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Turbulent Syngas Jet Flames in a Heated Coflow at Elevated Pressure

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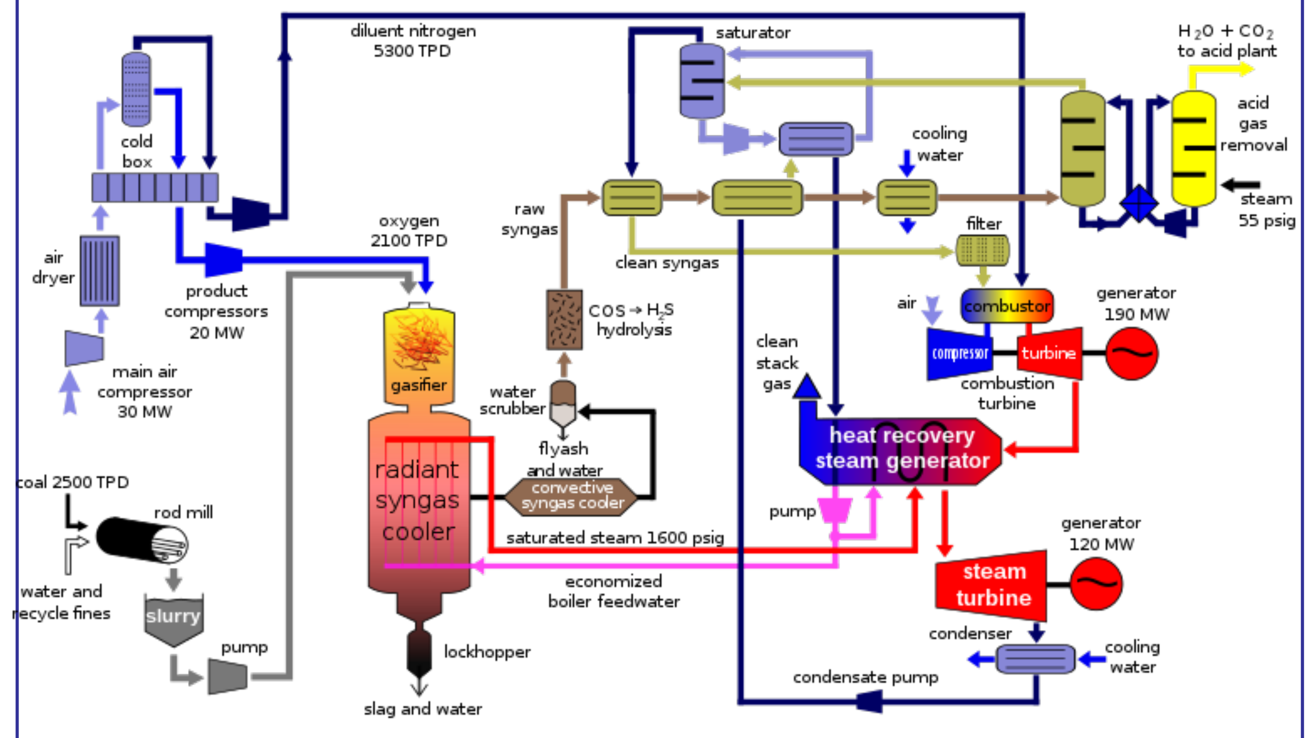
Introduction

- The transition to zero net carbon emissions is of the utmost importance to combat the future of global warming. This can be done by finding cleaner and renewable fuels that have very low carbon emissions associated with them. A promising technology is the Integrated Gasification Combined Cycle (IGCC), where coal and other biowaste material are gasified into Synthetic gas (Syngas). The IGCC has two main positive aspects; it can adapt to different types of liquid and solid fuels and can be coupled with Carbon Capture Storage (CCS) technology to reduce carbon emissions. The IGCC further boasts very high efficiency and low emissions compared to other counterparts. The syngas produced from the cycle mainly consists of Carbon monoxide (CO) and Hydrogen, with other smaller fractions of Nitrogen, Methane, Carbon dioxide, and Water.
- Syngas flames have been studied extensively in the literature due to their potential as an alternative fuel to traditional hydrocarbons such as natural gas. Fundamental, studies have been conducted on flame speed, ignition delay time, and chemical kinetics. Some work has been done at atmospheric conditions as well as high pressure for Syngas flames.
- No data exists for real combustor conditions at high pressure and preheated reactants for syngas.



Methodology

- The High Temperature and Pressure Duct is firstly demonstrated in this work. The HTPD is an 8-meter-long experimental rig in the high-pressure combustion lab shown in Figure 1. The burner used in this study is a simple jet in a hot coflow burner.

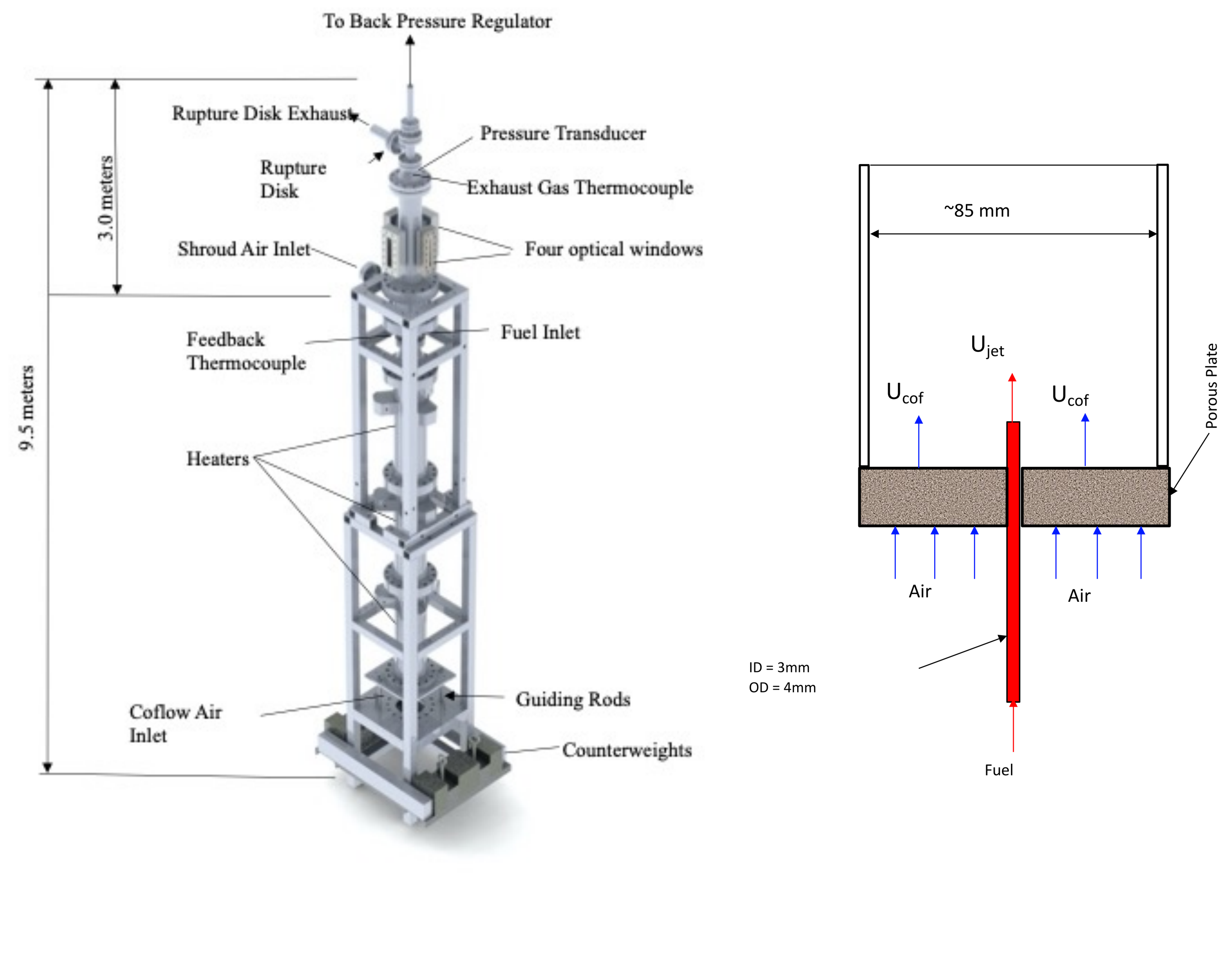
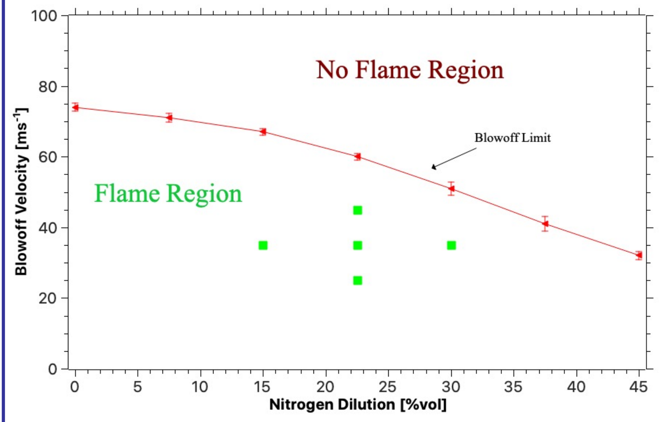


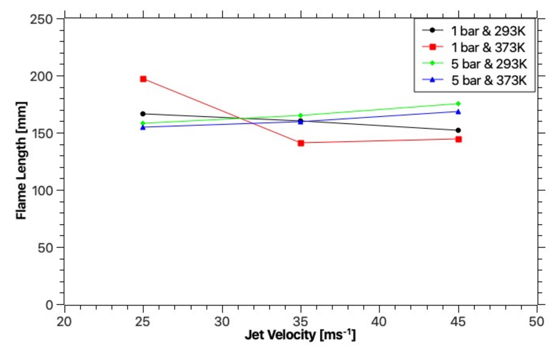
Figure 1. High Temperature and Pressure Duct 3D Rendering

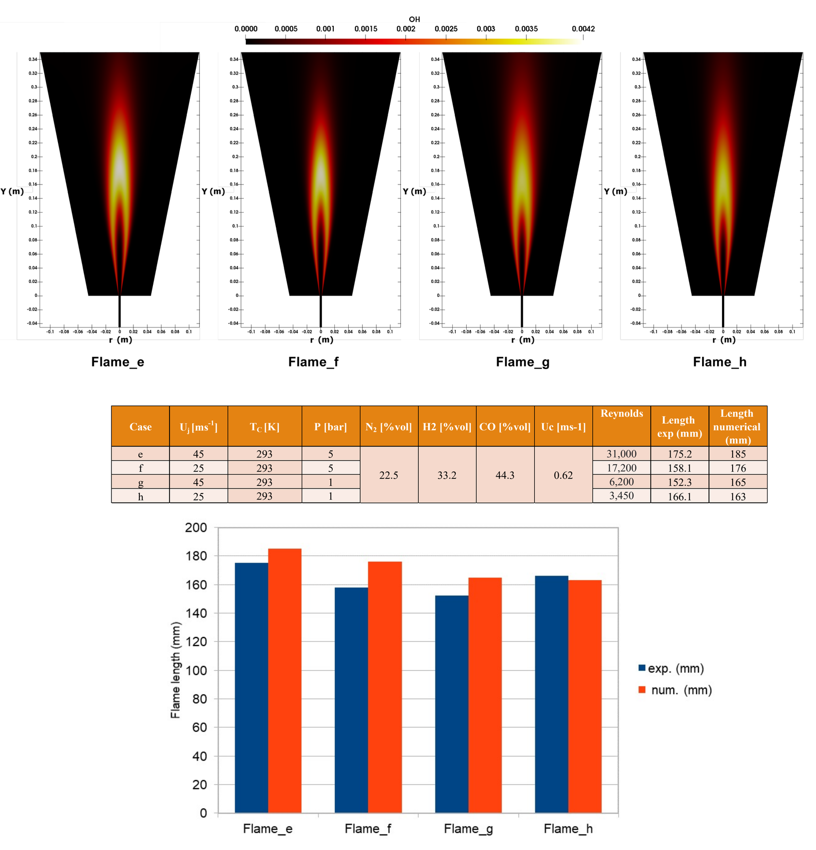
- In the first portion of the study, the fuel composition is varied from 0% to 45% Nitrogen dilution while gradually increasing the jet velocity to understand the stability of the flame with respect to nitrogen dilution, pressure, and coflow temperature.
- In the stable region, 5 flames are down-selected with varying jet velocity and nitrogen dilution at the four different environmental conditions (Atmospheric, High Pressure, Heated Coflow, and Combined) resulting in 20 different flames shown in the table below.

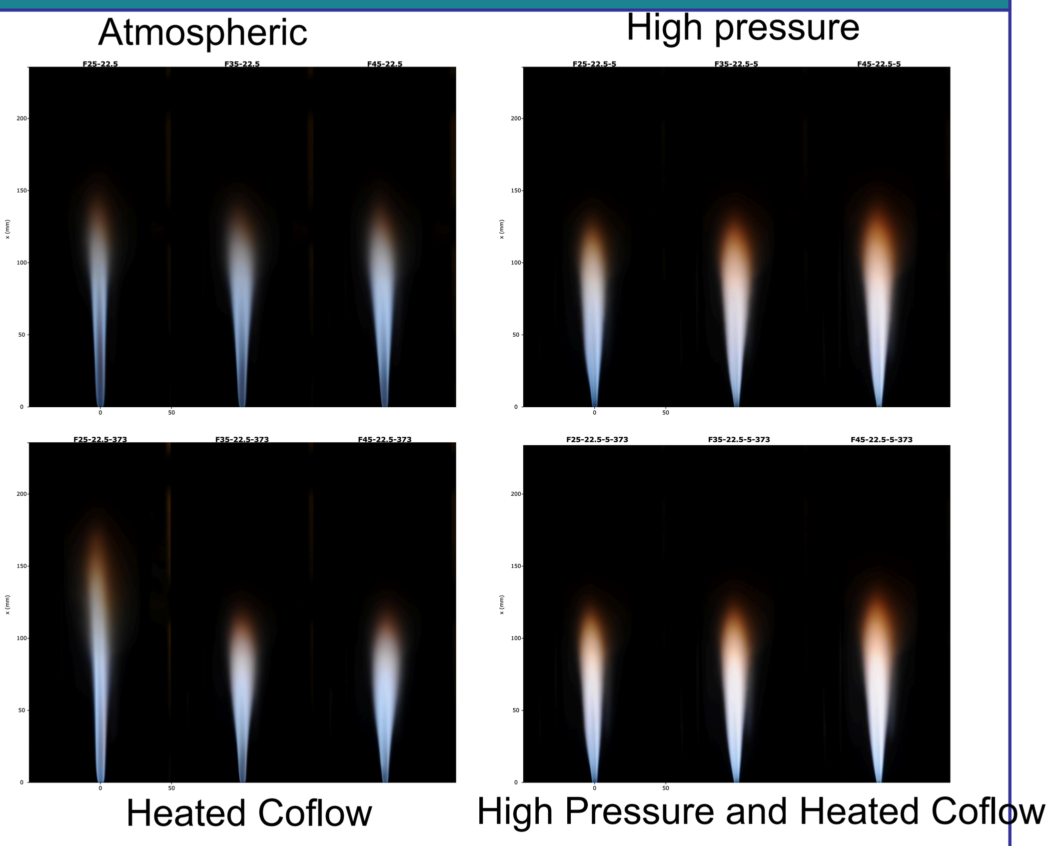
Case	P	T_c	U_j	N_2	Reynolds	U_c	Designation
Baseline	1	293	35	22.5	4,800	0.62	F35-22.5
Constant U_j	1	293	35	15	4,700	0.62	F35-15
	1	293	35	30	4,900	0.62	F35-30
	1	373	35	22.5	4,800	0.62	F35-22.5-373
	1	373	35	15	4,700	0.62	F35-15-373
	1	373	35	30	4,900	0.62	F35-30-373
	5	293	35	22.5	24000	0.62	F35-22.5-5
	5	293	35	15	23,500	0.62	F35-15-5
	5	293	35	30	24,600	0.62	F35-30-5
	5	373	35	22.5	24,000	0.62	F35-22.5-5-373
	5	373	35	15	23,500	0.62	F35-15-5-373
	5	373	35	30	24,600	0.62	F35-30-5-373
Constant N_2	1	293	45	22.5	6,200	0.62	F45-22.5
	1	293	25	22.5	3,450	0.62	F25-22.5
	1	373	45	22.5	6,200	0.62	F45-22.5-373
	1	373	25	22.5	3,450	0.62	F25-22.5-373
	5	293	45	22.5	31,000	0.62	F45-22.5-5
	5	293	25	22.5	17,200	0.62	F25-22.5-5
	5	373	45	22.5	31,000	0.62	F45-22.5-5-373
	5	373	25	22.5	17,200	0.62	F25-22.5-5-373

Results









Summary

- The first test of HTPD capability has been conducted.
- The temperature of the coflow and pressure have been observed to affect the flame length.
- Coflow temperature decreases flame length at significantly high Reynolds number, however at low Re flame length is increased.
- The stability of the flame is not affected by the pressure and temperature. Increasing the nitrogen dilution leads to a nonmonotonic decrease in jet blow-off velocity.
- Initial simulations show a similar flame length to experimental results with around ~10% deviation at maximum.

Ongoing Work

- OH* measurements are currently being conducted to accurately measure the flame length.
- Flame structure measurements using OH-PLIF are currently being done to investigate the effect of pressure and temperature on the flame.
- Further simulations are being conducted for the remaining cases.