State of the Art HVAC

There's more to HVAC than heating and cooling

BY KRISTOF IRWIN

Photos courtesy of Matt Risinger and Air Rite By Design

Americans live most of their lives immersed in a fishbowl of air of their own making. The qualities of this air are readily controllable and impact health, comfort, and well-being. Alas, being invisible, air gets less attention than the building enclosure; but it's no less important to understand or to do well.

I'm the principal of Positive Energy, a full-service building-science consulting firm based in Austin, Texas. Among the services we provide to architects and builders are heating and cooling system design, building pressure testing, duct pressure testing, system commissioning, and duct-flow balancing and verification.

We serve a high-end custom-home market where clients are willing and able to spend the money to get an HVAC system whose quality matches the quality of the rest of the building. In an industry where the lowest common denominator often controls, we are focused on providing top-quality solutions for our clients. In this story, I'll talk about the principles and practices that guide our designs for state-of-the-art HVAC systems.

HEATING AND COOLING EQUIPMENT

These days, we prefer to specify VRF equipment, which represents the future of the HVAC industry. VRF stands for "variable refrigerant flow," and modern VRF equipment offers advantages in at least three areas: efficiency, occupant comfort, and zoning capability.

In the old days, air-conditioner or heat-pump compressors had two modes of delivering power: either full on or off. More recently, dual-stage and unloading compressors have come into the market

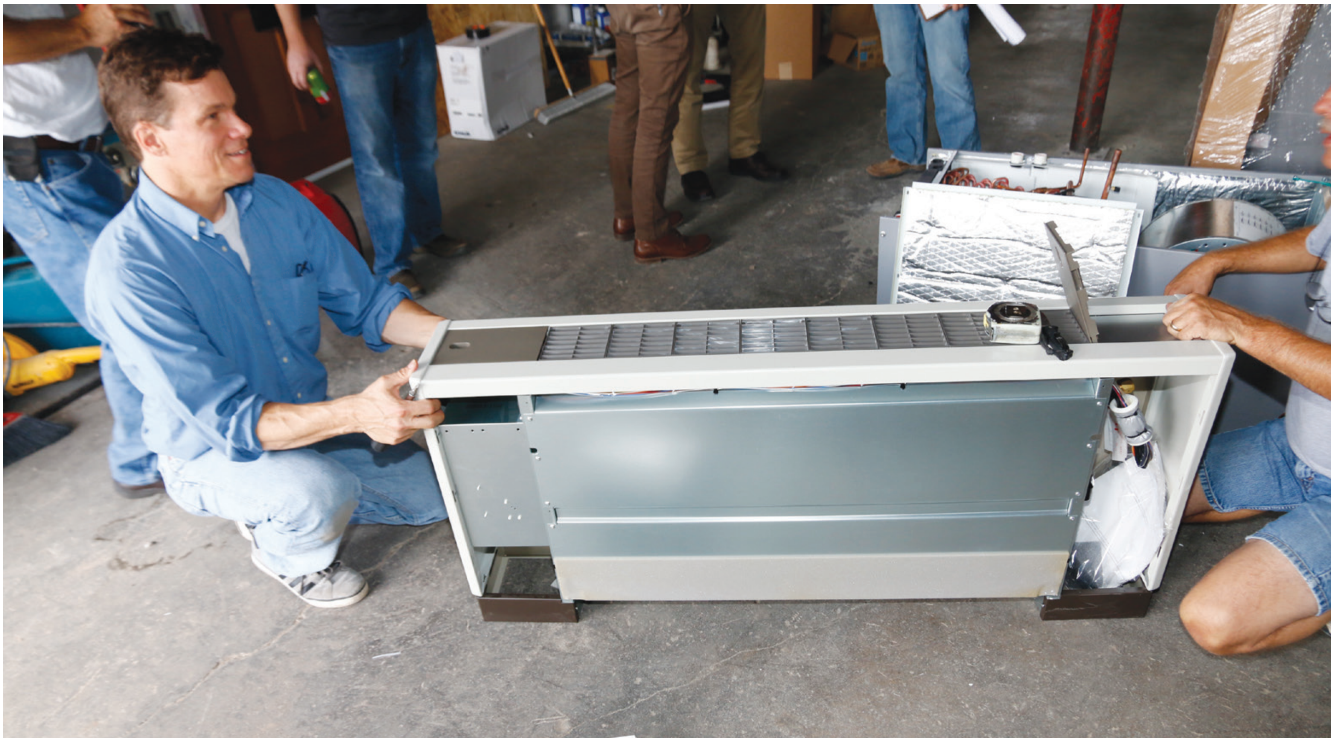
Gilbert Rosipal of Air Rite By Design of Austin, Texas, wires up a Mitsubishi variable refrigerant flow (VRF) outdoor unit. Controls in the compressor allow the system to ramp its power up and down gradually, dialing back to as low as 15% of full capacity when appropriate to address "part-load" conditions.

that add a second option at either 50% or 65% of full capacity. VRF is a generation ahead of that dual-stage equipment. What VRF supplies is the ability to continuously vary the capacity of the machine. The goal is to vary the rate of heating or cooling to match the rate of heat leaking out or in through the building enclosure.

I use a car analogy to explain the difference. Suppose you hop into your truck to go somewhere, and the rules are, you have to floor the accelerator all the time, and you control the speed of the truck by turning the ignition key on and off. That's standard single-stage equipment. With VRF, you now have a gas pedal: You can smoothly vary the power output of the engine depending on how fast you need the vehicle to go. A 4-ton VRF compressor like the Mitsubishi City Multi can smoothly vary its power from 48,000 Btu/hour all the way down to 15% of that, or anywhere in between.

That capability in the VRF equipment allows it to efficiently manage what we call "part-load" conditions, when standard equipment suffers from the problem of over-sizing. ACCA Manual J is the industry standard manual for sizing HVAC equipment. Manual J is often referred to as a load calculation. A word is missing there, however: It's actually a *peak*-load calculation. The Manual J load is representative of the peak heating and cooling loads you're going to see in your climate zone for 1% of the hours throughout the year. Designers size their equipment to handle the peak load, but the vast majority of the time, your building will not see loads that high. It will see loads at part-load conditions, when one-stage equipment runs in a less efficient stop-and-start mode that causes more wear and tear on components. VRF equipment, with its ability to match power to the load, is able to meet part-load conditions more efficiently.

Another reason a VRF heat-pump compressor is more efficient than a standard compressor is in the design of the compressor motor. The electronically commutated (ECM) motors in these units are driven by an inverter, which has the capability of adjusting not just the frequency of the current being delivered to that motor, but also the voltage. By playing with those two parameters in concert, the motor achieves the highest power factor possible at any given speed and any given load that the motor is under. This improves the Energy Efficiency Ratio (EER) of the equipment (which expresses how many Btu of heat are moved for every watt of energy you purchase). Simply put, you're getting more heating or cooling per watt out of the VRF equipment at any speed. We're getting more mechanical work than we were with the previous generation of equipment, for the same amount of power. So even at peak load, a 4-ton VRF system with an inverter drive runs much more efficiently than a 4-ton single-stage or dual-stage system sitting next to it.



The author examines a Mitsubishi PFFY compact air handler. This small unit is useful for handling the heating and cooling requirements of peripheral zones in a building and can be one of multiple air-handling units connected to the same outdoor VRF compressor.

You can think of this in terms of the amps required to start and run the compressor motor. A standard single-stage 4-ton unit will take about 100 amps of power to get started and then will run at about 40 amps continuously once it gets going. A 4-ton Mitsubishi City Multi will start out at about 2 amps, then it will ramp up slowly if necessary to meet the demand, up to about 24 or 26 amps. When the temperature in the space approaches the set point, the VRF unit will slowly reduce power and creep up to the set point, and, guided by its software, will then run just hard enough to maintain the temperature at exactly that set point. Traditional equipment will overshoot the set point, shut off, and then wait until the temperature rises above the set point again before it starts up again.

In practice, the lower amp draw combined with the precise control of the VRF unit adds up to a savings of 20% to 40% in energy consumption. And because with a properly functioning controller, the unit maintains a rock-steady set point, it also provides better comfort, without swings in temperature.

AIR HANDLERS AND ZONING

The outdoor compressor is linked to indoor units by refrigerant lines. Depending on the size and model, a VRF compressor can handle anywhere from several indoor units up to dozens of units (in the case of big commercial equipment running on three-phase power). The homes we're designing for typically have single-phase power, so we're restricted to the equipment that can run on single-phase. We typically call for one or more Mitsubishi City Multi S-Series compressors, rated at 3, 4, or 5 tons, each of which can serve eight independently controllable indoor units.

The indoor units could be anything from wall-mounted units or ceiling cassettes to variable-speed vertical or horizontal air handlers (commonly known as "multi-position") much like the form factor of air handlers for a traditional system. Our clientele has not embraced the visible wall-mounted units, so we typically specify one or more Mitsubishi multi-position air handlers and conventional ductwork. This form factor also leverages our ability to impact architectural decisions early in the design process.

When it comes to zoning and duct design, there have to be conversations with the owners and the architect. Many in the industry, particularly residential, have grown accustomed to a process based only on an installation and not on any planning during the design stage. Architects don't always consider the air distribution system when they're drawing house plans, but they should; that's like working a Sudoku puzzle but only looking at the columns and not the rows. Not leaving room for the "lungs of the building" is

An installer for Air Rite By Design of Austin, Texas, assembles metal ductwork on a jobsite. Positive Energy specifies metal duct for all installations because of its durability and for sanitary reasons. Once installed, the ductwork is buried inside permanent building assemblies and is difficult and expensive to access or replace, so durability is a key aspect of quality.

not really a full design. By "room," I mean two things: both room in the design process, and room within the architectural and framing designs. I want architects to be thinking about the air distribution system early enough in the process that the ductwork can be allowed for. The simple concept of an integrated process, one that aligns architectural, structural, and mechanical designs, is catching on strongly because it's simple, it's effective, and it improves outcomes.

As for zoning, that requires a conversation with the customers on how they plan to live in the space as well as an analysis of the building. We zone the building by load profile and use profile. Load profile means, for example: "This room is facing east. That room is facing west. This room's on the first floor with very little exterior load and glazing. This room's on the third floor." So those are different load profiles.

You can also zone based on use profile: "This is the bedroom; it's not occupied during the day. This is the central core. It's rarely occupied at night." Those will be different zones. "These two rooms are occupied by a teenage daughter and an 8-year-old son. They're not going to want things the same, so give each their own control."

In the case of the east and west sides of the building, we may choose to give each zone its own outdoor compressor. That way, during a season with chilly nights and warm days, if the sun starts to overheat the east side in the morning while the west side is still cool enough to need heating, we can handle both needs at once.

But most zones aren't going to have opposite needs, so multiple zones can usually be run off the same compressor using refrigerant lines and controls. In that case, we give each zone a dedicated air handler and air distribution system that serves that area. Because we can have multiple air handlers served by the same outdoor system, VRF gives us the flexibility to do that and keep the initial cost down. This also minimizes the footprint necessary for all the equipment.

Sometimes, we have a situation where the zones are too small even for the smallest air handler. In that case, we do "air-side zoning"—we zone the areas using dampers and controls in the duct system served by a single air handler. And occasionally, there's a point load, such as a laundry room or a garage, that is best handled by a wall-mounted unit.

DUCT SYSTEMS

Duct-board box plenums and flex-duct supply lines are typical in our market. We don't do things that way; we specify metal duct for all our designs. Here's our reasoning: People put a lot of effort into

An installer for Air Rite By Design tapes insulation on a duct. Even though the ducts are within the conditioned envelope, they still must be insulated. At right is a multi-position air handler for a variable refrigerant flow (VRF) system. The air handler is suspended from the roof framing with threaded rod and vibration-damping couplings.

constructing a durable, functional building enclosure. You have one chance to get it right, and then it's inconvenient to fix it forever. The ductwork is the same way: It's a durable, functional, passive assembly; you have one good chance to get it right, and then it's inconvenient to fix it forever. Air distribution systems matter for the life of the home. It only makes sense to do it right when you have the chance.

Metal duct is appropriate for that situation. Metal is a durable material. It will last the life of the home, if attached well and done well. And it's a recyclable material, so at the end of its life cycle, there is something we can do with it.

Metal has a natural galvanic action that retards the growth of mold, bacteria, viruses, and protozoa. With air quality in mind, we always aim for fiber-free air distribution systems. The nooks and crannies of duct board and the turbulence created by flex duct spiral pressure liners do not help keep distribution systems clean. ("Clean" is another way of saying free of food, or substrates on which to grow unhealthy indoor microbiomes.)

This is perhaps the key consideration: An air distribution system moves tens of thousands of pounds of air every day. It will do so with either a lot of friction, very little friction, or somewhere in between. Using low-friction metal distribution systems based on the principles of fluid mechanics is analogous to having the right amount of air in your tires. Rolling resistance resists motion. So does friction in duct systems.

FILTRATION

Why filter the air in a home? It's just dust, right? Oh, if only it were "just dust"—bits of leaves or soil, or even gross things like skin flakes. But dust is like a candy-coated M&M, and the candy coating is things like chemical pollutants and biotoxins. You breathe those things in with the dust, and if the particles are small enough, they can lodge in your lungs. The best way to keep from being exposed to those toxins is to filter the air, with at least a MERV-13 filter integrated with the air handler.

The MERV-8 filters that many installers put in are touted as being 99% effective at catching dust. But all they catch is larger dust that your bronchial cilia are capable of catching and expelling from your system. MERV-8 filters are there only to keep the air conditioner coil from fouling. They're not there to protect the health of the people in the building. ASHRAE has recommended MERV-13 as a minimum since 2015. Based on our expertise in indoor air quality, and to conform with ASHRAE standards, we specify MERV-13 filtration at a minimum; this captures most of the smaller particles that your

Under humid atmospheric conditions when temperatures are moderate, air conditioning systems by themselves can't effectively control indoor humidity. Here, an Ultra Aire dehumidifier is ducted into the air distribution system of a central heating and cooling system. The dehumidifier independently manages humidity, responding to its own controls.

bronchial tubes won't catch and clear. If the clients are sensitive, we may go up to MERV-16 or even to a whole-house HEPA filter.

FRESH AIR AND DEHUMIDIFICATION

Humidity control is important for occupant comfort and for building health. If you maintain the air relative humidity (RH) in an acceptable range of 35% to 55% (or 50% to 55% in hot, humid climates), the occupant's thermal comfort will be satisfied over an expanded range of sensible temperatures. That can make up for situations like an overheated sunroom: If I keep it dry, I am able to evaporate moisture off the occupants' skin, which is part of cooling.

Controlling moisture also helps maintain the stability of trim or of musical instruments in the house.

But most importantly, dry air is critical for the health of human occupants of the building, because humid air supports the growth of all the organisms in the "microbiome" of the home. Fungi, bacteria, and other organisms battle for supremacy in a humid environment, and they release biotoxins that cause human health problems. If we keep the air dry, we take away a major factor in that health threat.

And as the energy code evolves, it's increasing the need to independently manage humidity. Tighter building enclosures, more insulation, and better windows are reducing the sensible load in the house. That means air conditioners—which are the only dehumidification equipment in most houses—are running less often. And if the air conditioner is not running, you're not removing humidity. Meanwhile, required fresh-air ventilation is bringing moisture into the home during much of the season.

So for our clients, we always specify a dedicated dehumidifier with its own controls. Typically, that is an Ultra Aire unit, because we have a good relationship with Ultra Aire, we have the ability to access its technical teams, and we have a solid track record with its product. We pull air from the conditioned space into the dehumidifier, and send it to the supply-air distribution system. We also use a dedicated damper-controlled ventilation port on the dehumidifier unit to draw in fresh air and distribute it using the heating and cooling air distribution system. (Note that this system needs to be designed to account for the additional volume of dehumidified air.)

The dehumidifier runs in response to relative humidity in the house. It doesn't run only when the air conditioner or heat is running. But it doesn't require the air handler to be running—the fan in the dehumidifier unit is sufficient to move the dry air where it needs to go.

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