

Combustion Optimisation

Introduction

Combustion optimisation for boilers and other combustion processes has long been an important issue with increasing fuel prices. There are many end users in Australia with fuel bills in excess of one million dollars. With typical costs of combustion optimisation systems and fuel savings in excess of 5%, pay back periods can be very short. This economy is based primarily on the measurement of oxygen in the flue gas.

Combustion Control with Oxygen Measurement

Combustion involves the burning of fuel to generate heat. To optimise the amount of heat generated, the level of available oxygen must be controlled to ensure all the fuel burns completely. The optimum air/fuel ratio is known as stoichiometric combustion. Figure 1A shows how combustion efficiency is optimised at stoichiometric conditions.

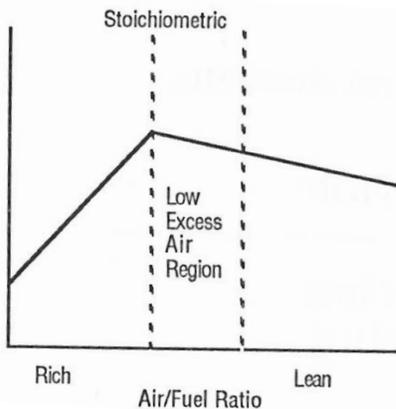


Figure 1A Combustion Efficiency

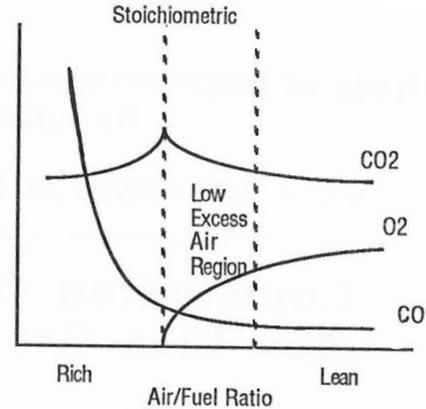


Figure 1B Combustion Products

Measuring the remaining oxygen in the flue gas provides a method of controlling the air/fuel ratio. Figure 1B shows a typical oxygen curve for varying air/fuel ratios.

If there is insufficient air to oxidise the fuel, efficiency will be reduced and unburnt combustibles and CO will be produced. Apart from inefficiency and pollution, this can also be potentially hazardous. If more air is provided than is necessary, complete combustion will occur, however efficiency will be reduced due to heat loss, as extra nitrogen and unused oxygen are heated and sent up the stack.

Burners operating without oxygen (or CO or CO₂) trim control have to be set with sufficient excess air to operate safely under varying atmospheric conditions, resulting in wasted fuel.

Why use Oxygen Measurement

Flue gas constituent curves show a similar change for both CO and O₂ measurements around stoichiometry. In fact at stoichiometry, carbon monoxide has more sensitivity than oxygen measurements, however it is rare that a burner can operate and actually achieve air/fuel mixing at stoichiometry.

It is normal for burners to be running with a small amount of excess air for efficient combustion. At this point the CO curve becomes flat with little sensitivity (refer to Figure 1B). For this reason, oxygen is generally chosen as a primary measurement. This is fortunate because oxygen probes and analysers are inexpensive compared to carbon monoxide measurement analysers.

There are however some exceptions. CO measurement is preferred where there is significant air infiltration in the flue gas stream, which would produce a positive error in O₂ measurement. CO measurement for control is also independent of the type of fuel being burnt. With multiple fuel burners, oxygen trim systems require multiple characterisations. Bed fired boilers use CO₂ measurement for control since bed firing involves oxidation, reduction and distillation processes within the bed.

The vast majority of combustion processes however are best controlled from flue gas oxygen measurement. It is common practice on large appliances or with hazardous applications such as dual fuel burners, which cannot have mechanical limits, to have oxygen trim with carbon monoxide override. An increase in carbon monoxide would signal a burner or trim system malfunction.

Control Strategy – Applying Oxygen Measurement for Combustion Control

Zirconia oxygen probes and analysers are used to regulate the fuel/air ratio in furnaces, kilns and boilers, from small package boilers to large power station boilers. Probes can be installed either in the high temperature combustion zone or in the lower temperature flue gas stream. For modulating burners, the system must be able to vary the flue gas oxygen level, depending on the firing rate of the burner. At lower firing rates, more excess air is required than at higher firing rates.

Oxygen trim systems automatically vary the oxygen level from low fire to high fire. The correct oxygen operating levels are normally established by measuring the CO level in the flue gas. The oxygen level is set so that the CO never exceeds about 300 parts per million.

On very large installations, such as power stations, the correct oxygen level in the flue gas is normally determined from mass balance measurements. When operating at optimum efficiency, it is unusual for a power station to be generating any CO.

When the oxygen measurement system is used for closed loop control, limits must be set so that it cannot produce dangerous fuel-rich conditions during system malfunction. On small installations, this is achieved with mechanical limits on the burner linkages. On larger installations, it is normally electronically limited. The oxygen signal is used as a trim signal with high and low alarms. Apart from savings in fuel costs, oxygen monitors and trim systems provide an early warning device for impending combustion problems.

REFERENCES: Adapted from "Combustion Optimization and Flue Gas Monitoring" (1990), Arthur Gould