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Electric Field Effect on Pollutant Production for Industrial Combustion Application

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Extended Abstract

Combustion of hydrocarbons produce ions through well-known chemi-ionization mechanisms [1, 2]. Ion production occurs predominately within the hottest zones of the flame, the flame front. When an external electric field is applied to a flame, free electrons are rapidly directed towards the anode leaving behind a positive space charge due to positive ions. This is because positive ions are slower to respond compared to the electrons due to their higher relative mass. Electron-neutral collisions can lead to vibrational excitation and ionization at higher electric field strengths [3, 4]. As the positive ions move toward the cathode, they can obtain velocities between 50-100 m/s, depending on the field strength. Ion-neutral collisions can induce stagnation points and/or neutral velocities on the order of a about 5 m/s [5]. These effects can lead to increased mixing particularly from the flame front. Depending on the geometry and arrangement of the electrodes the combustion efficiency, pollutant production, and heat transfer can all be controlled due to these mechanisms.

The objective of this research is to study electrical effects on industrial relevant flames. Electrical aspects of flames have been studied in laboratories for more than a century [6]. Observations have shown that electric fields can alter the flame speed, increase stability, increase heat transfer, reduce pollutants, and increase combustion efficiencies. However, the prospect for industrial application remains uncertain. Industrial flames are significantly different then the open-air, benchtop flames that are typically studied. Industrial flames are produced within furnaces creating much hotter environments (550^{o}C - 1100^{o}C) and operate at higher firing rates (100 kW – 50,000 kW). The hotter environment can drastically alter transport properties which should change these electrical effects and large-scale flames require much higher applied voltages. Hotter environments and larger flames have not yet been studied with externally applied electric fields. This preliminary work focuses on studying in-furnace electric field effects on small flames (5-15 kW) but in hotter environments (550^{o}C-1100^{o}C). Later work will focus on scaling to larger flames but will not be presented here.

Two different electrode geometries were studied in a specially designed, electrically isolated furnace. The first geometry consists of one electrode protruding into the flame and the burner nozzle acting as the other electrode. When an electric field is present the flame becomes significantly more luminous, the production of CO decreases with increasing corrected NOx. Furthermore, the temperature of the exhaust decreases, and the flame zone becomes hotter. Highspeed video was used to capture the changes of the flame as the voltage is applied. The second electrode geometry utilizes the nozzle as one electrode and a second electrode just past, but not touching, the flame. When an electric field is applied using this geometry, the NOx is seen to decrease while the CO increases. The temperature becomes hotter in the flame zone and the exhaust temperature decreases. These effects were studied over many equivalence ratios using propane as a fuel.

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