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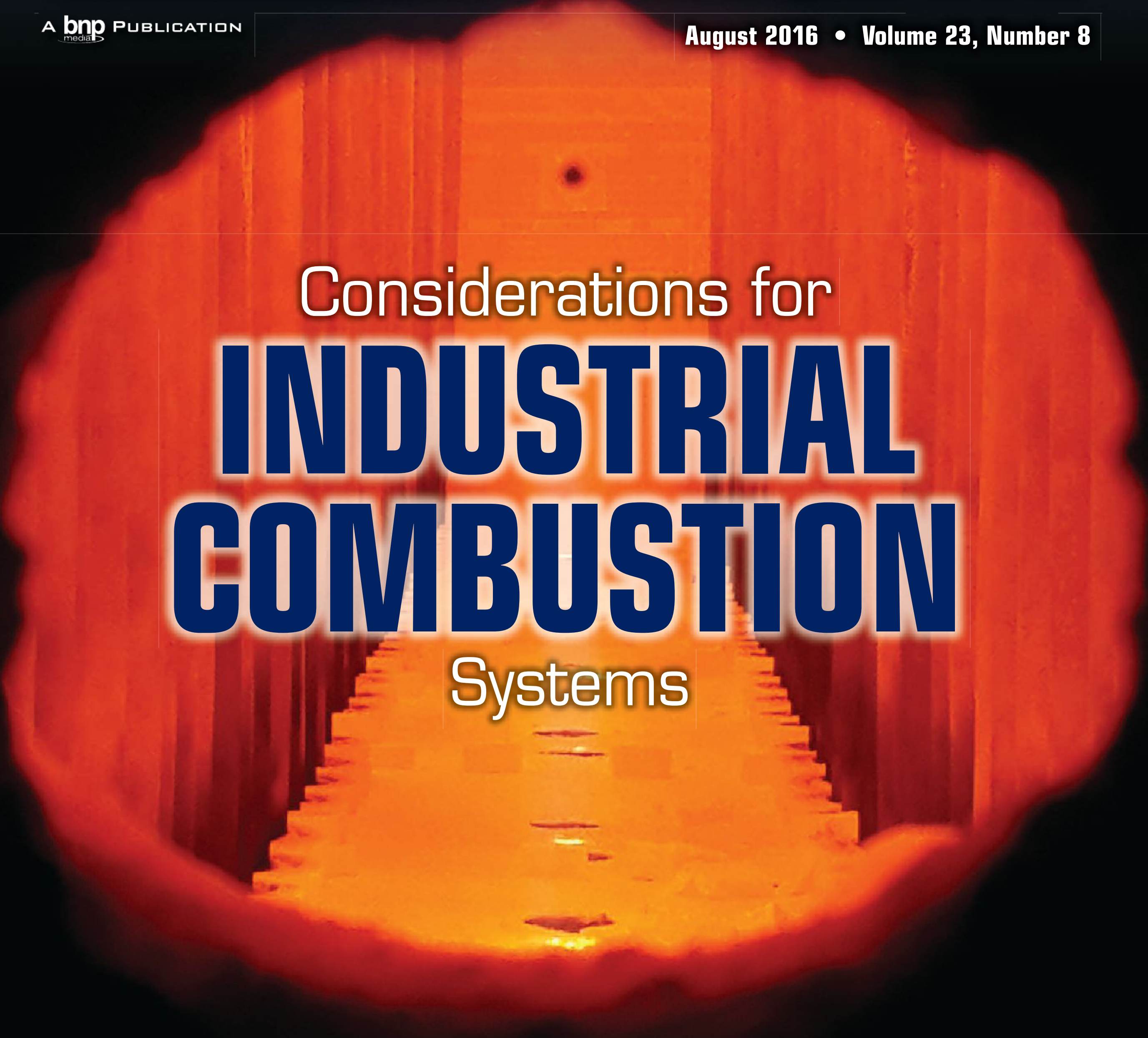

Considerations for INDUSTRIAL COMBUSTION Systems

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COMBUSTION CONTROLS FOR BOILERS

Understand the advantages and disadvantages of combustion control schemes used on the burners for industrial watertube and firetube boilers.

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Steam generated from boilers is used in many industrial processes, including manufacturing, refining, chemical processing and power generation. The burner is the heart of a boiler system, providing the necessary combustion of fossil fuels. Yet, if the burner is the heart, then the combustion controls — which manage air and fuel flow to the burner — are the brains of the boiler system. Airflow must be controlled and balanced, and sufficient quantity must be provided to ensure complete fuel combustion with minimal unburned hydrocarbons. At the same time, too much airflow can decrease boiler efficiency. This balance is determined by the combustion control scheme.

This article will discuss the typical combustion control schemes that are used on watertube and firetube boilers and present advantages and disadvantages for each scheme. For the purpose of discussion, it is assumed that the burner fuel is either gaseous or liquid (oil), not a solid fuel. Also, it is assumed that there is one burner per boiler and that there is a combustion-air fan (the burner is not a natural-draft design).

Burners can be thought of as fuel and air blenders. It is the burner's job to mix the air and fuel properly so that all the fuel is burned.

Stoichiometric airflow can be calculated based on a fuel composition. For example, natural gas composition is mostly methane with smaller amounts of ethane, nitrogen, carbon dioxide and other gases. The stoichiometric air-to-fuel ratio for natural gas is approximately 16 lb of air per pound of fuel.

Burner airflow also includes excess air. This is the amount of airflow added to the stoichiometric airflow requirement. It is typically 10 to 15 percent, depending upon the burner design characteristics. Excess air is necessary to ensure the fuel is completely burned. However, as stated above, it also needs to be minimized as the extra flow decreases boiler efficiency.

The three basic types of combustion control schemes are:

- Single-point positioning. This scheme also is called linkage.
- Parallel positioning. This scheme also is called called linkageless.
- Metering.

Let's take a closer look at each, from lowest to highest cost.

Single-Point Positioning

Single-point positioning (SPP) combustion control is the easiest to understand and the easiest to maintain from an operational

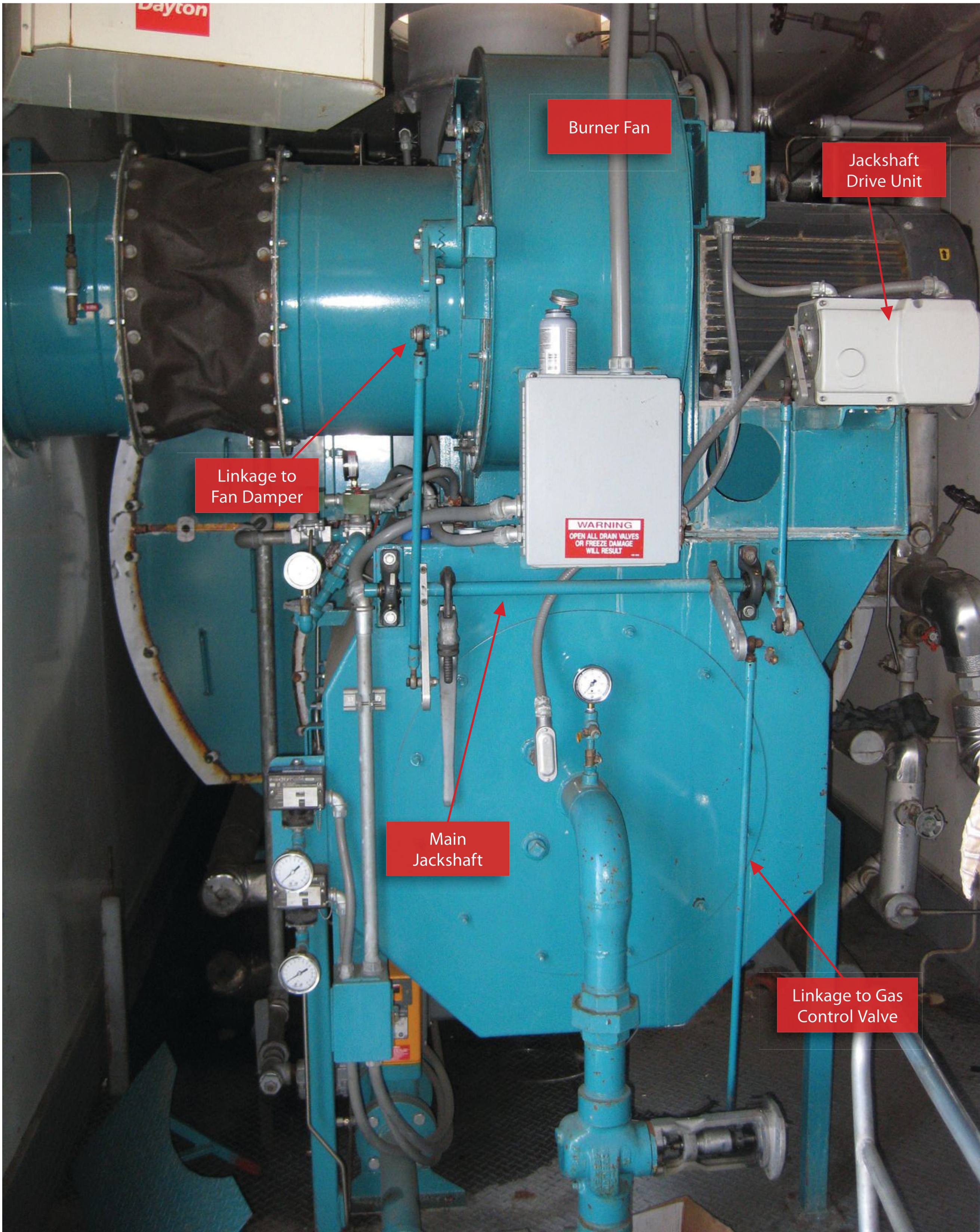

FIGURE 1. This small burner has single-point positioning combustion controls.

standpoint. Fuel and air — and sometimes flue-gas recirculation — are mechanically linked using a jackshaft with linkage arms to form an all-mechanical system. (Flue-gas recirculation, or FGR, is one method used to reduce burner NO_X emissions. It involves redirecting some of the stack gases or flue gases back through the burner.)

Combustion control with single-point positioning typically is used on smaller units, including watertube boilers sized at 50,000 pph and less as well as firetube boilers that are 800 hp or less. The main jackshaft is modulated based upon the firing-rate demand. This, in turn, moves the air and fuel linkage arms, opening and closing the air damper and fuel control valve (figure 1). These linkage movements control the firing rate of the burner.

The firing-rate demand is a function of the steam demand from the boiler. For boilers, the industry standard is to calculate demand based on steam pressure. An error function is generated using the difference between the setpoint value and the measured value. For example, if the setpoint is 150 psig, and the boiler pressure is actually 130 psig, the error is 20 psig. This means that the burner has to fire harder to meet demand.

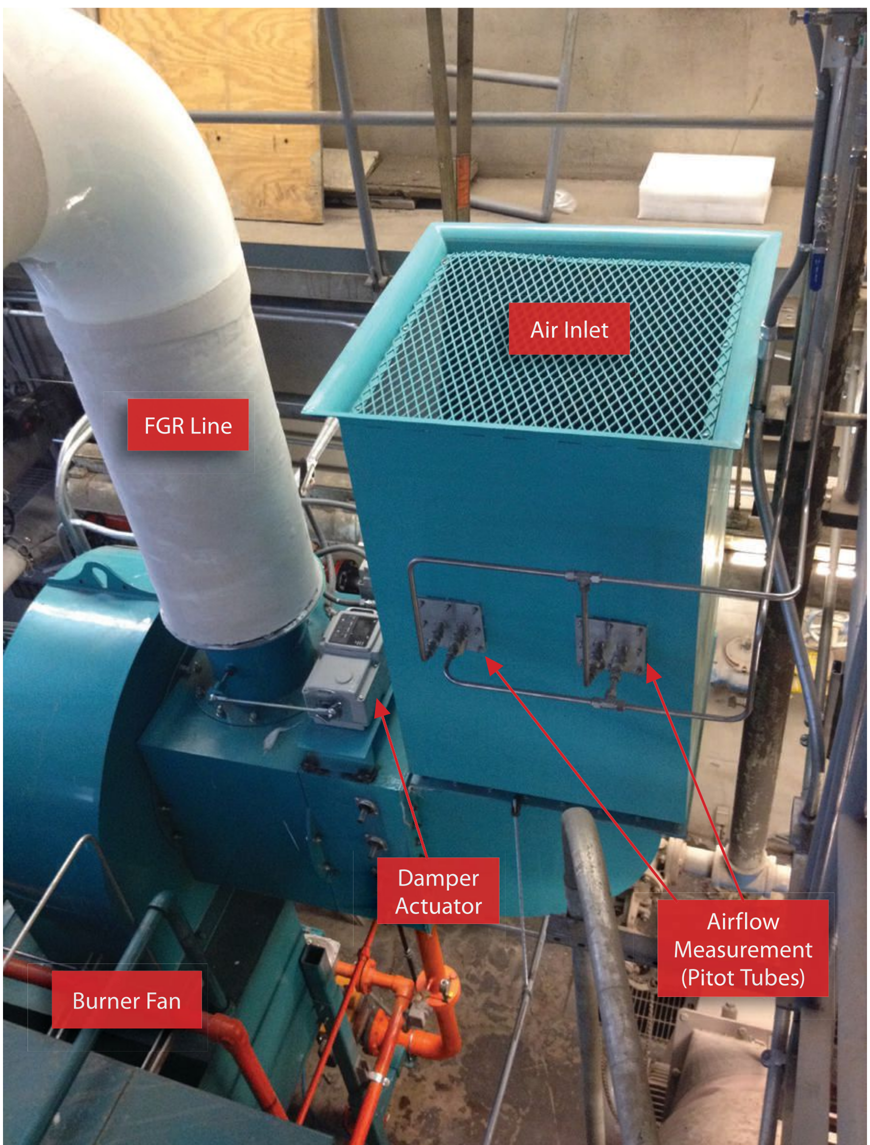

FIGURE 2. The metering system uses an airflow measurement device.

The demand signal, which is what determines the firing rate of the burner, typically is calculated using an algorithm with proportional, integral and derivative functions, also known as PID control. The proportional function takes the error value (20 psig in the previous example) and applies a constant or a gain to the signal. The integral function uses the accumulation or summation of past error values to give a corrective action based upon past performance. The derivative function deals with possible future error values, giving a predictive correction.

Single-point positioning combustion control uses a single PID loop, meaning there is one input and one output. The input is the boiler pressure, and the output is the firing-rate demand. Two big advantages of this system include the simplicity and ease of maintenance. In addition, it is safe: If the jackshaft drive unit failed, it would fail in position at the mechanically set air-fuel ratio.

The disadvantages include:

- The hysteresis effect. This is where, over time, the linkage connections get worn, causing inaccurate positioning of dampers or valves.
- All devices need to be physically close to each other due to limitations on linkage lengths.
- Frequent adjustment can be required.

Because this system does not apply any correction for changes in air (or fuel) density, the boiler system typically requires retuning (i.e., readjustment of air and fuel linkage settings) at least twice a year when the average ambient temperature changes. It also means that the boiler may not operate as efficiently as possible because changes in air density will cause flow variances for a fixed air damper position.

Parallel Positioning

Parallel positioning combustion control is a step up in complexity and cost from the single-point positioning combustion control system. Instead of air and fuel devices linked together, individual actuators drive

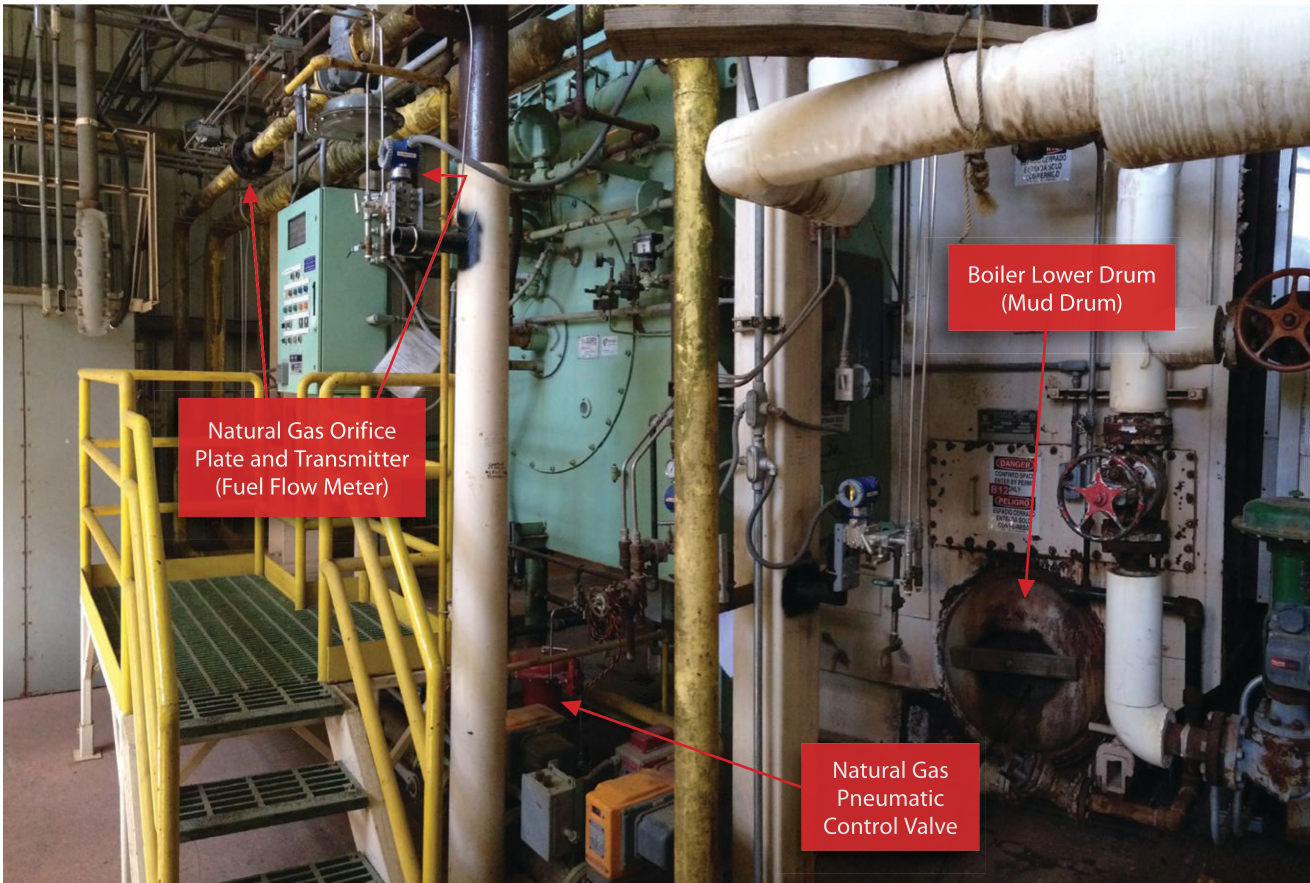

FIGURE 3. A metering system employs a fuel flow measurement device.

each item. A sample system could include a pneumatically operated fuel control valve, a pneumatically operated air damper actuator and a variable-frequency drive (VFD) to modulate the fan speed.

A key requirement to this system is position feedback. Because it is not mechanically linked, each device needs to provide proof of position to ensure enough airflow is being provided.

Similar to single-point positioning combustion control, this is also a single PID loop. The only difference is that there are multiple outputs — one for each device. For example, for a simple gas-only system with no FGR, the input would be steam pressure. The outputs would be the fuel gas control valve position and the air damper actuator position. Once again, position feedback would be used as inputs into the system to confirm device position.

By adding an extra PID loop, air density correction can be incorporated using O_2 trim. A stack O_2 probe (which indicates burner excess air) would be the input, and the output would be a correction to the airflow signal (typically a ±10 percent multiplier). This would help maximize boiler efficiency because the airflow is adjusted as the ambient air temperature changes.

Another efficiency-saving device is a fan VFD. Combustion-air fan-power requirements are greatly reduced at lower boiler loads by reducing fan speed. The fan laws state that power is proportional to the ratio of fan speeds raised to the third power. For instance, if the fan is running at half speed, the power savings can be as high as one-half to the third power, or one-eighth of the original amount. This can be a significant reduction in the electricity bill.

The advantages of this system include the potential efficiency savings and the ability to be applied to larger boilers. The main disadvantage is the potential for air and fuel flows to get out of adjustment, which creates an unsafe situation. (However, this risk is mitigated using position feedback.) This system is also more complex, requiring more qualified operational personnel than what is needed for single-point positioning combustion control.

Metering

Metering is the best system for boiler efficiency, but it is also the most complex and the most costly. It is similar to parallel positioning in the fact that the air and fuel devices are driven by individual actuators, but now air and fuel flow meters are added (figure 2 and 3). The flow meters provide fast-acting feedback signals to the system, which can influence fuel or air flow changes in many ways. For example, if foreign matter was induced into the fan inlet and blocked part of the flow, airflow would be restricted and the airflow meter would detect this. Also, metering systems have an extra safety feature called cross limiting. This function checks that fuel flow is always less than the measured airflow, and airflow is always more than the measured fuel flow.

There are more PID loops with this system: one for the steam pressure (this is the firing-rate demand), one for each fuel, and one for air. The fuel-loop inputs would be firing-rate demand and fuel flow. The output would be fuel control valve position. Similarly, air-loop inputs would be firing-rate demand and airflow. The output would be air damper actuator position. O_2 trim and fan VFD also can be added for increased boiler efficiency.

A metering scheme is the best system for boiler efficiency. The main disadvantage is that it is the most complex system, requiring qualified operational personnel and increased maintenance.

The selection of the burner control system can affect boiler operation, maintenance and efficiency. A single-point positioning scheme is the least expensive and simplest system available while a metering scheme is the most costly and complex. It also is the most efficient option. A parallel-positioning scheme falls right in the middle of the two in regards to cost and complexity. The ability to be applied to larger boiler systems provides both parallel positioning and metering with an added advantage. Evaluate your specific situation and use this information as a guide to assist in the selection process for your boiler burner control system.

With single-point positioning, the boiler may not operate as efficiently as possible because changes in air density throughout the year will cause flow variances. A metering scheme is the best system for boiler efficiency.

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