Nitrogen Release From Biomass

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Introduction

- Energy Independence and Emissions (including greenhouse gas emissions) are the motivating factors for energy related policy in the US and abroad
- Biomass combustion, specifically co-firing of biomass with traditional fuels is one of the best practical solutions to achieve CO_2 reduction
- Biomass combustion produces some benefits and some drawbacks relative to coal, fuel oil, or natural gas
- Increased formation rates of NO have been observed in practice when biomass is co-fired or fired on its own compared to coal

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Objective

Determine the nitrogen evolution for biomass and co-firing of biomass with coal

Hypothesis:

1. Most biomass fuels release nitrogen in the form of amines in contrast to coal which tends to release nitrogen in the form of HCN

Method:

1. Measure NH_3 and HCN concentrations (and all major species) in a realistic reacting flow for both coal and biomass
2. Compare measured results with comprehensive combustion code
3. Use experimental data to determine residence times and temperatures for use in a plug flow reactor, full-mechanism calculation

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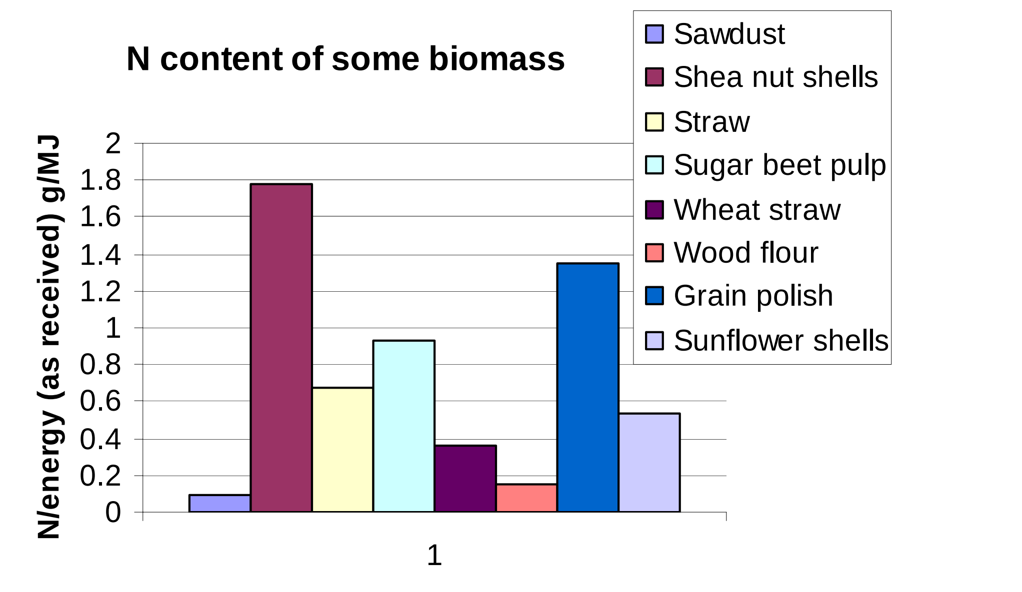
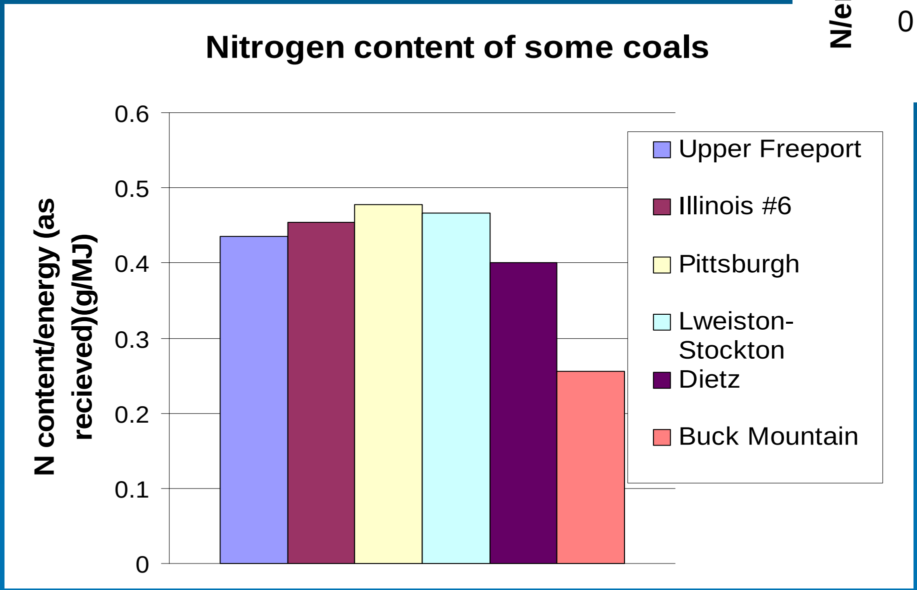
Background

Nitrogen Content of Biomass and Coal





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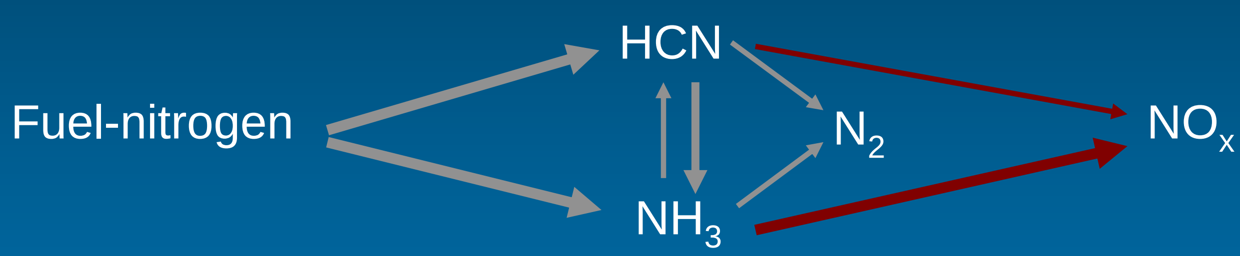
Background

Coal →

Devolatilization (Normal Fuel Rich)	**Oxidation** (Fuel Lean)
Gas Phase N (HCN) →	NO, NO_2, N_2
Solid Phase N (Pyrolic, Pyradinic) →	



Biomass →

Devolatilization (Normal Fuel Rich)	**Oxidation** (Fuel Lean)
Gas Phase N (NH_3) →	NO, NO_2, N_2
Solid Phase N (Amines) →	

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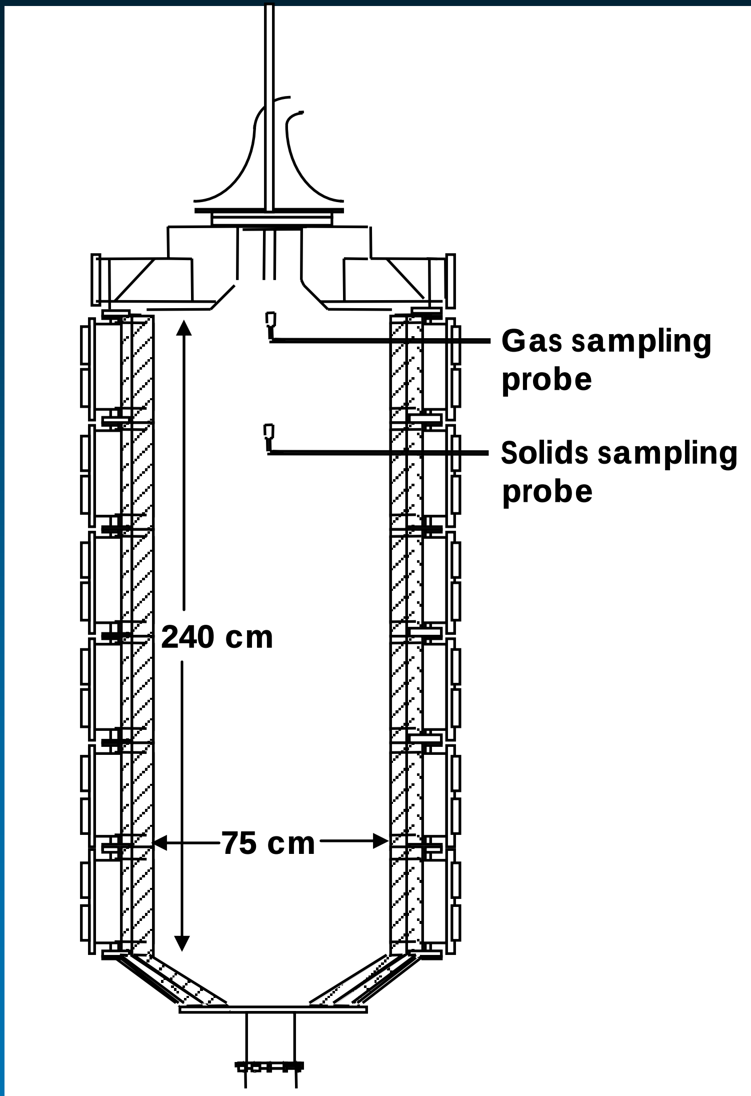
Experimental Setup



BYU – Burner Flow Reactor – BFR

Fuels

Utah Blind Canyon
Illinois #6
Straw
Sawdust

Measurements

CO_2, CO, SO_2 – NDIR
NO, NO_2 – Chemiluminescence
O_2 – Paramagnetic
HCN, NH_3 – FTIR

Solids – HCNS

Average Velocity – Hot Wire

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Test Matrix

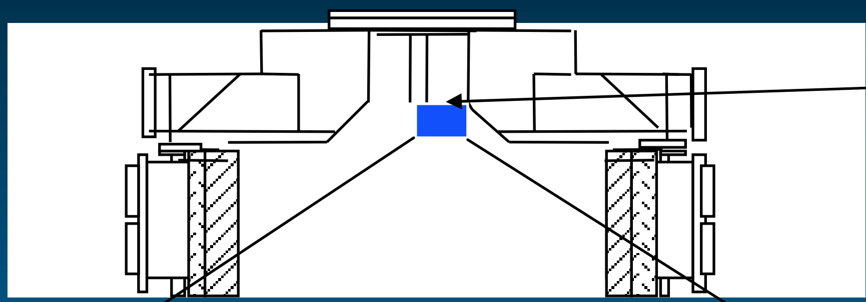
	Mass Fraction of Fuel / Test No.								
Fuel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Black Canyon	0.3	1	0.3	0.5					
Illinois #6							0.3	0.3	1
Sawdust			0.7			1		0.7	
Straw	0.7			0.5	1		0.7		

Fuel Properties (mass fractions)

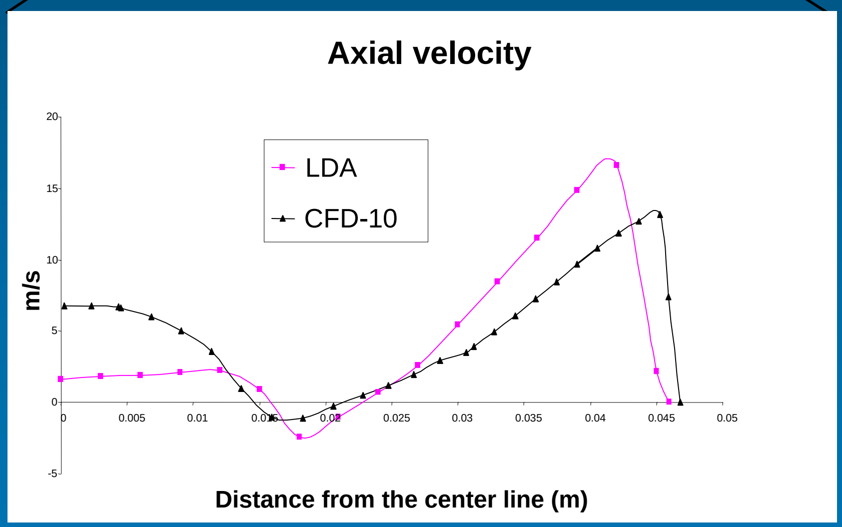
	Black Canyon	Illinois #6	Sawdust	Straw
N	**0.015**	**0.018**	**0.003**	**0.009**
C	0.681	0.681	0.462	0.418
H	0.053	0.048	0.058	0.054
O	0.101	0.107	0.416	0.385
S	0.005	0.015	0.001	0.001
Heating value (kJ/g)	**27.8**	**28.5**	**18.0**	**15.9**
Moisture	0.031	0.064	0.055	0.059

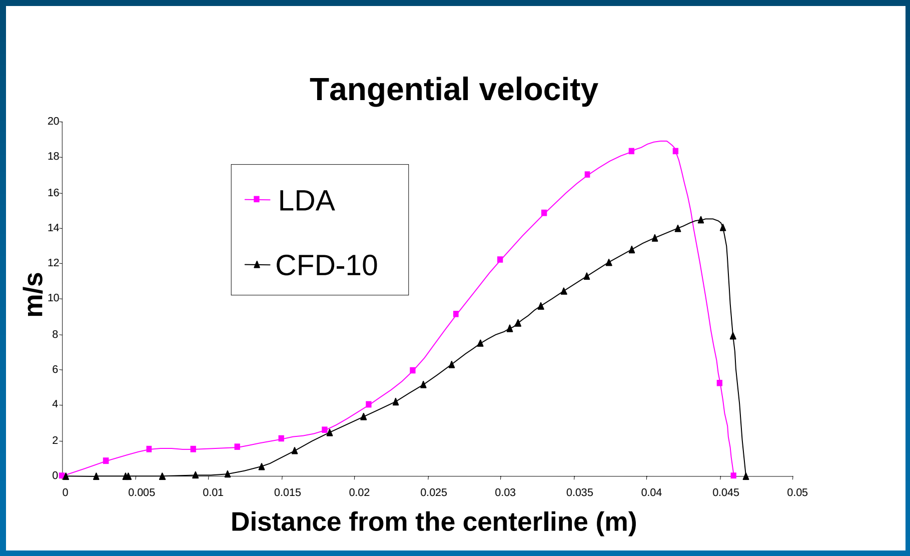
Results – Cold Flow, Swirl Generator

The swirl generator has been modeled to produce accurate inlet conditions for the reactor



Reactor inlet – Swirl generator outlet





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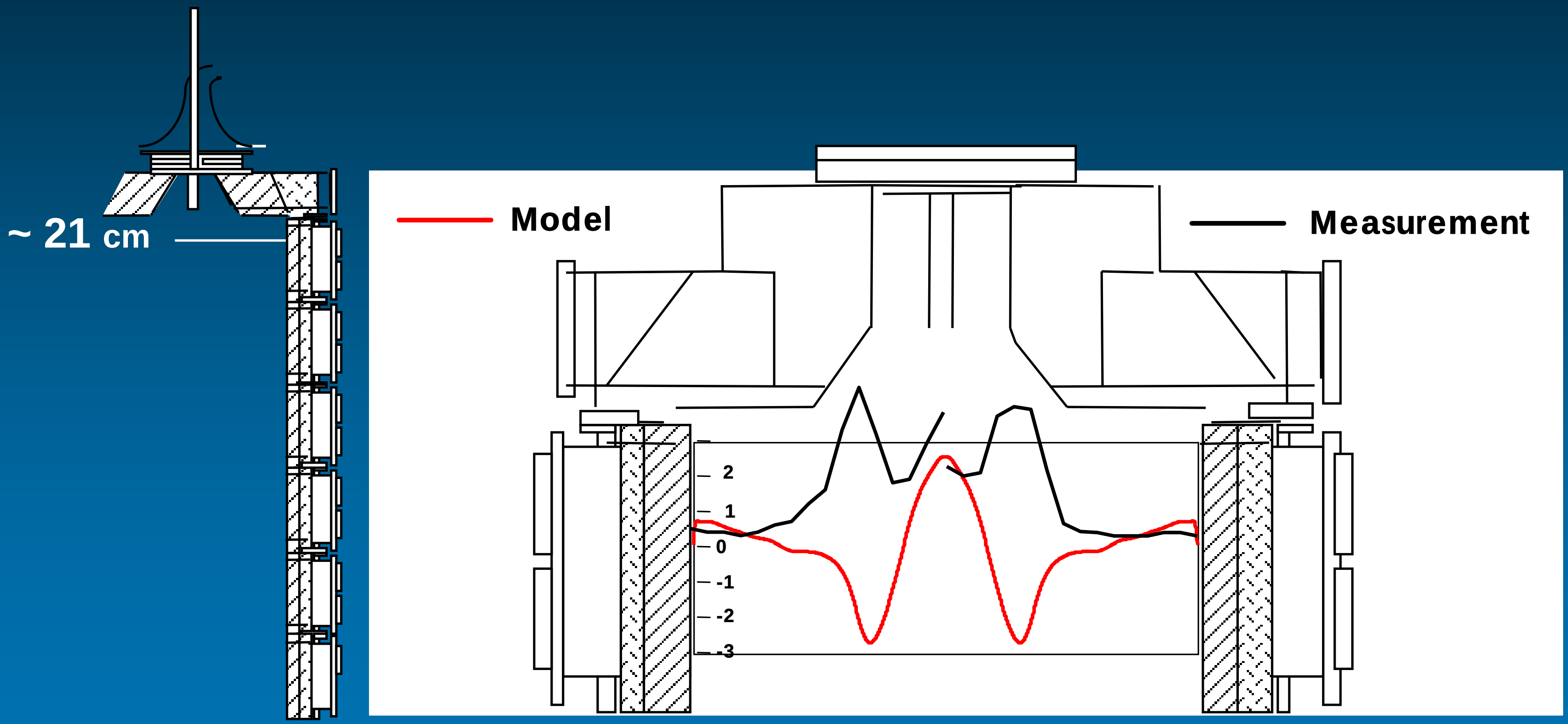
Results – Cold Flow

Cold-flow Velocity Measurements and Modeling
Note that the hot wire measurement can not determine the direction, only magnitude



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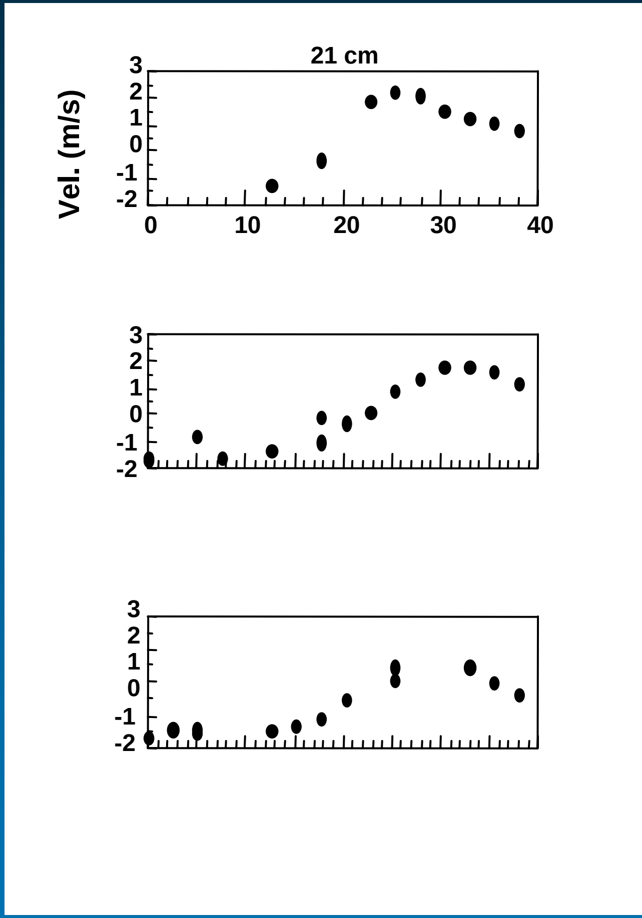
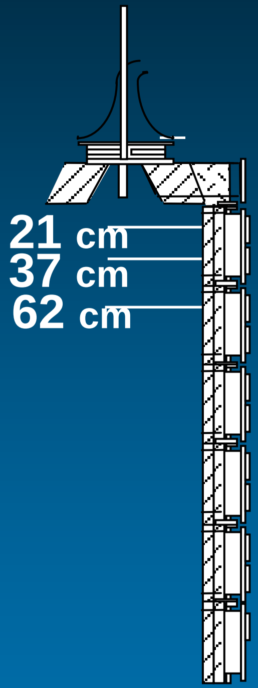
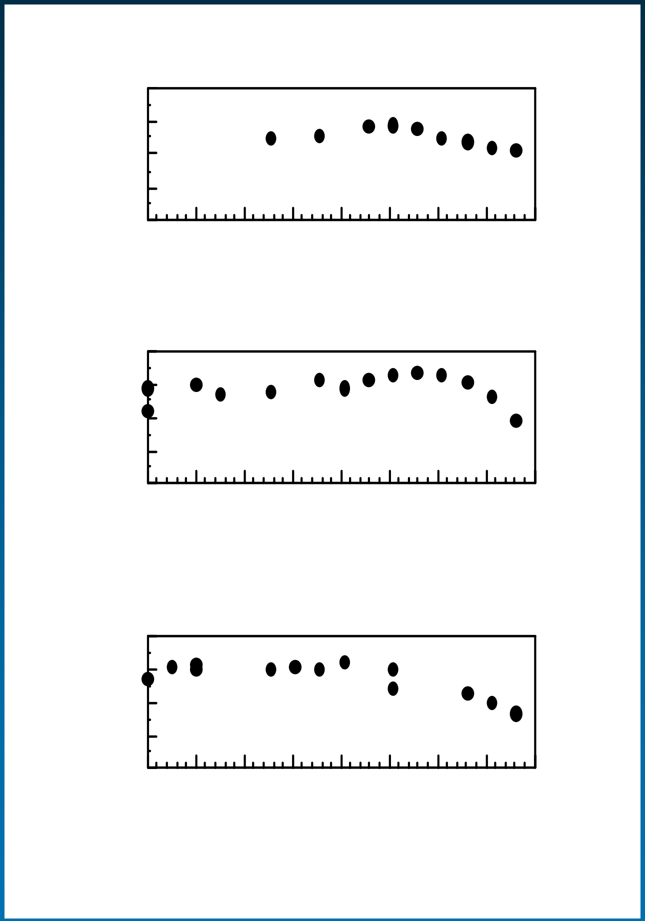
Results – LDV

Average Axial Velocity





Average Tangential Velocity

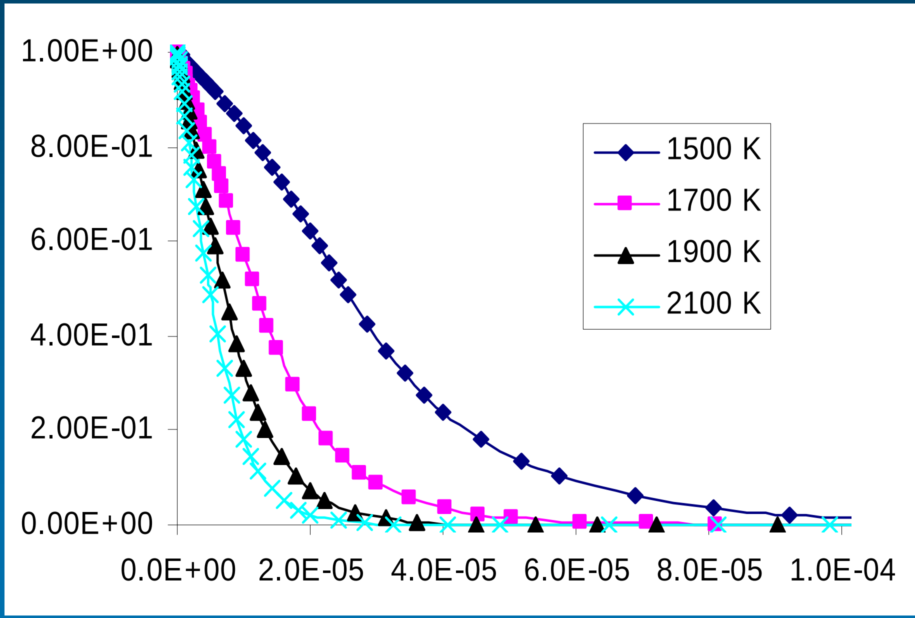


Results – Chemkin

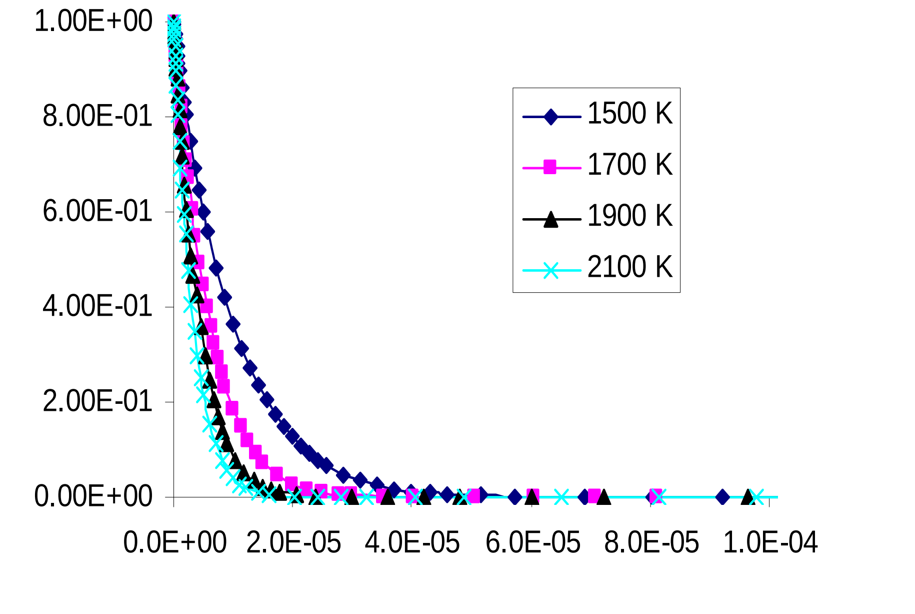
GRI_Mech 3.0

Initial Condition: ψ_{CO} = .9, C_2H_2 – NH_3, C_2H_2 - HCN

HCN / HCN_0



NH_3 / $NH_{3\,0}$



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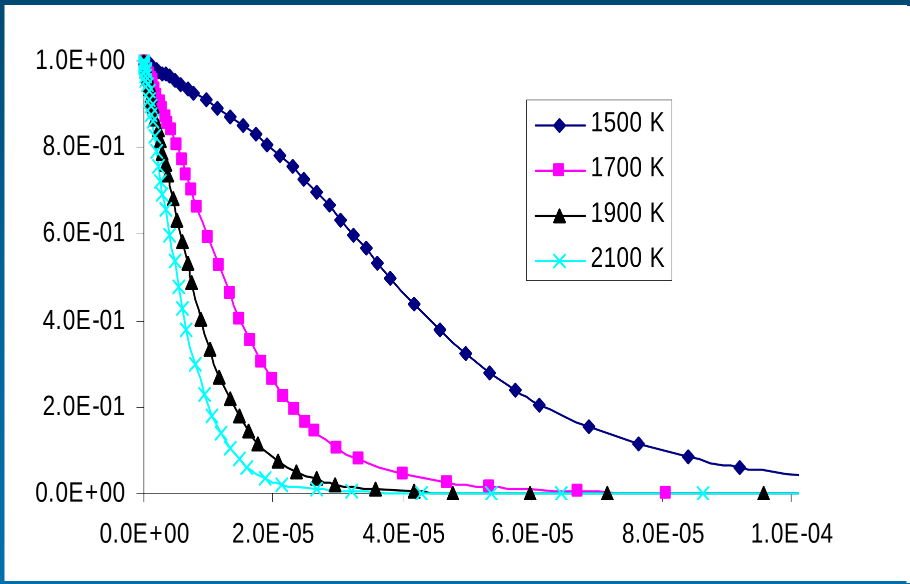
Results – Chemkin

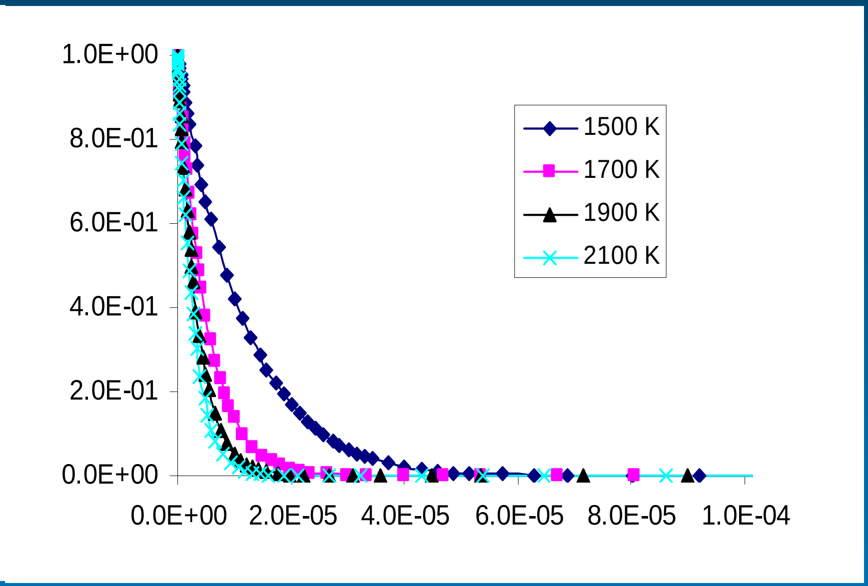
Kilpinen - 97

Initial Condition: ψ_{CO} = .9, C_2H_2 – NH_3, C_2H_2 - HCN

HCN / HCN_0



NH_3 / $NH_{3\,0}$



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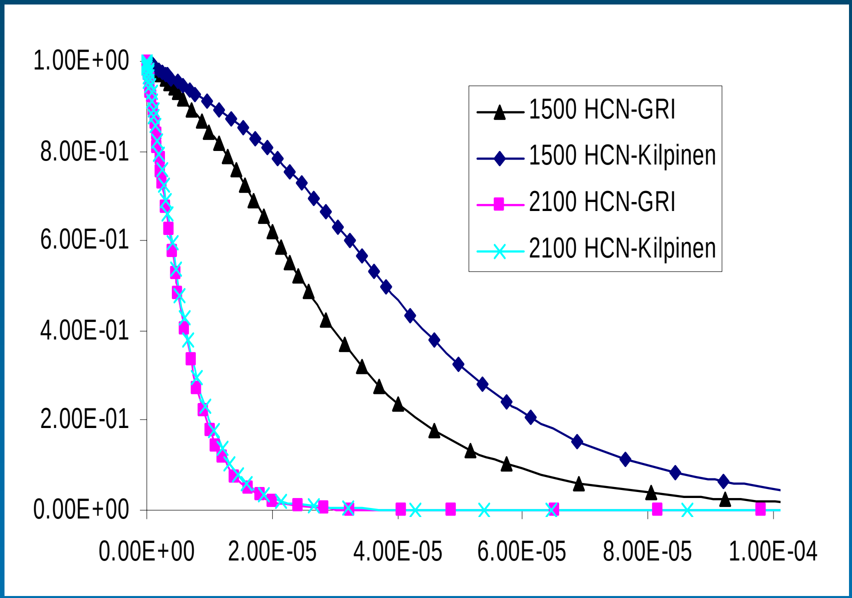
Results – Chemkin

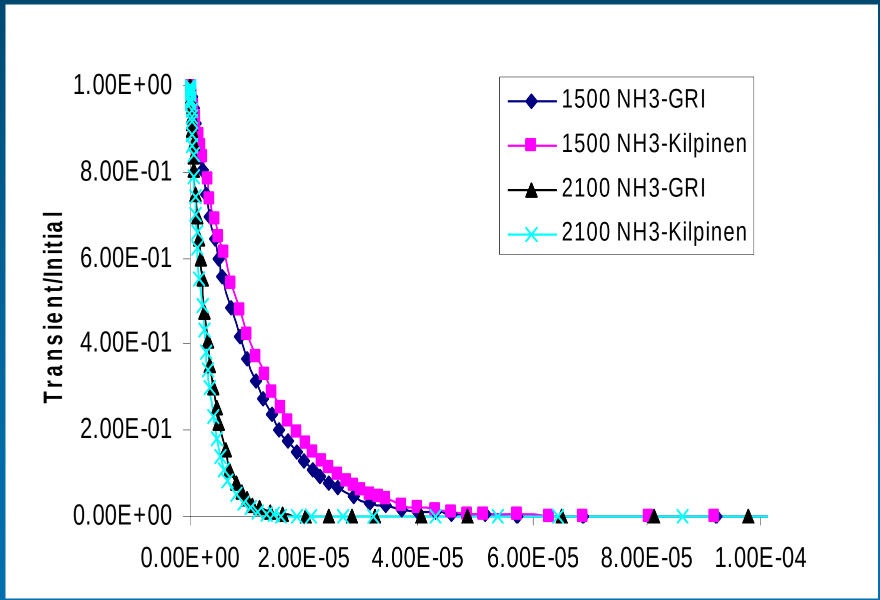
Comparison of Mechanisms

Initial Condition: ψ_{CO} = .9, C_2H_2 – NH_3, C_2H_2 - HCN

HCN / HCN_0



NH_3 / $NH_{3\,0}$



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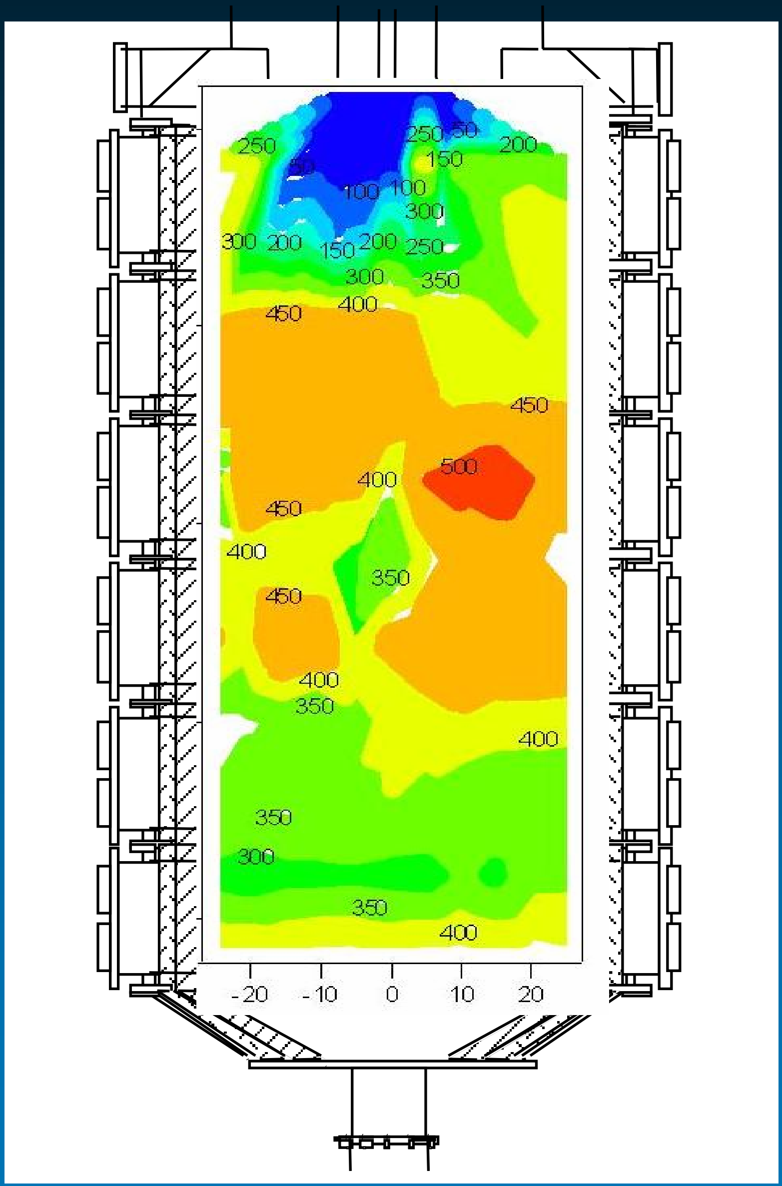
Results – Gas Sampling - NO



NO Contour Map For Straw

- The map was obtained on 3 different days of testing
- Peak NO values reach approximately 450 ppm
- The NO takes a considerable time to form, approximately 300 ms
- Symmetry is relatively good in the reactor
- Transient behavior and radial variations are primarily in the top two sections (80 cm)

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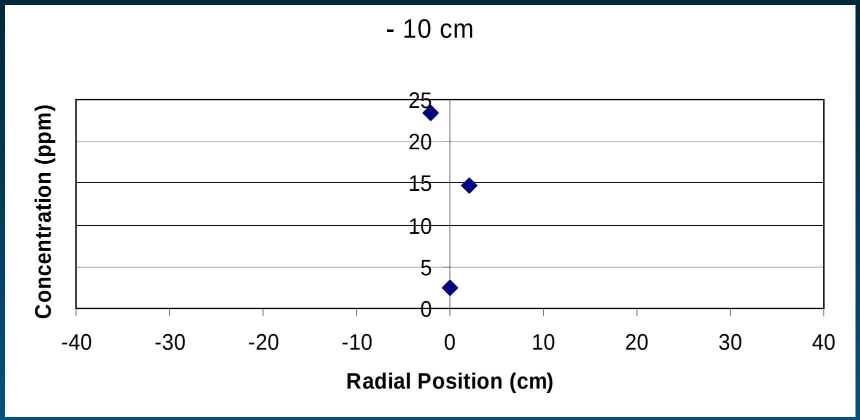
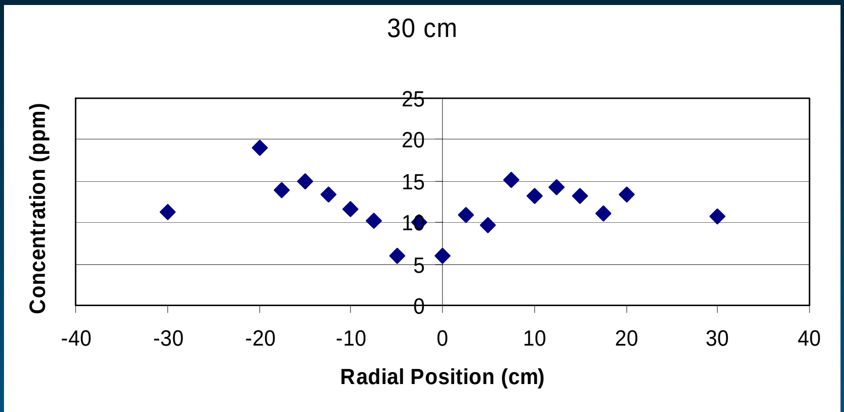
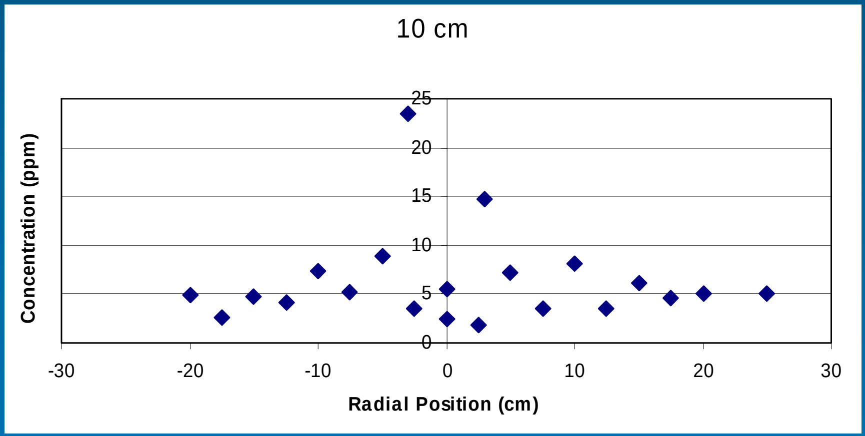
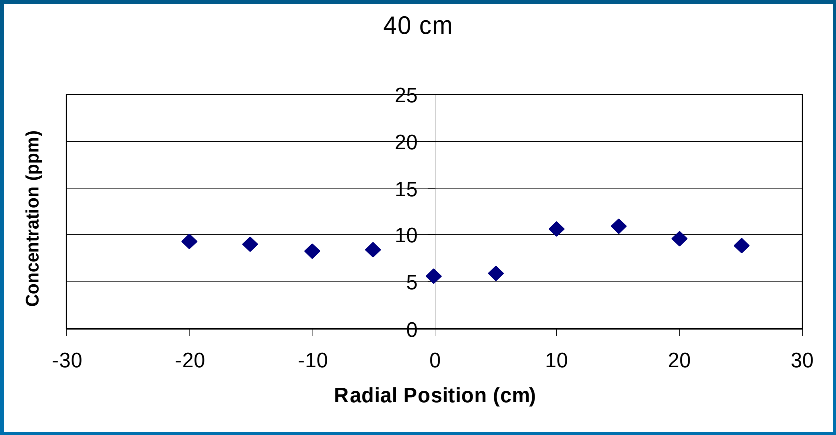
Results – Gas Sampling, NH_3









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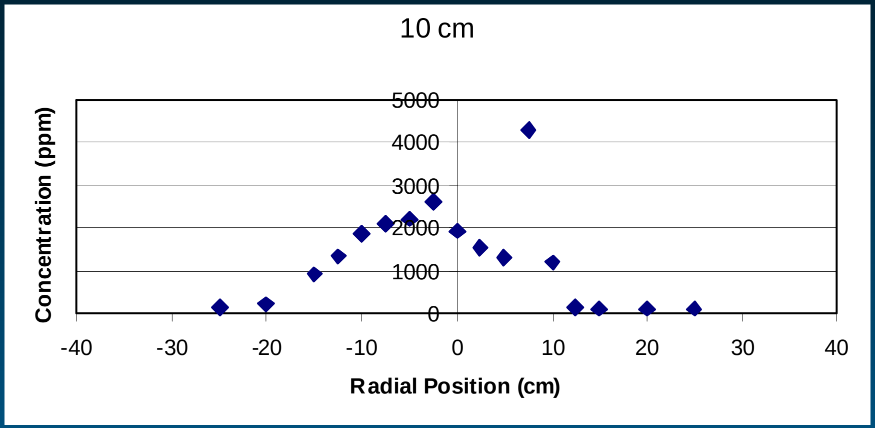
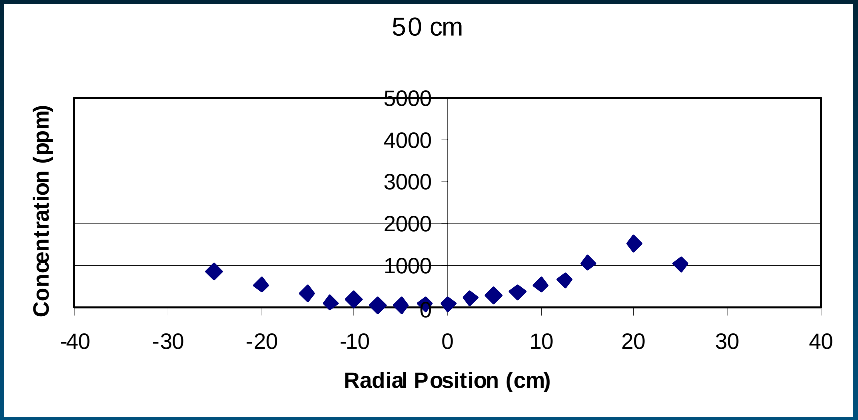
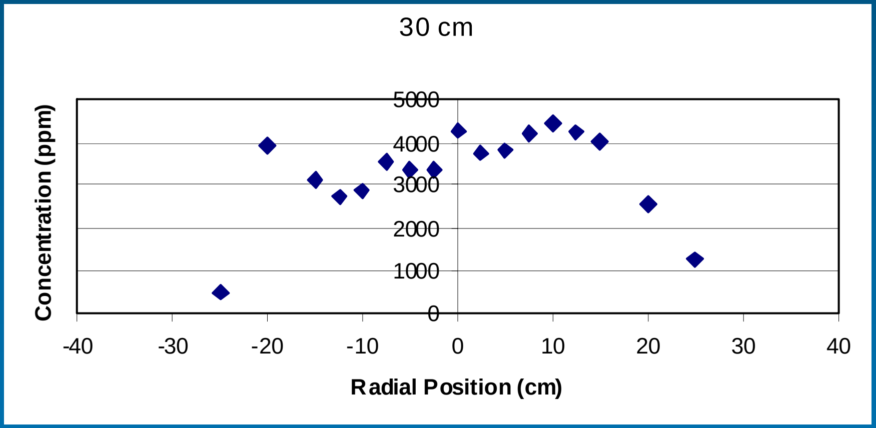
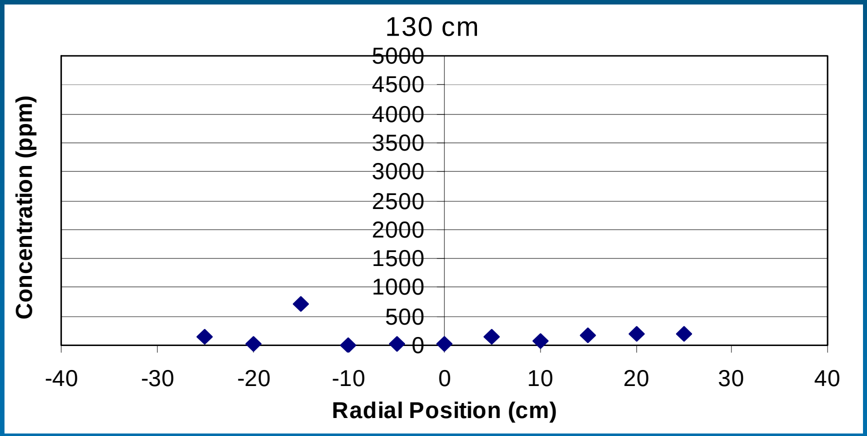
Results – Gas Sampling, NH_3









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Summary

Nitrogen is expected to evolve to NH_3 during biomass devolatilization while coal is thought to produce HCN

Existing kinetic mechanisms for NO formation appear to predict HCN to be more stable than NH_3, which seems inconsistent with full scale biomass combustion results where biomass is more likely to produce NO.

The BFR reactor is currently configured to burn biomass, coal or co-firing of biomass and coal

Initial sampling in the fuel rich region of the BFR shows significant amounts of NH_3 formation for Straw.

Species data collection for coal, biomass and co-firing are in progress.

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