Combustion Control

Problem

Until recent years, only the largest boilers could justify sophisticated combustion controls. Now, higher fuel costs and occasionally limited fuel availability make it necessary for users to improve boiler efficiency. Government regulations force compliance with stringent air pollution and safety standards. Combustion control have also become more important because boiler loads are being varied to meet needs, rather than operating at full capacity and wasting fuel and steam. Similar concerns are causing the metals-processing and heat-treating industries to consider improved combustion control for their furnaces and other fuel-fired processed.

Solution

Use of more advanced digital controls for automatic combustion control provides improved efficiency and stability under carrying loads and eliminates the need for operator input during load changes. A fuel-air ratio control system is required to perform the following functions;

- Maximize boiler combustion efficiency and minimize fuel use
- Minimize smoking and air pollution, especially on load changes
- Help ensure safe operation
- Maintain steam pressure of furnace temperature at the desired level
- Minimize oxidation of product during heat treating.

Honeywell can provide a control system featuring *UDC3500 Process Controller*. The package is well-suited for boilers in the range of 15,000 to 150,000 lbs/hr. It offers;

- Pre-engineered compatibility
- Single source convenience
- Pre and Post-sale technical support
- Field Proven equipment
- On and Off-line configuration and alarms capability

Combustion Process

The most common fuels consist of carbon and hydrogen. Combustion is the rapid oxidation, i.e., rapid combination with oxygen, of a fuel release heat. Stoichiometric, or perfect, combustion combines the exact proportions of fuel and oxygen to obtain complete conversion of the carbon and hydrogen to yield water vapor, carbon dioxide, and heat. The ideal proportions of fuel and air vary directly with the BTU content of the fuel. Too much air results in energy losses up the stack. Insufficient air results in loss of heat generation due to incomplete fuel combustion.

A certain amount of excess air is required to ensure that complete combustion occurs within the combustion chamber and to compensate for delays in fuel-air ratio control action during load changes. The ideal amount of excess air varies with the type of fuel and the equipment design. When combustion air is preheated and forced into the burner, it may be necessary to provide both temper and pressure compensation to ensure accurate measurement o air flow. It may also be necessary to provide flow compensation for gaseous fuels. Flow compensation for temperature and pressure variations can be economically provided using a single Honeywell SMV 3000 transmitter for each flow steam. The correct fuel-air ratio established during initial start-up and is then re-checked periodically.

Fuel gas composition is an excellent indication of combustion efficiency. Combustion efficiency is a measure of how effectively the heat content of a fuel is transferred into usable stable heat. Oxygen (O_2), carbon dioxide ($C\ O_2$), and carbon monoxide (CO) are the three gases available for monitoring combustion effciency.

Oxygen monitoring is the most popular approach for several reasons. It has a measurable single-value relationship with excess air; it is insensitive to other flue gases; and it is independent of fuel composition. Zirconium oxide sensor technology makes oxygen monitoring the most cost-effective, accurate and reliable approach currently available. Of course, there are certain precautions to observe. The sampling location must to carefully select to minimize effects of stratification and infiltration of tramp air, which will falsely raise the O_2 reading. In addition, to ensure safe burner conditions, it is usually necessary to control flue gas oxygen to 1.5% or higher to ensure complete combustion of fuel.

CO_2 on the other hand, exhibits its highest signal level at stoichiometric conditions, but at other conditions it is dual-valued, meaning CO_2 concentrations exists for both fuel-rich and air-rich conditions. This makes automatic control very difficult. In addition, CO_2 versus excess air levels vary with different fuels.

CO monitoring and control can provide very close to stoichiometric combustion by ensuring the absolute minimum of excess air. This is because CO is a direct measure of combustion and is independent of air infiltration. Unfortunately, the ideal CO level is near 200 ppm (parts per million) which is less than 0.02% CO. This low level requires relatively expensive sensing techniques and computerized signal conditioning, which can usually only be justified on large boilers or process heaters.

Combustion Control System Description

A fuel-air metering control system is essential for efficient combustion in boilers, furnaces, and other large fuel-fired heating processed. These systems vary in complexity from the simple metered approach to the complex cross-limiting system, which is used to ensure safe firing during load changes. Automatic oxygen trim of the fuel-air ratio via feedback control is a further refinement to ensure safe and efficient operation.

Cross-limiting Meters Systems

The cross-limiting metered approach, shown in Figure 1 is used for boiler combustion controls when large or frequent load changes are expected. This is a dynamic system that helps compensate for the varying speed of response of the fuel valve and air damper. It prevents a "fuel-rich" condition and minimizes smoking and is pollution from the stack.

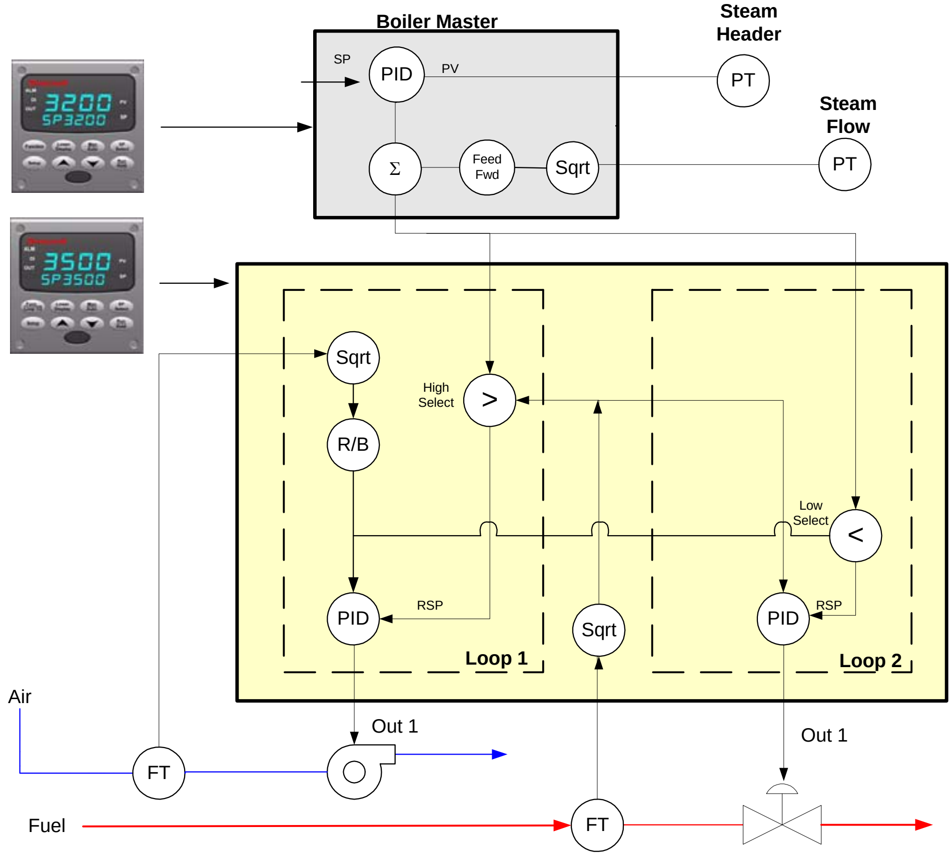

Figure 1 Lead-Lag, fuel/air ratio control plus demand control

The system, also know as a lead-lag parallel-series metering system, operates as follows. In steady state the steam demand, fuel flow, and air flow signals to the high and low selectors are equal. Upon a demand increase, the selector blocks the increase, forcing the air flow process variable to become the set point for the fuel flow controllers. The high selector passes the demand signal to the air controller's set point. This means fuel flow cannot increase until air flow has begun to increase, i.e., air increase leads fuel increase.

When demand drops, the low selector passes the signal to the fuel flow controller set point, while the high selector passed the fuel flow process variable signal to the air flow controller setpoint. This means air flow cannot decrease until fuel begins to drop; i.e., fuel decrease leads air decrease.

This strategy avoids a fuel-rich condition, regardless of the direction load change, by automatically switching to the appropriate series metering system during transient conditions.

Oxygen Trim

Automatic oxygen trim of the fuel-air ratio is used to reduce excess air, and therefore excess O_2, to nearly stoichiometric combustion efficiency. In addition to improved efficiency, lower excess air helps reduce corrosion and air pollution by minimizing formation of NO_x, CO_2, and SO gases.

Here's how the system works. An oxygen (O_2) sensor measures the percent O_2, in the flue gases and transmits the data to an oxygen controller, which adjusts the fuel/air ratio until O_2 setpoint is reached via feedback control.

The O_2 corrected fuel/air ratio is applied to the linearized combustion air flow signal. The O_2 analyzer completes the feedback loop. The O_2 controller output signal should have high and low limits and alarms to protect against possible malfunction or misreading by the oxygen analyzer/transmitter, which could cause an incorrect and potentially unsafe fuel-air mixture. This is illustrated in Figure 2.

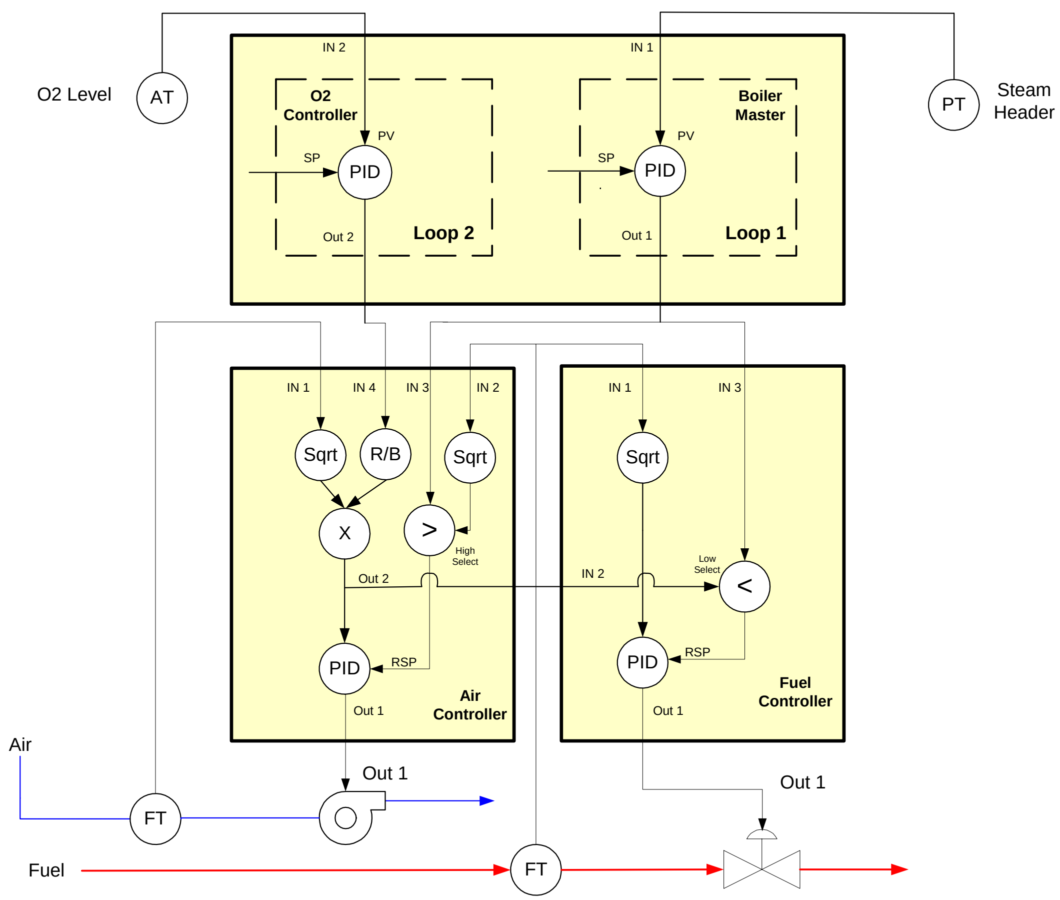

Figure 2 Lead-Lag, fuel/air ratio control plus O_2 control and demand control

The O_2 controller's setpoint can be generated by a characterized function of steam flow or heat demand from a remote signal. This is desirable because load changes and cyclic firing often require varying amounts of excess air for efficiency and safety. For example, a boiler requires more excess air low loads than at high loading. This is because much more efficient operation and combustion stability is achieved at high loads, which leads to lower excess air requirements and potential fuel savings. Steam flow is an ideal indication of boiler loading. The characterized signal is obtained by using an 8-segment characterizer to shape the desired setpoint relationship to steam flow, or a ratio-bias device to generate a straight-line approximation of the steam flow load versus excess oxygen requirements for each specific fuel. High and low limits are applied to prevent unrealistic extreme setpoints for the O_2 controller.

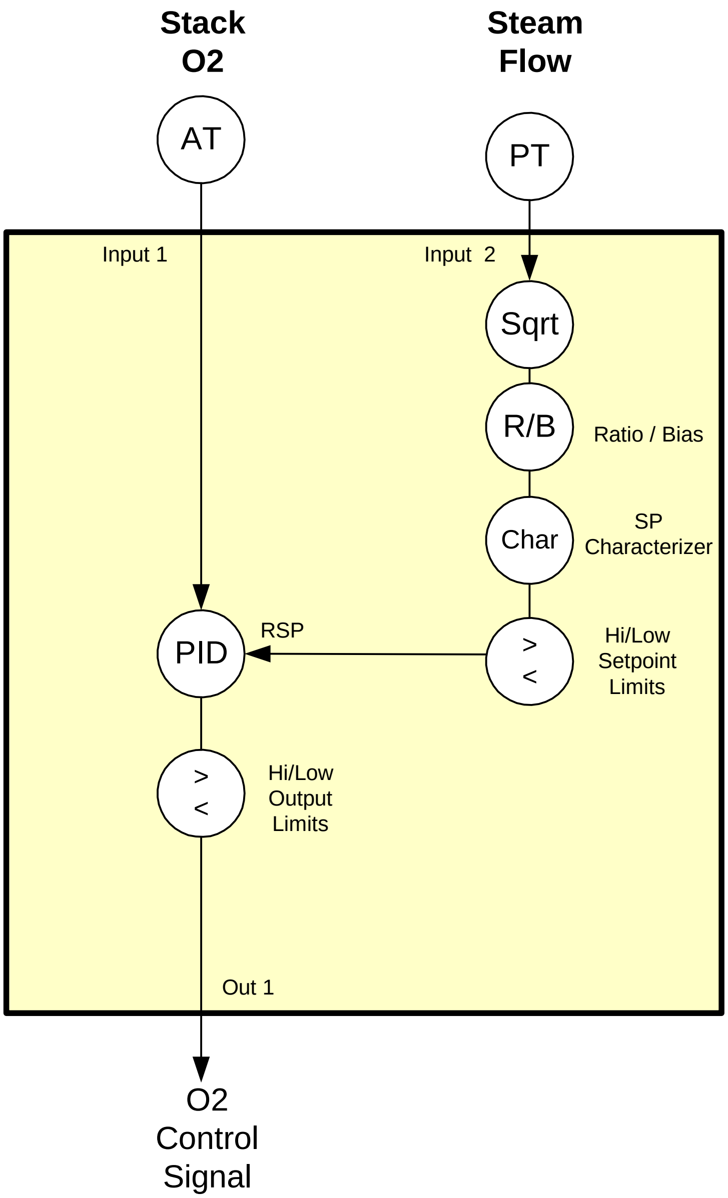

Figure3 shows automatic O2 trim applied to the cross-limited (lead-lag) system.

Controllers

The fuel flow and air flow controllers are two-mode (proportional plus integral) controllers with remote setpoint configuration. The firing rate demand signal is generated by an indication two-mode pressure controller (referred to as the boiler mater).

Honeywell's UDC 3500 Process Controller can handle both fuel flow and air flow control in a single instrument. The device contains the high and low sectors, ratio setting, and square root extraction in one-panel mounted (1/4 DIN size) unit with vertical bar graphs plus digital displays. This arrangement is shown in Figure 1.

It is often more preferable for the operator to be able to easily see and control both fuel and air flow loops simultaneously, especially during upset conditions when a few seconds delay could cause a fuel-rich condition. Note also that for multiple-burner boilers, NFPA standards require continuous and usable displays of fuel and air simultaneously. This requirement is easily met buy using two UDC 3500s.one dedicated to fuel and one dedicated to air. This is illustrated in Figure 2 for a lead/lag system with oxygen control. This approach could also be similarly implemented for the basic led/lag system in Figure 1 by using a separate UDC 3500 for Loop 1 and Loop 2. Note that it is still possible to economically use two loops in one UDC 3500 by combining the oxygen controller with the steam pressure controller.

Oxygen Controller

This application requires a two-mode (proportional plus integral) controller with adjustable output limits to protect against extreme control signals due to malfunction or erroneous readings by the O_2 transmitter.

Honeywell recommends a UDC 3500 Process Controller to control O_2 and provide the multiplier function in one device. This device also contains all the signal conditioning necessary to characterize the remote setpoint signal in addition to providing the O_2 controller function described above.