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A study of the combustion characteristics of ceramic forced draught premixed burners using propane and butane

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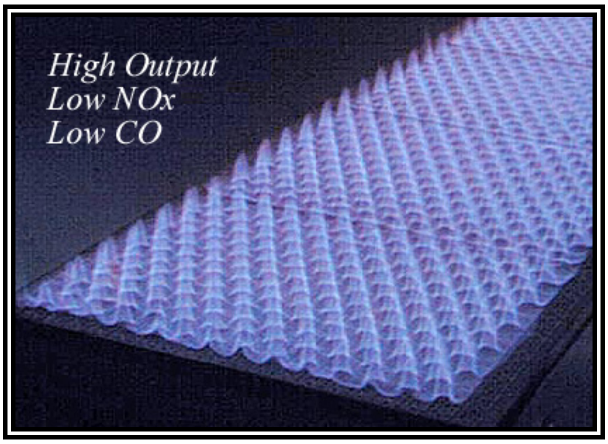
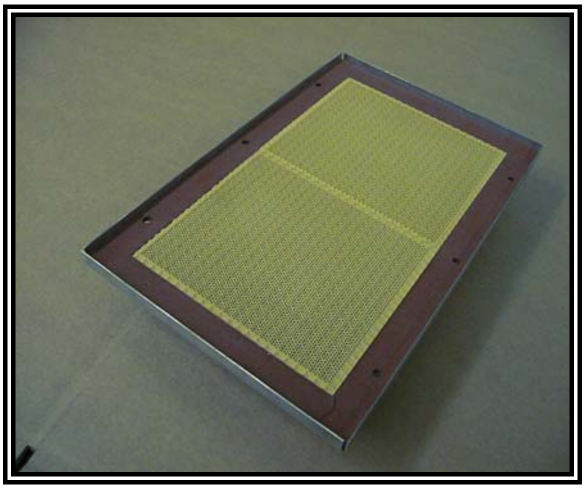
Introduction

Greater use of condensing boiler technology in many European countries has been driven by increasingly stringent national policies on reductions in carbon dioxide (CO_2) emissions in line with international commitments. These commitments are generating a world-wide demand for higher efficiency heating appliances and a requirement for premixed burners that are compatible with the various gases typically used throughout Europe.

R&D on ceramic premixed burners at Aeromatix has to date focused predominantly on those using 2nd family gases (e.g. methane) for the UK market. Across mainland Europe there are more applications required to operate using 3rd family gases (e.g., propane and butane).

This market is increasingly important to boiler manufacturers aiming to introduce cost-effective high-efficiency appliances that are internationally compliant.





Propane and butane have higher burning velocities than methane, which results in higher burner temperatures and an increased propensity for light-back. This paper provides an overview of research at Aeromatix to define operating characteristics of ceramic premixed burners burning propane and butane, particularly in relation to the light-back threshold.

What is light-back?

The term 'light-back' refers to the condition whereby a flame propagates through the burner ports igniting combustible products within the burner body. Light-back can be prevented by maintaining a kinetic balance between the mixture velocity and its burning velocity; however the reverse effect is flame-lift which is equally critical to overall flame stability. Burners must be able to operate with a range of gases, a range of gas-to-air mixtures, and a range of rates of input. These parameters collectively determine the limiting criteria for burner design.

Four factors affect the propensity for light-back: gas properties, port geometry, air/gas ratio, and turn down requirement.

Until the late 1990s most domestic gas burners worked on the principle of entrained aeration driven by the kinetic energy of the gas. Burner port design was thus a compromise between aeration, port loading, and stability.

The dependence of aeration on gas supply was a major factor affecting light-back; if the gas supply was shut off aeration and port velocity diminished in direct proportion until the balance with burning velocity was exceeded and light-back occurred. Avoiding light-back became a function of port design.

Air/gas ratio controls have been available since the widespread introduction of forced draught premixed burners in domestic boiler applications. Controlling the dilution of the gas mixture in relation to heat input is fundamental to flame stability and to avoiding light-back. Air/gas ratio controls are now considered essential for controlling a forced draught fully premixed flame.

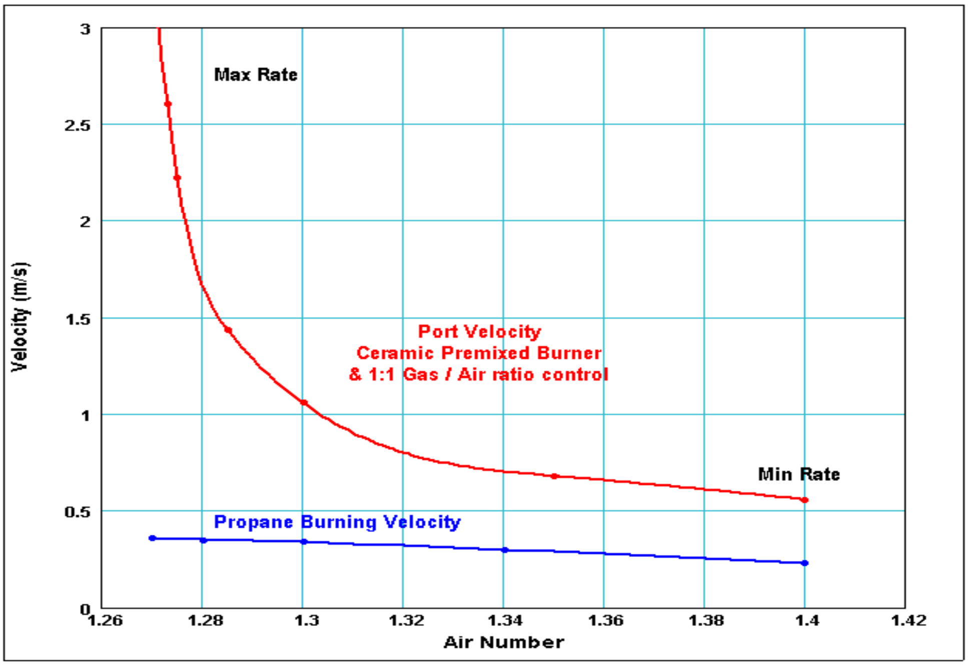
Air/gas ratio controls

Pneumatic air/gas ratio controls induce a gas flow by the air flow delivered from a fan. The device commonly used is a venturi which creates a gas pressure in direct proportion to the air pressure.

A valve governs gas delivery and incorporates an offset which allows the gas pressure to be adjusted by a constant amount below the instantaneously generated air pressure. This is termed a 'negative offset'; at the maximum gas input rate the offset is small relative to the total air pressure, as the gas input rate is reduced the offset becomes an increasing proportion of the total pressure, causing the burner to become progressively lean until the limit of combustibility is reached.

Figure 1 shows the effect of a typical air/gas ratio control characteristic on the port velocity of an Aeromatix ceramic premixed burner in relation to the burning velocity of propane.

Figure 1 ~ Velocity of mixture through burner ports compared to the burning velocity of Propane



The negative offset air/gas ratio characteristic (Figure 1) shows the air number to increase from 1.27 to 1.44 from maximum to minimum rate, this characteristic is typical of a correctly adjusted premixed burner control system. Increasing air dilution causes a levelling of the port velocity such that it is always greater than the burning velocity of propane thus preventing the possibility of light-back.

What is soak-back?

Soak-back is an additional failure mechanism for ceramic burners that can occur if the plaque is exposed to very high levels of radiant heating. Owing to the non-conductive properties of ceramic materials this heat cannot easily be dissipated and results in a gradual 'soak back' of the radiant surface through to the gas entry side ultimately causing light-back.

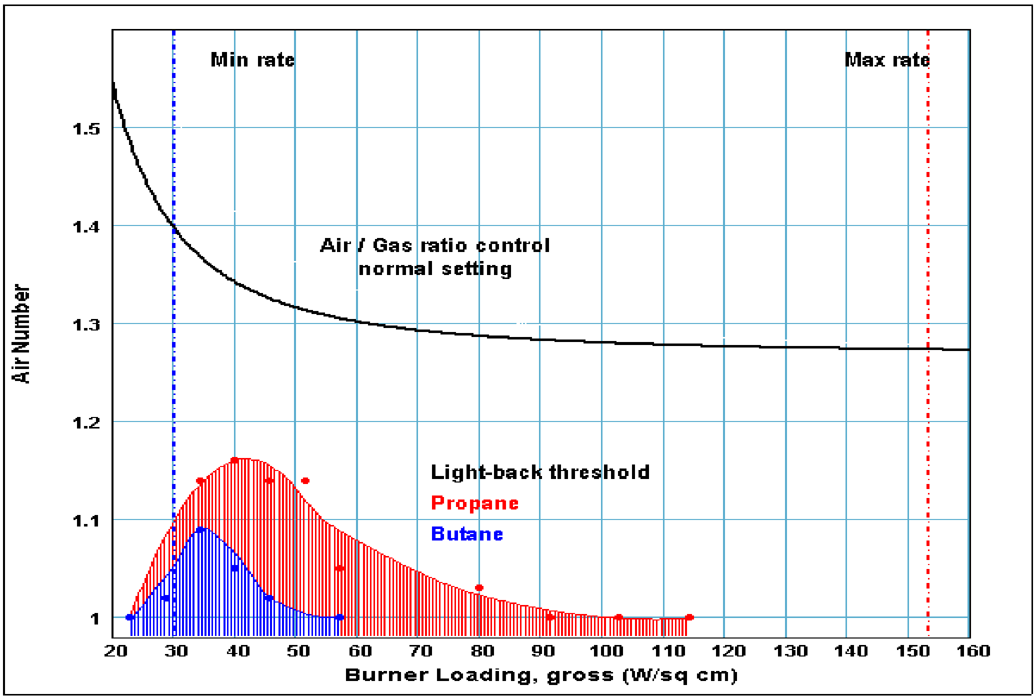
Figure 2 shows the outcome of an experiment to quantify the operating boundaries of the soak-back mechanism using an existing production boiler but with additional controls to permit independent adjustment of fan speed, heat input, and air number.

The light-back threshold curve was determined by progressively reducing the air number until the onset of soak-back. The test ended when light-back occurred. The test was repeated for a burner loading range of 25 to 115 W/cm^2.

A combination of flame speed, level of aeration, and loading determine the proximity of the flame to the ceramic surface and thus the potential for heating the surface to a radiant condition.

The experiment showed that the onset of soak-back only occurs at a dilution significantly below the normal operating conditions for the boiler tested and that this is near the minimum operating rate (see Figure 2). A sufficiently dilute condition at low loading prevents the onset of soak-back completely. At high loading the flame is elevated from the plaque surface reducing the radiant heating effect and so preventing the onset of soak-back. The air/gas ratio would have to be significantly out of tolerance to coincide with the soak-back threshold curve. The onset of soak-back was also found to depend on additional heat radiation from the ignition and ionisation electrodes.

Figure 2 ~ A normal Air / Gas ratio control compared with experimental light back data



Radiation intensity is dependent on electrode area, proximity to the plaque, and flame height, so the maximum radiation occurs over a narrow heat input range, shown in Figure 2 by a peak in the threshold curve at about 40 W/cm^2. Excessive radiation from a large electrode or other component could increase the light-back threshold, bringing it closer to normal operating conditions.

Conclusions

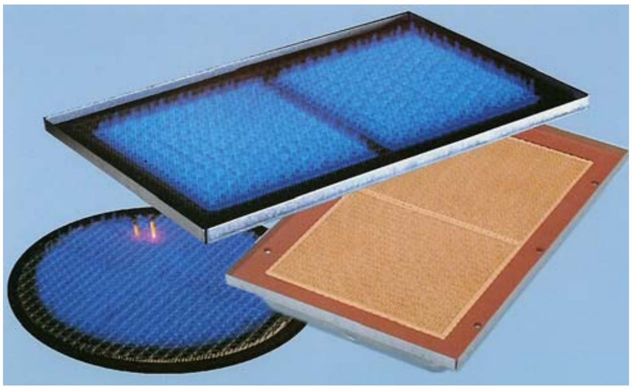
Light-back and soak-back have been investigated for a typical Aeromatix forced draught ceramic burner operating on propane and butane. These failures could only be provoked by adjusting the air/gas ratio to an abnormally rich condition and by modulating the burner to a low rate such that an extreme radiant condition resulted.

While the small port size of the ceramic plaque inherently resists light-back under normal operating conditions, it is the ability of the air/gas ratio system to control the dilution of the air/gas mixture in relation to the heat load and the effect of this on the port velocity that has the greatest impact on light-back prevention. With a typical air/gas ratio characteristic there is no possibility of either light-back or soak-back when burning propane or butane.

The inability of the ceramic plaque to dissipate very high levels of radiant heat was demonstrated by simulating the conditions required to initiate soak-back. However, these conditions are deemed so remote from normal operating conditions that the non-conductive properties of ceramics do not increase the risk of soak-back.

Tests showed that the risk of soak-back was increased locally by back radiation from the ignition and ionisation electrodes. This illustrates the importance of collaboration between burner and appliance manufacturers during the early design stages.

End



Rob Parsons holds a B.Sc. in mechanical engineering and has worked with Aeromatix for the past 12 years as a senior advanced development engineer specializing in the development & application of forced draught premixed ceramic gas burners. Before this he worked for 6 years in the research department at Potterton International investigating methods for reducing emissions from domestic heating boilers.

Aeromatix Limited, established in 1946, is one of the world's leading manufacturers of gas burners for domestic and industrial applications. Since 1995 this innovative company has focused on the development of fully premixed gas burners in response to European legislative requirements for higher efficiency and lower emission heating appliances.

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