Alternative Combustion Technology for High Hydrogen Content Fuel

Technologies proposed By SIEMENS for Flashback Mitigation

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- Micro mixing Nozzles approach
- Low Swirl Burner
- RQL combustion Technology

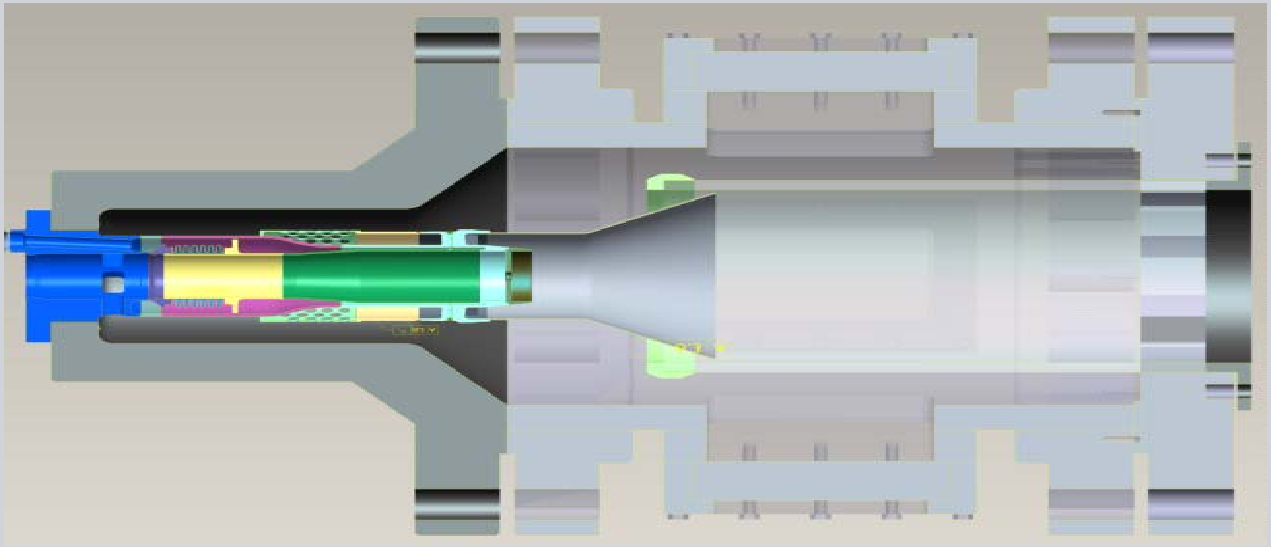

Fig: Georgia tech high pressure test rig

Current work focused on RQL combustion technology and conceptualize for Experiments at Georgia tech test rig

Outline

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- Introduction
- Motivation
- Objectives
- Key Challenges
- Baseline Aero design of the combustor
- Development of Network model with GENEAC for NOx and pressure drop
- Summary and Future work

RQL ---Definition and Motivation

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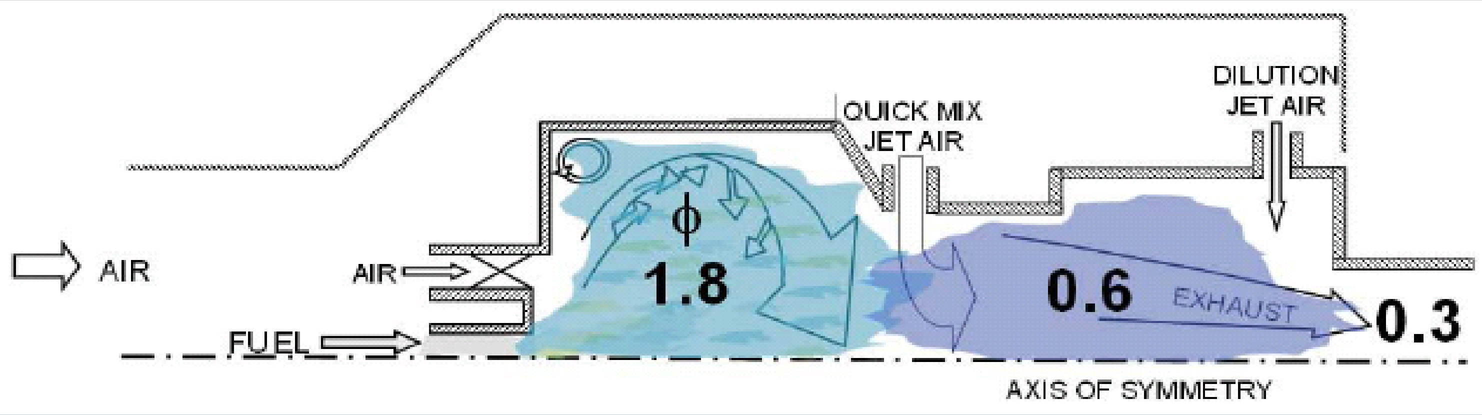
- Rich Burn in the primary stage, Quick Mix in the second stage and again Lean Burn in the third stage.

- Potential to reduce flashback



Source:http://www.netl.doe.gov/technologies/coalpower/turbines/refshelf/handbook/3.2.1.3.pdf

Motivation

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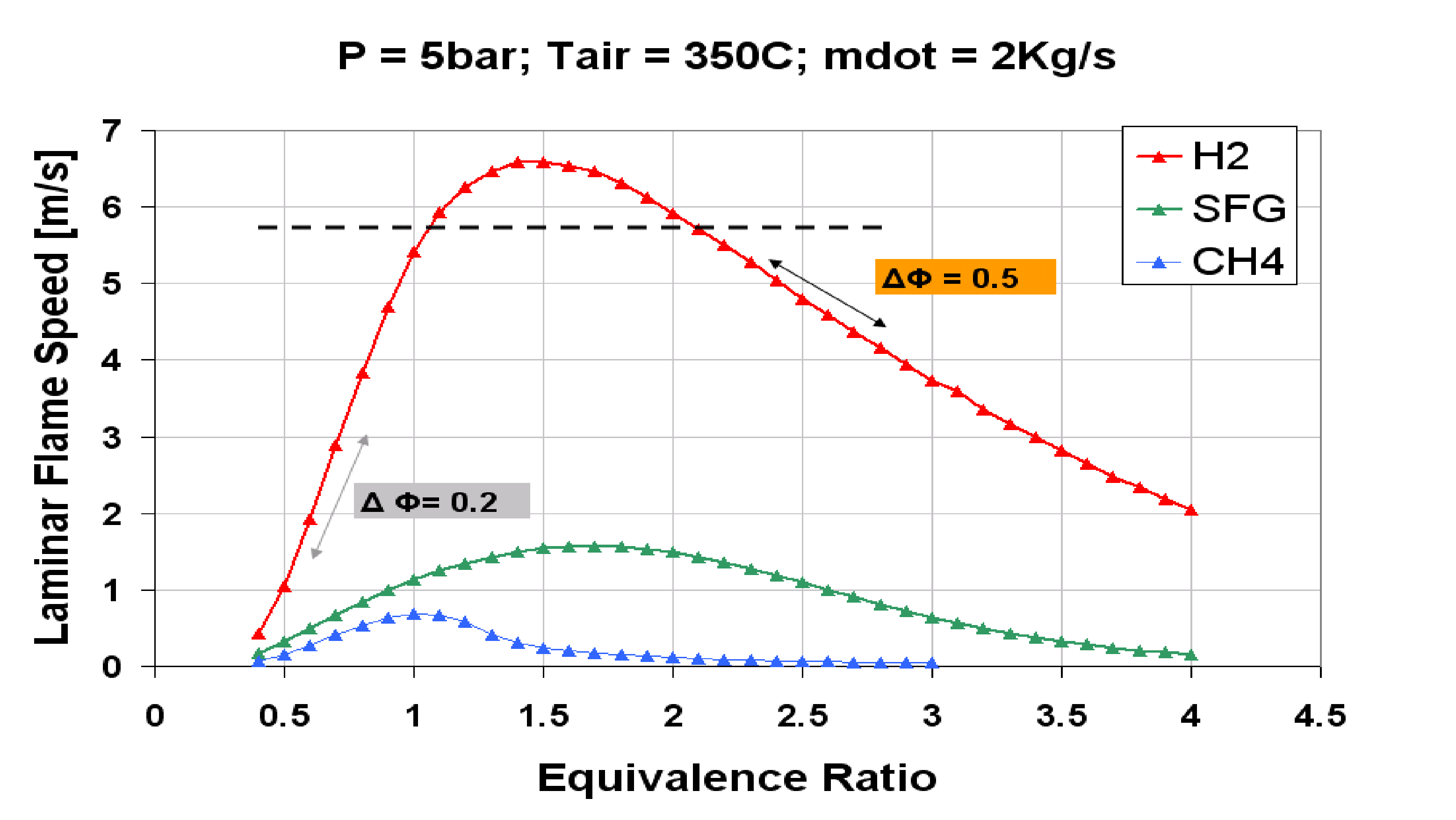

Source: GENEAC

Flame speed gradient with respect to Phi is lower at rich condition –increase stability regime and reduce flashback

Objectives

- Fundamental understanding of the proposed RQL combustion method

- Aero design of the combustor for different fuel compositions:
    - 80%H_2-20%CH_4-Air
    - 80% H_2-20% CO-Air
    - 50% H_2-50% N_2- Air
    - 80% H_2-20% N_2- Air
    - 100% CH_4-Air

- Perform kinetic and emission calculation for each composition using GENE-AC reactor model

- Parametric modeling of the RQL combustion method for above specified fuel composition

Key Challenges

- Designing the Quick Mix section

- Develop a network model with GENEAC for better NOx emission prediction based on mixing parameters

- Develop a network model with GENEAC to calculate pressure drop

Literature Review

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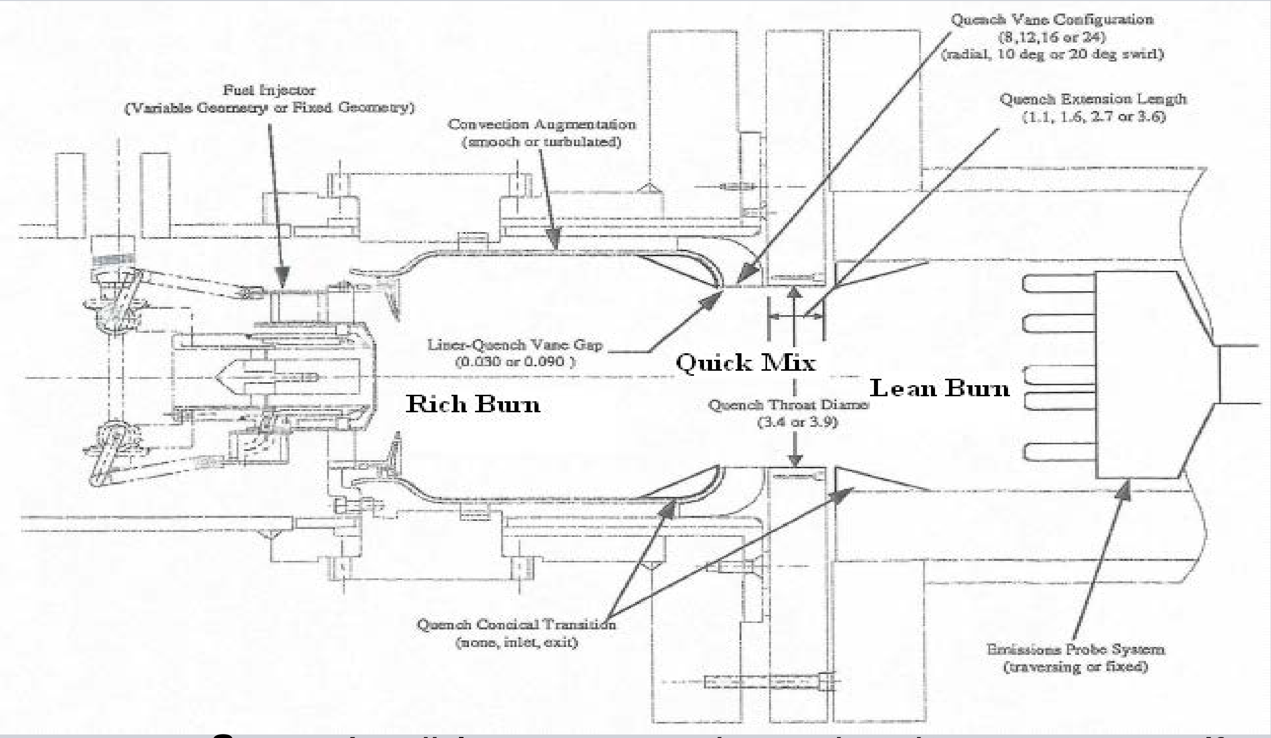
•Glenn Research Center, NASA has focused on RQL combustor for High speed civil transport (HSCT) aircraft.
Operated by liquid fuel
Investigated NOx and CO emission as a function of inlet temperature, Residence time, pressure drop, inlet pressure



Source:**http://gltrs.grc.nasa.gov/reports/2004/CR-2004-212881.pdf**

•Operating condition:

Inlet temperature=450-650 C

Number of orifices=8-24

Pressure=6-10 bar

Literature Review

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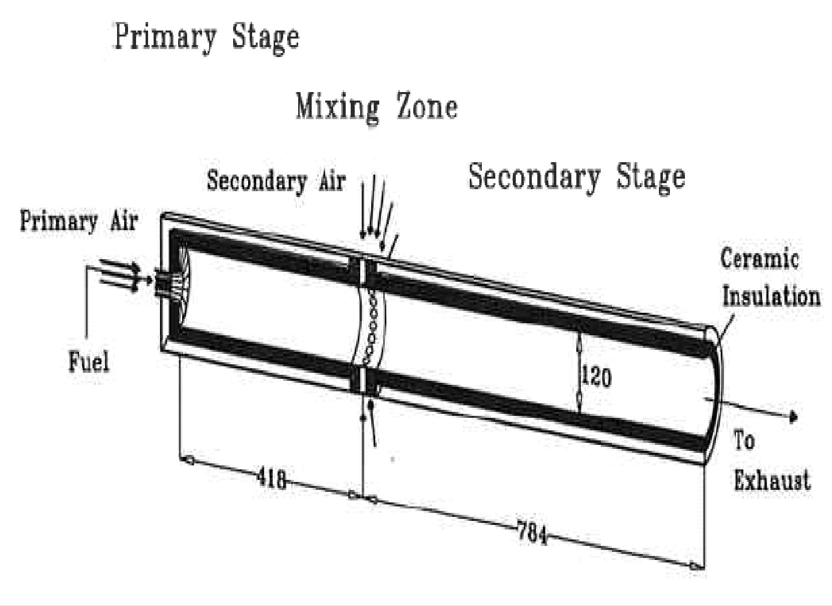
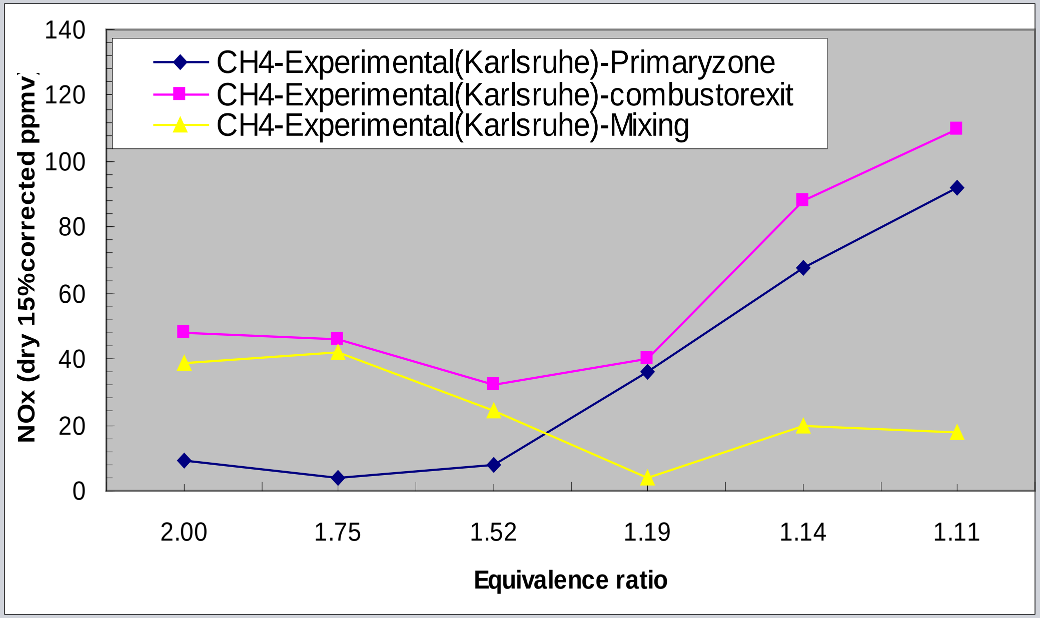
•University Karlsruhe, Germany (Author: Meisl J. et al) has been investigated RQL under gas turbine operating conditions

The authors focused on the effect of pressure on NOx emission at both primary and combustor exit location

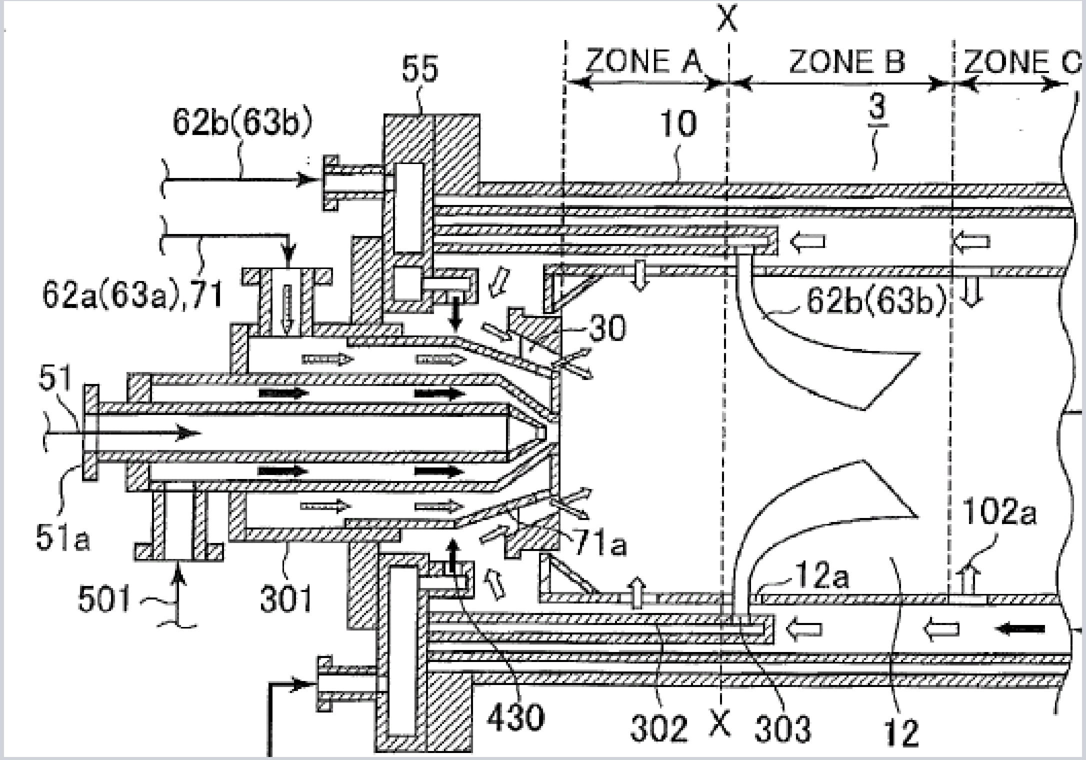




Source: **Meisl J. et al, “Influence of pressure on NOx emissions in Rich-Lean combustion”**

Literature Review

•Hitachi, Ltd. invented RQL combustor for hydrogen containing fuel ensuring low NOx emission



Source: Koizumi et al. "Low NOx combustor for Hydrogen-containing fuel and its operation"

Aero design of the Combustor

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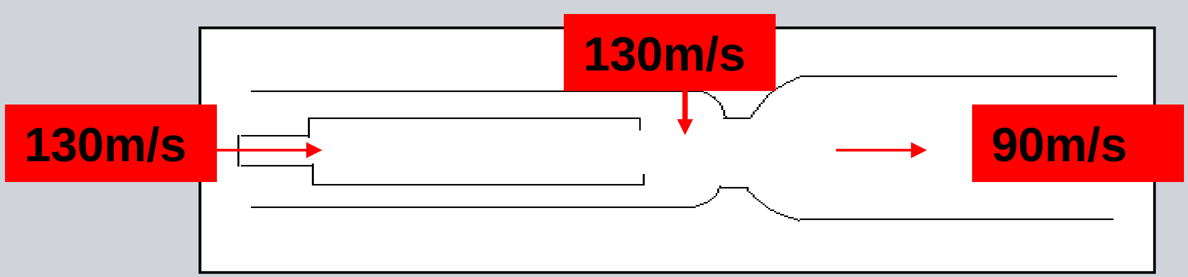
Design Space:

Air mass flow rate=2 kg/s
Air split 70-90%, Pressure drop=4-5%
Residence time=10-15 ms
Inlet fuel temperature=200C
Inlet air temperature=450C
Lean flame zone temperature=1500C



2-D sketch of the combustor

Aero design of the Combustor

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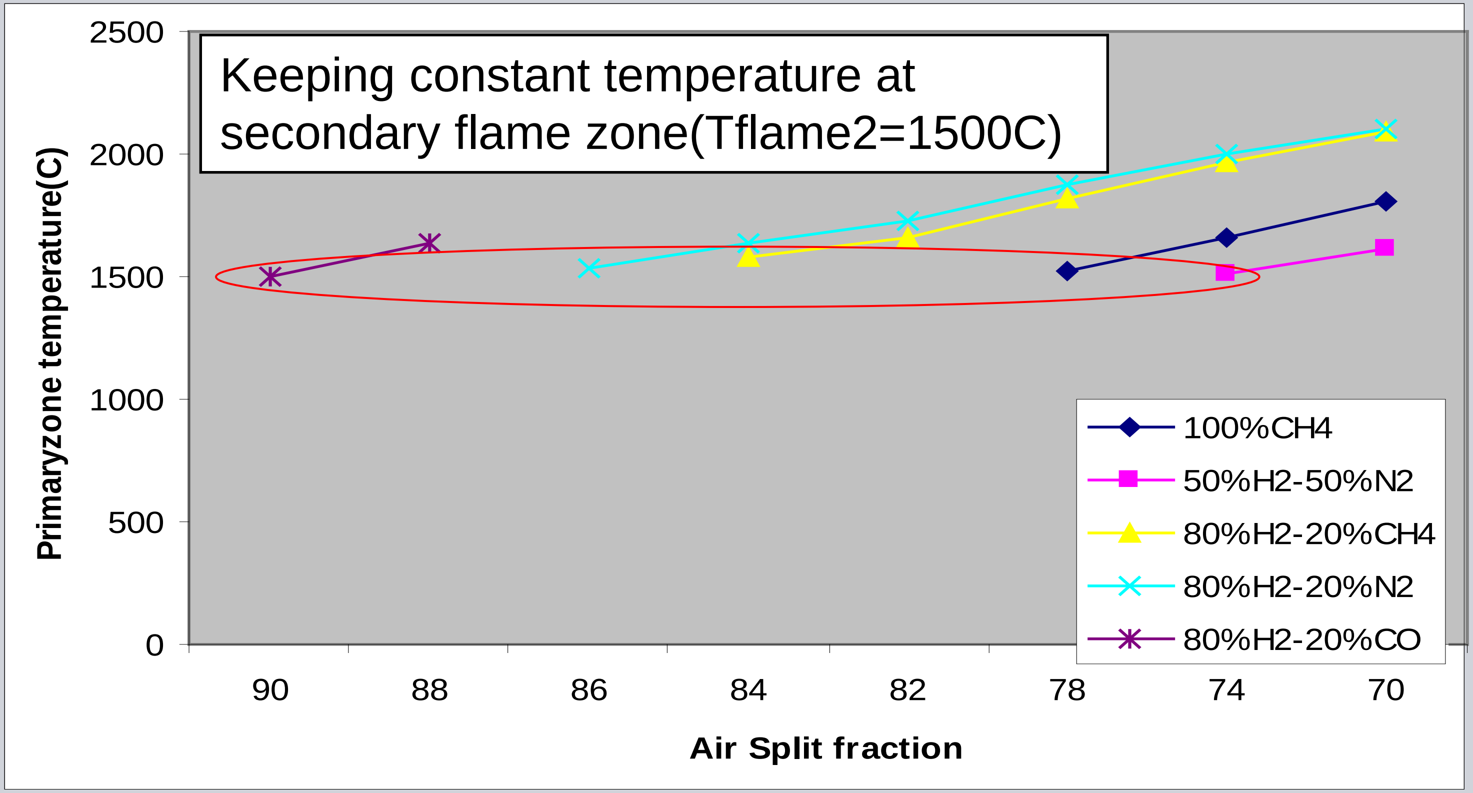

Air split fraction varies from 74-86% for all specified fuel compositions except 80%H2-20%CO

Aero design of the combustor

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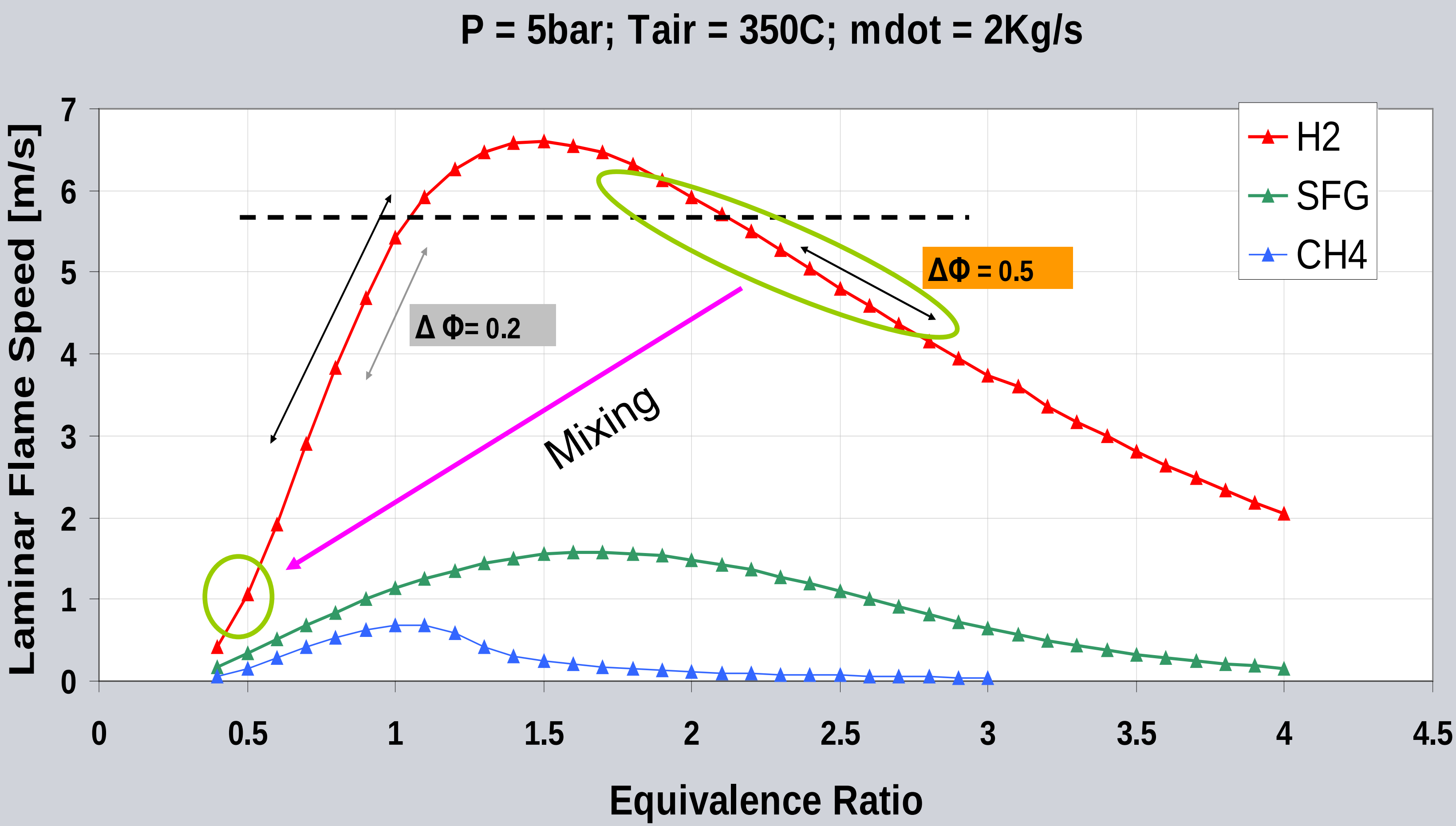

Source: GENEAC

Flame regime is moving from rich to lean condition through mixing

Jet to cross flow Mixing profile using Holdeman correlation

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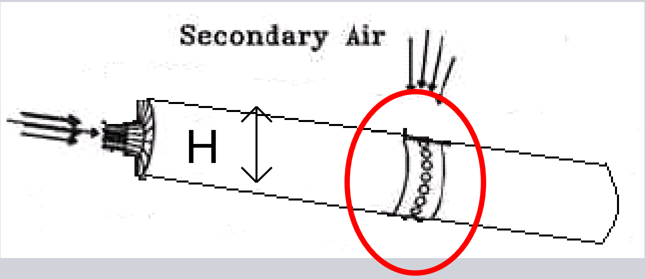

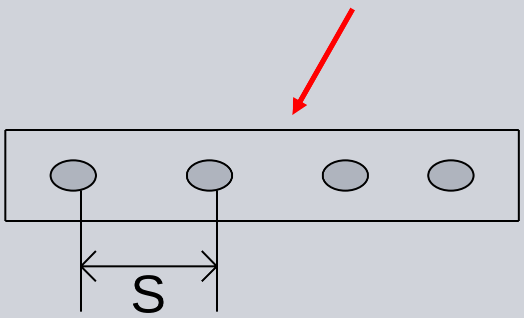

Key parameters:

Spacing between each orifice, S
Jet to cross flow momentum ratio, J
Combustor diameter, H
Number of orifices, N
Orifice diameter, D

S/H ratio plays major role for better mixing profile

Jet to Cross flow mixing profile

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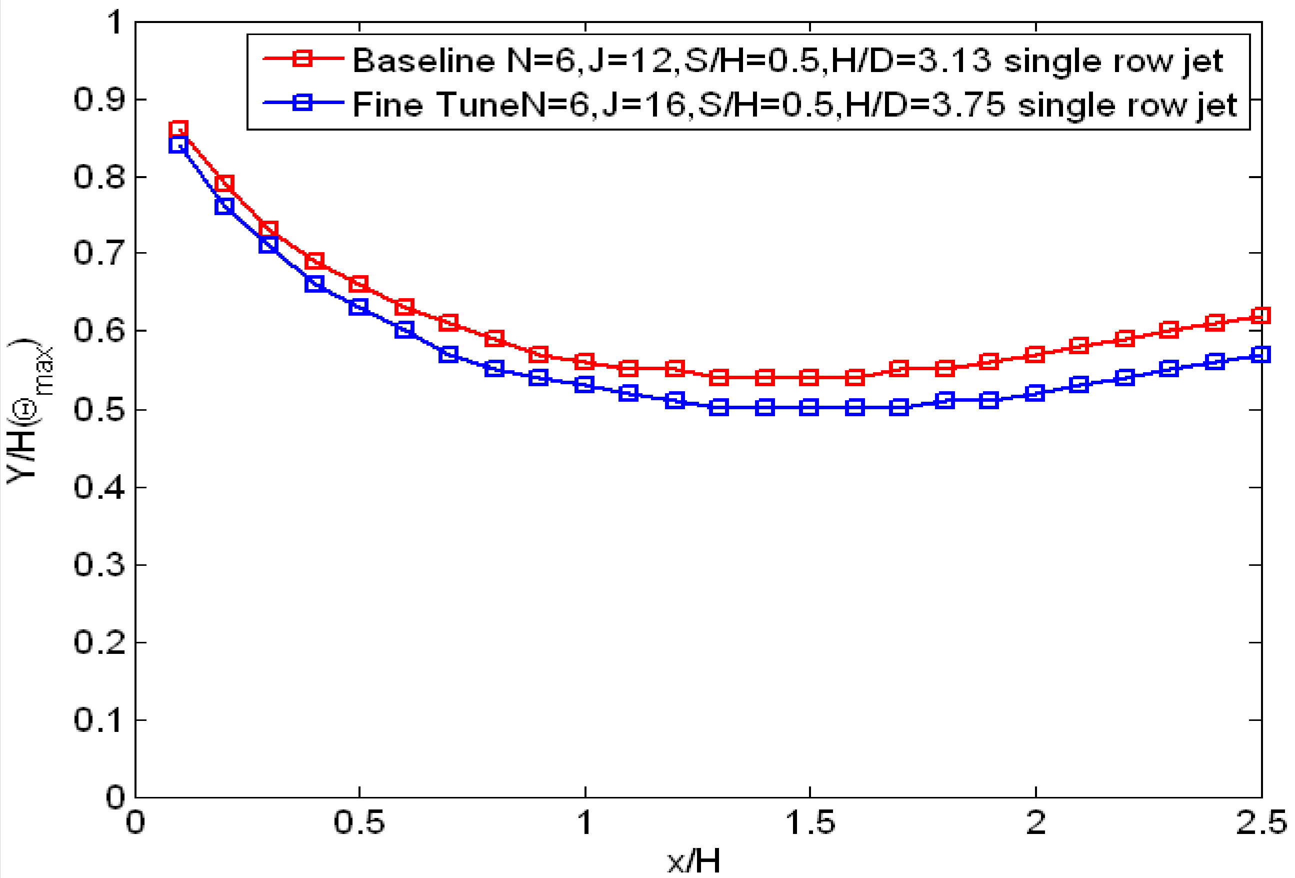

Fine tune aero design shows better mixing profile compared to baseline case

Baseline Geometry of RQL test rig

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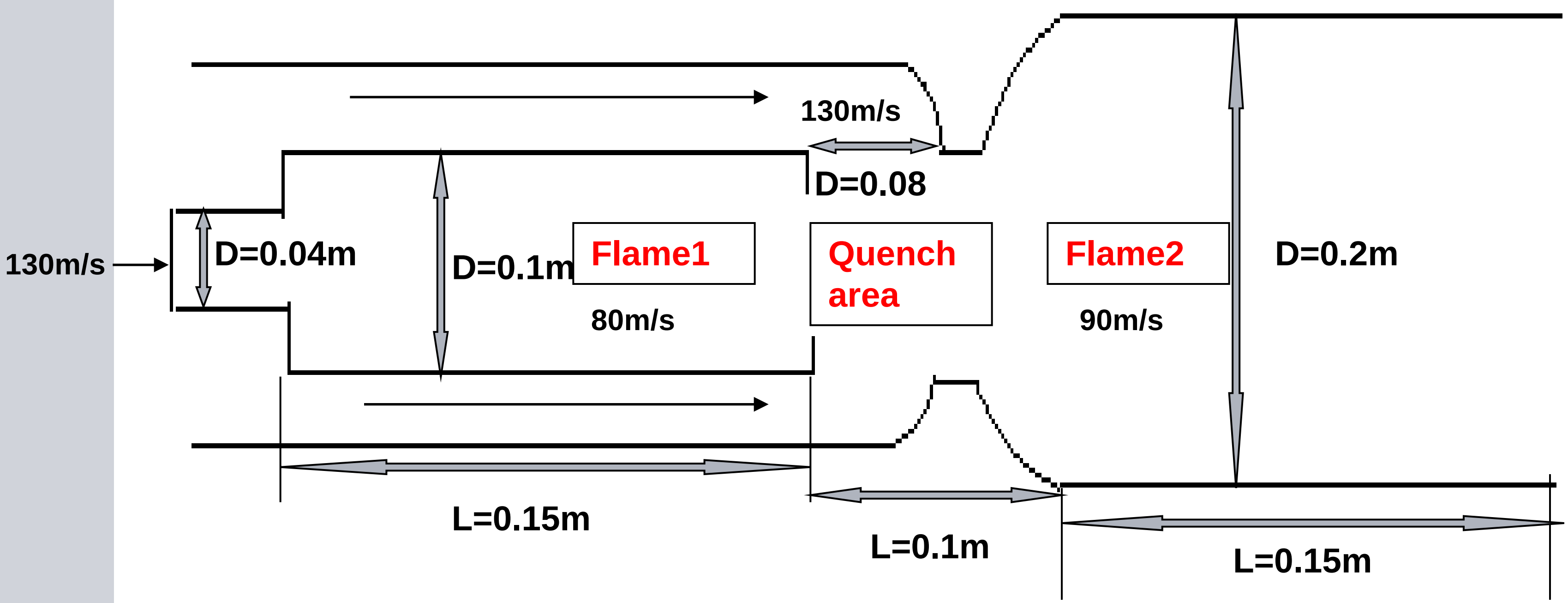

Dimensions are best fit for Georgia Tech test rig.
Ready for developing CAD model for CFD analysis

Network model for pressure drop (reacting)

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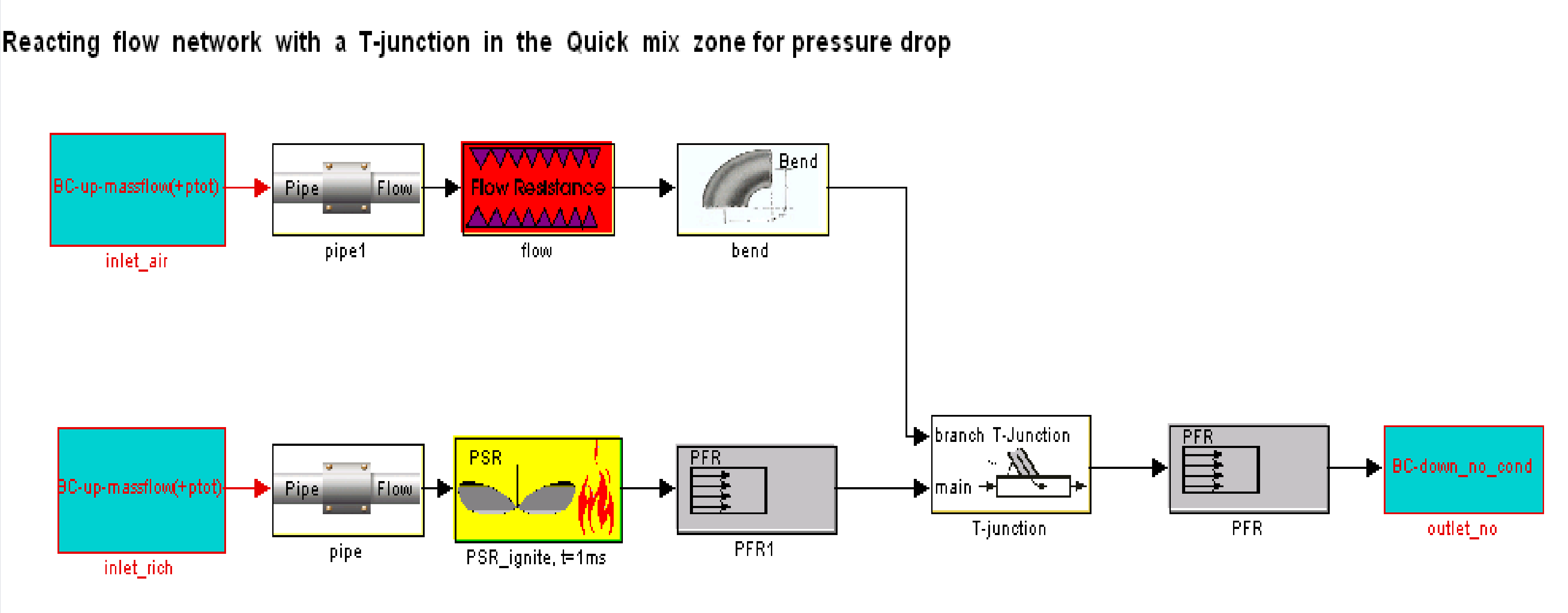

Calculated pressure drop in reacting condition is approx 4.4%[model verified with Luis Betancourt in Mulheim]

Emission Analysis

Validation of GENEAC Network model with Experimental data

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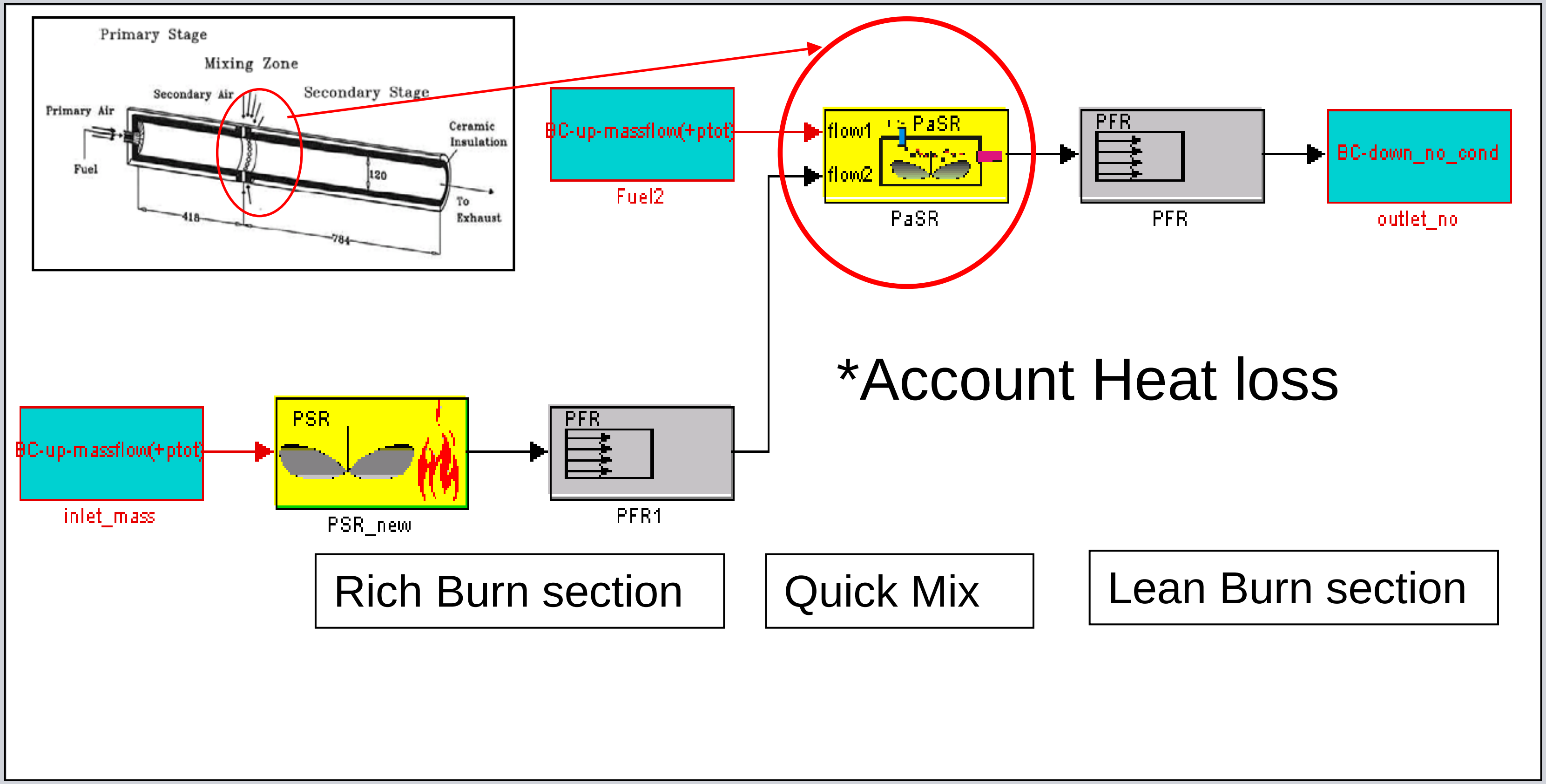
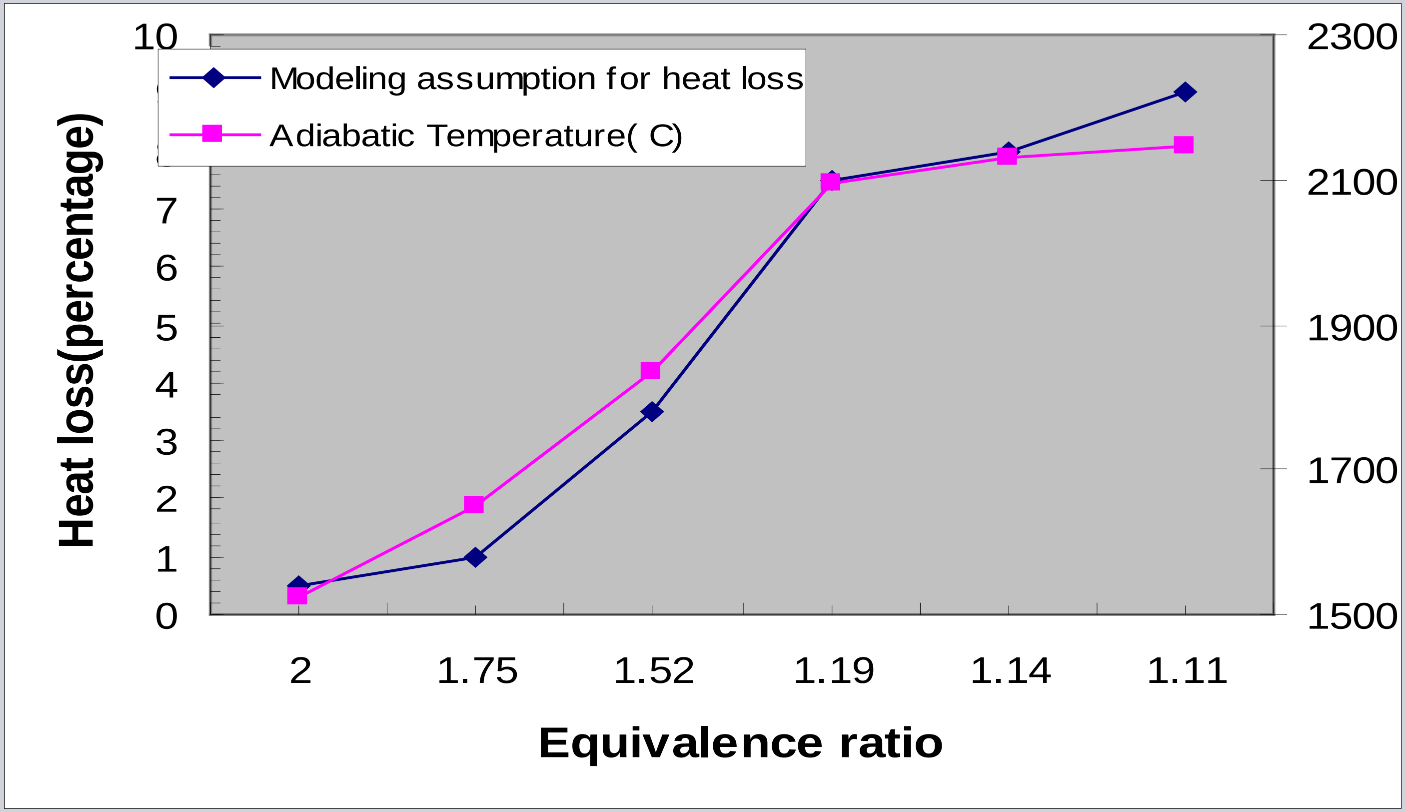


Baseline Network Model With GENEAC

Validation of GENEAC Network model with Experimental data



Heat loss calculation is based on a function of adiabatic temperature of each operating condition

Validation of GENEAC Network model with Experimental data

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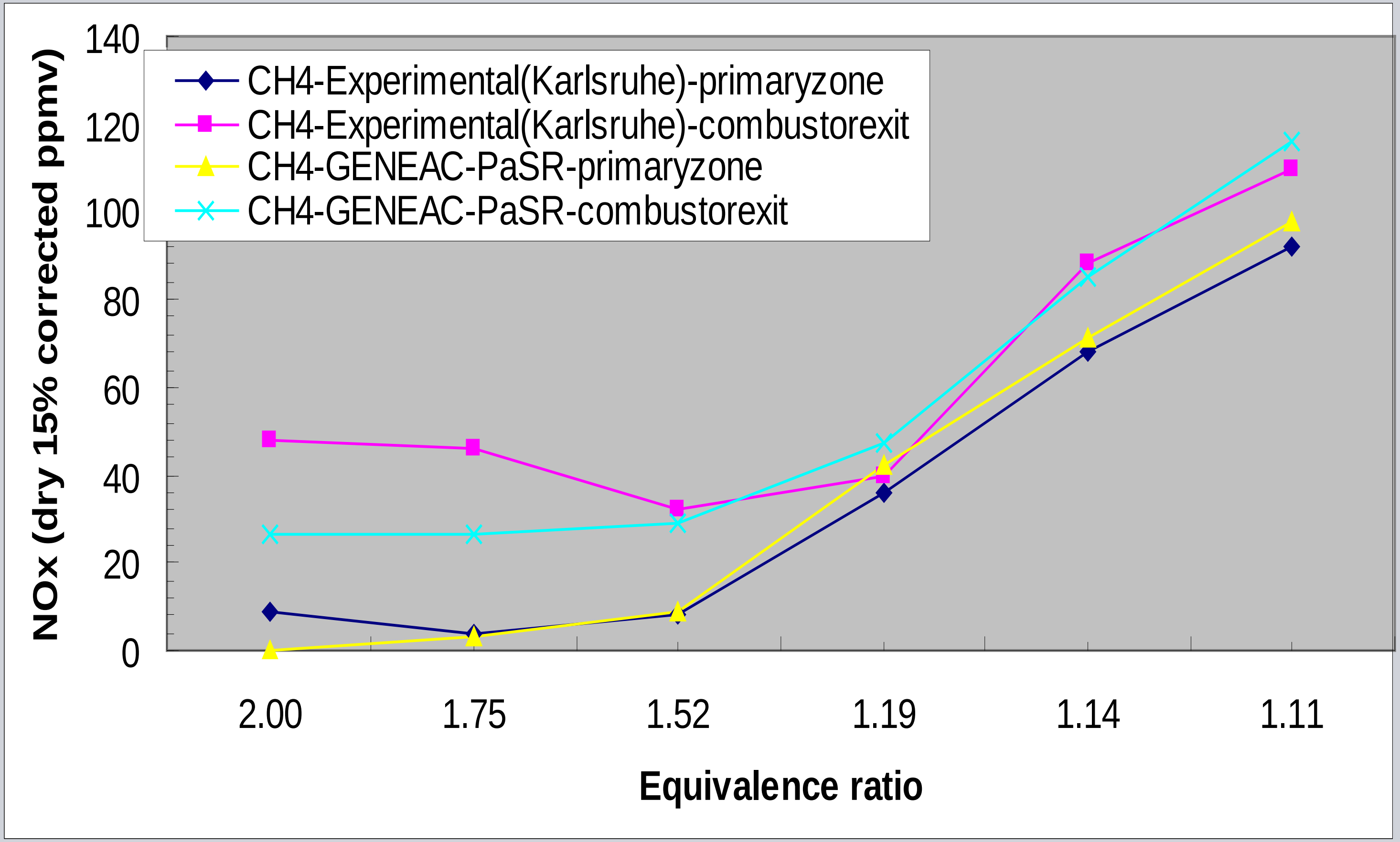

NOx emission using GENEAC at both primary and combustor exit location fairly agree with experimental data

Network Model With GENEAC

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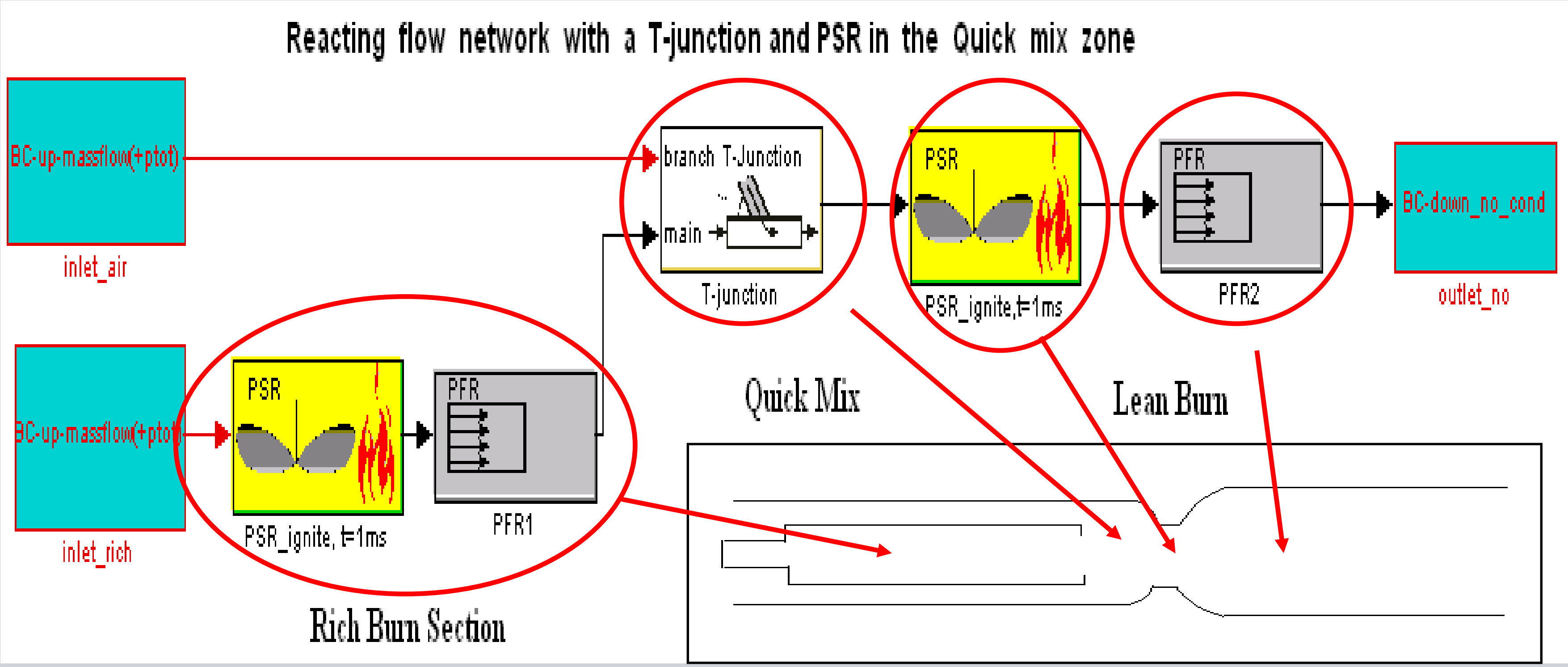

Ideal case considering perfect mixing at quick mixing section and complete combustion

NOx emission trend using GENEAC Network Model

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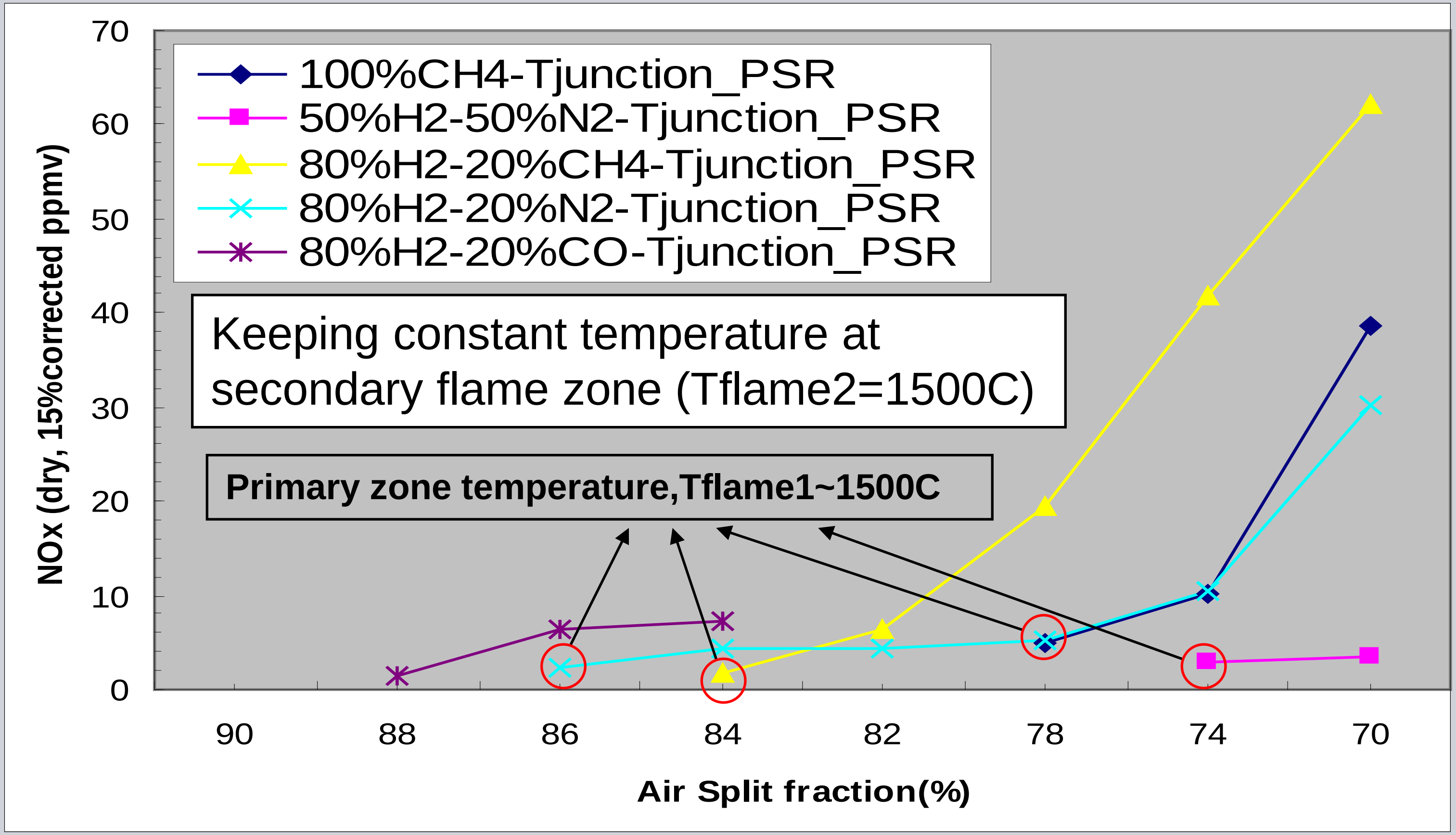

Among all fuel compositions 50%H2-50%N2 produce less NOx at lower air split fraction

Combustor exit temperature Trend

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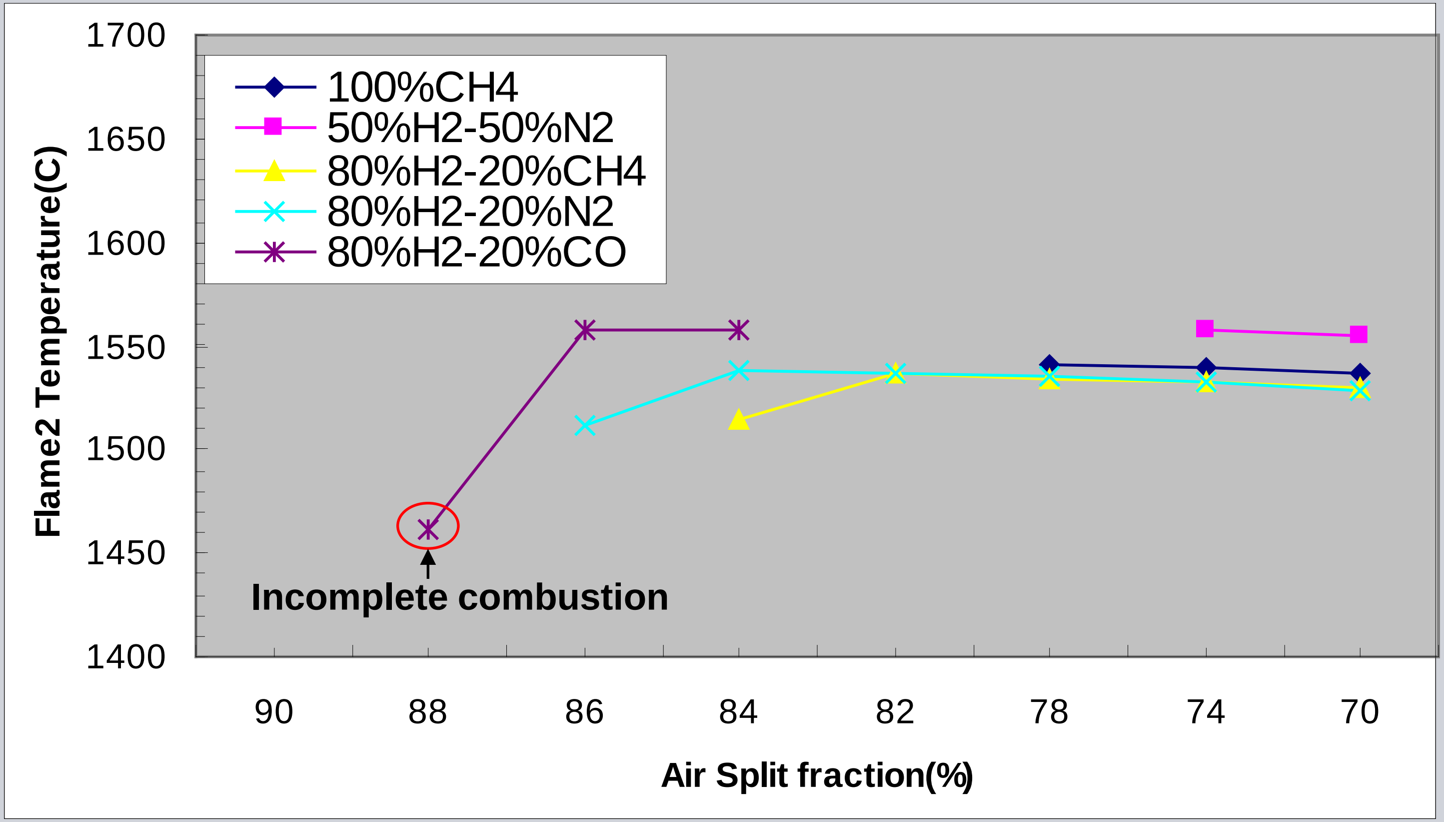

Combustor exit has almost constant temperature for all fuel compositions as expected

Network Model With GENEAC

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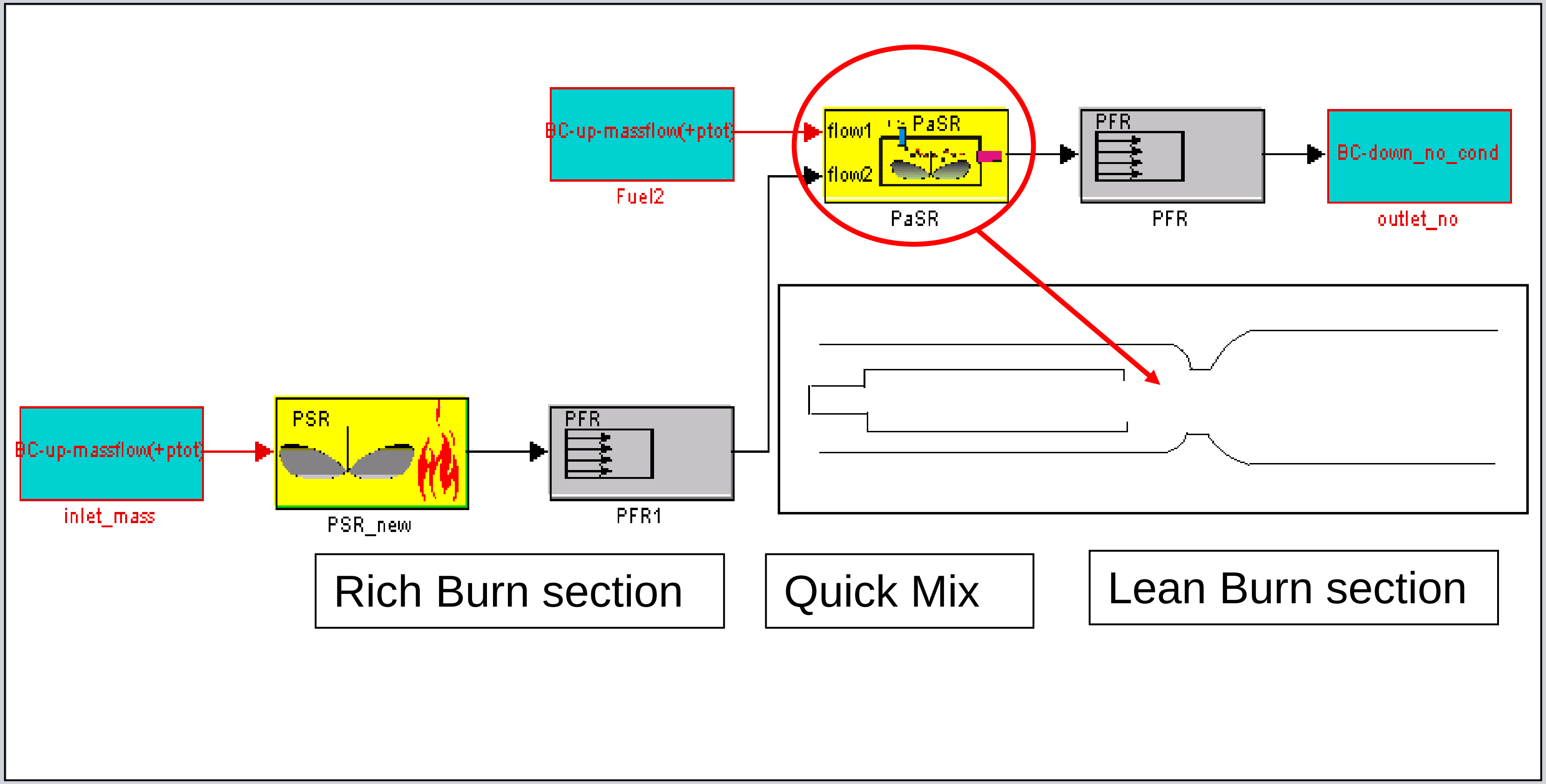

Baseline Network Model With GENEAC

NOx emission trend Using GENEAC

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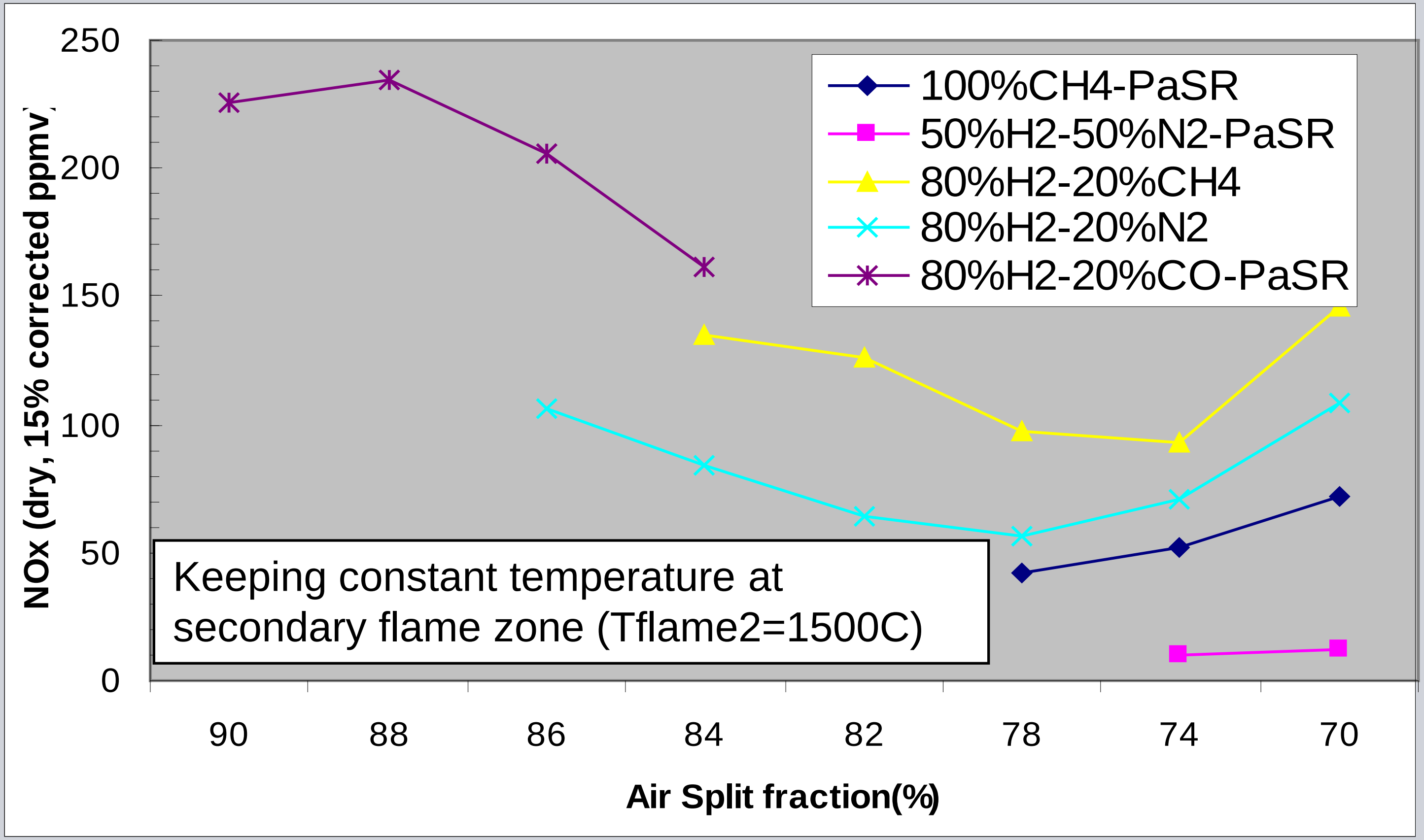

NOx production is higher even at higher air split by using PaSR reactor in the quick mix section

Combustor exit Temperature Trend

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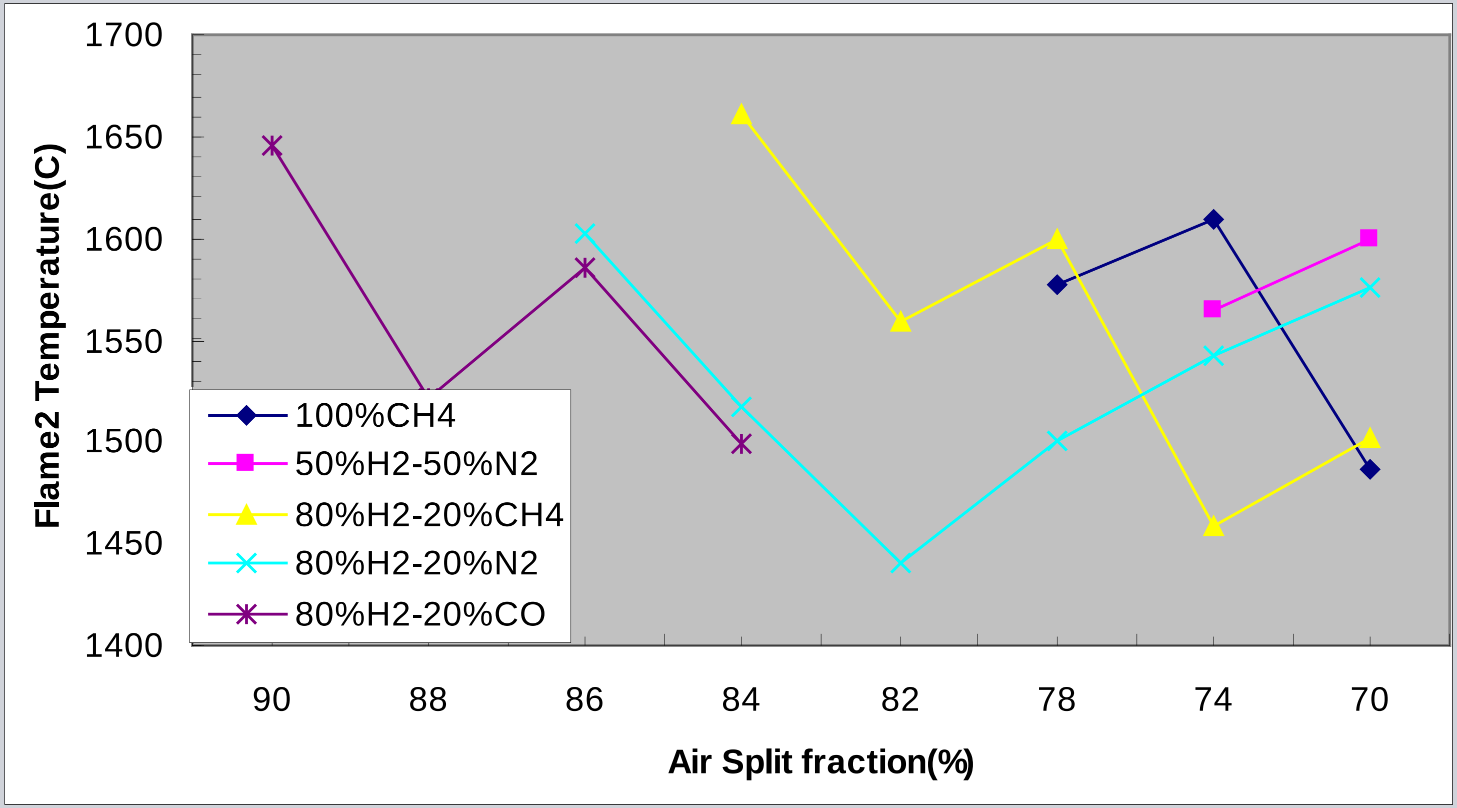

Non Physical result, Flame 2 temperature not converged. Number of particles used in the PaSR reactor was too small.

Conclusion

- Aero design looks promising in terms of pressure drop
- NOx emission is controlled by maintaining Air split fraction
- Mixing would be major challenge to ensure the feasibility of the RQL combustor

Future work-
Optimization of proposed concepts

- CFD modeling of the quick mix zone for better understanding of the mixing

- Development of more realistic network model for pressure loss calculation

- Develop a network reactor that can represent quick mix zone more accurately for predicting better NOx emission.

Thank You