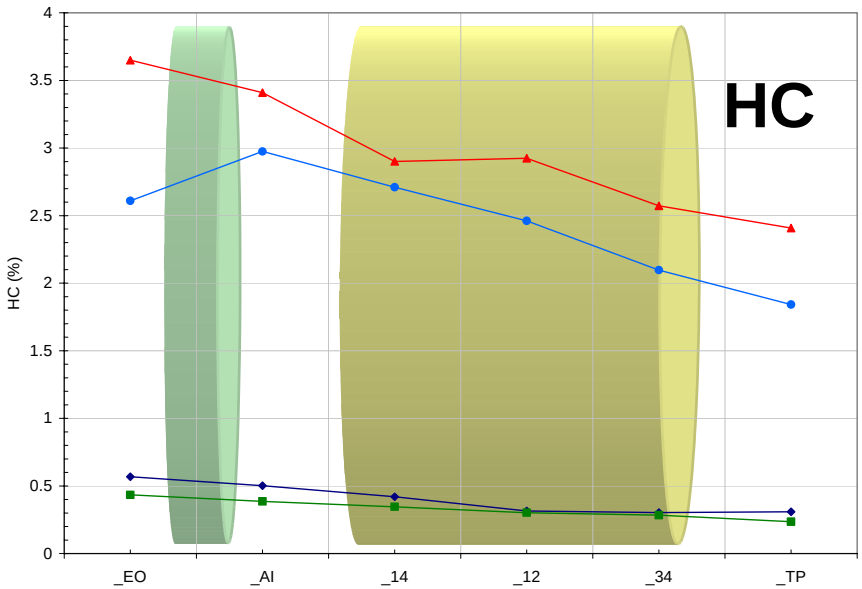
Low Ba LNT: Reductants vs. Catalyst Position

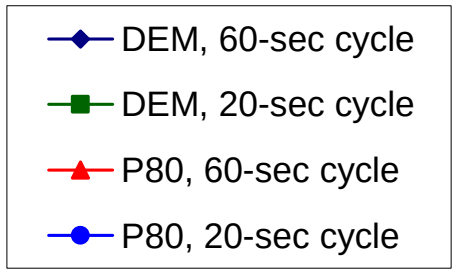
Reductants → 3-sec Average During Regeneration





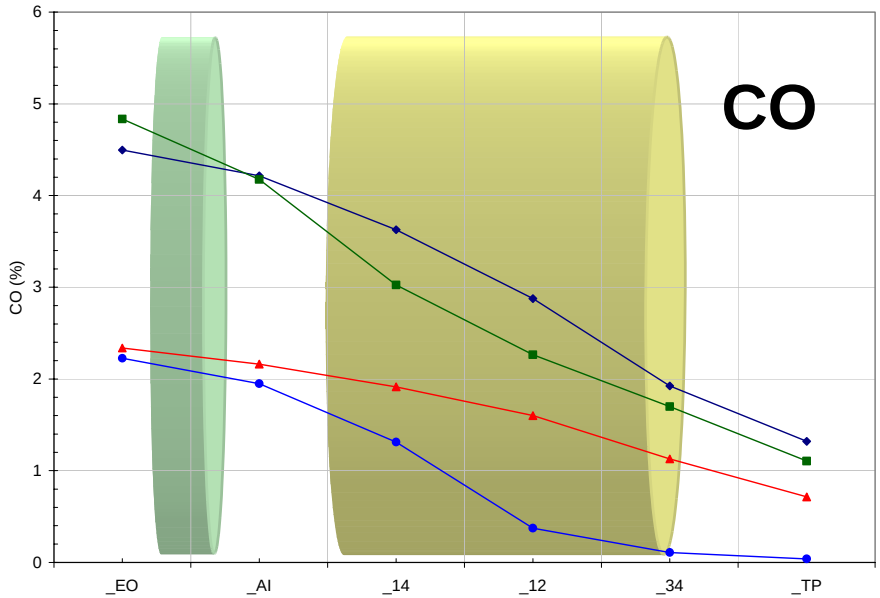
Reductant slip out of LNT (over regeneration)

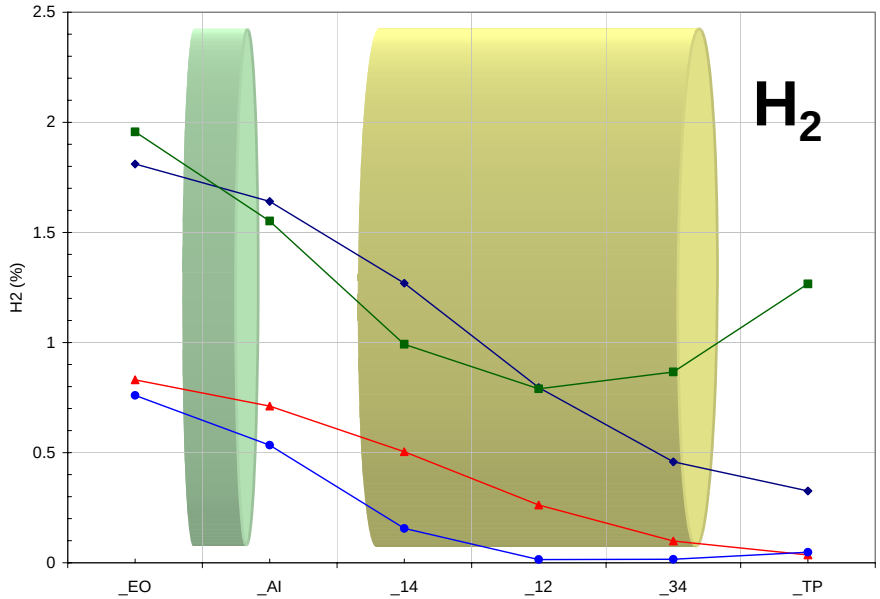


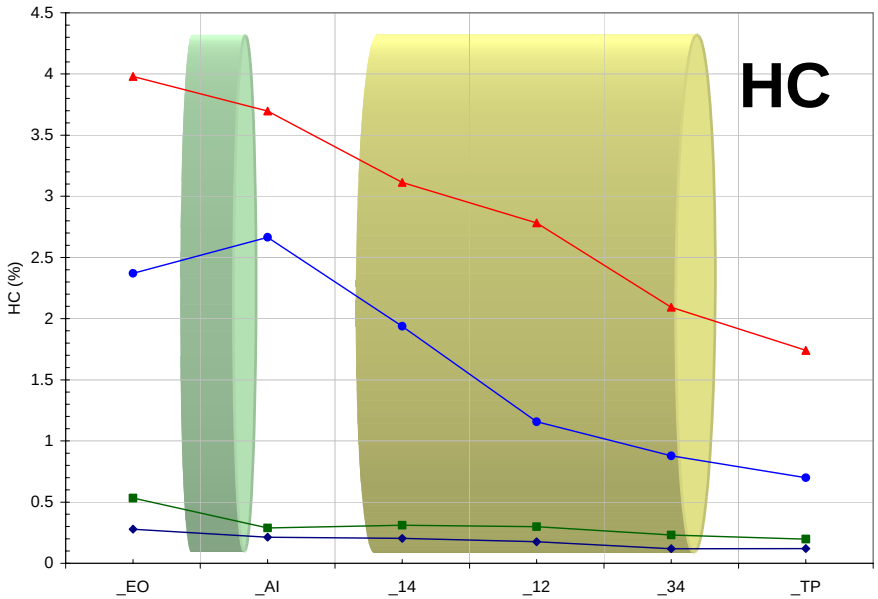


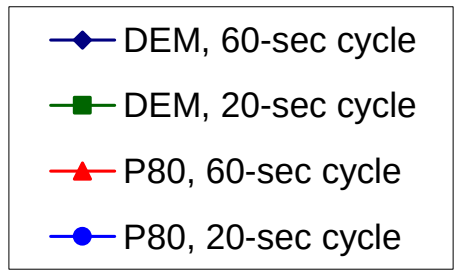
Medium Ba LNT: Reductants vs. Catalyst Position

Reductants → 3-sec Average During Regeneration



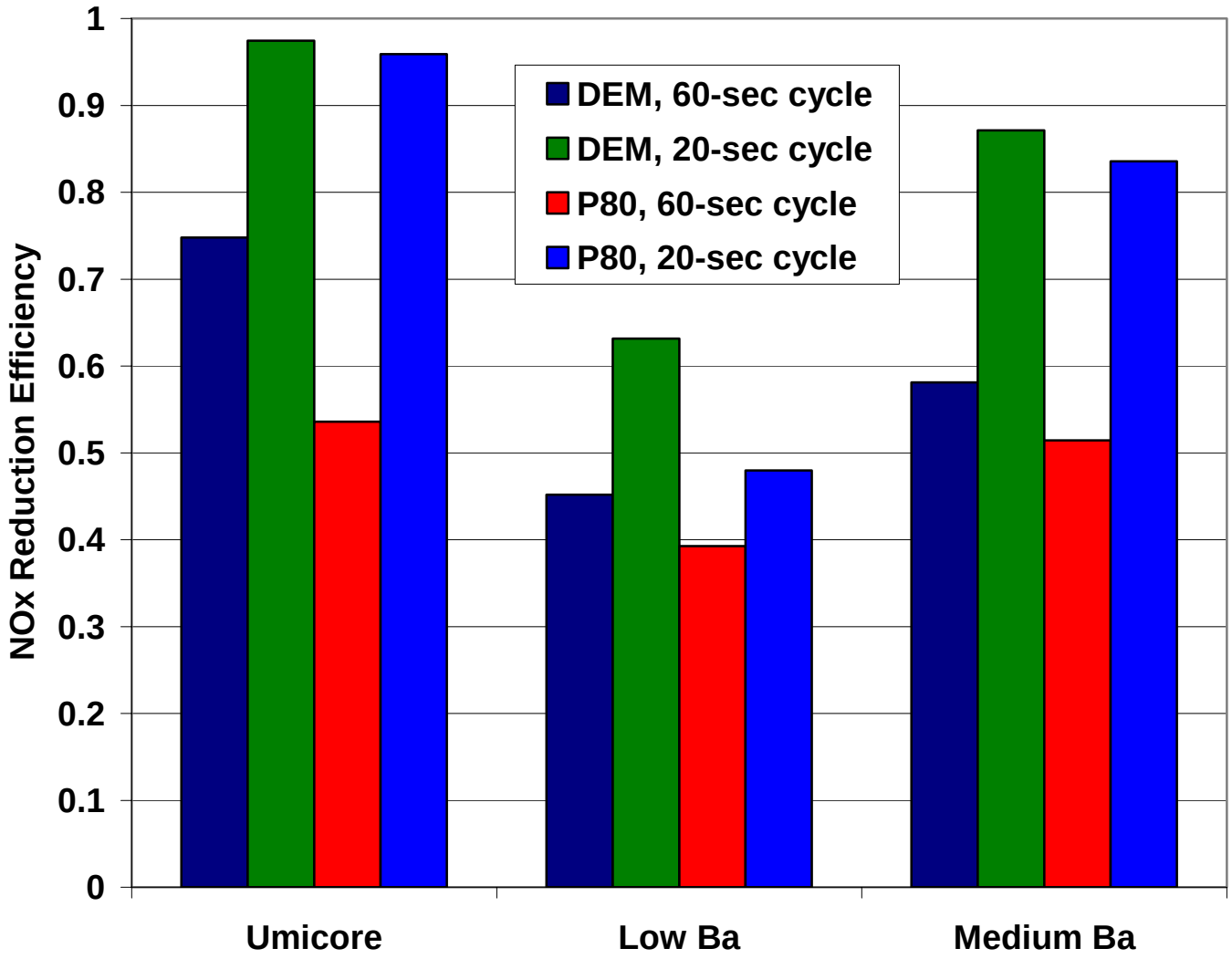




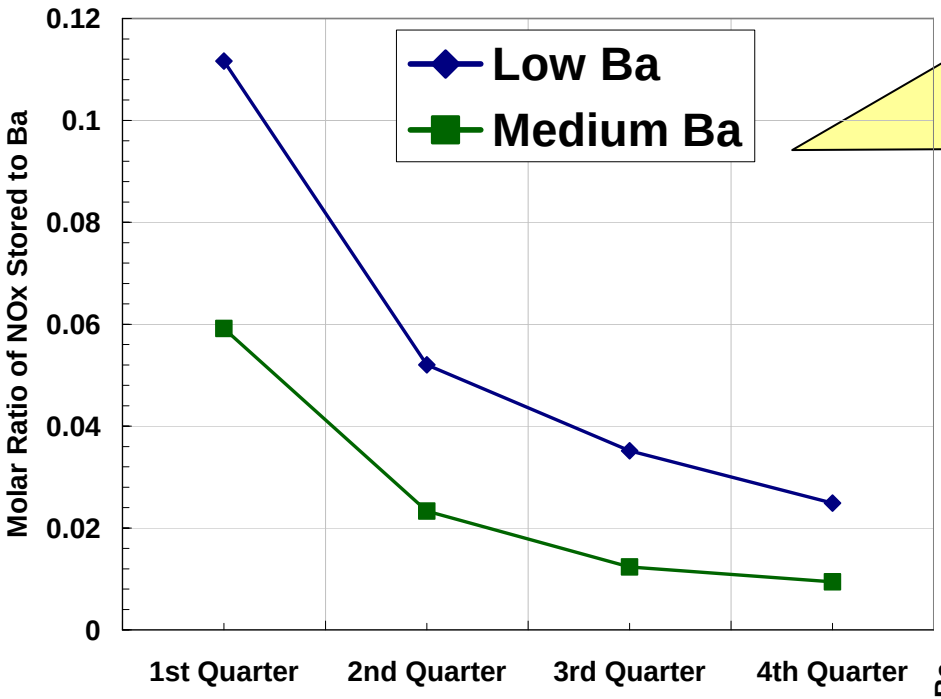


NOx Reduction Efficiency

- **Umicore LNT has best performance followed by Medium Ba LNT**
- **Trend in strategies the same, but differences smaller for Low Ba LNT**

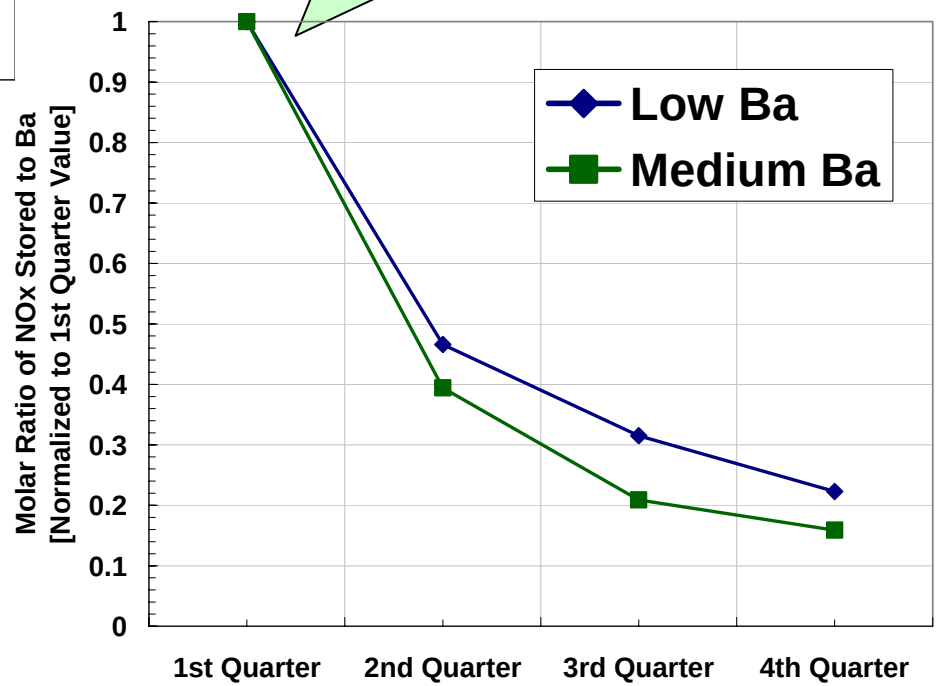


Efficiency of Ba for Model Ba LNTs [DEM, 60-sec cycle]



Analysis:
(1) Determined moles of NOx stored in each quarter of LNT
(2) Calculated moles of Ba in each quarter of LNT
(3) Obtained molar ratio of NOx stored per Ba

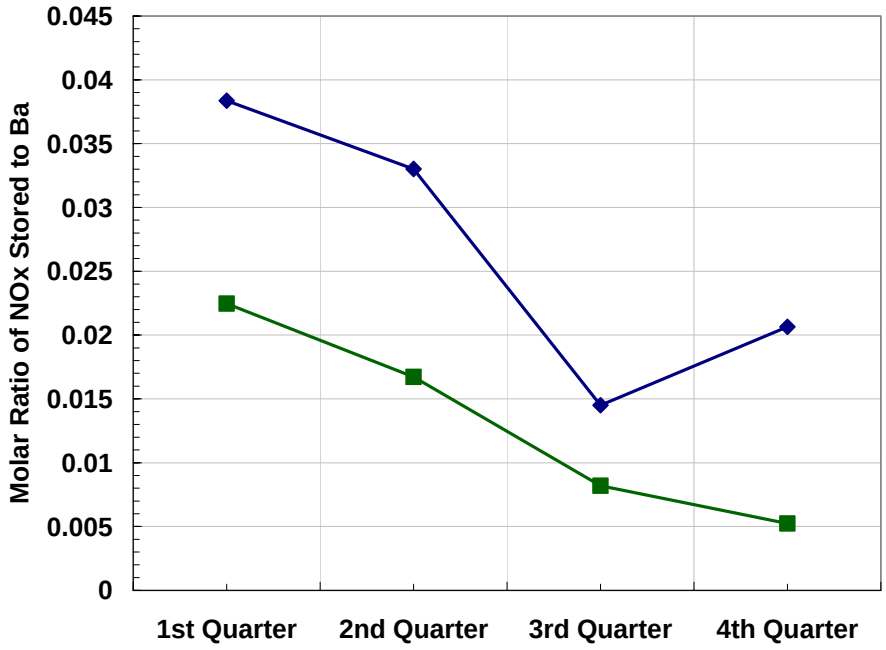
Normalized to 1st Quarter Value

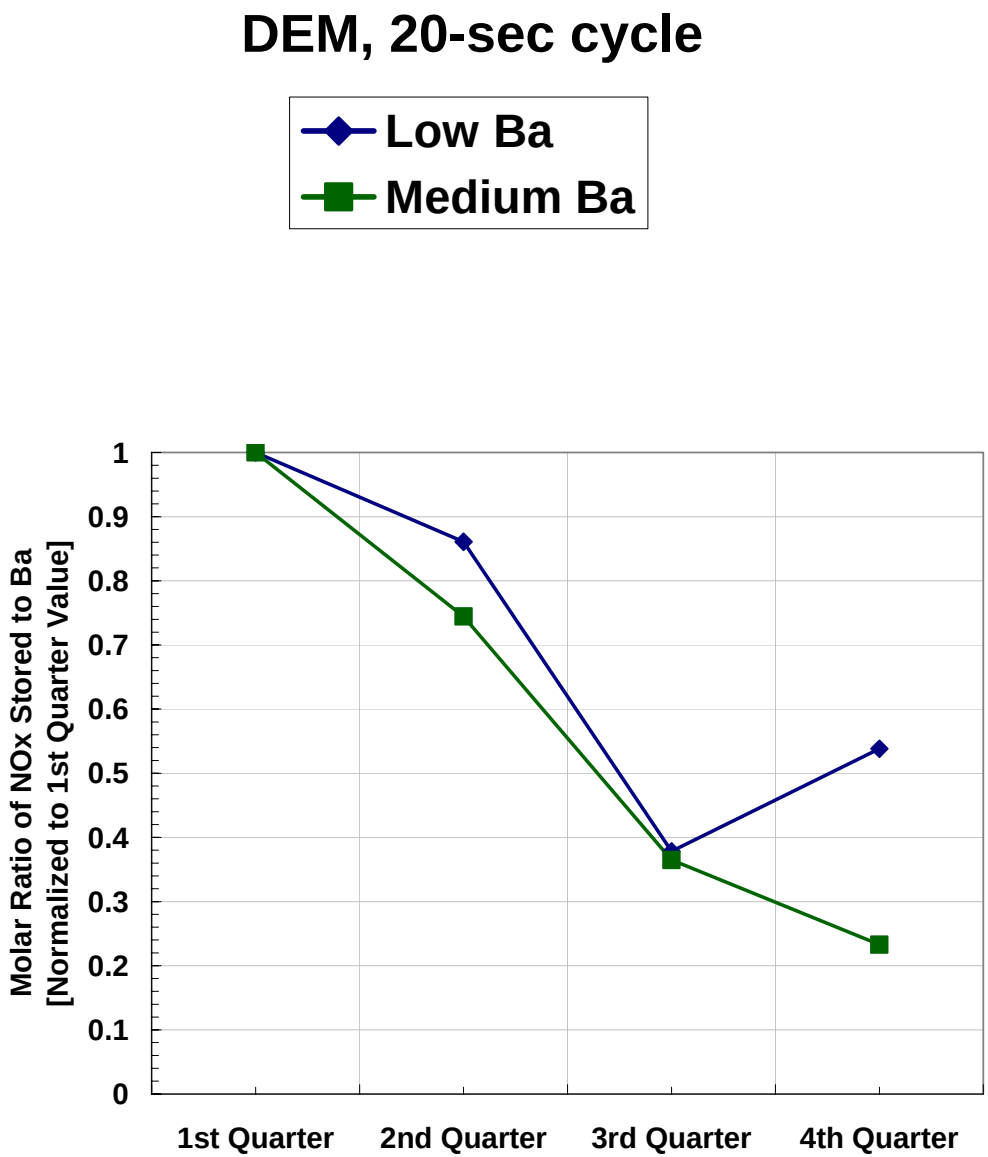


- **Ba sorbate component of Low Ba LNT is more efficient than Medium Ba LNT**

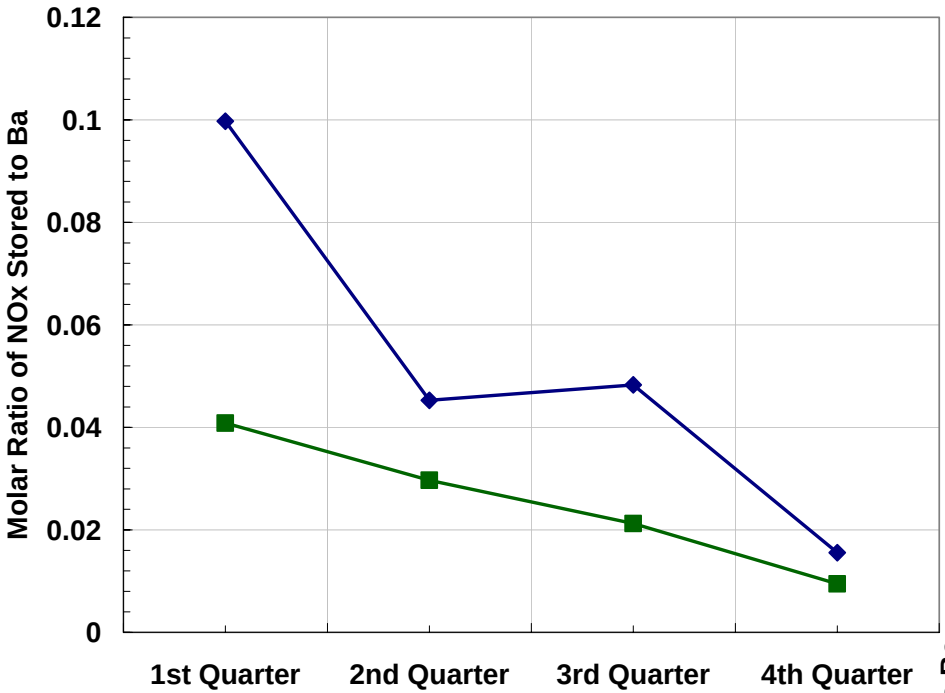
- **However, normalized data shows similar trend of NOx storage along catalyst flow axis**

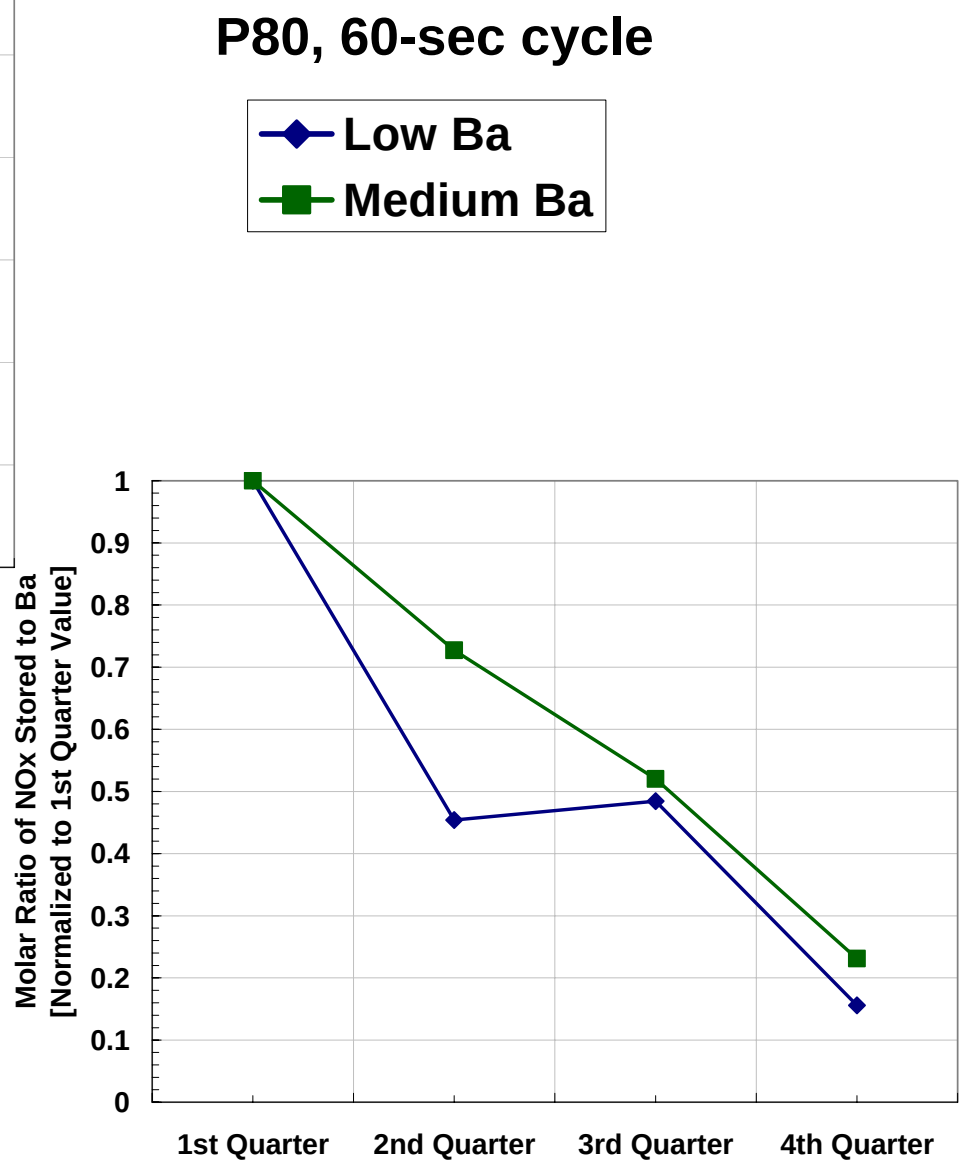
Efficiency of Ba Component for Model Ba LNTs



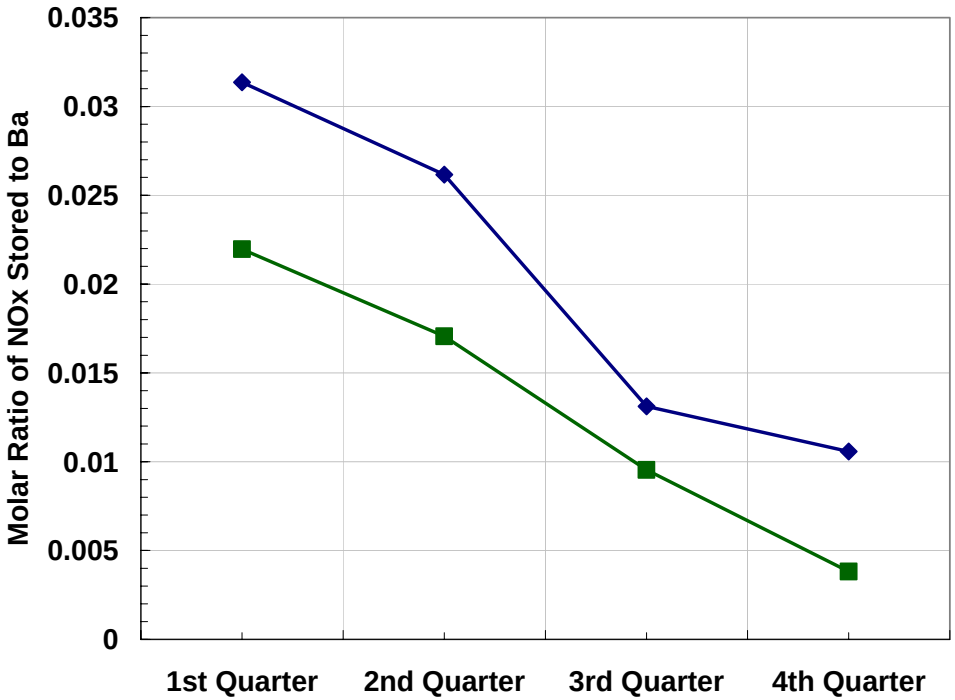


Efficiency of Ba Component for Model Ba LNTs

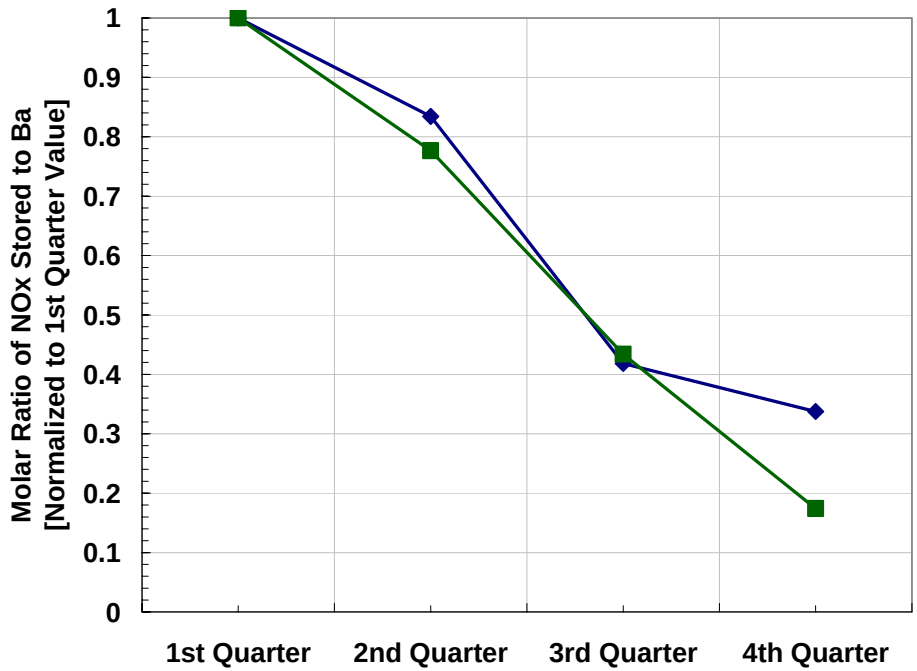




Efficiency of Ba Component for Model Ba LNTs

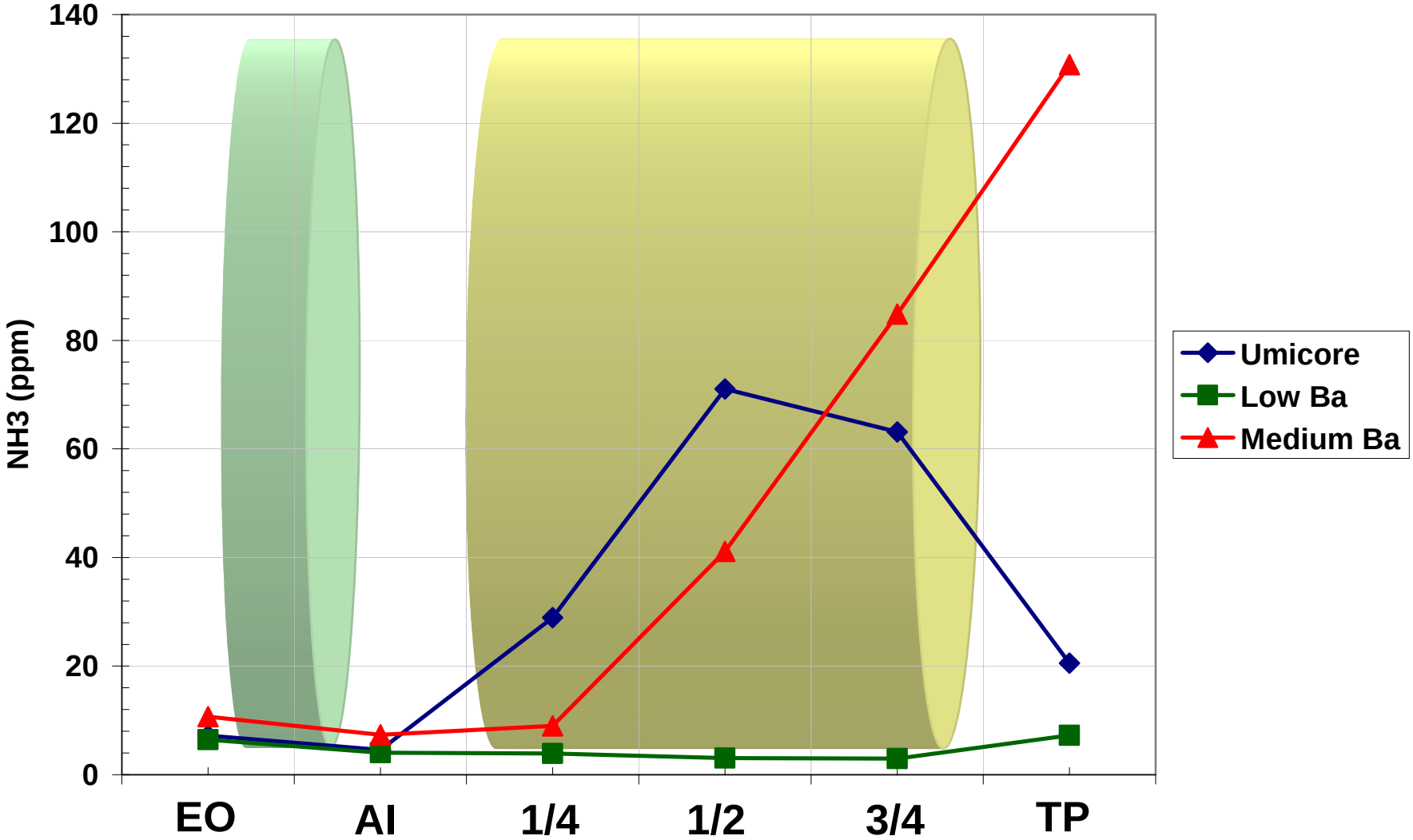


P80, 20-sec cycle



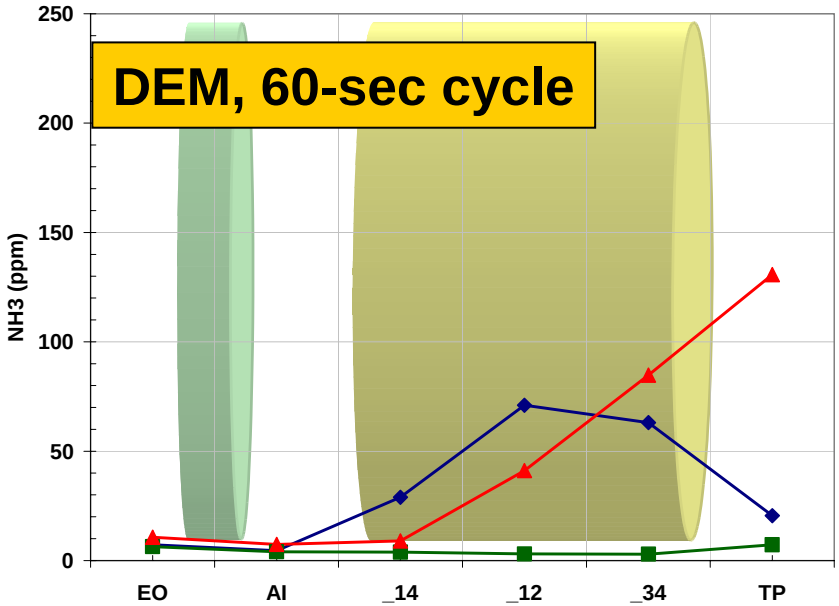
NH_3 vs. Catalyst Position for DEM, 60-sec Cycle

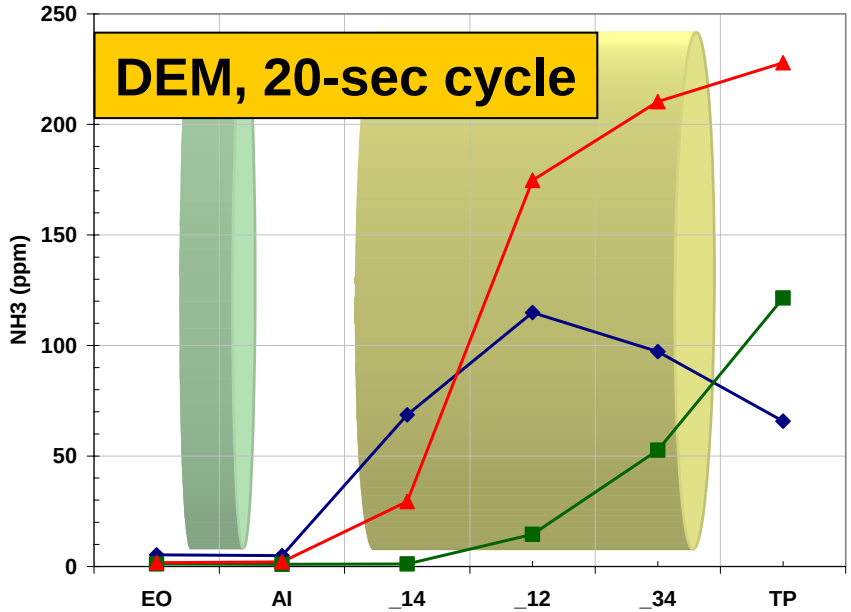
- **Lower Ba loading results in lower NH_3 formation***
- **NH_3 level decreases in downstream half of LNT for Umicore LNT**

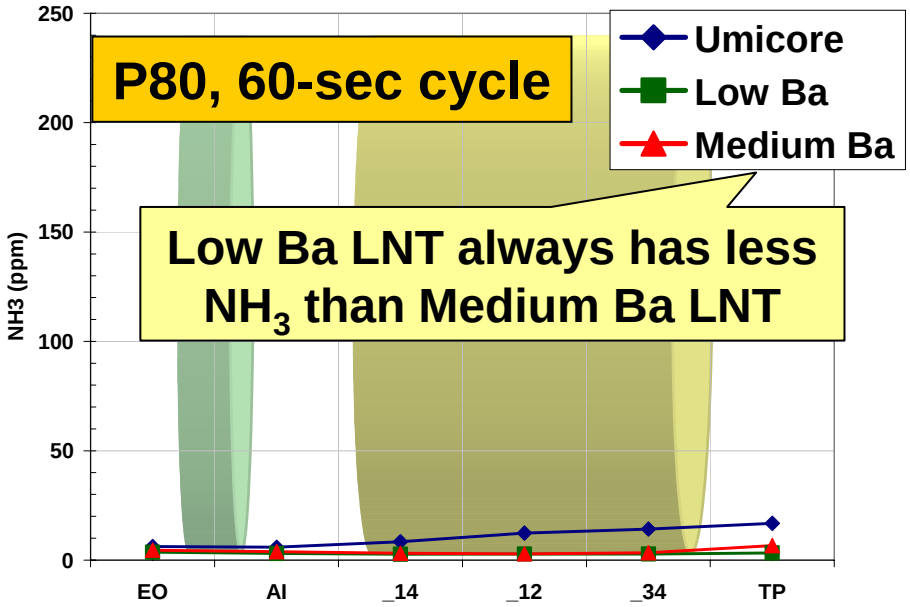


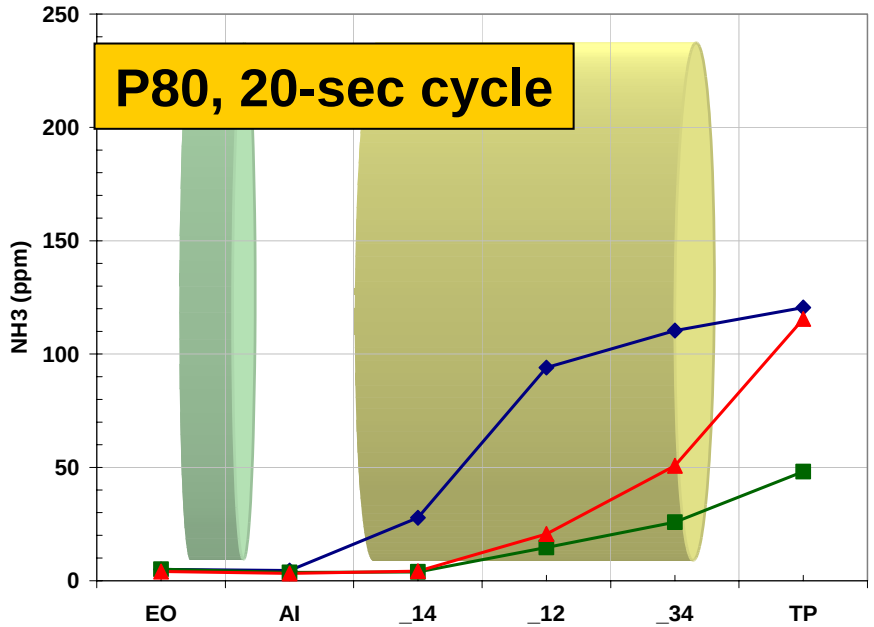
*Consistent with Castoldi, et.al., *Catalysis Today* **96** (2004) 43–52

NH_3 vs. Catalyst Position for All Four Strategies



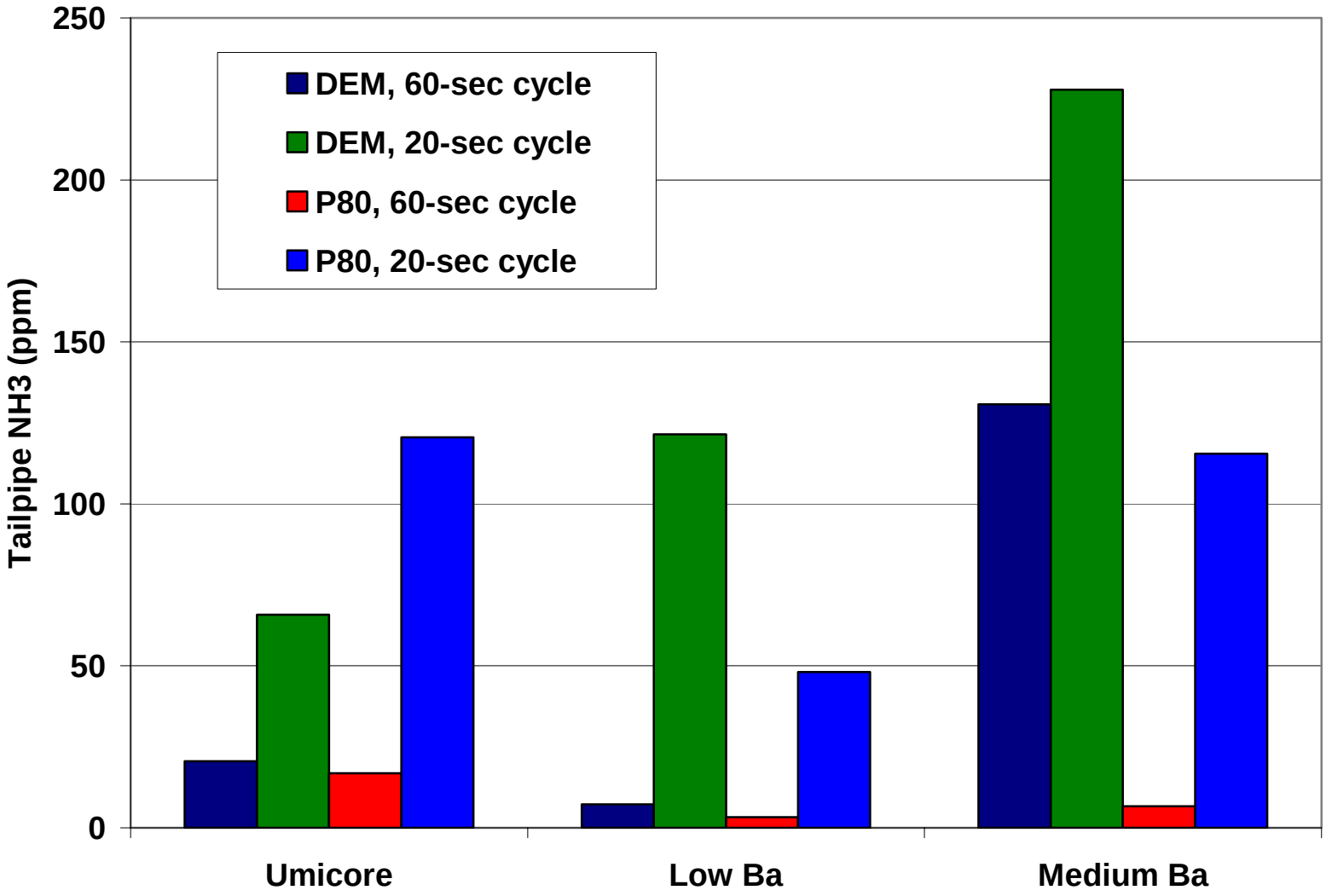






Tailpipe NH_3 Comparison

- **Low Ba LNT generally gives lowest NH_3 formation**
- **All LNTs have loading/regeneration conditions that cause NH_3**



Summary

- **Three LNT catalysts studied on engine platform with different regeneration strategies and lean-rich cycle periods**

- **NOx Reduction Performance**
  - **Umicore LNT gave best performance**
  - **Model Ba LNTs showed NOx capacity propotional to Ba loading**

- **Storage Site Efficiency**
  - **Lower Ba loading resulted in higher efficiency of NOx storage per Ba on a molar basis**
  - **However, saw similar trend in molar NOx storage per Ba along catalyst flow axis**

- **N_2 Selectivity**
  - **Lower Ba loading led to less NH_3 formation (higher N_2 selectivity)**
  - **NH_3 formed in 1st half of Umicore LNT was consumed in 2nd half of LNT**
    - **Suspect oxygen storage of CeO_2 component a factor**

Other Notes

- **Data will be posted on CLEERS website in similar format to previous data sets from Mercedes platform**

- **Data from Sulfur Study (presentation at December 2006 CLEERS teleconference) has been posted to CLEERS site**
  - **www.cleers.org**
  - **CLEERS Home > Databases > Test Stand/Vehicle Component Data > Mercedes 1.7l – DOC – LNT Sulfation/deSulfation study with intracatalyst speciation**

- **Current studies on engine platform focusing on LNT performance with High Efficiency Clean Combustion (HECC) engine combustion modes**