Cool Diffusion Flames and Their Applications on Earth

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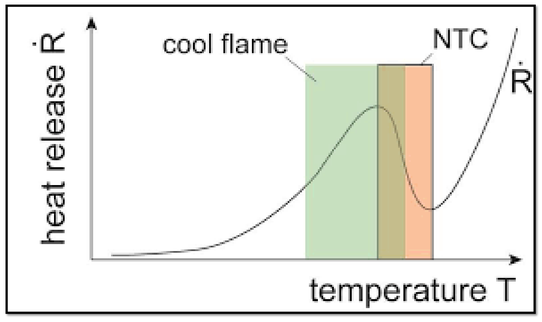
Motivation:

- Cool diffusion flames are a type of diffusion flame that burns at a peak temperature of around 700 K
- These flames are unique because of their low peak temperature and the fact that heat release rate decreases as temperature increases, leading to a Negative Temperature Coefficient (NTC) region.
- Cool flames can possibly be applied to gasoline engines to make them more efficient
- More research on the chemistry of cool flames can help improve the models that use cool flames in these emerging engine technologies

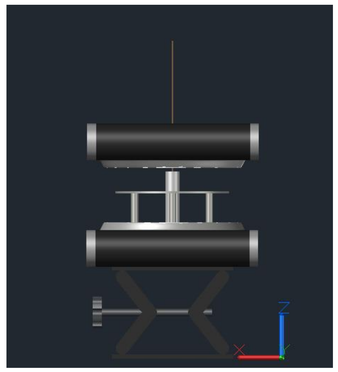


Methods:

January-May 2023: Optimization

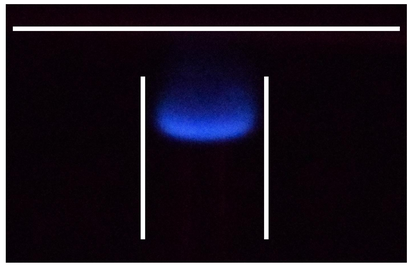
- Utilized 2 grams of 5 different hydrocarbons (pentane, hexane, heptane, decane, dodecane) in each test
- Goal of getting the most stable burning cool flame as possible for future testing
- Tests were performed on a dual hot plate setup in which the bottom hot plate was heated near the boiling point of each hydrocarbon, and the top hot plate was heated to around 400-420 °C
- Thermocouples attached to the top and bottom hot plate as well as one that could be manually lowered into the flame were used to measure key temperatures
- An intensified camera was used to monitor flame movement during testing, and a DSLR camera for clean pictures

AutoCAD Drawing of Dual Hot Plate Apparatus Used in Testing



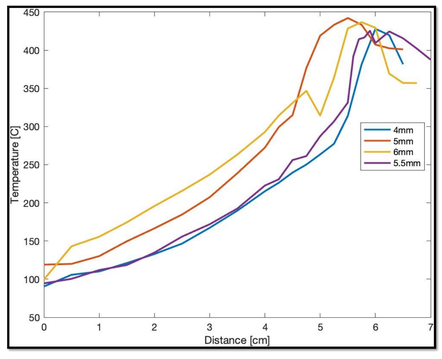
Model created by graduate student Zilin Zhang

Heptane Cool Flame Image, Burning Inside the Test Tube

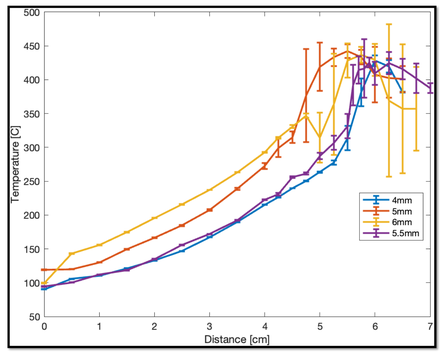


White lines signify boundaries of the tube and upper hot plate

Heptane: Gap Size Effects on Temperature Distribution Throughout Test Tube (No Error Bars)

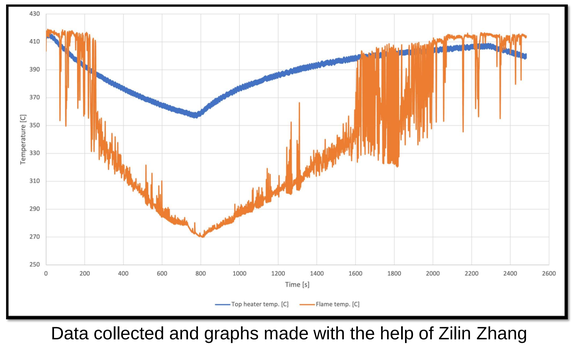


Heptane: Gap Size Effects on Temperature Distribution Throughout Test Tube (Including Error Bars)



* Legend represents gap size between the top of the tube and top hot plate

Heptane: Temperature of Upper Hot Plate and Flame Temp. Vs. Time



Data collected and graphs made with the help of Zilin Zhang

Methods (continued):

August-December 2023: Extinction, Ignition, Temperature Change, and Gap Testing

- Focused solely on heptane (experimentally produced the most stable flame) to study the effect of changing gap sizes between the tube and upper hot plate on flame stability and temperature
- When the flames stabilized, the thermocouple was lowered to the bottom of the tube, and average temperatures over 5 second intervals were taken at intervals of .5 or .25 cm starting at the top of the fuel pool
- Also tested when extinction/ignition of a heptane cool flame would occur based on the temperature of the upper hot plate by slowly lowering and raising its temperature until extinction and ignition occurred.

Results:

- Heptane flames at a bottom hot plate temperature of 105-110 °C proved to be the most stable of the fuels, with little vertical movement once ignited
- Decane and Dodecane flames proved relatively stable, with slightly more vertical movement than heptane flames.
- Pentane and hexane fuels proved the least stable due to their low boiling points
- Gap sizes of 5 and 5.5 mm proved to be the best for flame stability and testing efficiency. Gap sizes of 6 mm and above had too much flame movement, while gap sizes of 4 mm and below ignited much more slowly
- Heptane cool flames with a gap size of 5 mm tend to start the extinction/ignition process at around 400 °C

Future:

- Obtaining similar data on extinction, ignition, temperature change, and gap size for other hydrocarbons as done for heptane
- Improving image quality for even clearer pictures of cool flames
- Various other possible tests with heptane
  - Increased heating of top plate
  - Minimum and maximum gap size possible for cool flame ignition
  - Improved accuracy/more trials of previously done tests