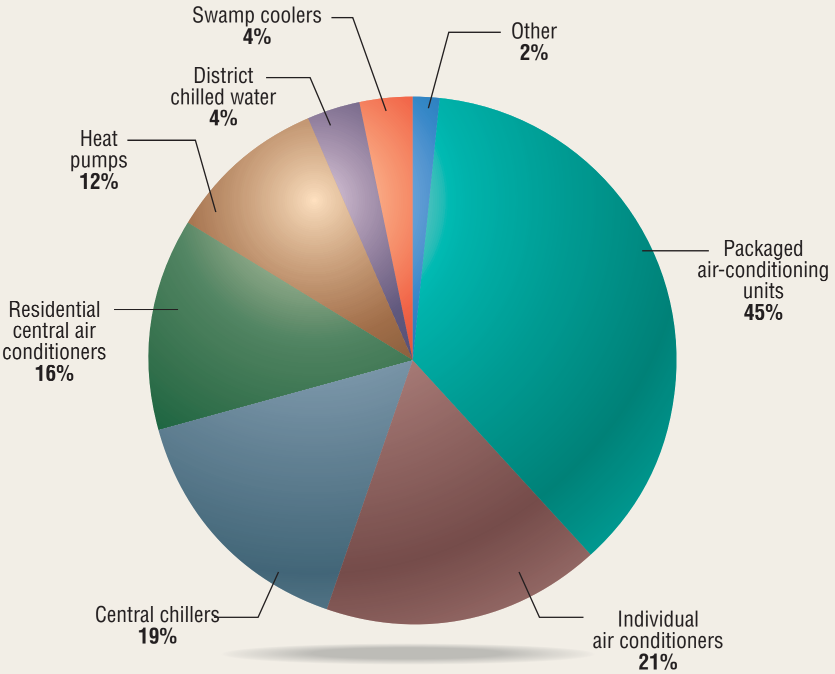
Specifying High-Performance Rooftop Units

By **MIKE WEST, PHD, PE** • Advantek Consulting Inc. • Melbourne, Fla.

The great majority of small- and medium-size buildings are conditioned by package rooftop or split-system air-conditioning units. Unitary HVAC units consist of factory-assembled systems. A typical packaged unit consists of a supply fan and filter, a return-air fan, a heating coil, an outdoor-air intake, and a mechanical-refrigeration system. Packaged equipment consists of one unit containing all components, while a split system consists of two parts: one containing the condensing coil, fan, and compressor (the condensing unit) outside and one with the rest of the components (the air-handling unit) inside. Geothermal heat pumps, sometimes referred to as earth-coupled, ground-source, or water-source heat pumps, are a specialized type of unitary equipment. They use the relatively constant temperature of the earth as the exchange medium instead of the temperature of outside air. This allows systems to reach higher efficiencies on hot days and cold nights.



HVAC unit type as a percentage of floor space.

ENERGY EFFICIENCY

Several manufacturers make special "high-efficiency" units by incorporating improved fan design and efficient motors, higher compressor and condenser efficiency, larger evaporator coils, and improved cabinet designs, among other innovations. "High efficiency" is not strictly defined. Even the best available units may not be sufficient to meet the energy-savings, comfort-control, or maintenance needs of all buildings. In these cases, the careful selection and specification of upgrade options is necessary. A number of terms are used to describe the energy efficiency of air-conditioning equipment. They are:

- Energy-efficiency ratio (EER). EER is

A member of HPAC Engineering*'s Editorial Advisory Board, Mike West, PhD, PE, is principal building-systems scientist for Advantek Consulting Inc.* (www.advantekinc.com)*. His expertise encompasses HVAC problem solving, design consulting, and product development.*

equal to cooling output, measured in thousands of British thermal units per hour (MBH), divided by power rating, or consumption of energy, measured in kilowatts.

• Seasonal energy-efficiency ratio (SEER). SEER is equal to cooling output, measured in thousands of British thermal units (kBtu), during a typical season divided by total electric-energy input, measured in kilowatt-hours, during the same period.

• Integrated part-load value (IPLV). IPLV is a weighted average of efficiency measurements at various part-load conditions. It is equal to an average of kilowatts per ton at four rating points.

• Coefficient of performance (COP). COP is equal to cooling output, measured in British thermal units per hour (Btuh), divided by energy input, also measured in Btuh.

All energy-efficiency ratings are a ratio of cooling or heating delivered vs. power consumed. Various standards dictate which rating is used for a particular class of equipment. EER is used for equipment with capacities greater than 5 tons and is a single-point rating at peak-load conditions. SEER is used for equipment with capacities of 5 tons or less and is an average EER rating during a typical cooling season. Unitary cooling equipment runs more efficiently at lower ambient temperatures, which SEER and IPLV take into account. IPLV and kilowatts per ton typically are used for larger equipment. Heat-pump performance in winter is rated using COP, which is a single-point rating, or heating seasonal performance factor, which is a seasonal average.

The recommended EER minimum for Energy Star buildings is 12. If economically feasible, EER ratings of 14 for air-source units and 16 for ground- or dual-source units should be considered. Operating EER can vary up or down by one point, depending on fan-speed setting and the proper matching of indoor- and outdoor-unit sections. Check these details to ensure rated EER is realized once equipment is operational.

DESIRABLE FEATURES

Certain features improve the long-term operating efficiency and maintainability of unitary air-conditioning equipment. The following features should be considered when specifying new equipment:

• *Easy-to-open access panels.* Hinged, tool-free filter access doors with tight sealing gaskets provide easy maintenance access and reduced air leakage. Panels requiring tools for entry make checking coils and replacing air filters more difficult and less likely to be done regularly.

Hinged access panels that can be opened without tools allow for easier and, likely, more frequent inspections and service.

• *Scroll compressors.* Advances in technology are delivering significantly higher efficiency ratings than traditional reciprocating compressors. Today's best compressors are more efficient, less expensive, and very reliable. New technologies include two-speed motors and inverter-driven variable-speed, scroll, and twin-single compressors.

• *Direct-digital-control interface.* Being able to monitor and even control package units from a central building-automation system (BAS) offers numerous benefits. Most manufacturers offer both open protocol and proprietary digital-control interfaces. If a building has numerous units and/or an existing control system, specify the correct compatible interface.

• *Multistage cooling.* Dual-refrigerant circuits, each with an independent compressor, can track more closely cooling load with frequent cycling, improving longevity and dehumidification. Unless conditions require a second circuit, only one compressor is used, consuming less energy per unit of cooling than a single-compressor unit. Traditional units, particularly those of smaller size, employ one compressor and operate in an "on" or "off" mode. Because equipment is selected to provide needed capacity at full-load conditions, and those conditions occur infrequently, a single compressor is effectively oversized for all conditions less severe than maximum design. This overcapacity leads to short cycling and higher operating and maintenance costs. Similar to an automobile in stop-and-go traffic, an air conditioner's overall efficiency is reduced by excessive cycling. More starts and stops accelerate equipment wear, which can lead to premature failure. Oversized systems use

	Relative cost	Humidity removal 5-ton unit, pounds of water per hour	Sensible-heat ratio sensible/total	Energy-efficiency ratio MBH/kw
Standard	$	30	0.74	13.3
Subcool bypass control	$$	58	0.59	12.0
Fan-speed control	$$$	44	0.66	12.6
Hot-gas reheat coil	$$$$	53	0.42	5.4
Subcool reheat coil	$$$$	54	0.61	12.0
Heat-pipe wrap-around	$$$$$	49	0.64	12.2
Moisture-exchange wheel	$$$$$$	56	0.55	13.3

TABLE 1. A comparison of dehumidification options.

more fan power for blowers and often exhibit more duct leakage because of higher duct pressure.

• *Active dehumidification.* Most package-unit manufacturers offer one or more active dehumidification options, some of which are much more energy-efficient than others. The cost range is considerable. Options that have been available for several years include hot-gas reheat, fan-speed control, subcool reheat, and heat-pipe wrap-around coils. Others that are relatively new include cross-flow moisture exchange and subcool bypass. Table 1 provides a comparison based on manufacturer-published data. Make a selection by balancing first-cost and energy-cost constraints and the project's performance requirements.

• *Filters.* Specify that units be configured to accept and be delivered with 2-in. MERV 8 to MERV 11 pleated air filters, or consider the specification of 4-in.-filter capabilities.

• *Thermostatic expansion valves.* Unlike a fixed-orifice or capillary tube, a thermostatic expansion valve (TXV) adjusts to changes in ambient and load conditions and maintains a unit's high efficiency over a wide range of refrigerant charges. During the life of a system, leaks and losses can reduce charges. The amount of liquid-refrigerant flow through a TXV is optimized automatically by the temperature of the refrigerant leaving the evaporator in relation to the pressure differential across the valve.

• *Check valves.* Solenoid or check valves installed to minimize pressure equalization during off cycles increase seasonal efficiency. A solenoid valve and/or a check valve or a one-way valve in a liquid line leaving a condenser can improve partial-load seasonal efficiency by reducing startup energy.

• *Filter minders.* A dedicated differential-pressure switch illuminates the "service," "check," or "filter" LED on a thermostat or an alarm on a BAS to indicate the need to replace a fully loaded filter before system efficiency is reduced further.

• *Fan drives.* Premium high-efficiency fan motors always should be specified. A one-step inverter can provide a second, lower-speed airflow to match compressor stages at about one-third the cost of full variable-speed capability. Multiple-speed direct-drive blowers preclude belt slippage, but operate less efficiently than variable-speed electrically commutated motors. "Gear" or "cogged" drive belts with belt tensioners are more efficient and last longer than smooth V-belts and pulleys.

• *Coil coatings.* Specifying a corrosion-resistant, anti-fouling coil coating is necessary for units located in air-quality non-attainment areas, downwind of industrial exhaust plumes, and in coastal regions.

• *Economizers.* Economizers provide the correct amount of outside-air ventilation and save energy in moderate climates during shoulder seasons. Sensors monitor indoor- and outdoor-air temperature and humidity. Whenever possible, outside air is used to provide "free" cooling by opening a motorized adjustable damper. Direct-drive systems are more reliable than linkage-driven systems because of fewer moving parts and adjustments.

• *Liquid pressure amplification.* Liquid pressure amplification (LPA), also called liquid refrigerant pumping (LRP), uses a pump to overcome head losses in liquid lines and dryers that otherwise would cause flashing (undesirable refrigerant boiling) ahead of expansion valves. With LRP suppressing flash gas, condenser head set point (temperature or pressure) can be changed to a lower value, generating significant savings. Little, if any, savings will be obtained by applying LRP to units that have floating head control or that do not operate much during the cooler temperature conditions necessary to accrue floating head savings.

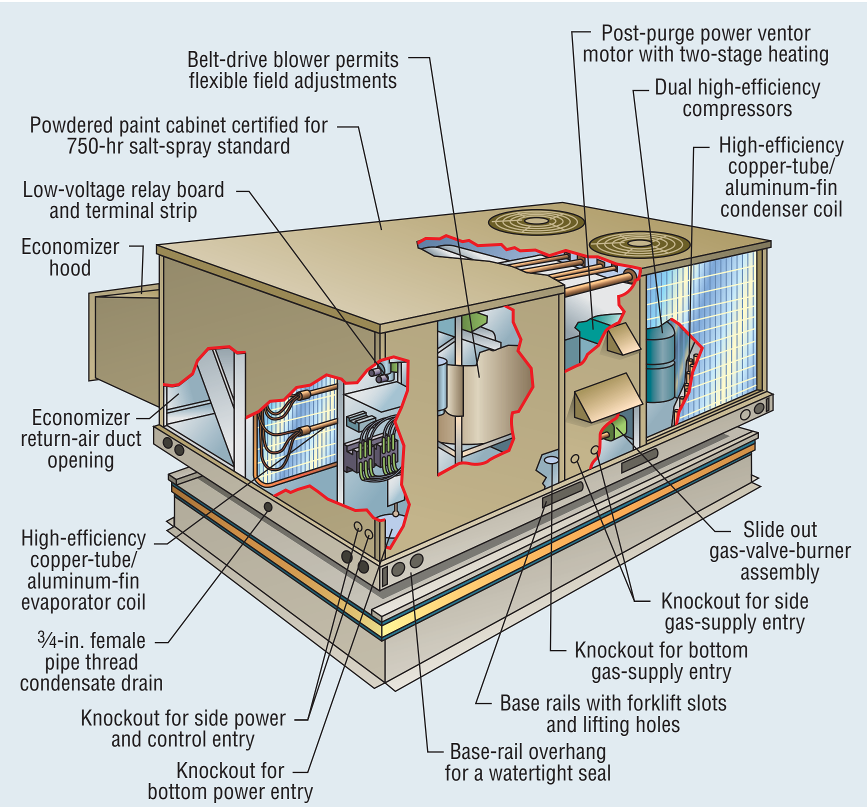
• *Desuperheating and subcooling.* This technology modifies a standard direct-expansion air-conditioning system with heat exchangers in liquid lines and/or hot-gas lines. It works best on hot days and in warm climates. Subcooling, which increases a refrigerant's cooling ability, is achieved with an external mini-cooling tower, evaporative cooling pad, or ground/well source water. Desuperheating, which reduces compressor discharge temperature, lowers compressor power use.

• *Ice storage.* Although the low evaporator temperatures needed for ice making tend to reduce the efficiency of compressors, the overall efficiency of ice storage systems may be higher than the efficiency of conventional packaged rooftop installations. One version of this technology can operate at night, when it is cooler, to meet daytime cooling demand. This flexibility permits a smaller compressor to satisfy a larger peak cooling load. Further, the system can shift the cooling demand to off-peak hours when electricity from the utility is generated more efficiently and at a lower cost.

DUCT CONSIDERATIONS

Air leakage and thermal gains/losses through ducts can rob system efficiency. In many commercial air-conditioning systems, duct systems pass through unconditioned spaces, which has negative thermal consequences. The insulation level of older duct systems tends to be only R-4 to R-6. Leakage rates typically are 10 to 15 percent of total-system airflow. Supply-air leaks lose expensive conditioned air and depressurize buildings, causing uncontrolled infiltration of outdoor air, which is surprisingly common and usually goes undetected. Return-air leaks add to loads and draw air from unintended locations. Flimsy duct construction often allows duct connections and joints to open and large leaks to form over time. Also, sealing between units and roof curbs and between units and ducts sometimes is overlooked during installation.

All of these issues present a strong case to clearly specify that duct systems be well-insulated and tightly sealed. The suggested leakage specification is a maximum of 3- to 5-percent leakage, which can be verified with a simple duct-leakage test performed by a test-and-balance (TAB) contractor. The suggested insulation thickness is 2.2 in. (R-6) to 3 in. (R-8). All joints should be sealed thoroughly and coated with duct mastic.



Desirable features for a rooftop package unit include dual compressors, a large high-efficiency condenser coil, and a direct-drive motorized economizer/fresh-air damper.

TAB AND COMMISSIONING

Although they somewhat resemble overgrown window units, rooftop package units are not "plug and play." Specify that TAB measurements include supply-air cubic feet per minute, fan revolutions per minute, external static pressure, and coil entering-air and leaving-air temperatures. The commissioning of unitary HVAC equipment focuses on documenting design intent, testing systems, correcting deficiencies, and providing operation and maintenance training to building occupants. Incorporating commissioning requirements into specifications is very important because contractors base bids on plans and specifications. Setting the expectation that commissioning will occur saves trouble during the construction process. The heart of the commissioning process is called functional-performance testing. For small packaged units:

- Check and verify the correct refrigerant-charge level. Cycle the unit through all operating modes and observe unit response relative to the control sequence of operation. Verify that the outdoor-air damper closes when the unit is off. Verify that the second compressor energizes and de-energizes as specified.
- Test the economizer and/or fresh-air damper. Verify that the damper actuator works and that the dampers move freely over their full range.
- Check sensor accuracy. Verify that the room, outdoor-air, return, and supply-air temperature; humidity; and carbon dioxide sensors are installed in a reasonable location and are displaying accurate readings. Measure the supply-air temperature.
- Verify the correct rotation of the compressor and supply- and condenser-fan motors.
- Verify the control set points and operating schedules according to the design documents.

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