# Church's Hydronic System Receives Makeover After Years of Neglect

## Comfort enhanced, energy use significantly reduced

Clearly, it was a case of mismanagement. After years of neglect and "Band-Aid" treatments, the mechanical system inside of the York County Council of Churches (YCCoC) facility in York, Pa., was a tangled mess. And there were potentially lethal issues to deal with, the facility recently having been evacuated because of alarmingly high carbon-monoxide (CO) levels. On top of that, the building's fuel bills were extraordinarily high.

Before visiting the mechanical room of the sprawling church complex, Dave Yates, president of York-based mechanical-contracting firm F.W. Behler Inc., wanted to get a feel for the overall comfort of the occupants. He soon found that the director's office was a sweat box, while several other areas were cooler than staff members liked, and the pastor's office was hotter than Hades.

As he entered the basement mechanical room, Yates saw that the water boiler's supply riser ran to the ceiling, where it wrapped around the room and dropped into a "nest" of circulators and a modulating three-way mix valve, the latter an apparent attempt at outdoor reset. At the valve, he noticed disconnected wires and a shaft locked in a fixed position. The boiler's primary loop did not have a circulator of its own.

"A hydro-air unit had piping that ran back to a very large steam boiler," Yates said. "A modulating zone valve regulating flow was perched in its supply line. I also encountered a vintage 1953 gas-fired water heater with its burner door lying on the floor."

*Formed in 1951, the York County Council of Churches is an ecumenical agency comprised of more than 130 Christian congregations in York County, Pa.*

### SOOT-SPEWING BOILER JACKET

Next to the hydro-air unit was a condensate feedwater tank with a twisted piping arrangement incorporating a condensate pump tank (missing its pump). On the floor sat a centrifugal pump wired to the steam boiler's low-water cutoff.

"The overflow pipe terminated at a floor drain, and it was wet," Yates said. "The feedwater tank was riddled with holes; condensate seeped from it at several points."

Before he could provide a solution, Yates had to diagnose the problem. This is what he found:

**Steam system.** Knowing that, "Steam systems must be sized to produce enough steam to completely fill the inside void of all radiators and piping connected to the boiler" (the "connected load"), Yates measured the volume of all radiation, including that from the convectors, radiators, and bare steel piping used as the heat source in the basement youth center, adding 30 percent to account for the "pickup" factor: the energy required to bring interconnected distribution piping to full temperature. The connected load and pickup factor totaled 196,248 Btu.

Regarding the CO incident and high fuel bills, Yates found:

- Refractory cement smeared around the door to the boiler's combustion chamber and soot streaks at various openings in the boiler's exterior jacket, which clearly indicated the escape of combustion gases.
- The boiler's rating plate indicated a maximum firing rate of 470,000 Btu. When Yates timed the gas meter (with only the steam boiler operating), he discovered it was being fed in excess of 1.2 million Btu. That explained the CO-production issue and reduced

operating efficiency.

• Although the one-pipe vapor system was designed to operate on ounces, not pounds, of pressure, the steam boiler's pressure controls were set to maintain 9 to 12 psi. According to Boyle's Law, if pressure is doubled, the volume of a gas will be halved. When the volume of steam is reduced, radiators and a connected load still need to be filled, which means a boiler must produce more steam. The higher the pressure, the more steam that will be required to fill a volume.

Yates also discovered an antique condensate return pump at the far reaches of the steam system. Judging by its looks and the debris that was concealing it from plain sight, the pump had not been serviced for decades.

Then there was the feedwater tank riddled with pinhole leaks. Its purpose was to act as a reservoir for returning condensate until the boiler's low-water cutoff sensed a need for water, closed its end switch, and energized the centrifugal pump connected to the feedwater tank. Yates could see that the pump could not overcome the high pressure in the boiler. This, in turn, caused the pump's impeller to cavitate and heated condensate to overflow from the feedwater tank. The heated water was rejected to the floor drain, where, in essence, energy disappeared down the sewer line. Lost condensate was replaced with fresh water, which contained a ready supply of corrosive oxygen, which led to sludge formation inside of the boiler, compromising efficiency.

To the rear of the boiler, Yates noticed a severely corroded return pipe. Just above it was an open pipe that disappeared into the chimney. The open pipe, connected to an ancient relief valve, clearly was leaking acidic condensate onto the return pipe.

Finally, there was the hydro-air unit, which represented a tiny load for the grossly oversized steam boiler. Why the unit was added to the steam system and not the water boiler was a mystery.

**Hot-water heating system.** While surveying the hot-water system, Yates:

• Discovered the hot-water boiler was grossly underfired. Underfiring can lead to sustained flue-gas condensation within a boiler, metal flue piping, and masonry chimneys. Excessive CO production and loss of system efficiency are likely.

• Quickly determined that a properly sized boiler would improve energy efficiency.

• Found that distribution piping within the boiler room was poorly installed.

• Saw that, in one zone, a circulator's flanges were joined with a pipe nipple. As a result, the zone circulated when-

## Circulatory Problems

The key challenge for Dave Yates, president of F.W. Behler Inc., was to solve the York County Council of Churches' (YCCoC's) circulation woes. He and his crew were faced with the evidence of many failed attempts to fix the system.

"We weren't there to patch it up," Yates said. "Our job was to make wholesale change, beginning with demolition and ending with a new, intelligent, energy-efficient system that would operate reliably for decades."

The ailing system's circulatory woes were many:

• A boiler and primary loop with no circulator.

• Multiple zones with a variety of antique circulator impeller sections with unknown flow characteristics.

• Zones that disappeared into a wild variety of hidden piping, heat-emitter, and valve configurations.

• A long-disabled three-way modulating valve that was used to force flow through the boiler. Flow varied depending on the number of circulators that were running. The system was operating purely in on/off mode, bouncing off of its upper limit, regardless of the actual British-thermal-unit load.

*This pre-engineered, preassembled Watts Radiant Hydronex pump panel serves as the primary pumping station in the YCCoC facility. Each of the four multispeed Grundfos circulators handles a separate hydronic zone, each with its own flow and temperature requirements.*

All of that, Yates said, "add(ed) up to a looming disaster. Installing a 96-percent-plus-efficiency boiler and marrying it to low-efficiency hydronic loops would have resulted in an underperforming system divorced from its potential to resolve the issues."

The key steps of Yates' plan were:

• Get a handle on the requirements of the primary loop, head loss through the primary loop, and head loss through the new modulating condensing boiler.

• Install circulators that can flex additional muscle as needed and overcome a wide variety of pumping-head-loss challenges.

Zones that needed and quickly received attention (the key challenge with each was determining head loss) were:

• The converted steam-to-hot-water hydrocoil.

• The heater, which was missing its circulator.

• The classrooms.

• The office complex.

ever another zone pump was activated.

• The automatic water-feed valve was not connected at the point of no pressure change and, thus, had the potential to overfill the system.

Yates also found that the boiler did not have a circulator of its own. A pump was needed to provide the flow required to match the boiler's net output. The burner's operation was governed by a flow switch that acted as an on/off switch whenever one of the zone circulators was activated. Given that there were three active circulators, it was clear that there was dangerously varying flow through the boiler. The boiler was maintaining temperature, which wasted fuel. And there was the oddity of a steam-pressure switch acting as a low-water cutoff.

**SOLUTION**

Within a few days, Yates' firm began the weeks-long process of providing a solution, which included:

• Installation of a new Burnham steam boiler properly sized to match the connected load.

• Elimination of the steam zone valves and movement of the hydro-air unit's energy input from the steam boiler to the hot-water boiler.

• Reduction of steam-system operating pressure.

• Replacement of all system circulators. Three three-speed Super-Brutes and a larger VersaFlo from Grundfos were chosen to optimize system performance. With the flick of a switch, speed and, thus, head and flow can be changed to meet the needs of the system.

• Benchmarking and verification of operating efficiency using a digital certified analyzer.

• Replacement of the feedwater tank and remote condensate pump.

• Installation of a Laars Mascot high-efficiency modulating condensing boiler with outdoor reset. The low-nitrogen-oxide, sealed-combustion, fully modulating boiler provides 96-percent system efficiency at high fire. It comes with a built-in condensate trap and auto air-elimination vent. With aluminum outer piping and plastic inner piping, it can vent up to 33 ft—45 ft for two-pipe installations.

"We chose the Laars condensing modulation boiler for this even though ... a standard-issue chimney-vented boiler might, at first glance, seem like a better choice for what's typically run as a high-temperature system," Yates said. "I'd have argued that same point a few years ago, but who says we have to run convectors at higher-than-condensing temperatures? The fact is, they work quite well when matched to outdoor-reset temperatures, and we use a modified reset curve so that the lowest temperature will be able to produce enough convection to offset the heat loss on milder days.

***This 199-mbh Laars Mascot direct-vent modulating condensing boiler serves as the YCCoC's primary hydronic boiler and supplies heat to a 50-gal. Bradford White indirect water heater installed to handle all domestic-water-heating needs.***

"We've seen the lowered fuel consumption given by mod-con boilers in exactly this type of application, and the fuel savings have been nothing short of remarkable," Yates continued. "Given the fact that on any given year, we only see true design conditions for about 10 percent of the heating season—putting the system in a condensing mode for more than 70 percent of the run time—it's a great solution."

• Installation of a Watts Radiant Hydronex pump panel.

• Installation of a Bradford White indirect water heater.

• Cleanup and removal of all discarded equipment.

According to Yates, the YCCoC project was rare in that there were so many opportunities to pick "low-hanging fruit" and so many options to enhance overall system performance and efficiency.

"In the end, we provided a sensible solution with greatly enhanced comfort," Yates said. "They've also seen a significant reduction in energy use."

According to YCCoC records, the organization's line-item budget for fuel dropped 33 percent—a savings of $3,660—from the previous year's heating season.

"While that's not an exact figure because it's not based on heating degree-days and actual fuel consumed, it is significant when you consider their operational costs were reduced while fuel-purchase costs actually rose," Yates said. "So, if you add in the rise in fuel costs, I'd guess their reduction in actual fuel consumed (ignoring costs) would more likely fall within the 35-to-40-percent range."

Add to that a smaller carbon footprint, and it looks like a match made in heaven.

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*Information and photographs courtesy of John Vastyan (*cground@ptd.net*), a Manheim, Pa.-based communications professional whose work focuses on the plumbing and mechanical, radiant-heat, and geothermal industries.*

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