DeSulfation of NOx Adsorbers: Studies with the SpaciMS Technique

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Project objective and targeted problem

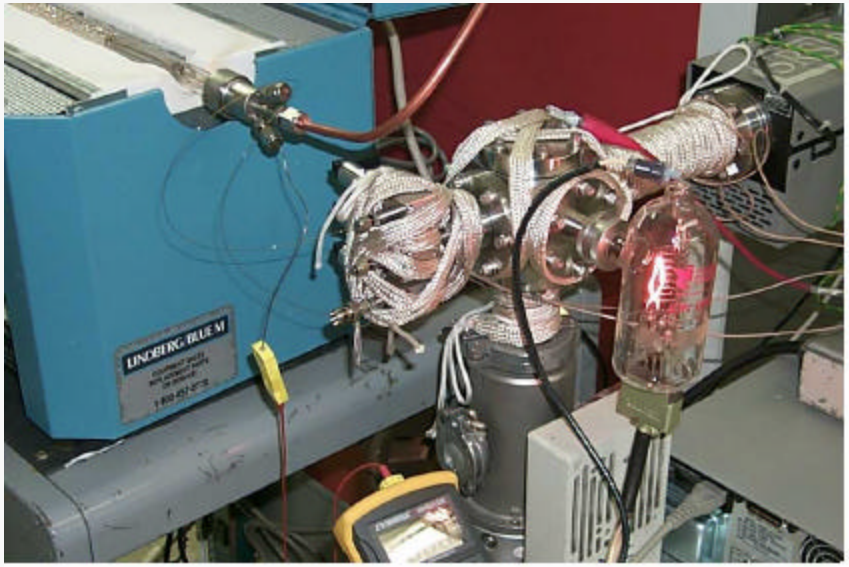
- Objective: Evaluate chemical species and conditions responsible for the performance of a NOx adsorber system on a CIDI engine

- Key technical barriers /issues targeted
  - NOx adsorber-catalysts highly effective for NOx control, but….
  - Data from multiple projects show rapid deactivation from fuel sulfur
  - S masking effect on HC reductant usage
  - DeSulfation effects on NOx adsorber catalyst

Approach

- Develop a capillary-inlet mass spectrometer for analyzing species within a NOx adsorber
- Deploy ten capillaries at points inside the NOx adsorber and at the entrance and exit
- Measure transient response during adsorption phase and regeneration phase
- Measure transient response during S masking and after subsequent deSulfation

SpaciMS : Spatial and Temporal Gas Analysis



- Minimally Invasive : 350-μm OD Capillary, μL/min extraction
- Fast : 32 ms/point standard, μs capability
- Amplitude : Excellent linearity and dynamic range
- Species : NO_X, O_2, CO_2, simple HC fragments

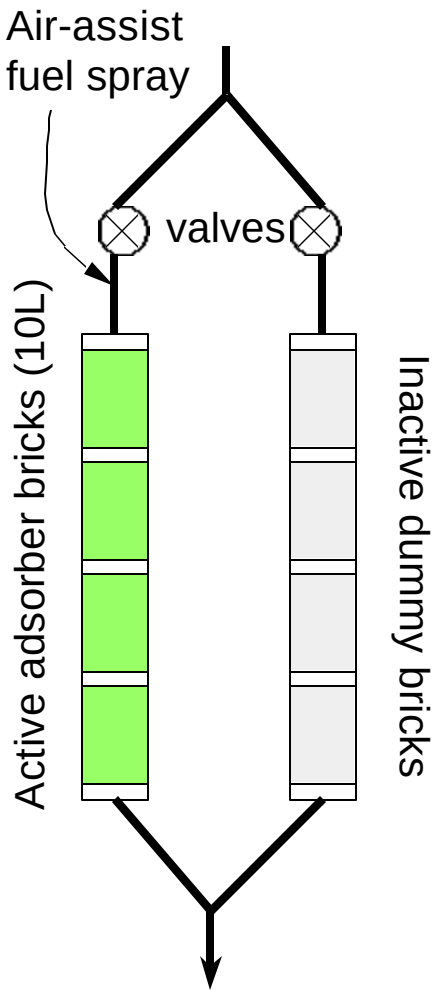
Experimental setup

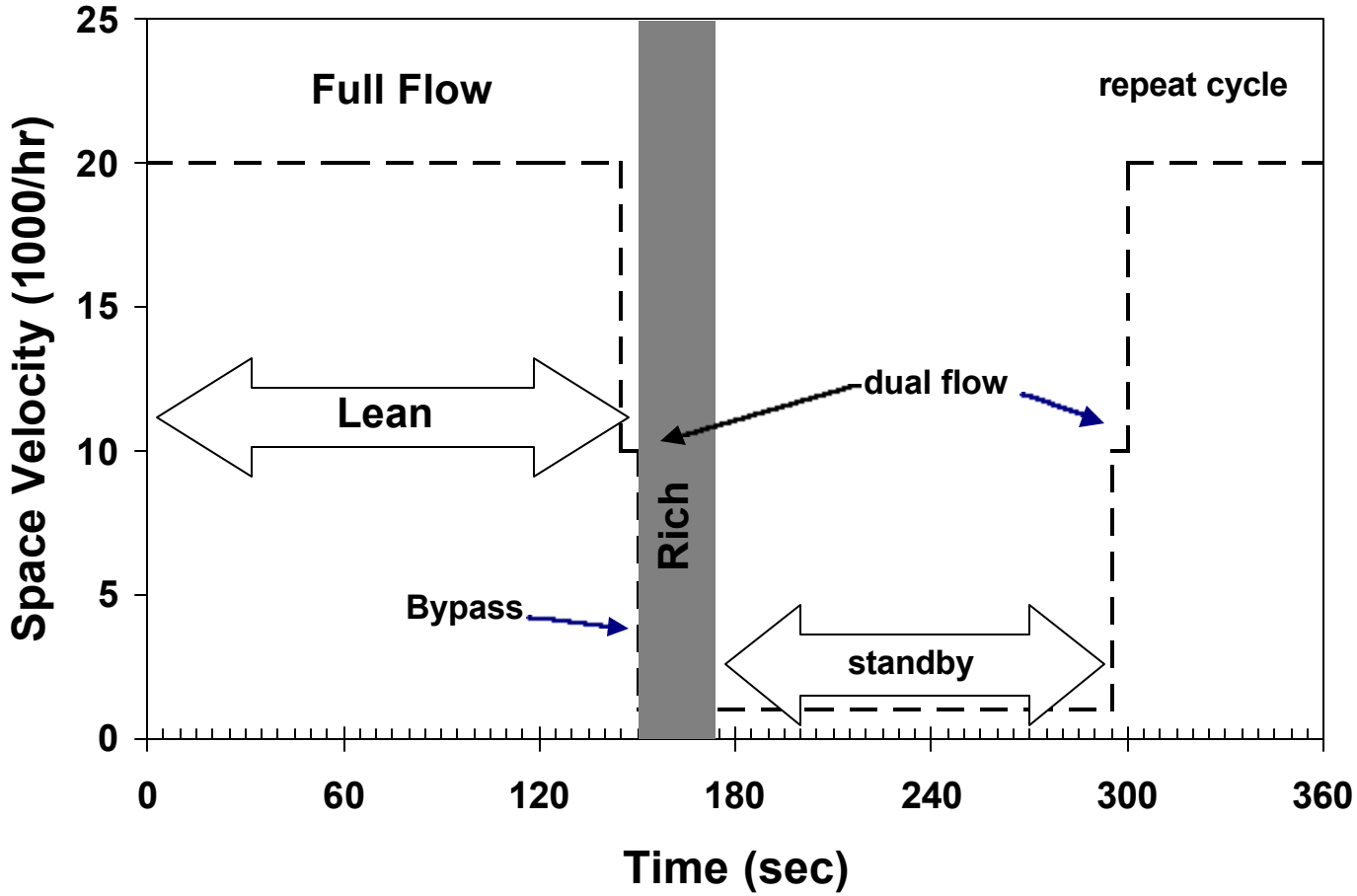
- Engine: Cummins 4B3.9T in gen-set @ 1800 rpm

- NOx Adsorber Catalyst: Dual path, four six-inch monoliths on active side, blanks on inactive side
- Space velocities: 20,000 hr^{-1} during full flow
  1,000 hr^{-1} during regen

- Regeneration: Air-assisted diesel fuel spray
- Regen Protocol: 5 min. cycle with 2.5 min. of full flow, switch to bypass, then 25 s of fuel for regen, switch back to full flow after total of 2 min.

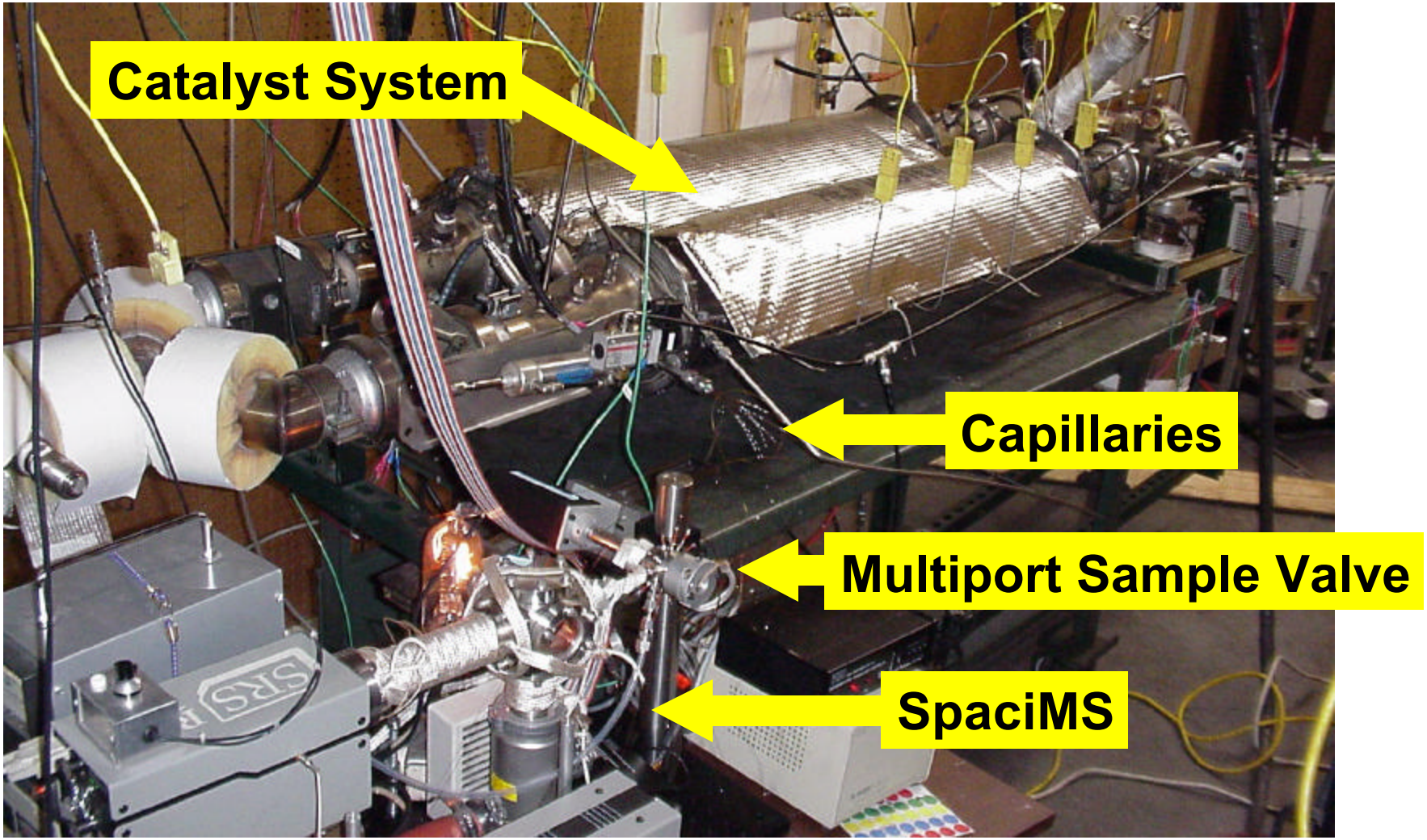
Experiments used in-pipe regeneration, dual-path catalysts, extended lean-rich strategy



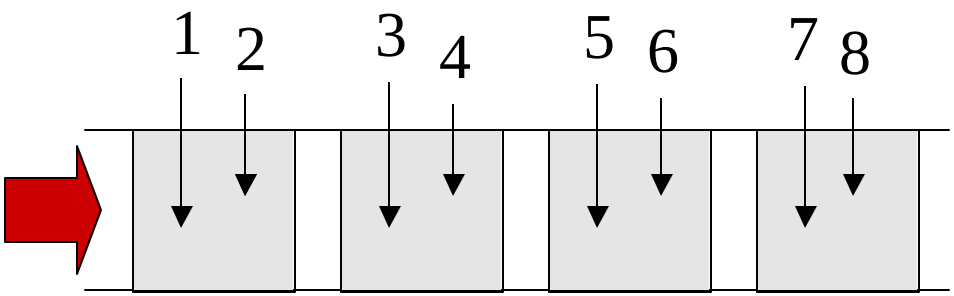


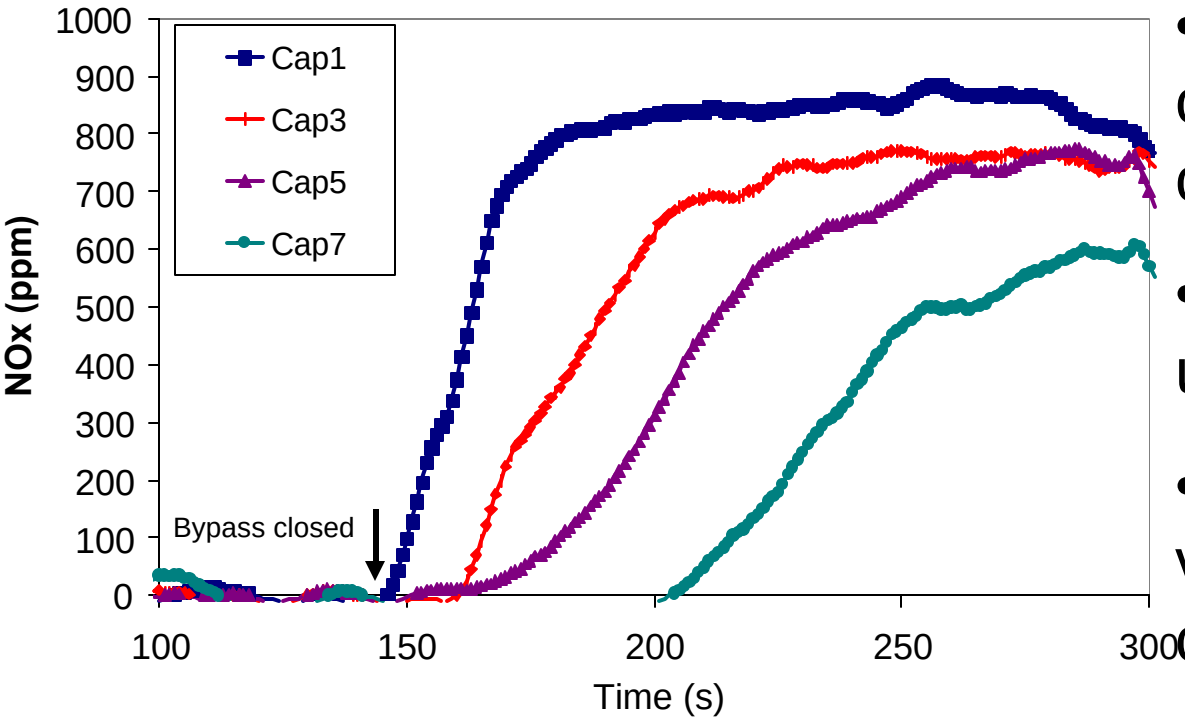
Large catalyst volume and extended lean-rich modulation times allow careful study of system transients - not intended as a prototype!

SCONOx Catalyst System and SpaciMS



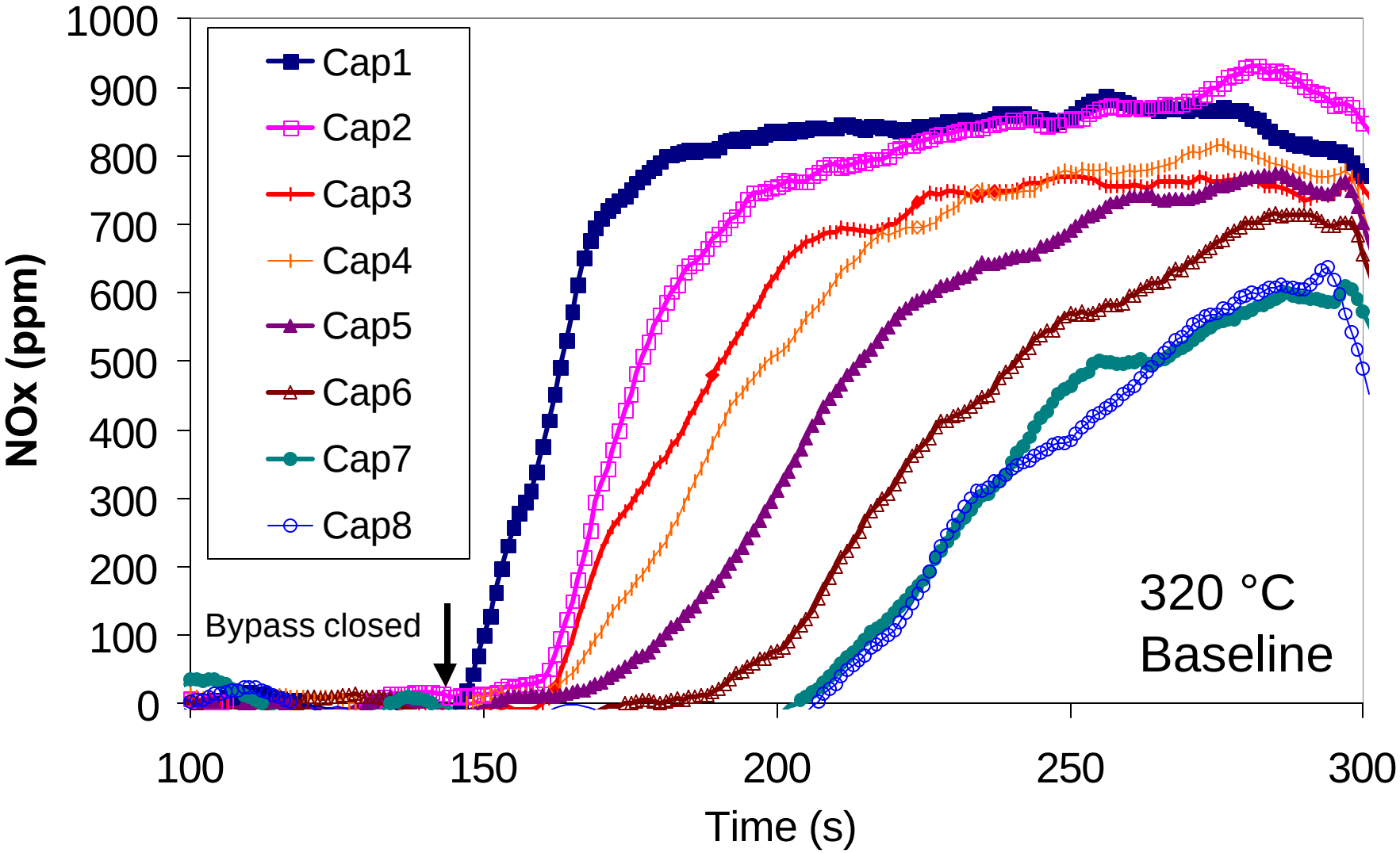
SpaciMS Resolves NOx-Loading Profile



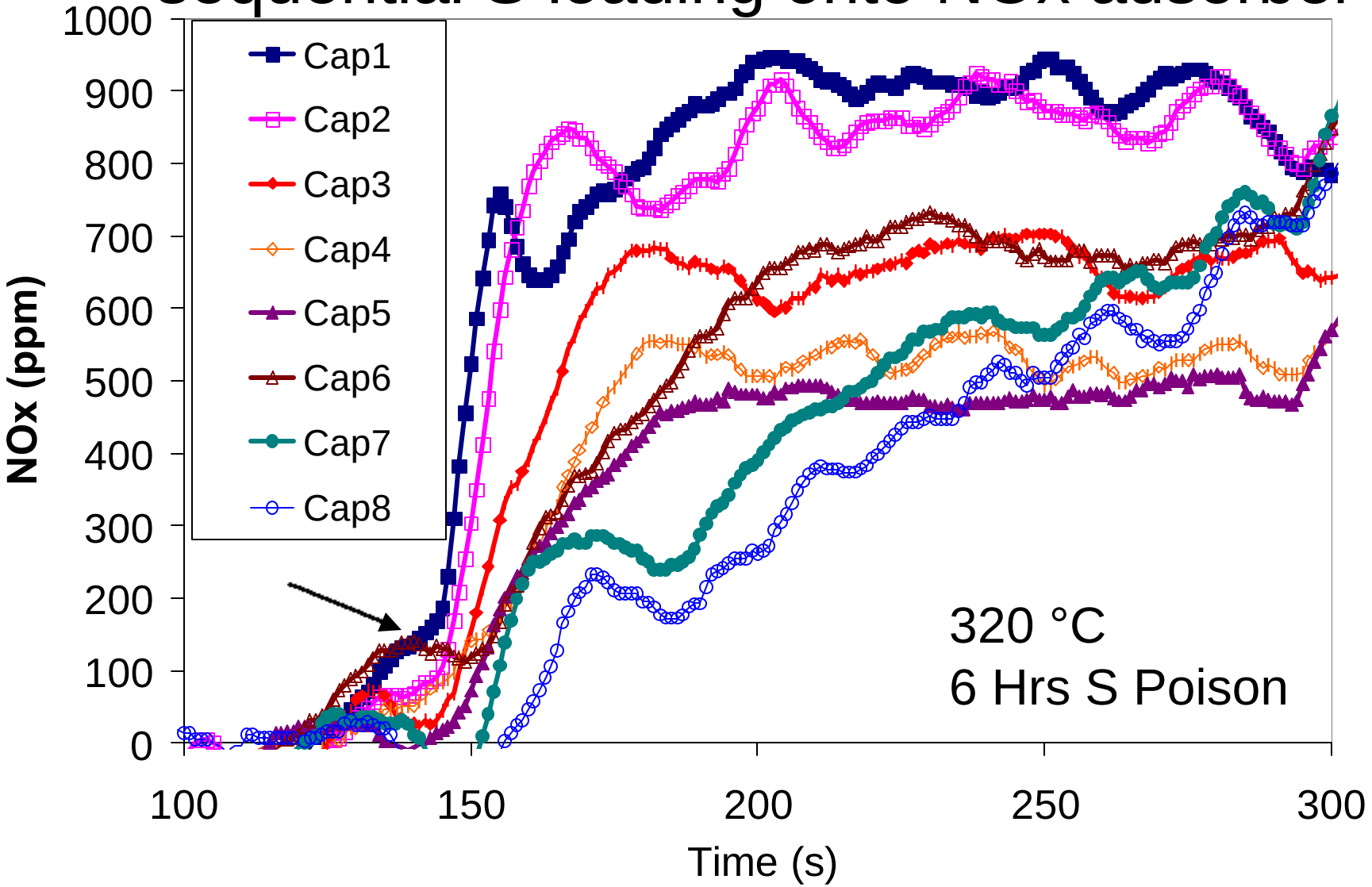


- Exhaust Sampled by 8 Capillaries Distributed Along Flow Axis
- Front third of first catalyst saturates within ca. 20 sec.
- Last catalyst is not used in initial 60 sec.
- Profiles can be used to verify and develop capacity-loading models

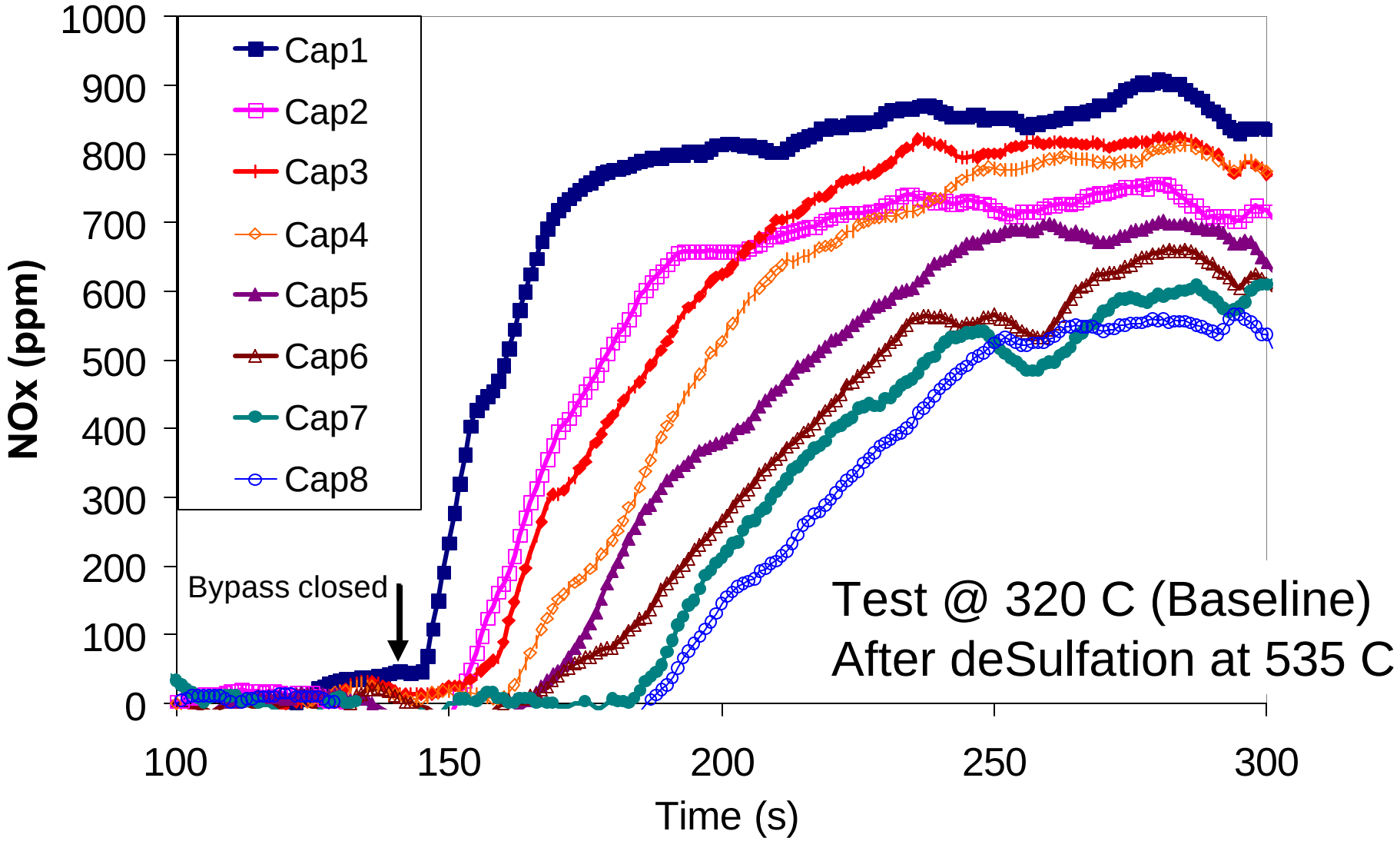
SpaciMS shows sequential loading profile



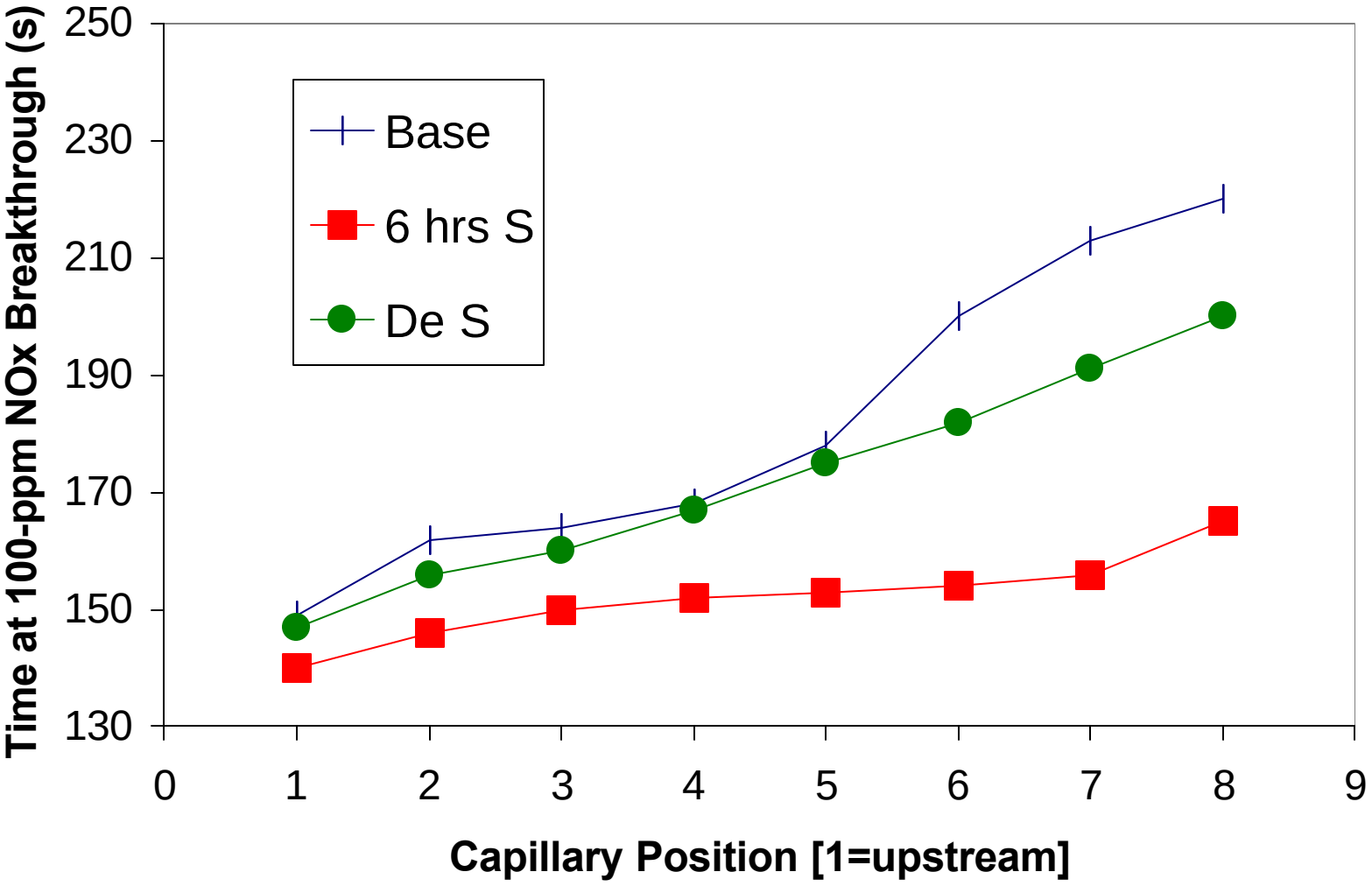
NOx profiles following S masking indicate sequential S loading onto NOx adsorber



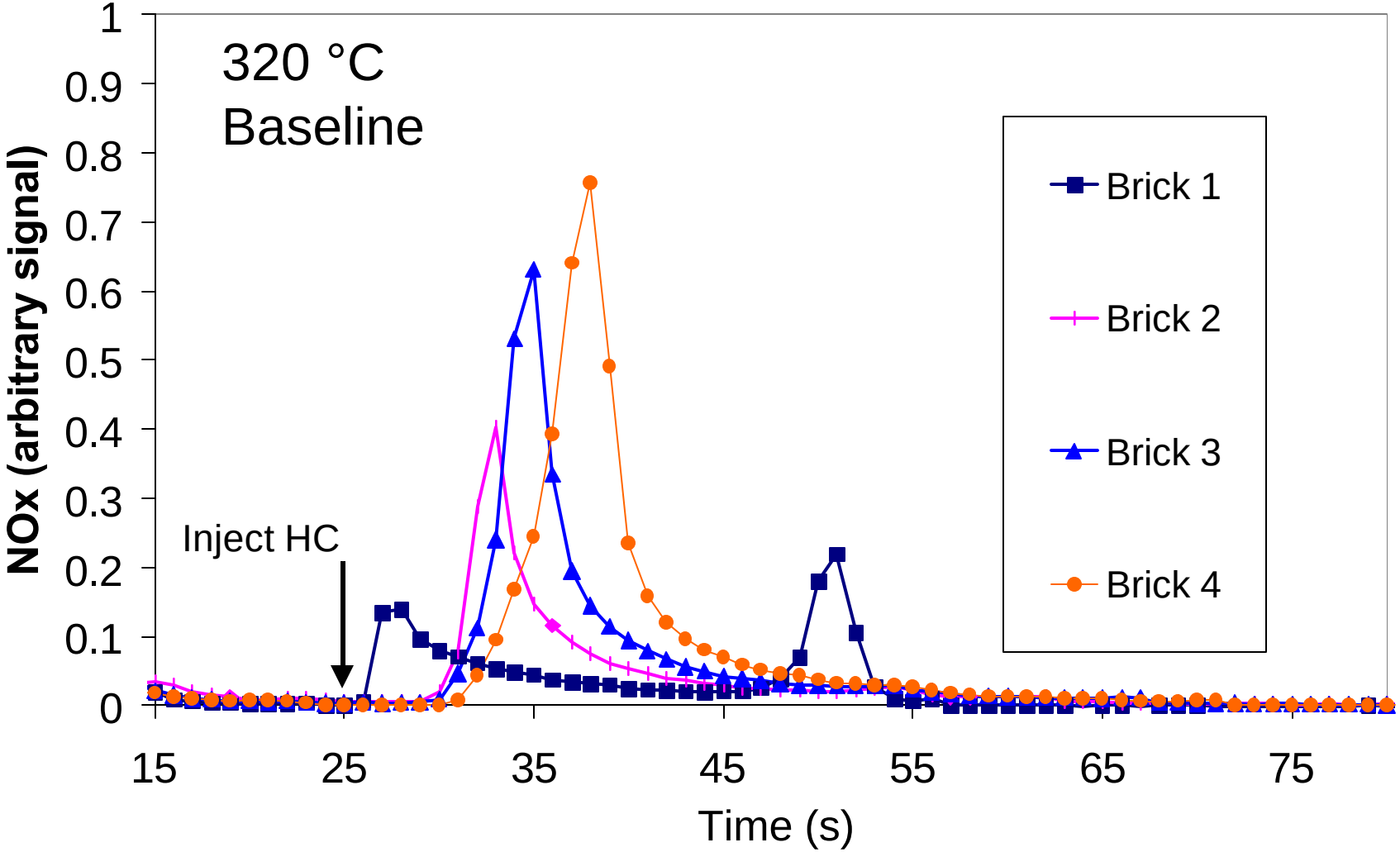
DeSulfation restores NOx activity



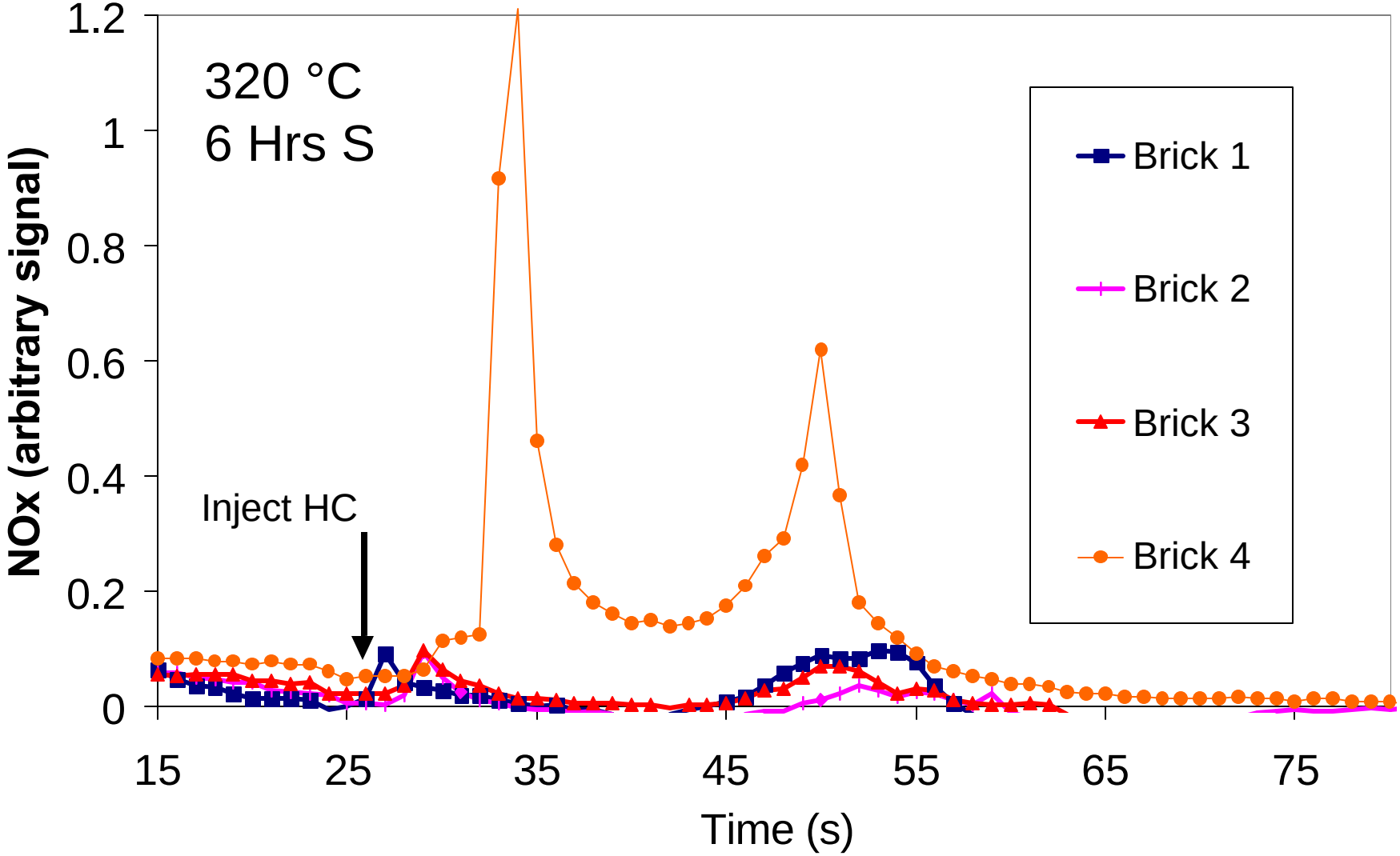
Efficiency of Downstream Catalyst Affected by deSulfation



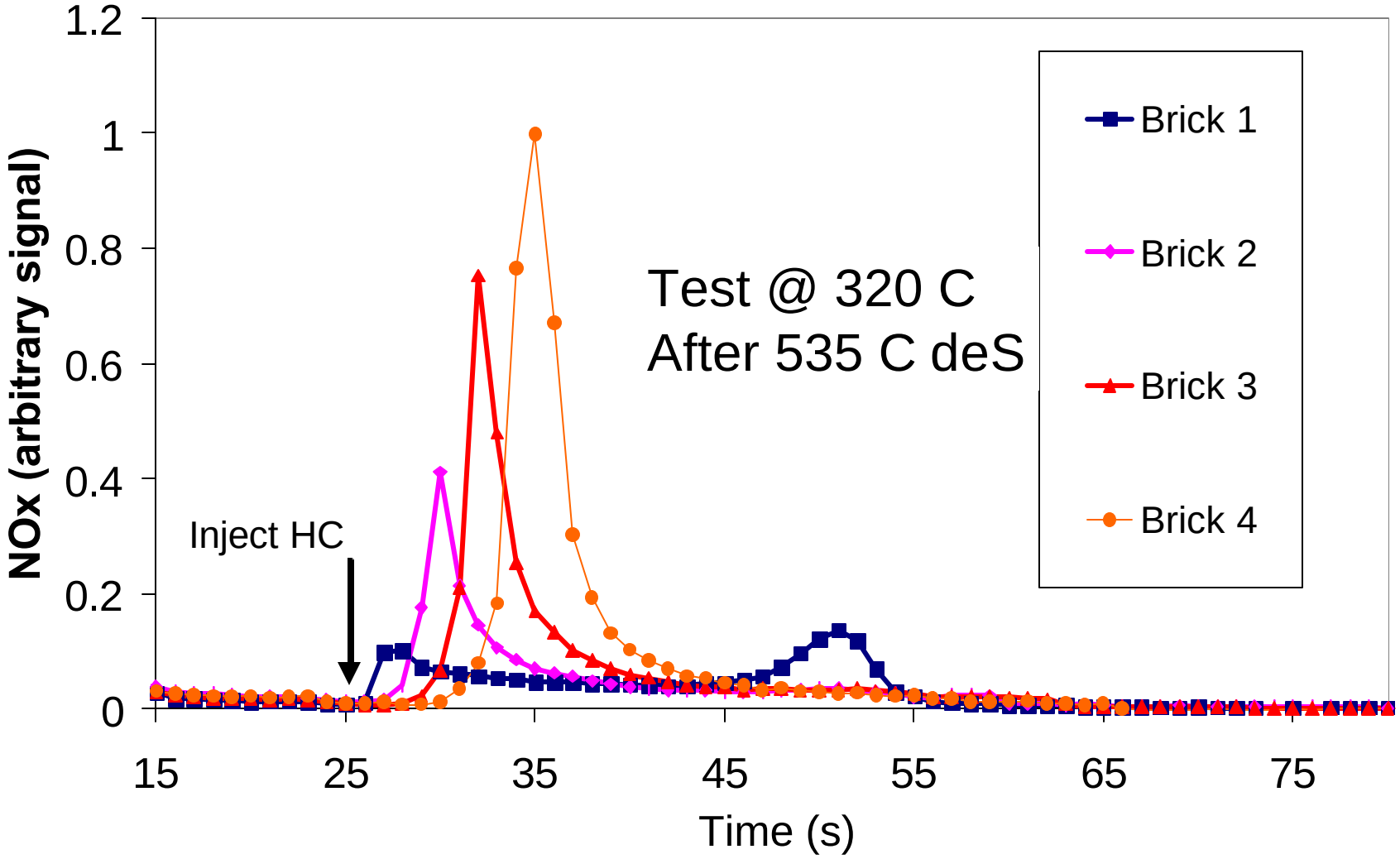
Start of regeneration produces NOx pulse



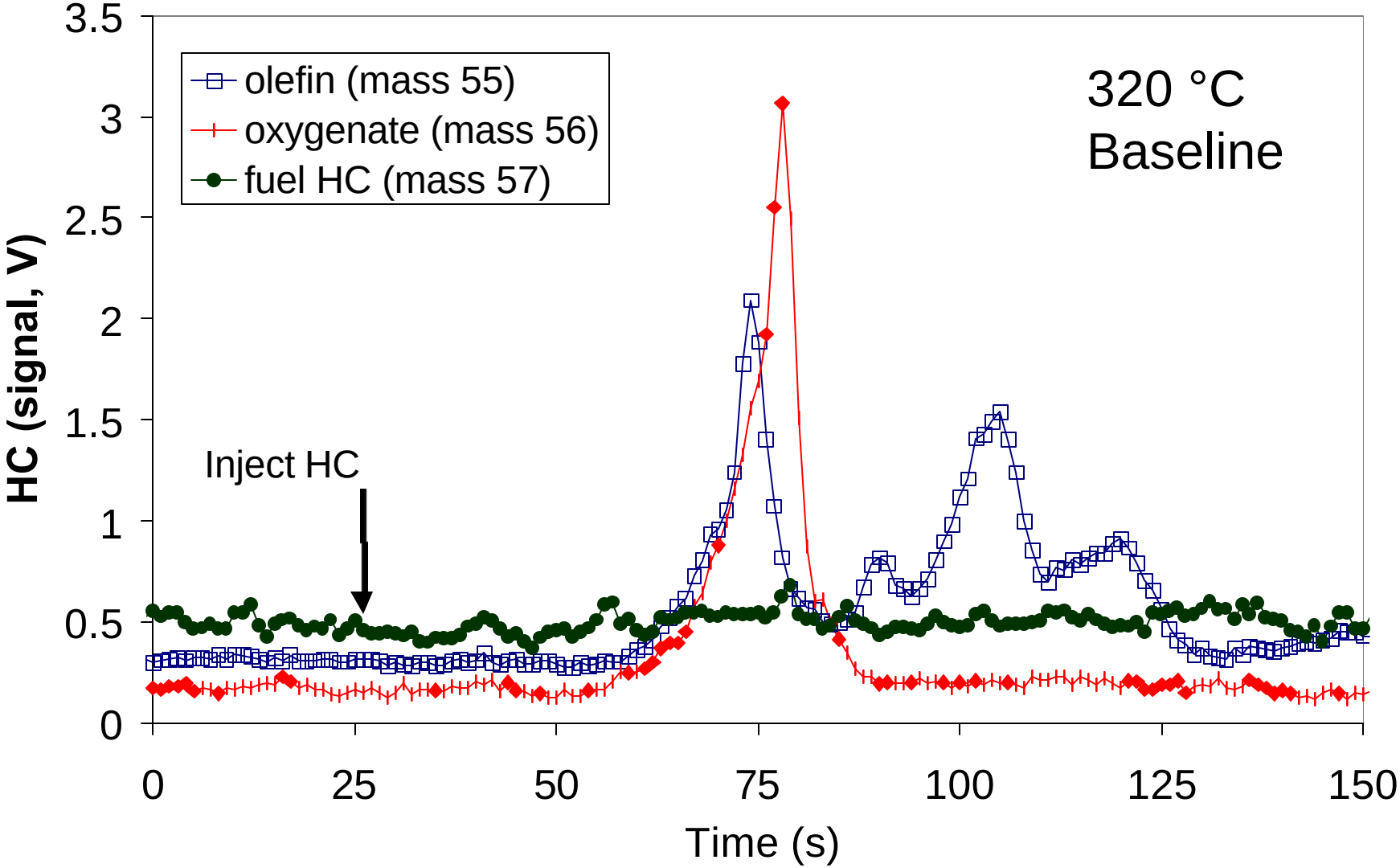
S masking affects regeneration activity



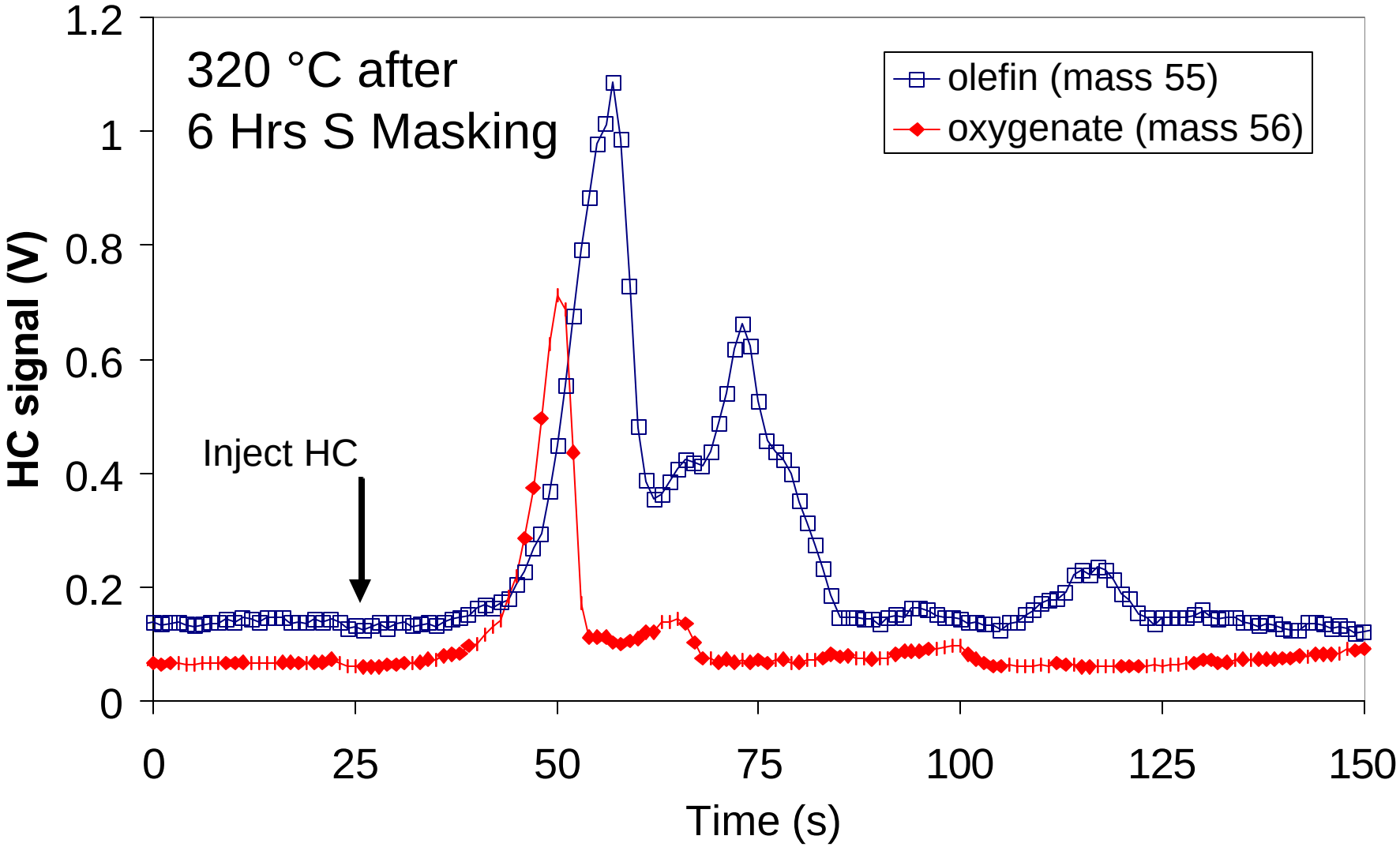
DeSulfation restores activity



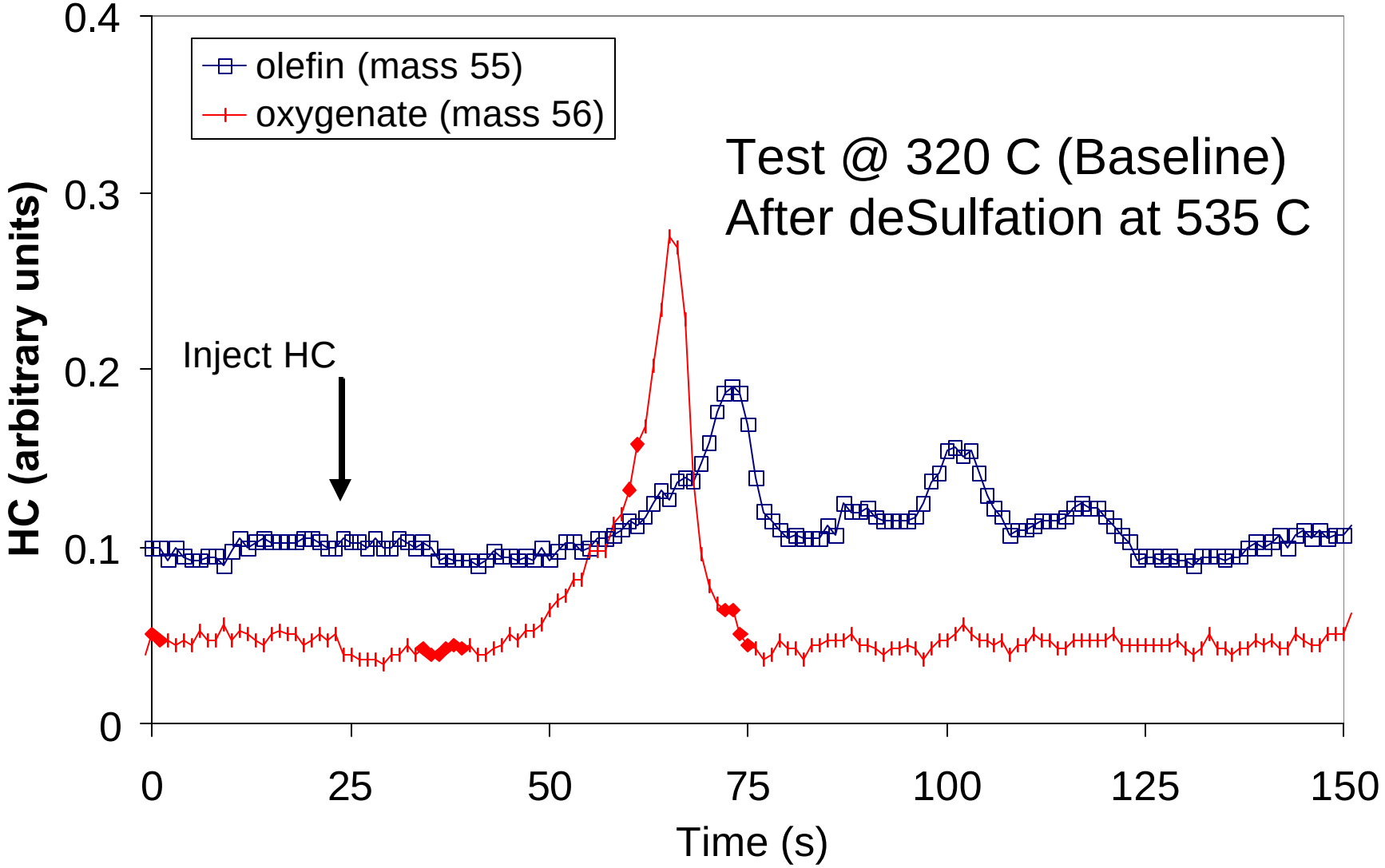
Fuel is reformed at front of Brick 1 (Capillary 1 data shown)



S decreases oxygenate formation (Brick 1)



De-sulfurization results in less HC reforming in Brick 1



Summary

- SpaciMS provides details of NOx adsorption and desorption
  - adsorption profiles
  - NOx pulses during regen and subsequent reduction
  - species dynamics for understanding HC role
- S masking observed to deactivate units sequentially
- DeSulfation returns NOx adsorber activity but may alter HC reforming
- SpaciMS data ideal for catalyst modeling