

Optimize multi-fuel boiler operation with modern control

Outline: As fuel prices rise and emissions regulations become tougher, companies must adopt new methods to remain profitable and sometimes just to survive.

Industrial production sites face many challenges, but for power and utility operations several challenges are especially acute, as increasing populations and per-capita energy use drive an inexorable rise in long term energy prices. To survive, companies must adapt by addressing power and utility energy costs; they must improve efficiencies, utilize cheaper fuels and eliminate waste. At the same time emissions control requirements are becoming more stringent and difficult to achieve.

This presents significant challenges for industry, yet it also presents an enormous opportunity. According to the International Energy Agency, the industrial sector has only realized 50 percent of the potential system/life cycle improvements in energy. Consider that energy is typically the largest controllable cost of manufacturing that can be affected locally at a site, and energy savings go directly to the bottom line. Depending on the size of a company’s operations, a 2 percent improvement in power and utility efficiency can bring £1 million benefit annually, Potentially even more significant is substituting 20 percent of traditional fossil fuel consumption with low cost/alternate fuel sources. This could bring an additional £2-3 million in annual return. Such improvement programs can be self funding at the start, and then yield a profit via sustained benefits — with additional advantage coming through improved maintenance and the avoidance of fines and shutdowns.

Penalties or taxes for CO2 production are already in place in some parts of the world and are likely to be more widespread in the future. Figure 1 shows that, if CO2 taxes are included, shifting from petroleum or electricity to biomass can reduce fuel costs to almost zero, and going to waste gas as an energy source could actually yield a “profit” through reduced emissions penalties.

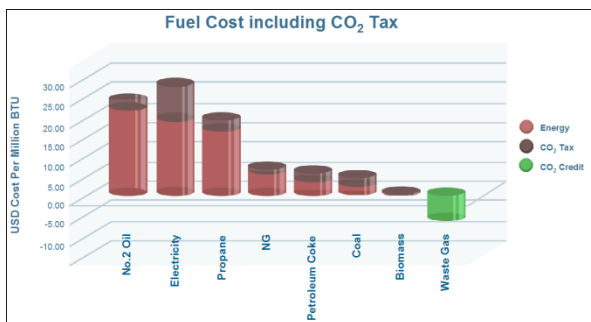


Figure 1: Fuel cost including CO₂ Tax

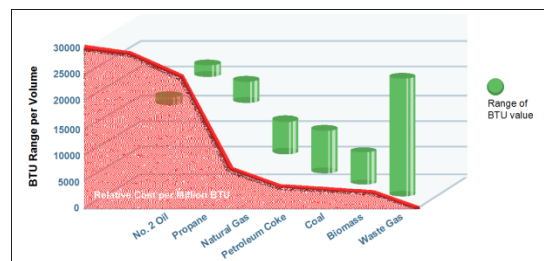


Figure 2: Fuel Variability

Fuel BTU variation

But optimizing a combustion process in the powerhouse to maximize efficiency and utilize low cost fuels at all times is difficult, especially when attempting to operate highly reliably and responsively. Changing load in the industrial powerhouse is a challenge, and an even larger challenge is fuel variability.

Natural gas is considered a stable and consistent fuel, but even this conventional fuel can vary in BTU per volume by $\pm 10\%$ over time. Combustion control systems must manage even this level of variability in order to optimize energy cost results.

In an effort to restrain costs, a large percentage of industrial boilers make use of both conventional and unconventional fuels. Most often, these unconventional fuels are being produced as byproducts of the main site production operations. Examples include off-gases in chemical plants and refineries, coke oven gas and blast furnace gas in steel mills, waste wood in a pulp and paper mill, or biogas at a food plant. These sources are often essentially a free source of energy for power and utility operations, but they are not typically available with consistent supply and they usually vary considerably in energy content per volume over time. Off-gas or waste liquids from a refinery or chemical plant can change dramatically as feedstocks and product mix change. This inconsistency is not conducive to running combustion processes in a stable manner, and therefore the use of unconventional fuel sources has traditionally been restricted. Low cost fuels have most typically been used in a base load manner, with traditional fossil fuels being used to achieve stability and follow load. This has often resulted in cases where off-gas is being flared while natural gas is being used to produce steam for production needs.

But how to control it

The concept of fuel to air curves began when automated combustion control techniques were first developed using pneumatic controls. The “curve” was actually a mechanical cam in a pneumatic actuator. When a combustion process control system was commissioned, the cams in the actuators for fuel and air control were shaped such that a safe amount of air was delivered for the fuel flow over the load range. The cams in the pneumatic actuators provided a fixed air to fuel ratio for any particular firing rate. These implementations were simple and reliable, normally prevented an unsafe fuel rich condition, and even provided a level of excess air management with an Oxygen trim function. But there was also a safety margin of additional air flow built into the implementations which resulted in combustion efficiency being compromised, and because of the magnitude of variability, Oxygen trim was not able to fully optimize operations. Figure 3 shows a typical pneumatic actuator

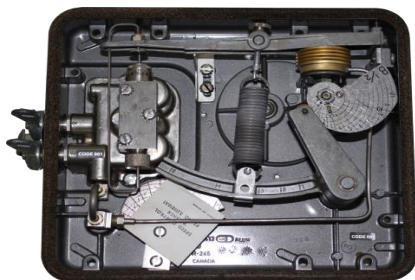


Figure 4: Pneumatic controller

Pneumatic controls were eventually replaced with electronic ones, which contained circuitry that emulated the actions of the cams in pneumatic controls. These controls were more somewhat more responsive and maintainable, but the control strategies that were implemented using this technology were essentially exactly the same as those that had been done previously.

In the 1980s computers entered the picture, and as they have developed the combustion process control engineer has been given the ability to implement complex calculations and a variety of control techniques that give tighter control. But even to this day, the traditional method of implementing fuel to air curves for combustion control has largely remained.

Using this control technique that was developed 60 years ago is no longer an option; there are too many variables, and performance requirements have become much more stringent.

Too much for conventional control methods

Conventional air/fuel curve based combustion control cannot handle optimization in the industrial variable fuel situation because it is based on fixed assumptions made at one point in time. As explained above, fuel feeds in a typical industrial site today are variable. In addition, equipment performance changes over time and ambient conditions are different every day. To avoid unsafe operating conditions the too-common response has been simply to increase the air flow rate. These “buffers” are added as shown in Fig. 4 to manage variations, but they result in inefficiency and emissions. Large amounts of expensive energy are sent up the stack in the excess air while fan loads are increased and emissions equipment is taxed. But how can a combustion process with so much variability be controlled?

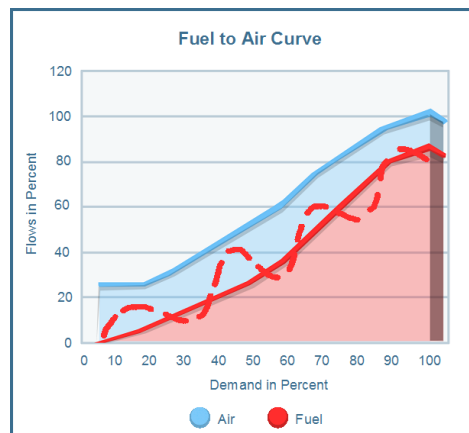


Figure 4: Fuel to Air Curve

A boiler control system that can.

In the final analysis, a boiler or heater has one control input: BTU demand. That demand may be expressed in terms of steam pressure or flow for a boiler or fluid temperature for a fired heater, but it all comes down to that one variable. It is the task of the combustion process and its control system to meet this demand optimally (which in practice translates to minimum cost and emissions) in spite of variations in fuel BTU content and rapid changes in demand. Done properly, this can turn a boiler from a cost center into a profit center, because it allows the use

of fuels that would otherwise be discarded as waste or, because they are derived from renewable sources, can provide greenhouse gas offset credits.

The most advanced combustion control systems available today have the ability to infer the BTU content of fuel continuously and in real time, exactly match the demand signal with a fuel (firing rate) signal, and calculate precisely the amount of air needed for optimal operation. In addition, these implementations allow a BTU of one fuel to be easily substituted for another such that the use of preferred fuels can always be maximized. How do they do it?

The answer is to eliminate the use of fuel to air curves and move combustion control to a totally mathematical and model based implementation. The control system should include a mathematical model of the boiler and a set of constraints using multivariable predictive control. This solution uses standard boiler instrumentation to derive a relative index of heat release in the furnace; once this is known specific firing rate requirements can be determined and fuel can be adjusted on a real time basis to stabilize furnace heat release. Adjusting incremental fuel supply along with dynamically correcting for excess air requirements results in a robust and reliable control methodology. This is much more than a refinement to existing technology; it is a quantum jump in control.

Some examples

This method has been put to use in industry with good results. One example is that of a multi-fuel boiler, which before optimization had large inconsistencies in steam from alternative fuel. A base load was carried on alternative fuel, while fossil fuel was used for header control. Sixty to 70 percent of steam was generated with alternative fuel. But because of control limitations the boiler was run with high excess oxygen of 8 to 10 percent and there were emissions issues.

Applying math and model based control yielded a 5 to 10 percent increase in steam generated on the least cost fuel, a 1 to 2 percent improvement in efficiency, a significant increase in demand swing response, and improved emissions performance.

In another case, a chemical plant diverted a waste hydrogen stream to a new boiler. Optimized control maximized hydrogen use while maintaining stability. Annual natural gas use was reduced by 1 Million BTU and CO₂ emissions were reduced by 30 percent.

A pulp and paper mill wanted to replace coal with biomass. Three boilers were retrofitted and a suite of advanced combustion control solutions. This resulted in a reduction in coal use of five tons per day and improvements in boiler turndown and powerhouse stability.

In another situation, a food plant installed a digester to make biogas from bio waste and converted a boiler to dual-gas operation. The application of combustion optimization maximizes biogas usage and reduces natural gas by 15 to 30 percent.

Summary

In today's business environment combustion processes must operate at optimally at all times, despite variations in load demand, fuel BTU content, and even fuel type. By using the latest control techniques, well operating multi-fuel boilers can often generate 90% of a plant's steam from waste and alternative fuels, operate in automatic control over 95% of the time, and maintain emissions to specified levels.

Author: Sam Thiara, Business Development Manager, Global Industrial Energy Solutions Group, Emerson Process Management

Captions

Fig. 1: If CO2 taxes are included, shifting from petroleum or electricity to biomass can reduce fuel costs to almost zero, and going to waste gas can actually yield a profit on fuel purchases.

Fig. 2: Different fuels have different variability in BTU content.

Fig. 3: The Fuel to Air curve in this pneumatic controller is the cam that controls air flow to match the firing rate. It works only if your fuel has consistent and specific BTU per volume. That is getting rare these days.

Fig. 4: Buffers added to accommodate variations contribute to inefficiency and emissions, and latency in responding to changes in demand causes a see-saw effect.