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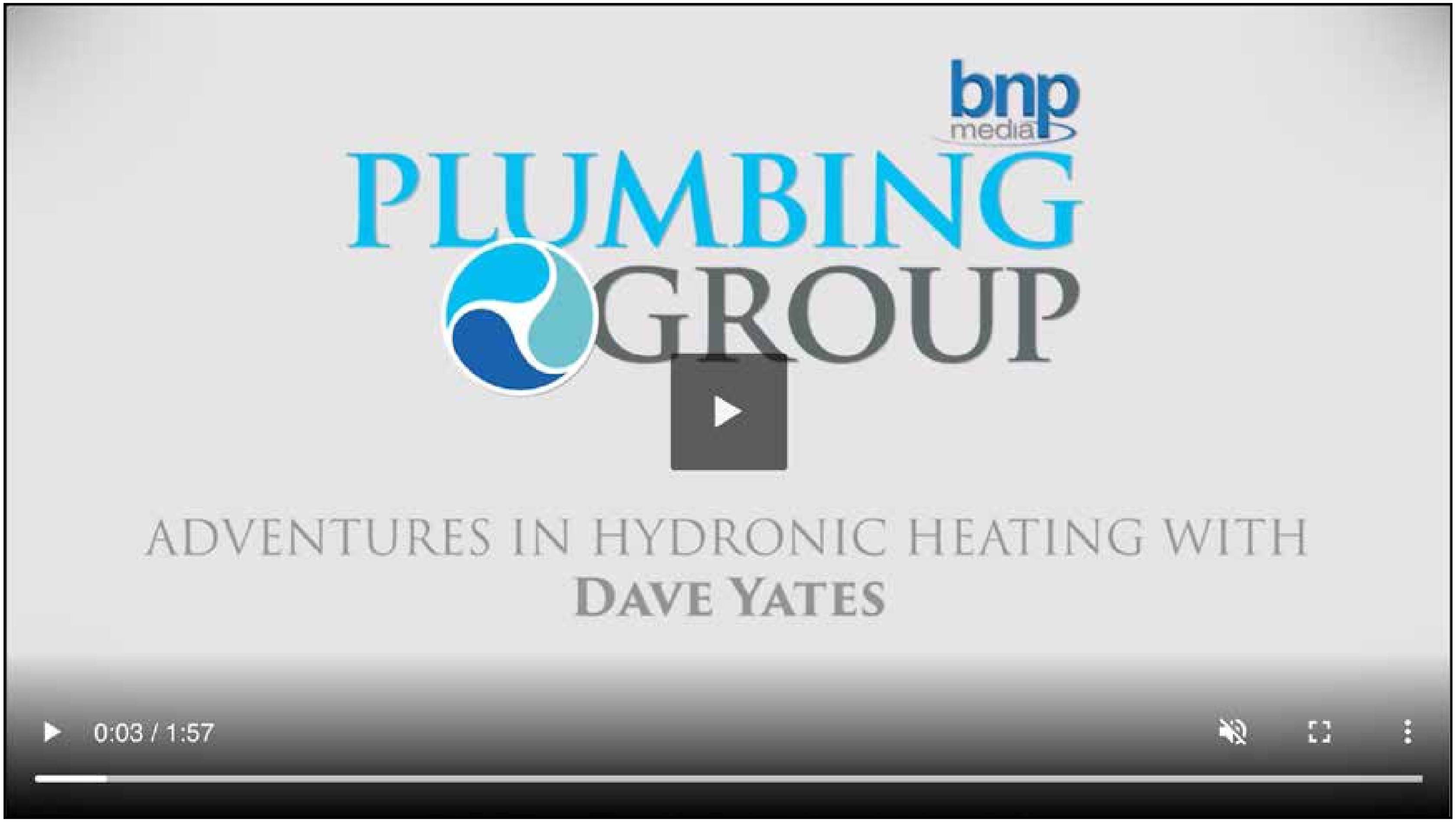
SUPPLYHOUSE TIMES

ADVENTURES IN HYDRONICS HEATING

With Dave Yates

VOLUME 1

A SPECIAL MESSAGE
FROM DAVID YATES



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Dave Yates began his career in the PHCP-PVF trades in 1972 with F. W. Behler, a third-generation plumbing/ HVAC firm he purchased in 1985. Yates also is an experienced teacher in the hydronics industry, serving as an adjunct professor and on the Technical Advisory Board for the Thaddeus Stevens College of Technology. He is is also very active in writing articles for industry trade publications including BNP Media's Plumbing Group, attending trade shows and speaking at events. He can be reached at dyates@fwbehler.com.

EDUCATIONAL **COLUMNS**

You Ask; They Tell; You Sell

At the AHR Expo in New York City a few years back, a group of us were on a panel to discuss things such as up-selling jobs during the past few "lean" years.

One fellow, former longtime industry journalist Bob Mader, asked me if I could be brief when discussing this issue because, "You tend to get wound up and very passionate when discussing how to upsell jobs." Guilty as charged! I gave that some thought later that night and came up with a six-word answer to upselling — the title of this column. Brevity that Bob could appreciate!

In the not-so-distant-past, our customers tended to replace their widgets (water heaters, boilers, furnaces, A/C units, etc.) when they were either broken or worn to the point where repairs were draining their wallets.

"High efficiency," back then, meant an 80% fossil-fueled or 8-SEER electric-powered widget. Then along came condensing 92% furnaces, followed by boilers, then 95% and even 98% combustion efficiencies, tankless water heaters that went from 82% to 98% efficiency and high-SEER/COP heat pumps, ECM motors (blowers and circulators), inverter-drive mini-splits, and geothermal.

Tax credits made the choice to upgrade a no-brainer. Right up until the tax credits stopped (solar and geothermal tax credits sunset in 2016). Upselling became a bit more challenging.

Truth be told, I don't persuade clients; they sell themselves. If I have a secret, it's the ability to listen, react and educate. In a nutshell, it goes like this:

You ask: The art of listening

"Are you having trouble with your widget?" That's almost always my first lead-in question after meeting the owner(s). It doesn't matter if the answer is yes or no! Up until this beginning point of active listening, they see you as a commodities broker — they will be looking at you as money-out-the-door and you'd best have the low bid if you want the work.

But it isn't really just about the price, and don't ever let anyone ever tell you otherwise. In order to get past the dollar signs, however, you need to draw out their reasons for why you are being asked for a price.

No matter if it's yes or no, the next question is this: "What are the issues?" That's what's called a leading question because it's not just a yes/no, and it allows me to dig deeper into why they are asking for pricing. What is driving them to seek out costs for a new widget? What I'm looking for are two things that are not technically related to the widget: I want to know what's important to them — and what is going to elicit an emotional trigger — what really hits home. Mine the conversation for these two golden nuggets and you're well on the way to a sale.

They tell: Problems, what's important and what they really wanted that drove them to call

In order to pry the real concerns from the potential clients, get them to discuss (with you responding so they realize you are listening and care) what matters to them by using open-ended questions that start with: why, describe, what, how, explain, tell me or help me; and avoid yes/no questions like the plague. Get out of the mechanical room and discuss the system. Studies have shown that the vast majority of homeowners are either dissatisfied or somewhat dissatisfied with their home's PHVAC systems.

"In order to get past the dollar signs, you need to draw out their reasons for why you are being asked for a price."

You sell: Solutions? We have solutions!

The last part of the sales call got us out of the widget's area and on to the system. After all, a new widget isn't going to resolve heating/cooling/hot water/ noise/imbalances/high fuel bills all by its lonesome self. The door is wide open by now for you to educate clients regarding ECV (energy conservation value) and ROI (return on investment). One of the most common responses by now is: "No one else bothered to ask us questions like this. You're obviously knowledgeable and have a solid grasp of what we need."

If they have been having trouble with their widget(s), they'll reveal the problems, and from that point on you simply need to provide resolution solutions. How cool is this sales tool? They just revealed what they wanted and all you needed to do is provide the solutions!

Ask for the sale: Do this before you leave

Before you go on any sales call, have some price ranges prepared based on past experiences. Good, better and best products along with some literature to hand them. If you offer financing, this is the time to go over the details. Explain how you, or your employees, will care for their property during the work and how the job will progress from start to finish. Tell them you'd like to order their new widget today and that you would like to schedule the work for a day/ time that is convenient for them. If they are hesitant, ask for and address any concerns. Ask for the sale again. If they still are not sold, follow up within three days.

We don't know what we don't know, but we sure can learn!

In addition to the expansive AHR tradeshow halls, an education track with a wide array of presenters can greatly enhance the value of attending the show while expanding your knowledge. Doing so can separate you from your competition back home, provide you with a reputation for outstanding performance and command higher profits.

In 1998, **Gary Hayden**, an engineer with Burnham Boilers, posted a hypothetical question on an internet site about installing air conditioning for a radiantly heated slab-on-grade addition with no attic for concealing ductwork.

I answered and he contacted me and asked if I would submit a bid. After the installation, Hayden suggested I should join the RPA (Radiant Panel Association) and submit the installation for the RPA's annual Showcase Awards. Thinking the whole thing a waste of time, I resisted, but if you know Hayden, you know he does not give up. I joined in order to get some peace and quiet, but that only egged Hayden on to insist I submit the installation and attend the 2000 RPA convention in Providence, Rhode Island.

I'll reveal how our installation fared in the juried contest later — read on!

Richard Trethewey, the plumber from "This Old House," was the keynote speaker and we (Lois attended the show with me) thought it would be cool to meet Trethewey, as we often watched the show and looked forward to his promotion of radiant heating.

Lois and I had, prior to attending the RPA convention, selected education tracks and first up for me was a class on hydronics by veteran BNP Media Plumbing Group columnist **John Siegenthaler**. Entering the room, I was confident my hydronic knowledge was pretty solid, but just a few minutes after Siggy, as he likes to be called, began speaking, while PowerPoint slides with formulas were displayed, I quickly realized my depth of hydronic knowledge was not that great. As the years went by, I took every class Siggy taught, and became certified for installation, design, and instructor in all things hydronic.

While attending the 2019 AHR Expo in Atlanta, Siggy was teaching "*Distribution Efficiency – The Often Overlooked Advantage of Hydronics Technology*" for the RPA (now Radiant Professionals Alliance). Course description: *This session defines the concept of distribution efficiency. It then compares the distribution efficiency of properly designed and poorly designed hydronic systems to that of forced air and VRF systems. It shows how to create state-of-the-art hydronic systems that maximize distribution efficiency, and how to estimate their diminutive operating cost. If you design hydronic heating or cooling systems, you need to understand and apply the concept of distribution efficiency in both design and marketing.*

"Promote the superior distribution of hydronics to 'energy conscious' people."

The story of a circaholic

Siggy illustrated a number of hydronic installations featuring banks of induction-motor circulators lined up like soldiers at attention. "Good craftsmanship, wrong approach," and thus began the details on Btu/h/watts to determine the often overlooked parasitic energy consumption of using large numbers of 87-watt circulators instead of just one or two low-wattage ECM circulators in conjunction with 1- or 3-watt zone valves.

I'd had my own epiphany in 2003 while attending the ISH convention in Frankfurt, Germany when I encountered a large display of low-wattage ECM circulators using a fraction of our USA-available circulators.

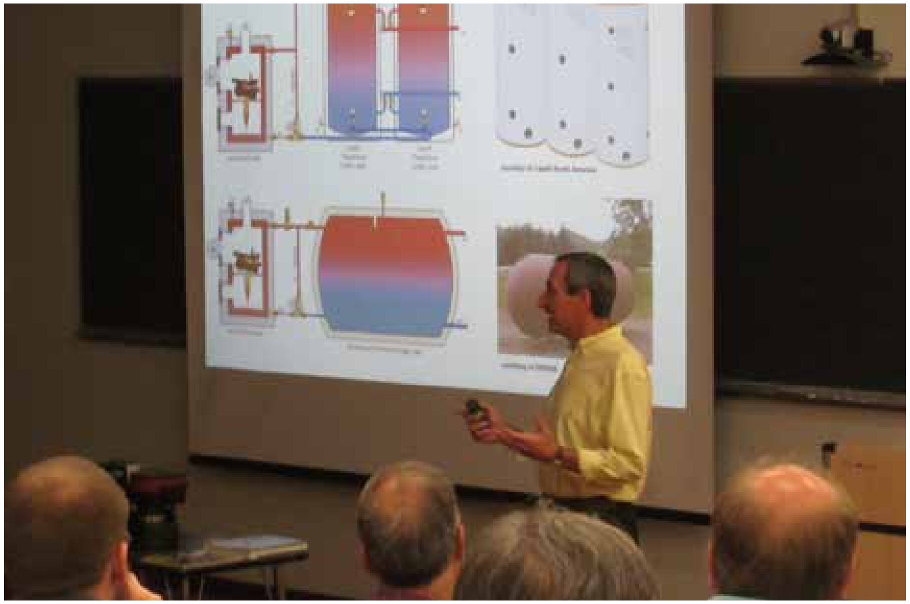
Like the slides Siggy was showing, I too was a circaholic quite pleased to be installing hydronic systems with multiple circulators — like the one in my own home with its 13 circulators. When ECM circulators finally became available in the U.S., I revised my home's system to two ECM circulators and ten 3-watt zone valves. My annual cost for delivering comfort energy dropped from $375.05 to $24.83! Fast forward to 2019 and I've reduced our energy consumption by more than $6,800.

In 2011, I became a reformed circaholic and began promoting and selling ECM circulators in conjunction with low-watt zone valves and sold those systems based upon not just modcon high-efficiency boilers, but with emphasis on the electrical efficiency side of the equation. Once presented to owners, the added cost was in their own best interest and we consistently won bids that were higher than our competition. Siggy turned to me and asked, "Dave, you're a recovering circaholic, right?" Hah! Guilty as charged, but reformed actually fits better.

Siggy went on to illustrate why a hydronic system can be up to 400% more efficient than air-based heating systems — when properly designed and backed that up with lots of detailed calculations.

Siggy's design guidelines for achieving high-distribution efficiency:

- Use valve-based zoning
- Use high-efficiency (ECM) circulators
- Use parallel distribution systems
- Use "short/fat" headers
- Use low-head-loss heat sources
- Use high delta-T to reduce flow requirements
- Evaluate lifecycle cost of using one-size larger piping



While attending the 2019 AHR Expo in Atlanta, Siggy was teaching "*Distribution Efficiency – The Often Overlooked Advantage of Hydronics Technology*" for the RPA. Here, Siggy is using the simple formula design load/watts to assess the distribution efficiency.

- Use the simple formula (design load/watts) to assess the distribution efficiency of your systems.

It was refreshing to spend time in Siggy's well-attended class.

Siggy's summary:

- High-distribution efficiency is a **distinct benefit** of well-planned hydronic heating and cooling systems.
- High-distribution efficiency also is a **very underutilized** concept when comparing hydronic systems to alternatives.
- **Don't just promote thermal efficiency** of heat sources.
- **Promote** the superior distribution of hydronics to "energy conscious" people. They will listen.

If I'm ever a judge for a contest on superior hydronic systems and you send in an entry with 34 high-efficiency circulators along a wall, **don't expect my vote!**

As for the 2000 RPA contest, we won an award for that radiant installation, and, thanks to the ongoing training via the RPA, we won additional awards including Best of Show in the following years.

As an ASSE 19210-certified instructor, I look forward to passing along what I've learned in the years to come. I highly recommend obtaining a copy of John Siegenthaler's "Modern Hydronic Heating," which is a required textbook for taking the RPA's ASSE 19210 hydronic heating and cooling course.

Return on Investment

Alan Mercurio and **George Lanthier** have recently moved their popular educational bulleting boards: "Oil Tech Talk - Chatter;" and "DragonTalk." Both are now private members-only sites on Facebook where we contractors can post pictures, comments and ask questions of each other in our never-ending quest to better our businesses while absorbing mentor-knowledge.

Do yourself a huge favor and join these sites.

On DragonTalk recently, **Chris Gagne** (Gagne HVAC out of Westminster, Massachusetts) asked: "I'm interested in the pros and cons of using pro-press fittings. Does the cost of the tool and extra cost in materials outweigh the time savings, and if you're doing a time and materials job, do you switch back to sweating joints?"

Think about how many times you've asked yourself the same question of "Is it worth the investment?" to purchase some widget, such as the press tools for copper, black iron and now refrigerant lines. At first glance, investing a grand or two sure does present a mental roadblock.

First look

Turning back the hands of time, was it worth the money to purchase pipe-pullers for cast-iron rubber-gasketed joints instead of using oakum and lead joints? After all, we had lead pots, and the lead tools required to keep on keeping on with the skilled craftsmanship of a properly caulked and poured lead joint. In our shop, as an apprentice, I had to offer up a week's pay to my employers in order to get them to allow me to demonstrate the labor savings. I did not lose that bet!

In 2003, I encountered pipe press tools at the ISH tradeshow in Frankfurt, Germany. I'm a hard-core tradesman who takes great pride in the skills learned over many decades. In some part of my psyche, I rail at advances that cheapen what it is we do — shortcuts that obviate our craftsmanship skills that were hard-earned. Hell, anybody can press a joint! The rational side of my brain recognizes the potential to

Photos courtesy of RIDGID.

become a sharper tool when it comes to bidding and obtaining work via the labor savings specialized tools, like this, offer. Outside, on the streets of Frankfurt, I spied a plumber's truck and had to peek inside. Press fittings for water and gasketed fittings for drainage lined the side bins. No soldering and no solvent cements needed!

As soon as the RIDGID ProPress became available here in the states, we purchased one. Was I concerned about this being a justifiable expense? You betcha! My bride, the bean counter and our office manager, certainly questioned my reasons for the outlay of cash. "Don't worry, it will pay for itself." You've seen the look too.

It's a winner

One of our first victories was a rush-bid on replacing one of three commercial water heaters in a hotel. No isolation valves present, so old-school would have required draining the hotel's hot water to a point where soldering would have been feasible. With the ProPress tool, we could minimize the down time and press on a valve within minutes to restore domestic hot water for the hotel guests. Bid won — money in the bank!

Photos courtesy of RIDGID.

Pressing fittings for water, oil, and gas saves time.

"Work smarter — earn more money — and enjoy that sweet ROI."

The post on DragonTalk caught fire and lots of mechanical contractors weighed in with their opinions and stories.

Eric Aune (Mechanical Hub) had this to say: "Oh boy. I'll have to hold myself back on this one. I don't know why I get so ramped up about it but here are a couple thoughts:

- Stop thinking about the cost of the fittings.
- The tool is costly, but it's a great investment in your company.
- The very first time you pull the trigger on the tool you're making your money back.
- Bid the jobs the same for time except complete them in a fraction of that time.
- Make more money and never burn your client's property.
- Make more money.
- Make more money.

"I could go on about why I'm a proponent and I've done so in the past. I'm also sure someone will comment about how it takes no skill and it's literally, singlehandedly ruining the trades. Haters gonna hate I guess."

To which **Charles Garrity** responded: "Eric, I don't know if you remember but I was very anti-ProPress for a very long time. I was in a situation where I had to buy the tool because nothing else would get me out of the jam I was in, in a manner I felt was satisfactory. The main to the building could not be found and the main shutoff inside the building would not hold water. I bought the tool and I have never looked back."

Mark Eatherton (executive director, RPA) summed it up: "Labor savings is *huge*. And as pointed out, in emergency situations where the water to a large complex cannot be turned off, I've cut out and replaced 1 1/2-inch copper ball valves with full flow. Got pretty soaked in the process, but saved about 6 hours in not having to go around and notify tenants of pending shutdown. *Uge* (said in the voice of the POTUS) labor savings. And labor is your most expensive commodity."

Work smarter — earn more money — and enjoy that sweet ROI.

RIDGID just released its next generation of standard pistol-grip press tool, the RP 350, at the 2020 AHR Expo in Orlando, Florida. The RP 350 eliminates service intervals and features 360-degree swivel for the tightest spaces.

What's in your radiant toolbox?

"All I ever do is staple-up."

That was my friend and competitor's response after he asked me to determine why a recent radiant heating installation was not working satisfactorily because the owners were ticked off. Staple-up installations consist of PEX tubing attached to the underside of the sub-floor with staples or similar fastener. The only direct contact for heat transfer is where the staples are located while the remainder of the PEX droops between fasteners much like wires strung between telephone poles.

Insulation, if present, and it was not in this case, cannot be packed tightly to the underside of the sub-floor and there needs to be a 2-inch air gap so the air, which is a poor conductor, can be heated to transfer its heat upward through the flooring into the living space. Carpeting with composite padding (the worst type for heat transfer) covered the radiant floors.

I wish I could tell you this was the exception to the rule, but after many forensic investigations into why so many failed radiant systems exist, there emerged a definitive pattern of things missing from the installers' radiant toolbox.

The toolbox

Lack of training. Universally common to failed or under-performing radiant heating or cooling systems is the absence of training. Had my friend availed himself of readily available training, he would have known that staple-up requires the hottest water temperature while delivering the lowest Btu per square foot when compared to other installation methods.

Instead of an average 170° F loop temperature, he could have achieved better results and met the space requirements for comfort utilizing water delivery temperature below 100°. Lower water temperature conserves energy.

Your customers will love the lower operating costs. Any class taught by **John Siegenthaler**, aka Siggy, is well worth your investment in time, as is obtaining a copy of Modern Hydronic Heating at www.hydronicpros.com. **Dan Holohan's** Pumping Away book will change the way you pipe hydronic heating and cooling systems for the better.

RPA training to ASSE 19210 shows that your knowledge of industry best practices, state of the art installation techniques and compliance with applicable codes and standards has been tested and certified — helping you stand out in a competitive market. Visit www.radiantprofessionalsalliance.org.

Failure to utilize a design program. Like taking a shot in the dark, not using a design program results in a high probability of shooting yourself in the foot! Look to PEX tubing and circulator manufacturers for installation and design methods training. Many have design software that is super easy to use and will enable you to provide first-class radiant heating and cooling systems. Look to PEX tubing manufacturers for installation/design education and software programs that are very easy to use. The same applies to circulator manufacturers.

Communication from the radiant contractor to the owners, and then all others on a construction site. If you are bidding to a general contractor, it is vitally important you communicate directly with the owners. You need to know their needs, wants and desires before you can design a radiant heating system.

Things like who is responsible if the electrician drills through a tube, or the flooring installer fails to follow the tubing pattern you laid out and, instead, uses it as the guide for the staples or nails! The general contractor has the gold and can withhold the cost from the subcontractor responsible — a very important bit of communication!

Tubing uncoiler. If you've never installed PEX tubing before, take my word for the fact that your bundle of tubing will quickly become a tangled mass looking much like a bowl of spaghetti if you don't use a tubing uncoiler. Don't ask me why I know this to be true.

Attaching PEX tubing. Wire ties with twist tool or plastic zip ties you need to cut off tails so they don't end up protruding through the freshly poured concrete surface both work well, but can be a back strain on larger jobs. If the job is large enough to justify the cost, invest in a rebar tie tool like the RB398 tools we use (bit.ly/2N3k2Jb).

This bad boy ties a triple wrap, twists it and cuts off the tie in under one second! This truly is a tool that will pay for itself in labor savings. We have used ours on over 30-miles of PEX tubing attached to both rebar and wire mesh with zero break downs.

Control joints in concrete. Another vital communication issue. Concrete will crack as it cures, so placement of control joints prevents random cracks that would be unsightly. Control joints are often saw-cut and the depth of the cut needs to be negotiated and agreed upon to avoid damaging your PEX tubing.

The PEX tube needs protection at the control joint to avoid crack-stress and we use strips of automotive ribbed plastic tubing (used to conceal bundled wiring under the vehicle's hood) that are quickly secured using the rebar tie tool.

Testing the loops before and during the concrete pour. If you plan on using water to pressurize the loops be sure to use a mix with hydronic glycol if there's any chance of freezing temperatures. PEX embedded in concrete that has water will freeze and split! Even if using compressed air, the moisture in the air can and will condense as temperatures fall, which can create an ice plug. That happened to us when we installed tubing in a three-foot thick floor and prestressed beams to create a radiant heated bunker to preheat aggregate that is added to the prestressed concrete beam molds.

Note to self: Do not stand in front of the loop that is not allowing air to flow. When the air pressure finally dislodged that ice plug, it sounded like a shotgun blast and we never did find the ice plug! We've had more than one commercial installation with outdoor air temperatures near 0° F and no ability to warm the PEX before wrestling it into position. Wear safety goggles because cold PEX can snap back if it slips your grip!

Patch kits. We always include costs for at least one of our installers to be present during concrete pours and ensure they have coupling repair kits — just in case. Knock on wood, we have never had tubing

"Ensure you do the job right the first time."

compromised during the concrete pour. If you have an installer present, they can control things like ensuring the metal knuckle(s) on a pumped pour are not allowed to rest on the tubing and the tines on rakes are always pointed skyward. No sharp tools and no tossing lit cigars into the tubing field. In fact, we have a strict no smoking policy during the concrete pour or while our tubing is exposed.

Another bit of communication: Will the owner even allow a loop to be repaired where concrete is to be installed? If not, you'll want to have extra PEX on the job site. We've had other trades drill through flooring and concrete where our PEX tubing is concealed. One thing I can guarantee you: If there is a radiant slab on grade and the home is treated for termites, they will find your tubing — repeatedly!

Expansion/contraction noises. One of the more common complaints I have investigated centers on noises generated as PEX expands. One home in particular stands out in memory. During the initial contact, the owners told me they had to turn off their radiant system at night in order to get any sleep. They were using portable electric space heaters overnight.

On the first day I was to visit, I asked them to leave the radiant heating system OFF so I could get an accurate sense of just how much noise they were experiencing. We turned the system ON and within a minute the tick-tick-tick noises became loud enough to wake the dead! On all three floors.

What in the world could possible cause so much noise in a radiant heating system? The installer had drilled 3-inch holes through the wooden joists and somehow managed to pack each one tightly with both supply/return PEX runs. Not only were noises being generated by PEX expansion against wood, but also by the constricted PEX against itself. Other noise complaints in other homes caused by cheap aluminum plates made from thin flashing material and staple-up systems.

Do it once and do it right: Cutting corners to dumb down the up-front cost costs more in the long run.

A Roadmap to energy conservation

Some would classify the following story as green or combating global warming or even as saving the planet.

I would simply call it a common-sense approach to energy conservation while designing an HVAC system replacement to take advantage of today's efficient and reliable equipment. This one garners no federal tax credit because it involves a church. Come along for a trip through this process — from inception to delivery — and I'll share with you the process I use and some fun ways to deliver the promise of comfort and economy.

The property committee at St. Paul's Church in Red Lion, Pennsylvania, had been working on resolutions for its heating and cooling systems for more than three years. The current HVAC systems had been installed in 1964 and the TTW (through the wall) A/C units in the sanctuary, offices and lounge were noisy, inefficient and several were no longer operational. The 16 one-ton TTW A/C units in the sanctuary incorporated a hot water coil for heating, and over time, they'd learned to cover the exterior grills with cardboard during winter to avoid messy and costly freeze-damage from split coils. With another hot summer approaching, and several non-functioning TTW A/C units, the church was feeling the heat from the congregation to finalize plans.

During this three-year journey, church officials had met with several mechanical contractors and knew the church needed a system-wide renovation. And that's where you and I begin our trip through this process. The property committee requested a proposal to replace the systems. During our initial visit, we'll discover the following:

The steam boiler, replaced in 1964, was firing at 1.8 million Btu/h. Its rating plate indicates a maximum firing rate of 1.5 million. Over-firing equaled wasting energy and large production of CO due to over-rich fuel-to-air mixture.

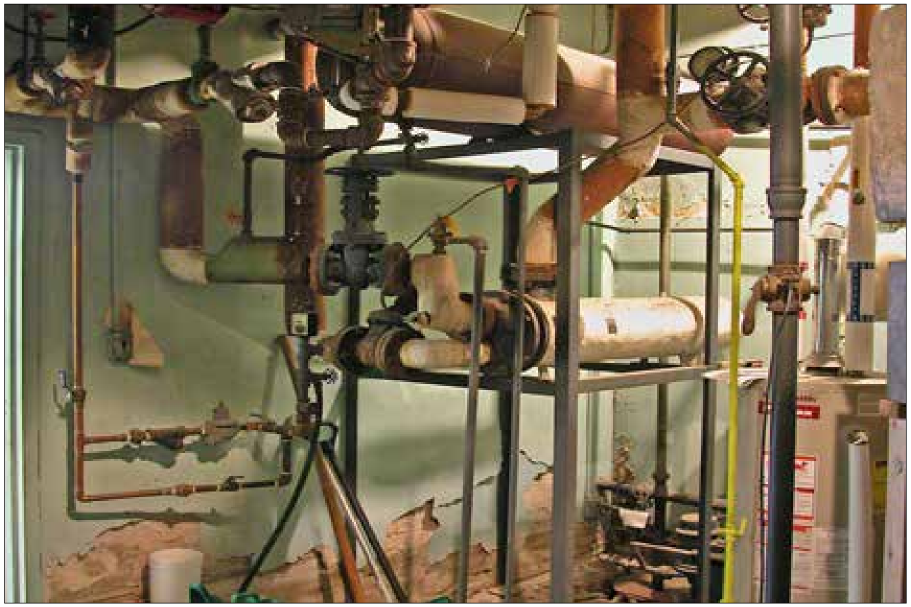
Photo credits for these 5000 series pics go to John Herr (now retired) pro shooter all other pics were provided by Dave Yates

OLD DUAL-AC HYBRID UNITS.

AN OLD LOUNGE THROUGH-THE-WALL AC UNIT.


Old oversized and inefficient steam boiler.


Old leaking radiators.


Steam to hot water station.


Old steam radiator that was oversized and could not be converted to hot water.

New thermal and water-to-wire high efficiency replaced long-outdated technology and gross innefficiencies.

The boiler's flue-collection box and draft diverter was being supported by a wooden 2-by-4 frame (fire hazard) because, as you can clearly see, the asbestos-covered flue pipe (large enough for Santa to slide through) weight had bent the heavy-gauge box where it meets the boiler's flue-gas outlet. A half-fast piece of metal hangar-strap was attached and looped over an overhead steam pipe for support, but did not work, and had cut through the pipe's insulation. Death lurked here, and I pointed out to the property committee, that no matter who got this job, this is a situation that demanded immediate attention.

The steam pressure switches were installed using iron-pipe pigtails, which do not meet code (must be brass) and are subject to clogging with rust-mud. I was surprised to discover these two switches were set to operate the boiler between 6 psi to 9 psi. Steam systems have a specific volume within the radiators, piping and boiler, which must be filled with steam. As you increase the system pressure, steam (which

Low wattage ECM circulators dramatically reduce energy consumption.

is a gas) is compressed. As steam is compressed, more of it must be made in order to fill the same volume, and that means burning more gas to do the same work of supplying heating. This was originally a vapor system designed to work on ounces, not pounds, of steam. Part of what I had to do next is educate the property committee about this issue that is wasting energy.

The 1964 addition utilized hot water for its heating via recessed wall convectors and those 16 hybrid A/C units. In the boiler room, I was confronted by a large steam-to-hot-water tube-in-shell heat exchanger, and a rat's nest of piping with old and tired circulators. Lots of used circulator parts were lying about, indicating past troubles. A nice application for a modcon (modulating condensing) boiler if the radiation can be made to work with varying temperatures.

I was more than a bit surprised to find that this steam boiler with its haphazard flue and high-pressure was set to run 24/7 until someone manually turned off the electricity to the burner! It was the motherlode of energy waste, and this point was driven home in my first report. Let's call it "The good, the bad and the ugly."

They've obviously had problems with unauthorized thermostat tweaking because the mechanical room had all the zone thermostats wired to remote thermistors that told these remote thermostats what the temperature is where they are located. The thermostats can be coded so access is limited. Not bad, but they may want a better way with remote access via the Internet by computer or cellphone. You'll never know if you don't ask, and what I was going to suggest, they most likely haven't yet heard about.

So far, we've only studied the boiler room. We'll need to move on to determine what's in the rest of the church buildings that are connected to each other as one larger complex.

In the older portions of the church, there are rooms hot-as-a-sweatbox, and entrances on both sides of the Narthex that rapidly become cold during winter as folks come and go. We're on the outer edge of the 1-pipe steam system, and the radiators are not connected across the top — meaning you cannot convert them to hot water.

The steam radiators — every one of them — had a pan or a cup placed directly under the air vents to catch condensate that was spitting up through each one, and there was noticeable water damage at each radiator's valve that stained the hardwood floors. These issues can be fixed by lowering the steam pressure, installing new air vents and repacking the valve stems or replacing the valves. There are other options – you just need to ask, listen and then provide the solutions. *You ask: They tell: You sell*. What they told me they wanted was a total surprise. Read on.

Narthex East's new Vertical RUNTAL panel RADIATORS. Dave installs the thermostatic radiator valve operator.

In the attic, there were two 5-ton air handlers serving the social hall. Someone fell or stepped on the metal fiberglass-wrapped trunk line collapsing it, which is severely restricting air flow. The insulation has rebounded to conceal the damage. No one was previously made aware of this issue. It needs to be corrected, and these were relatively new A/C systems they will most likely want to keep, but there was a better way to run them that will conserve energy. The filters were dirty, and there were lots of old, discarded filters liter the area. The condensate drains had dips where gunk was collected. We'll explain everything in our report.

The kindergarten room on the lower floor had the only 2-pipe steam radiators. The kitchen just off this room and adjacent to the boiler room had a stretch of commercial fin-tube baseboard as part of a hot-water zone installed upside-down near the ceiling! The old steam lines were capped off. If you or I had installed that baseboard like that, it would never have worked, and we'd be back to do something a bit more conventional! A bit of creative 1964-era work.

The men's room in the lower level had a 1-pipe flat steam radiator mounted horizontally on the ceiling. The ladies' room had a hot-water

Photos courtesy of John Herr.

Mike Keefer and Dave Yates showing church committee members what to expect with the new modern look.

Mike Keefer finds room for the Fujitsu air handler under the choir loft.

Mike Keefer patching the prior TTW hybrid hydronic/AC units after sealing and insulating the wall cavity.

Dave Yates and Mike Keefer observing refrigerant charge during commissioning.

Fujitsu floor console units were installed where the TTW units had been.

recessed wall convector because it's located in the 1964 addition.

As noted before, the sanctuary had 16 hybrid 1-ton A/C with a hydronic coil for heating and the remainder of the spaces upstairs had hot-water recessed wall convectors, as did all the lower-floor classrooms, offices and lounge. That left just the three window-shaker A/C TTW units. On the day I was there, it is quite windy and air leaked past the TTW hybrid units like a sieve!

After spending a day playing mechanical detective, it's time to write the report and spend some time with the property committee on the evening of its next meeting. But first, we need to know if that boiler is right-sized: A connected-load survey for all the steam radiators/convectors (Burnham Heating Helper – see page 64: https://file.ac/vtYJ3julp2E/Heating%20Helper%202018.pdf ; and a building heat loss for the hydronic side.

Bear in mind that I was striving to explain everything I had discovered in plain English and not use the jargon I would when talking to a fellow tradesperson. If you lose the audience at this stage, you won't be likely to get the work. I was stunned to find they no longer wanted anything to do with steam – they wanted high-efficiency boilers or else a geothermal system, and they were interested in mini-split inverter heat pumps to replace those 1964 rattle-trap A/C units. They asked me to supply them with installation and operating costs for next month's property committee meeting. I was also requested to provide long-term costs, lifecycle costs and payback for each system.

The total heat loss using Manual-J was slightly less than 650,000 Btu/h, and that included a 15% pickup factor for the hot-water piping. That meant the old boiler was pumping a minimum of 1.12 million Btu/h straight up the chimney if all zones were on every time it ran and, remember, it's on 24/7 until someone manually turns off its power. But this system was divided up into nine separate zones – meaning still more energy was sent to heat the great outdoors! How does a system get this far off course?

Hot-water system: The tangled rat's nest of piping will be relatively easy to strip away while adding properly-designed zone pumping using ECM circulators to slash parasitic energy consumption, while transferring comfort energy from source to use. The added cost will be easy to justify. There was an easy route for venting modcon boilers, and it made sense to incorporate two that would work as a team during bitter cold weather and individually during milder weather. That will allow for a greater turndown ratio to avoid short-cycling during milder weather. In order to complete the desire for conservation of energy, a low-head-loss modcon is needed so that the primary circulator won't be a glutton for watts.

A/C and heating for sanctuary, offices and lounge: No question, those 16 rattle-traps needed to go, and likewise for the three TTW window-shakers. No attic space above the vaulted sanctuary ceiling, and no room above the finished lower-floor classroom ceilings to conceal ductwork meant new chilled/hydronic floor console or Freon-based mini-split units. Looks as well as quiet efficient operation were of paramount importance.

Inverter-driven mini-split heat pumps have evolved in recent years to provide good heating performance in bitter cold weather without a need for any resistance-elements to supplement output, and floor-console units would mimic the look they already were accustomed to seeing (and hearing). Eight 2-ton floor console models could replace the 16 one-ton units while occupying less space and operating so quietly that Pastor Clark could preach at a whisper-volume if he so desired. A tri-zone set of wall-hung inverter mini-splits could serve the offices and lounge.

I attended more of the property committee meetings to provide suggestions, and while reviewing the numerous cost factors, they begin to narrow down the choices. Geothermal was an early casualty and the following systems were chosen by the property committee:

- Triangle Tube 399,000-Btu/h Prestige Cascade System modcon boilers with control package and racking system that also functions as part of the hydronic piping.
- Triangle Tube Smart-40 indirect water heater.

- Grundfos Alpha ECM zone circulators utilized to automatically alter flow as thermostatic radiator valves open/close.
- Myson flat-panel radiant radiators in place of all steam radiators with vertical models in both Narthex entries.
- Ecobee thermostats so that the hydronic zones can be monitored and altered remotely. If a zone fails to respond to a call for heating (or cooling in the older-side chapel-now-social hall), an e-mail alert will be sent.
- Fujitsu inverter-driven mini-split heat pumps for the sanctuary, offices, lounge and two-classroom HVAC. One thing that's been bugging the choir: They tend to get a bit warm in their robes and would like that comfort issue resolved. The choir sits/stands adjacent to the elevated platform where the pulpit and altar are located — this is just right for adding a concealed mini-split air handler.

Much as I wished that contracts were signed and we could have started demolition, there was one major hurdle remaining: Give a presentation before the assembled congregation on a future Sunday morning. They would be casting the final vote! The property committee chairwoman explained she does not expect a favorable result and hopes that I wouldn't be too disappointed. They had been at this task for more than three years, and after we had invested well over 200 hours on the designs and reports. Who wouldn't be disappointed?

D-day: They say public speaking is one of the toughest things to do, and as my wife and I sat listening to the property committee chairwoman go over the proposed contract, we could audibly hear a gasp from the congregation when she revealed the cost. Not a good sign. My knees were knocking, heart was clamoring for a way to leap out of my chest and I was striving to maintain a look of serene calm as I made my way to stand by the altar and speak. I had prepared a short presentation about what we discovered regarding their energy usages and a thumbnail sketch of the ultra-efficient energy-conserving equipment included in the proposal. The floor is opened for questions.

Storming the beach: I'll freely confess: I'd spent weeks asking myself any questions that could possibly come up after the presentation to the congregation — things I'd want to know if I was sitting in the congregation audience. At first: Pregnant silence, and then, a hand went up. He was not at all pleased to know how much energy had been wasted by that grossly oversized boiler. "How did you determine the connected load you described?" And just like the crack of a starter-pistol, the race was on with what seemed like a million questions! "Those new-fangled boilers — what's the heat exchanger made of — they'd better not be aluminum." I hadn't expected that curve ball. A number of congregants looked like they would judge me by that response alone, but the Triangle Tube boilers use stainless steel heat exchangers.

That led to this question, more of a comment: "We hate our high-efficiency condensing boiler because of the high annual costs to keep it clean. Has to be torn apart to be serviced, which takes hours." Without hesitation, I explained that one benefit of the Triangle Tube's heat exchanger is that it is partially self-cleaning, and will not require such a high level of maintenance, but will require an annual checkup to check operation and determine when the more detailed cleaning is necessary.

That gave me an opportunity to talk about setting them up with a maintenance contract. Last, but not least, questions about electrical power consumption came up because of our pending deregulation in Pennsylvania at the time. I'd hoped for that one because all of the chosen equipment is miserly where power consumption is concerned. After most of an hour, the questions were all answered and although there were some I hadn't anticipated, my homework and self-questioning enabled me to quickly answer all of them.

On or off the island — vote now: The longest 10 minutes of my career elapsed while ballots were handed out and collected. Only three nay votes out of more than 150 cast! We were ready to start this glorious undertaking and had an opportunity to socialize following the service.

Rome wasn't built in a day, and if you're new to the technology, you'll want to seek out the training before making the leap. You've got my e-mail address and I'll do my best to lend you a hand along the way if you want to get on board as an energy conservationist.

PS: I promised to reveal a trick regarding the Narthex entries. Four vertical flat-panel radiant radiators on each side greet those who enter. Backing up into that nook bathes you in delightful soothing radiant comfort. Pastor Clark may well need a large spatula to peel away congregants — especially arthritic ones — who don't want to vacate this cocoon of comfort! No thermostats here, wired or wireless. Just a thermostatic radiator valve and hydronic piping connected to a Grundfos Alpha Delta-P circulator that "sees" the pressure change as the thermostatic valves open/close and sends Btu in flows to match the need to offset the rapidly changing conditions as folks open/close doors. Old Man Winter creeps in only to be met by variable-speed radiant comfort. No more hot spots — or cool spots, as all areas that had suffered before are now equipped with thermostatic radiator valves.

PPS: The two 5-ton A/C units serving the social hall were turned into a two-stage system by using the multi-stage feature of the Ecobee thermostat. In milder weather, only one is required, which saves energy and improves dehumidification.

Dave Yates 2020 update: These systems did save energy and fossil fuel usage while dramatically upgrading the comfort level in all areas of the church. St. Paul's reported back that its gas usage had been reduced by almost 80% and the electric bills for AC were 70% lower! We have seen similar reductions in electric and fossil fuel use following similar projects in churches and residences. Taking the time to adequately study the existing conditions as well as performing an accurate heat loss/gain is absolutely essential for a successful conclusion.

One detail I left out: We did not have the low bid, not by a long shot. What we did have was the best, most accurate details and had established trust along the way, so that the church committee had faith our proposal was in its best interest.

The chicken or the egg?

I'm sitting in a classroom taking the mandatory training class to be eligible to participate in the PA Keystone Help program that provides low-interest loans for folks to upgrade their home's energy efficiency. Most in attendance are insulation, general, window and door contractors. There are a few mechanical contractors.

The instructor begins by asking, "What's the first best investment: Upgrade the shell by sealing infil-exfiltration air leaks, adding insulation, installing new windows and doors, or replacing the heating and air conditioning equipment? You can only afford to do one or the other."

I was seated in the front row. He called on me to give the answer! I knew what he wanted to hear, and I didn't want to get off on the wrong foot before class even started, because there was going to be a graded test at day's end. He had no idea that I'd previously crunched the numbers. Why lie when the truth will do.

"It depends," I said. "Let's use the average 2,250-square-foot home as the example. If you replace the heating and air-conditioning equipment with modulating-condensing gas-fired and/or electric-powered inverter-drive variable-speed units for $15,000, and the building envelope upgrade costs $7,500, then the first, best investment is the HVAC equipment. The fuel costs avoided will pay for the other upgrades and, here's the best part, as they make those upgrades — just in case they don't do them all at once — the variable-speed models will automatically adjust themselves to be right-sized for the lower heat loss/gain of the home."

As I spoke, I could see the look on his face clearly indicated he thought I was, shall we say, not playing with a full deck of cards.

"Well, I'd expect that since you're a mechanical contractor, but that's the wrong answer," he said.

"Hang on a minute," I said. "Let's say you do go all-in on the building envelope upgrade. Now you have HVAC equipment that's grossly oversized. The air conditioning will cool too quickly and fail to dehumidify properly while the heating will also short-cycle, causing both to operate at lower efficiencies. While they will think they're doing better because their fuel and power bills will be lower, they are now wasting a good portion of the energy they think they are conserving."

He clearly wanted to move on, so I shut up and kept quiet for the rest of the day.

The best way to illustrate the which-is-the-best-first-investment deal is to validate the findings using a few tools: Manual-J for heat loss/gain; blower-door test; actual current operating costs (to judge the accuracy of the first two); and the home's new conditions following the envelope upgrade. I'll use a 2,369-square-foot home where an independent energy audit was performed before and after to reinforce the findings and a design-day-temperature of 0° F.

It's important to understand that old-style on-off equipment is right-sized for just 10% of any given heating/cooling season. As outdoor weather temperatures moderate, the operating efficiencies suffer by as much as 40%. An appliance operating at 85% at 0° outdoor air temperature may be operating as low as 45% at 70° outdoor temperatures.

Modulating-condensing, ECM variable-speed motors and inverter-driven equipment are right-sized for 90% or more of any given heating/cooling season, and equipment operating efficiency will improve as outdoor weather moderates. Based on our past experience, weather-responsive modulation reduces operating costs by more than 30% when compared to on-off fixed-speed appliances.

They avoid $1,330.75 and they will be blissfully unaware their equipment is short-cycling under adverse conditions that will shorten its lifespan. If they bank the avoided costs, the savings will finally catch up to the HVAC upgrade costs in the 18th year.

They will avoid $1,527, and with some discipline can bank that toward the building envelope upgrades. The savings will catch up to the cost for upgrading the building envelope in the eighth year.

In reality, they can reinvest incrementally in the building envelope upgrades and reach the ultimate goal of maximum energy conservation in less time as costs for heating/cooling are reduced.

Why? Because modulating equipment will resize itself to match the building's heat loss/gain as those changes are implemented.

Mastering the outdoor reset curve

Does it make any sense to install hot-water boilers that are sized to match design-day ambient outdoor air temperatures?

Every time they turn on, they run full-tilt as if every day is at outdoor design temperatures (coldest weather you experience based on ASHRAE guidelines).

Upfront cost may be the deciding factor when presented the choice between a chimney-vented lower efficiency versus a direct-vented high-efficiency modulating condensing boiler. Or maybe it's the perception that the installer is working with a "high-temperature" hydronic system — such as fin-tube baseboard where the operating temperature range is 160°/180° F.

The problem with installing a boiler that matches the building's heat loss at design-day conditions is that it is oversized for roughly 90% of the heating season. As outdoor air temperatures rise, the boiler cycles more frequently, which adversely impacts its operating efficiency because it fires to that 180° limit virtually every time there is a call for heating.

What is outdoor reset (ODR)? ODR monitors the outdoor ambient temperature, and you program the ODR control to limit the highest and lowest water temperatures. Water temperature to the heat emitters varies as necessary to make the heat output equal to the heat loss of the building.

Modulating condensing ultra-high-efficiency boilers have outdoor reset on board, yet, we too often encounter ones that were installed and set to operate at their maximum water temperature, and the outdoor sensor was never installed.

The building owners were led to believe they were getting a 95% efficiency boiler, when, in fact, the actual operating efficiency mimics that of the lower-efficiency, chimney-vented boiler. The PVC exhaust

piping often is discolored due to the dry exhaust gas temperature exceeding its maximum safe temperature rating.

Add the outdoor sensor, replace the PVC exhaust (never, ever use foam-core PVC), and follow the installation manual to program ODR. Most will require you select the design-day outdoor air temperature; the hottest water temperature; and the coolest water temperature. Input for warm weather shutdown (at what outdoor air temperature will you no longer need the boiler to supply heating) provides the last required input to establish the ODR curve. You don't have to do the math.

Adding ODR to an existing lower-efficiency, chimney-vented boiler makes perfect sense. A properly adjusted reset curve will reduce your customers' energy consumption by 10% or more. However, some after-market ODR controls require you select the turndown ratio from 2.0 to 0.2.

The Reset Ratio = (T supply)   (T outdoor).   T supply = the required change in supply water temperature. If that's a maximum of 140° F and minimum of 80°, then the T is 60.   T outdoor = the change in outdoor air temperature between zero heat loss to your design-day temperature. That might be 70° and 0° = a T of 70. 60 70 = .86, and that's where you set the dial on your ODR control.

Hydronic systems utilizing cast-iron baseboard and/or radiators present an ideal application for adding ODR. If you take the time to do a heat-loss calculation on a room-by-room basis, you can determine what water temperature will be required on your design-day at 0°. To do that, you need to determine the EDR (equivalent direct radiation). See Chapter 5 of the Burnham Heating Helper.

(usboiler.net/library/USBoilerReport/heatinghelper/offline/download.pdf)

Next, you convert the square feet of EDR to Btu/h output by multiplying EDR x the output per square-foot using the water temperature chart on the bottom of Page 71 of the Burnham Heating Helper (use link above).

Locate the output, based upon water temperature, that meets the room's heat loss on the design-day temperature. The vast majority of hot-water hydronic heating systems have heat emitters that are substantially oversized, and it is not uncommon to find you need 140° or less instead of the prior 180° being supplied. Not only will your customers be much more comfortable, their heating bills often will be dramatically lower due to utilizing ODR, and because you have lowered the system's maximum operating temperature.

A rough rule of thumb is that for every 3° we lower the system's operating temperature, operating efficiency increases by 1%.

Is it feasible to utilize ODR with hydro-air systems? Absolutely! However, you will need to raise the lower limit to deliver air that will "feel" warm. Most systems will feel adequately warm with a 120° to 130° supply water temperature on the low side of the ODR curve.

Baseboard, too!

Forget the 160/180 old standard for water temperature. Here too, you can utilize the manufacturer's technical literature to determine heat output per lineal foot of fin-tube (active) element, and if there is a significant amount of bare copper enclosed in baseboard enclosure (dummy baseboard), you can use the Burnham Heating Helper to locate the Btu/h per lineal foot and add that together for the net output. Match that to your room's heat loss to determine actual required temperature on a design day, but limit the lower end to the lowest listed temperature.
https://www.slantfin.com/wp-content/uploads/2015/11/FineLine-30-Ratings-514.pdf

Check out this free presentation:
www.heatspring.com/courses/mastering-the-outdoor-reset-curve

No heat-loss calculation? No work for you!

"I just spoke with a very nice woman in your office. We are trying to get a new hot water boiler. We have had three contractors out to give us bids. The quotes range from $5,800 to more than $11,000. I have been researching the boilers online and have read negative feedback on some of them. I found your company on www.heatinghelp.com."

"Our house is a two-story colonial (2,500 square feet). I received quotes for a Peerless oil- fired cast-iron boiler, a Columbia steel boiler, a Burnham (PV8H3) cast-iron boiler, and a Weil-McLain boiler. It is hard to know who to trust and which boiler is the best."

"Our service company told me that we need a new boiler when they came in August to perform the annual maintenance. They also suggested a new one last year and several years ago when the economy tanked. Last October, we paid $585 to re-pipe the relief valve to code, replace the oil filter and replace a leaking mixing valve, although they suggested we get a new boiler instead.

If you have any advice, I would appreciate it."

Did any of the contractors measure your home to determine the actual heat loss on a room-by-room basis? If not, they are accepting your existing boiler's output rating at face value.

"No, however, one out of three contractors measured all the baseboards in each room."

Do you have a separate water heater or do you get the domestic hot water from a coil in your existing boiler?

"We get our hot water from the coil in the existing boiler."

Do you have access to natural gas?

"No."

Do you have cast-iron radiators, baseboard (copper tubes with aluminum fins behind the cover) or convectors (a cabinet, typically 24 inches tall) either recessed into the walls or mounted up against the walls?

"We have baseboards".

Were you able to obtain desired indoor thermostat settings last year? If so, do you recall hearing the boiler turn on/off and about how long it was off between on cycles during the coldest weather?

"We were able to maintain desired heat settings last year. We were warm and only used 667 gallons of oil, which is low. The year before we used 703. I don't really remember the time between on and off."

Why are you interested in replacing the existing boiler? Worn out or due to high fuel costs?

"We purchased this boiler 16 years ago in an emergency situation in the middle of winter. Apparently bolts on coil were not tightened by a previous oil company during the first three years so there is leaking and corrosion. Also, some of copper pipes are leaking."

Sixten is relatively young for a good-quality cast-iron boiler. From your description, it sounds like the only real issue is the leaking at the coil/plate area along with the corroded copper water lines. If true, you have options available to avoid the cost for a new boiler if your existing boiler is close to being correctly sized. I don't know how old your home may be, but I often find the owners, or previous owners, have upgraded things such as insulation in the attic, new, more efficient windows and/or doors. Changes in the building envelope virtually ensure the existing boiler will be oversized, and the odds are good that it was over-sized from day one.

"I am not sure if our boiler is the right size. We put all brand-new windows, doors, garage doors, vinyl siding and new roof on our house less than 10 years ago."

Those changes alone ensure it is oversized. Oversized boilers have lower operating efficiency and can have a shortened lifespan, too. Given that the boiler is oversized, you'll be ahead of the game by installing a new right-sized boiler. Pay close attention to the stated operating efficiency. A few percentage points will make a long-term financial difference. Most important, however, is which brand does the chosen contractor feel is your best buy because that will most often be the brand providing the best support to them for parts and technical service.

The nitty gritty

First and foremost: Absent a thorough heat-loss calculation done on a room-by room basis, the contractors are simply repeating history. The one who measured the baseboards has done what's commonly called a connected-load survey. That's assuming they measured just the finned/tube lengths and not the total length of the enclosure.

I rarely meet a correctly sized boiler or baseboard system. The heat-loss calculation (I use Manual-J, which is universally recognized and accepted by all authorities having jurisdiction in the United States), tells me how many Btu/h are needed on the coldest day of the year. I then cross-reference that to the rated output of active (tube with fins) baseboard output per lineal foot, which indicates how hot the water needs to be to meet the heat loss on that coldest day. As a general rule, for every 3° F I can lower the existing water temperature (likely set for 180/160° = 170° average), your energy consumption drops by 1%. If I add outdoor reset to the boiler, you can add another 10% to 30% reduction in fuel usage. If your new boiler is a heat-on-demand-only appliance, that will eliminate most of the stand-by heat loss: Boilers are not well-insulated and have relatively high stand-by heat losses.

You should consider some options for DHW (domestic hot water).

Least expensive up-front cost is an electric water heater, but costs more to operate than other methods.

Depending on space (cubic-foot air volume of free air space — min of 800 cubic feet), a heat pump water heater will be the least expensive method for heating DHW. Rebates may be available from your utility provider, which can make this a very attractive option.

An indirect water heater can be added and "seen" by the boiler as just another heating zone. The boiler would run only when the indirect tank's sensor indicates it needs thermal energy. The boiler would no longer sit there maintaining 180° or hotter water temps 24/7/365. Conserves energy.

You have three zones (three zone valves and one 87-watt-power-consumption circulator) and there is significant energy conservation available by utilizing an ECM (electrically commutated motor) circulator that would use a fraction of the current electrical consumption (see video link below).

Step 1: Heat-loss calculation on a room-by-room basis. **Absolutely required**.

Step 2: Compare each room's heat loss to the active baseboard to determine actual hottest water required. **Absolutely required if you want to conserve energy.**

Step 3: If a new boiler is chosen, incorporate outdoor reset. Must do steps 1 and 2 to know where to set the outdoor reset curve, which will lower the boiler's upper limit as outdoor air temperatures rise.

Step 4: Avoid the use of an internal coil and decide which DHW alternative option is best for your application.

Step 5: If you keep your existing boiler, disable and repair the leaks, turn this into a heat-on-demand-only appliance, and go back to Step 4.

The final results can be fairly dramatic. The home in this video saw more than a 70% reduction in fuel usage.
www.youtube.com/watch?v=Yz5yiFwPh1k

PVC combustion venting

Should PVC Schedule 40 pipe and fittings continue to be permitted for combustion exhaust venting?

You and I have come across PVC that has gone from white to many colored shades — from light yellow to tan to almost looking like ABS black. We all know that is due to overheating and you, like me, have probably seen deformation from overheating.

In some cases, it's due to PVC having been used for combustion venting for standard (chimney-vented or should have been!) water heaters, 80% efficiency boilers or furnaces and other flagrant violations of codes. No, I'm talking here about "proper" PVC combustion venting applications that are manufacturer approved. What can, and does, really frighten me is seeing foam-core PVC utilized for combustion venting for boilers and water heaters.

So, what's up with furnaces using PVC? I don't see the same change in weird colors as with boilers? High-efficiency furnaces see relatively steady-state conditions with return air around 68° F and supply-air around 120° — providing the ductwork was properly sized, allowing full flow across the heat exchanger. You can safely assume a 20° (average) increase in the exhaust vent over the supply air temp, which keeps the PVC well within its safe range for maximum temperature limits.

Boilers, on the other hand, have a far different operating range with an upper limit of 205° for modcons. In more than a few cases where the PVC was an odd color, outdoor reset had never been utilized and the installer had set the modcon to run up to its maximum temperature limit! 205° + 20° = 225°.

What is the safe operating range for PVC in venting applications? I reached out to **Brian Fenske** at Navien for help:

"Many anti-PVC venting advocates have continued to argue the piping standards regarding PVC pipe used as venting systems referencing plumbing standards. ASTM Standard, ASTM D1785 standard applicable to PVC plastic pipe and fittings includes the following note: This standard specification for PVC pipe does not include requirements for pipe and fittings intended to be used to vent combustion gases."

D 1785 is the specification for poly vinyl chloride (PVC) plastic pipe, Schedule 40, 80 and 120. The scope of this specification covers PVC pipe in Sch. 40, 80 and 120 for pressure applications, where the operating temperature will not exceed 140° F. This scope is where many misunderstand the application and requirements of PVC in an appliance venting situation. The use of acceptable PVC pipe for venting of gas-fired appliances in accordance to manufacturers' installation and operation manuals are never subjected to measurable pressures. Pressure applications do not occur in an appliance gas-fired combustion venting system thus, D1785 plumbing standard, 140° limitations does not apply.

"Boilers, on the other hand, have a far different operating range."

According to PVC pipe and fitting manufacturers, Schedule 40 PVC DWV has the following ratings:

- Maximum temperature: 158° F, 70° C;
- Minimum temperature: -13° F, -25° C;
- Melting point: 176° F, 80° C;
- Tensile strength: 6,500 psi.

The 149-degree melting and breakdown of Schedule 40 PVC continues to be tossed out there as a limit when it is false. This temp concerned is derived from the temperature pressure charts of PVC in water-use applications under a minimal pressure of 20 psi. Appliance venting is not under any measurable pressure. The real limitation is 158 degrees, and we as manufacturers limit and control our appliances at 150 degrees through internal safeties."

The answer I was looking for: The actual limitation is 158° for maximum sustained exhaust limitation. In theory then, boiler water temperatures above 138° will result in exhaust temperatures that will exceed 158°. No wonder we see discoloration in PVC exhaust vent piping.

There already are places in the U.S. where PVC cannot be used for combustion venting: New York City and Las Vegas will not allow any plastic combustion venting in commercial applications.

What about Canada? I'd heard they placed restrictions on using PVC. Fenske had this to say: "It's not officially banned as a product in Canada just has a required approval and this continues to confuse the industry. Especially those who live outside of Canada. In Canada, they use a standard CSA B149.1 Natural Gas and Propane Installation Code which requires all special venting material to be certified to ULC S636.

"Essentially, what that means is System 636 has two distinct materials (PVC and CPVC), each with a unique temperature rating. These venting systems are approved as Type BH vents and are designed for negative or positive pressure venting of gas-fired appliances. This is the same PVC and CPVC that we use, but is approved as a system.

"In other words, the company IPEX pushed this thorough as a standard. All it is, is materials like what we use but with labels to make sure installers don't mix improper pipes, fittings and solvents. And for that, those same items are 5 times the cost we are familiar with."

Aren't water heaters therefore safe? After all, they arrive from the factory set for 120°, so given the 20° increase in stack temperature; they are well under the 158° noted, right? When new, yes, but scale can inhibit heat transfer, which can cause the stack exhaust temperature to rise well above 158°.

I turned to another trusted mentor: **Steve "Wheels" Wieland** who is with NTI Boilers. "I have seen PVC in all colors: white, yellow, tan, brown, pink, purple, black … gone. In my territory, PVC is outlawed in all five boroughs of New York City. www.nyc.gov/html/dob/apps/pdf_viewer/viewer.html?file=2014CC_FGC_Chapter5_Chimneys_and_Vents.pdf&section=conscode_2014

I am under the impression that the national code now reads (or will) that PVC cannot be used if supply temps exceed 140°."

We also discussed other issues and Wheels noted there is some discussion regarding UV degradation that might lead to odd colors in PVC. Think of all the PVC cleanout risers (for those who can't cut them flush with grade) and fresh air vents that are 100% exposed to UV and have been for decades! Still white? In addition, I'm not seeing a visible color difference between interior PVC combustion piping vs. the exterior counterpart. Not to mention the millions of PVC plumbing vents poking out of rooftops across the U.S., and around the world. They all still are white, so riddle me that Batman. Maybe we just need to rub SPF-50 on the PVC combustion vents?

Is there an alternative that can handle the higher-than-158° exhaust gas temperatures? Absolutely: Polypropylene, which can handle a sustained flue gas temperature of 230°. Lightweight, easy to handle and fast installation time makes this more-expensive-than-PVC product not only competitive by reducing labor, but reduces your liability, too.

We have used Centrotherm (www.centrotherm.us.com/Home.aspx) PP flue piping and chimney liners on multiple occasions for modcons, combi boilers and high-efficiency tankless water heaters. Knowing any one of those appliances has the potential to exceed 158° flue gas temperatures, it makes perfect sense to use PP for combustion venting.

For more information, Google polypropylene vent pipe manufacturers and check with your local wholesalers to find out which products they stock.

CASE **HISTORIES**

Icebomb!

Who comes up with the terms utilized for weather events such as "Bomb Cyclone?"

As if there exists a single mechanical contractor who needed one more panic-stricken customer frantically seeking help as calls stacked up thicker than a platter of pancakes. Some of the coldest record-breaking (day-after-day-after-day) temperatures in the past 100-years — pretty much anywhere in the continental United States.

As a journeyman plumber in 1976, I spent a wintry Sunday evening on a date at a remote cabin in the woods along the bank of a frozen trout stream. We had walked the half-mile through a foot of snow due to the lane not being plowed. A roaring fire protected us from knowing the mercury was dropping like a stone, and the walk back to my car was pure misery.

The wind-chill was a record -50° F! The next morning, my boss dropped me off to break up a sidewalk so we could excavate, expose the curb valve, and install a new copper water service.

An hour later, he returned, observed a small area of powdered concrete, and asked why the sidewalk was still intact. I handed him the 18-pound sledgehammer. It didn't take him long to realize this was an exercise

in futility. We rented a tow-behind air compressor and for the next three weeks I installed new water services. The ground frost level had by then, reached more than 5-foot depth on the shady side of our city streets.

Then in 79, shortly after venturing out on my own, an overnight low, well-below-zero, lit up my phone. One of the first calls was in a row home with hot-water standing cast-iron radiators. The risers to the second floor bay window radiator froze first, which stopped flow to the radiator, followed by the radiator starting to freeze. As the ice expanded within the piping and radiator, pressure continued to build until the weak link, a portion of the end section, decided to leave the room via a sidewall to their sewing room. Meanwhile, the rest of their hydronic system continued to work and was oblivious to the second-floor front room Icebomb mayhem!

Now, its 2017-2018, frozen pipes, cracked boilers, heating equipment stressed beyond capacities for weeks without relief, people who have never had pipes freeze, and I'm talking folks well into their 80s, heat pumps that couldn't heat with their electric resistance backup heat unable to maintain desired indoor air temps, and heating systems designed for "normal" ASHRAE-design-day conditions (default in my Manual-J for where we live is a balmy 13° F) that could not provide desired indoor comfort settings.

Just days before the U.S. was gob-smacked with the December Polar Vortex, a customer's cast-iron hot water boiler was discovered to be leaking because she had received a surprisingly high water bill. Thinking a toilet must be running, she scheduled a service call and our tech heard water tricking into a floor drain near the boiler. Closer inspection revealed the end section was cracked. She elected to replace, rather than attempt a repair for her 30-year-old boiler. Then the sudden cold snap settled in and all hell broke lose for mechanical contractors everywhere.

She agreed to delay the installation and we assured her that if the leak became an emergency, we would move her to the top of the list (which was growing exponentially). Her call a few days later put up multiple red flags: it was only 59° in her home and would not get any warmer. Granted, we were getting tons of calls regarding, "My thermostat is set to 78°, but it's only 65°. Do I need a new thermostat?" but something was obviously wrong and had to be figured out before replacing her boiler.

My guess was the leak had grown to a point where the boiler could not keep up or perhaps the aquastat was set lower than the normal 160°/180° range, or that the heat load simply exceeded the boiler's capacity. I've encountered more than a few of this manufacturer's boilers with the aquastat getting out of calibration by 20°, so I was expecting I might find it set for 160°/180° but maintaining 140°/160°.

"A customer's cast-iron hot water boiler was discovered to be leaking because she had received a surprisingly high water bill."

Imagine my surprise to find the boiler's burner off on limit with outgoing delivery temp at 180°. After dropping to 160°, the burner's climb to 180° was slow, but steady. All the convectors on the first floor (thermostat on an inside wall here) were hot and their air dampers wide open. Nothing blocking air flow at the base openings. Windows and doors had been upgraded from single-pane to double-pane with urethane-insulated weather-stripped doors.

Two convectors on the second floor were air-bound with their air vents painted shut. First time they had heat in her son's bedroom in years! Checked the attic, which had R19 insulation that was intact. Sloppily installed AC with the air handler in the attic and all ceiling-located registers. Second floor registers all exhibited streaking around their perimeters, indicating they need to be sealed to stop air leakage. Every room had ceiling lights, which is another air leakage issue. Bath fan exhausts into the attic, which is like leaving a window open a crack.

Back to the boiler, which was cruising along at 180°. The only recourse was resetting the aquastat to 180°/200° to increase the Btu output of the convectors. The relief was knowing the boiler was not undersized. If anything, it is oversized, but just about at its limit for the existing bitter record-breaking cold weather.

The heat emitters are only undersized at the moment due to air leakage created following a slap-dash central AC installation. Once her home's air leakage is addressed, and most homes lose around 40% of their thermal energy due to exfiltration, she won't have any trouble maintaining indoor comfort. Peeling back the fiberglass insulation around the ceiling registers and 4-by-4 boxes above the ceiling lights revealed airborne charcoal-black soot/dirt. If nothing else, fiberglass will reveal air leakage spots as will thermal imaging. Several companies (Thermal and Flir being two examples) make relatively inexpensive infrared attachments for your smartphones.

Sometimes (actually more often than not) you have to look beyond the HVAC equipment to determine why your customers are experiencing comfort issues. In this case, at first glance, it made no sense: A home with upgraded windows and doors was stuck at 59° when, according to the customer, had heated comfortably way back in 76 and 79 with leaky single-pane windows and poorly sealed doors.

Ideally, this customer should upgrade the building envelope before installing an on-off boiler, and with a full-blown Manual-J heat loss done on a room-by-room basis, that is then compared to each room's convector(s) capacity at various water temperatures to determine just how hot the water has to be to matched to the room's heat loss on a design-day.

Working the numbers

I use an Excel spread sheet to track each room's performance and typically see a fairly pronounced difference. The poorest-performing room then dictates the outdoor reset curve, and with a modcon boiler that includes a boost feature to insure you can program a rise in water temperature above the design-day limit, you can rest assured you won't get a 3 a.m., call complaining "your" boiler can't keep up with my thermostat setting. It's always "Your boiler," "Your AC, etc.," whenever something goes wrong, right?

Truth is, she cannot afford to both replace her on-off boiler and upgrade the envelope at the same time, and although she can obtain a zero-interest loan through a program we set up at our bank, she doesn't qualify for the increased cost for a modcon.

Between a rock and a hard place, we could resort to one of many consumer finance programs, but I cannot in good conscience offer finance company loans where our customers are charged credit-card interest rates where they end up paying for two or three boilers over time.

We worked hard to set up zero-interest loans for our customers, and while we pay an up-front fee, just like the bite the credit card companies take when our customers use credit cards to pay bills, we get paid immediately and the customer then deals with the bank. It's a win/win for all and it's a great sales tool. It's not like folks are sitting around thinking boy, we'd best be saving up the coin needed to replace the boiler/furnace/AC equipment that going to die at the worst possible moment.

Zero interest? Are you freaking kidding me? Can we replace the AC at the same time? Upselling effortlessly.

While we're on the subject of upgrading the envelope or replacing the HVAC equipment, I landed in some hot water during a classroom setting over this issue. Seems like I was almost always in hot water during high school, so it was not to be avoided in my adult-ed class. Hope you enjoy a look back to this March 1, 2011 column "The chicken or the egg."

Dumb as a box of rocks

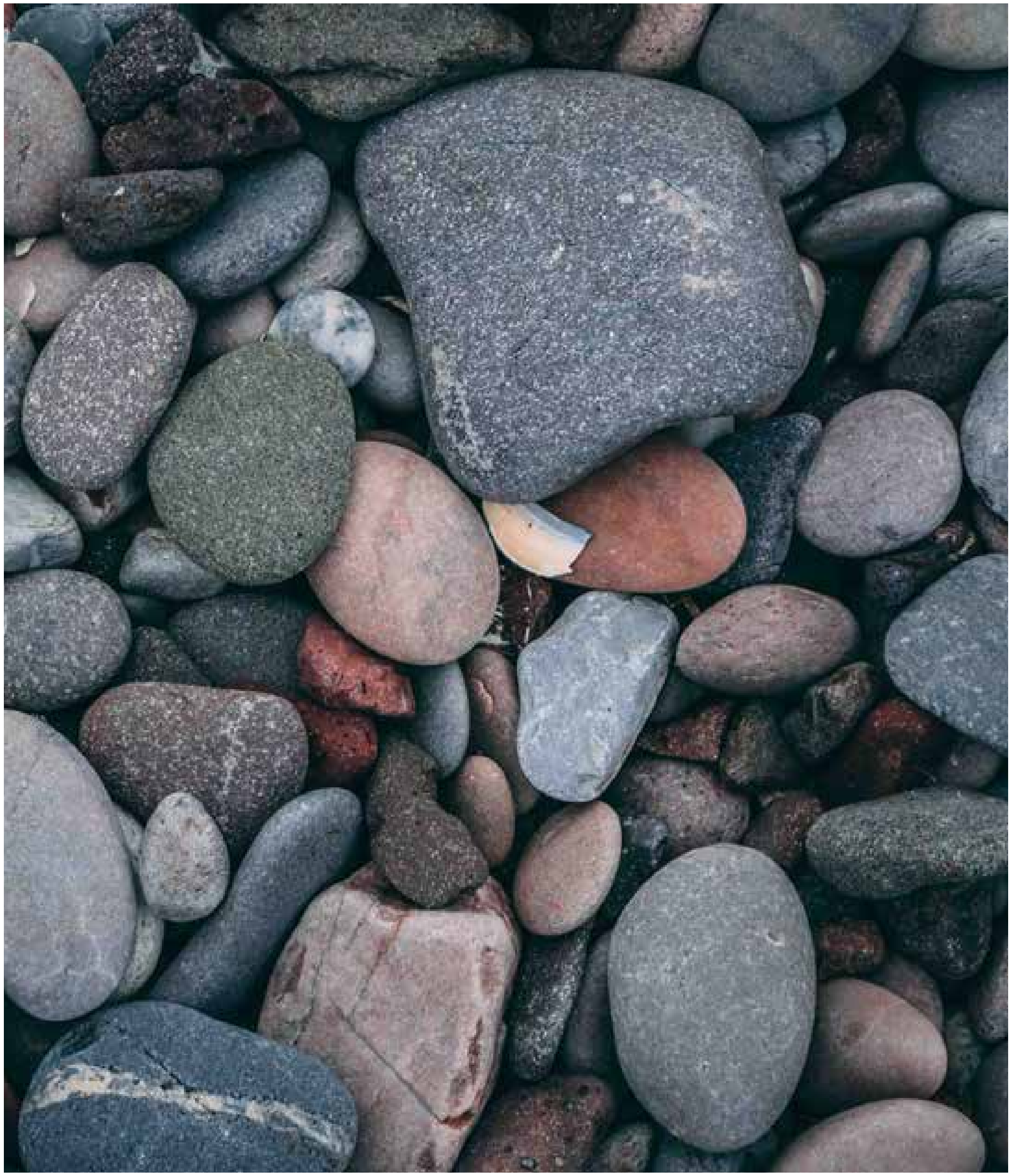
The first and last time we had been on this large country club golf course and housing development, it was owned by a nefarious character that was a known cheat. Contractors had a hard time getting paid, if at all.

And, of course, they wanted a second opinion on the clubhouse boiler. Our contracts have a clause that grants us the right to charge 2% per month interest on any past-due amount as well as incorporate all lawyer fees and court costs if collection becomes necessary.

Apparently, they did not read that clause. We did confirm the boiler was beyond repair and, as requested, provided an estimate for its replacement with three high-efficiency modcon boilers. When the payment from the Florida-based owner was late, I emailed the owner and included the contract with the clause highlighted. She asked for more time: I gave her 24 hours to FedEx a check or the lawyers would be unleashed. We had the check the next day.

Two years later, I received a phone call from a gentleman interested in purchasing the entire country club complex. The Florida owner was embroiled in lawsuits and owed hundreds of thousands of dollars in back taxes. A Florida judge had removed the owner from legally doing anything financially with the estate. The employees had not been paid and all had, at the same time, simply walked out the doors.

Our first site visit was like being the last two people alive while everyone else had simply vanished.



DUMB AS A BOX OF ROCKS

In the pro shop, the cash registers and computers were all ON and all merchandise was on display. Candy for sale sat untouched on the sales counter. The forced hot air was on and running. Next door in the restaurant, all the kitchen equipment was running. Gas pilots were on to multiple pieces of fryers, grills, and multi-burner stoves and ovens. Here too, the HVAC systems were running. One walk-in cooler housed cases upon cases of beer and wine with multiple bottles of uncorked wine – queued up in anticipation of the next by-the-glass order.

The visitors' center had no heat. A GlowCore boiler in the mechanical room was turned off and had been drained. As soon as the water feeder was turned on, you could hear the heat exchanger spraying water, and it didn't take long for water to flood the combustion air intake filter housing.

Well, that explained why the old air filter canister was sitting on top of the boiler! No outdoor reset had been connected, so the boiler was as dumb as a box of rocks. A number of broken igniters indicated the issue many of us experienced with GlowCore boilers: they ate igniters like a kid eating candy on Halloween! We replaced the boiler with a new NTI Trinity fire-tube boiler sized to the building's heat loss and added the outdoor reset. No need to run the outlet water temperature above 140° F, which allows return water temperatures low enough to be in condensing mode for maintaining peak operating efficiency.

The reset curve was given a range of 100 to 140°. With its onboard boost feature, the TFT will automatically ramp up the water temperature to the programmed maximum we allow if, and only if, space temperature cannot rise to meet the thermostat setting.

Boost, a feature found on many modcon boilers, allows you to program a more aggressive reset curve with no fear of an angry middle-of-the-night call from a cold customer.

Here comes the cold

While still owned by the Florida individual, a bitter cold spell settled in. A convector on the third floor of the clubhouse mansion froze and ice expansion split the coil. On the next sunny day, this south-facing room received enough solar heat gain to thaw the convector.

The boiler's water feeder did its job by recognizing the loss of pressure and began adding water to the system. How long this ran was unknown due to the mansion being unoccupied.

Water raining down through all three floors and then into the basement mechanical room eventually shorted out the fire alarm system. We responded in the middle of the night, but could not enter the mechanical room due to the water literally raining down onto all the mechanical equipment and controls, many of which were 3-phase. The building's water and gas were disabled for the night.

The next day, we bypassed the third-floor convector, dried out the controls and restored the heat. A single Lochinvar boiler had replaced the old boiler we'd given a second opinion on. Once again, no outdoor reset in spite of the fact the Lochinvar one incorporates outdoor reset if you choose to use that to lower your customers' operating costs.

What we discovered during this restoration process was that this 4-pipe hydronic hot/chilled water system wasn't just blind to outdoor temperatures, there was no communication from the occupied areas: the boiler and chiller were manual on/off, and ran 24/7 while circulating hot water and/or chilled water via large base-mounted multi-horsepower pumps 24/7. Upstairs at the dozens of fan/coil units, each was equipped with zone valves to divert heated or chilled water through their coils. Wall-mounted thermostats communicated only with the individual convectors. This system was literally an energy hog — made so by being dumber than a box of rocks.

Happy ending: We gave this mansion's mechanical systems a fully functioning autonomous brain and upgrade in operating efficiency.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In harm's way

Five years ago, I visited a home to find out why they were not able to maintain 68° F during colder weather.

Hot-water baseboard was installed on the upper floor with radiant tubing embedded in concrete for the daylight basement area. Also observed: an 80,000 Btu/h modulating condensing boiler with a twisted-sister attempt at primary/secondary piping, no thermal mixing for the radiant zone, and an indirect water heater feeding into a live electric water heater. The venting was PVC and discolored due to the fact no outdoor sensor was installed, therefore no outdoor reset, and the boiler was bouncing off of its 195° limit! No condensing for that modcon. The installer was bankrupt and no longer in business.

Schedule 40 PVC is rated for 140° maximum and at 180°/195° (the programmed range the installer used), the vent line was discolored due to exceeding its temperature limitation. A Manual-J calculation revealed the home had a 112,000-Btu/h heat loss when it was 13° outdoors (default ASHRAE design day for our area).

They did not like my price.

A month ago, they called again. You know I had to go: like a moth to a flame! The second installer also was bankrupt and out of business. Installer No. 2 had corrected the primary/secondary piping and added mixing for the radiant zone. A second 80,000-Btu/h modcon had been added.

Once again, no outdoor sensors, so no outdoor reset, and now both boilers were being run as one, and both were bouncing off their 195° limit! The old 80K modcon's Giannoni (looks like a Slinky laid on its side) heat exchanger had sprung a leak while the second, now a five-year-old boiler, was clogged with combustion debris and on hard-lockout.

Back to square one with not enough heat! Both PVC exhaust lines were heat-discolored. The homeowner explained that they felt our price five years ago was too high and went with the lower price.

Shortly after the installation, the new PVC exhaust vent had fallen apart because the installer had forgotten to solvent-weld the fittings. Their CO detector went off. It also was obvious no combustion analysis had been conducted, as no holes were present in the PVC exhaust on the newer modcon.

They wanted both of their 80K modcons repaired, and they were mildly interested in outdoor reset. I reluctantly agreed to check on the parts cost, but knew we weren't about to actually do the work. My intent was to ascertain the costs for repairing both boilers and then quote the installation of a new modcon with a fire-tube-style, low head-loss heat exchanger.

Fortunately, I had their Manual-J heat-loss calculation and the room-by-room live baseboard (tube with fins) so that we could properly program an outdoor reset curve. For example, take a room with a 5,000-Btu/h heat loss at design day conditions with 20 feet of "live" Slant-Fin Fine Line 30 3/4-inch copper fin-tube baseboard. That equals 250-Btu/h required per foot of baseboard.

Checking Slant-Fin's chart for this baseboard reveals our hottest water temperature required is slightly below 130°: perfect for utilizing a modcon, and the outdoor reset curve could be set to operate from 110° to 130°. Truth be told, we'll actually set it to operate between 90° and 130° if the homeowners are willing to experiment with water temperatures below what is listed on the chart. (www.slantfin.com/images/stories/Technical-Literature/ratings_fineline30_r.pdf).

Back to the PVC venting issue: My own at-home experiments conducted over the past two decades and a virtual parade of modcon boilers revealed that the exhaust temperature is a fairly constant 10° above the outgoing boiler supply-water temperature. That means this home's twinned modcon vents were seeing an average of 190°/205° every time the boilers ran. Because they are oversized for the home's 112K heat loss at design-day conditions, they will hit the 195° limit before the zones can be satisfied.

Once again, I was told our price was too high. I wished them luck and assumed I'd see them again in five years. A few months passed when their name popped up in my email. Was I willing to match someone else with a lower price?

No.

More time passed and they once again emailed to say they did their own online research and found a lower-priced modcon boiler. Was I willing to install that model? Before answering, I did my own online research and discovered the model they had chosen had a Giannoni-style heat exchanger. Rather than simply say no, I gave them a side-by-side comparison to illustrate why the modcon boiler I had suggested was far superior and required less annual maintenance.

Knowing their twinned boilers had never been given an annual cleaning, I included cost projections for annual maintenance on both boilers. I ended my message by saying I was not interested in being their installer if they wanted to repeat history with a Giannoni heat exchanger.

Another month of silence passed by and I assumed they had gone with the cheaper boiler/contractor. Yesterday I received an email asking us to install the better boiler. "How soon can you start?"

New PVC will be OK for venting due to incorporating outdoor reset and running exhaust temperatures below the high-limit-temperature of 140°. We often use polypropylene, which has a high temperature limit of 230°. If you haven't tried polypropylene, check out the flexible chimney liner kits for that next modcon or high-efficiency tankless water heater installation (not all manufacturers have accepted polypropylene yet) where sidewall venting is not easily available and they have what is about to become an unused chimney.

How to meet snow-melt system challenges

"Dave, we recently installed a new concrete ramp and sidewalk for a two-bay firehouse. We placed PEX tubing in the area before pouring the concrete for melting snow and ice. Would you be willing to give us a price on connecting this to the existing boiler? The prices we have received so far range all over the map. The highest ones are way outta line."

The general contractor's foreman is a good guy. I've known him for a long time. Was there any insulation under the slab? "No." How many loops? "Nine." How far apart are the tubes? "'12' on centers and an average of 2 inches below the 9-inch-thick concrete." A jobsite visit was arranged so that I could reverse-engineer the system required to meet the expectations of a snow/ice-free ramp/sidewalk area for the paid firefighters.

I am indebted to the RPA (Radiant Professionals Alliance) for the training that enables me to provide professional designs and installations for hydronic and electric snow-melt systems. Hitch that wagonload of knowledge up to the Uponor snow-melt design program, and I am confident the finished product will easily meet the customer's stated wishes. It also grants you the ability to determine if a partially installed system will be able to meet expectations.

First step: Measure the snow-melt area, which was 1,910 square feet.

Next step: Visit the interior to examine the PEX loops and the existing boiler. Instead of nine loops, there were five loops of 3/4-inch potable PEX. They were not labeled, so no idea which ones go together, although that's no more difficult than purging one line at a time with air or water to find its mate. The cast-iron boiler has a 180,000 Btu/h net output. PEX also has feet of tubing listed on the tubing, but the leader lengths were too short for footage to be seen on all the ends.

Potable PEX means there is no oxygen barrier. A heat exchanger and stainless steel or bronze circulator would be required on the snow-melt side. A 9-inch-thick slab with tubing located 2 inches below the surface raises a concern under normal circumstances, but the GC on this job does its own concrete work and had installed the tubing, so if it was damaged via saw-cut joints, the costs would be theirs to bear.

Normal saw-cut depth is one-fourth of the slab's thickness, which would have been 2.25 inches deep. If you are installing hydronic or electric radiant or snow-melt systems, communication is an essential element, and the system installer cannot assume the concrete crews will be aware of your tubing/wire depth or location. Diving down to a safe depth at predetermined saw-cut or control joints is the only way to protect your work. It's also a good idea to protect PEX with corrugated slit plastic conduit (like you see under the hood of your truck for bundling wires) where you know the concrete is going to crack.

The price is right

Why would previous prices be "all over the map?" At first glance, this doesn't look like a big deal. Add two manifolds for supply/return; pipe it across the basement to the boiler; fill up the system with at least a 30% glycol solution and take the money. End of story? Hardly.

My Uponor design program revealed a ton of information. The parameters were out-of-bounds, which required I go into the advanced design sections to bend several guidelines to near break-points because the program flags you for issues likely to cause problems.

The cast-iron boiler has a net output of 180,000 Btu.h. This is a fairly large two-bay firehouse, and upon returning from a fire in winter, that's many tons of frozen steel and hardware to warm. Even if the boiler was oversized by as much as 50%, turning on a large snow-melt system would have the potential to drag down the hydronic water temperature well into sustained flue-gas-condensation range, which would stress the boiler and lead to severe internal corrosion. The Uponor design program revealed the snow-melt load was well in excess of 200,000 Btu/h. The chimney isn't large enough to accept a second boiler large enough to accommodate the snow-melt load ("just add a second boiler").

> **"Returning from a fire in the winter means many tons of frozen steel and hardware to warm."**

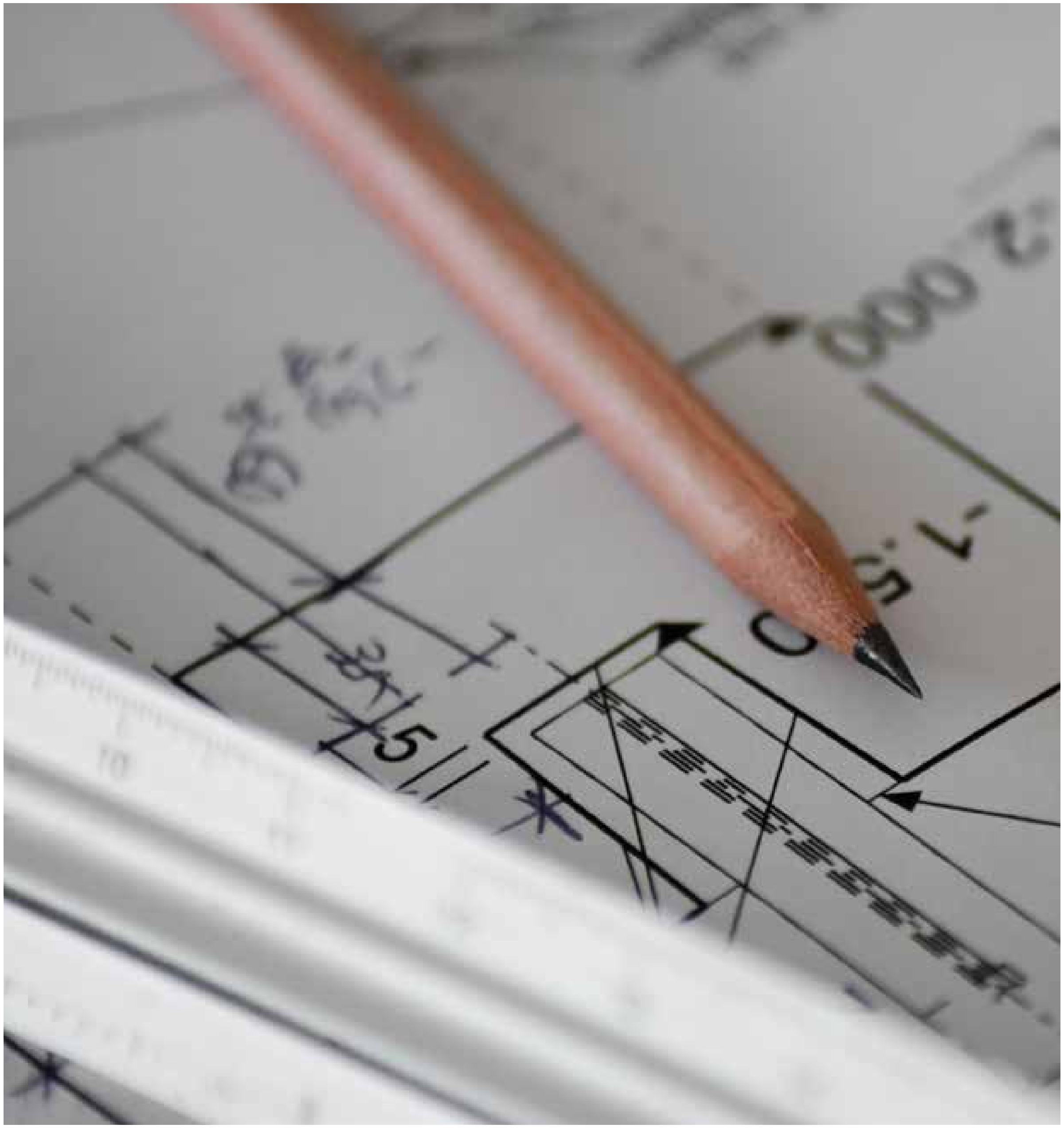
Uponor's design program also revealed a need for a circulator that could handle more than 60 feet of head (resistance to flow) with a 30% glycol mixture at 23 gpm. Add more glycol and the head loss increases. Potable tubing (no oxygen barrier) means all components on the snow-melt side must be nonferrous. When selecting a circulator, you must account for the more viscous glycol solution. Fortunately, the Uponor design program does the math for you.

A large number of options would be available: none of them cheap. Reverse engineering clearly revealed that any low-ball bidders had not done their homework (if any at all).

If the GC hires them to install the BOS (balance of system) components, those firemen may well be left inside in the cold while still having to shovel snow/ice off of their ramp and sidewalk.

The firemen's expectation (I asked) is that the snow will not accumulate – even during blizzard conditions.

Profit from math



I hated math in public high school!

Being dyslexic presented numerous opportunities to reverse numbers, and the red checkmarks and notes saying "can do better" or "doesn't apply himself" only added to my aversion from all things related to mathematics! A career in the trades led to night school where math once again reared its ugly head. However, this time the math had real meaning and led to resolving real-world problems. Over time, math also led to higher profits.

More than three decades ago, I provided a quote for a large, private residence to replace an aging 1.35-million Btu/h boiler. An elderly woman lived in the 6,500-square-foot home constructed in the late 1800s. That's almost 208 Btu/h per square foot: Not even if they threw open the windows and left all the doors ajar!

At the time, I was convinced her boiler was oversized. The mere mention of reducing the Btu/h size convinced her I was trying to rip her off. Funny how some visits, like hers, stick in the memory banks. She sent me packing.

Two years ago, a return visit found the once stately mansion had been converted to apartments. The new landlords were more interested in cosmetics and remodeling, which included new kitchens and baths (no complaints here!), than in doing anything with the beast in the basement in spite of my urging them to consider its replacement with a high-efficiency boiler or boilers (for redundancy).

Then, a few months ago, one of the twinned water heaters developed a pinhole in its flue-tube and needed to be replaced. Why not do both since the pending regulation changes in April 2015 (https://www.cashacme.com/resources/naeca-2015-regulations/) will spike costs?

And that's when the landlords began lamenting how much the home was costing them for DHW and heating. Last year's Polar Vortex got their attention and drained their wallets: $10,000 for natural gas! "Is there anything we can do to reduce our costs? How long will it take to get a return on the investment?"

There's money for you in math! It literally takes longer to take the measurements than it does to run a computer-based Manual-J calculation.

However, like any computer program GI = GO (garbage in = garbage out), so training is advised (https://www.elitesoft.com/web/hvacr/elite_rhvacw_info.html). I have reviewed Manual-J calculations that were seriously flawed that, unfortunately, resulted in grossly over- or under-sized equipment being installed or, worse yet, ended up resulting in expensive lawsuits.

The Manual-J calculation revealed the actual heat loss on a design-day (coldest day) for this 6,500-square-foot apartment building was less than 250,000-Btu/h! That's one heck of a reduction from 1.35 million Btu/h, and not the first time a heat loss or heat gain calculation gave me serious pause for thought. A difference that large meant I would review my inputs.

What if my inputs turned out to be garbage? No one to blame but me if that turned out to be true. Fortunately, there was an easy way to crosscheck the heat-loss calculation: a connected load survey!

Truth be told, this was a necessary step to take in order to be able to define what water temperature would be required on a design-day

"A few hours invested in doing the math enabled both the customer and us to profit handsomly."

so that I could determine exactly where to target the upper water temperature limit for the outdoor reset curve. The connected load for the home's standing cast-iron radiators revealed the heat-loss calculation was spot-on.

Standing cast-iron radiators make wonderful companions for outdoor reset. The room-by-room heat loss can then be divided by the square feet of EDR (equivalent direct radiation) of each radiator. Once you know the Btu/h required per square-foot EDR, you compare that to the Btu/h output at various water temperatures until you meet or exceed the required output to meet the room's heat loss on design-day conditions.

For example, a room has a 13,919-Btu/h heat loss on a design-day of 13° F (ASHRAE guideline for my area). The radiators in this room have a 140-square-foot EDR. At 170° average water temperature (boiler set to run 180/160°), each square-foot gives off 150 Btu/h. 140 x 150 = 21,000 Btu/h. 13,919/140 = 99.42-Btu/h per square-foot required on that 13° day. I can lower the water temperature to 145°, and that's the hottest water needed on the coldest day. The outdoor reset curve can be adjusted to carve out the maximum ECV (energy conservation value) and provide the owners with an excellent ROI (return on investment).

I'd love to share this easy to do math with you – for free! Follow this link from the RPA (Radiant Professionals Alliance) website at www.heatspring.com/courses/free-lecture-mastering-the-outdoor-reset-curve.

Naturally, the landlords had sought out two other bids. I would too, given the dollar amount for the job. Both of our "competitors" simply took their direction from the tag on the boiler. A few hours invested in doing the math enabled both the customer and us to profit handsomely.

Technology pains

At a recent AHR convention in Orlando, Florida, technology was a prominent feature built into virtually all the products on display.

From smart thermostats to equipment that actively communicates with other HVAC components as well as water heaters (if the same brand), all of it available via your smartphone, via email, or from your tablet or computer.

Data logging and energy usage reports are becoming the norm, rather than the exception. The downside is the lack of free-flowing communication between brands. Pretty soon you'll need more screen space to display all the apps you'll need to troubleshoot and/or monitor your customers' mechanical widgets! Floating about in the cloud is all good and well – that is – until a storm cloud brews up a perfect storm.

Case in point: I once stated we would never have a fax machine in our office. We didn't have computers back then in the technological dark ages either. Less than a year later, we had both! The fax machine became a vital necessity for moving business contracts at the speed of Ma Bell's phone lines. Parts diagrams could be faxed within minutes. The internet opened our horizons too while email began to edge its way into day-to-day business transactions. Oddly, the fax machine is going the way of the Dodo bird in favor of text messaging, social media and email.

A few weekends ago, GoDaddy began promoting a “new look” for its email login. They’ve been an exceptionally reliable host for our business email, so we did not expect the change would cause any issues.

However, the Saturday the change took affect, login in became a no-go: type in your ID and password only to be taken right back to the same login page. Given that it was over a weekend, and based upon their past rapid resolution to glitches, we figured they’d have it resolved by Monday. A few hours later, the old login page was back and access to email was easy. So, the new login page was not ready to launch. Funny, but you’d think they would have ironed out the kinks before launching.

Monday, the new login page was back and we couldn’t log in to access email. Other sites could be accessed, so it had to be GoDaddy, right? A call to tech service did not resolve the issue. Bids were being prepared and I sent a completed multi-page proposal to our printer. It’s wireless, of course, and a communication error message appeared on screen. We rebooted the router (multiple times) and our computers, too, but no dice. Turned out our DSL (digital subscriber line) was down. Widespread outage in our area, but anticipated to be back up and running by 4 a.m. the next morning. Our smartphones utilize Verizon wireless, but GoDaddy login was still a no-go. We were in the midst of a perfect technological storm, and that’s when it struck me: technology has become the lifeblood of our business operations.

During this technology blackout, we were in the middle of negotiating a bid for a large commercial project with an out-of-state general contractor. I needed to use DocuSign and email back the executed contract and work was to start the same day due to their exceptionally tight construction timeframe.

“Help newbies learn to troubleshoot for the inevitable time a perfect technology storm rolls in.”

No internet, no email, no executed contract! Business no longer moves at Ma Bell’s speed, it moves at the speed of light. Makes me almost nostalgic for rotary dial phones and snail mail.

When DSL service was restored, not the next day – two days later — that caused our router to become brain-dead – memory completely wiped out. All internal settings had to be manually keyed back into its brain. Technology is supposed to enable us to be more productive, and when it works well, it does. When it falls apart, it becomes a nightmare and a huge black hole of wasted time.

Which brings me back to the recent AHR and technology leaping into our mechanical widgets at a frenetic pace. I worry that the new generations of service techs entering these trades will be totally dependent upon technology and will not possess mechanical trouble-shooting skills for times when the on-board technology goes dark.

No longer will they need to know how to calculate superheat or subcooling, the digital gauges will do that for them, send it to their smartphones and/or email that information back to the office. No longer will a tech need to troubleshoot. The onboard technology will have done that before (s)he was dispatched with the required part(s) in hand.

For the techs who learned the trades before technology was running the show, help the newbies learn to troubleshoot for the inevitable time when a perfect technology storm cloud rolls in to keep them in the dark.

SPECIAL WHITE PAPER

The biggest loser

Blissful ignorance: For most of the past four decades, my hydronic training centered on choosing a circulator that met or exceeded the required gpm rate while overcoming the system's head losses in each zone.

Our hydronic piping zones were like fat, wide highways where traffic was light with very little need on our part to pay close attention to those kinds of details, and there were few choices for residential circulators. Pretty much one size fits all. Zone valves were prone to failure and leaking, so I became a devout advocate for utilizing circulators, which were reliable and long-lived — unless you over-oiled the motor-bearing cups.

New mixing strategies emerged: PEX tubing with radiant heating; hi-head-loss boilers; injection temperature zones; 4-, 3- and 2-way mixing valves; and the need to comprehend Cv values corresponding to the required gpm flow rates each dictated which circulator was chosen based on the manufacturers' hydraulic curve.

The need to properly size circulators to their corresponding zone of responsibility became much more critical, and model choices expanded exponentially. Our focus was centered on providing customers with high-efficiency heat sources while utilizing heat emitters designed for efficient delivery of comfort-energy. Miserly fuel use coupled with hydronically-delivered comfort — it couldn't get any better than that. Or could it?

Electricity was as cheap and abundant as were fossil fuels. If I were to place a bet, I'd bet 95% of installed circulators are grossly oversized — wasting giga-watts of power if viewed as a whole. From start to finished hydronic systems, the CYA (cover your ass-sets) process layers-on energy-fat:

- Heat-loss design programs build in a cushion to account for construction anomalies;
- Cv-values for valves add a bit more CYA;
- Piping friction loss calculations add still more fat;

My first ever encounter with low wattage ECM circulators - WOW moment.

I was a circaholic: two high-head circulators to overcome the steep head loss in the boiler's HX and 10 zone circulators.

- Heat emitters;
- Designers often add their own CYA;
- Circulators are then chosen based on the fattened total, and I suspect they too incorporate a bit of fat by the manufacturers with respect to the flow charts; and
- When in doubt, system installers tend to use the next larger more powerful size.

And yet, no one complained because the systems designed and installed have virtually all worked. No one paid attention to the energy consumed while transferring thermal comfort from our 95% efficiency boilers to the heat emitters. We always knew there was some CYA built in from conception to delivery, but how much remains a mystery: 50% to 95% perhaps? My eyes were opened during trips to the ISH trade shows in Germany where system-wide energy use was a focal point. A wall of ECM (electrically commutated motor) variable-speed 5- to 45-watt circulators stopped me dead in my tracks.

Fast forward to today

Modulating/condensing boilers squeeze virtually every last penny out of the combustion process. Fossil fuels had long ceased to simply be cheap and abundant, and starting in the 1970s, we had witnessed ever-tightening increases in building envelope energy-conservation construction. As the boxes we lived in became more frugal with energy losses/gains, our heating appliances too started an efficiency climb upward.

Over the past five years, we've witnessed efficiencies nearly attain 100%, which are rapidly becoming the accepted norm. When coupled with a low-temperature comfort-delivery system (radiant floors, walls, ceilings; radiant panels; free-standing cast-iron radiators, etc.), both comfort and efficiency are enhanced. However, there remained a weak link in this chain of efficient production and use of energy for comfort — the delivery system.

In 1993, we built our new home and I was determined it would be heated using a hydronic radiant system with every room having its own zone. My high-efficiency condensing boiler did not modulate, so a buffer tank was required to accommodate my 10-zone system. Outdoor reset was accomplished by an external control that overrode the boiler's control to alter its high-limit setting. The burner and all my circulators were simple on/off devices. While gas consumption was a concern, little thought was given to the power consumption of my 13 circulators (10 zone circulators; 1 indirect water heater circulator; and twinned hi-head circulators to overcome the high head loss through the boiler).

In 2005, I installed our first modcon boiler — a 93% efficiency model. Outdoor reset was now an internal function that modulated both the burner and outlet temperatures. An immediate increase in our comfort was noticed and without prompting, my family asked what I'd done to create the difference?

Changes in delivery temperature were much more gradual and glided up/down as outdoor weather changes occurred. One other thing I noticed: runtimes for my burner and system circulators increased to almost constant-use. We also noticed an increase in our electric utility bills.

Ghost loads and PV solar

By early 2007, I'd already installed solar thermal for our home's domestic hot water system and began focusing on my home's power consumption. Plans to incorporate a solar PV system were started and, as they say, the devil was in the design details. Ghost-loads were at the forefront of PV green-speak and the fact that a $1 reduction in power consumption equaled a $3 reduction in the cost for a solar PV system convinced me to purchase a Kill-a-Watt meter to aid in putting my home on an energy diet — a "Biggest Loser" contest of sorts.

I was surprised to find that my home's ghost-loads (toaster, coffee pot, computer, TVs, wireless router, etc.) totaled just 28 watts when not in use, which accounted for only $2.25 of our monthly energy bill: Pennies instead of nuggets of gold. Aside from lighting, where CFL (compact fluorescent) light bulbs were able to cut 100 watts to 26 watts, a 74% reduction in energy use per fixture, and purchasing Energy Star-rated appliances, there wasn't much else I could do to trim my home's apparent appetite for energy. Or was there?

Drive-by watt-rage — Focus on passracitic losses

Imagine my shock when I first checked my wet-rotor circulators and discovered they were using 87 to more than 130 watts each. I should stress that I was using three separate brands of wet-rotor circulators. Our three relay-control boxes were consuming 10 watts each per-hour year-round, while my 10 zone circulators enjoyed extended runtime because I was using a well-adjusted outdoor reset curve. Turn on all 10 zones and the one primary circulator and my power consumption was a whopping 1,186 watts! I'd found the motherlode of fat to be trimmed from my home's energy body.

Run hours and outdoor reset

My heating zone (SE Pennsylvania) indicates we can expect 2,250 run-hours per year for older style on/off equipment. By downloading a day-by-day low/high temperature chart for the past 12 months, it was easy to determine if any heating might be required, and project run-hours based on that information. Each month's HDD (heating degree days) confirmed there was a potential for 4,200 hours of heating when utilizing an outdoor reset curve adjusted to virtually match our home's heat loss. Assuming a 70% runtime for my primary circulator (because the 10 zones would overlap their extended runtimes) granted an approximate 3,000 run-hour projection for the primary loop circulator. If I allowed for a 67% runtime average for my zone circulators, they each would see 2,800 run-hours. One last item to add that uses power — the zone control panel(s).

Crunching the numbers

We currently pay 11-cents per kWh: 1-kWh = 1,000-watts. If my run-hour projections were correct, our hydronic radiant heating system's power consumption would look like this:

Components	Watts Used/Run Hr.	Total Run Hrs.	Total kWh Consumed	Cost $ per kWh	Annual Operating Costs
Primary Circ	136	3,000	408	0.11	$ 44.88
10 – Zone Circs	1,020	2,800	2,856		$314.16
3 – Control	30	8,760	262.8		$ 28.91
Total			**3,526.8**		**$359.04**

We would consume 3,526.8-kWh and that would cost $359.04 per year. If I assume a 50% increase following deregulation (1/1/2011) of electric utility rates, my new rate will be 16.5-cents per kWh and absent any changes, my cost to move thermal energy from boiler-to-radiant-floors would increase to $538.56. Yikes!

Components	Watts Used/Run Hr.	Total Run Hrs.	Total kWh Consumed	Cost $ per kWh	Annual Operating Costs
Primary Circ	136	3,000	408	0.165	$ 67.32
10 – Zone Circs	1,020	2,800	2,856		$471.24
3 - Control	30	8,760	262.8		$ 43.36
Total			**3,526.8**		**$538.56**

Watt to do?

Looking back at ISH while looking forward caused me to seek out more education regarding ECM vs. induction-motor circulator technology and how they each work. Last but not least, would investing in ECM circulators make cents?

- AC (alternating current) induction motors run at one set speed using full power. The majority of induction motor circulators are substantially oversized, which compounds the wasted power-consumption. Hydraulic erosion and audible noise issues often result, which can lead to premature failure of system components and customer complaints.
- DC (direct current) ECM motors use a brushless permanent-magnet rotor with variable-speed inverter (converts AC to DC) drive technology. ECM motors run much cooler, often at surrounding ambient temperatures. ECM motors are a great choice for those who want to increase the circulator efficiency, dramatically reduce power consumption and conserve energy. Software-enhanced control of an ECM motor can reduce energy use by more than 80%!

The grand experiment

Pruning my energy tree meant searching for the lowest wattage devices available and, taking this one step farther, I wanted to gauge costs based on what we would typically charge a customer. I found zone valves that utilize just 3 watts of power when "on" for $105.54 each. The ECM 5- to 45-watt circulators work seamlessly by ramping their speed up/down as zone valves opened/closed, and its selling price would be $315.02. A second circulator was required to handle our lower floor's low-temperature slab system. If I were selling this as a retrofit system to one of our customers, their investment would look like this:

10 – 3-watt zone valves	$1,055.38
2 – ECM circulators	$ 630.04
Miscellaneous materials	$ 332.50
Labor	$1,800.00
Total invested	**$3,485.42**

Where the rubber meets the road

My newly designed system with the two ECM 5- to 45-watt circulators and ten 3-watt zone valves has been up and running for the entire 2009-2010 heating season. During this time, data-logging with the Kill-a-Watt meter indicated my run-hour projections were on target. Initially, both ECM circulators ramped up to 45-watts, but began learning my zones' system curves and, over three weeks-time, I watched the watt readouts fall until they settled into an established pattern. Testing has confirmed the zone valves use just 3 watts each. The ECM circulators have varied their wattage use considerably: from 5 watts to a maximum so far of 28-watts, as zone valves open/close, but on average less than 16 watts. I've cut my thermal-transfer power-use by 93.4%.

My Power Consumption History			
Heating Season	Total kWh	Heating Degree Days	Total Season Costs
2007 - 2008	3,404.73	5,767	$374.52
2008 – 2009	3,409.55	5,775.2	$375.05
2009 - 2010	225.73	5,528.7	**$24.83**

Return on investment

There are several ways to look at a customers' ROI. Simple payback or the savings earned each year as if their investment were in a fixed asset that paid dividends — like the stock market. Let's look at both.

THE BIGGEST LOSER

During 2009-2010 with an 11-cent per kWh rate, I would expect my old system to have used $359.04 and my new system cost was $24.83 for an attractive savings of $334.21. If I divide that by my renovated system cost, I see a ROI of 9.6%, which is better than anything the stock market or real estate has been providing for years.

However, as electricity rates increase, the ROI gets better! Next year's deregulation at 50% will yield the following: Old system = $538.56; New system = $37.25; savings = $501.31; and ROI = 14.37%.

For my 11 circulator retro-fit system:

Electrical Rates	11-circ System	2-ECM, 10- ZV System	Annual Savings	ROI
11-cents kWh	$359.04	$24.83	$334.21	9.60%
16.5-cents kWh	$538.56	$37.25	$501.31	14.37%

In terms of simple payback with the electricity increase in 2010 and an annual 5% bump in the rate, I'm looking at a bit more than 6-years.

If ROI doesn't get your attention, let's look at long-term costs with a 5% annual increase in the cost for electricity following deregulation and include this first year with its 11-cent per kWh rate. After 20 years my system costs should look like this:

Projected Electrical Rates -Year	11-circ System	ECM + ZV System	Annual Savings
11-cents kWh 2010	$359.04	$24.83	$334.21
16.5-cents kWh 2011	$538.56	$37.25	$501.31
(5% yearly increase) 2012	$565.49	$39.11	$526.38
2015	$623.45	$43.12	$580.33
2020	$795.70	$55.04	$740.66
2025	$1,015.54	$70.24	$945.29
2030	$1,296.11	$89.65	$1,206.46
Total	**$16,806.13**	**$1,162.41**	**$15,643.72**
Projected Savings over 20-years		**$15,643.72**	
Average ROI over 20-years		**24.67%**	

Would you say no? Would you ignore the savings potential? Mine was a retrofit that replaced a functioning 10-zone hydronic system. What if we were to consider the cost differences between installing a typical 6-zone system from scratch? Let's start over.

From scratch: The labor won't be any different, so we'll look at the cost difference in materials only. Six wet rotor circulators vs. the combined six 3-watt zone valves and 1 ECM 5- to 45-watt circulator. Using standard markup rates for all materials, the cost difference is just $398. While I've increased the initial system cost, the ROI in my 11-cent per kWh year just skyrocketed to 42.2% (see following tables).

The comparison between the old-style energy-hog and new-style energy-miserly systems:

Old Style System Material Cost		New Style System Material Cost	
6 – Fixed Speed IFC Circulators	$550.00	6 – ZV	$633.00
		1 – ECM circ	$315.00
Total	$550.00	Total	$948.00

Operating costs for the typical six-zone system, old style vs. new style:

Operating Cost				
Electrical Cost kWh	**6-circ System**	**1-ECM, 6-ZV System**	**Annual Savings**	**ROI**
11-cents	$192.93	$24.83	$168.10	42.2%
16.5-cents	$289.40	$37.25	$252.15	63.4%

In terms of simple payback, I'm looking at less than two years to recoup the added $398 investment.

It's clearly a win-win scenario for everyone involved. I've reduced my system's thermal-energy-transfer consumption by a bit more than 93%, slashed my operating costs, and virtually eliminated passracitic energy losses. In addition to having a much greener carbon footprint, I have a fatter wallet.

But, this grand experiment has raised a few questions:

- Do we, as an industry, need to revise our methods for designing hydronic systems to more accurately reflect actual values?
- Do we need to rethink conventional and accepted methods for sizing circulators?

The use of ECM circulators is "new" for North America hydronic system designers/installers, but this technology has been used for more than 10 years in other countries.

Longevity isn't the issue — acceptance and adopting a new mindset was my own personal challenge. After this first heating season's performance, I am convinced ECM-driven circulator technology offers a true win/win for everyone involved. The technology in use in my home revealed — dramatically — that my 11-circulator system was on an electrical steroid-induced power trip in spite of my having matched each zone circulator to the conditions indicated during the design process 18 years ago.

From my point-of-view, both questions raised can be answered with a resounding "yes."

THANK YOU

STAY TUNED FOR OUR NEXT EDITION

- Coming in late June – your FREE Volume 2 continues the Dave Yates Adventures in Hydronic and Water Heating!

✓ Combi-Boilers – The rise, demand, and applications for Combi-Boilers

✓ Tank vs Tankless? There is room and applications for both!

✓ Hungry? How about a nice Cold Water sandwich? – or how to avoid one.

✓ How to correctly size Indirect Water Heater off a Boiler

✓ And more Columns & features from Dave's best - PLUS this next issue will contain new original content not yet published!

Don't miss it – you will learn and be entertained!