Transforming Fossil Fuels into Heat or Hydrogen: preliminary experimental study of methane decarbonization using a laminar premixed flame.

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BACKGROUND

Greenhouse gases, in particular CO_2, are the main cause of climate change. This project was motivated by finding an alternative way of using natural gas to produce heat for industrial facilities with reduced CO_2 production. The main purpose of this project was to investigate pyrolysis of natural gas with a medium-scale set-up (8 kw). Natural gas can be decomposed into hydrogen and carbon black at high temperatures. Hydrogen can be used as a clean fuel and carbon black is a valuable raw material for many industries such as tire, rubber, ink and pigments.

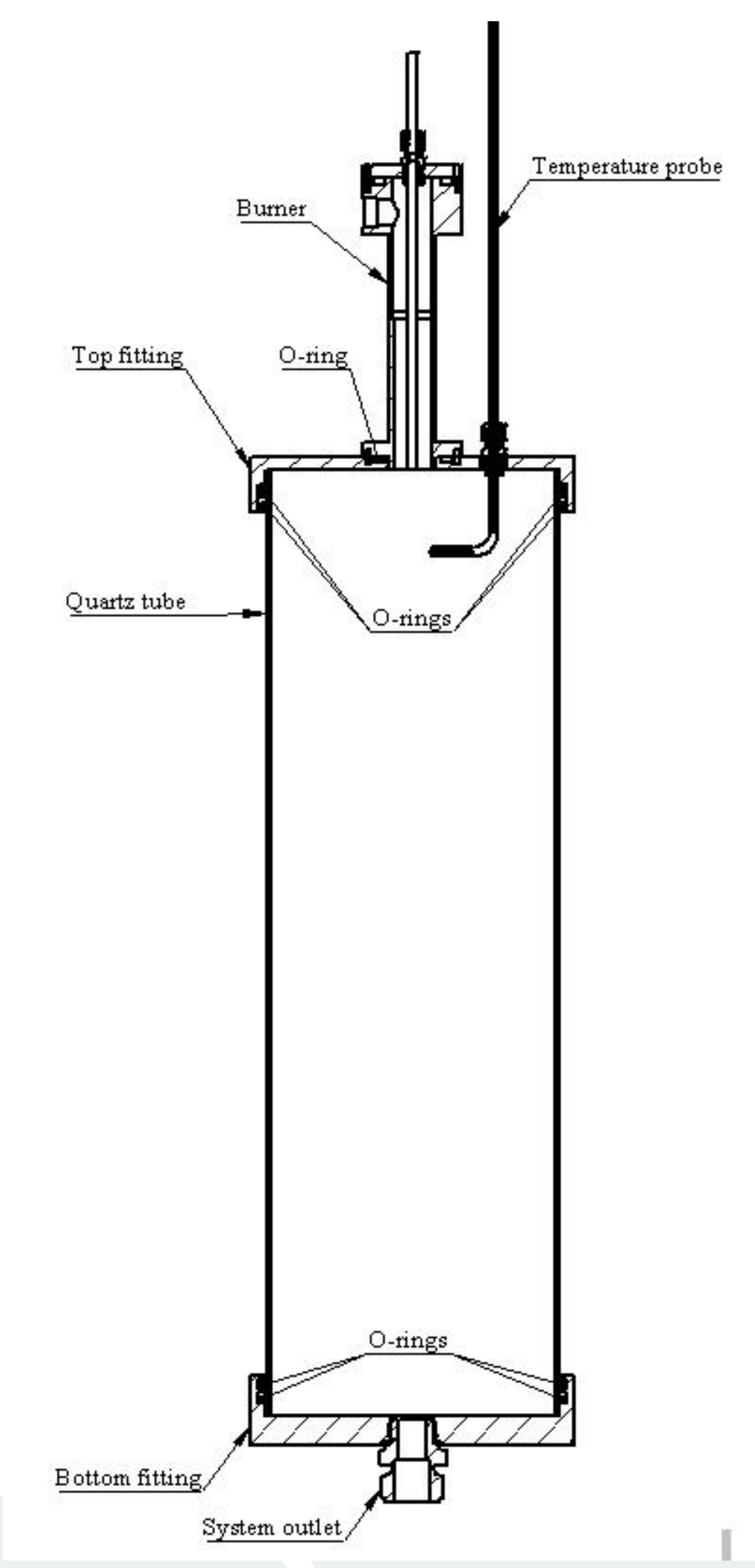

Figure 1. Experimental Set-up drawing with details

PROJECT OVERVIEW

Experimental set-up and results:

A burner was designed to provide an inverted laminar premixed flame within a cylindrical quartz tube of 68 cm length and 20 cm diameter that is closed at both ends other than for inflows for the flame and the methane to be decomposed, and an outflow for the products formed. The quartz chamber is filled with circular blocks made of alumina silicate ceramic as insulators , these blocks have OD of 19.8 cm and ID of 4 cm. Propane fuel with a flow rate of 1.370 slpm and air with flow rate of 35.0 slpm were mixed in a static mixer to form the premixed flame, and methane co-flow of various flow rates from 0 to 5 slpm was introduced after the flame to be decarbonized.

The concentration of each component at the exhaust was measured by a gas chromatography analyzer (Agilent GC 7890b model). For stoichiometric flame, different methane flow rate (0 to 5 lpm)was introduced into the system and results are shown in Fig. 3.

Carbon particulates are sampled with a preheated nitrogen dilution system, and the size distribution of particles formed by pyrolysis is measured by a scanning mobility particle sizer (SMPS). Dilution ratio is calculated using simultaneously measured CO2 concentrations in exhaust products and diluted samples. Particle size distribution of generated particles are shown in Fig. 4.

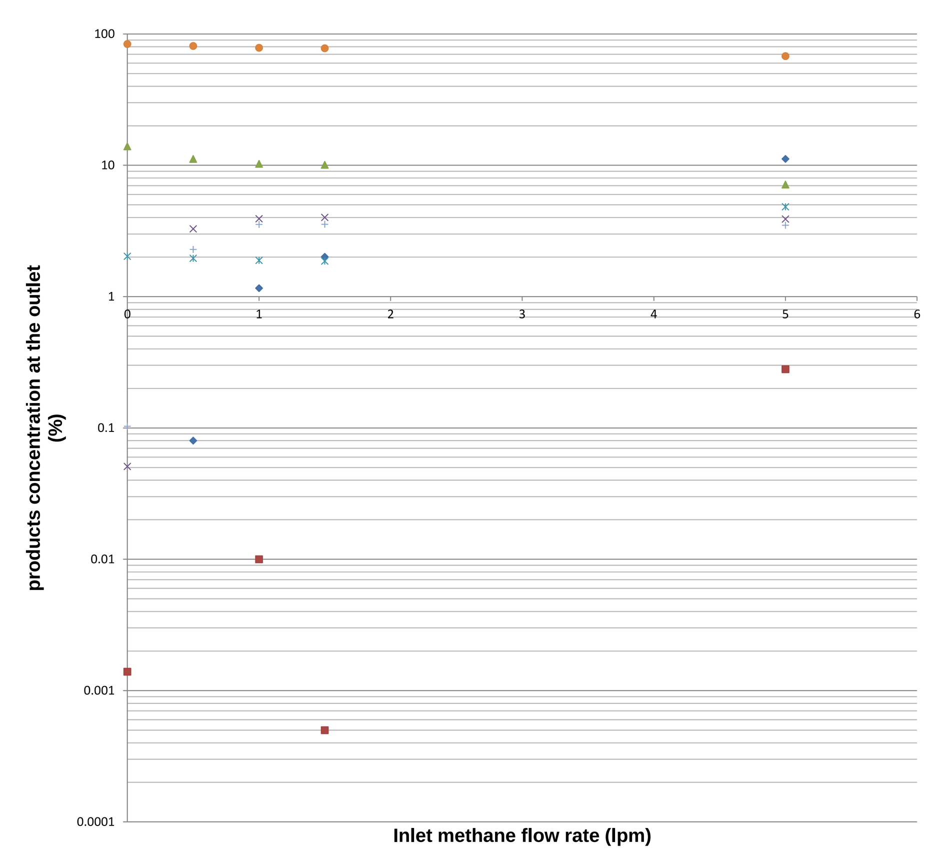

Figure 3. Products concentration (%) for various methane flow rates (lpm)

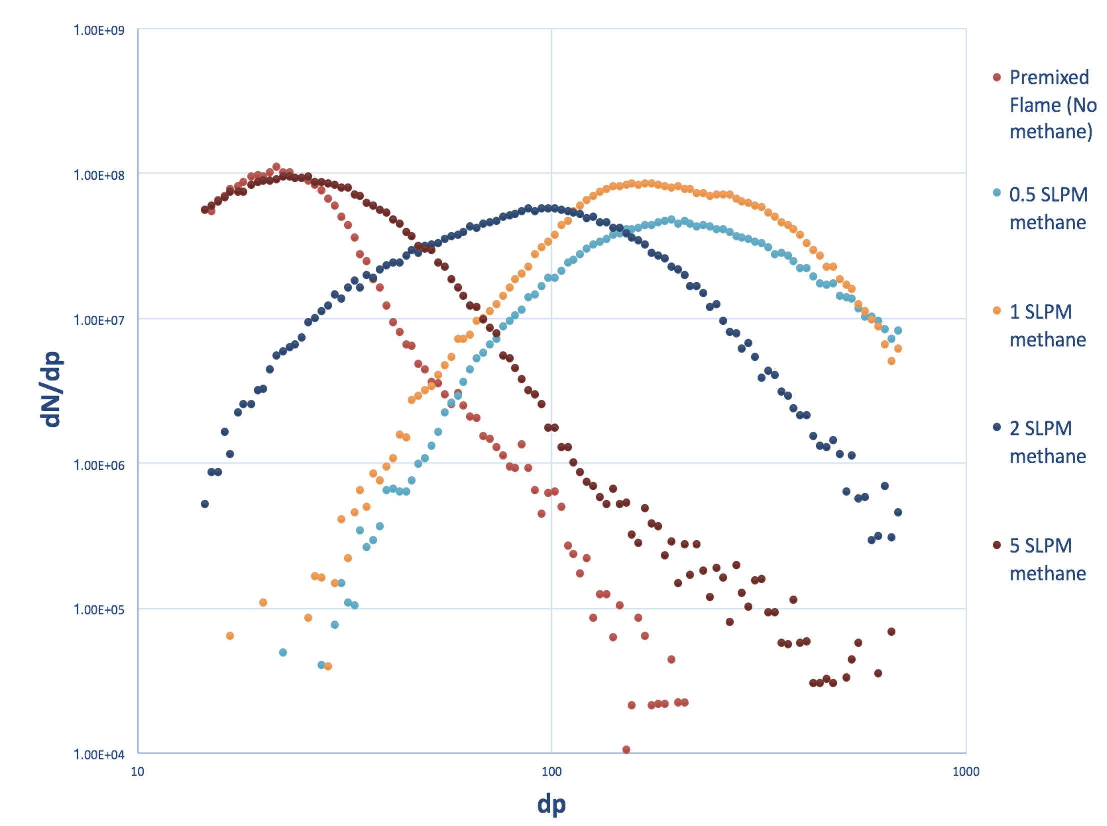

Figure 4. Particle size distribution with different methane flow rates (0.5 – 12 SLPM)

THEME OVERVIEW

Carbon Capture, Utilization & Storage

Hydrocarbons will continue to serve as an essential energy source while the world transitions to a lower-carbon energy economy, but can we prevent the use of those fuels from contributing to the accumulation of CO2 in the atmosphere? Existing technologies can capture carbon, but these methods can be costly and energy-intensive. Extracting energy without burning fuels, improving CO2 capture efficiencies if they are burned, and finding effective ways to store or reuse captured carbon may be essential to ensuring it does not enter the atmosphere.

SHORT-TERM OBJECTIVES

The goal of this study was to establish an experimental model to investigate methane pyrolysis using an inverted premixed flame for the first time. A set-up was designed to provide a flow of methane through an inverted laminar premixed flame inside an enclosed oxygen free environment and observe and measure the conversion of methane into hydrogen and carbon black. Another goal of the project is characterizing the produced carbon black and investigating the effects of temperature and residence time on conversion rate and carbon black characteristics.

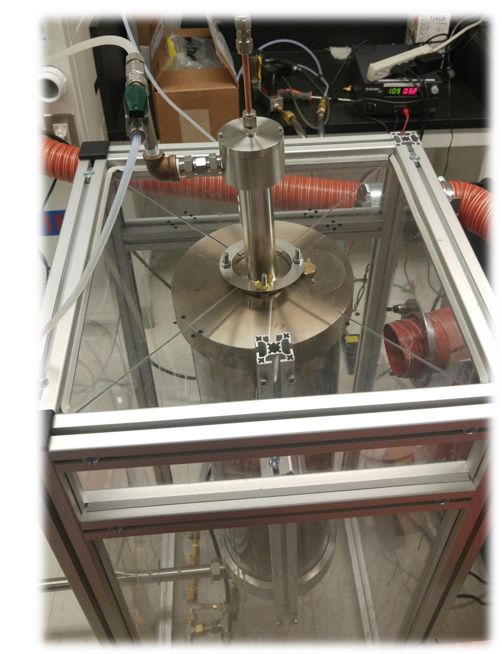

Figure 2. Experimental Set-up

OUTCOMES

i. Temperatures inside the quartz chamber was measured by a K type thermocouple for different points, result shows that after introducing methane a small region around the flame has temperatures over 1100 ºC.

ii. Increasing the pyrolysis temperature lead to higher conversion rates. This happened after adding insulation blocks into the system.

iii. Increasing methane flow rate at the inlet for flow rates over 1 lpm won't have a significant effect of methane conversion into hydrogen.

iv. Increasing methane flow rate would increase CO concentration and reduce CO2 concentration, as the methane breaks the bonds of CO2 molecules and free an oxygen atom and turns CO2 molecule into CO.

v. Median size of carbon particles is highly affected by methane flow rate.

vi. Methane flow rates of 0.5 and 1 SLPM are more suitable for generating larger carbon particles.

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