By DUNCAN CAIRNIE

HEATING/PIPING/AIR CONDITIONING
HPAC
ENGINEERING

Linkageless Burner Control

Linkageless control systems help reduce greenhouse gases

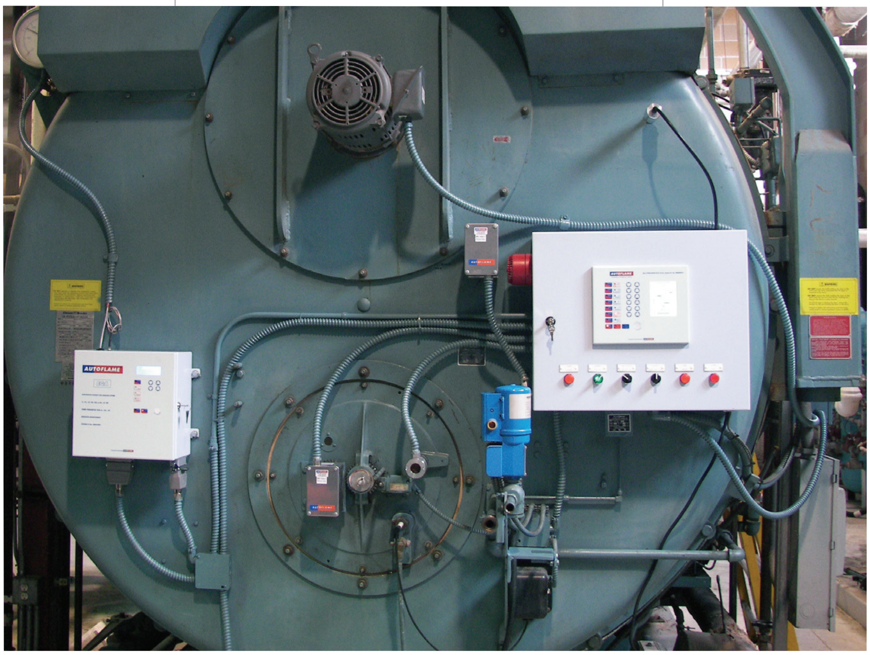
During the early 1980s, the first electronic fuel-to-air-ratio combustion-control system was introduced. Today, the focus is on the energy savings and emissions monitoring this technology can deliver, in addition to providing boiler-house solutions.

Equipment such as a linkageless control system coupled with an exhaust-gas analyzer, can help reduce energy consumption and harmful emissions. This system controls the combustion process with microprocessor technology. Benefits of linkageless burner control include optimized combustion, repeatability, improved safety control, maximum turndown, fuel and energy savings, and reduced emissions.

Green Solutions

Whether curtailing carbon emissions and nitrogen-oxide (NOx) output or participating in carbon trading, countries are reducing harmful greenhouse gases worldwide. Changes in human-induced activities have been a major cause of the increase in atmospheric greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), NOx, and water vapor. The largest contribution comes from fossil-fuel combustion, such as that used in transport, power production, and heating.

In an effort to combat the effects of greenhouse gases, the Kyoto Protocol was adopted on Dec. 11, 1997, in Kyoto, Japan. The objective of the protocol is the "stabilization of greenhouse-gas concentrations in the atmosphere at a level that would prevent



Exhaust-gas analyzer with linkageless control unit.

University Saves Money, Energy With Boiler Controls

Statistics showing actual emissions and cost savings for a Boston university over a 10-year period make a compelling case for linkageless control and continuous-emissions-monitoring software.

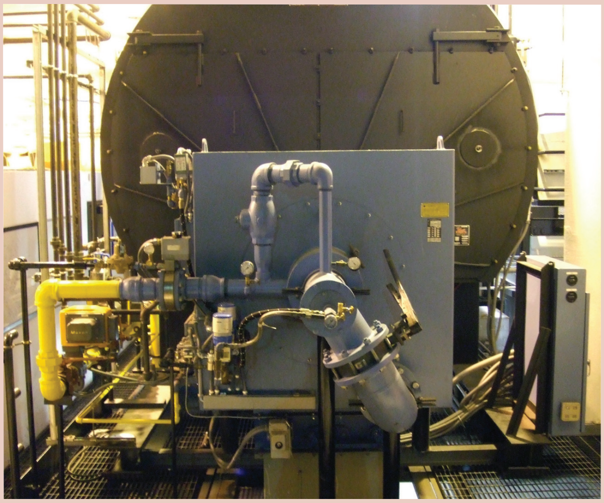
Prior to 1985, most of Northeastern University's (NU's) heating, domestic-hot-water, cooking, and process loads were supplied by a district steam supplier. The costs and apparent inefficiencies of purchased steam were evident, and NU decided to develop its own steam plant through a phased-construction process.

By 1988, three boilers had been installed. Then the campus expanded, increasing load requirements and making the addition of two more boilers necessary. In 1997, NU worked with George T. Wilkinson Inc., a Boston-based engineering firm, to invest $160,000 to convert the mechanical linkages on its five boilers to linkageless control systems, complete with variable-speed drives and exhaust-gas analyzers. A sixth boiler was added in 2005. The plant now serves 40 buildings over 3.8 million gross square feet and provides for the heating, cooling, domestic-hot-water, cooking, and other process needs of the facility.

NU's actual fuel usage and emissions data have been collected over the last 10 years. In 1997, NU burned more than 288,000 MBtu of gas and more than 8,000 MBtu of oil. This produced more than 20 tons of nitrogen oxide (NOx) and almost 17,500 tons of carbon dioxide (CO_2). In 2007, the university burned 431,917 MBtu of fuel and produced 22 tons of NOx and 25,000 tons of CO_2 with linkageless control. About 135,000 MBtu—almost 50 percent—more fuel was utilized with less than a 10-percent increase in NOx.

When NU upgraded its combustion system, Geoff Wilkinson, president and chief executive officer of George T. Wilkinson Inc. and Wilkinson Mobile Boilers Inc., thought the university never would reduce its greenhouse-gas emissions along with its energy and maintenance costs.

The "system was new to everyone in the U.S. back in 1995 ... and (George T. Wilkinson Inc.) still at that time didn't know the entire capabilities of the systems, especially the exhaust-gas analyzer as it relates to the more modern environmental impact of 2007 and beyond," Wilkinson said.



Northeastern University's boiler room.

The advancements in emissions-reduction technology for fossil-fuel-fired boilers has been at the forefront of NU's program to reduce greenhouse-gas emissions. With a maximum output of 5,100 bhp, NU's six firetube boilers can generate 180,000 lb of steam per hour at 15 psig, making the university's plant one of the largest, cleanest, and most efficient low-pressure steam-boiler plants in the world.

Specified with pre-installed combustion controls, the most recently installed 1,000 bhp boiler meets ultralow-NOx requirements (less than 9 ppm) and burns natural gas as its primary fuel. These figures would not have been attainable without the use of the linkageless control system and exhaust-gas analyzer.

NU has saved 238,028 MBtu, or $1,809,124, with optimized combustion control and fuel consumption. Based on a 1997 gas price of 85 cents per therm, these are conservative figures. Including $50,000 saved on electrical consumption and $235,000 saved on maintenance, NU has saved more than $2 million by installing linkageless control systems. The return on investment is estimated at 1.14 years. With these fuel and electricity savings and maintenance and emissions reductions, linkageless controls now can be complete boiler-house solutions.

dangerous anthropogenic interference with the climate system." Initially, industrialized countries that committed to greenhouse-gas reduction—known as Annex 1 countries—were to reduce greenhouse gases by at least 5 percent between 2008 and 2012.

The United States would have to reduce its greenhouse-gas emissions currently projected for 2010 by almost 25 percent to meet the designated level. Therefore, many U.S. facilities and companies have been trying to monitor, reduce, and be more precise about the emissions they produce.

An arrangement under the Kyoto Protocol, the Clean Development Mechanism (CDM), allows Annex 1 countries to invest in projects that reduce greenhouse gases in developing countries as an alternative to their own more expensive greenhouse-gas-reduction projects. Measuring baseline emissions and monitoring subsequent emissions are key to each CDM project. This monitoring ensures that any emission reductions claimed are real, measurable, and verifiable and would not have occurred without the project.

Emissions monitoring is possible with an exhaust-gas analyzer, which can measure exact levels of harmful gases released into the atmosphere by industrial boilers, plants, etc. When an exhaust-gas analyzer is coupled with a data-transfer interface (DTI), emission levels can be recorded and tabulated, providing an auditable record of emission reductions that can satisfy CDM-project monitoring requirements.

Currently, more than 780 CDM projects are registered in 48 countries, and approximately 1,320 additional projects are in the process of being registered. By 2012, these projects are expected to generate 2.2 billion carbon credits, each of which is equivalent to 1 ton of CO_2.

Maximizing Boiler Efficiency

There are two requirements for maximizing the efficiency of a boiler. First, the fuel/air ratio should be optimized to ensure complete fuel combustion and to keep excess-air levels to a minimum. Second, a combustion system should monitor a boiler's target temperature or pressure for an immediate response to changes in external conditions.

Mechanical systems that traditionally use cams, linkages, and jackshafts to characterize the fuel/air ratio with their inherent hysteresis cannot achieve the sustainable accuracy required to maintain optimum combustion and fuel efficiency. Hysteresis losses and slop change combustion values over time and vary combustion efficiency when firing rates are increased or decreased. Therefore, these systems have to be set up as air-rich, which reduces their efficiency.

A U.S. Environmental Protection Agency (EPA) document, "Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency," states that 10-percent excess air (2-percent oxygen [O_2]) is optimal to guarantee complete natural-gas combustion. However, these levels of excess air typically are unattainable in the boiler industry. Further, it is impossible to reach this combustion quality with mechanical systems. There is a tendency to run burners with about 50-percent excess air (7.5-percent O_2). This dilutes combustion products, increases combustion flow rates and stack temperatures, and reduces combustion temperatures and energy transfer into the medium. These factors lead to reduced boiler efficiency.

With a programmable linkageless control system, it is possible to optimize combustion quality for boiler/burner load requirements. A linkageless combustion-control unit can display positioning data for several individually controlled channels, such as fuel, air, flue-gas recirculation, and atomizing air. It checks the relative positioning of these channels 50 times per second, ensuring safety and accuracy. This enables the system to achieve "locked-on" near stoichiometric fuel/air mixing throughout a boiler's fuel-input range while maintaining exact temperature or target pressure values.

Whether the firing rate is increased or decreased, the maximum error in degrees angular rotation between positioning motors is 0.1 degree at any position in the load range. This allows a burner to run at its optimal combustion efficiency (i.e., minimal excess-air levels) throughout the firing range.

Boiler/Burner Cycling

Cycling is another boiler-efficiency issue. It is essential to have accurate proportional-integral-derivative (PID) control to reduce the effects of cycling on a boiler. A linkageless combustion-control system incorporates a load controller with full-user 10-term variable PID control to ensure temperatures are accurate within 2˚F and pressures are accurate within 1 psi/0.1 bar.

Reducing burner cycling can mean substantial energy savings. Every time a burner starts or stops, a boiler goes through a pre- and post-purge in which four volume changes must occur for safety. Meanwhile, cool air is forced through the boiler, causing the boiler to cool, the water temperature to decrease, and the steam pressure to drop. The water-temperature decrease occurs because the boiler and refractory effectively are heating the air. (This is similar to the way in which combustion gases heat a boiler and refractory.) This means that thermal movement goes from the boiler into the combustion chamber, not from the combustion gases into the boiler. The thermal movement forces the burner to start more frequently and ramp to a higher firing rate.

Cycling and cooling does not affect the boiler's combustion efficiency but does affect its overall efficiency. Because cooling results from the purge process, run time is longer to return boiler pressure or temperature to the required set point increases, creating further fuel losses. In an ideal application, a boiler starts and runs for a prolonged period.

Single- vs. Multiple-Parameter Control

Use of an exhaust-gas analyzer expands the benefits of linkageless combustion control. An exhaust-gas analyzer measures and displays O_2, CO_2, carbon-monoxide (CO), nitric-oxide (NO), nitrogen-dioxide (NO_2), NOx, and sulfur-dioxide (SO_2) exhaust temperature and combustion efficiency. An exhaust-gas analyzer's built-in continuous-emissions-monitoring software monitors instantaneous and totalized emission output for each fuel as a weight (cubic feet) and mass (pounds or tons). Because of the software, data collected from the exhaust-gas analyzer can be submitted as an emissions report for a boiler and/or plant annually, quarterly, or monthly.

Information from the exhaust-gas analyzer is fed back to the linkageless combustion-control unit, which corrects the air-damper position in small increments. This ensures that the original commissioning data is adhered to, irrespective of variations in stack pressure, barometric conditions (such as air temperature and pressure changes), or changes in fuel temperature and quality.

A linkageless-combustion-control-exhaust-gas-analyzer three-parameter trim control in which a burner's combustion performance is mapped for commissioned values and air- and fuel-rich combustion has been developed. With this feature, the three main parameters of combustion—O_2, CO_2, and CO—are measured.

More than an O_2-trim system, the exhaust-gas analyzer/linkageless combustion-control system trims O_2, CO_2, and CO. Single-parameter control does not truly reflect the combustion within a burner or boiler, which can lead to dangerous conditions. For example, if only O_2 is measured and trimmed, then CO, CO_2, and NOx cannot be cross-referenced. Therefore, even if O_2 readings are correct, changes in ambient conditions (such as barometric-pressure changes) or fuel- or stack-pressure changes can cause CO formation to rise significantly (greater than 100 ppm).

Another more dangerous problem can occur when O_2 is introduced into a boiler through badly maintained gaskets and small gaps in the boiler's flue ways. Because flue gas is measured at

It is essential that all of the exhaust parameters from the combustion process be measured.

a boiler's exit, this could lead to higher anomalous O_2 readings, even if actual combustion is good. The exhaust-gas analyzer continually checks and cross references the three parameters, ensuring that unsafe conditions cannot occur.

Energy, operations, facility, and production managers and building-services engineers are under increasing pressure to demonstrate a commitment to ensuring a greener future. They also are being pressured to specify equipment that not only can keep energy bills to a minimum, but also lower greenhouse-gas emissions. Therefore, it is essential that all of the exhaust parameters from the combustion process be measured. To determine the exact outputs of a boilerhouse or power plant in a safe and controllable manner, it is important to measure O_2, CO_2, CO, NO, NO_2, and SO_2 to obtain a true depiction of what is being exhausted into the atmosphere.

A complete boilerhouse solution, the linkageless-control-system/exhaust-gas-analyzer combination offers energy savings and reduced emissions.

About the Author

Duncan Cairnie is the systems applications manager for Autoflame Engineering Ltd., which manufactures combustion-control systems to reduce energy consumption and harmful emissions. He studied mechanical engineering, fluid dynamics, and thermodynamics at the University of Cambridge in Cambridge, England, where he earned his bachelor's and master's degrees. He can be contacted at ***dcairnie@autoflame.com.***