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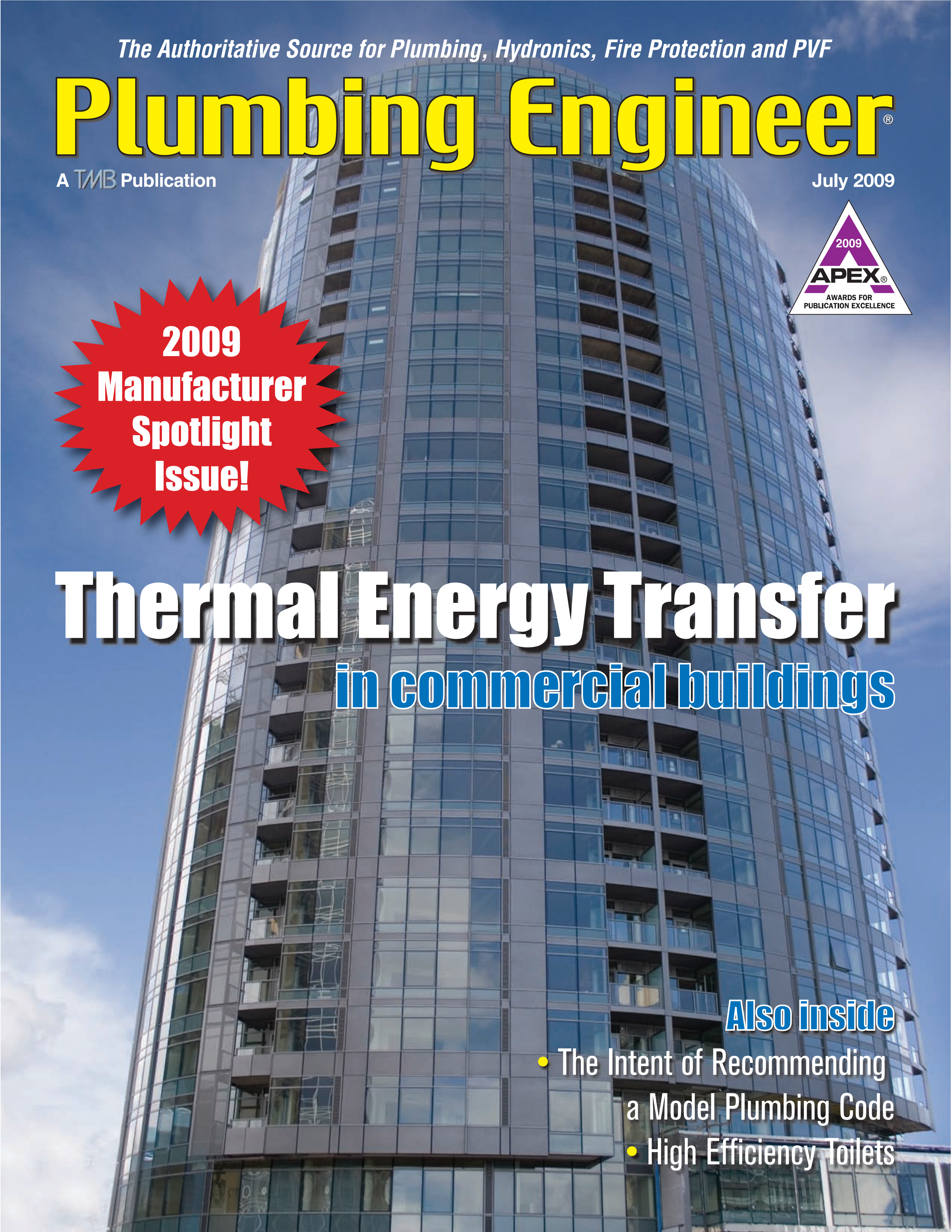

2009 Manufacturer Spotlight Issue!

Thermal Energy Transfer in commercial buildings

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Thermal Energy Transfer Key to Commercial Building Efficiency

BY JOHN VASTYAN

Without question, the 'green' tsunami has hit our shores

The "wave" I'm referring to, of course, isn't a rogue monster from the deep, yet it is in response to seismic shift in the building industry happening on a global scale. And though we Americans now embrace the need for change, conceptually, we've only just begun to shape it substantively.

Though in the opinion of many Asians and Europeans — with a twinge of annoyance at our weary pace — we've resisted the need to develop and support green technology far too long. Renewable energy development has just begun to supplant our voracious thirst for fossil fuel.

If there's a silver lining to our current economic woes — fueled by the, well, lack of cheap fuel — it's the wake-up call we received, encouraging, at last, serious introspection about how we handle the need to move toward greater energy efficiency on a broad scale.

Solar thermal, wind, biomass and biogas, hydrogen, photovoltaic and geothermal technology; all are now among the renewable energy sources being developed at a greater pace that anticipated just a few years ago. Related to geothermal is one of the fastest growing trends in the commercial building industry: the use of water source heat pumps, or water-loop heating and cooling systems.

"Water-loop technology has been around for decades, though now — pushed by rising energy costs and the 'call to arms' by the USGBC and the advantages of LEED certification — interest in the technology is gaining rapidly," said John Bailey, vice president of sales and marketing for Oklahoma City-based ClimateMaster, Inc., the world's largest supplier of water source heat pump systems. "We refer to the water-loop process as 'thermal energy transfer.'"

600% efficiency + 3-year paybacks

The newest generation of water source heat pump heating and cooling technology for large buildings has pushed operational efficiencies into the 500 to 600 percent range. That is: for every unit of energy used to operate the equipment, the system delivers five to six units of energy in return.

That's smart use of energy. Add new and sophisticated controls to the picture, system integration with building automation systems, and supplemental energy sources like photovoltaics and hydrogen cells . . . and you begin to see the potential for how quickly the commercial building market is evolving.

Water-source heat pumps move heat very efficiently. The best models will extract 5 kWh of heat from the water loop for every 1 kWh of electricity used to power the compressor and fan, delivering all 6 kWh as heat into the air. This 6-to-1 ratio is called the COP (Coefficient of Performance), and can be equated to a 600% efficiency level.

By comparison, the very best fossil fuel furnaces and boil-

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ers produce heat at less than 100% efficiency. Heat is then removed from the air (cooling mode) at similar efficiencies, providing EER (Energy Efficiency Ratio) levels over 20 Btu/Watt [5.86 Watt/Watt].

With the potential for of-the-charts efficiency performance, building owners are now at attention. When the design engineer can calculate a three- to four-year payback for new equipment (or perhaps even shorter than that in some instances), there's real incentive to install new technology – many of the systems ideal not only for new construction, but also for retrofit application.

At last year's AHR Expo in New York City, Bailey said he wanted to show me something outside. He led the way. When the door opened, a blast of cold air reminded us of the very real need for indoor comfort control. From the Javitts Center, we had a decent view of the city's impressive skyline.

With the sweep of his hand, he directed me to the landscape. "Take a look. Thirty to 40 percent of the high-rise buildings you see have some form of water-loop technology," he said. "But few people realize it. The industry's changing, and the market for this new technology is growing quickly. The technology continues to improve steadily and yet a large number of building owners still haven't heard the news."

Thermal energy transfer Water-source heat pump, or thermal energy transfer (TET) systems provide highly efficient zone-controlled heating and cooling throughout a building by circulating water in a closed piping loop to move and exchange thermal energy. With such technology a building has, within it, many separate heat pumps, connected by closed-system water loops that transfer thermal energy with great efficiency.

Compared to traditional two-pipe, central chiller-based building systems, the installation of water-sourced equipment often saves 10 to 15 percent in the initial cost or up to 20 to 30 percent of the installed cost when compared to a four-pipe system. A high efficiency chiller is typically 10 to 15 percent less efficient than a water source heat pump (TET) system, operationally, while a standard chiller performs 30 to 50 percent less efficiently. Maintenance costs are often 10 percent higher with chiller-based systems. Heat pump life expectancy is about 20 years; a chiller will typically serve for 20 to 25 years. And, with a thermal energy transfer system, maintenance needs are also typically low.

Individual heat pumps add or remove heat from the air within each zone as required to meet its unique heating or cooling load. During zone heating, they extract needed heat (thermal energy) from the common water loop. During zone cooling, heat is rejected into the water loop where it can then be shared with all other heat pumps throughout the building. It's in this way that rejected heat — which is wasted to the outdoors in most HVAC systems — is fully utilized before any new energy source is used to heat or cool the building.

Bailey explained that all buildings contain year-round sources of thermal energy, or internal heat gains, that are recovered and recycled by a thermal energy transfer systems, such as:

Lighting — The electrical energy used for lighting in most structures varies from 1 to 4 Watts per square foot (11 to 13 Watts per square meter).

People — We emit thermal energy ranging from 300 to 500 Btus per hour [88 to 147 Watts] depending upon our activity.

Equipment — The energy consumed by equipment such as computers, printers, copiers, pumps and motors is emitted as heat.

Solar gain — Perimeter zones with large glazed areas may require daytime cooling even during cold weather.

The cast-off thermal energy within the building envelope recovered in the water loop of a water-source heat pump system can be used for most purposes that require heat, such as:

Space heating — Water-source heat pumps in zones that require heating will extract thermal energy from the water loop.

Water heating — Water-to-water heat pumps can be equipped to extract thermal energy from the water loop to heat domestic hot water, swimming pools and spas, or to serve hydronic loads such as radiant heat or snow-melt systems.

Ventilation — Dedicated "outside air" heat pumps extract thermal energy from the water loop to heat outside air used for ventilation.

The heat "pumping" concept

Water-source heat pumps use a simple vapor compression refrigerant circuit to efficiently provide zone heating or cooling. During the cooling mode, heat is extracted from the air and rejected into the water loop. During heating mode, the process is reversed, with heat being extracted from the water loop and rejected into the air. Thus, thermal energy is transferred, or "pumped" between the air and the water loop, in either direction, on demand.

Why water?

In a word: efficiency. Water is the most efficient way to move thermal energy.

A two-inch water pipe can carry the same amount of cooling as a 24-inch air duct, requiring up to 90% less transport energy in the process and taking up far less space. The mass of the water loop also provides thermal storage, allowing a substantial amount of heat to be carried from occupied periods into morning warm-up. The advantage of thermal storage is not a capability found with traditional HVAC systems.

Water-source heat pump heat exchangers are both compact and efficient. This is because of the high mass and thermal conductivity of water. Water-source heat pumps — unlike tra-

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Thermal energy transfer plays a key role in winning a project's LEED certification. At one end of the mechanical system, boilers provide back-up heat and a small chiller offers supplemental cooling. Water-sourced heat pumps move thermal energy throughout the building year-round. Unwanted heat is discarded by the rooftop cooling tower.

ditional HVAC systems that are inefficiently tied to outdoor dry bulb temperatures — operate at lower condensing temperatures because they are linked to the outdoor wet bulb temperature when using a cooling tower, or deep earth temperature when using a ground heat exchanger. This leads to higher efficiencies and longer service life.

Water-loop heat pump systems combine water-source heat pumps on a common piping loop with a heat rejector and boiler, which are used to maintain the circulating water temperature within a controlled range, typically from 60°F to 95°F. The most common heat rejectors are open cooling towers with isolating heat exchangers, closed-circuit evaporative coolers, or dry coolers.

Each zone heat pump uses the water loop to provide heating or cooling at any time, during or after hours, regardless of the operating mode of the other heat pumps. This is accomplished without the duplicate operation of heating or cooling systems, or the double waste inherent in reheat modes.

Water-to-water heat pump systems also operate very efficiently under part-load conditions, such as when a small portion of the building remains occupied after hours. Only the required zone heat pumps are used, unlike systems that must keep a large central plant in operation at an inefficient scaled-back capacity in order to serve a small portion of the load.

A typical building has a perimeter with outside exposure that is directly affected by variable outdoor weather conditions and a core without outside exposure that is virtually unaffected by the weather. In order to understand the energy sharing benefits of a water-source heat pump system, the

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interaction of the loads in the core and perimeter zones must be studied throughout the year during occupied periods, with internal gains, and unoccupied periods with temperature setback/setup and little or no internal gains.

To illustrate this, the following are the main energy consuming operating modes of an office building in a temperate climate.

Summer, occupied: Typically, all zones require cooling and are rejecting heat into the water loop. The heat rejector maintains the maximum water loop temperature according to a predetermined set-point (fixed or outdoor reset). The boiler is off.

Winter warm-up: During recovery from night setback, most zones will require heating and will be extracting heat from the water loop. The boiler maintains the minimum water loop temperature according to a predetermined set-point. The heat rejector is off. The warm-up period is typically one hour or less per day.

Winter, occupied: Because of internal heat gain, most core zones require cooling. Most perimeter zones will require heating. Because heat is being simultaneously rejected into and extracted from the water loop, both the boiler and the heat rejector will remain in the "off" mode much of the time. And this is the essence of thermal energy transfer: the inherent sharing of energy within the water loop minimizes boiler and heat rejector operation and provides maximum system efficiency.

The many advantages of water-to-water systems include:

Year-'round individual control. Each zone heat pump provides individual temperature control. This allows each occupant to control heating or cooling regardless of season, during or after hours, regardless of what other zones are doing. Zones served by single heat pumps can be as small as 200 square feet or as large as many thousands of square feet.

Energy savings. Water-source heat pumps provide zone heating and cooling at the highest rated levels of efficiency. The water loop inherently recovers much of the energy needed for heating the building, minimizing boiler use. Water-loop heat pump systems operate efficiently under partial occupancy and at part-load conditions. They also eliminate the double energy waste of zone reheat (cooling with subsequent reheating), which is common in many HVAC systems.

Tenant metering. The majority of the system operating cost occurs at the zone heat pumps, which can be metered at the tenant level. Thus, each tenant pays for only what they use.

Quiet operation. Though large central chillers and high-speed, high-static fans may produce noise and vibration, modern water-source heat pumps operate with great stealth, even thought they're often located within occupied spaces. Sound levels produced by the latest models are greatly reduced by the

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use of new compressor technology, variable speed fan motors and sound-isolating designs. Quiet operation has become a fundamental requirement for many tenants.

Low initial cost. Water-source heat pumps are factory assembled and tested, usually incorporating all zone-level controls and hydronic accessories, greatly reducing on-site labor. They use basic low-pressure duct systems and, in some configurations, no ducts at all. The water loop is uninsulated and requires only two pipes, a supply and return, and can even be designed in a single pipe configuration. The central aspects of the system (pump, boiler, heat rejector) require a minimum of temperature controls and valves. These benefits lead to one of the lowest initial costs among HVAC systems.

Space is maximized; retrofitting is easy. Compact, zone heat pumps can be hidden within ceilings, installed in closets, or directly mounted within the occupied space. The elimination of large central station air handlers and associated ductwork, central chiller plants, and complex four-pipe distribution systems greatly reduces mechanical space requirements. The space-saving attributes, or easy-re-zoning to permit tenant changes also make water-loop heat pump systems ideal for the retrofit of existing buildings, especially historic structures with limited space for mechanical rooms or for mechanical chases above ceilings.

Downtime is minimized. Unlike large central systems, failure or maintenance operations on a water-source heat pump only affect the single zone served. Redundancy is usually provided for the minimal central components of a water-loop heat pump system. This improves tenant satisfaction and reduces the risk of lost rent.

Simpler design. With a wide variety of pre-engineered configurations, water-source heat pumps can easily be selected to fit varying locations and loads. Due to a minimum of controls, basic low-pressure duct systems, and simple piping the design time required for a water-source heat pump system can be much less than that for comparable HVAC systems. Projects can be completed faster and at lower design costs.

Simple control. Control can be as basic as a unit or wall-mounted thermostat for each zone heat pump. If desired, factory-mounted DDC controllers allow zone heat pumps to be directly connected to a central building management system. The only other controls necessary are those needed to maintain the water loop temperature.

Simpler to commission and maintain. Many HVAC systems take months to properly commission due to complex air and hydronic balancing or the debugging of complicated control systems. The simple, straight-forward design of water-loop heat pump systems greatly reduces this process. Zone heat pumps are available with DDC controllers, automatic water flow control valves and other accessories as a factory-assembled and tested unit. Basic low-pressure duct systems require minimal balancing. The systems are also uncomplicated, requiring only basic air conditioning service skills to maintain.

Recent advancements also include the use of zero ozone-depleting HFC-410A refrigerant, further enhancing the operational efficiency of water-to-water heat pumps. Some units use 100% outside air. Other sophisticated systems offer a dehumidification option (see sidebar), allowing designers even greater flexibility when meeting more stringent building requirements. ■

John Vastyan owns Common Ground, a trade communications firm based in Manheim, Pa. His journey into the heart of hydronics is entering its 22nd year.

Product Application

ClimateMaster's ClimaDry™ dehumidification option, allow designers great flexibility in using water-source heat pumps as the solution for today's building design requirements.

The patented ClimaDry dehumidification option is an innovative means of providing modulating reheat without the complication of refrigeration controls. ClimaDry is hot gas generated reheat, which uses one of the biggest advantages of a water-source heat pump – the transfer of energy through the water piping system. ClimaDry simply diverts condenser water through a water-to-air coil placed after the evaporator coil. If condenser water is not warm enough, the internal "run-around" loop increases the water temperature with each pass through the condenser coil.

ClimaDry benefits

The system is like no other reheat option on the market today. Proportional reheat is controlled to the desired leaving air temperature set point (factory set point of 72°F), no matter what the water loop temperature is. Because dehumidification operation usually takes place under less than full load cooling conditions, it's important to have a reheat function that provides 100% reheat in the spring and fall when the water loop is cool. Supply air temperature is field adjustable to +/- 3°F [+/- 1.7°C] for even greater flexibility with the optional potentiometer.

This is a key advantage over standard on/off, non-modulating hot gas reheat (HGR) refrigeration based-reheat circuit systems. HGR needs higher condensing temperatures to work well, typically 85°F [29°C] entering water temperature (EWT). With HGR, cooler water temperatures produce cooler supply air temperatures, which tend to overcool the space, requiring additional space heating from another source or a special auto-change-over relay to allow the unit to switch back and forth between reheat and heating. In most instances, HGR cannot provide 100% reheat, though ClimaDry can, claims ClimateMaster, making it an ideal solution for spaces with high latent loads like auditoriums, theaters and convention centers, and also for spaces where humidity is a problem.

With the ClimaDry option, return air from the space is conditioned by the air-to-refrigerant (evaporator) coil, and then reheated by the water-to-air (reheat) coil to dehumidify the air while maintaining the same space temperature, thus operating as a dehumidifier.

The moisture removal capability of the heat pump is determined by the unit's latent capacity rating. Latent capacity equals total capacity minus sensible capacity. For example, at 85°F [29°C] EWT, the moisture removal capability (latent capacity) of a ClimateMaster GC036 is 9.6 Mbtuh [2.8kW].