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APPLICATION DATA

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Procidia Control Solutions
Combustion Management Solutions
Full-Metered, Cross-Limited Control

INTRODUCTION

This paper is the third in a series that discusses Combustion Management Solutions. This installment discusses Full-Metered, Cross-Limited Control.

The benefits of full-metered, cross-limited control are:

◊ Improves boiler efficiency by compensating for variations in fuel and combustion airflows
◊ Improves boiler safety with active constraints over the air/fuel combustion mixture

BACKGROUND

The primary function of the combustion control system is to provide air and fuel to the burner at a rate that satisfies the firing rate demand while optimizing the combustion mixture. The control system design, configuration, and daily operation must provide for the safety of operating personnel and for economy of operation.

Maintaining an optimum combustion mixture is critical in meeting the requirement for safety and economy. Insufficient air results in incomplete combustion and poses a health and safety hazard. Incomplete combustion forms carbon monoxide, which is a health hazard if combustion gases escape into the plant area. In extreme cases, unburned fuel remains in the combustion gases. This is a severe safety hazard because fuel rich combustion gases can auto-ignite when they mix with a stream of fresh air. Of course, poor mixing of air and fuel at the burner can also result in incomplete combustion. From an economic standpoint, incomplete combustion reduces boiler efficiency and results in higher fuel cost.

Too much air also results in higher fuel costs because energy is wasted heating excess air. However, the combustion control system should operate with a slight amount of excess air to insure complete combustion and minimize formation of carbon monoxide.

Full-metered control means that both fuel and airflow are measured and controlled separately. Metered control recognizes that variations in fuel feed pressure affect fuel flow and variations in draft pressure affect combustion airflow. In parallel positioning control (see AD353-102), the fuel valve and air damper respond to the firing rate demand in a fixed relationship. When a variation in fuel flow occurs, the firing rate control loop compensates for it directly by adjusting the demand. The problem is that airflow is inadvertently changed affecting the air/fuel ratio. The result is a reduction in boiler efficiency. Variations in airflow directly affect the air/fuel ratio. Full-metered control permits the independent adjustment of combustion air and fuel flows in order to maintain optimum air/fuel ratio. The benefit of this control system is improved boiler efficiency.

Cross-limited control is “safety logic” superimposed on a full-metered control system. In the event of a mechanical failure (e.g. jammed fuel valve, blocked air damper), it is possible to create a fuel rich combustion mixture. Cross-limited control prevents combustion airflow from falling below fuel flow and fuel flow from exceeding airflow.

MEASUREMENT

Full-metered control is a cascade control strategy that requires three process variable measurements. The measured variable for the primary loop is steam header pressure. There are two secondary loops with fuel flow and combustion airflow being the secondary loop measured variables.

Steam Header Pressure
Steam header pressure can be measured using a gauge pressure transmitter.

Fuel Flow
The flowmeter chosen for fuel flow depends on the type of fuel used.

<u>Fuel Gas</u>
The most common fuel gas is natural gas, but may also be propane or a mixture of these. This is normally metered using a differential pressure type flowmeter and primary element such as an orifice plate. Select an instrument with high turndown capability. Additional features such as an integral square root extractor are also useful.

<u>Fuel Oil</u>
The fuel oil flow can be measured using a coriolis flowmeter. It measures mass flow, is not affected by pressure or temperature, and has a high turndown ratio for accurate mass flow measurements across a wide range of flow rates. Another common alternative is to use a differential pressure transmitter with remote seals.

Fuel oils are available in a wide range of grades, identified by numbers. For fueling boilers, the most common fuel oils are 2 and 6. Fuel oil requires atomization in order to burn. Number 2 fuel oil is light enough that it can be atomized at normal temperatures but number 6 fuel oil requires heating for it to flow.

Airflow
Airflow measurements are typically made using a Pitot-array sensor and a draft-range differential pressure transmitter. Pitot-array sensors detect the dynamic pressure or the pressure of a stream of flowing air. The differential pressure transmitter measures the difference between the static and dynamic pressures. Volumetric airflow is proportional to the square root of the differential pressure. Measured pressures are low, usually less than 5 in. wc.

CONTROL

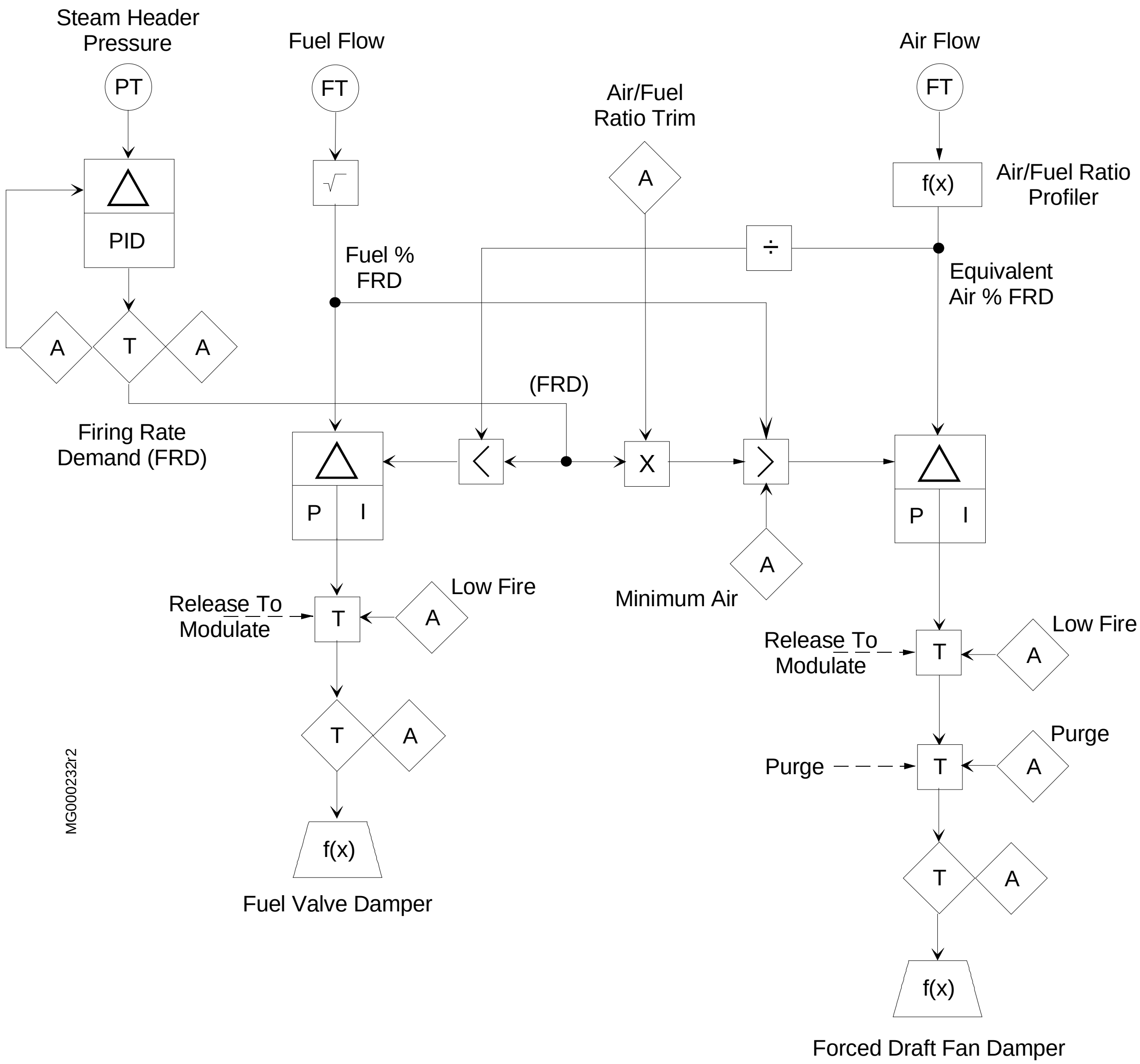
The full-metered, cross-limited control system is the standard control arrangement for steam boilers. The SAMA[1] diagram on page 3 illustrates the control logic. Full-metered control is a cascade control architecture where the firing rate control loop is the primary loop and the fuel flow and combustion airflow loops are secondary control loops.

Firing Rate Control Loop
The firing rate control loop regulates the boiler firing rate in order to satisfy steam demand and maintain drum pressure at setpoint. It is a feedback control loop and uses PID control. The process variable is drum pressure, typically measured in psig, with the setpoint entered manually. The controlled variable is the firing rate demand (FRD). FRD is the cascade setpoint for the fuel flow and combustion airflow control loops. Proportional gain, integral action and derivative action are typically employed.

Physically, FRD represents the energy demand (for example, BTU/hr). In single fuel applications, it is easier to define FRD as percent of full scale fuel flow or 0-100%FRD. This technique simplifies the air/fuel ratio control logic.

Fuel Flow Control Loop
The fuel flow control loop delivers the specified FRD from the firing rate control loop. Variations in fuel feed pressure affect the flow rate and the flow control loop compensates for these variations. The process variable is fuel flow and it

[1] *Scientific Apparatus Makers Association*



Full-Metered, Cross-Limited Combustion Control

is defined in %FRD units. Physically, %FRD is the percent of full scale fuel mass flow rate. Mass flow transmitters typically provide a linear flow output signal. In gas flow applications where flow is measured using differential pressures, a square root extractor is used to linearize fuel flow.

The SAMA diagram shows fuel flow measured with a DP transmitter. When flow is measured, a feedback control loop is established and PID control is used. This is a cascade loop where the setpoint is the FRD from the firing rate loop.

Normally, flow control loops use proportional gain and integral action only. The controlled variable is 0-100% valve opening and it modulates the fuel valve actuator. Mechanically characterizing the fuel valve actuator to provide linear flow with % valve opening improves the response of the fuel flow control loop. The auto/manual transfer switch is available for commissioning and characterizing the air/fuel ratio. It is disabled during normal operating conditions.

Combustion Airflow Control Loop
The combustion airflow control loop provides sufficient air for the specified FRD from the firing rate control loop. Variations in draft pressure affect the airflow rate and the flow control loop compensates for these variations. The process variable is airflow and it is defined in %FRD units.

In the SAMA diagram, the characterizer function block converts the airflow measurement into %FRD. Physically, %FRD is the percent of full scale fuel mass flow. In the air control loop, %FRD is the equivalent air required for %FRD mass fuel flow. During commissioning, the boiler is run at several loads and the corresponding fuel and airflow rates are recorded. Flue gases are monitored in order to determine optimum airflow.

Flow rate data is used to configure the characterizer function block. The characterizer profile defines the optimum air/fuel ratio. Seasonal changes affect the moisture content and density of air, and this affects the amount of air required to burn a pound of fuel. Since airflow measurements are volumetric, it is necessary to adjust the air/fuel ratio. In the SAMA diagram, the fine adjustment is represented as a manual ratio input, Air/Fuel Ratio Trim. Adjustment can be automated with an excess oxygen trim control, see AD353-104.

Combustion airflow control is a feedback control loop utilizing PID control. It is a cascade loop where the setpoint is the FRD from the firing rate loop. It is important that the process variable and setpoint be in the same engineering units, %FRD. Normally, flow control loops use proportional gain and integral action only. The controlled variable is 0-100% damper opening and it modulates the forced draft fan damper. Mechanically characterizing the damper to provide linear flow with % damper opening improves the response of the airflow control loop. The auto/manual transfer switch is available for commissioning and characterizing the air/fuel ratio. It is disabled during normal operating conditions.

Cross-Limited Control
Cross-limited control insures that fuel flow does not exceed equivalent combustion airflow. Since both fuel flow and airflow are defined in %FRD units, the comparison logic is simplified. In the fuel flow control loop, the FRD setpoint is compared to the actual air %FRD flow and the smaller value is selected using a “low-select” function block. This prevents fuel demand from exceeding available airflow.

In the combustion airflow control loop, the FRD setpoint is compared to the actual fuel %FRD flow and the greater value is selected using a “high-select” function block. This prevents air demand from dropping below actual fuel flow. For safety reasons, a minimum airflow is always maintained. In a Model 353 controller, the SEL (Hi/Lo Signal Selector) function block supports three inputs and an ORSL (Override Selector) function block can be used to provide an alarm signal.

This control strategy is often called a “lead-lag” circuit since the airflow will always “lead” the fuel on an increase in FRD (the low-select on the fuel setpoint requires the airflow to increase before fuel) and lag the fuel on a decrease in FRD (the fuel flow must be lower than airflow for the air setpoint to be decreased).

Burner Safety Management Interface Signals
The burner safety management system (BMS) is a separate logic controller responsible for boiler safety. It insures the safe ignition of the burner flame. It also monitors the boiler and closes the fuel safety shut-off valves in the event of a hazardous condition. The SAMA diagram above illustrates typical BMS interface points.

Purge Command
The first step in the ignition sequence is to purge the furnace or fired tube of any residual fuel. The purge command opens the forced draft fan damper to the full open position. It overrides the controlled variable.

Low Fire Command
After the purge step, the fuel actuator and air damper are brought to the low fire position. This is the condition where the burner can be safely ignited. In the SAMA diagram example, the low fire command is not shown as a separate command. In some applications, the stand-by position is the low fire position. If the low fire command is used, it will override the control variable.

Release to Modulate Command
After a flame has been established, the BMS releases the combustion controller to regulate steam pressure. The release to modulate command enables the firing rate and both flow control loops. While in stand-by mode, the firing rate control loop is typically in setpoint tracking mode.

APPLICATION SUPPORT

The next publication in this series is AD353-104, O_2 Trim Control. User manuals for controllers and transmitters, addresses of Siemens sales representatives, and more application data sheets can be found at www.usa.siemens.com/ia. To reach the process controller page, click **Process Instrumentation** and then **Process Controllers and Recorders**. To select the type of assistance desired, click **Support** (in the right-hand column).

The control concepts in this publication can be developed into a controller configuration using the Siemens i|config™ Graphical Configuration Utility.

Combustion management configurations can be created and run in the following Siemens controllers:

- Model 353 Process Automation Controller
- Model 353R Rack Mount Process Automation Controller*
- i|pac Internet Control System*
- Model 352*Plus* Single-Loop Digital Controller*

* Discontinued model