From Mechanical to Electronic Control on industrial burners

Understand how using electronic controls can help significantly reduce a cost you thought you'd already optimised

Every Plant Manager knows the cost of materials and labour but how many know the proportion of energy costs that relate directly to production? Energy costs are considerable in many of the industries that employ process heating but energy is treated as a utility, an overhead. So, you negotiate a good price for your fuel and electricity and you keep your energy costs under control but are you missing something?

Similarities between car engines and industrial burners

Car engines and industrial burners both convert fuel to energy; both employ combustion techniques and both emit pollutants but the similarities do not stop there: the car engine has become a high performance engine, more efficient and less polluting. Relays, coils and distributors have been supplemented by engine management systems. Carburettors have given way to fuel injection systems. Lambda control has improved economy and reduced pollution while exhaust gas re-circulation has further reduced emissions.

Controls for industrial burners have also changed: mechanical cam fuel:air ratio control, the equivalent to the carburettor, has been replaced by self checking fuel:air ratio electronic control,. Oxygen trim, the burner's equivalent to lambda control has been added and flue gas re-circulation reduces emissions as it does in the car. Performance has been improved by increasing turn down ratios through more flexible control strategies and fan speed control and by better matching of load and demand from embedded 3 term PID circuits. Software options such as boiler lead / lag control improve boiler / burner utilisation and communications software be greatly enhances information flow.

Most of the improvements to burner controls have been introduced in the last few years. These controls can be specified on new burners or retrofitted to existing plant. It is now possible to reduce energy costs, to lower emissions and to obtain trending information for management decisions. Self checking controls with automatic logging and dial-out can release boiler house manpower for other process applications.

Mechanical cams and linkages

Consider a typical industrial boiler with mechanical cam control and let us assume that the burner has recently been serviced. At high fire, the oxygen level in the flue gas would have been set at a safe level - slightly above optimum - to allow for changes in conditions that affect combustion. Then, say the ambient temperature swing is say 10 to 20 ^{o}C in a 24 hour period and accept that as the air temperature increases, air expands and becomes less dense, resulting in less oxygen per cubic metre being delivered to the burner. If moisture is present in the air it will cause displacement again reducing the oxygen being delivered to the burner. When burning oil, viscosity, calorific value and filter condition will all cause variations in combustion and when firing on gas the gas supply pressure and calorific value of the gas will both cause variations in combustion.

The burner engineer will make allowances for any backlash in the linkages associated with the cam and taking the above variables into account, will set the cam to ensure that the oxygen cannot fall too low. After all, if the oxygen level in the flue gas is too low the risk of explosion is increased. In addition the risk of emissions containing unburned fuel will also be increased, and fuel could be wasted. When oxygen is low the flame from the burner lengthens which can cause damage to the tubes in packaged fire-tube boilers. However, if the engineer sets the oxygen level too high, there will be an increase in excess air and heat will be lost up the stack. So, the engineer sets the cam's high fire point at a safe position above optimum and wastes heat up the stack.

The engineer's next aim is to achieve a maximum turn-down ratio for the burner. (Turndown is the ratio of high fire to low fire. For example a turn-down of say 7:1 would mean that the low fire fuel flow would be $1/7^{th}$ of the high fire fuel flow.) With mechanical cam controls the ignition point determines and is the same as the low fire point. For essential safety reasons, each time the burner starts up the boiler is purged with ambient air which cools the boiler.

The turn down on a gas only burner might be 7:1 but on dual fuel burners the turn down is often only 3:1. meaning that on – off cycles are more frequent. If a boiler cycles on and off every 10 minutes then the number of purge cycles per day is 6 x 24 = 144. If purge typically takes 3 minutes, then we could have 3 x 144 = 432 minutes of purge every day. ie 432 minutes of cold air being blown through the boiler.

By maximising the turn-down ratio:

1. Burner on/off cycles are minimised.
2. Heat is not taken from the vessel and wasted up the stack.
3. The boiler can more readily respond to increases in load.
4. Expansion/contraction cycling, which increases boiler down-time, is minimised.

At low fire, fuel flow is at its minimum and efficiency is less important than at high fire, so the engineer concentrates on acceptable combustion consistent with achieving maximum turn-down ratio and a reliable start-up. Again, he sets the oxygen level high.
The other points on the cams are set to give a smooth curve between low and high fire with emphasis on achieving best practical efficiencies at mid fire and above.
Mechanical cams and linkages have been around for so long that their limitations have been forgotten and everyone, including the plant manager, believes that they have their burners set and operating at maximum efficiency. However, it would be more accurate to say that a burner has been set to give the best possible result within the scope of the controls available.

Electronic controls can reduce the energy bill.

When an electronic fuel:air ratio control is retro-fitted the existing PID control, modulation motor and the cams and linkages are removed and servo motors (actuators) are fitted to air dampers and fuel valves.
Likewise, when electronic control is specified on a new burner the burner arrives with its new control and its servo motors factory fitted.
Using electronic controls,plant personnel can expect several benefits.

No backlash.
Linkless burners have no backlash. On a frequently modulating burner energy savings of up to 1% are common.

Increased turndown.
On an electronic control, the low fire point can be set lower than the ignition point which means that the turn-down ratio can be increased. In addition, burner on/off cycles and their associated cold air purges also can be reduced, which will result energy savings.
While savings from reduced on/off cycles will vary with boiler utilisation, savings of 5% have been reported on a burner that prior to conversion had an on/off frequency of approximately once every 10 minutes.

A second PID control.
Some electronic fuel:air ratio controls have two internal PID modulation circuits. If a plant does not run continuously then this second PID control's setpoint can be used to switch the boiler to a lower steam pressure or hot water temperature during periods of reduced activity. One manufacturer employing this approach is LandRover in Solihull. The company uses hot water for paint drying in their paint shop but the process is held on stand-by at night. Using a second boiler setpoint provides energy savings of approximately 10% pa.

Fan speed control.
With mechanical cam control and with basic electronic fuel:air ratio controls processors sacrifice combustion efficiency at low fire to achieve an improvement in burner turn-down. Some air dampers leak and even when fully closed the air flow can be significant. In effect, processors can reduce the fuel valve setting but cannot reduce the air to match. Combustion efficiency can be improved at low fire if the fan speed is reduced.

Fan speed control is an easy to add option on some electronic controls. By adding fan speed control burner turn-down can be increased without compromising efficiency, and additional fuel savings can be achieved. The benefits of variable speed control do not end here: When an inverter is used to slow the speed of an ac electric motor, electrical energy savings result. For example, when a fan motor is slowed to 25Hz ie to half speed an 80% electrical energy saving is achieved.

Oxygen trim.
Oxygen trim is a closed loop system available as an option on some electronic fuel:air ratio controls. Oxygen trim was employed on industrial boilers / burners 15 years ago - about the same time that Lambda control was first used on cars. But, the oxygen probes on some early trim systems suffered from

short operating lifetimes. More robust probes now are available.
Oxygen trim automatically and continuously compensates for the variables that affect efficient combustion. You will recall that on mechanical cam controls the engineer set the oxygen level high to retain a margin of safety. When oxygen trim is included the oxygen levels can be set at their optimum level. In addition, if the trim control is adaptive then it will contribute energy savings of approximately 2% to 3%.

Boiler sequencing (lead/lag) control and Communication Software.

Some electronic fuel:air ratio controls incorporate boiler sequencing and communications software. Boiler sequencing control enables the plant operator to achieve better utilisation and additional energy savings are possible. Communications software provides vastly improved information. Depending on the software package, the PC can display a dynamic plant mimic with live values, commissioning data and operating parameters.
Some packages include data logging on the PC's hard drive.
Flue gas temperature trend data can indicate when boiler servicing is due and oxygen trim trend data can indicate when burner servicing is due.

As you can see, it is possible to reduce unit cost by reviewing your burner control strategy.