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Thermal analysis of an enriched flame incinerator for aqueous residues

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Abstract

The use of oxygen to enrich the combustion air can be an attractive technique to increase capacity of an incinerator originally designed to operate with air. If incinerator parameters such as operation temperature, turbulence level and residence time are fixed for a certain fuel supply rate, it is possible to increase the residue consumption rate using enriched air. This paper presents the thermal analysis for operation with enriched air of an aqueous residue experimental incinerator. The auxiliary fuel was diesel oil. The theoretical results showed that there is a considerable increase in the incineration ratio up to approximately 50% of O_2 in the oxidiser. The tendency was confirmed experimentally. Thermal analysis was demonstrated to be an important tool to predict possible incinerator capacity increase.

1. Introduction

The insertion of oxygen in the combustion air can be an attractive means of increasing incineration rates of a system originally designed to operate with air [1–3]. Nitrogen present in air is an inert gas,

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Nomenclature

a	number of moles of pure oxygen
b	normalised oxidant excess
c	number of moles of residue
C_i	pressure correction factor for the *i*th gas component, non dimensional
Cp_j	specific heat of the *j*th component, kcal kmol^{-1} K^{-1}
CV	control volume
D	chamber diameter, m
$h^0_{\mathrm{f}i}$	enthalpy of formation of the *i*th component, kcal kmol^{-1}
h_L	water latent heat of vaporisation, kcal kmol^{-1}
H_P	enthalpy of combustion products, kcal
H_R	enthalpy of reactants; kcal
l_b	mean beam length, m
LHV	fuel low heat value; kcal kmol^{-1}
M	gas average molecular weight, kg kmol^{-1}
$\dot{m}_\mathrm{f}$	mass flow rate of fuel, kg s^{-1}
$\dot{m}_\mathrm{res}$	mass flow rate of residue, kg s^{-1}
$\dot{m}_\mathrm{t}$	total flue gas mass flow rate, kg s^{-1}
n_i	number of moles of the *i*th component
p	pressure, atm
p'	partial pressure, atm
Q_wall	heat lost through the chamber wall, kcal
$\bar{R}$	gas universal constant, atm liter K^{-1} mol^{-1}
T_s	gas temperature, K
T_w	wall temperature, K
V	mean gas velocity, m/s
α_g	gas absortivity, non dimensional
$\Delta\varepsilon$	spectral correction factor
ΔH_RES	energy transferred to the residue, kcal
Δh_{T_s}	enthalpy increase from 298 K to T_s, kcal kmol^{-1}
ε_i	emissivity for the *i*th gas component, non dimensional
ε_g	gas emissivity, non dimensional
ε_w	wall emissivity, non dimensional
μ	gas dynamic viscosity, kg m^{-1} s^{-1}
ρ	gas density, kg m^{-3}
σ	Stefan-Boltzmann constant, W m^{-2} K^{-1}.

absorbing heat that could otherwise be utilised for incineration. With air enrichment, the combustion process will occur with reduced overall gas flow rate and improved thermal efficiency. In most waste incineration processes such a reduction in flue gas volume will lead to more complete waste destruction and, consequently, to higher consumption rates. The benefits of oxygen enrichment can be achieved at very low levels of enrichment, from 21 to 25% oxygen in air, up to 100% oxygen.