Flame Height and Heat Release Rates at Ignition Phase

Andrew Cilento (Chemistry ’18), Dr. Nicole Eyet, Dr. William Ryerson

Introduction:

- Fire is considered to be unpredictable, which can prove problematic for fire/arson investigations
- Heat can transfer through three major ways, conduction, convection, and radiation
- Oxygen flow can be restricted to a fire when a flame is placed against a wall or in a corner
- Environmental conditions like humidity, wind gusts, and temperature impact fires
- Fire is controlled predominantly by the fire triangle: oxygen, fuel, and heat
- This is an investigation on how fire behaves in its early stages and how different factors impact the height of the flame

Experimental:

- Pools of acetone were placed in small crucibles and were lit in different corner angles: 90°, 135°, and 180°, and different environmental conditions 3°C, 12°C, 19°C
- This was done five times for each angle
- During the first minute of ignition phase, a camera captured the whole crucible and the height of the flames
- For the Heskestad equation: A crucible filled with acetone was placed on a scale attached to a Vernier device, and the acetone was ignited, the loss was mass was measured due to burning

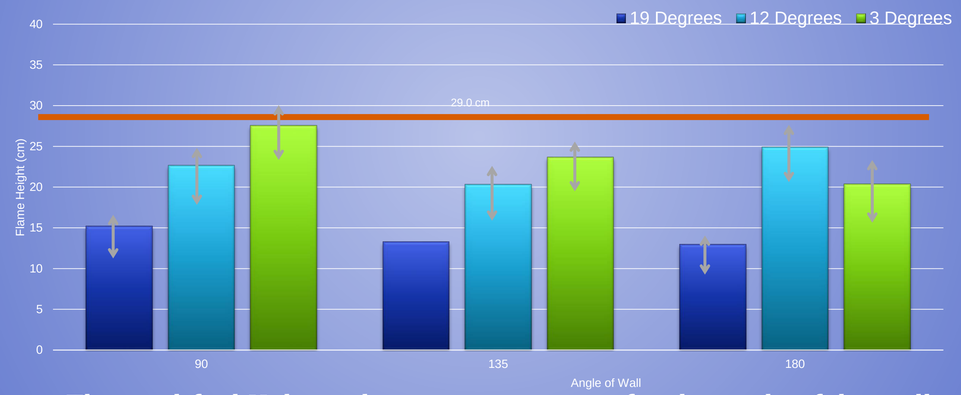
Acknowledgements:

- I would like to thank Dr. Eyet and Dr. Ryerson for their help, support, and use of their cameras,
- I would also like to thank Douglas Brown for the free usage of his tracker software

Results:

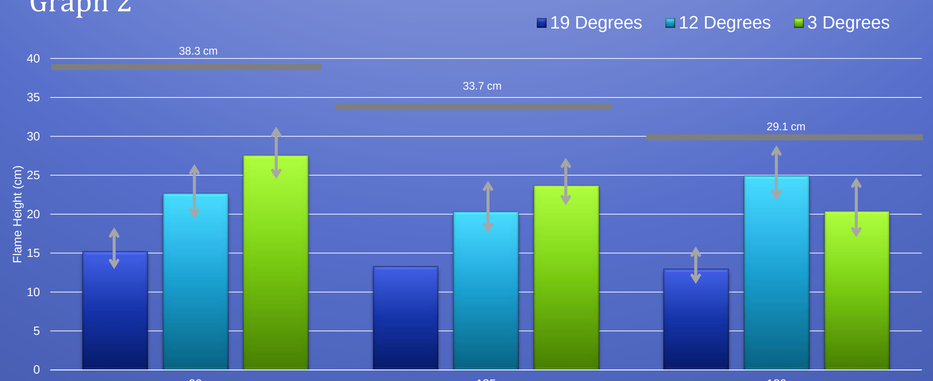
- The Heskestad equation is used to predict the flame heights at ignition phase based on the size of the pool of acetone
- Z_f=$0.23Q^{2/5}$−$1.02D$
- Z_f = visible flame height (m)
- Q = heat release rate (kW)
- D = diameter of the pool (m)
- The data collected from all the data points of the flame heights for the different angles on the different with the Heskestad equation are found on Graph 1

Graph 1



- The modified Hekestad equation accounts for the angle of the wall that the pool of acetone was placed next to
- Graph 2 includes the same data collected however it is compared to the modified Heskestad equation
- Z_f=$0.17(kQ)^{2/5}$

Graph 2



Discussion and Error Consideration:

- Each of the trials contains at least 500 data points of the flame heights measured from Tracker from 5 trials for each angle and ambient temperature
- Based on the two graphs, the unmodified Heskestad equation seems to fit the data more closely
- There is a trend that the colder the weather, the higher the flame heights during ignition phase are
- There is another trend that smaller the angle of the corner, the higher the flame height appears to be
- All of the values are lower with the modified equation and only one value overlaps with the unmodified equation
- Standard errors are included in the graphs
- Acetone pool size and mineral fiber boards were kept constant
- Wind gusts and other weather factors may have added to error
- Human error in calibration of Tracker software was determined to be ±0.5 cm

References:

1. Office of Justice Programs. A Guide for Investigating Fire and Arson. https://www.nij.gov/topics/law-enforcement/investigations/crime-scene/guides/fire-arson/Pages/welcome.aspx (accessed 11/25/2017).
2. DeHaan, J. D., *Kirk's Fire Investigation*. Sixth Edition ed.; Julie Levin Alexander: Upper Saddle River, New Jersey, 2007.
3. Bonsor, K. Weather's Role in Wildfires. https://science.howstuffworks.com/nature/natural-disasters/wildfire2.htm (accessed 11/25/17).
4. Stratton, B. J. Determining Flame Height And Flame Pulsation Frequency And Estimating Heat Release Rate From 3D Flame Reconstruction University of Canterbury, Christchurch, New Zealand, 2005.