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A Study of Radiative Flameless Combustion in a Furnace

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ABSTRACT

In this work radiative flameless combustion (RFC) was investigated experimentally, by Chemkin calculations, and an analytical model with radiation was developed to determine the dimensionless parameter space where RFC is possible.

The experimental results show ultra-low NO, CO and THC and also show that UV emission corresponding to OH is considerably reduced in flameless combustion. This is confirmed by Chemkin calculations. Both the experimental and Chemkin results show that increasing the preheat temperature for the same recirculation rate changes flameless to flaming combustion, indicating more complex requirements for flameless combustion.

This led to the development of the analytical model where both steady-state and transient solutions were obtained in the optically thin limit by noting that: (i) nearly isothermal environment is associated with flameless combustion, and (ii) the chemical reaction must be spread out over the largest possible length scale, i.e. $(D_\infty/\alpha_o)^{1/2}$. These hypotheses are consistent with Chemkin calculations. The steady state solutions established the boundaries in the parameter space within which RFC is possible.

Three important non-dimensional parameters were found: (i) The Boltzmann number $'\mathfrak{B}'$; (ii) The Damkohler number $'A'$, and (iii) The dimensionless Arrhenius factor $'\beta'$. These, in addition to the equivalence ratio $'\phi'$, define the parameter space for RFC. It was also found that the Damkohler number must be small for flameless combustion to be possible and that the Boltzmann number expands the flameless combustion domain. Available experimental data agrees with this analysis.

Keywords: Flameless Combustion, Radiation, Furnaces, Model