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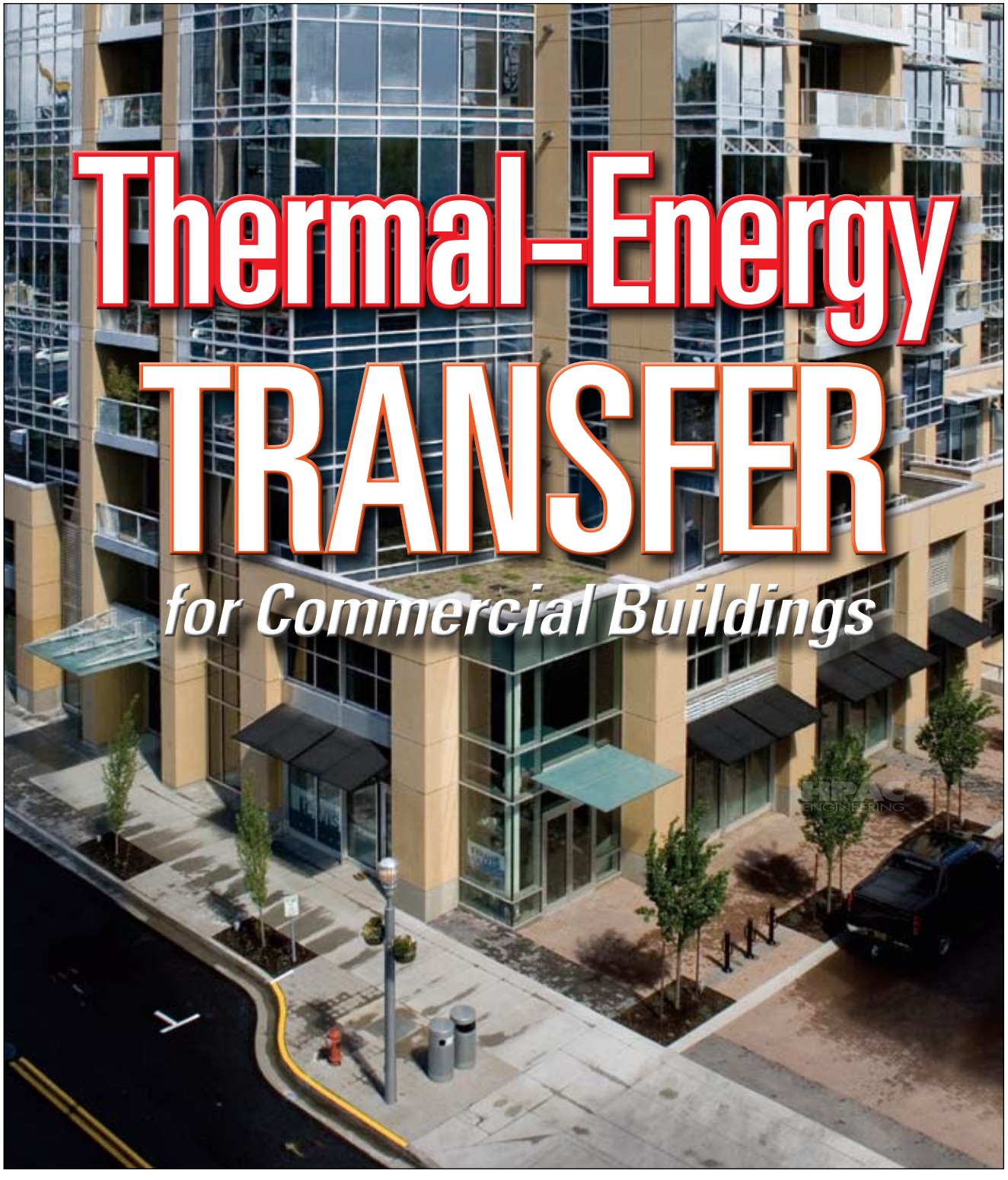

Thermal-Energy TRANSFER

for Commercial Buildings

Thermal-Energy Transfer

for Commercial Buildings

Rising energy costs, growing influence of LEED Green Building Rating System reviving interest in water-loop technology

One of the most rapidly accelerating trends in the commercial-buildings industry—driven by rising energy costs and the growing influence of the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) Green Building Rating System—is the use of water-source-heat-pump (WSHP), or thermal-energy-transfer (TET), systems.

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The latest generation of WSHPs can extract as much as 5 kwh of heat from a water loop for every 1 kwh of electricity used to power a compressor and fan, delivering 6 kwh of heat to the air. This 6-to-1 ratio, or coefficient of performance, can be equated to 600-percent efficiency.

THERMAL-ENERGY TRANSFER

A TET system is comprised of highly efficient heat pumps interconnected by way of a closed water loop. Each pump, using a simple vapor-compression refrigerant circuit, satisfies the air-comfort requirements of the zone in which it is installed.

When heat is needed, the pumps extract thermal energy from the water loop and reject it into the air. When cooling is needed, they extract thermal energy from the air and reject it into the water loop, where it is available for use by other heat pumps in the building, rather than wasted to the outdoors.

Photo courtesy of ClimateMaster Inc.

Water-source heat pump featuring R-410A refrigerant with a scroll compressor.

All buildings contain year-round sources of energy that can be recovered and recycled by a TET system. These include:

- *Lighting*. The electrical energy used for lighting in most structures varies from 1 to 4 w per square foot.
- *People*. Humans emit thermal energy ranging from 300 to 500 Btuh (88 to 147 w per hour), depending on their activity.
- *Equipment*. The energy consumed by computers, printers, copiers, pumps, motors, and the like is emitted as heat.
- *Solar gain*. Perimeter zones with large glazed windows may require daytime cooling, even during cold weather.

The thermal energy recovered by a WSHP system has many uses, including for space heating, water heating (domestic hot water, swimming pools and spas, radiant-heat systems, snow-melt systems), and ventilation.

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WHY WATER?

Water is the most efficient way to move thermal energy. A 2-in. water pipe can carry the same amount of cooling as a 24-in. air duct, while requiring up to 90-percent less transport energy and taking up far less space. Another advantage is thermal storage, provided by the mass of a water loop. Thermal storage allows a substantial amount of heat to be carried from occupied periods into morning warm-up.

WSHP heat exchangers are both compact and efficient. This is because of the high mass and thermal conductivity of water. WSHPs operate at lower condensing temperatures than traditional HVAC systems because, when used with a cooling tower, they are linked to outdoor wet-bulb temperature, and, when used with a ground heat exchanger, they are linked to deep-earth temperature. This leads to higher efficiencies and longer service life.

WSHPs are combined with a heat rejector and a boiler, which are used to maintain the temperature of circulating water within a controlled range—typically, 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 heat pump uses the water loop to provide heating or cooling at any time, regardless of the operating mode of the other heat pumps. This is accomplished with neither the duplicate operation of heating and cooling systems nor the double waste inherent in reheat modes.

Water-to-water heat-pump systems are highly efficient under part-load conditions, such as when a small portion of a building remains occupied after hours. In such cases, only the required zone heat pumps are used.

ENERGY SHARING

To understand the energy-sharing benefits of a TET system, one must understand the interaction of loads in

System Configurations

Vertical stack/high rise. Vertical-stack, or high-rise, units typically consist of a cabinet and a slide-in chassis. The cabinet includes riser piping, a blower section, controls, a drain pan, and hardware for flush-mount installation, while the chassis contains refrigeration components. Such a system can be ducted or ductless. A return-air panel completes the installation.

A vertical-stack/high-rise system offers a number of installation advantages. With piping pre-attached to the cabinet, all that a contractor has to do is connect the risers from the floor below to the floor above. Also, a cabinet can be shipped and installed ahead of a chassis to avoid on-site damage and storage issues.

Servicing a vertical-stack/high-rise unit involves minimal tenant disruption. The chassis can be removed quickly, while all electronics typically are of the "quick-connect" variety, and water connections are made via flexible stainless-steel braided hoses.

Console. Non-ducted console units are suitable for perimeter areas and for single non-partitioned zones, such as motel rooms and hospital rooms. They also are suitable for single or multiple fixed interior spaces. Furnished with a decorative cabinet, they typically are located within the room or space to be conditioned—usually, on the floor at the outside wall.

Vertical water-to-air. Space-saving vertical water-to-air units commonly are used in apartments, condominiums, and core areas of office buildings. Air is distributed through ductwork. Units can be installed where a room acts as a return-air plenum or equipped with return-air ducts. Heavy-density insulation provides acoustic absorption.

Horizontal water-to-air. Ducted horizontal water-to-air units are concealed within ceilings. They come with factory-installed hanger brackets for use with threaded rod and isolation grommets.

To minimize sound, use of a discharge duct—ideally, one attached to the return-air inlet—with at least one change of direction is recommended, as is use of acoustical ceiling tiles.

Large-tonnage horizontal and vertical water-to-air. The capacity of large-tonnage equipment typically ranges from 60,000 to 300,000 Btuh. Vertical units are designed for free-standing application in mechanical rooms and closets with ducted discharge and either ducted or non-ducted return. They are connected to closed water loops and provide either heating or cooling. Horizontal units, with capacities of up to 120,000 Btuh, typically are ceiling-hung.

Water-to-water. Water-to-water heat pumps provide either chilled or hot water while still taking advantage of heat transfer through a building's loop piping system. Typical applications include fan coils/air handlers used to pre-treat outside air, radiant floor heating, snow/ice melt, industrial-process control, and domestic-water heating (usually, with an optional plate-type heat exchanger).

Rooftop water-to-air. Rooftop water-to-air systems provide all of the benefits of packaged water-to-air systems while saving mechanical space. Typically, they are supplied with extended-range water and refrigerant circuits for both water-loop and ground-loop applications. The retrofit of a water-source rooftop unit provides a 40- to 50-percent increase in efficiency over an air-to-air system.

Dedicated outside air. Dedicated-outside-air units allow designers to incorporate an outdoor-air-treatment system into a building. Also, they provide substantial operating-cost savings and work in conjunction with space-conditioning WSHPs. Horizontal, vertical, and rooftop configurations are available in capacities of up to 100 tons. Horizontal and rooftop units also are available with an energy-recovery wheel.

the core and perimeter zones of a building during occupied periods with internal gains and unoccupied periods with temperature setback/setup and few or no internal gains throughout the year. For example, 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 extract 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 typically is one hour or less per day.

• Winter, occupied: Because of internal heat gain, most core zones require cooling. Meanwhile, most perimeter zones require heating. Because heat is rejected into and extracted from the water loop simultaneously, both the boiler and heat rejector are off much of the time. This is the essence of TET: The sharing of energy within the water loop minimizes boiler and heat-rejector operation and provides maximum system efficiency.

Typical Applications

Apartments and condominiums. Applications can be multiunit high-rise or garden-type complexes. Advantages over conventional systems include individual metering, individual-tenant control, lower first cost, lower maintenance costs, diversity of operation, and domestic-water heating.

Hotels and motels. TET systems can provide total comfort for rooms of all sizes, even large public spaces. Regarding hotels and motels:

• Ducted and free-standing WSHPs are designed for quiet operation.

• Individual units protect against complete shutdowns.

• TET systems maximize economy of first cost and minimize operating and maintenance costs.

• WSHPs provide individual guest control.

• WSHPs can provide recreational, restaurant, laundry, and domestic-water heat recovery.

• TET systems can be designed with front-desk control and a low limit.

Photo courtesy of ClimateMaster Inc.

A technician completes the installation of a vertical-stack unit in an upscale condominium.

Schools and dormitories. TET systems are widely specified for school construction and renovation. Benefits include:

• Elimination of tampering and vandalism from concealment of units.

• Individual control.

• Easy adaptation for fresh-air control.

• Night-setback controls and daytime programmed operation.

• Ease of operation and maintenance.

Office and commercial buildings. Most office and commercial buildings contain constant sources of heat that can be recovered easily. To attract tenants, owners and developers can offer individual year-round temperature control with a minimal first cost and low maintenance and

ADVANTAGES

Advantages of water-to-water systems include:

• *Year-round individual control*. Each zone heat pump provides individual temperature control. This means occupants can control heating and cooling around the clock, regardless of the season and what is happening in other zones. Zones served by a single heat pump can be as small as 200 sq ft or as large as many thousands of square feet.

• *Energy savings*. WSHPs provide zone heating and cooling at the highest rated levels of efficiency. The water loop recovers much of the energy needed to heat a building, minimizing boiler use. WSHP systems operate efficiently even at part-load conditions. Also, they 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 cost of operating a TET system is incurred at the zone-heat-pump level, where tenant metering can be implemented. Thus, each tenant pays only for what he or she uses.

• *Quiet operation*. Modern WSHPs operate with great stealth, even when located in occupied spaces. The latest models utilize new compressor technology, variable-speed fan motors, and sound-isolating features.

• *Low initial cost*. WSHPs are factory-assembled and tested and usually incorporate all zone-level controls and hydronic accessories. They use basic low-pressure duct systems or, in some configurations, no duct system at all. The water loop is uninsulated and requires no more than two pipes—a supply and a return. The pump, boiler, and heat rejector, meanwhile, require a minimum of temperature controls and valves. All of this leads to one of

operating costs. Additional tenant and owner advantages include:

- Minimal downtime in the event of malfunction.
- Night-setback controls.
- Programmable daytime controls.
- Off-hour controls.
- Flexibility in partitioning.
- Quiet operation.
- Flexibility in design, meaning spaces can be completed as needed.
- Separate metering.
- Quick installation.
- A two-pipe fan-coil system easily can be converted to WSHPs to heat some spaces and cool others simultaneously.

Shopping centers and malls. Central shopping centers and malls are much like office buildings in that they contain large areas where heat can be recovered. Also, they often have multiple tenants, each requiring its own control. With a TET system, tenant spaces can be metered separately. Also, a TET system provides economy of operation and lower first cost. What's more, large mechanical rooms and ducts are avoided, which translates to more rentable space.

Supermarkets. Today's supermarkets use a variety of refrigeration equipment for the storage, preservation, and display of food. These include ice machines, walk-in freezers, and refrigerated display cases. All of this equipment gives off heat. With WSHPs, this heat can be harvested and used for general store heating or transferred to adjacent stores on the same system.

Computer centers. Computer centers and areas with multiple computer workstations can produce a significant amount of heat. This heat can be absorbed and used in other parts of the building or other buildings altogether. In some cases, enough heat can be recovered from computers to heat an entire complex.

Restaurants. Water-to-water systems can transfer heat to preheat incoming air required to replace air exhausted from kitchen hoods or to make domestic hot water for dish washing.

Medical buildings, nursing homes, and hospitals. Decentralized zoned units provide the diversity required to meet many different patient, clinical-service, laboratory, and diagnostic needs. They are well-suited for medical buildings, nursing homes, and hospitals because of isolated air supply, which prevents room-to-room contamination.

Industrial plants. Most industrial plants have exhaust- and makeup-air needs. A properly designed TET system can take advantage of operational processes to recover heat and use it to maximum advantage.

the lowest initial costs among HVAC systems.

TET systems often cost 10- to 15-percent less to install than traditional two-pipe—and up to 20- to 30-percent less to install than traditional four-pipe—central, chiller-based systems.

• *Maximization of space, ease of retrofit*. As compact as they are, zone heat pumps can be hidden in ceilings or closets or directly mounted in occupied spaces. This, along with simple rezoning, makes water-loop-heat-pump systems well-suited for retrofit applications, particularly historic structures with limited space for mechanical rooms or mechanical chases above ceilings.

• *Minimal downtime*. If a WSHP fails or requires maintenance, only the zone served by that WSHP is affected. With 100-percent redundancy typical for central components, there is little or no loss of service. A vertical-stack unit typically can be repaired, serviced, or replaced within an hour or two. A unit installed above a ceiling may require additional time, but rarely more than a couple of hours.

• *Simple design*. With an assortment of pre-engineered configurations (see "System Configurations" sidebar), WSHPs are appropriate for various locations and loads. Additionally, with minimal controls, basic low-pressure duct, and simple piping, they can be designed faster and more cost-effectively than other HVAC systems.

• *Simple control*. Control can be as basic as a unit- or wall-mounted thermostat for each zone heat pump, or zone heat pumps can be connected to a central building-management system via factory-mounted direct-digital controllers. The only other controls necessary are those needed to maintain water-loop temperature.

• *Simpler commissioning and maintenance*. Many HVAC systems take months to commission properly because of complex air and hydronic balancing and/or the debugging of complicated control systems. The simple, straightforward design of TET systems greatly reduces that process. Zone heat pumps are available with direct-digital controllers, automatic water-flow control valves, and other accessories as factory-assembled and tested units. Meanwhile, basic low-pressure duct systems require minimal balancing and only basic air-conditioning service skills to maintain.

INDOOR-AIR QUALITY

ANSI/ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*, requires significantly larger amounts of fresh outdoor air for buildings. The challenge is how to introduce, condition, and deliver that air. Traditional options such as two- and four-pipe fan-coil systems must be upsized significantly to handle the additional conditioning load. This means larger, more expensive units and piping and larger boilers and chillers. In comparison, water-source systems take up less space and cost less to operate while introducing 100-percent outdoor air.

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