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Characterization of Emissions of Wax-Based Products During Combustion

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Characterization of E3 Additive Performance in Surrogate Petroleum Products

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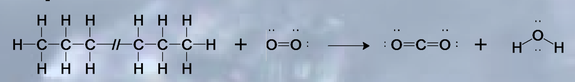
E3 Fuels

- E3 Fuels is a Boise based company that has developed an additive that reduces emissions during combustion of fossil fuels
  - These emissions have immediate and long-term negative effects on environmental and human health
  - Their proprietary formula is claimed to:
    - Be biodegradable, renewable, and sustainable
    - Reduce particulate emissions by 98%
    - Increase fuel efficiency 10-24%
- Preliminary testing of additive performance in wax-based products looks promising

Hydrocarbon Combustion

Propane Flame (C_3H_8)

Complete:



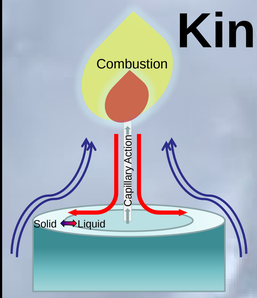
Incomplete:

Paraffin Flame (C_nH_{2n+2}) n = 19-35

- Longer hydrocarbon chains cause other by-products
- These emissions cause a rise of indoor pollutants[1]
- Symptoms associated with indoor air quality are the number one environmental health issue doctors face[2]

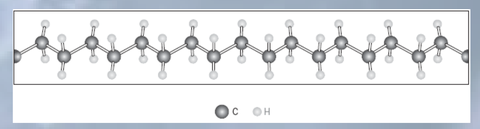
1: Pagels, J., et al., *Chemical composition and mass emission factors of candle smoke particles.* Journal of Aerosol Science, 2009. **40**(3): p. 193-208.
2: Jones, A.P., *Indoor air quality and health.* Atmospheric Environment, 1999. **33**(28): p. 4535-4564.

Kinetics of Candles



- Paraffin is the widest used product in candle making in the US.
- Paraffin is a hydrocarbon chain with the formula of:

$$C_nH_{n+2},\ n = 19\text{-}36$$



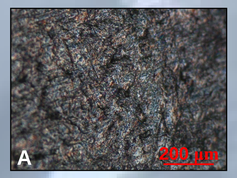
Candle Manufacturing

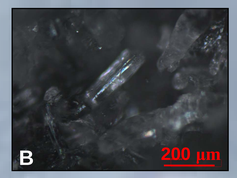
- Pillar candles, dimension 38 x 50 mm
- HTP-31 cotton wicks protruding 13 mm
- Paraffin wax (CAS 8002-74-2)
- Wax was heated to a pouring temperature of 80 C
- Additive was mixed and immediately poured into molds

Particulate Emissions Testing

- Emissions collection hood, left, utilizes a vacuum system to draw emission through a Whatman GF/C 1.7 µm glass microfibre filter.
- The mass of the filter was obtained before and after the experiment to 10 µg.
- 5 g of paraffin was combusted during each test.

Microstructure

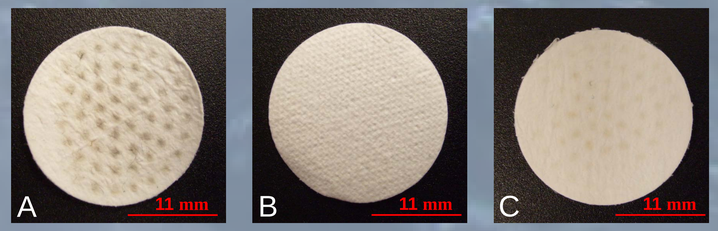




- Figure A:
  - Pure Paraffin
  - Amorphous
- Figure B:
  - 128:2.5 (Paraffin to E3)
  - Crystalline

- Two unique microstructures were observed in the paraffin: amorphous and crystalline.
  - Pure paraffin and the 118:1 ratio exhibited amorphous structure.
  - Large ratios of E3 became a catalyst for crystallization. The driving force of this reaction is unknown.
  - All higher ratios showed crystalline structures which severely deteriorated the mechanical properties of the paraffin.

Particulate Emissions



- Additive could decrease the size of particulates to smaller than 1.7 µm. This could be the reason for no measureable mass change in filters B and C.

Filter	Paraffin to Additive Ratio	Mass Change	Spots
A	118:0	+1.3%	dark black
B	118:1	none	none
C	118:20	none	light burnt orange

Conclusions

- Additive shows a visual reduction in particulate emissions
- Preliminary results show a reduction in particulates greater than PM 1.7
- Small concentrations of E3 exhibit reductions in particulate concentrations
- Successful proof of reduced emissions will result in a decrease in the negative effects candles have on indoor air quality

Future Work

- Obtain additional data on particulate mass during combustion. This will be completed using both previous method and additional instrumentation that give particulate counts and gas emission data.
- Statistical analysis of particulate mass gain in vacuum hood.
- Capture and analysis of gaseous emissions.