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An Alternate Approach to Flue Gas Heat Recovery

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Abstract

Many solid fuel-fired boilers are equipped with an economizer and air heater (Figure 1) to provide economical heat recovery and hot air for good combustion. There are practical limitations to how much energy a given economizer/air heater arrangement can absorb. An economizer is limited by the water-side approach to saturation temperature and feedwater inlet temperatures. This is especially true for power plants seeking maximum cycle efficiency by utilizing multiple feedwater heaters. Similarly, an air heater is limited by combustion equipment air temperature requirements and dew point considerations.

If the boiler is equipped with air quality control systems (AQCS), the need to match AQCS equipment to a specific gas temperature profile further complicates the design.

This paper will explore an alternative approach to flue gas heat recovery. In this approach, Babcock & Wilcox Power Generation Group, Inc. (B&W PGG) integrates a watercoil air heater and the economizer surface to achieve final exit gas temperatures lower than what is economically possible with traditional economizer/tubular air heater technologies. Lower stack temperatures directly correlate to higher boiler efficiencies. The patent pending technology effectively balances the heat rejected by the flue gas to the heat absorbed by the combustion air and feedwater by proportioning water flow between the watercoil air heater and economizer banks.

This unique approach increases the temperature differential between the feedwater and the flue gas thus improving overall heat transfer rates. The result is a compact modular-component surface arrangement. The system will accommodate higher feedwater temperatures while still achieving lower stack gas temperatures for improved boiler and steam cycle efficiency. Being a modular design, the strategic component arrangement promotes AQCS equipment integration. Additional benefits include lower fan parasitic power and the capability of controlling gas temperatures for varying fuel or boiler operating loads and conditions.

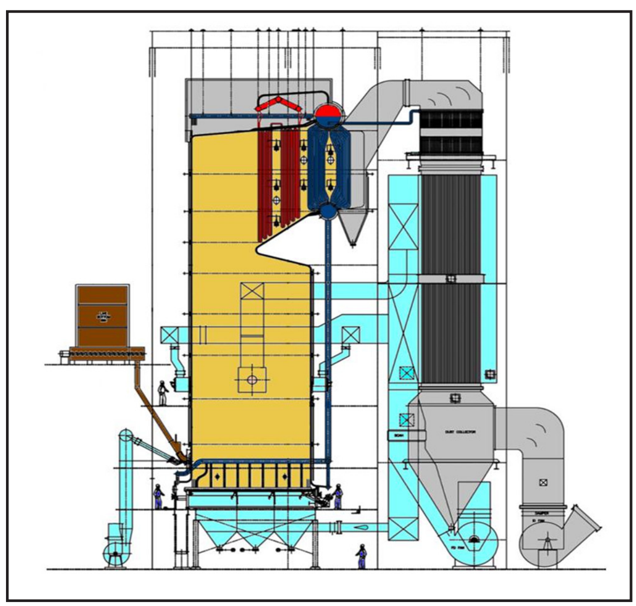

Fig. 1 Typical economizer and tubular air heater arrangement.

Traditional economizer/air heater arrangements

Economizers and air heaters perform a key function by providing high overall boiler thermal efficiency. This is accomplished through the recovery of low level (i.e., low temperature) energy available in the flue gas before it is exhausted to atmosphere. Generally, for each 40F (22C) flue gas that is cooled by an economizer and/or air heater, the overall boiler efficiency increases by approximately 1%. Economizers recover the energy by heating the boiler feedwater; air heaters heat the combustion air. Hot air enhances the combustion of many fuels and is critical for ignition and stable combustion of high moisture fuels.

Economizers and air heaters are positioned in the gas stream to maximize heat recovery and provide the most reliable and economical design. Saturation temperature and feedwater temperatures limit economizer size while an air heater may be limited by dew point temperature considerations.

In most cases, an economizer is located after the superheater and/or generating bank and before the air heater. The economizer is sized with the maximum surface possible while avoiding feedwater steaming. Alternately, for high moisture fuels requiring high combustion air temperature, economizer sizing is based on the required air heater absorption.

Because of the ash, sand and char in the flue gas, a recuperative (usually tubular) air heater is the norm. The air heater typically is the last boiler heat trap. Once the combustion air temperature requirements are met, additional air heater surface is used to minimize the stack temperature. As the flue gas temperature approaches the air inlet temperature, the amount of air heater surface required increases exponentially. A reasonable stack temperature for a unit with a recuperative air heater is in the 320 to 350F (160 to 177C) range. Above a 350F (177C) stack temperature, the sensible heat loss is detrimental to boiler efficiency. A stack temperature lower than 300F (149C), although possible, requires significant air heater surface, a substantial support structure and is prone to dew point condensation, fouling and corrosion.

Economizer/watercoil air heater arrangements

An economizer coupled with a watercoil air heater is an effective backend surface arrangement that improves boiler performance. With this arrangement, the watercoil air heater is a surrogate for the tubular air heater. Gas (or air) to water heat exchangers are more effective heat exchangers than gas to air; hence, the overall surface requirements are much less. Single or multiple watercoil air heater banks can be used as dictated by combustion air requirements. They can be readily incorporated into the boiler's air system arrangement.

Utilizing watercoil air heaters with economizers can yield a lower stack temperature for a given operating condition than what is economically possible with regenerative or recuperative air heating. This unique arrangement increases the driving force between the water and flue gas. The increased driving force improves the heat transfer resulting in a more compact arrangement than is typically seen in the industry today. A boiler efficiency improvement of 1 to 2% can be realized. Higher efficiency means less heat (fuel) input per pound of steam and lower generation of criteria pollutants. For input driven installations, the higher efficiency means more steam generated per pound of fuel. The use of watercoil air heaters avoids the inherent dew point condensation concerns (pluggage) and could potentially require fewer sootblowers.

With this approach the designer has the latitude to configure the economizer and watercoil air heater components to maximize effectiveness. The boiler arrangement is simplified because the economizer and watercoil interconnections are feedwater piping rather than cumbersome flues and ducts. As an option, extended surface (finned) economizer technology can further reduce pressure part requirements. The use of watercoils versus tubular air heaters also reduces draft loss and air resistance, which translates into smaller fans and lower parasitic power requirements.

To meet permitted stack emissions, power boilers will require air quality control systems (AQCS). For Industrial MACT compliance, much lower carbon monoxide (CO) levels could increase nitrogen oxides (NO_X) emissions. In some nonattainment areas, this may dictate the use of a selective catalytic reduction (SCR) system for NO_X control. Industrial MACT compliance may also require dry sorbent injection (DSI) for HCl control and a fabric filter or electrostatic precipitator (ESP), and perhaps a mechanical dust collector (MDC), for particulate control. In some cases, activated carbon injection may be required for mercury, dioxin and furan control. Each air pollution control component requires specific gas temperature windows or limits to function properly. These AQCS temperature requirements complicate the boiler surface arrangements beyond those stated above for combustion air temperature and boiler efficiency.

For biomass firing, B&W PGG's preferred approach to the AQCS arrangement is as follows: dry sorbent injection (sulfur removal), powdered activated carbon (PAC) injection (for mercury and dioxin and furan control), a fabric filter (particulate removal including DSI reagent and PAC) and a clean, low dust SCR. For grate-fired units, an MDC would be included upstream of the fabric filter. This overall arrangement places the SCR catalyst in the most favorable location for sustained reactivity. The DSI system is effective at gas temperatures in the 400 to 600F (204 to 315C) range. Certain reagents allow a higher upper temperature limit. DSI injection occurs between or after the economizer banks prior to the fabric filter. The key is to provide sufficient resident time for the reactions to occur. Economizer surface is sized to give a 400 to 435F (204 to 224C) gas temperature to the fabric filter (or ESP). Finally, immediately downstream of the fabric filter is the ammonia injection grid and SCR. The desired SCR gas temperature target is 425F (218C). SCR gas temperatures are dictated by upstream DSI and fabric filter components. This arrangement results in a clean/low dust SCR that avoids excessive exposure to acid gases and dust-borne poisons that reduce catalyst life. To maximize boiler efficiency, a finishing economizer bank is installed after the SCR to minimize the gas temperature leaving the stack. Watercoil air heaters are located on or near grade, integral to the combustion air ductwork and forced draft air system.

Optimized economizer/watercoil arrangements

Beyond the approach to saturation and the avoidance of dew point condensation, the AQCS equipment specific gas temperature requirements present a significant thermal design challenge. A physical arrangement that meets all functional requirements is difficult to achieve without compromise. A novel approach is to strategically arrange economizer and watercoil air heater surface among AQCS components and selectively control the feedwater flow to them. As shown in Figure 2, full feedwater flow enters the boiler setting as a single stream. Within the setting, the feedwater flow is split into two streams. Flow control valves proportion feedwater between the watercoil air heater and economizer banks to meet the desired thermal operating conditions. Controls will provide a stable gas temperature profile to the AQCS equipment while accommodating boiler load changes and fuel variability without functional sacrifice.

This system lends itself to boilers with high feedwater temperatures to the boiler boundary; i.e., installations with multiple feedwater heaters. This gives the designer an opportunity to minimize watercoil air heater size and quantity. Most solid fuel boilers stage their combustion air. Stoker-fired units have undergrate and staged overfire air systems. Likewise, bubbling fluidized-bed boilers have bed air and a similarly staged overfire air system. The use of multiple watercoil air heaters conveniently integrated with underbed/grate and overfire air systems results in simplified ductwork, fans, dampers and control systems.

Biasing the feedwater between selected economizer banks and watercoil air heaters promotes good combustion and low uncontrolled NO_x, CO and volatile organic compounds (VOC) emissions. Optimizing uncontrolled emissions allows proper sizing of the downstream pollution control equipment. Further, the ability to bias feedwater flow between the watercoil air heaters and economizer banks provides feedwater temperature operating flexibility. During load changes and upset operating conditions, flow controls can maintain a safe feedwater subcooling margin as required for positive boiler circulation characteristics.

The physical arrangement of AQCS equipment with traditional economizer/tubular air heater components can

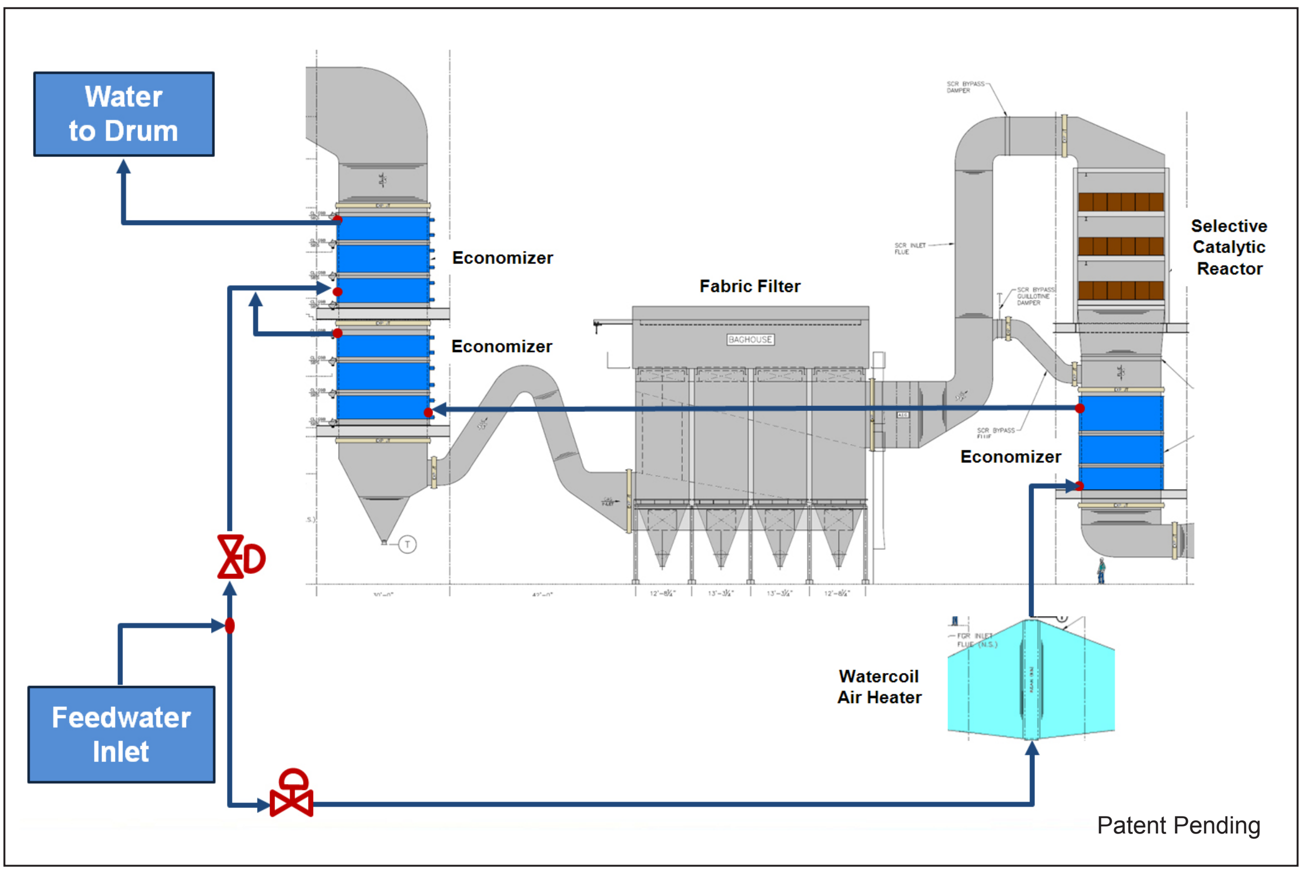

Fig. 2 Air quality control system temperature control.

be a significant challenge. The use of shop modularized economizer banks and watercoil air heater modules eases erection requirements. Ultimately, the boiler backend can be configured in a low profile setting that minimizes structural steel and building volume. Many components can be located on grade, or in the case of the economizer banks, can be co-located within a single structural steel bay.

Conclusions

The use of modular economizer and watercoil air heaters with biased feedwater flow improves the overall thermal effectiveness of the boiler and environmental equipment islands. Eliminating a traditional tubular or regenerative air heater and replacing it with flow biased watercoil air heaters results in a more compact design that is more efficient and operationally flexible. With this technology, the boiler and environmental equipment has the capability of accommodating fuel variability and load swings without jeopardizing the life or functionality of critical components. From a capital cost standpoint, a greenfield unit is less expensive due to substantially less structural steel. Foundation requirements are less and overall, the plant is easier to erect. Operating costs are less due to improved boiler efficiency, lower fuel costs, reduced reagent demand and lower parasitic power.