NOx from Gaseous and Prevaporized Fuels Burned Lean-Premixed at Atmospheric Pressure in Single-Jet Stirred Reactors

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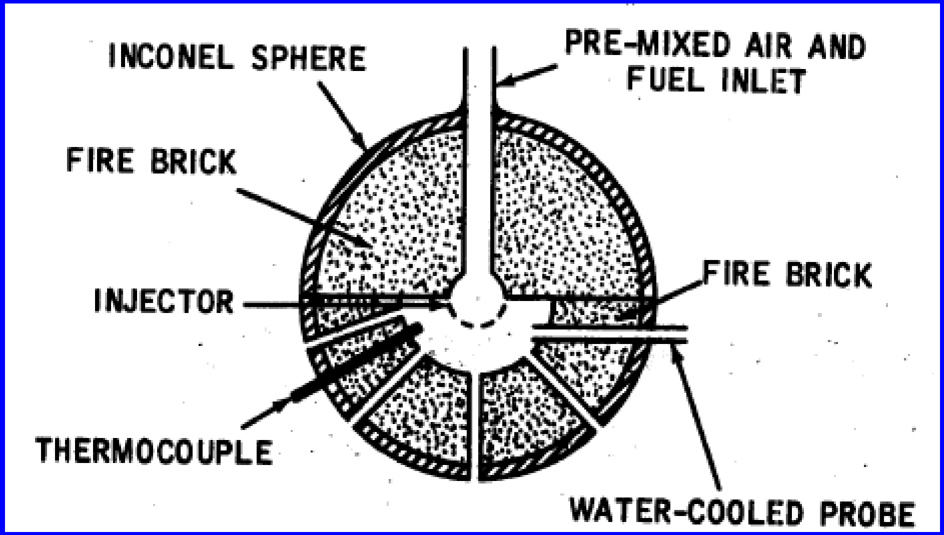
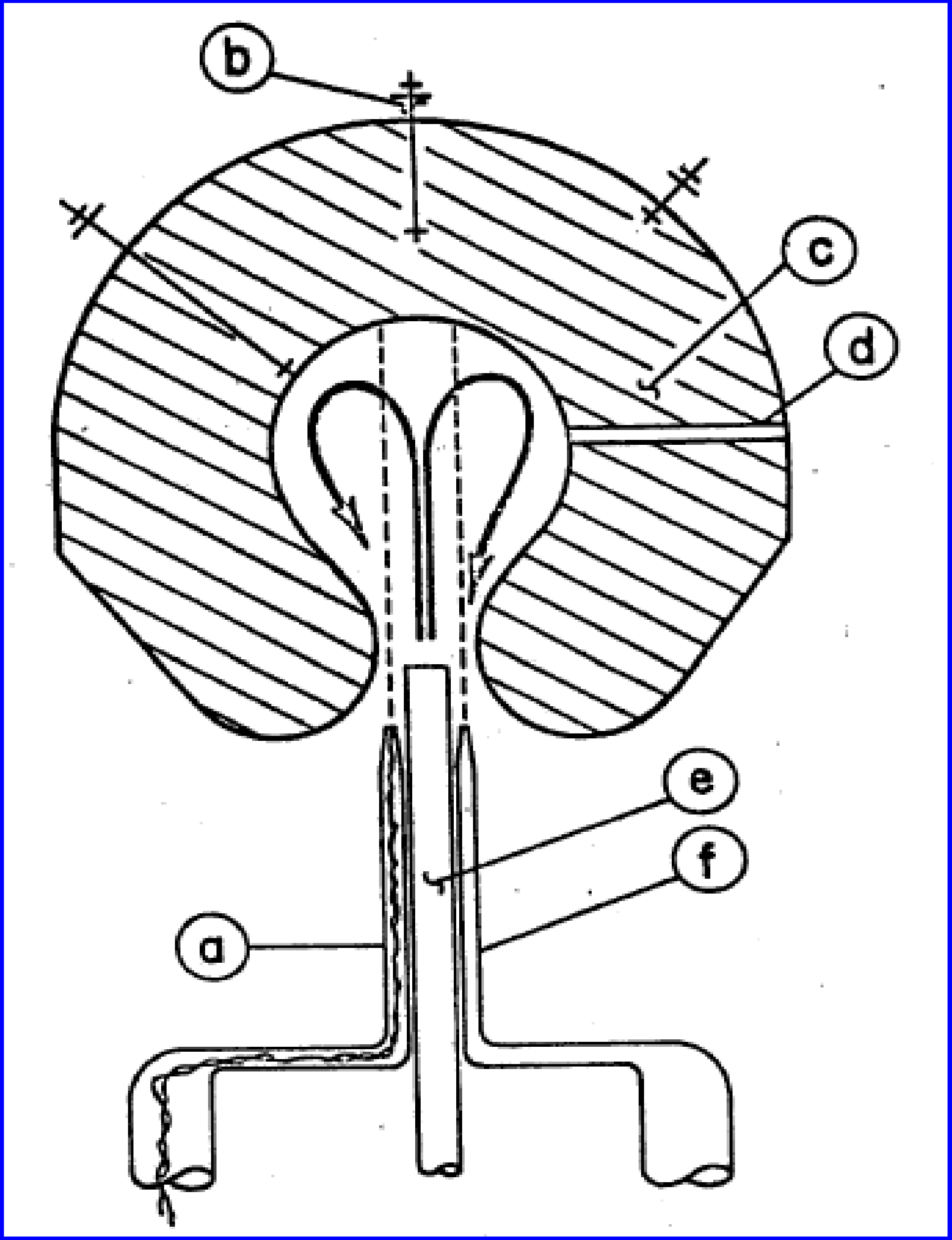
5th US Combustion Meeting
Organized by the Western States Section of the Combustion Institute
and Hosted by the University of California at San Diego
March 25-28, 2007



Modified Longwell-Weiss reactor (hemisphere rather than full sphere), Engleman, Bartok, Longwell, and Edelman (14th Combustion Symposium). Multiple (40) small (0.5 mm) jets. 19 mm reactor cavity radius. Mean residence time of 1.5-4 ms. Uniform temperature profiles within reaction zone reported. Authors state combustor "operated in a manner that approaches a well-stirred reactor." Modeled as micro-mixed PSR, requiring near-molecular homogeneity.



Single-Jet Stirred Reactor

Well-Stirred Cases:

- Nearly uniform T
- T drops with increase in loading
- Operate near blowout
- Relatively slow burning fuels

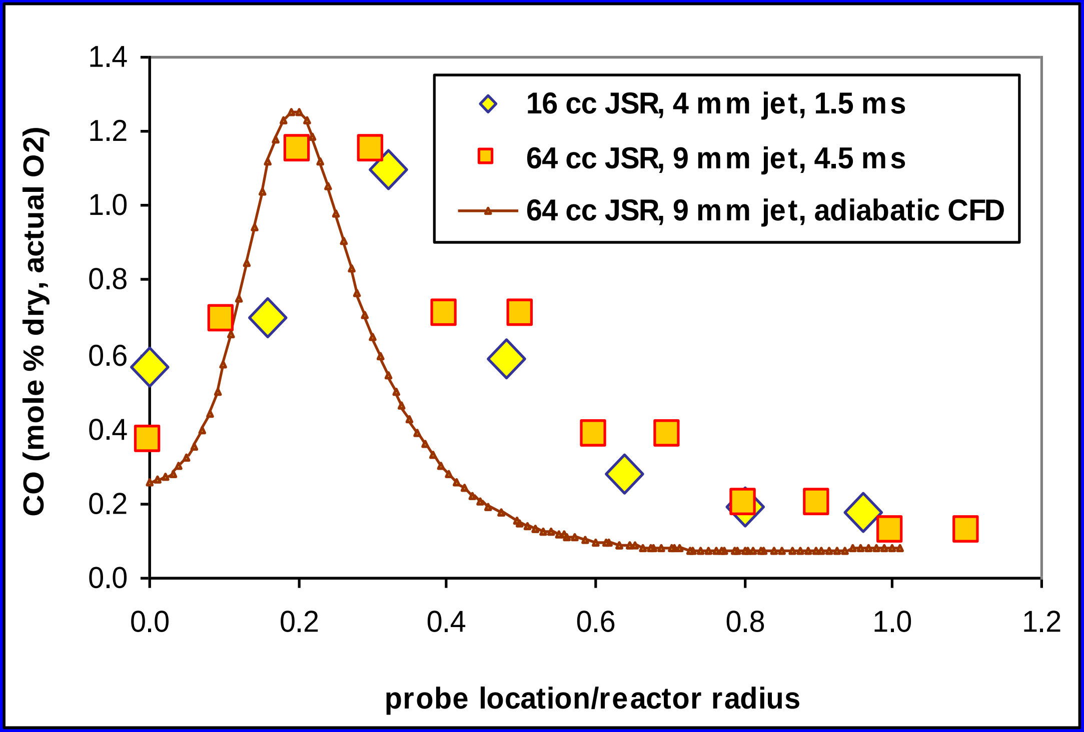
Ammonia combustion:
Pratt and Starkman
12th Combustion Symp.
Conical reactor similar to one shown.

Carbon monoxide combustion for study of nitrous oxide route to NO. (CS&T, 1974).

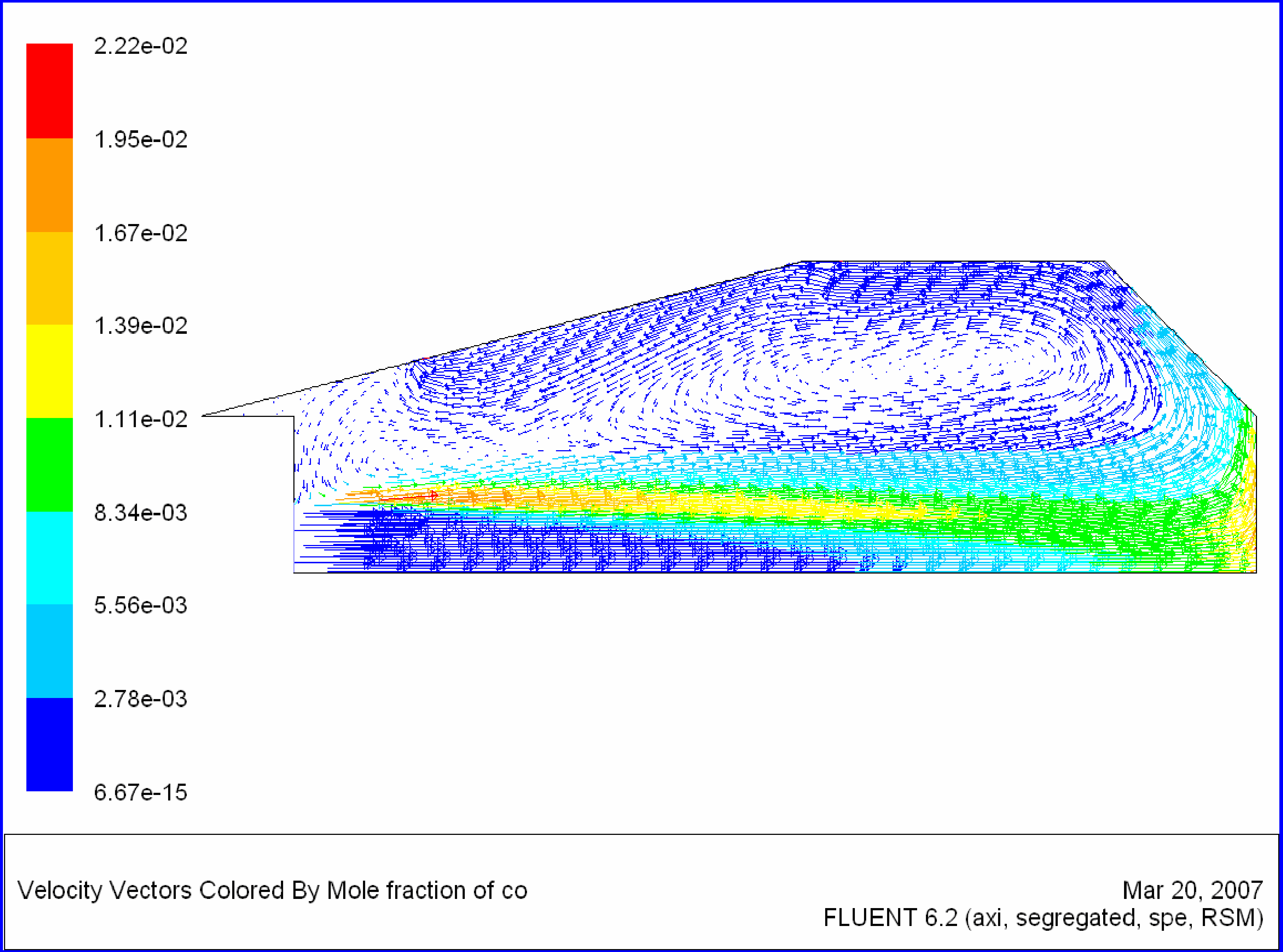
Other Well-Stirred Cases
Single-Jet Stirred Reactors

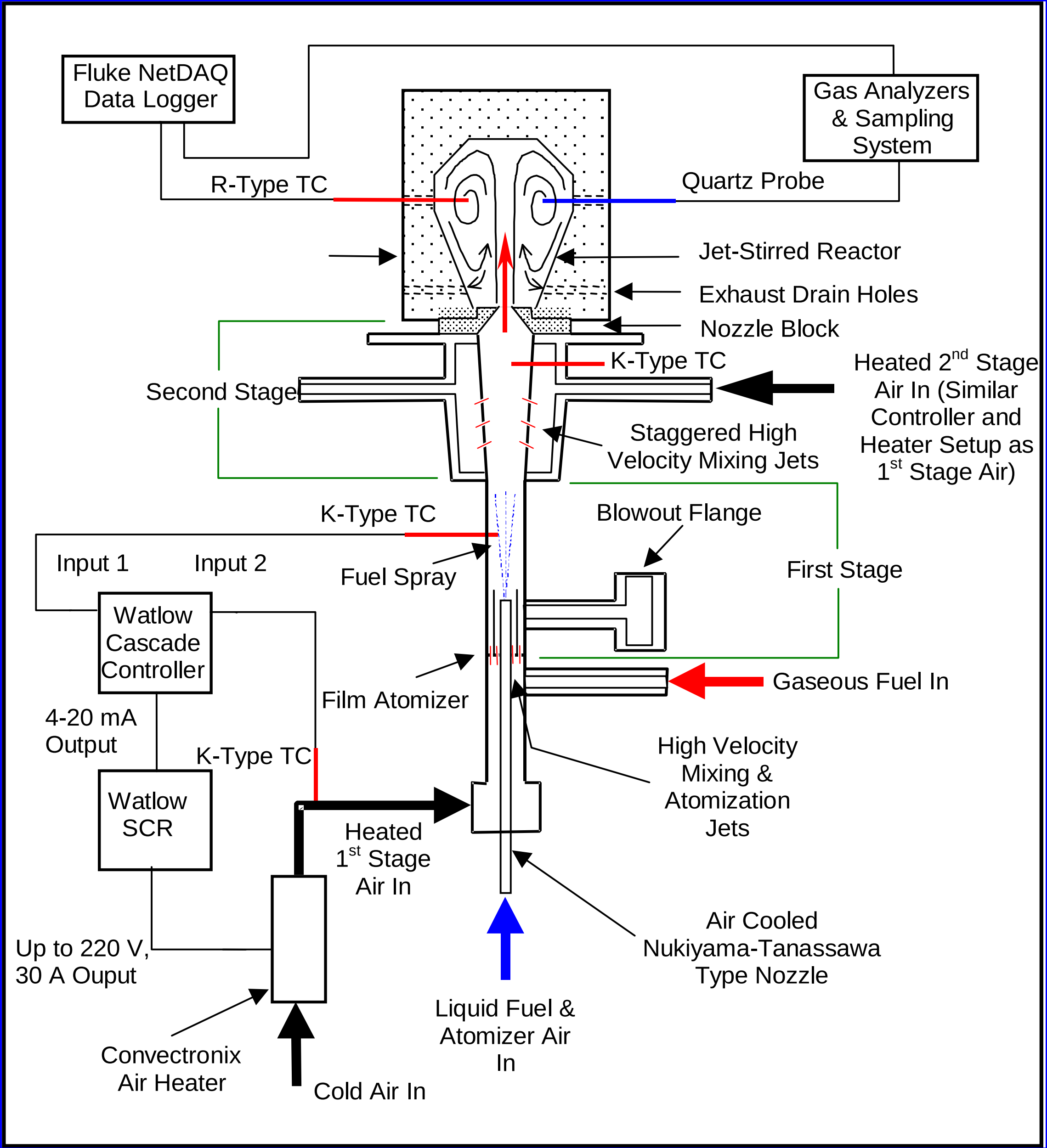
- **Jet-stirred reactor for the study of high temperature oxidation (1000-1300K).**
  - Jet of vitiated air injected with small amount of fuel or model compound.
  - Oxidation of model compounds of interest for biomass volatiles combustion: Thornton, Malte, Crittenden (21^{st} Combustion Symposium).
  - Oxidation of CO, ethylene, and n-pentane also studied.
- **Lean-premixed combustion of methane.**
  - High-pressure (6.5 atm), short mean residence time (0.5 ms), nearly adiabatic reactor: Rutar, Malte, and Kramlich (28^{th} Combustion Symposium).
  - Da < 0.15
  - NOx and CO measurements modeled as micro-mixed PSR.

Single-Jet Stirred Reactors with Flame Structure – Remainder of Talk



- Reactors used to study lean-premixed NOx and CO as a function of fuel type for similar flow velocities and temp's.
- From centerline to outer wall, flame structure shows: 1) jet with initial reaction, 2) flame zone with peak CO and NO formation rate, and 3) post-flame recirculation zone. See figure at left.
- Recirc zone: CO burnoff, nearly uniform T and NOx.
- Da ≅ 1-5, Re-turb ≅ 1200

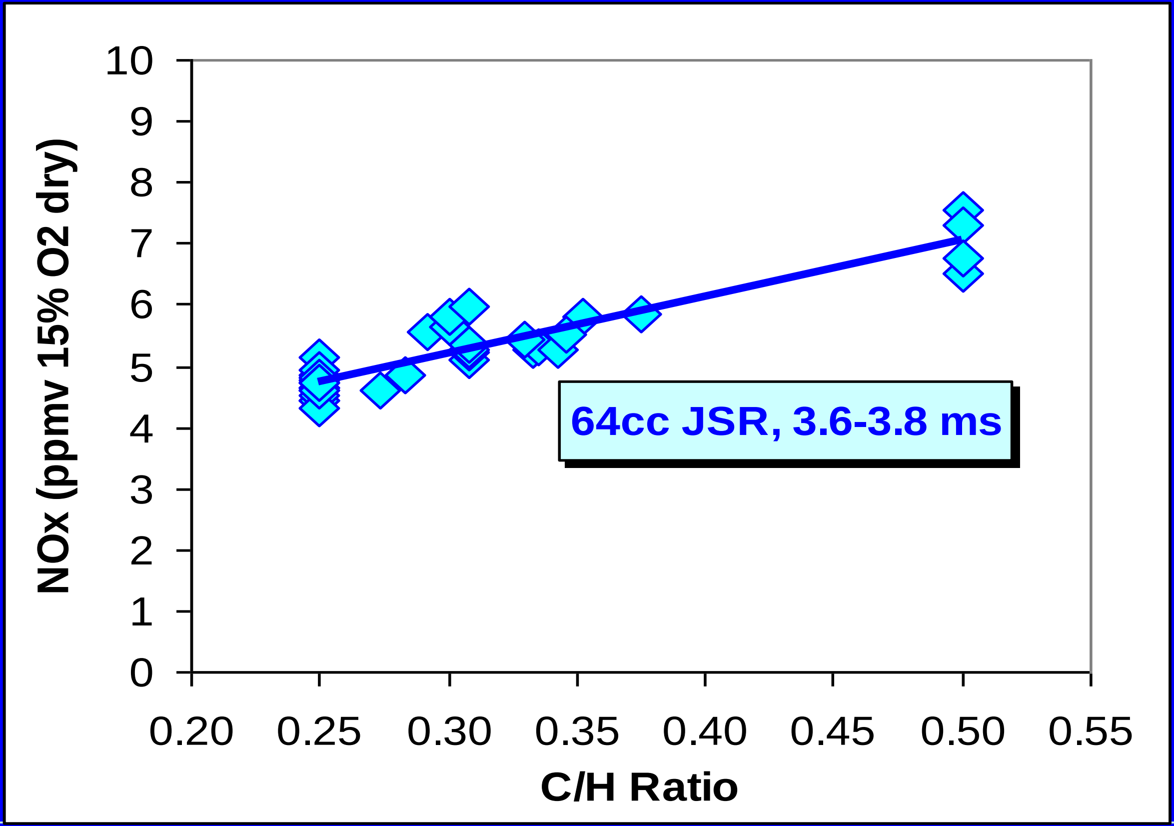

2.22e-02
1.95e-02
1.67e-02
1.39e-02
1.11e-02
8.34e-03
5.56e-03
2.78e-03
6.67e-15
Velocity Vectors Colored By Mole fraction of co
Mar 20, 2007
FLUENT 6.2 (axi, segregated, spe, RSM)



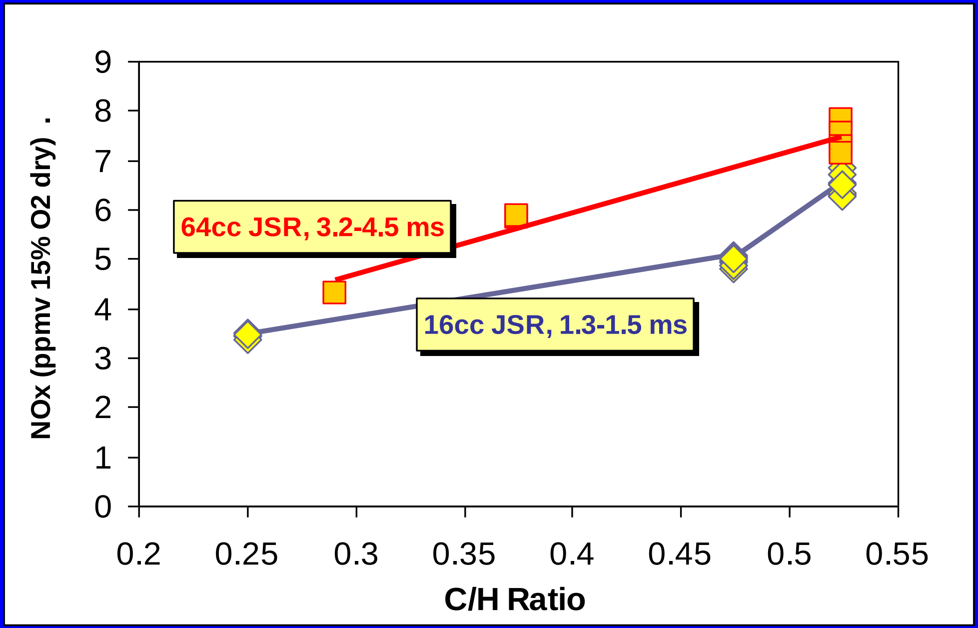
Single-Jet Stirred Reactor coupled to Staged Prevaporizer-Premixer (SPP) Injector

16 cc JSR with 4 mm nozzle

64 cc JSR with 5.6 mm nozzle



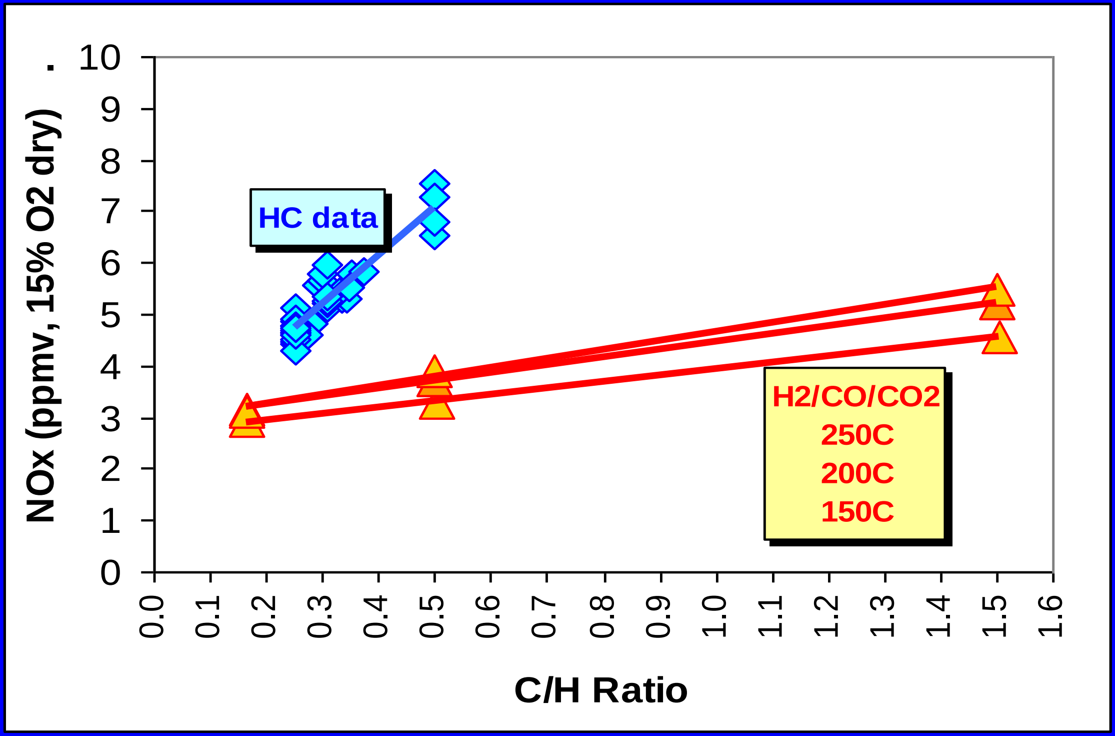
NOx versus gaseous fuel blend for C1-C4 alkanes and ethylene. 64 cc JSR with 5.6 mm nozzle. Combustion temperature is 1790 K, inlet temperature 425-575 K, nozzle jet velocity 250-300 m/s. Mean residence time is 3.7 ms. Fuel and air are premixed in the SPP. All data taken for recirculation zone. Measured NOx (and CO) are well predicted with CRN model, with all NO pathways contributing.



JSR-SPP measurements extended to liquid fuels: light naphtha at C/H 0.48, and #2 diesel at C/H 0.53. 1790 K. ~1 ppm NOx for #2 diesel is caused by FBN.

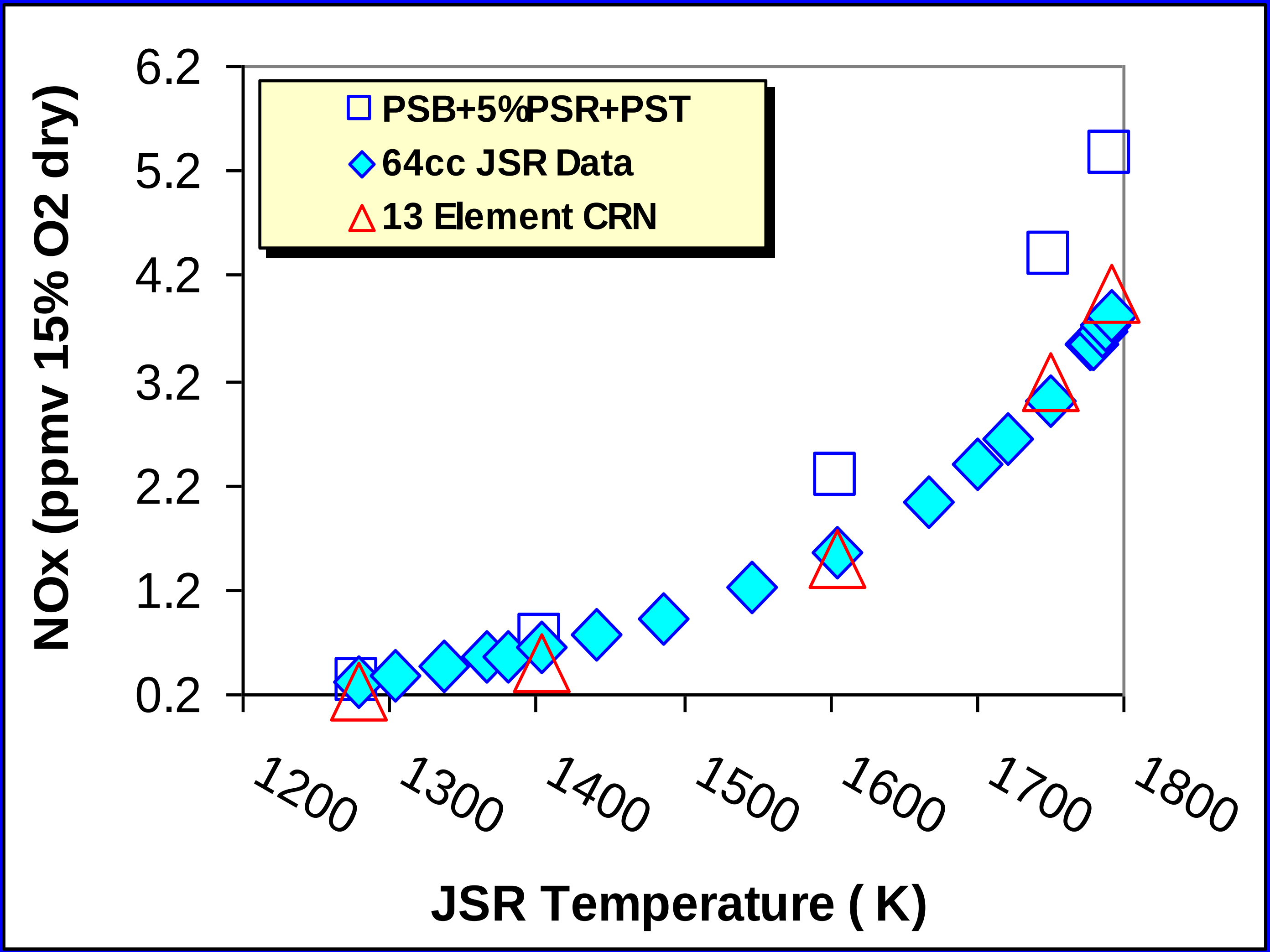
Ryan Edmonds ran the 16 cc JSR at high loading-short residence time condition, which reduced NOx formation.

Andrew Campbell Lee diagnosed outlet of SPP injector using laser scattering, and showed 1) no fuel droplets (except when fuel line vapor lock occurred), 2) good spatial uniformity of the fuel vapor-air ratio, and 3) a low ratio (0.1) of STDEV/MEAN of the time-varying Rayleigh scattering signal from the laser beam passed through the fuel vapor-air mixture.

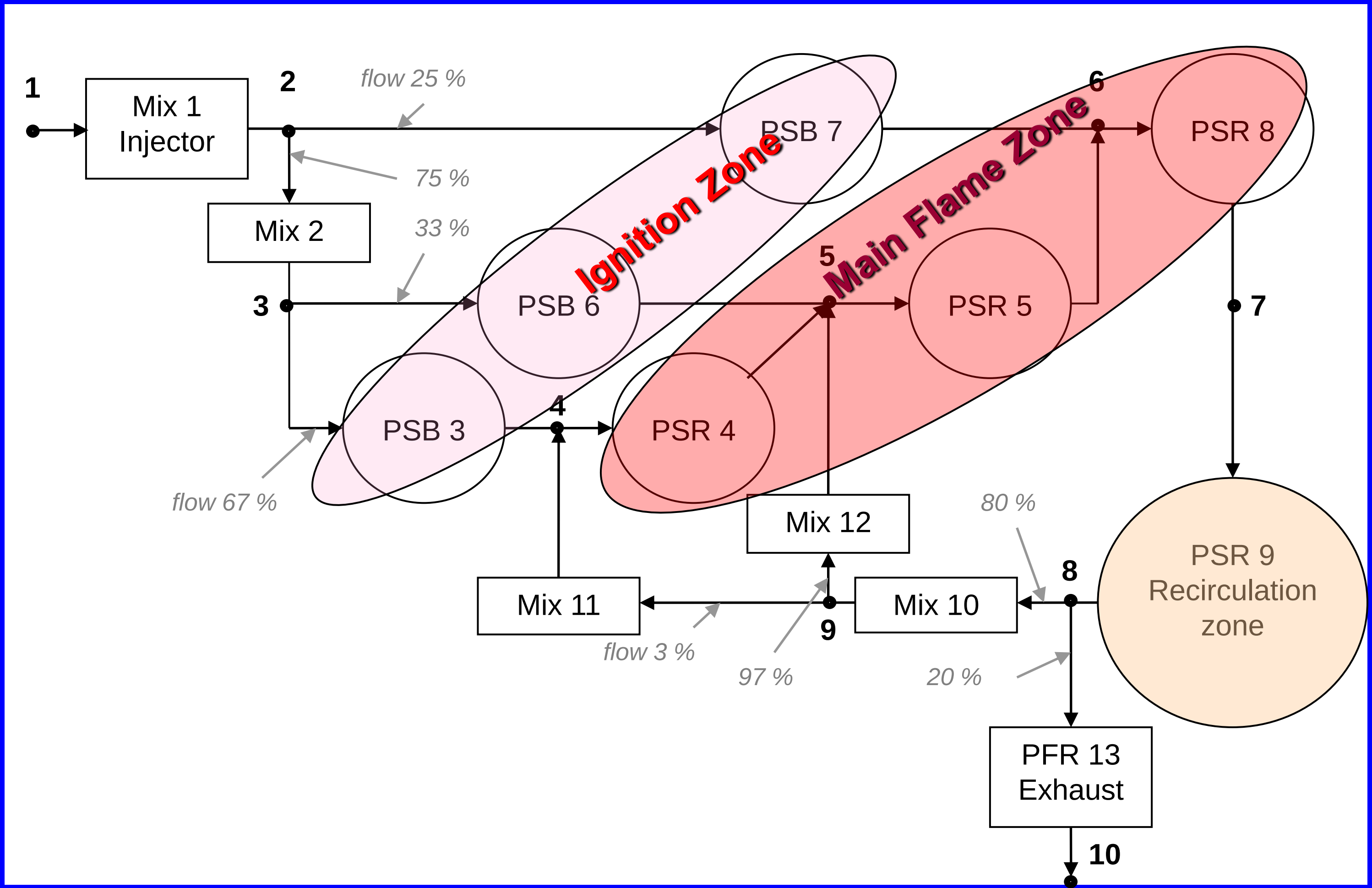


NOx as a function of fuel carbon to hydrogen ratio for $H_2/CO/CO_2$ blends. The CO_2 is 20 mole %; the C/H ratio is based on the CO/H_2 ratio. 64 cc JSR with 5.6 mm nozzle. 1790 K. Inlet temperature:150, 200, 250 C.

Hydrogen Combustion

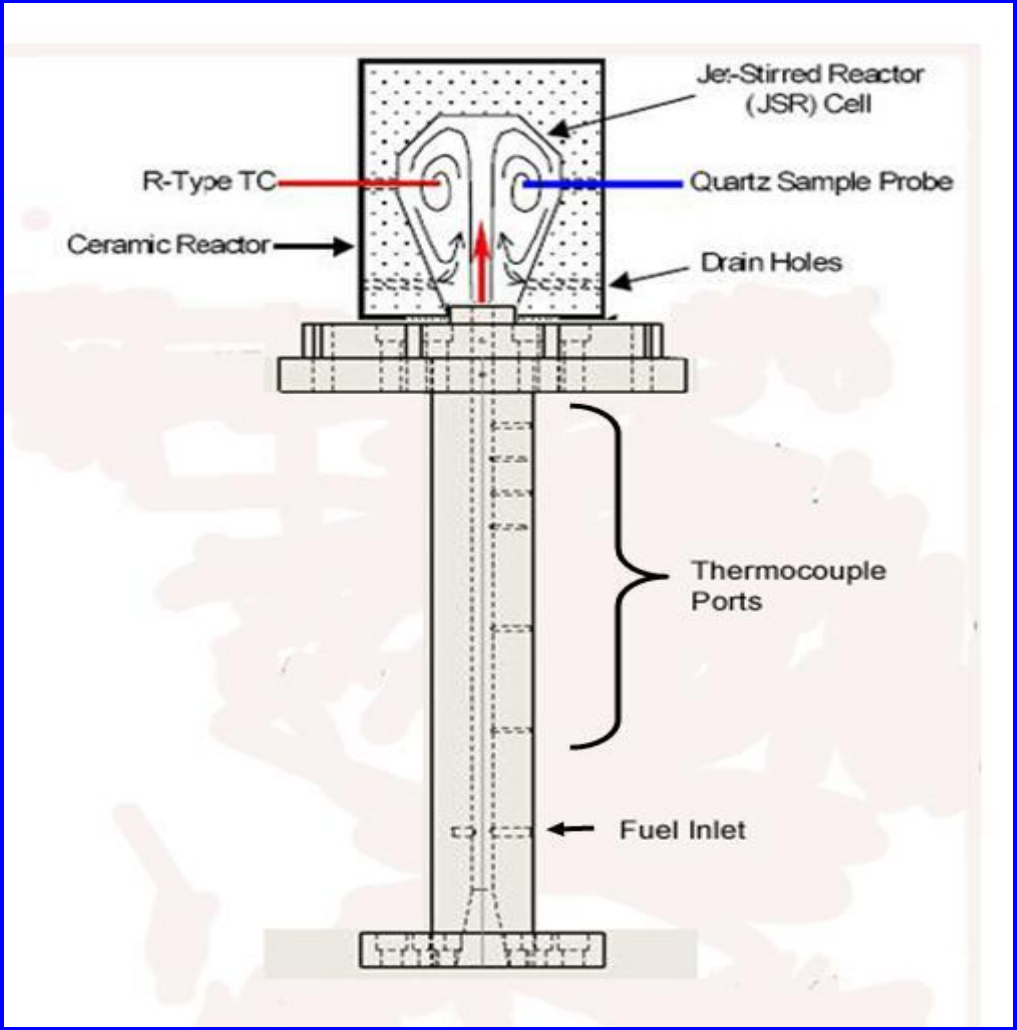


13-Element CRN for Single-Jet Stirred Reactor
(jet enters at upper left, exhaust drains at lower right)



Flame structure is represented by seven PSR reactors

Ongoing Work



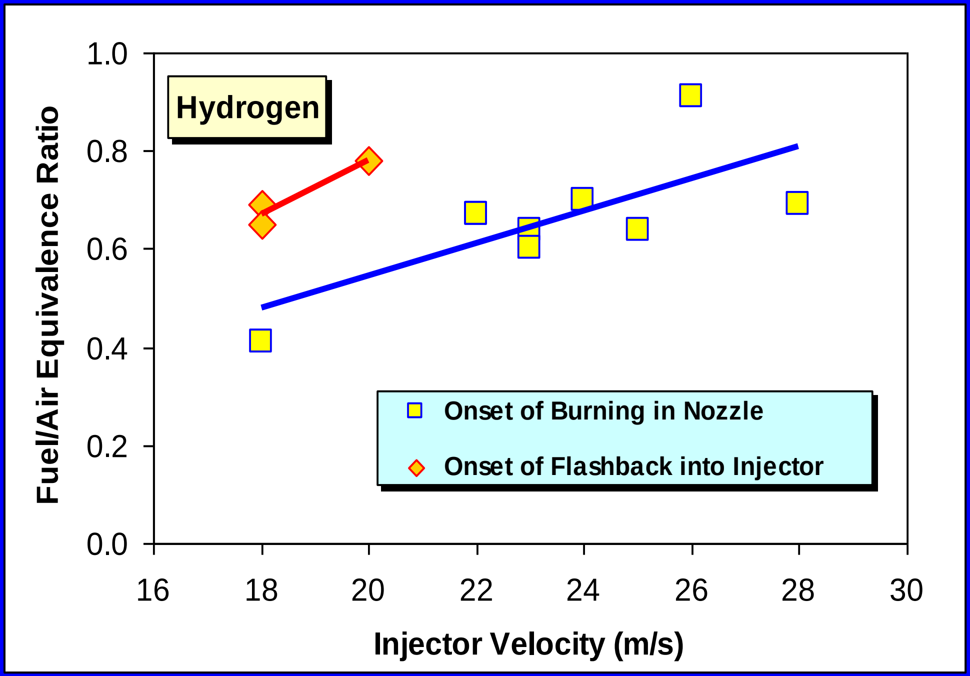
Single-Jet Stirred Reactor coupled to Tube-and-Spoke Injector

64 cc JSR, 9.0 mm tube/jet

60-80 m/s inlet velocity

3-4 ms mean residence time

Examine gaseous fuel interchangeability



With air preheat and hydrogen-containing fuels, there is a risk of flashback within the low-velocity tube-and-spoke injector. Onset of two situations plotted for H2-air, using 64 cc JSR with 6.35 mm tube: 1) burning in nozzle without propagation of flame upstream into injector, 2) flashback into injector. No air preheat used in these initial experiments. Injector velocity based on air and hydrogen flow rates at unheated inlet condition.

The End