# BURNER SETTING using a COMBUSTION ANALYSER

## 1. INTRODUCTION

In principle fuel combustion takes place when the carbon and hydrogen molecules in the fuel react with the oxygen molecules in air to form carbon dioxide ($CO_2$) and water ($H_2O$). Energy is released during the reaction.

The exact volume of air required per unit of fuel can be calculated if the carbon and hydrogen content of the fuel is known. Air contains 20,9% oxygen by mole mass. Complete combustion at this theoretical ratio is known as **stoichiometric** combustion. This is generally impossible to achieve in practice due to limitations inherent in burner equipment in getting every oxygen molecule in contact with every hydrocarbon molecule, and burners therefore always need to operate with some excess air to achieve complete combustion. Only 20,9% (oxygen) of this excess air is actually useful in the combustion process, the other 79,1% (Nitrogen) merely absorbs energy which is then lost up the stack. Excess air must therefore be kept to a minimum.

When there is insufficient oxygen available for complete combustion, carbon monoxide (CO) is formed. CO is thus a product of incomplete combustion and less energy is released when it is formed, reducing combustion efficiency. Incomplete combustion is most often visible as black smoke and can cause soot build up in heating appliances.

Optimal combustion thus happens when products of combustion (flue gas) contains:

- No or low CO – 0 to 20 ppm.
- High $CO_2$ – 12% to 16% dependent on fuel type
- Low $O_2$ – 1% to 5% depending on combustion appliance efficiency

## 2. Setting the Burner

### 2.1. Minimising CO

To minimise the formation of CO ensure that sufficient air is being supplied to the combustion zone. This would typically be done by adjusting the air damper on the burner or on the secondary air fan(s) to increase the air/fuel ratio, or reducing the fuel pressure to the nozzle to reduce the amount of fuel introduced.

If adjusting the air supply/fuel pressure does not reduce/eliminate CO production then check fuel atomisation characteristics. The fuel must be broken up into fine droplets and intimately mixed with sufficient air for complete combustion. Check the following:

1. **Fuel Viscosity** - make sure that the fuel viscosity is correct for the burner type. Increase the fuel temperature to reduce viscosity in heavy oil installations. Typically, the lower the viscosity the better the atomisation, but be aware that some rotary cup burners can be problematic at very low viscosities. When using heavy fuel oils make sure that the fuel heaters are working and set correctly and that there is good fuel flow at temperature right up to the burner nozzle.
2. **Fuel Pressure** – the fuel pressure at the nozzle tip is of paramount importance, particularly on pressure jet burners. Take into account the viscosity of the fuel, the higher the viscosity the higher the pressure required. In a test done on a small boiler, a zero CO reading was obtained at 800kPa using paraffin, a 1300kPa fuel pressure was required for LO10. Remember, altering the fuel pressure will alter the flow rate through the nozzle and the burner air damper must be adjusted accordingly.
3. **Nozzle Condition** – worn nozzles may create areas within the spray cone where the fuel is not adequately atomised. These areas are often visible as dark areas within the flame or as “sparklers” or “fireflies” on the flame periphery. Replace worn nozzles, as worn nozzles nearly always cost more in the loss of fuel efficiency than the cost of replacement nozzles. Partially blocked nozzles cause a pressure drop at the nozzle tip resulting in poor atomisation and may result in a change in the air/fuel ratio.
4. **Swirl (Baffle) Plate Setting** – On some burners this can be used to adjust air speed and flame shape. (Be aware that changing the swirl plate position may also change the air pressure profile within the burner and the air supply may need adjustment.) The swirl plate can become blocked by the accumulation of dust or carbon between the swirl guides, inhibiting air supply. A carbon build-up indicates direct fuel impingement on the swirl plate, which should be rectified immediately. Ensure that the burner is kept clean and correctly set.
5. **Fuel impingement** – poorly directed flames may directly strike the combustion appliance wall or refractory. This will cause the fuel to condense , reducing atomisation. Ensure that the flame does not hit the furnace walls or refractory by adjusting the flame length and width or change to a different nozzle angle. Note that flame impingement often indicates that a burner or appliance is being over-fired, which may result in costly damage occurring. Impingement is often detected by the production of white smoke and the formation of “clinkers in the furnace”.
6. **High furnace back pressures** – these can be caused by blocked air passages in the appliance (e.g. the boiler tubes). The burner blower will be unable to provide adequate air at the normal pressure for optimum combustion. Airways should be regularly checked and cleaned. High flue/back end temperatures and furnace

backpressures are good indicators of this problem and should be closely monitored.

7. **Shut-off/Solenoid Valve Integrity** – fuel may leak through a faulty shut-off valve whilst the burner is off. This will accumulate in pools of fuel on the combustion chamber floor and CO will be formed as this is burnt away during subsequent burner runs. Faulty valves represent a serious fire/explosion risk and should be repaired immediately.

8. **Blower Restrictions** – check the burner blower suction and delivery for blockages (loose or disconnected dampers, rags, dirt accumulation). Also check that the damper and modulation motor are functioning correctly.

### 2.2. Maximising $CO_2$ and Minimising $O_2$

Most combustion analysers measure only Oxygen levels in the flue gas and use an empirical formula to derive $CO_2$ levels. This means that the lower the measured $O_2$ level is, the higher the calculated $CO_2$ level will be. The lowest achievable $O_2$ level (highest $CO_2$) varies from appliance to appliance and burner to burner. A glass furnace may be set up to give low $O_2$ levels of 1-3% whilst an $O_2$ level of ~5% is barely achievable on some boilers.

To minimise $O_2$ levels ensure that all equipment is set up for minimum CO production (see 2.1.). Start the burner and wait for the appliance to reach operating temperature, do not try and set a burner when the appliance (especially the furnace refractory) is not up to normal operating temperature. Lock the burner in the minimum firing position (low flame).

Increase burner air supply or reduce fuel pressure until the flame is very bright and there is no visible smoke. Measure the CO and $O_2$ concentrations. The CO level should now be at it's minimum (0-20ppm). Slowly reduce the air supply or increase fuel pressure until the CO level begins to rise. Reverse the procedure (increase air or decrease fuel supply) until the CO level returns to the previously determined minimum level. The burner low flame should now be optimised.

Set the burner to the high flame position and repeat the above procedure. If the burner has an intermediate (medium) firing position, repeat again at this setting. Fully modulating burners may need to be set at a number of points, the burner documentation should provide more detailed information.

## 3. Conclusions

The following conclusions should be noted:

3.1. Burners cannot be accurately set by eye.

3.2. A combustion analyser is an invaluable tool in setting up burners.

3.3. Savings of 3% to 9% of the fuel bill can be saved on correctly set up burners.

3.4. A good working knowledge of combustion theory and the combustion equipment is essential to the successful running of heating appliances.

3.5. Nozzles need to be replaced regularly as they are subject to wear.

3.6. Appliance and burner/nozzle cleaning needs to be carried out on a routine basis.

3.7. Fuel supply needs to be provided continuously at the correct temperature and pressure, with instrumentation to verify this.

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