Designing With High-Efficiency Gas-Fired Boilers

AERCO

Heat You Can Bank On

Market-Proven Solutions From an Award-Winning Company

When AERCO introduced a condensing and fully modulating commercial boiler in 1988, it essentially created the high-efficiency category in North America. And since then, AERCO has continued to lead the way with technological innovations that make higher capacity, full-featured products available to more commercial customers in a wide variety of applications.

In 2004, when many conventional equipment manufacturers were just beginning to introduce energy-efficient products, AERCO was recognized with a Technology Leadership Award by Frost & Sullivan for its 15+ year contribution to the high-efficiency market. No competitor can match AERCO products when it comes to market-proven designs that have withstood the test of time. AERCO's hope is that this booklet will enable the company to share some of its experience.

Five Designs and Five Applications

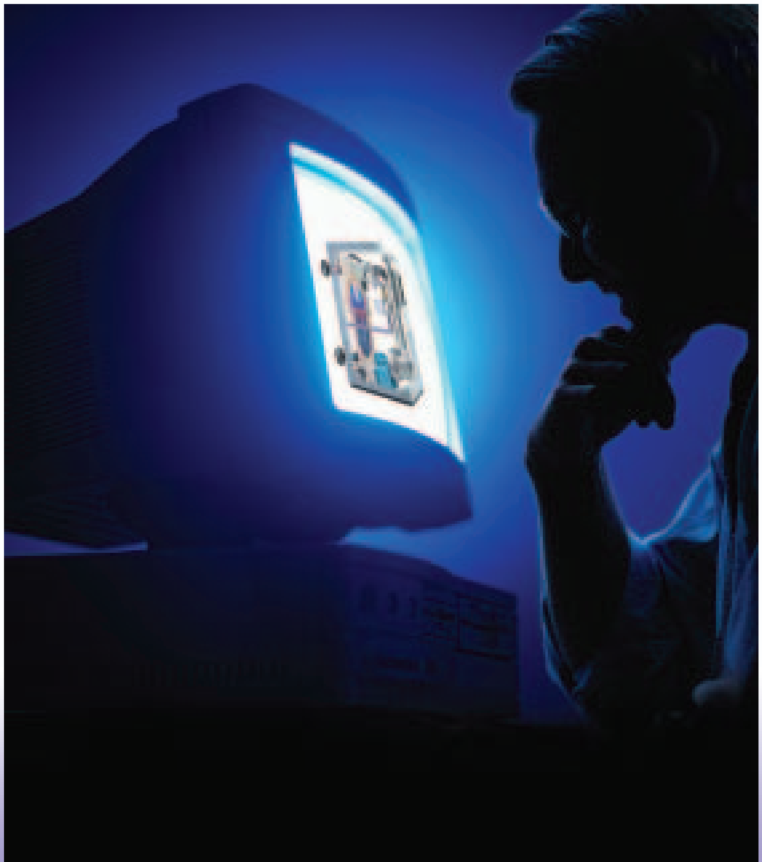
This booklet examines several high-efficiency system designs: a traditional hydronic loop, a high ΔT option, a two-pipe system, a combination hot water and space-heating system, and a water-loop heat pump alternative. Each review is accompanied by a real-world case study. Together, the materials explore some of the different high-efficiency design options available to consulting engineers and facility managers. They demonstrate how AERCO's equipment perfectly complements – and can further improve – the energy efficiency and installation cost of each system.

AERCO Boilers Support Innovative System Designs

AERCO's boilers are uniquely suited to a variety of high-efficiency hydronic systems. Among their most important features, AERCO boilers offer unsurpassed modulation and are constructed specifically to operate in condensing mode.

With burner turndown as high as 20:1, AERCO equipment precisely matches boiler output to real-time building demand. Such robust modulation increases the boiler's thermal efficiency when operating at part-load and contributes to overall energy efficiency by minimizing cycling losses. And by eliminating wasteful overshoot, AERCO equipment delivers the precise temperature control required for applications where loop temperature regulation is of the utmost importance to successful equipment operation.

Because AERCO boilers are designed to operate in condensing mode, they can increase system efficiency by at least 11%-12% while eliminating the need for all dedicated piping and pumping equipment that is required to protect non-condensing equipment. With no risk of thermal shock, AERCO boilers are the perfect complement to low-temperature hydronic system designs. Designed to drain freely and constructed with the highest-quality materials, AERCO boilers resist the corrosive effects of acid condensate, a byproduct of the condensing process.



Essential Tools for High-Efficiency

AERCO: An Engineering Partner

Elegant product designs and reliable manufacturing are important parts of AERCO's success. However, the company also prides itself on having one of the most qualified and experienced staffs in the business. From the front office to the factory floor, engineers comprise nearly 25% of the staff. AERCO has also assembled an impressive network of sales representatives with considerable HVAC knowledge and engineering backgrounds.

As the pioneer of the high-efficiency market, AERCO has gained significant experience implementing high-efficiency systems. AERCO is eager to work with consulting engineers and facility managers, as a partner in the system design process, to create the most energy-efficient and cost-effective HVAC solution possible.

All of the case studies presented in this booklet feature the following AERCO products. For more information on the full line of AERCO high-efficiency space- and water-heating products, please visit the AERCO Web site at www.aerco.com.

AERCO Benchmark Boiler

AERCO's 2.0 MBTU/hour Benchmark boiler can reduce total project and life cycle costs while delivering energy efficiency, quiet acoustics and lower operating costs. Benchmark can also support natural gas with propane backup applications to take advantage of discounted "interruptible" gas rates, or where dual fuel capability is mandated.

The condensing heat exchanger design is built to withstand thermal shock and eliminates the need for boiler pumping equipment to lower the size, cost and operating expense of components throughout the entire heating loop. The forced-draft modulating burner operates with 20:1 turndown to deliver up to 98% thermal efficiency, while simplifying the venting system.

Each 2 million BTU/hr. stainless steel unit fits through 30" doorways, and occupies a footprint of 12 sq. ft., with zero sidewall clearance for easy installation. Removable enclosure panels and rear access to all piping simplify lifetime maintenance. Compatible with popular EMS software, the units can be remotely controlled and provide detailed LCD diagnostics.

AERCO KC1000 Water Heater

Energy-efficient and cost-effective for commercial and industrial applications, each 1 million BTU/hr. natural gas- or propane-fired unit features a condensing design and 14:1 modulation to maintain +/-4°F temperature control, achieving 93% to 99% efficiency under variable flow conditions. Overshooting and cycling are virtually eliminated. No storage tanks or temperature averaging equipment is needed. Each 78"H x 22"W x 57"D unit maximizes venting flexibility and is available with a low NOx burner option.

AERCO KC1000 Hydronic Boiler

Quiet and cost-effective to operate, these 1 million BTU/hr. natural gas- and propane-fired boilers save space, reduce project costs and can be equipped to meet stringent NOx emissions standards. A condensing design eliminates secondary piping, and 14:1 modulation supports +/-2°F temperature control to achieve 95% seasonal efficiency. Easy-to-use, remotely accessible controls integrate with EMS systems.

AERCO's Boiler Management System (BMS)

AERCO's BMS offers remote access and control of boiler plants of up to 32 units, and is fully compatible with buildingwide energy management and building automation systems via Modbus open protocol. Designed to maximize the operating efficiency of condensing gas-fired boilers capable of unmatched 20:1 and 14:1 unit turndown, the BMS offers customers sequential or parallel application flexibility, constant or remote-set point operation, and provides 100% control of auxiliary equipment while equalizing module runtime in the boiler plant. EMS- and BAS-equipped customers can be notified of faults throughout the boiler plant and can remotely examine and control 35 aspects of each unit's operation through a single connection point.

High-Efficiency Boilers Revolutionize Traditional Hydronic Loop

Much of what we consider to characterize the design of a "traditional" hydronic heating loop has been strongly influenced by the operating limitations of gas-fired boiler equipment – a product category that has remained virtually unchanged for generations. Aspects of standard system design – such as 180°F supply/160°F return temperatures, 20°ΔT designs, primary/secondary piping and temperature control at the terminal units, as well as ducting and venting accommodations – are a result of design engineers' efforts to support and/or protect conventional boilers. And, over time, these practices have worked their way into the engineering subconscious. Today, the availability of a new breed of high-efficiency boilers is challenging many common practices, as well as supporting new approaches in hydronic system design to vastly improve the cost and energy efficiency of the traditional heating loop.

Increase Efficiency

A variety of conventional design practices, including greater-than-140°F return-water temperatures, conservative 20°ΔT parameters and primary/secondary boiler piping, represent an interrelated design effort to prevent older styles of direct-fired boilers from condensing in the heat exchanger. Despite its tremendous benefits – at least 11%-12% increase in system efficiency – the power of condensing has been avoided in the world of conventional direct-fired boilers. Few systems leveraged this important physical principle.

Condensing is a process that occurs when water vapor found within the boiler's combustion gases is forced into a liquid state. Releasing approximately 1,000 BTUs of heat for every pound of liquid created, this change of state occurs when the water vapor falls below its dew point. Importantly, it happens naturally – as a result of exposure to a cool heat exchanger surface when less-than-135°F return water is brought to the boiler! While clearly desirable from an efficiency perspective, the resulting condensate created in the heat exchanger is, however, slightly corrosive.

Since conventional boilers are constructed of materials that cannot support sustained condensing operations, traditional hydronic systems were designed to be conservative, complicated and costly. In contrast, AERCO high-efficiency boilers are engineered to condense. Their heat exchangers are manufactured from superior materials and are designed to drain freely to withstand years of condensing operations with no significant corrosion. AERCO equipment can even withstand thermal shock. Consequently, AERCO equipment can be installed directly into the main loop. By eliminating the piping, pumping, mixing valves and other dedicated components historically used to protect the boiler from cool return-water temperatures, specifying AERCO boilers enables system designers to simplify the hydronic loop and reduce project costs. And customers benefit from increased efficiency and lower maintenance costs for the life of the system.

Improve Client Comfort and Controls

On/off firing limitations and crude temperature control, two key shortcomings of conventional gas-fired boilers, have also negatively impacted the design and smooth operation of the heating loop. While owners had to contend with the long-term expense of boiler cycling, system designers needed to compensate for temperature overshoot. As a result, traditional designs rely heavily on valve operations and bypasses at the terminal units to handle changing loop-water temperatures at the expense of client comfort.

Conventional boilers operate with an on/off temperature switch (aquastat) or crude temperature controller. In addition, combustion is limited to on/off or very modest (3:1, 2:1) burner turndown. As a result, any call for heat is met with the full (or near-full) capacity of the boiler as sized for peak conditions on design day. Not only does this disproportionate response cause the boiler to repeatedly cycle on and off, it can also cause valve hunting and poor temperature control at the terminal units. Consequently, engineers were forced to design systems that would reliably handle an accepted 10°F-20°F variance in supply water, while customers paid the price for boiler limitations in their seasonal fuel bills.

In contrast, AERCO high-efficiency boilers combine precise temperature control with full burner modulation (20:1 and 14:1 turndown) to precisely and cost-effectively match plant output to heating demand. AERCO boilers use a PID temperature controller to maintain the supply water within ±2°F. And after determining what the load and temperature requirements are, the controller can modulate the AERCO burner in precise 1% increments. This allows the boiler to change input/output to match the load exactly. So part-load conditions, which characterize the majority of the heating season, are met with a perfect part-load response, regardless of the capacity of the boiler. There is no temperature overshoot, and it can operate over the entire modulate range in as little as four seconds. AERCO's unmatched turndown, coupled with latent energy recaptured during condensing, can generate as much as 30%-40% increase in efficiency versus conventional hydronic systems.

In fact, AERCO products actually become more fuel-efficient at part load. While a five-unit Benchmark boiler plant can deliver anywhere between 100,000 and 10 million BTU/hr., it requires less fuel for five units operating at 60% of capacity to meet a 6 million BTU/hr. load than it would for just three of the units firing at 100%. And AERCO's part-load efficiency can be effectively leveraged by using the AERCO Boiler Management System (BMS) to coordinate the operations of multiple units. Both the BMS as well as individual AERCO unit controllers provide access to comprehensive operating information on up to 35 data points to support advanced energy management programs. Rather than continuing to design traditional hydronic systems to compensate for poor boiler controls, with AERCO equipment system designers can leverage indoor/outdoor reset schedules, remote set points and even full integration into Building Automation and Energy Management Software to fully maximize the fuel savings available to today's building owners.

Save Space

Setting aside adequate building and mechanical room space to support conventional boilers has been a long-standing challenge of building design. And while the emergence of modular equipment has helped to shrink the size of mechanical room somewhat, there are still significant materials and construction expenses associated with atmospheric intake ducting, natural draft exhaust venting and fixed flow pumping requirements of conventionally designed boilers.

AERCO boilers offer the widest variety of venting options. Whether units are common-vented through a ceiling or individually vented through a sidewall, the forced draft design of AERCO equipment can dramatically reduce the length and width of flue runs. This translates to reduced project costs and more useable building space. Even within the confines of the mechanical room, AERCO equipment is doorway-size with a small installed footprint. Its ability to support variable flows (and withstand no-flow conditions) eliminates the need for dedicated pumping equipment to save both money and space.

Looking Forward

This article has examined some of the traditional weaknesses of a very simple hydronic system design. Yet when AERCO high-efficiency boilers are inserted into the loop, the system is simplified even further. The remainder of this booklet examines additional approaches to system design in which AERCO's features can be leveraged to reduce project and operating costs.

Colorado Springs Re-Entry Center Chooses High-Efficiency Heating and Domestic Hot Water Solutions

When Envision Mechanical Engineering was hired to design the heating and domestic hot water (DHW) systems for the Cheyenne Mountain Re-Entry Center, there were two major stipulations. “We needed to implement an energy-efficient solution, and it had to easily tie into the facility’s Invensys Building Automation System (BAS),” said Nick Sauer, president of Envision Mechanical Engineering. “Specifying AERCO Benchmark boilers for space heating and AERCO KC1000 water heaters for DHW allowed us to meet those objectives and helped to keep initial construction costs down for the 2003 construction project.”

Domestic Hot Water for a Dormitory-Style Setting

Located in Colorado Springs, Colorado, the Cheyenne Mountain Re-Entry Center is a 128,000 sq. ft., four-story building designed to house 780 inmates as they prepare to re-enter society through government-sponsored work programs. “Because the building has a dorm-style setting, with full-service showers, a full-service kitchen and a full-service laundry, its domestic hot water needs are quite large,” said Sauer. “To meet these needs, we chose three gas-fired AERCO KC1000 1.0 million BTU/hr. water heaters to supply 140°F water to the DHW recirculating loop. Tempering valves were added for shower temperature control. Storage tanks were not used.”

The KC1000 units deliver 93%-99% thermal efficiency under variable flow conditions while maintaining precise +/- 4°F temperature control. Designed specifically to operate in condensing mode, the heaters were piped to accept 40°F city water directly without temperature blending. Each KC1000 unit is capable of 14:1 burner turndown to precisely meet the facility’s fluctuating domestic hot water demands. The three heaters will support 1.4 gpm to 55 gpm loads without cycling.

In addition to minimizing wasteful cycling, the water heaters actually operate more efficiently at part load. As the firing rate drops from 1 million BTU/hr. to 70,000 BTU/hr., thermal transfer across the surface of the heat exchanger increases to maximize operating efficiency. This is crucial because the majority of each water heater’s operating hours will be spent running at part load.

Modulation is Key to Efficient Space Heating

The Envision team anchored the space-heating system with two high-efficiency, gas-fired AERCO Benchmark boilers. Each 2.0 million BTU/hr. condensing boiler offers 20:1 burner turndown. As a result, the Cheyenne Mountain Re-Entry Center’s boiler plant can fluctuate from 100,000 BTU/hr. to 4.0 million BTU/hr. without cycling the boilers on and off.

Just as with the KC1000 water heater, the Benchmark boilers also operate more efficiently at part load. To fully exploit the boiler plant’s inverse efficiency profile, Envision used the AERCO Boiler Management System (BMS) to coordinate operation of the boilers to achieve the highest seasonal efficiency.

The AERCO BMS maximizes plant efficiency under any part-load condition. For example, if the building requires the plant to fire at 400,000 BTU/hr., the BMS will split the load evenly between the two boilers rather than having one unit bear the full load. The two units, each running at lower firing rate, will require less fuel to meet the demand than if only boiler were employed.

Condensing Operations Increase Efficiency and Cut Project Costs

In their overall design of the space-heating system, the Envision engineers set the supply and return temperatures on the heating loop at a 40°F ΔT, ensuring that the boilers will be in condensing mode approximately 90% of the time. This design approach boosts efficiency 11%-12% while reducing upfront equipment and installation costs.

Bringing low-temperature (less than 135°F) return water to the boiler has a cooling effect on the heat exchanger. When water vapor, found in the combustion chamber gases, is exposed to this relatively cool surface, it changes into a liquid state. The change of state releases approximately 1,000 BTUs of heat for every pound of liquid created, turning more of the fuel into usable heat. This recaptured energy would otherwise be lost up the flue.

Because AERCO heat exchangers are manufactured from superior materials and are designed to drain freely, they can withstand years of condensing operation. This enabled the Envision team to place the boilers directly onto the loop without the piping, mixing valves and other temperature-averaging components used to protect conventional boiler plants from cool return-water temperatures. And the high ΔT design helped the engineers to cut construction costs beyond the mechanical room as well. The system's low flow rate allowed for smaller pipes, valves and pumps with less electrical draw.

Easy Integration With Invensys Building Automation System

The AERCO BMS seamlessly integrates the boiler plant with the facility's BAS via a Modbus interface. This allows facility managers to control overall plant operations and monitor up to 35 aspects of each boiler's operation via a single connection between the Invensys BAS and the AERCO BMS.

"Controlling the heating plant through the Invensys system simplifies facility management. We can easily coordinate the operation of many of the building's electric and mechanical systems. And the Benchmark's advanced control systems enable facility managers to collect extensive data from each boiler and periodically evaluate how the plant is operating," said Sauer.

Small Units for a Cozy Space

The added bonus of the AERCO Benchmark and KC1000 units was their small size, which allowed Envision to easily overcome the limitations of a small, 1,200 sq. ft. mechanical room. With a footprint of 12 sq. ft. and zero sidewall clearance for each Benchmark boiler, and measurements of a 22" wide x 57" deep footprint for each KC1000 water heater, both plants fit with room to spare.

"The relatively small size of the AERCO equipment, combined with its energy efficiency, flexibility and reliability, made it the ideal choice of our energy-efficient puzzle," said Sauer. "We were able to build flexible, highly efficient, simple systems that are maintenance-friendly and cheaper to install than standard solutions. The building is set to open in August of 2005, and we expect very happy customers."

Cheyenne Mountain Re-Entry Center – Colorado Springs, Colorado

High ΔT Cuts Project Costs and Increases Fuel Efficiency

A 20ºF temperature differential (ΔT) between supply and return water temperature has long been a standard in hydronic heating system design. However, standard design – which usually involves a 180°F supply-water temperature and a 160ºF return temperature – doesn't yield the highest possible efficiency. Systems modeled around a high ΔT, which utilizes temperature differentials of greater than 20ºF, and low return-water temperatures – return temperatures that fall significantly below the standard 160ºF – can reduce capital spending on mechanical systems while significantly increasing operating efficiency. When AERCO modulating and condensing boilers are added to this equation, the advantages become overwhelming.

Why is 20°F ΔT the standard?

Why has the 20°F ΔT system emerged as the de facto standard for hydronic heating design? One explanation is mechanical. There is less stress on the boiler when supply water of 200°F or 180°F returns a mere 20°F cooler. With water temperatures so close, there are no significant, rapid or repeated expansions and contractions of the heat exchanger. The danger of thermal shock is minimal. While conventional 20°F ΔT systems bring an element of "boiler protection" into the design, they do so at the expense of cost-effectiveness.

An underlying reason may have more to do with mathematics and the design engineers' comfort with an easily conceived and implemented system. Consider the formula for measuring energy output:

	BTU/hr.=500 x ΔT x GPM
Plugging in the 20°F ΔT yields:	BTU/hr.=500 x 20°F x GPM BTU/hr. 10,000 x GPM 10,000 BTU/hr.=1 GPM @ 20°F ΔT
In commercially sized applications this translates easily to:	1,000,000 BTU/hr.=100 GPM 3,000,000 BTU/hr.=300 GPM

In short, maintaining the 20°F ΔT model keeps the numbers simple, and the chance of mathematical errors is reduced. It's easy to understand how such a standard emerged. Unfortunately, this simplicity does not translate to the highest efficiency.

While a 20°F ΔT system makes for an easy and safe design, customers pay a high price in terms of the short- and long-term cost-effectiveness of the system.

High ΔT Cuts Project Costs

Look once again at the formula for measuring energy output. As the temperature differential is increased, lower flows will produce the same energy output. For example, if you raise the system's ΔT to 40°F, then GPM is cut in half. This is true each time the temperature differential is doubled.

	BTU/hr. =500 x ΔT x GPM
Plugging in the 40°F ΔT yields:	BTU/hr. = 500 x 40°F x GPM BTU/hr. = 20,000 x GPM 20,000 BTU/hr. = 1 GPM @ 40°F ΔT
In commercially sized applications this translates to:	1,000,000 BTU/hr. = 50 GPM 3,000,000 BTU/hr. = 150 GPM

The ability to output the same energy with a lower flow rate has a tremendous positive impact on the economics of the system. Pumping capacity is reduced, making smaller-size equipment with less electrical draw appropriate. For example, by cutting the flow in half, a 10 hp pump can be replaced by one outputting 1.25 hp. Similarly, smaller pipe sizes can be used throughout the system to cut materials and installation costs.

Even though the high ΔT system may require a greater number of copper heating coils in the terminal units, this often has only a minimal effect on first project costs. In warm climates, where these units are primarily sized to accommodate a greater number of cooling coils, the size of the units themselves may not increase. Even in colder climates where larger boxes may be needed, their cost can still be significantly less than the cost represented by larger piping and pumps.

The ability of AERCO boilers to handle variable flow rates (even no-flow conditions) and their extremely low water-side pressure drop reduce project costs even further. Their condensing capabilities make it possible to install these units directly on the heating loop with no risk of thermal shock. Eliminating primary/secondary piping, pumping and mixing valves further simplifies the overall system and lowers materials costs.

Low Return-Water Temperatures Increase Fuel Efficiency

The biggest advantage AERCO gas-fired boilers offer is the performance efficiency and ongoing fuel savings they provide in low-temperature systems. AERCO boilers are designed to condense flue gases within the heat exchanger for increased thermal efficiency. The unique heat exchanger design has been field-proven for more than 17 years to withstand the corrosive impact of condensing operations.

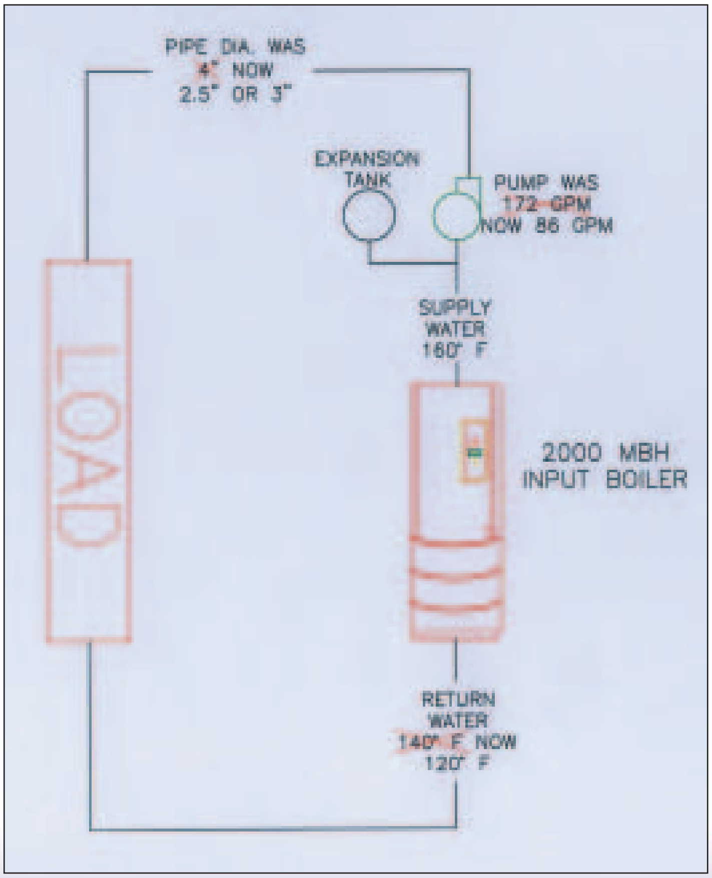
The condensing process frees additional energy in the form of latent heat to increase efficiency by as much as 11% to 12%. Engineers are encouraged to design systems that utilize low return-water temperatures (<135°F) to foster this process. In such an environment, the water vapor found within the exhaust gases has the opportunity to drop below its ≈135°F dew point and begins to condense when it contacts the heat exchanger surface. This releases additional energy that would otherwise be lost up the flue.

Adding Modulation to the Efficiency Formula

The unmatched modulating capabilities of AERCO boilers take the potential fuel savings a step further. Offering turndown ratios of 20:1 and 14:1, AERCO boilers are designed to increase output in precise 1% increments to match the boiler's firing rate to actual demand in real time. Modulation allows the AERCO unit to fire continuously at lower loads to minimize cycling losses. This steady operation also helps maintain a constant temperature throughout the system to eliminate wasteful overshoot. AERCO's efficiency actually increases at partial load, offering customers the greatest seasonal fuel savings.

An Efficient Conclusion

By increasing the ΔT and decreasing flow of the hydronic loop, designers can build smaller, streamlined heating systems. And where low-temperature water is returned to a condensing and modulating AERCO boiler, long-term fuel savings will be even more significant.



AERCO Anchors High-Efficiency Heating System in 22-Story Government Building

Built in downtown Boston in 1975, the McCormack Building has always relied upon the city's district steam supply to provide space heat and domestic hot water. As it was initially designed, the government facility also depended upon two 1,200-ton steam-absorption chillers for cooling. However, rising energy costs during the ensuing 25 years, coupled with an office automation upsurge, culminated in a $6 million HVAC overhaul in 2003. Coordinated and implemented by the Massachusetts Bureau of State Office Buildings (BSOB), the 22-story building's agency responsible for operating the state buildings, the new gas-fired heating plant and gas/electric hybrid approach to cooling promises to save the state approximately $530,000 annually in utility costs.

Steam Heating and Electric Cooling Provides a Temporary Solution

As part of an energy-saving program starting in the mid-1980s and continuing through the '90s, the original steam-absorption cooling system was abandoned in favor of electric centrifugal chillers. To compound matters, the computing revolution that has taken place over the last 20 years has increased demand on the building's electrical system exponentially. Because of this increased electrical demand, just two of the three chillers were able to be utilized to cool the 660,000 sq. ft. facility. BSOB was forced to rely on a temporary electrical feed from a nearby building to run the third chiller.

The rising costs of both electricity and steam were turning the hybrid plant into an economic and logistical quagmire. In 2003, BSOB undertook a renovation that included replacing the chillers installed in the 1980s with new electric chillers, adding two new gas-fired absorption chillers and anchoring the entire heating loop with high-efficiency AERCO boilers. This combination plant provided redundancy for both the gas-fired and electric systems, giving the building the choice between either energy supply. The renovation project also enabled the McCormack building to utilize 134a, a more environmentally friendly, CFC-free refrigerant. Because of BSOB's tight planning and project management, the building never lost a minute of production during the entire 11-month, $6 million renovation and upgrade.

The Move to AERCO Gas-Fired Heating Equipment

"High-efficiency gas-fired equipment that would allow the state to take advantage of the less expensive gas utility rates was the best choice to power the heating system in the building," said John Killelea, senior mechanical engineer for BSOB. "However, we were careful to look beyond the boilers – to maximize the energy efficiency of the total hydronic heating loop – when designing the system. Not only will it reduce long-term operating expenses for the building, this approach helped us contain the initial project costs as well."

"We chose to anchor our heating plant with 13 AERCO 2.0 million BTU/hr. Benchmark boilers," added Killelea. "Because the mechanical room was on the building's 22nd floor, we wanted small units that could be moved easily through standard-size doorways and would be easy to pipe up and vent. However, the main reasons that we decided on the Benchmark was because of its great turndown and its ability to support systems designed with a significant hydronic loop temperature differential."

Turndown Translates to Seasonal Efficiency

Each floor of the building is divided into six zones of automation, with all HVAC equipment tied into a building energy management system to provide a coordinated response. Consequently, the boiler plant output must constantly fluctuate to satisfy the changing needs of individual area requirements.

The key to Benchmark's efficiency is its 20:1 modulating design, which ensures an energy-efficient response to variations in building demand over the course of day and the course of the year. Rather than incur burner cycling losses and wasteful overshooting, each

Benchmark boiler can run on as little as 100,000 BTU/hr. – or 5% input – precisely matching the boiler's firing rate to actual building demand. To fully leverage their modulating capability, the 13 units function as a single system under AERCO's Boiler Management System (BMS). This system regulates the individual units as a unified plant, providing them with precise firing instructions to ensure maximum efficiency at all times. The BMS also consistently rotates the lead boiler in the plant so that each unit receives approximately the same amount of work over the course of a season.

A System Designed to Control Costs

Heating loop designers employed a 30°F-40°F ΔT on the system and have configured the Benchmark boiler plant to maintain 180°F supply water with a 150°F-140°F return temperatures. "As we increased the temperature differential across the loop, the flow rate required to maintain the same energy output level dropped significantly," said Jeff Rosen, mechanical division manager of J.F. White Contracting Company. "Taking advantage of the ability to deliver the same energy at lower flows had tremendous positive impact on the economics of the system. Pumping capacity was reduced, allowing us to use smaller-size valves and pumps with less electrical draw to further ease the electrical burden on the building. The fact that we could use smaller-sized equipment also had a large impact on keeping within our construction budget."

The ability of AERCO boilers to handle variable flow rates (even no-flow conditions) and their extremely low water-side pressure drop were extremely advantageous in this environment. With no risk of thermal shock, the condensing units were hooked right into the heating loop with no primary/secondary piping, pumping and mixing valves. This helped to make better use of the mechanical room's space and further lowered material costs.

A Design With Room to Grow

Although the current configuration doesn't deliver return water below 135°F, which would capitalize on the Benchmark's condensing capabilities to increase operating efficiency as much as 11%, engineers at the McCormack Building can easily take advantage of this option in the future.

"We've only been running the units for one winter and are planning to lower temperatures in the future," said Killelea. "The new system's innovative design and our choice of robust, performance-proven equipment fulfill our governor's directive to reduce operating costs by 10% and offer room to grow."

McCormack Building – Boston, Massachusetts

The Rebirth of the Two-Pipe System

Prior to the advent of modern air conditioning, two-pipe systems were the design standard for climate control. However, as early system designers began to collocate both heating and cooling equipment on a shared piping loop, problems with manual switchovers and humidity control ensued. Before long, two-pipe systems were abandoned in favor of the four-pipe design, which has emerged as the industry paradigm over the past 20 years.

However, as a result of the technological advances made in the name of energy efficiency, two-pipe systems are experiencing a major resurgence. High-efficiency boilers and chillers, combined with modern digital sensors and energy control systems, have reduced the drawbacks of the two-pipe option while amplifying its strength as a simpler and cheaper approach.

While such advantages certainly merit serious consideration for new construction, two-pipe designs are especially suited to retrofit applications. It has never been easier or more affordable to install air conditioning in an existing building. And the ability to switch quickly and easily from heating to cooling mode makes today's two-pipe systems a realistic option for the widest variety of climates.

When properly designed and implemented, two-pipe systems are cheaper to build, take up less room, use less energy and are easier to maintain than their more complex four-pipe counterparts. Two-pipe systems require half the piping – thereby reducing the number of valves, connectors, pumps, heat exchangers and expansion tanks required. Not only will a project's materials costs drop considerably, but the labor expense for installation will be drastically reduced. And fewer valves and couplings, and the need for just two distribution motors and a pair of expansion tanks, mean less clutter in the boiler room.

AERCO Condensing Boilers Streamline the System and Increase Operating Efficiency

With a heat exchanger specifically constructed to withstand thermal shock and the corrosive impact of condensing operations, AERCO boilers can readily tolerate the lower temperatures that characterize changeover conditions in a "shared" heating/cooling loop. In fact, the ability to accept return-water temperatures as low as 40°F means that AERCO equipment can be located directly on the primary loop with no need for secondary piping, dedicated pumping, auxiliary heat exchangers or mixing valves. Not only does this reduce initial installation and material costs, these simplifications will also reduce operating and maintenance expenses for years to come.

In addition, the AERCO boiler's extremely low water-side pressure drop and ability to handle variable flow rates (even no-flow conditions) are equally well-suited to the pressure conditions found in many cooling applications. And the exceptional operating efficiency of condensing operation and modulation control (20:1 turndown for the Benchmark; 14:1 for the KC1000) translate to tremendous fuel savings over the life of the equipment.

Advanced Controls Capabilities: Another Piece of the Modern Two-Pipe Equation

Today's advanced control technologies also help make the two-pipe model easy to understand, operate and maintain. And given their ability to help identify and resolve problems quickly, emerging buildingwide Energy Management Software (EMS) systems are another important component of a well-designed system.

Modern two-pipe system designs require just one valve to switch the system from heating to cooling and utilize a single pair of pumps to circulate warm or chilled water to remote heat exchangers. The motor-driven valve is automatically actuated by a command from the operating software. Well-placed sensors, combined with smart controls that can be manipulated, keep the hardware simple. The simplicity of these systems, as well as the lack of valves that need to be turned, helps minimize maintenance.

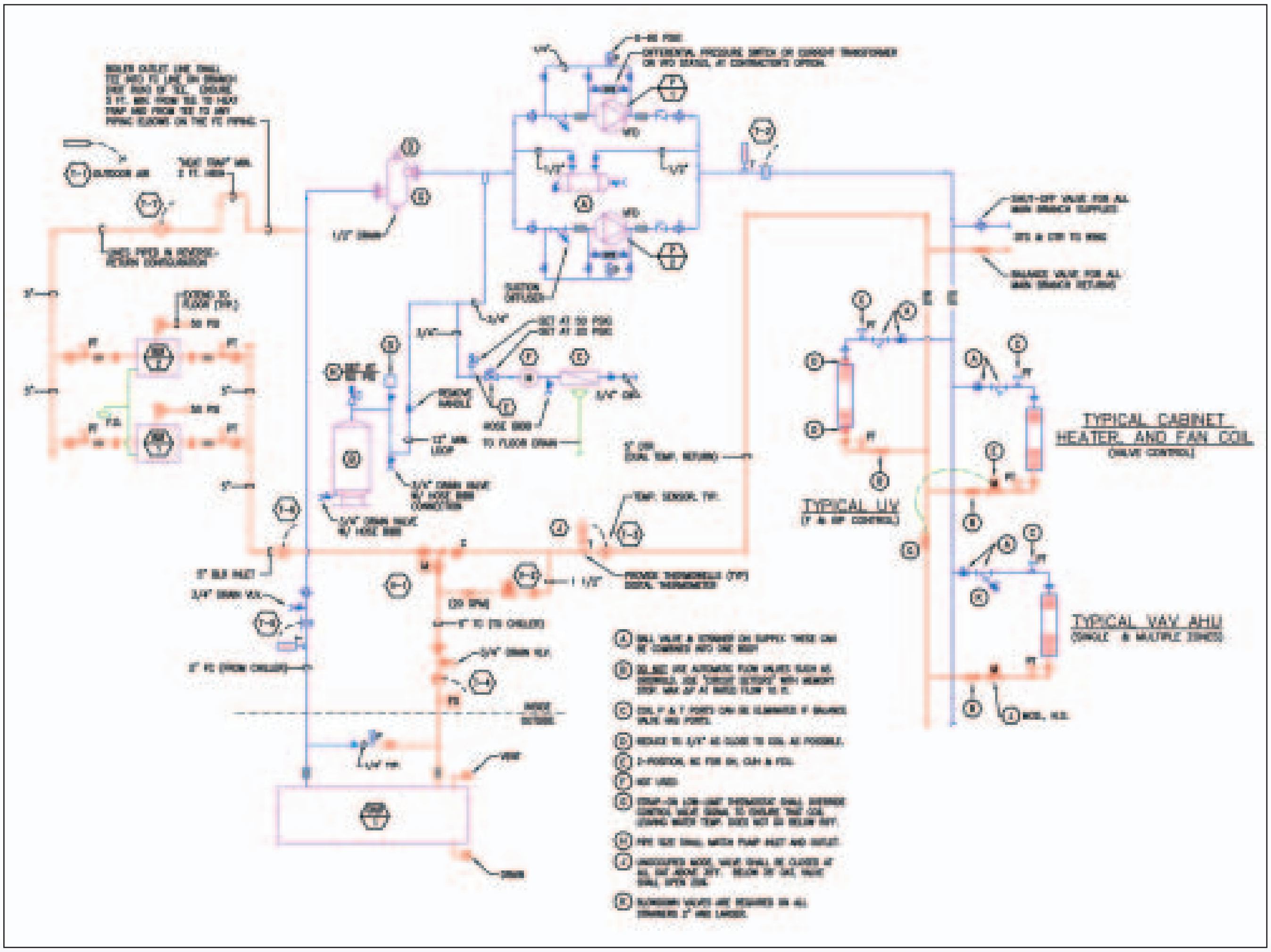
An EMS to regulate boiler temperatures as an inverse function of outside air temperature will also help maximize the system's overall efficiency. An EMS makes it possible to monitor and display temperatures and flow rates throughout the system and is capable of automatically controlling the all-important switch from heating to cooling – and vice versa. It is also responsible for setting flags when valves exceed their tolerance and displaying information that enhances the effectiveness of both routine and special maintenance work.

To enable facility managers to easily integrate AERCO gas-fired boilers and water heaters into their building's EMS system, AERCO's C-More™ boiler unit controller and AERCO's BMS multiple boiler management system both support Modbus open protocol technology. This standards-based open protocol, is widely used throughout the building controls market.

No Longer the Inferior Option

The four-pipe system is still the industry standard. But for those looking for a cheaper, simpler and more space-conscious alternative – especially in the case of retrofit jobs – the two-pipe system has emerged as a viable, and in some cases superior, alternative. The combination of AERCO's state-of-the-art boiler technology and advanced controls integration capabilities has helped to make the two-pipe system a design trend of the future.

Two-Pipe Mechanical Schematic



Hydronic Two-Pipe System Cuts Costs for New Indiana Middle School

Floyd County faced a unique set of challenges when tasked with the design of a climate control system for the brand-new, 274,952 sq. ft. Highland Hills Middle School in Floyds Knolls, Indiana. The county had a limited budget and no access to natural gas, and only 1,540 sq. ft. had been dedicated to the facility's mechanical room. To overcome these obstacles, a hydronic two-pipe system operated on a propane-fired AERCO KC1000 boiler plant was implemented.

"Two-pipe systems cost less to build, take up less room, consume less energy and, because of their simplicity, are easier to maintain than the standard four-pipe system," said Bill Wiseheart, director of facilities for Floyd County. "This is because they use half the piping, and half the number of pumps and actuators."

Automated Technology Eliminates System Limitations

The primary limitation of two-pipe systems is that heating and cooling equipment could not run simultaneously on the shared piping loop. Two-pipe designs require a switch from heating mode to cooling mode, and vice versa. In the past this could only be achieved via a difficult, labor-intensive process. But with today's modern Building Automation Systems (BAS), the changeover can be both easy and fast.

"Our mechanical room contains eight 1.0 million BTU/hr. KC1000 propane-fired boilers, two chillers and two system pumps with variable-frequency drives," said Wiseheart. "Seven of the AERCO boilers are connected through AERCO's Boiler Management System (BMS), which is connected, along with everything else involved in the building's climate system, to our BAS. The eighth boiler is used exclusively to control the temperature of the school's swimming pool."

Each classroom has heat-monitoring sensors, and teachers have the ability to adjust each room by a 3º-4ºF range. When the temperature either rises above or falls below the loosely established outside air temperature 60ºF changeover point, the BAS automatically switches the system over. The entire automated process takes only twenty minutes. The BAS will lock out the boiler system, actuate the single changeover valve from heating to cooling and enable the chiller plant. The BAS then monitors the water temperature as it cools. As it drops below room temperature, the BAS will change the HVAC equipment from heating to cooling.

"Despite the ease of the automated switch, the frequency of changeovers has not been excessive," said Wiseheart. "ASHRAE standards maintain that the building must supply 15 cu. ft. of outside air per student. This means that if the building is running a little hot, instead of switching the entire climate control system over to cooling, we can bring the temperature down a bit by venting in some of the cool outside air while still running the hydronic plant in heating mode."

High Efficiency Two-Pipe System Saves School Money

Installing high-efficiency equipment ensures that the short-term cost savings of two-pipe designs deliver long-term fuel savings for the life of the building. When in heating mode, two-pipe systems generally deal with lower, wider-ranging water temperatures than four-pipe designs. With its condensing capability and resistance to thermal shock, the KC1000 boiler provided the perfect engine for the heating system.

"When the loop is in heating mode, it runs at a maximum temperature of 120ºF and a minimum temperature of 80ºF," said Wiseheart. "The AERCO units are specifically designed to run at these low and frequently changing temperatures without any risk of thermal shock. This meant that the boilers could be installed directly onto the heating loop. And because the KC1000 boiler's combustion chamber and heat exchanger are constructed specifically to operate in condensing mode, the low water temperature of the hydronic loop is an asset that enables the AERCO units to operate more efficiently, increasing fuel savings while lowering operating costs."

By turning more of the boiler's fuel into usable heat, condensing within the heat exchanger increases efficiency by as much as 12%. This process occurs naturally when the water vapor, created as a by-product of the combustion process, cools below its dew point (≈135°F). However, as the latent heat is extracted from the water vapor, a mild acid condensate remains on the surface of the heat exchanger. While this acid can severely damage most boilers, the KC1000 units are constructed with the highest-quality materials and are designed to drain freely.

The KC1000 boiler's other major capability, its 14:1 turndown, contributes significantly to fuel savings. Each KC1000 can run with approximately 70-75,000 BTU/hr. – or just 7% input – and can gradually increase in precise 1% increments until firing at 100%. This eliminates burner cycling losses and wasteful overshoot, which stem from a strictly "on/off" burner operation. Furthermore, the lower the unit's operating rate is, the higher its thermal efficiency will be. Through the control of the AERCO BMS, the units act as one system running all seven units in tandem. For example, each unit would run at approximately 30% to meet a 2 million BTU/hr. building load.

"The eighth AERCO boiler is used exclusively for the building's swimming pool," said Wiseheart. "The pool temperature is kept at a constant 82ºF range, which means that the heating loop is set at 140ºF. Unlike conventional boilers, no extra piping is needed to protect the AERCO boiler, and if there is a valve malfunction, 180ºF water won't go rushing into the pool."

The Highland Hills Middle School opened its doors to students in September 2004.

The Role of High-Efficiency Boilers in the Water Loop Heat Pump System

The simplicity, efficiency and flexibility of a water loop heat pump system makes it a popular design option in modern climate control for both new construction and retrofit applications. Smart designs are anchored by high-efficiency boiler plants to preserve the system's streamlined design and promote reliable operations.

Zone-Specific Control and Long-Term Flexibility in a Single Closed Loop System

Water loop heat pump systems support both heating and cooling using a single closed loop. This shared-loop approach reduces project (and operating/maintenance) costs by eliminating the need for separate piping, pumps, valves and other equipment while delivering zone-specific climate control. In addition, this system design also offers flexibility over the life of the building.

In a water loop heat pump system, individual heat pumps are placed throughout the hydronic loop. A large zone may employ three or four heat pumps to ensure comfortable temperatures, whereas a single device may support the load in smaller spaces. Importantly, each unit operates autonomously. In a single building, some of the heat pumps can be working to heat some rooms (i.e., individual offices) while others are simultaneously working to cool other parts of the facility (i.e., a crowded cafeteria or auditorium).

Since heat pumps can be easily added and/or moved if the structure or role of rooms in the building changes, long-term changes to a facility's internal space do not pose major climate control issues. If a large auditorium is divided into individual offices, fewer heat pumps may be able to handle the heating/cooling requirements of the smaller, individual-occupant spaces. Similarly, the needs of a new computer room, whose equipment generates quite a bit of heat, can also be easily addressed.

Temperature Control on the Loop: A Critical Factor

Each water loop heat pump, controlled by its own thermostat, either heats or cools the supply water circulating through the building loop to achieve the designated "comfort level" in each building zone. For example, an ambient room air temperature of 70°F might serve as a heat pump's switching point between heating and cooling mode. When room temperature falls below 70°F, the supply water on the loop provides the heat source used to warm the room. If the room temperature rises above 70°F, the supply water on the building loop offers a heat sink – absorbing the excess heat rejected by the device in its cooling mode.

For reliable heat pump operation, water temperature circulated on the loop must be 55°F-95°F. When water temperature on the loop approaches the upper limit, a common rejection device (i.e., cooling tower circuit) is activated. When water temperature on the loop approaches the lower threshold, a boiler is called upon to add supplemental heat to the loop. Proper operation of these devices is critical; if water temperature on the loop falls outside of these 55°F-95°F bounds, individual heat pump(s) will shut down and must be reset manually. And what was initially an asset of the system – its decentralized design – can quickly become a liability for the maintenance department.

In light of this critical requirement, smart designers choose to anchor the system with equipment designed to accept low loop temperatures and able to deliver precise temperature control.

Condensing Boilers Support Simplicity and Efficiency

AERCO condensing boilers have been specifically designed to accept the low return-water temperatures that characterize water loop heat pump systems. They don't require auxiliary heat exchangers or mixing valves needed to protect conventional boilers from either condensing operations or thermal shock. By eliminating these ancillary equipment requirements (as well as their associated installation and maintenance costs), AERCO boilers complement the streamlined style of the overall heat pump system design.

While such significant upfront cost savings can be an important consideration, long-term energy savings associated with high-efficiency boilers may even be more important. In the presence of the low return-water temperatures of the building loop, AERCO boilers will automatically operate in condensing mode to increase the energy efficiency of the system at least 11%-12% versus conventional boiler equipment.

Full Modulation and Advanced Controls Promote Reliable System Operation

As outlined earlier, maintaining 55°F-95°F temperature in the loop is critical to prevent tripping individual heat pumps and disrupting system operations. Consequently, the boilers regulating supply water temperature must be both quick to respond and precise. The ability to manage the boiler plant via a buildingwide automation or energy management software program is equally desirable.

Full-fire cycling and temperature overshoot, which characterize the operation of conventional on/off and limited modulation boilers, can easily disrupt the operation of a water loop heat pump system. In fact, a 10°F-20°F swing in temperature control is considered typical of conventional boiler equipment. In contrast, AERCO boilers are equipped with a patented air/fuel valve design that supports up to 20:1 burner turndown to perfectly match system demand. An individual AERCO boiler can deliver 5% to 100% of BTU/hr. capacity based on real-time demand with ±2°F temperature control. By connecting multiple units via AERCO's Boiler Management System (BMS), system designers can regulate the boilers as one complete system to achieve even greater turndowns – 40:1, 60:1, 80:1 and so on. Heat pumps closest to the boiler won't be inadvertently tripped by an exaggerated response to a call for heat by a conventional boiler. And from an energy savings standpoint, the AERCO units actually perform more efficiently when operating at part load – another strong argument against conventional equipment.

Whether a large heat pump system requires an AERCO BMS to orchestrate multiple boilers, or a single boiler is all that is necessary to add supplemental heat into the system loop, AERCO equipment can be easily integrated into building automation software via a non-proprietary, open communication protocol. Linking the individual heat pumps, the boiler and the rest of the HVAC equipment into a facility's overall energy management system enhances the zone-specific control of the heat pump system design, resulting in greater occupant comfort as well as maximum energy savings.

Hybrid Systems Offer a Cost-Effective Design Option

With the growing popularity of geothermal technologies, it is important to consider the advantages of hybrid designs in cool-climate areas. In short, the heating field associated with geothermal applications in colder climates can be vastly greater than the heat sink area needed to support cooling. Where land space or project costs are limited, hybrid designs that pair a smaller geothermal field with a condensing boiler plant sized for auxiliary heat offer a cost-effective and energy-efficient approach.

Water Loop Heat Pump System Ensures Long-Term Flexibility for Colorado Shopping Mall's Climate Control System

When drawing up plans for the climate control system of the two-level, 700,000 sq. ft. FlatIron Crossing mall in Broomfield, Colorado, mechanical engineers and designers at Seattle-based Abacus Engineered Systems were presented with a situation common to shopping centers. The retail space inside the mall would be in continuous flux. This meant that any permanent HVAC system would have to be extremely adaptable to the frequent changes that occurred among the 153 small retail spaces.

"When you deal with a mall, you are dealing with a continuously changing internal landscape," said Wes McDaniel, vice president of the Energy Solutions Division of Tour Andover Controls, parent company of Abacus Engineered Systems. "Stores are continuously opening and closing, and changing their sizes and dimensions. However, when you're designing a climate control system, you're trying to design for a certain space to ensure maximum comfort for all tenants and visitors. This is where our problem lies."

To solve this problem at FlatIron Crossing, the mechanical engineering team employed a water loop heat pump system because of its flexibility, its efficiency and its zone-specific climate control.

The Heat Pumps Provide Climate Control Flexibility

"In addition to their ability to support both heating and cooling, it is relatively easy to place heat pumps anywhere along the loop," said McDaniel. "Each retail space can have its own. If a store's space doubles during a future renovation and extra heat pumps are required to provide adequate heating or cooling, they can be added without incurring major construction costs."

This ability to easily add or move pumps along the loop provides the ultimate in long-term flexibility – any time a space is changed, the heat-pump configuration can be adjusted without the facility having to undergo a major renovation project. In fact, FlatIron Crossing has a unique agreement with its tenants. Each tenant, when moving into a new retail space, or in cases when they add to their own space, has to pay for its own heat pump(s).

Designing the Low-Temperature Loop

Low water temperatures – more specifically a 55ºF-95ºF loop parameter – are a major requirement for water loop heat pump designs. The engineering team chose to anchor the heating side of the system with five high-efficiency 2.0 MBTU/hr. AERCO Benchmark boilers to reduce both the initial project costs and long-term operating costs of the system.

"The team recognized that because the AERCO boilers are designed to condense, they can accept cool return water directly from the building loop," said McDaniel. "This enabled us to simplify the mechanical room and avoid the expense of supplemental piping and mixing valves that would have been required with non-condensing equipment. And the mall gets the added benefit of increased system efficiency to reduce fuel consumption in the long term."

Condensing is a natural process that occurs when water vapor, found within the boiler's combustion gases, is forced into a liquid state. Releasing approximately 1,000 BTUs of heat for every pound of liquid created, this change of state occurs when the water vapor falls below its dew point as a result of its exposure to a cool heat exchanger surface. Consequently, bringing <135°F return water into the boiler increases energy efficiency by as much as by 11%-12%.

Importantly, the stainless steel construction of the Benchmark's heat exchanger, and its freely draining design, protects the boiler from both thermal shock as well as the corrosive impact of the acidic condensate.

Unmatched Modulation Delivers Fitting Support

The mall's heat pumps operate within a loop temperature range of 55ºF-95ºF, and individual units will shut down if water temperature falls outside this range. "Conventional on/off boilers offer limited temperature control, and supply temperature swings of 10%-20% are common," said McDaniel. "Not only is cycling a waste of energy, it can cause individual heat pumps to shut down – requiring each to be reset manually by the maintenance crew at the mall."

Each Benchmark boiler is designed with a 20:1 combustion turndown. The five-unit boiler plant at the mall precisely matches supply and demand by varying output between 100,000 and 10 million BTU/hr. Such smooth temperature control helps ensure the reliable operation of the heat-pump network and offers exceptional part-load efficiency for even greater fuel savings.

"The design for FlatIron Crossing relies on AERCO's Boiler Management System (BMS) to coordinate operations and maximize system efficiency," said McDaniel. "The engineering team knew that Benchmark boilers run more efficiently at part load – that is, having three boilers running at 20 percent is more efficient than running one unit at 60 percent. So they designed the mall's system to operate with five units acting as one heating component. This reduces fuel consumption and helps equalize run time to ensure that some units don't endure more wear and tear than others."

An Added AERCO Advantage

An added advantage of the AERCO units is their small size. Each Benchmark unit occupies a 12 sq. ft. footprint and can be installed with zero side clearance. The mechanical room at FlatIron Crossing measures only 30 ft. by 6 ft. In addition to each set of side-by-side boilers, it contains a 3,000 gallon storage tank that supports the system's cooling tower. It is co-located inside the mechanical room to prevent the water from freezing in the winter.

FlatIron Crossing Mall – Bloomfield, Colorado

A Case for Combination Systems: Space Heating and Domestic Hot Water

The availability of high-efficiency boilers make the case for "combination systems" more compelling than ever. Combination systems, which support both space-heating and domestic hot water (DHW) requirements from a single boiler plant, have a unique ability to minimize total capacity requirements for a given project. In addition to helping reduce the initial capital investment, a combined system may also be the only way to overcome restricted fuel input or space limitations. Employed in a dual-service role, AERCO high-efficiency boilers deliver greater operating efficiency to both the water- and space-heating functions of the system.

Reduced Investment in Plant Capacity

A combined space- and water-heating plant is not the simple sum of the heating modules and DHW modules that would be required if these systems were designed independently. While everyone agrees that the size of the combined system's load is decidedly smaller, opinions vary as to how to properly size a combined heating load.

AERCO has successfully applied the following guidelines, outlined in the formula and table below, to size combined systems for more than 17 years:

$$\frac{\textbf{Domestic Water Load}}{\textbf{Heating Load}} = \textbf{Diversity Factor}$$

Diversity Factor	2	1	.8	.6	.5	.4	.3
Percentage of DHW Load Added to Space Heating Load	60%	50%	40%	30%	20%	10%	0%

The combined system's water-heating load is but a fraction of what would be required to support independent systems. Importantly, as the load requirements of the facility drop, so does the capital investment for boiler equipment as reflected by diminishing BTU/hr. requirements.

While there will always be exceptional projects, designers can confidently reduce total plant capacity when boilers are employed in a dual-service role (for both space and DHW) based on a number of strong assumptions. First, the space-heating plant is sized for the lowest outdoor temperature. Such design conditions may occur for only a few days, if not hours, of the entire heating season. In addition, most boiler plants are sized to compensate for the initial "pickup" load and losses for a facility. Since the building must be brought to a comfortable temperature before occupants begin using hot water, peak demand for both space heat and hot water are not likely to coincide. In fact, most designers would agree that maximum space-heating requirements do not typically occur at the same time demand for hot water peaks. For many projects, they are as different as night and day.

Better Than Average Efficiency

With less capacity and capital investment required in a combination system, AERCO's high-efficiency boilers go one step further to reduce operating costs for the life of the system. AERCO boilers deliver greater operating efficiency than conventional equipment. While this may be obvious on the space-heating side of the equation, it is equally true for domestic water heating.

The best conventional hot water heaters are rated at only 82% efficiency. This is superior to conventional boilers and is a reason, along with boiler cycling, used to justify the separation of systems. However, 82% operating efficiency lags behind the operating performance of AERCO boilers. At 100% fire rate, in a non-condensing application, AERCO boilers deliver 86% efficiency. And with full-range modulation unmatched in the industry – 20:1 and 14:1 burner turndown – cycling losses are minimized. In fact, thermal efficiency actually increases as AERCO's firing rate drops. In a condensing application, a unit operating at 5% of total capacity can deliver up to 98% efficiency without sacrificing ±2°F supply temperature control.

How It Works

In a combination system, AERCO boilers are piped in a multiple unit arrangement as if for a large space-heating plant, and their operation is coordinated by the AERCO Boiler Management System (BMS) and Combination Control Panel (CCP) accessory. Those boiler modules designated for domestic water production are isolated from the heating system by a normally closed two-way motorized valve. Upon DHW demand, the valve isolates the DHW boilers and diverts boiler water to feed an external heat exchanger and storage tank loop to supply the domestic water. Upon demand, the isolated (combination-duty) boilers produce constant temperature supply (70°F-220°F) by operating in internal set point mode.

The CCP controls the firing of combination-duty boiler modules and the associated accessories for domestic water heating. The CCP can prioritize the space-heating or domestic-water-heating role and can alter a unit's mode of operation during peak periods. In addition to this pre-programmed control panel, a variety of wiring diagrams are available to support additional control alternatives. It is possible to allocate more than one unit in the boiler plant for DHW backup where demand is great. To fully leverage the cost savings associated with modulation in a multiple-unit plant, the combination-duty module can also automatically return to space-heating support when DHW load is met.

The Benefits of an Expanded Heating Plant

When control of the combination-duty boilers is transferred to the BMS to support the space-heating function, customers reap additional fuel-saving benefits of AERCO's inverse efficiency profile. Since operating efficiency increases as firing rate drops, the more units employed simultaneously – the lower the total fuel consumption of the plant as a whole. Not only do the combination-duty boilers increase the redundancy of the heating plant in an emergency, they also contribute to reduced fuel consumption when they supplement plant operations. The AERCO BMS will employ the maximum number of units available – all firing at the lowest possible load – to satisfy demand. So a customer with a combination system will consume less fuel than if he had been operating a dedicated space-heating loop with fewer boiler modules.

Combination System Provides Efficient Alternative for Virginia Apartment Complex

When the 22-story Lincoln Towers residential apartment complex opened in 1990, five 1.76 million BTU/hr. hot water heaters and three 1.76 million BTU/hr. boilers sat atop each of its twin towers to supply its 720 apartments with heat and hot water. However, Arlington, Virginia's winters ravaged the rooftop installation. From the very beginning, ice would continually develop on the boilers and water heaters at night and then melt in the warmer afternoon hours, causing the heating and hot water plants to break down on a regular basis.

In 2002, Lincoln Towers hired a team of engineers from Consolidated Engineering Services, Inc., an Arlington-based firm, in conjunction with Holman Boiler Repair of Springfield, to remedy the problem by relocating the hot water and heating plants to a more hospitable location in the complex's underground parking garage. The arrangement presented two large hurdles for the contractor and engineering team to overcome. Lincoln Towers set aside only five parking spots, just 600 sq. ft., as the space within which to raise walls and build the new heating plant. The new plant location was not only small, it was also underground and more than 150 feet away from one of the apartment towers.

"Given the small space we had to work with, a combination system using high-efficiency boilers to support both space-heating and domestic hot water requirements from a single plant was the best solution," said Andrew Huck, who served as the senior engineer on the project. "This approach reduced the construction budget and offered the customer long-term fuel savings."

Reduced Plant Capacity Minimizes Project Costs

The Consolidated team installed 10 AERCO 2 million BTU/hr. Benchmark boilers in the new space to serve as the system's anchor. "The original design, with separate boilers and water heaters atop each tower, provided more than 28 million BTU/hr. total capacity," said Huck. "By combining the space- and domestic-water heating loads, and consolidating the plant in a single location, we were able to effectively support the complex with a 20 million BTU/hr. capacity plant. This dramatically reduced the overall cost of the project."

A combined system will always be a fraction of the size of independent space and domestic hot water plants. Dedicated space-heating plants are engineered for the lowest possible outdoor temperatures, which may occur for just a few hours on one or two winter nights during an entire heating season. All the remaining days of the year, this extra capacity can be working to support the domestic-heating load. Especially in an apartment building, demand for both space heat and hot water will virtually never peak simultaneously.

"This idea is most effectively demonstrated in a typical AERCO combined system installation, where one or more boiler units literally swing back and forth between dedicated support of the domestic-water-heating system and standby availability to support increased space-heating demand," explained Huck. "But such an approach would have required separate piping loops – one for the space heating and one for the domestic hot water – to be run to each of the towers. Whatever savings we had reaped in terms of boiler equipment would have evaporated in the face of piping expenses. To keep costs low, we reverted to a more conventional design approach."

The Consolidated Design

The engineering team decided to run one set of pipes to the pre-existing mechanical rooms that existed in each tower. The new boiler plant provides constant 160°F supply water to support each building's heat pump and domestic hot water systems.

Each building employs a water source heat pump loop for space heating. Designed to run with 70°F water, the space-heating loop uses temperature sensors, situated downstream of the boiler loop supply, to activate modulating two-way control valves to ensure constant temperatures. When loop temperatures rise beyond acceptable limits during warmer days, the water from the loop is routed to a cooling tower located on the roof of each building. If loop temperatures get too cool, the control valves open to inject the 160°F boiler supply water into the heat pump loop as needed.

Each building employs a domestic-water, double-wall, plate-and-frame heat exchanger and a 200-gallon storage tank to support its domestic hot water (DHW) requirements. The 160°F boiler feed water is routed as needed via a three-way control valve through the plate-and-frame unit to heat incoming 40°F city water to 140°F for storage. When the tank aquastat drops to 120°F, a pump is activated to re-circulate the stored water through the plate-and-frame heat exchanger until the tank set point of 140°F is reached.

Condensing Application Promotes Long-Term Fuel Savings

With AERCO boilers anchoring the system, the engineers automatically increased the energy efficiency of the DHW system. The best conventional hot water heaters are rated at only 82% efficiency. At full firing rate, in a non-condensing application, AERCO boilers deliver 86% efficiency. But to help Lincoln Tower really cut long-term fuel costs, Consolidated's system design maximized opportunities for condensing operations.

"The more energy or heat given up to meet the space and DHW loads, the lower the return-water temperature coming back to the boilers," said Huck. "Rather than go with the traditional 180°F, we designed the boiler plant to deliver 160°F supply water. We were still able to meet 140°F DHW requirements, but starting with the lower supply-water set point increases our opportunities to operate the AERCO boilers in condensing mode. This translates to an 11%-12% increase in the plant's operating efficiency."

Condensing occurs when water vapor, which exists in the boiler's combustion gases, is forced into a liquid state. Releasing approximately 1,000 BTUs for every pound of liquid created, this change of state happens naturally as the water vapor contacts a heat exchanger surface that has been cooled by <135°F return water entering the boiler. And because AERCO units are constructed with the highest-quality materials, the corrosive condensate, a harmful byproduct of condensing, has no adverse effects on the heat exchanger.

Precise Boiler Modulation Increases Part-Load Efficiency

Each of the 10 Benchmark boilers features 20:1 burner turndown. The boiler plant can support any load between 100,000 to 20 million BTU/hr. without temperature overshoot or wasteful cycling. And more important, as each unit's firing rate drops, its operating efficiency actually increases.

To maximize fuel savings, plant operation is coordinated by AERCO's Boiler Management System (BMS). The BMS ensures that boiler plant output exactly matches system demand while maximizing the number of units – all operating at the lowest possible firing rate – in operation. AERCO's BMS is also connected to the Lincoln Towers building automation system.

A Final Note

"The one major advantage of the underground plant was that we were able to easily vent the boiler plant directly into the parking garage's pre-existing ventilation system," said Huck. "Since the new plant went online three years ago at Lincoln Towers, the days of cold apartments and cold showers are gone."

Lincoln Towers – Arlington, Virginia

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