Application of Various Flow-Reactor Capabilities to the Aftertreatment Research

2nd CLEERS Workshop

October 16-17, Detroit (MI)

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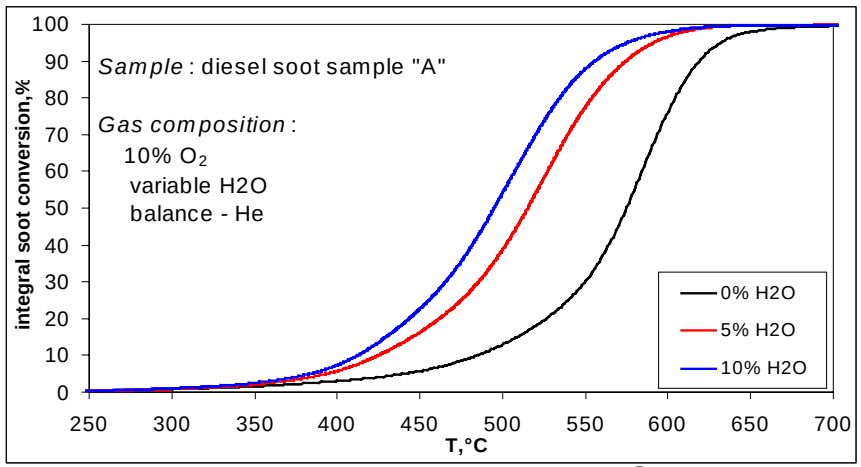
Flow-Reaction Systems

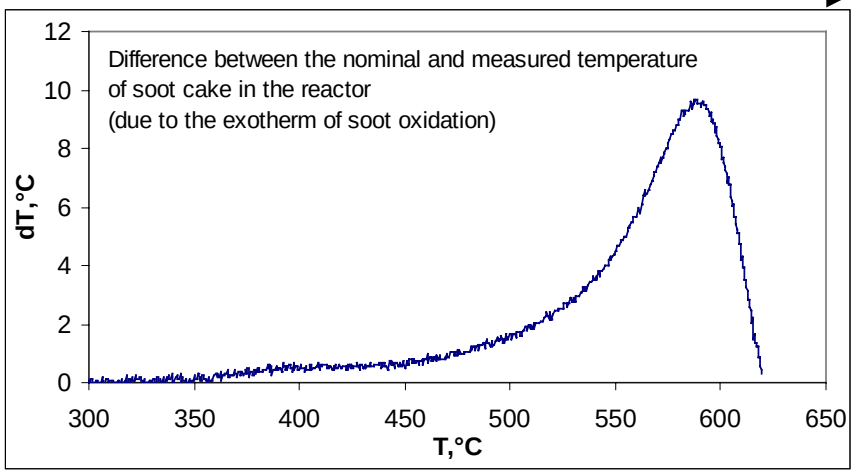
Support to the Modeling:

- identify major elementary steps vs. conditions
- determine related quantitative parameters

Common features of the reaction systems:

- **Independent** control of the parameters
  - Example: Effect of H_2O on soot oxidation rate.





- **Accurate** control of the parameters
  - *gas composition* and *temperature* measurements.

Different Reaction Systems

Adapting to the application:

- **Analytical capabilities:**
  - Steady-state vs. fast transient

- **Material balance:**
  - N_2 balance capabilities

Chemistry vs. Engineering:

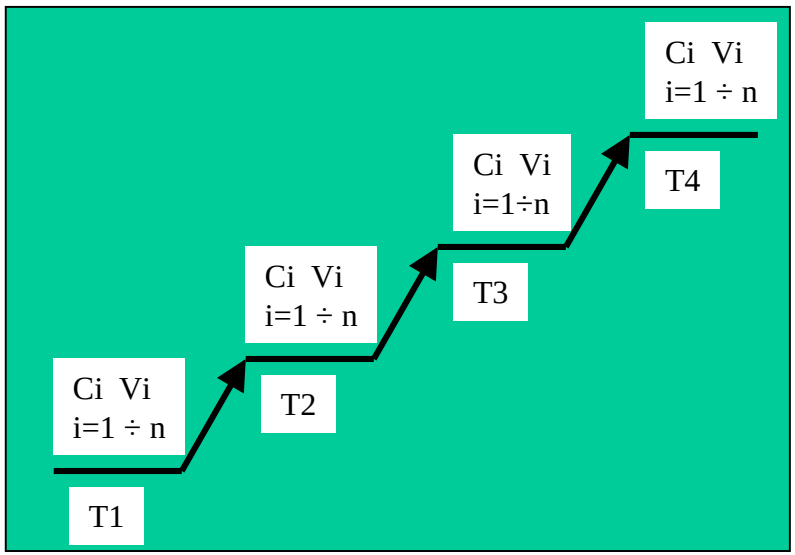
- **Scale (sample type):**
  - “Micro”- and “Pilot”- reaction systems

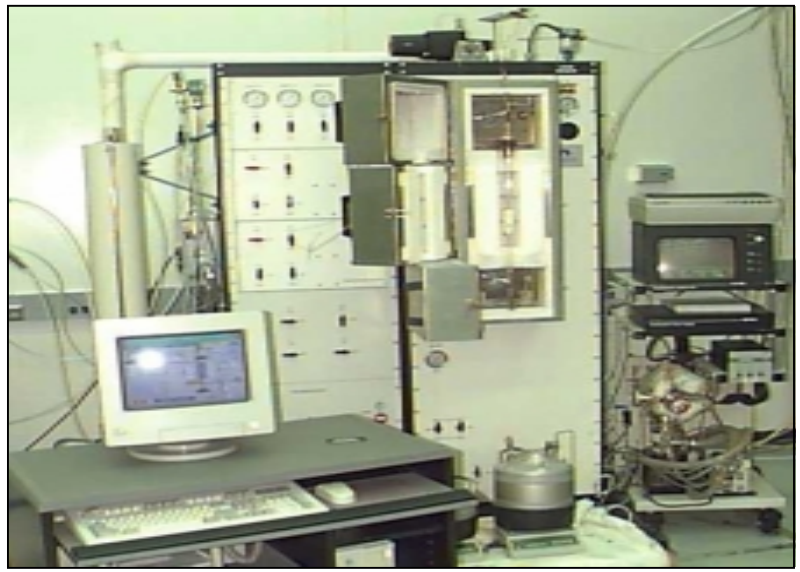
I. Analytical capabilities:

A. Steady-State:

Examples of possible applications:

- Lean NOx catalysis
- Urea-SCR
- SOx traps





*The **AMI-2000** reaction system at Cummins*

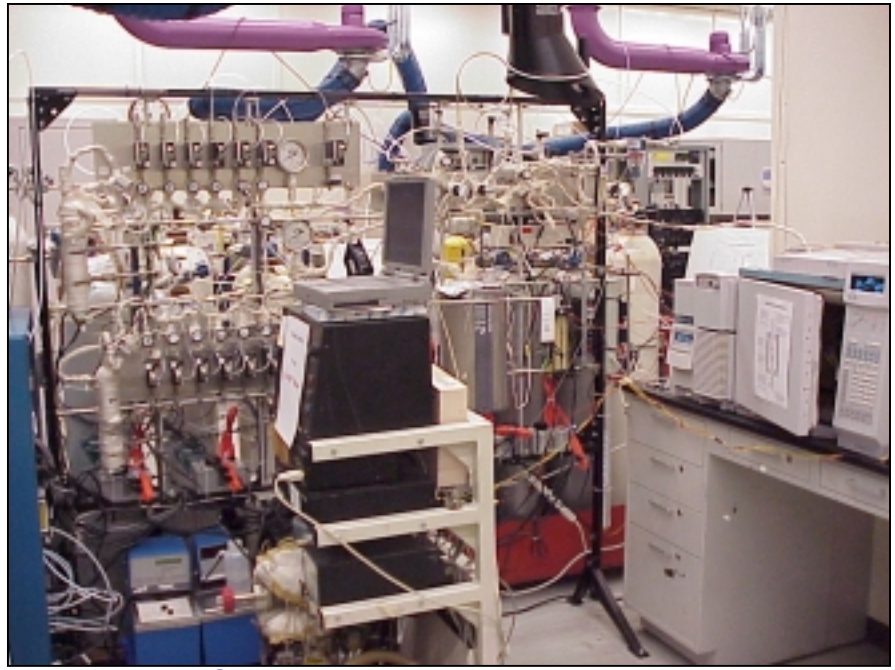
Current application: steady state studies of **sulfur trap** catalytic kinetics, mass transfer, catalyst aging, and regeneration processes

I. Analytical capabilities:

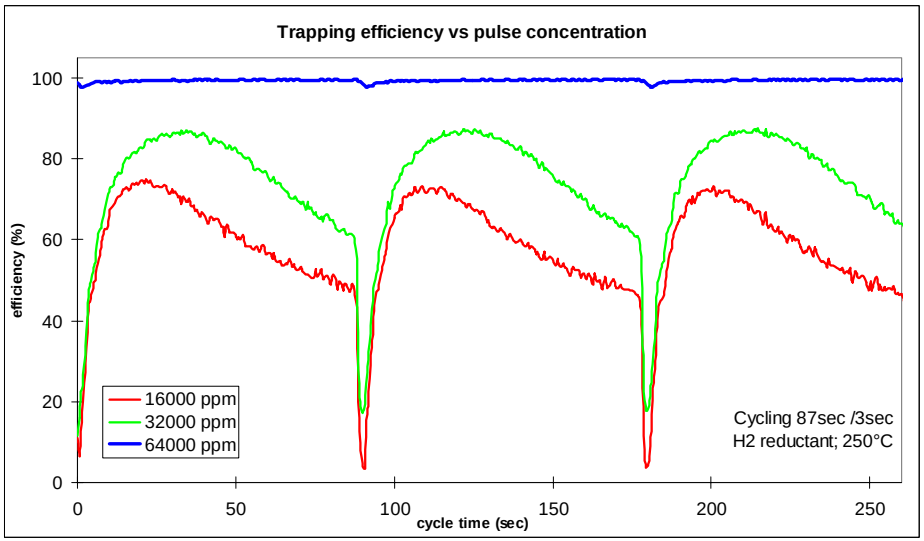
B. Fast-Response:

Example of possible application:

- NOx adsorbers
- Also, provides advantages for other studies (e.g. soot combustion)



*The **fast-response Micro-reaction system** recently created at Cummins*



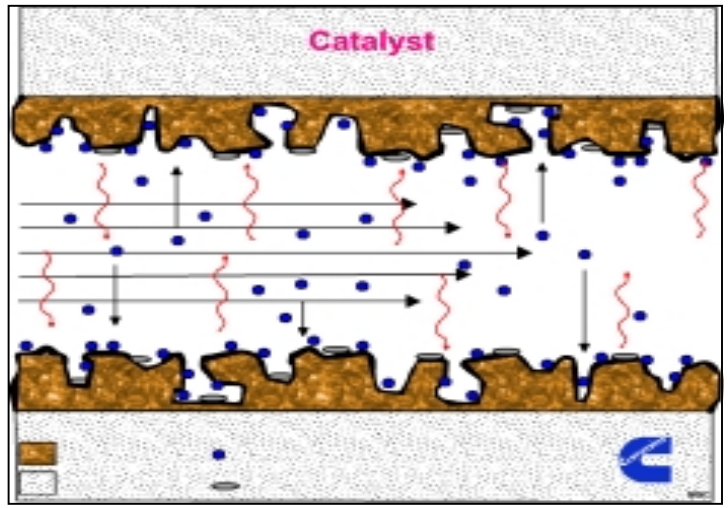
Example: NO_x adsorber regeneration data, obtained by **Shell/Equilon** using their reaction system

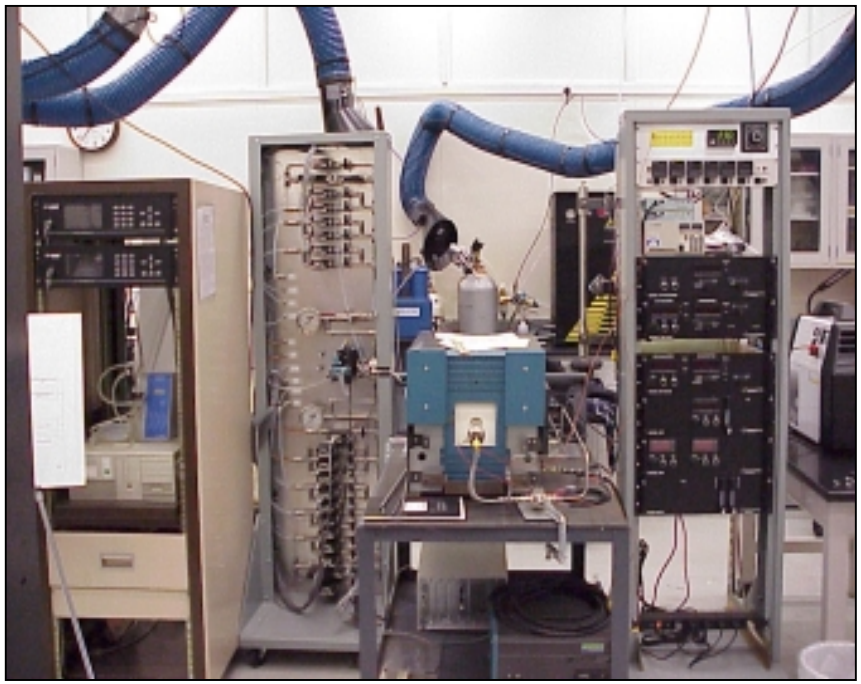
II. Scale

A. “Micro”-reaction systems:

Focus: chemical kinetics

Samples:powder (or a single channel of monolith)





B. “Pilot”-reaction systems:

Focus: chemical kinetics + heat and mass transfer effects

Samples: monolith cores

*The **fast-response Pilot-reaction system** created at Cummins*

III. Material balancing capabilities

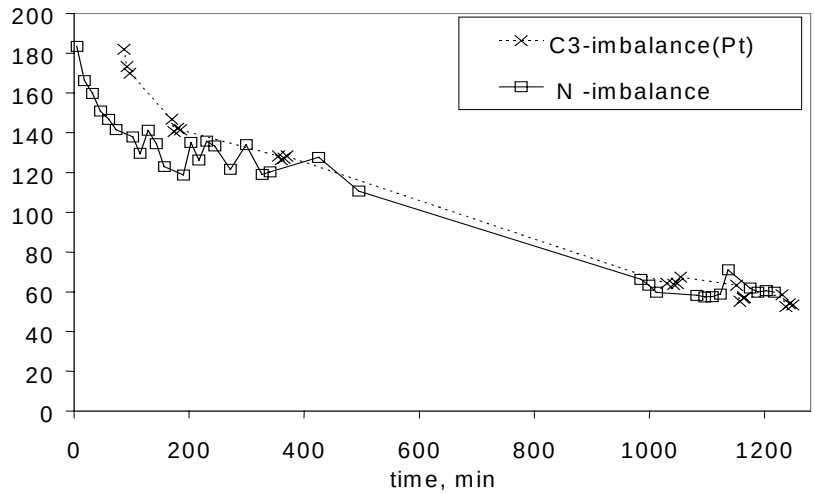
Nitrogen balance:

$$\frac{(NO_{x(out)} + N_{2(produced)} + N_2O_{(produced)} + \ldots) + NO_{x(\text{“stored”})}}{NO_{x\,(in)}}$$

- N_2 could not be used as a carrier gas (He, Ar, etc.)
- Heat- and mass-transfer may be affected by the nature the carrier gas focus on the “micro” systems (kinetics)
- Capabilities: Micro-reaction system at Cummins is equipped for N-balance studies.

Example[1]:

Data on NOx imbalance vs. time-on-stream for plasma-assisted NOx catalysis revealed significant storage of NOx (might have been wrongfully interpreted as NOx abatement otherwise).



[1] **G.B. Fisher, C.L. DiMaggio, A.Yezerets, M.C. Kung, H. H. Kung, S.Baskaran, J.Frye, M.R.Smith, D.R.Herling W.J. LaBarge and J.Y.Yan. " *Mechanistic Studies of the Catalytic Chemistry of NOx in Laboratory Plasma-Catalyst Reactors*". SAE paper 2000-01-2965.**

Conclusions

- Flow reaction systems represent essential tool for developing knowledge required for ***predictive*** models.
- Different reaction capabilities (sometimes physically incompatible in one system) may be required for different ***applications*** and ***levels*** of understanding.
- Advanced reaction systems developed by Cummins (and also available to us from our partners - EmeraChem, Shell/Equilon) can cover any major aftertreatment technology at various phenomenological levels.