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Commercial Unitary Air Conditioners

Commercial unitary air conditioners can be one of the largest energy users in a building. Since these systems are notorious for being undermaintained and neglected, you may be able to achieve significant energy savings and improved occupant comfort through operations and maintenance practices. Use these procedures to plan and track your packaged air-conditioner upgrade progress.

SCHEDULING

Schedule equipment to shut off or set back during unoccupied and unnecessary periods.

There's no easier way to save energy than turning off equipment when it's not needed. The savings from turning equipment off varies, but it typically reduces unitary air-conditioner energy consumption by 10 percent. Two of the most common strategies for shutting down equipment are scheduling and lockouts.

Scheduling turns equipment on or off or sets back thermostats depending on time of day, day of the week, or day type. For example, scheduling can prevent needless operation of equipment after hours and on weekends, eliminating one of the largest energy wasters in commercial buildings. A feature called *optimum start*, offered by building automation manufacturers, can further increase energy savings by automatically starting a system no earlier than necessary based on daily weather variations. Additionally, systems can be turned off before all occupants leave the building because temperatures will not change quickly enough to affect occupant comfort.

Lockouts are commonly used in unitary air conditioners to prevent compressors from operating under certain conditions. For example, an air conditioner compressor can be locked out when the outside air falls below a certain temperature. Lockouts may be included with the internal controls, but a better method is to use the building automation system (if it exists).

VENTILATION RATES

Adjust ventilation rates based on usage or occupancy levels.

Many building codes in the U.S. base their ventilation requirements on the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) Standard 62.1, “Ventilation for Acceptable Indoor Air Quality,” which requires that commercial buildings bring in a specified minimum amount of fresh air. To adhere to this standard, the choice made in most buildings is to ventilate at the fixed minimum rate per person based on building type and assumed occupancy (usually the building’s design occupancy). A more energy-efficient way to ventilate for buildings with variable occupancy is demand-controlled ventilation (DCV), which allows building operators to bring in and condition only the air necessary based on the actual occupancy. In a DCV system, sensors monitor the indoor CO_2 levels and send a signal to the HVAC controls to regulate the amount of outside air coming in.

DCV systems save energy by reducing the need to heat or cool outside air. The only system change is the ratio of recirculated air to outside air; fan power is usually unaffected. DCV systems can save from $0.05 to $1.00 per square foot per year, depending on occupancy schedule and climate.

The overall cost for installing DCV has dropped substantially in recent years, opening up new opportunities for savings and spurring changes in some building codes. Also, several HVAC equipment manufacturers now offer DCV-ready unitary air conditioners and variable-air-volume (VAV) boxes. This equipment is shipped with terminals for the CO_2 sensor wires and controls that are preprogrammed to use a DCV strategy. By limiting installation costs to the cost of mounting the sensor and running wires to the air conditioner or VAV box (wireless models are also available), DCV-ready HVAC equipment substantially reduces the cost of DCV.

Use care when planning a DCV retrofit to ensure that adequate air quality is maintained. Of paramount concern is the location and quantity of CO_2 sensors. Although it might be tempting to install a single CO_2 sensor in the return-air duct for the entire building, this could lead to situations where the average CO_2 level is acceptable but the level in specific, highly occupied spaces (such as an especially crowded store or restaurant) is too high. For this reason, it’s typically more effective to install CO_2 sensors in each high-occupant-density or high-diversity space and use them to command the minimum position of their respective VAV boxes. Many energy codes that permit DCV also have required minimum ventilation and airflow rates (such as 0.15 cubic feet per minute per square foot). Be sure to confirm local requirements before

committing to a project.

Some free tools are available to evaluate potential energy savings from DCV:

- Carrier Hourly Analysis Program
- Honeywell Demand Control Ventilation Savings Estimator

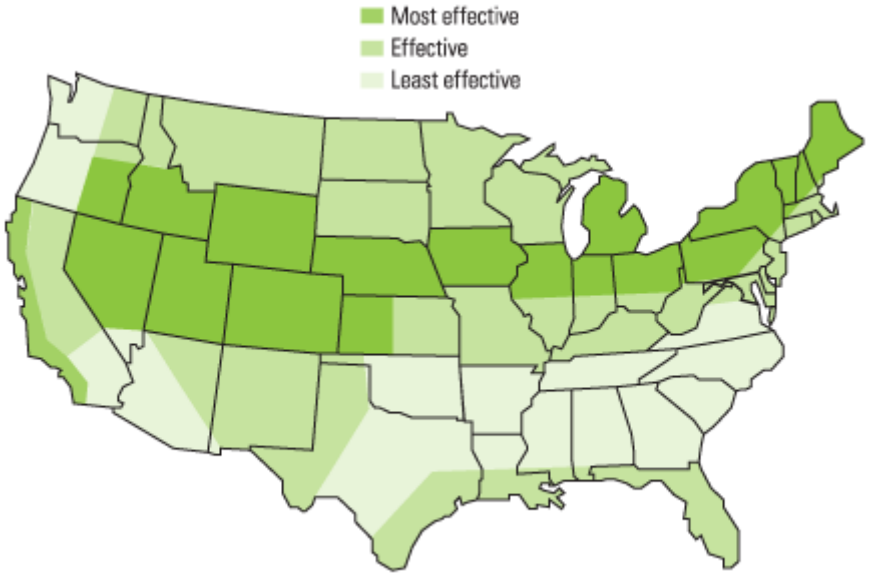
NIGHT PRECOOLING

Use night precooling to save energy and reduce peak demand.

In many climates, temperatures at night are cool even when daytime temperatures exceed economizer limits. With precooling, the air handler and economizer flush the building with night air to cool down the building mass. The cool mass then acts as a heat sink the following day, absorbing heat from internal gains and reducing the amount of energy needed for cooling. **Figure 1** shows the relative effectiveness of night precooling in different climates.

FIGURE 1: Relative effectiveness of night ventilation as a cooling strategy

Night ventilation (precooling) is most effective where nighttime temperatures are low and cooling loads are significant.



Courtesy: Passive Solar Journal

Setting controls for night precooling can save a significant amount of energy depending on your location. Studies indicate cooling energy savings for a typical office building range from 5

percent in Phoenix, Arizona, to 18 percent in Denver, Colorado. Night precooling also reduces peak demand. Simulation analyses show that precooling an 80,000-square-foot, 2-story retail building in Oakland, California, would reduce energy consumption by 13.2 percent of the total energy consumed for cooling and reduce electrical demand by 13.9 percent of the total demand attributed to cooling.

Night precooling has the potential to be more cost-effective than mechanical thermal storage because it eliminates the need for installing pumps and tanks. However, it does require special control hardware and software. This technique also has the additional benefit of introducing extra fresh air to a building, which can improve air quality and raise customer satisfaction.

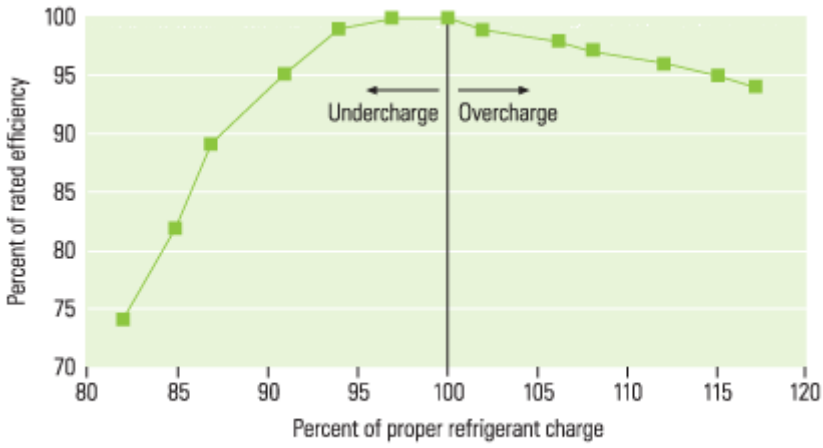
REFRIGERANT CHARGE

Ensure proper refrigerant charge.

Unitary direct-expansion systems often are under- or overcharged due to poor installation and maintenance practices. These units are “critical-charge” systems (there’s no liquid receiver to buffer the flow of refrigerant) and thus are sensitive to the amount of refrigerant in the system. Low or high charge levels reduce the efficiency of the unit (**Figure 2**).

FIGURE 2: The effect of refrigerant charge on efficiency

Undercharging or overcharging can reduce overall efficiency of unitary direct-expansion systems.



Courtesy: The Trane Company

Undercharged systems suffer from reduced energy efficiency and cooling capacity. This is indicated by abnormally low pressures on both the high- and low-pressure sides of the

system, frosting on the evaporator entrance, a warm suction line, a cool liquid line, warm supply air, or continuous compressor operation. In an undercharged system, the evaporator is starved for refrigerant—and what refrigerant does make it into the evaporator is boiled and superheated quickly by the supply air. Undercharged systems usually result from a leak.

In an overcharged system, cooling capacity and energy efficiency decline, but not as severely. Excess liquid refrigerant backs up in the condenser, which increases head pressure. This in turn makes the compressor work harder to provide the same amount of cooling and can potentially damage the compressor.

Overcharging is common for a couple of reasons:

- *Incorrect charging method.* Systems are often charged on a cool day to the recommended design pressures for both the high and low sides. Without using the “blanket trick” (see the section on capillary tube systems), the unit will be overcharged.
- *Air-side problems.* If reduced air flow causes ice to form on the evaporator coil, a technician may add refrigerant to raise system pressures and melt the ice. This “corrects” the icing problem, but it also overcharges the unit.

There are at least a half-dozen methods to ensure proper refrigerant charge, ranging from measuring the length of sweating pipes to peering into sight glasses (small portholes in the liquid line). However, engineers and experienced technicians generally agree that the most accurate way to check and correct refrigerant charge is to measure the superheat and subcooling. How to do this varies based on the type of refrigerant-metering device in the unit.

Capillary tube systems. A capillary (cap) tube is a long constriction in the refrigerant pipe, separating the high-pressure condenser from the low-pressure evaporator. These systems can be charged simply by measuring superheat. However, condensing pressure must be at the design level. For example, on a cool day the condenser runs at a lower pressure, so less liquid refrigerant flows into the evaporator and superheat increases. One way to avoid this problem is the blanket trick: Use blankets, plastic sheets, or cardboard to restrict air flow into the condenser. This artificially raises condenser pressure to design conditions and allows accurate superheat measurement. Another approach is to correlate proper superheat with ambient temperature using tabular data from the manufacturer.

Thermostatic expansion valve (TXV) systems. Expansion valves are common in units 10 tons and larger. A TXV automatically adjusts refrigerant flow to achieve correct superheat. If

refrigerant charge is very low, the TXV stays fully open and superheat will be very high. As refrigerant is added, superheat drops to the proper level and the TXV begins to control refrigerant flow. Once this control is accomplished, the correct charge must be determined by adjusting the liquid refrigerant's subcooling to the correct level—usually about 10° to 15° Fahrenheit. So with TXV systems, both superheat and subcooling must be checked.

Be aware that measuring superheat and/or subcooling is often not done because it's not the simplest task. Superheat and subcooling concepts are often misunderstood, the measurements are only meaningful when correlated with loads on the condenser and evaporator, and measuring superheat requires patience. Therefore, it will take an experienced and motivated person to ensure that this approach is taken.

ECONOMIZERS

Ensure proper economizer operation.

Economizer commissioning and maintenance are vital to proper operation and energy savings. A large number of newly installed economizers don't work properly, and problems increase as they age. The New Buildings Institute compiled the results of several field studies conducted between 2001 and 2004 in the western U.S. in a report for the Northwest Power and Conservation Council and Regional Technical Forum. It found that out of 503 rooftop HVAC units, 64 percent had failed or maladjusted economizers.

Economizers fail for a variety of reasons—ranging from faulty mechanical components (such as stuck or broken linkages) to improper control settings. To make matters worse, malfunctioning economizers often waste much more energy than they were intended to save. If an economizer breaks down when its damper is wide open, peak loads can shoot up as cooling or heating systems try to compensate for the excess air entering the building. A computer simulation of an office building in arid Phoenix, Arizona, shows that a damper permanently stuck in the wide-open position could add as much as 80 percent to that building's summer peak load—assuming the building had enough cooling capacity to meet the higher load.

Using robust controls and a regular maintenance program can increase the likelihood that economizers function as intended. Before calling an HVAC expert to test the economizer, building operators can conduct four general tests to determine whether the economizer requires additional troubleshooting. For details, see "Outside Air Economizers: Making Them Work Right for You" (PDF), a Eugene Water and Electric Board Tech Brief.

Note that all economizers are not created equal. The simplest and most common type is the basic drybulb economizer that controls the outside-air damper based on a specified temperature setpoint. An enhancement to this approach is an enthalpy (or total energy content) economizer, which accounts for both the temperature and the humidity of the outside air and can improve energy savings by not cooling with outside air under high-humidity conditions. One of the most advanced economizer control strategies available today is a *differential enthalpy* system, in which two enthalpy sensors are installed—one for the outside air and the other for the return air. Under the differential control strategy, when there's a need for cooling the system preferentially uses whichever air source (outside or return) has lower enthalpy.

It was recently discovered that one of the most widely used economizer drybulb sensors, the Honeywell C7650, has operational problems and should be replaced. As documented in "Commercial Rooftop HVAC Energy Savings Research Program—Bench Test Report" (730 KB PDF), the New Buildings Institute found that this sensor activated economizer operation at lower outdoor temperatures than expected. This problem has likely been reducing economizer performance in dry climates with limited nighttime temperature swings. Honeywell redesigned the sensor to mitigate these problems, and a replacement model is now available as the C7660A.

ZONE-LEVEL EQUIPMENT

Adjust zone-level equipment to maintain performance.

As facilities age, zone-level equipment often falls out of calibration or into disrepair, impairing its ability to provide comfort and undermining overall system performance. Fixing zone-level problems can lead to more comfortable occupants as well as upstream energy savings. Zone-level equipment consists of zone-mixing dampers such as double-duct mixing dampers and variable-air-volume (VAV) mixing boxes, hot water or electric reheat coils, and thermostats that control this equipment in response to user preferences. There are many common energy-saving opportunities to consider at the zone level.

Recalibrate thermostats. In systems with pneumatic controls, the thermostats periodically require recalibration—typically every 6 to 12 months—to regulate space temperature more accurately. Thermostat calibration should be checked if there are comfort complaints, but it's preferable to evaluate the thermostats on a regular basis as a proactive maintenance measure.

Test damper operation. For systems with zone dampers, periodically perform functional testing for the damper, linkage, and actuator to ensure proper operation. In older buildings where maintenance has not been rigorous, it's likely that some of the zone dampers are frozen in position, rendering them ineffective at regulating comfort. Because evaluating and repairing nonfunctional zone dampers can be time-consuming and costly (especially in large malls that may have hundreds of zones), consider allocating a portion of the annual maintenance budget to evaluate a certain portion of common-area and tenant VAVs per year. For example, in a facility with 100 VAV zones, the maintenance budget might include time and money to evaluate 25 VAV zones per year.

Ensure proper reheat operation. In zone-level reheat systems, evaluate performance to maintain comfort and prevent excessive energy use. For hot water reheat systems, verify operation of the hot water reheat valve to ensure that it opens and closes in response to control system commands. Check the coil itself to confirm that water is flowing through when it's supposed to and that the coil isn't clogged. Confirm the sequence of operation to make sure the reheat coil only operates when it's supposed to.

For a single-duct VAV system, the reheat coil typically operates after the VAV damper has reached its minimum airflow position while the zone is calling for heat. If the reheat system is electric, verify proper operation of the coil in response to system commands. Verify the capacity of the electric coil by measuring its input power with an amp probe or true root-mean-square power meter. Compare the calculated value with the nameplate value. If the calculated value is much lower than the nameplate value, the coil may have burned-out elements and may require replacement.

Disable reheat systems where applicable. For constant-volume reheat systems, consider whether the zone-level reheat systems can be disabled during the summer. Some facilities with electric reheat systems have successfully shut off the reheat coils at the breaker during the cooling season, leading to significant energy savings. In conjunction with this change, it may be necessary to adjust the supply-air temperature to avoid overcooling certain spaces. It may also be necessary to leave the reheat coil breakers active in certain spaces (such as interior zones) to maintain comfort.

For multistage terminal units, consider permanently disconnecting the highest stage in milder climates because it's rarely needed. Another option, especially in areas with high electrical demand charges, is to use the building automation system to limit the number of reheat coils that are on at one time, cycling through different areas in a building. This is particularly applicable when equipment that was scheduled off is restarted, but could also be done to

some extent during the day—focusing first on satisfying the biggest loads, then cycling on the reheat for other parts of the building. This can significantly reduce peak demand without sacrificing comfort.

Regulate static pressure. Dual-duct systems typically include static balancing dampers for the hot and cold ducts (also called hot and cold “decks”). The purpose of static balancing dampers is to regulate the static pressure in the hot and cold ducts in response to zone demands. Over time, these systems (consisting of a static pressure sensor, damper, actuator, and linkage) can fall into disrepair. Failure of the static balancing dampers can cause significant energy waste and discomfort. For example, if the static balancing damper for the cold duct is stuck in a nearly closed position, none of the zones will have an adequate source of cold air—leading to overheating.

COILS

Clean condenser and evaporator coils.

To maintain efficiency in a vapor-compression cooling system, it’s important to keep condenser and evaporator coils clean. Dirt on the evaporator coil causes two problems: It reduces system airflow and it directly degrades the coil’s heat-transfer efficiency (which significantly cuts cooling capacity). As with clean filters, clean coils produce less airflow resistance than dirty ones. Although cleaned coils can increase fan speed and thus fan energy use, it produces a net energy savings for the system.

A 1999 study by the Proctor Engineering Group estimates that unmaintained condenser coils will gradually degrade unit efficiency by 5 percent over 17 years, but by up to 30 percent over 20 years. Unmaintained evaporator coils will degrade unit efficiency by 2 and 6 percent, respectively, over the same time periods. However, harsh environments or high equipment loading can shorten these time periods by a factor of three.

Inspect the evaporator coil at least annually to make sure the filters are doing their job. Shining a light through a coil is one way to inspect it, although wavy “enhanced” fin designs can make this type of check difficult. Another approach is to measure supply-fan amperage and filter/coil pressure drop (with fresh filters). If the amps are lower and the pressure drop is higher than last year’s measurement (also with fresh filters), then the coil is dirty and needs to be cleaned.

Unlike the evaporator coil, the condenser coil is exposed to unfiltered outdoor air and collects more dirt as a result. Thus, cleaning a dirty condenser is typically one of the most cost-

effective energy-efficiency practices available for rooftop unit maintenance. If a dirty coil reduces the cooling ability of the air blowing across the condenser coils such that the condensing temperature is raised from 95° to 105°Fahrenheit, then cooling capacity will be cut by 7 percent and power draw will increase by 10 percent.

The best tool for this maintenance job is a power washer that feeds cleaning solution into a high-pressure water flow. Some companies specialize in performing this type of cleaning for a competitive price. They typically use tank trucks and custom self-contained equipment. Spray-on cleaning solutions intended to be used with a brush and a hose will not do a good enough job cleaning the coils, even though they may brighten the outer surface. A rigorous condenser cleaning requires before-and-after measurements of the temperature difference across the coil to verify the effectiveness of the cleaning. These measurements should be included in a report to the owner or supervisor. Power washing, if done improperly (for instance, using the wrong spray angle or excessive pressure), can damage coils by bending the fins—or even breaking them off if the coil is old. This cleaning task isn't complicated, but it should be done only by those trained in the proper use of the necessary equipment.

FILTERS

Clean filters.

Filters play two important roles: They help maintain indoor air quality and they protect downstream components of an air-handling system (the evaporator coil and fan) from accumulating performance-crippling dirt. As with clean coils, clean filters produce less airflow resistance than dirty ones. Cleaning them can increase fan speed and thus fan energy use, but it also allows for proper airflow to facilitate heat transfer from the coils. As needed, also inspect and clean the inlet screens that filter large debris for the outdoor air ducts.

Filter-change intervals can be based on the pressure drop across the filter or, more commonly, based on calendar scheduling or visual inspection. Scheduled intervals should be one to six months, depending on the pollutant loading from indoor and outdoor air. More frequent changes may be required during the economizer season because outdoor air is usually dirtier than indoor air.

Measuring pressure drop is the most reliable way to rate filter loading. However, this approach requires some effort because most rooftop units don't have built-in pressure taps. You can make taps by drilling into the cabinet wall and installing quarter-inch tubing with removable caps. A technician can then use a hand-held pressure meter or manometer to check filter status (to get accurate readings, cabinet access panels must be shut tightly, with all screws

replaced). In facilities with predictable and regular filter loading, pressure measurements can be used to establish the proper filter-change interval; thereafter, filter changes can simply be scheduled.

Automated pressure tracking is a further step in filter management. It makes the most sense for very large rooftop units (20 tons or larger) and for large, custom-built air handlers. There are two ways to track pressure automatically:

- Install transducers that feed pressure-drop data to a building automation system so that building operators can inspect the data or respond to an alarm triggered when pressure drop exceeds the design limit. Unfortunately, this strategy has a long payback when applied to small rooftop units because high-precision pressure transducers are costly.
- A less expensive option is to use a differential pressure switch that flips from “off” to “on” at a certain pressure difference across the filter. However, these switches require time and care to calibrate, and one experienced service technician tells us that they cause more problems than they solve.

When changing filters, also be sure to inspect the frame and clips. It’s essential to use correctly sized filters with the spacers in place, and if clips are used, none are missing. If there are any areas not covered by a spacer, frame, or filter, the air will “short-circuit” and introduce dirty air into the interior of the unit.

FANS

Verify fan/motor assembly performance.

After cleaning the coils and filters, verify that the motor amperage is as expected. If there’s a discrepancy, this could indicate that the motor is failing or the fan assembly needs maintenance.

ROOFTOP UNITS

Replace existing rooftop units with new high-efficiency models if they are old and in need of substantial repairs.

Efficiency levels for packaged rooftop units (RTUs) have gradually increased over the past 15

years, so it's worthwhile looking at existing equipment with an eye towards a high-efficiency upgrade. In the small size range for example, the number of units with an energy-efficiency ratio (EER) of at least 10.4 has grown from only 14 percent of available models in 1993 to at least 65 percent of available models in 2007. Units in this size range now have EERs as high as 12.7, so upgrading an older unit to a new high-efficiency model can produce substantial long-term energy savings.

Especially in warmer climates, high-efficiency units have the potential to provide significant reductions in lifetime energy costs and can recover their incremental costs quickly—in as little as two years (**Table 1**). Based on the most recent data available, 7-ton units with an EER of 11 have an incremental cost of around $550 compared to standard 8.9 EER units. Note that since packaged RTUs are primarily used for cooling, those that also provide heating generally don't offer a high-efficiency option for the heating component.

TABLE 1: High-efficiency RTUs are most cost-effective in warmer climates

High-efficiency rooftop unit systems (RTUs) have relatively high incremental costs, but they save money through their reduced energy consumption. When replacing an aging RTU with a new 7-ton unit, you can recover the incremental costs of purchasing a high-efficiency 11-EER unit over a standard 8.9 EER unit. Warmer climates yield paybacks in less than 3 years while cooler climates yield longer paybacks. This calculation assumes a $550 incremental cost of the high-efficiency unit and an electricity rate of $0.10 per kilowatt-hour.

City	Standard-efficiency RTU (8.9 EER) annual energy consumption (kWh)	High-efficiency RTU (11.0 EER) annual energy consumption (kWh)	Annual electric cost savings at $0.10 per kWh ($)	Simple payback (years)
Tampa, Florida	14,591	12,051	253	2.2
Austin, Texas	13,902	11,466	243	2.3
Chicago, Illinois	4,538	3,811	72	7.6
New York, New York	4,501	3,779	72	7.6
Los Angeles, California	2,135	1,758	37	14.8
Seattle, Washington	1,470	1,247	22	22.0

Notes: EER = energy-efficiency ratio; kWh = kilowatt-hour

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Replacing existing RTUs with high-efficiency units can make economic sense, especially as existing units near the end of their typically 15-year life expectancies. Older units are not only inherently less efficient, but their efficiency generally decreases with age. In addition, you'll not only see an overall drop in energy consumption when you replace aging equipment, you'll also increase system reliability and reduce summer peak demand charges. An HVAC design

consultant can use building simulation software to conduct an analysis that accounts for local weather variations throughout the year and part-load equipment performance.

Many RTUs are manufactured to meet minimum efficiency standards established in 1992. However, standards for three-phase equipment under 65,000 Btu per hour capacity were raised by the Energy Independence and Security Act of 2007 to match the existing levels for single-phase equipment in this size range, effective June 2008. In addition, the Energy Policy Act of 2005 will raise the minimum efficiency levels by 25 to 30 percent for RTUs between 65,000 and 760,000 Btu per hour capacity, effective January 1, 2010. Both Energy Star and the Consortium for Energy Efficiency (CEE) have established efficiency specifications for high-efficiency RTUs that are about 25 percent greater than the current federal standards, but will likely be updated after the federal minimum standards are increased.

To identify high-efficiency models, consult the following:

- The Air–Conditioning, Heating, and Refrigeration Institute (AHRI) is the main source of information about energy-efficient RTUs. AHRI maintains an Online Certifications Directory (available in both print and electronic formats) that includes products from all AHRI member-manufacturers.
- The CEE maintains an easy-to-use Directory of ARI-Verified Equipment that lists RTUs with capacities less than 65,000 Btu per hour using both three-phase (commercial) and single-phase (residential) power.
- Energy Star also establishes criteria for high-efficiency commercial air conditioners and provides a list of qualified units at Light Commercial Heating & Cooling .

A number of utilities offer incentives for commercial customers who purchase energy-efficient RTUs. These rebates are often based on the Tier 2 standards created by the CEE High-Efficiency Commercial Air Conditioning and Heat Pump Initiative. Rebate programs typically pay customers around $30 per ton for high-efficiency units larger than 65,000 Btu per hour.

When replacing an RTU, be sure to inspect the air distribution system, including the ductwork and terminal systems where feasible, to ensure that the performance of your new equipment isn’t undermined by other system deficiencies.

EVAPORATIVE COOLING

Install a direct evaporative cooler to cool the supply air.

Direct evaporative coolers blow air over a wet surface. Heat in the air evaporates moisture from the surface, thereby lowering the air temperature. Although these systems typically use less than a quarter the energy of vapor-compression air conditioners, they're often restricted to industrial or warehouse applications in drier climates because they add moisture to the building air supply. Their suitability for a particular application depends on the cooling load and the range of outdoor wetbulb temperatures (a metric that incorporates both the temperature and humidity level of the air). Because evaporative cooling requires a moving air stream, an equal amount of indoor air must be exhausted from the building as is being supplied.

When comparing direct evaporative coolers, the most relevant metric to use is the *effectiveness* of the unit. Effectiveness is a term that quantifies, as a percentage, how close to the wetbulb temperature the unit can reach. Air that reaches 100 percent relative humidity in an evaporative process emerges at the wetbulb temperature, the theoretical limit for direct evaporative cooling. The effectiveness of such a (rare) cooler would be 100 percent. Achieving more than 90 percent effectiveness in a direct cooler is difficult, requiring very thorough mixing of water and air. Most evaporative air coolers operate with 70 to 90 percent effectiveness using wetted fibrous or corrugated pads or media.

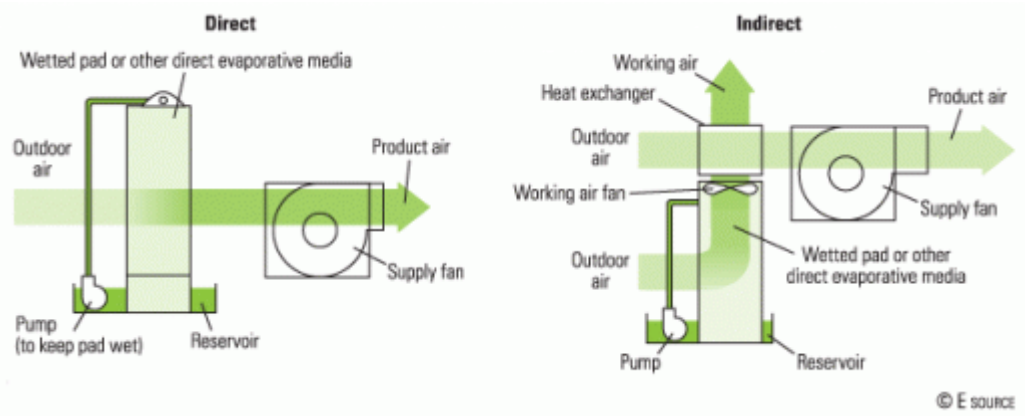
Install an indirect evaporative cooler to cool the supply air.

Indirect evaporative coolers use the evaporative cooling process without adding moisture to the building supply air. This makes them suitable for a wider range of applications including offices, and they can be combined with traditional compressor-based systems. They can take a couple of forms:

- *Self-contained indirect cooler.* The building supply air (or primary airflow) flows through a crossflow heat exchanger toward the second stage. The building exhaust air (or secondary airflow) is evaporatively cooled and passed through the other side of the heat exchanger, thereby removing heat from the supply air (**Figure 3**). This approach can be used in many climates because the outdoor humidity levels don't significantly affect the evaporative cooling process.
- *Tower/coil approach.* A cooling tower produces cool water that's fed to a separate finned cooling coil in the supply airstream.

FIGURE 3: Direct and indirect two-stage evaporative coolers

A direct evaporative cooler adds moisture to the building supply air, whereas an indirect evaporative cooler does not. A two-stage or indirect-direct evaporative cooler uses an indirect stage first before passing the building supply air through a direct stage. The darker colored arrows indicate that moisture has been added to the airstream.



Install a two-stage cooler to cool the supply air.

Two-stage or indirect-direct evaporative cooling (IDEC) employs both an indirect and a direct stage, as its name implies, and thus can produce air cooler than possible with either stage alone. The first stage uses an indirect cooling section to cool the air without adding moisture. The air is then directly evaporatively cooled in the second stage. This produces air at a temperature lower than the outdoor wetbulb temperature, which is not possible with direct evaporative cooling alone. Because the two-stage approach introduces less moisture to the air than direct evaporative cooling alone, it can be used in more building types. But because IDECs still rely on the evaporative cooling process, they work best in dry western U.S. climates. To ensure that peak cooling needs are met, especially on humid days, enlist the help of a HVAC designer to properly specify system components.

Install a direct evaporative cooler to precool condenser air.

Evaporative condenser air precooling systems have been available for many years for both small and large air-cooled systems. Large units typically use flat rectangular rigid-media blocks with a sump and pump placed over the intake side(s) of the condenser coil. These types of systems can theoretically provide much of the same savings as evaporative condenser air conditioners, although there’s no independent research to quantify their savings potential.

Directly cool condenser air and indirectly cool supply air with the DualCool.

The DualCool employs two different approaches in one design intended for packaged rooftop units 15 tons or larger. It uses a direct evaporative cooler to precool the condenser air and an indirect evaporative cooler to precool the building supply air. As with other evaporative coolers, the DualCool works better in drier climates. Originally designed by the Davis Energy Group, an HVAC consulting firm, it’s now offered by Integrated Comfort Inc.

A 2003 study by the Heschong Mahone Group consulting firm provides some savings estimates for the DualCool. The study estimates that units in Fresno, California, (a hot, dry climate) and Santa Rosa, California, (a milder, more humid climate) delivered annual energy savings of 24 and 16 percent, as well as demand savings of 0.43 and 0.19 kilowatts per ton, respectively.

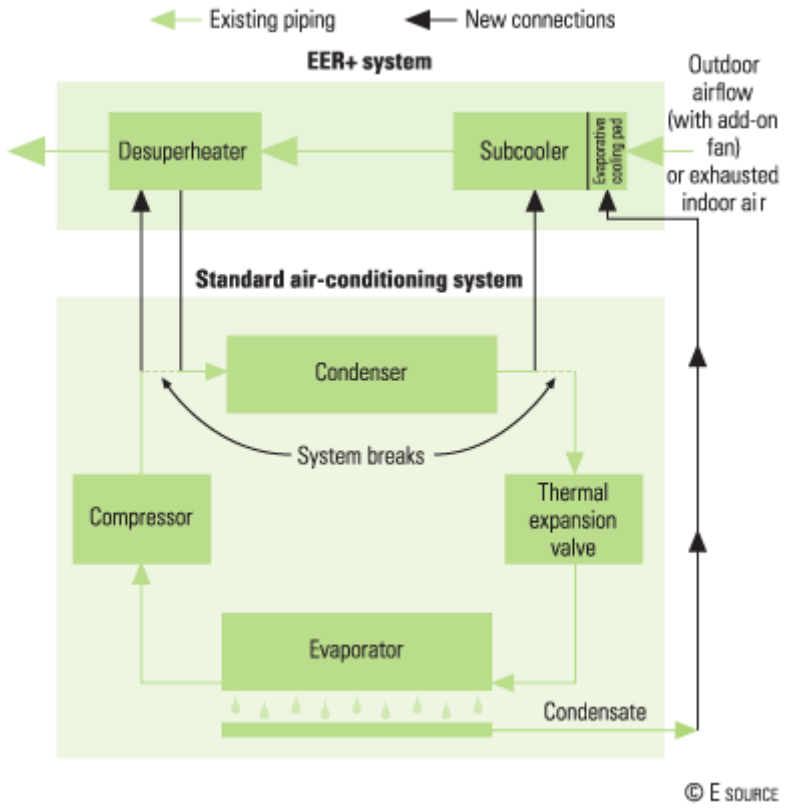
Desuperheat and subcool refrigerant with the EER+.

The EER+ is a heat-exchange module that can be attached to both existing air-cooled air

conditioners and heat pumps to increase their efficiency. Manufactured by Global Energy Group, the module works by capturing waste condensate water from the RTU and routing it over evaporative cooling pads; building exhaust air or outdoor air is blown across the pads (**Figure 4**).

FIGURE 4: EER+

In the EER+ module, an evaporative cooling pad uses condensate water to subcool and desuperheat the refrigerant.



The resulting evaporative cooling removes superheat from the air conditioner refrigerant after the compressor and subcools it after the condenser—thereby increasing the efficiency and capacity of the system. Most climates can use the EER+ if the exhaust air from the building is used because outdoor humidity will not significantly affect the heat exchangers. However, when using outdoor air in humid climates, the efficiency increase will not be as great as it is in dry climates.

The EER+ system can boost energy savings by as much as 40 to 50 percent, but the efficiency gains depend on the efficiency of the existing system: The lower the efficiency of the existing system, the more benefit the EER+ can offer.

The EER+ costs from $400 per ton to $1,100 per ton installed, depending on the size of the

unit (smaller units are more expensive per ton). It's available in capacities from 6 to 100 tons. Larger capacities can be accommodated by connecting multiple units. Paybacks vary based on the cooling load of the building.

DEHUMIDIFICATION

Install a hybrid desiccant air-conditioning system.

Desiccants dehumidify air and can be regenerated through heating to drive out the absorbed moisture. The heat used for desiccant regeneration generally comes from gas, steam, or waste heat from the building—and the cost of this heat is typically much lower than the cost of electricity used for conventional dehumidification.

Traditionally, desiccant systems have been targeted to humid climates or to applications that require tight control over humidity—like hospitals, museums, and supermarkets. But new hybrid air-conditioning/desiccant systems are more efficient than previous desiccant technology. The higher efficiencies, coupled with changing building standards, are now making such systems appealing for applications where humidity control is still important but less critical—such as restaurants and office buildings.

Changing building standards are making desiccant systems more appealing now for two reasons. First, to meet code, some buildings are admitting more outdoor air than their original design specified, leading to a larger need for humidity control. Second, where increasingly stringent energy-efficiency standards make the sensible (dry-air) cooling load lower than the humidity load, it's more challenging to handle humidity.

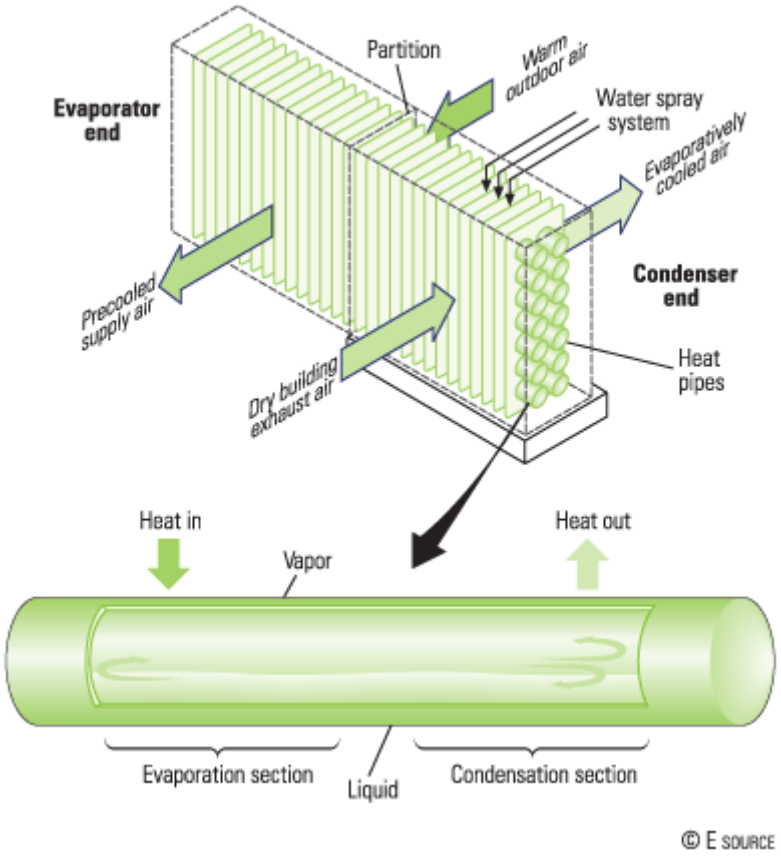
For example, ASHRAE (the American Society of Heating, Refrigerating, and Air-Conditioning Engineers) Standard 90.1, which is often adopted directly or indirectly in local building codes, has increased many efficiency requirements compared with the standards in place before the 1990s. Most of these changes have reduced the sensible cooling load (the portion of a building's heat load unrelated to humidity) but not the latent cooling load (the portion of a building's heat load contained in the moisture in the air). For instance, efficient lighting required by newer standards gives off less heat, but it doesn't reduce the moisture content of the air. A sensible load that's much lower than the latent load makes it more challenging for conventional air conditioners to condition the air properly without increasing energy use. Desiccant systems offer another way to meet these challenges.

Install heat pipes.

Heat pipes are another technology that can be used with unitary air conditioners to dehumidify the air in humid climates, yet still cool the air efficiently. They consist of multiple finned tubes that connect two heat exchangers—one located on each side of the air conditioner's evaporator coil (**Figure 5**). Each heat-pipe tube contains a fixed amount of working fluid that's been sealed in at a specific pressure. These fluids are typically refrigerants, but other fluorocarbons and even water can be used, depending on the application.

FIGURE 5: Indirect evaporative cooling with a heat pipe

If one end of the heat pipe is in a dry airstream (summer ventilation air entering a building, for example) and the other end is in an evaporatively cooled stream of building exhaust air, heat pipes can efficiently cool the ventilation air without adding moisture.



As supply air passes through the evaporator end of the heat pipe, the tubes precool the air by absorbing heat. The precooled air then passes through the air conditioner's evaporator, which can remove about 90 percent more water than a conventional evaporator. After the heat pipe refrigerant absorbs the heat, it travels to the condenser section to release the heat and then cycles back to the evaporator section to continue the dehumidification process.

Note that these systems are not frequently installed and would require a payback analysis to verify their cost-effectiveness.

Install heat-recovery devices.

Heat recovery is one of the most effective ways to optimize energy efficiency for buildings that require high levels of ventilation and that have high heating loads. Exhaust air from the HVAC system is a primary source of useful waste heat. Transferring the energy from the exhaust air to the incoming outdoor air reduces the energy required to condition the incoming air.

Several heat-recovery technologies are available, including rotary heat wheels, plate-and-frame heat exchangers, runaround coils, and heat pipes—each suited to specific applications. Consult vendors and engineers to determine the best match for a given building. Depending on the application and technology type, these systems can reclaim more than half of the heat that would otherwise be lost, significantly reducing the amount of heating energy required. To justify installing a heat-recovery device, a thorough payback analysis must be conducted.

BUILDING AUTOMATION SYSTEMS

Install a building automation system.

The building automation system (BAS) has become the accepted technology used in controlling HVAC as well as other systems. Existing buildings can be retrofitted with a BAS, which has been shown to provide economically beneficial improvements in energy efficiency and occupant comfort. A BAS can save an average of about 10 percent of overall building energy consumption, and for older or poorly maintained buildings, the savings can be even greater. In addition to saving energy, these systems may also reduce overall building maintenance costs.

Many existing older-generation BASs only have start/stop control capabilities. For better control over a unitary system, consider expanding the existing system by adding more control points to monitor supply air, return air, and zone temperatures.

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