Every year, the seasons come and go. Predictability can be helpful, but seasonal challenges themselves can be plentiful and tedious. Winter arrives with its cold temperatures and disruptive precipitation. When it comes to heating spaces—from office buildings to schools to health and wellness facilities—the challenge is to not just get the heating needed, but to do it effectively and efficiently.

Historically, heating in cold climates has put industry professionals to the test. Many heating systems do not perform as the temperature drops, causing end users to rely on auxiliary heat, and often on fossil fuels. These are both things an energy- and money-conscious market is looking to move away from.

Heating in cold climates has also required clever product design and development. Heat pumps, for example, have historically been troublesome in extreme cold climates. Below 17°F, an auxiliary heat system, such as a gas-fired boiler, was needed. In many places throughout the country electricity was a much more accessible, affordable fuel than gas. The result was a technological gap—the need for heat pumps that could operate in even the coldest weather. Today, those heat pumps exist. “Advanced heating technology” was developed to address these very issues, and heat pumps can now offer impressive performance in even the coldest climates—with no need for auxiliary heat.

Applying VRF in Cold Climates

Using variable refrigerant flow systems to get the heating needed by occupants effectively and efficiently.
The U.S. Energy Information Administration claims that as much as 40% of a building's operating costs are tied to HVAC and other mechanical systems. It is important to minimize operating costs while achieving other goals like reliable performance, a modern appearance and personalized comfort. Variable refrigerant flow (VRF) is an HVAC technology that minimizes operating costs. It makes the most of square footage and budget while offering energy-efficient technology that provides superior occupant comfort.

**VRF results**

VRF divides a building's interior into zones, each of which can be operated separately. This is possible because of the outdoor units' inverter-driven compressor that varies its motor rotation speed, allowing it to precisely meet each zone's conditioning requirement while reducing overall power consumption. For VRF with heat recovery, one room can even be cooled while another is simultaneously heated. In this case, the system's total capacity is distributed to each indoor unit via a branch circuit controller. The following benefits result in personal comfort control for occupants.

- **Precise temperature control**—Fixed-speed compressors in conventional HVAC systems are either running at full power or are off. In the U.S., a zone exhibits partial-load conditions more than 90% of the time. Conventional systems cannot handle these partial load requirements, resulting in energy fluctuations and poor setpoint satisfaction. VRF offers full-range variable capacity to deliver only the amount of conditioning to match a zone's cooling or heating demand. Working in tandem with integrated controls and sensors that measure loads for each zone, the compressor seamlessly adjusts speeds to maintain the desired zone temperature. This function, along with a low-profile ducted or ductless design, typically increases energy efficiency about 25% over conventional ducted systems, partly due to the energy lost by forcing air through ductwork.

- **Elimination of hot and cold spots**—Just because a building is located in a cold climate does not mean that every occupant requires the same temperature for their space. VRF's ability to treat hot and cold spots via zoning capabilities and simultaneous cooling and heating ensures everyone's comfort.

- **Quiet operation**—VRF operates at lower decibel ratings; some brands between 19 and 34 dB. A whisper comes in at 35 dB.

**How it works**

How is it possible to provide full rated heating capacity at 0°F (or below depending on the manufacturer) while offering substantial heating capacity at -13°F? As the outdoor temperature drops below freezing, heat pumps traditionally faced decreased performance as the rate of the refrigerant flow circulating through the system dropped, reducing the amount of heat generated. Newer technology solves that problem via a "flash injection circuit" or by injecting a portion of the refrigerant into the compressor at a lower temperature than normal (the refrigerant temperature is decreased when it bypasses the outdoor coil and recollects heat energy in a heat exchanger), reducing the temperature inside the compression chamber.

**Figure 2** VRF operating levels can range between 19 and 34 dB.

**Figure 3** A visual representation of how a VRF system can maintain high heating capacity despite colder outdoor temperatures.
In the case of VRF with heat recovery and advanced heating technology, simultaneous cooling and heating operation is generally available down to -4°F. As an example, while the technology is too new to have an industry-wide definition available, the system capacity chart and indoor unit heating discharge temperature chart (Figure 4) show actual examples of VRF with advanced heating technology’s performance.

In the case of VRF with heat recovery and advanced heating technology, simultaneous cooling and heating operation is generally available down to -4°F (instead of the 14°F associated with most manufacturers’ standard version of VRF). Having the ability to cool and heat simultaneously during negative ambient temperatures is necessary in applications such as office buildings that need to serve both workers sitting all day (requiring heating) and occupants using gym facilities (requiring cooling) even as the temperature drops. Between -4°F and -25°F, a VRF system with heat recovery and advanced heating technology will operate in heating mode only.

The result of this technology is 100% capacity at 0°F and 85% capacity at -13°F, as an example. Again, while the technology is too new to have an industry-wide definition available, the system capacity chart and indoor unit heating discharge temperature chart (Figure 4) show actual examples of VRF with advanced heating technology’s performance.

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Defrost Cycle

None of this, of course, would be possible without a defrost cycle. For VRF with advanced heating technology, modern defrost cycles de-energize the reversing valve; stop the indoor unit fan motor, preventing cold air from being distributed into the conditioned space; stop the outdoor unit fan, allowing the outdoor coil to increase in temperature to more efficiently eliminate ice build-up; and operate the compressor frequency at a high speed, increasing the discharge gas’ temperature.

A VRF system with advanced heating technology looks at three variables to determine when a defrost cycle should be initiated: outdoor ambient air temperature, cumulative compressor operating time and outdoor pipe temperature. The cycle auto-terminates either when the maximum defrost time is reached or when the outdoor pipe temperature has reached or exceeded a pre-set level for a pre-set amount of time (e.g., 50°F for two minutes). End users will find that defrost cycles
occur more often when it is warmer out, for example 32°F and snowing, than during periods of extreme cold given the lack of moisture in the air. Regardless of the temperature, end users likely will not notice the defrost cycle taking place at all. If their system stops heating during a defrost cycle, heat will only be absent for a few minutes.

Some manufacturers also offer a technology that creates heating capacity even during a defrost cycle. This happens by defrosting one section of the condenser coil at a time. The resultant operation shows a marked increase in heating capacity during defrost (from 0% to up to 60% depending on the outside temperature), as well as a small increase in overall heating capacity.

This technology takes different forms depending on the manufacturer. Some use hot gas defrost, others reverse defrost and others use a hybrid. With some manufacturers, a hybrid of hot gas and reverse defrost can take place in a single module, making the technology applicable to smaller projects. Some manufacturers have developed efficiency evaluation tools that demonstrate the advantages, simulating the life cycle cost and other calculations for old and new buildings. Figure 5 shows the output from two actual simulations. The bottom chart compares the life-cycle cost of VRF with advanced heating technology to water source heat pump (WSHP) and variable air volume (VAV) systems. The top chart compares the Energy Use Intensity of VRF with advanced heating technology to WSHP, VAV and packaged terminal air-conditioners.

### Conclusion

For decades now, VRF has enabled building professionals to push the envelope in many parts of the country. With advanced heating technology, VRF is now a solution, not a challenge, in extreme cold climates, making it an enticing option no matter the geographical location.

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