Cooking Without Gas

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Introduction

Many consumers prefer the performance of gas ranges over electric stoves because of the short time it takes to heat cookware. We were tasked to develop an electrically powered convective stove that performs similar to a gas range for consumers that are currently restricted to the use of an electric stove.

Goal

Develop and design a cooking system that utilizes superheated air to cook food. The cooking performance and specifications needed to match, or out-perform, a conventional gas stove.

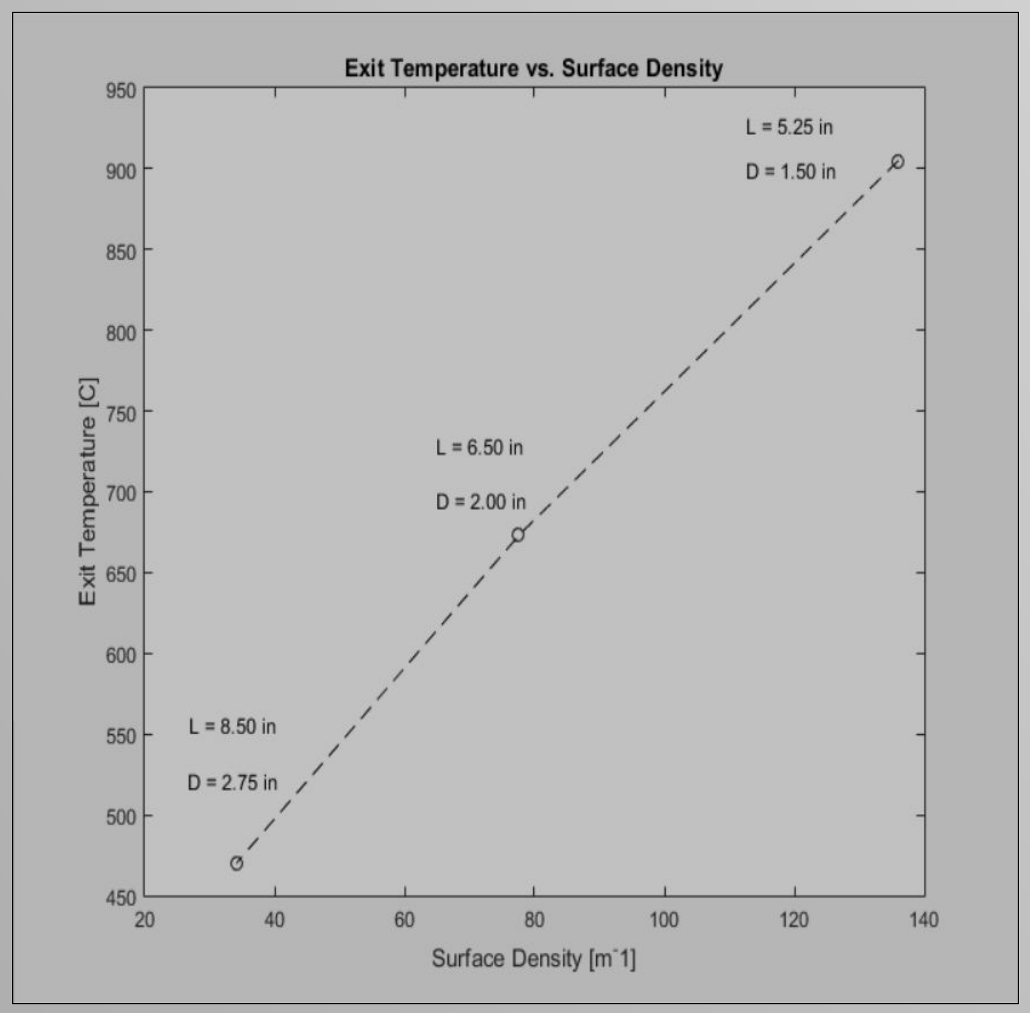
In order to reach that goal:

- Superheat air to approximately 1000 ℃
- Boil water within a similar amount of time as a gas stove (~6 minutes)
- Aesthetically resemble a conventional gas cooktop and include safety features (i.e. LED lights indicating the stove is turned on)

Analytical Model

The Log-Mean Temperature Difference method was used to calculate key design features, such as optimal tube length and inner diameter.

The exit temperature was measured as a function of surface density, which is defined as the ratio of volume of air to heating coil surface area.



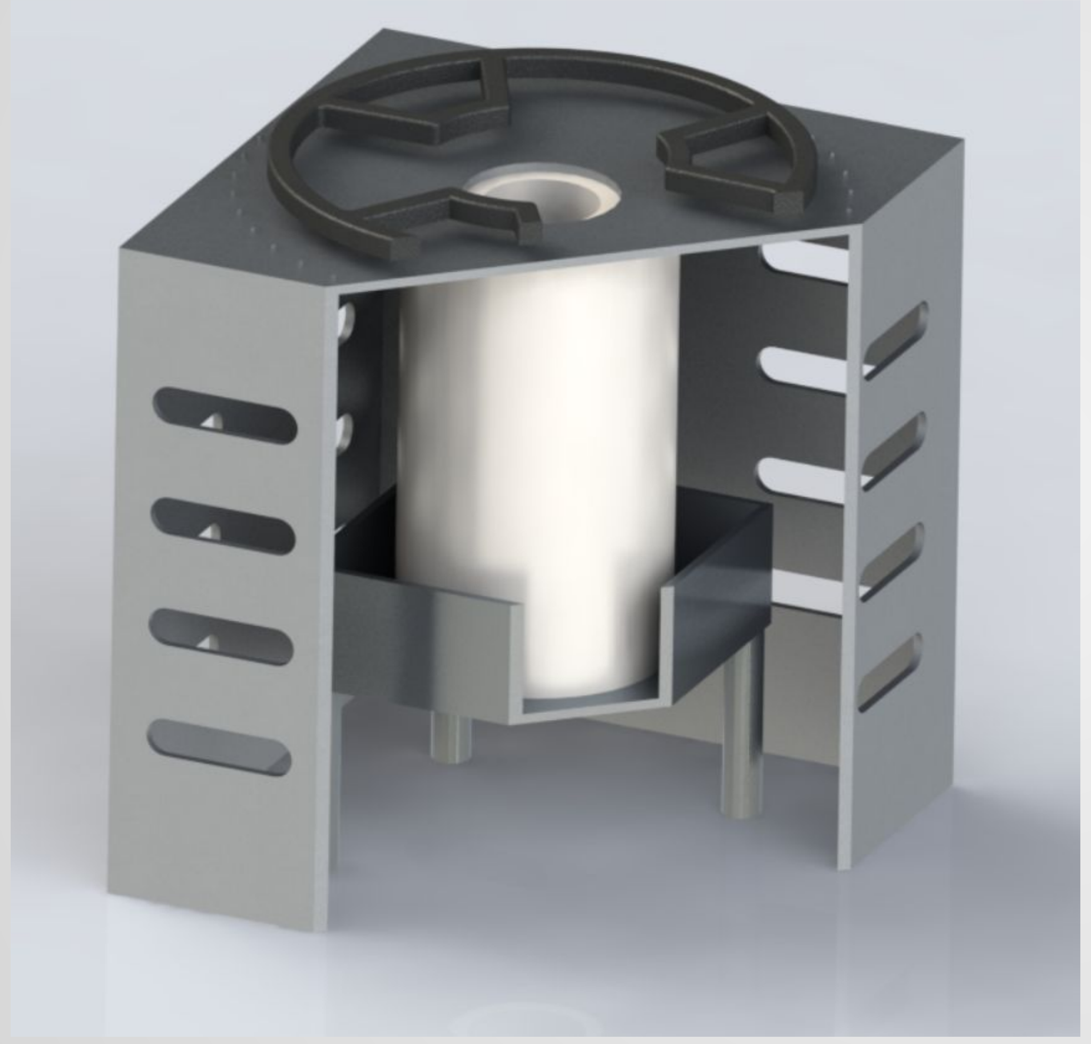
Plot illustrating the relationship between surface density and exit temperature.

Design

All key dimensions and design aspects of the superheated cooktop were determined using the analytical model. For simplicity, the design only incorporates one cooktop, instead of the usual four-top of conventional ranges.

The stove design consists of the following components:

- Firebrick chimney with an inner diameter of 1.5 inches and a length of 5.25 inches
- Two, 24 gauge, high resistance nichrome wires
- Ceramic core to support coiled nichrome
- 240 V power source and variable transformer
- 240 V, AC fan rated for .99 W



Housing for the firebrick tube, electrical system, and heating element.

Firebrick chimney used to insulate the heating element.

The heating element design which consists of two, 24-gauge nichrome wires coiled in a helical pattern around a ceramic core.

Results

	Design Dimensions: D_{inner} = 1.50 inches, L = 5.25 inches					
Voltage Input (V)	120	144	168	192	216	240
Air Temperature (°C)	446	532	630	750	813	852
Air Temp. with Fan (°C)	430	536	618	721	834	912

The table illustrates the tube design reached higher temperatures once airflow was included.

Coil Length (m)	Resistance (Ω)	Current (A)	Voltage output (V)	Power per Coil (W)
6.60	38.30	5.63	120	375.98
		6.75	144	541.41
		7.88	168	736.92
		9.00	192	962.51
		10.13	216	1218.17
		11.25	240	1503.92

The table displays the resistance, current, voltage output, and power input of the system.

Fixed Variables	Water temperature (° C)	Time (min)
Voltage output = 95% (228 Volts); Air speed = 4.4 m/s; Volume of water = 500 ml	50	3:56
	60	5:25
	70	7:06
	80	8:52
	90	10:34
	95	12:31

Time to reach given water temperatures. Water begins to boil at 94.44 °C in Salt Lake City, UT (4300 ft).

Conclusion

The directed hot air flow produced by this device is able to boil water, but not in a comparable time to a gas stove. The output air reached a maximum temperature of 912 °C and boiled water in ~12 minutes, as compared to a gas stove being able to boil water in half that time. Due to the materials used, we were 78 °C short of meeting the 1000 °C specification. Theoretically, we would be able to match the performance of a gas stove with higher output air temperatures. This design may be improved by using tungsten wire, which has a melting temperature of 3422 °C (nichrome: ~1400 °C), but would require an oxygen barrier to prevent oxidation.