Related Commercial Resources

CHAPTER 49

ROOM AIR CONDITIONERS AND PACKAGED TERMINAL AIR CONDITIONERS

ROOM AIR CONDITIONERS

ROOM air conditioners are encased assemblies designed primarily for mounting in a window or through a wall. They are designed to deliver cool or warm conditioned air to the room, either without ducts or with very short ducts (up to a maximum of about 48 in). Each unit includes a prime source of refrigeration and dehumidification and a means for circulating and filtering air; it may also include a means for ventilating and/or exhausting and heating.

The basic function of a room air conditioner is to provide comfort by cooling, dehumidifying, filtering or cleaning, and circulating the room air. It may also provide ventilation by introducing outdoor air into the room and/or exhausting room air to the outside. Room temperature may be controlled by an integral thermostat. The conditioner may provide heating by heat pump operation, electric resistance elements, or a combination of the two.

Figure 1 shows a typical room air conditioner in cooling mode. Warm room air passes over the cooling coil and gives up sensible and latent heat. The conditioned air is then recirculated in the room by a fan or blower.

Heat from the warm room air vaporizes the cold (low-pressure) liquid refrigerant flowing through the evaporator. The vapor then carries the heat to the compressor, which compresses the vapor and increases its temperature above that of the outdoor air. In the condenser, the hot (high-pressure) refrigerant vapor liquefies, giving up the heat from the room air to outdoor air. Next, the high-pressure liquid refrigerant passes through a restrictor, which reduces its pressure and temperature. The cold (low-pressure) liquid refrigerant then enters the evaporator to repeat the refrigeration cycle.

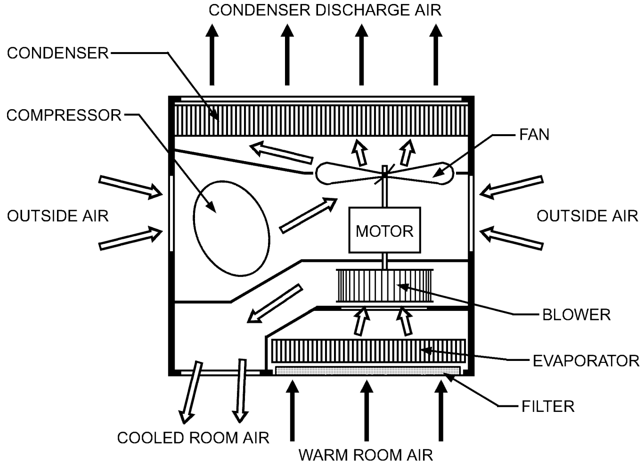

Fig. 1 Schematic View of Typical Room Air Conditioner

SIZES AND CLASSIFICATIONS

Room air conditioners have line cords, which may be plugged into standard or special electric circuits. Most units in the United States are designed to operate at 115, 208, or 230 V; single-phase; 50 or 60 Hz power. Some units are rated at 265 V or 277 V, for which the chassis or chassis assembly must provide permanent electrical connection. The maximum amperage of 115 V units is generally 12 A, which is the maximum current permitted by the *National Electrical Code*® (NEC) for a single-outlet, 15 A circuit. Models designed for countries other than the United States are generally for 50 or 60 Hz systems, with typical design voltage ranges of 100 to 120 and 200 to 240 V, single-phase.

Popular 115 V models have capacities in the range of 5000 to 8000 Btu/h, and are typically used in single-room applications. Larger-capacity 115 V units are in the 12,000 to 15,000 Btu/h range. Capacities for 230, 208, or 230/208 V units range from 8000 to 36,000 Btu/h. These higher-voltage units are typically used in multiple-room installations.

Heat pump models are also available, usually for 208 or 230 V applications. These units are generally designed for reversed-refrigerant-cycle operation as the normal means of supplying heat, but may incorporate electrical-resistance heat either to supplement heat pump capacity or to provide the total heating capacity when outdoor temperatures drop below a set value.

Another type of heating model incorporates electrical heating elements in regular cooling units so that heating is provided entirely by electrical resistance heat.

DESIGN

Room air conditioner design is usually based on one or more of the following criteria, any one of which automatically constrains the overall system design:

- Lowest initial cost
- Lowest operating cost (highest efficiency)
- Energy-efficiency ratio (EER) or coefficient of performance (COP), as legislated by government
- Low sound level
- Chassis size

The preparation of this chapter is assigned to TC 8.11, Unitary and Room Air Conditioners and Heat Pumps.

- Unusual chassis shape (e.g., minimal depth or height)
- Amperage limitation (e.g., 7.5 A, 12 A)
- Weight

The following combinations illustrate the effect of an initial design parameter on the various components:

Low Initial Cost. High airflow with minimum heat exchanger surface keeps the initial cost of a unit low. These units have a low-cost compressor, which is selected by analyzing various compressor and coil combinations and choosing the one that both achieves optimum performance and passes all tests required by Underwriters Laboratories (UL), the Association of Home Appliance Manufacturers (AHAM), and others. For example, a high-capacity compressor might be selected to meet the capacity requirement with a minimum heat transfer surface, but frost tests under maximum load may not be acceptable. These tests set the upper and lower limits of acceptability when low initial cost is the prime consideration.

Low Operating Cost. Large heat exchanger surfaces keep operating cost low. A compressor with a low compression ratio operates at low head pressure and high suction pressure, which results in a high EER.

Compressors

Room air conditioner compressors range in capacity from about 4000 to 34,000 Btu/h. Design data are available from compressor manufacturers at the following standard rating conditions:

Evaporating temperature	45°F
Compressor suction temperature	95°F
Condensing temperature	130°F
Liquid temperature	115°F
Ambient temperature	95°F

Compressor manufacturers offer complete performance curves at various evaporating and condensing temperatures to aid in selection for a given design specification.

Evaporator and Condenser Coils

These coils are generally tube-and-plate-fin, tube-and-louvered-fin, or tube-and-spine-fin. Information on the performance of such coils is available from suppliers, and original equipment manufacturers usually develop data for their own coils. Design parameters to be considered when selecting coils are (1) cooling rate per unit area of coil surface (Btu/h·ft^2), (2) dry-bulb temperature and moisture content of entering air, (3) air-side friction loss, (4) internal refrigerant pressure drop, (5) coil surface temperature, (6) airflow, and (7) air velocity.

Restrictor Application and Sizing

Three main types of restrictor devices are available to the designer: (1) a **thermostatic expansion valve**, which maintains a constant amount of superheat at a point near the outlet of the evaporator; (2) an **automatic expansion valve**, which maintains a constant suction pressure; and (3) a **restrictor tube (capillary)**. The capillary is the most popular device for room air conditioner applications because of its low cost and high reliability, even though its refrigerant control over a wide range of ambient temperatures is not optimal. A recommended procedure for optimizing charge balance, condenser subcooling, and restrictor sizing is as follows:

1. Use an adjustable restrictor (e.g., a needle valve), so that tests may be run with a flooded evaporator coil and various refrigerant charges to determine the optimum point of system operation.
2. Reset the adjustable restrictor to the optimum setting, remove it from the unit, and measure flow pressure with a flow comparator similar to that described in ASHRAE *Standard* 28.
3. Install a restrictor tube with the same flow rate as the adjustable restrictor. Usually, restrictor tubes are selected on the basis of cost, with shorter tubes generally being less expensive.

Fan Motor and Air Impeller Selection

The two types of motors generally used on room air conditioners are the (1) low-efficiency, shaded-pole type; and (2) more efficient, permanent split-capacitor type, which requires using a run capacitor. Air impellers are usually of two types: (1) forward-curved blower wheel and (2) axial- or radial-flow fan blade. In general, blower wheels are used to move small to moderate amounts of air in high-resistance systems, and fan blades move moderate to high air volumes in low-resistance applications. Blower wheels and cross-flow fans also generate lower noise levels than fan blades.

The combination of fan motor and air impellers is so important to the overall design that the designer should work closely with the manufacturers of both components. Performance curves are available for motors, blower wheels, and fans, but data are for ideal systems not usually found in practice because of physical size, motor speed, and component placement limitations.

Electronics

Microprocessors monitor and control numerous functions for room air conditioners. These microelectronic controls offer digital displays and touch panels for programming desired temperature, on-off timing, modulated fan speeds, bypass capabilities, and sensing for humidity, temperature, and airflow control.

PERFORMANCE DATA

In the United States, an industry certification program under the sponsorship of the Association of Home Appliance Manufacturers (AHAM) covers the majority of room air conditioners and certifies the cooling and heating capacities, EER, and electrical input (in amperes) of each for adherence to nameplate rating. The following tests are specified by AHAM *Standard* RAC-1:

- Cooling capacity
- Heating capacity
- Maximum operating conditions (heating and cooling)
- Enclosure sweat
- Freeze-up
- Recirculated air quantity
- Moisture removal
- Ventilating air quantity and exhaust air quantity
- Electrical input (heating and cooling)
- Power factor
- Condensate disposal
- Application heating capacity
- Outside coil deicing

Efficiency

Efficiency for room air conditioners may be shown in either of two forms:

1. Energy efficiency ratio (EER—generally for cooling)
   (Capacity in Btu/h)/(Input in watts)
2. Coefficient of performance (COP—generally for heating)
   (Capacity in Btu/h)/(Input in watts × 3.412)

Sensible Heat Ratio

The ratio of sensible heat to total heat removal is a useful performance characteristic for evaluating units for specific conditions. A low ratio indicates more dehumidification capacity, and hot, humid areas like New Orleans and arid locales like Phoenix might best be served with units having lower and higher ratios, respectively.

Energy Conservation and Efficiency

In the United States, two federal energy programs have increased the demand for higher-efficiency room air conditioners. First, the Energy Policy and Conservation Act of 2005 (Public Law 1094-58) provides a commercial building deduction for energy-efficient building improvements, and provides tax breaks for those making energy conservation improvements to their homes. Second, the National Appliance Energy Conservation Act of 1987 (NAECA) provides a single set of minimum efficiency standards for major appliances, including room air conditioners. The room air conditioner portion of NAECA originally specified minimum efficiencies for 12 classes, based on physical conformation, with minimums ranging from 8 to 9 EER and applying to all units manufactured on or after January 1, 1990.

The U.S. Department of Energy (DOE) issued increased minimum efficiency standards that became effective October 1, 2000 (*Federal Register*, September 24, 1997). (See Table 1) Four additional classes were created, two of which cover casement-type units. The minimum standards range from 8 to 9.8 EER. For the most popular classes (cooling-only units with louvered sides ranging in capacity from less than 6000 to 20,000 Btu/h) the minimum standards are either 9.7 or 9.8 EER. Table 2 shows the U.S. Environmental Protection Agency (EPA) and DOE's ENERGY STAR® requirements for room air conditioners. ENERGY STAR-qualified room air conditioners use at least 10% less energy than minimum-efficiency models. The EPA's ENERGY STAR Web site provides additional information on qualifying products (EPA 2008).

Table 1 NAECA Minimum Efficiency Standards for Room Air Conditioners

Class	Reverse Cycle	Louvered Sides	Capacity, Btu/h	Minimum EER as of January 1, 1990	Minimum EER as of October 1, 2000
1	No	Yes	< 6000	8.0	9.7
2	No	Yes	6000 to 7999	8.5	9.7
3	No	Yes	8000 to 13,999	9.0	9.8
4	No	Yes	14,000 to 19,999	8.8	9.7
5	No	Yes	≥ 20,000	8.2	8.5
6	No	No	< 6000	8.0	9.0
7	No	No	6000 to 7999	8.5	9.0
8	No	No	8000 to 13,999	8.5	8.5
9	No	No	14,000 to 19,999	8.5	8.5
10	No	No	≥ 20,000	8.2	8.5
11	Yes	Yes	< 20,000	8.5	9.0
12	Yes	No	< 14,000	8.0	8.5
13	Yes	Yes	≥ 20,000	8.5	8.5
14	Yes	No	≥ 14,000	8.0	8.0
15	Casement Only		—	*	8.7
16	Casement Slider		—	*	9.5

*Casement-only and casement-slider room air conditioners were not separate product classes under standards effective January 1, 1990. These units were subject to applicable standards in classes 1 to 14 based on unit capacity and presence or absence of louvered sides and reverse cycle.

Table 2 Room Air Conditioners ENERGY STAR Criteria

Product Class	NAECA Criteria Minimum EER	ENERGY STAR Criteria* Minimum EER
< 8000 Btu/h	9.7	10.7
8000 to 13,999 Btu/h	9.8	10.8
14,000 to 19,999 Btu/h	9.7	10.7
≥ 20,000 Btu/h	8.5	9.4

*ENERGY STAR criteria for room air conditioners are 10% above the NAECA criteria. Currently, only units *without* reverse cycle (heating function) and *with* louvered sides are considered for ENERGY STAR status. Minimum EER should be used to determine qualification for ENERGY STAR label. Values are rounded to single decimal and meet specification of 10% more efficient than new NAECA standard.

All state and local minimum efficiency standards in the United States are automatically superseded by federal standards. Many other countries have or are considering minimum efficiency standards, so such standards should be sought as part of the design process.

Whether estimating potential energy savings associated with appliance standards or estimating consumer operating costs, the annual hours H of operation of a room air conditioner are important. These figures have been compiled from various studies commissioned by DOE and AHAM for every major city and region in the United States. The national average is estimated at 750 h per year.

The estimated cost of operation is as follows:

$$C = RHW/1000$$

where

C = annual cost of operation, $/year
R = average cost, $/kWh
H = annual hours of operation
W = input, W

High-Efficiency Design

The EER can be affected by three design parameters. The first is **electrical efficiency**. Fan motor efficiency ranges from 25 to 65%; compressor motors range from 60 to 85%. The second parameter, **refrigerant cycle efficiency**, is increased by enhancing or enlarging the heat transfer surface to minimize the difference between the refrigerant saturation temperature and air temperature. This allows using a compressor with a smaller displacement and a high-efficiency motor. The third parameter is **air circuit efficiency**, which can be increased by minimizing pressure drop across the heat transfer surface, which reduces the load on the fan motor.

Higher EERs are not the complete answer to reducing energy costs. Energy efficiency can be increased by properly sizing the unit, keeping infiltration and leakage losses to a minimum, increasing building insulation, reducing unnecessary internal loading, providing effective maintenance, and balancing the load by using a thermostat and thermostat setback.

SPECIAL FEATURES

Some room air conditioners are designed to minimize their extension beyond the building when mounted flush with the inside wall. Low-capacity models are usually smaller and less obtrusive than higher-capacity models. Units are often installed through the wall, where they do not interfere with windows. Exterior cabinet grilles may be designed to harmonize with the architecture of various buildings.

Most units have adjustable louvers or deflectors to distribute air into the room with satisfactory throw and without drafts. Louver design should eliminate recirculation of discharge air into the air inlet. Some units use motorized deflectors for continuously changing the air direction. Discharge air speeds range from 300 to 1200 fpm, with low speeds preferred in rooms where people are at rest.

Most room air conditioners are designed to bring in outside air, exhaust room air, or both. Controls usually allow these features to function independently.

Temperature is controlled by an adjustable built-in thermostat. The thermostat and unit controls may operate in one of the following modes:

- The unit is set to the cool position, and the thermostat setting is adjusted as needed. The circulation blower runs without interruption while the thermostat cycles the compressor on and off.
- The unit uses a two- or three-stage thermostat, which reduces blower speed as room temperature approaches the set temperature, cycles the compressor off as temperature drops further, and, if temperature drops still further, finally cycles the blower off. As room temperature rises, the sequence reverses.

- The unit has, in addition to the preceding control sequence, an optional automatic fan mode in which both the blower and compressor are cycled simultaneously by the thermostat; this mode of operation requires proper thermostat sensitivity. One advantage of this arrangement is improved humidity control because moisture from the evaporator coil is not reevaporated into the room during the *off*-cycle. Another advantage is lower operating cost because the blower motor does not operate during the *off*-cycle. The effective EER may be increased an average of 10% by using the automatic fan mode (ORNL 1985).

Disadvantages of cycling fans with the compressor may be (1) varying noise level because of fan cycling and (2) deterioration in room temperature control.

Room air conditioners are simple to operate. Usually, one control selects the operating mode, and a second controls the temperature. Additional knobs or levers operate louvers, deflectors, the ventilation system, exhaust dampers, and other special features. Controls are usually arranged on the front of the unit or concealed behind a readily accessible door, but may also be arranged on the top or sides of the unit, or on an infrared remote control.

Filters on room air conditioners remove airborne dirt to provide clean air to the room and keep dirt off cooling surfaces. Filters are made of expanded metal (with or without a viscous oil coating), glass fiber, or synthetic materials; they may be either disposable or reusable. A dirty filter reduces cooling and air circulation and frequently allows frost to accumulate on the cooling coil; therefore, filter location should allow easy monitoring, cleaning, and replacement.

Some units have louvers or grilles on the outdoor side to enhance appearance and protect the condenser fins. Sometimes, these louvers separate the airstreams to and from the condenser and reduce recirculation. When provided, side louvers on the outside of the unit are an essential part of the condenser air system because they improve air movement to the condenser. Care should be taken not to obstruct air passages through these louvers.

Room air conditioners, especially those parts exposed to the weather, require a durable finish. Some manufacturers use a special grade of plastic for weather-exposed parts. If the parts are metal, good practice is to use phosphatized or zinc-coated steels with baked finishes and/or corrosion-resistant materials such as aluminum or stainless steel.

The sound level of a room air conditioner is an important factor, particularly when the unit is installed in a bedroom. A certain amount of sound can be expected because of air movement through the unit and compressor operation. However, a well-designed room air conditioner is relatively quiet, and the sound emitted is relatively free of high-pitched and metallic noise. Usually, fan motors with two or more speeds are used to provide a slower fan speed for quieter operation. To avoid rattles and vibration in the building structure, units must be installed correctly (see the section on Installation and Service).

Excessive outdoor sound (condenser fan and compressor) can be irritating to neighbors. In the United States, many local and state outdoor noise ordinances limit outdoor sound levels.

SAFETY CODES AND STANDARDS

United States. The *National Electrical Code*® (NFPA *Standard* 70), ASHRAE *Standard* 15, and UL *Standard* 484 pertain to room air conditioners. Local regulations may differ with these standards, but the basic requirements are generally accepted throughout the United States.

Canada. CSA International developed the standard for Room Air Conditioners (CSA *Standard* C22.2 No. 117), which forms part of the *Canadian Electrical Code*.

International. Two useful documents that might assist the designer are (1) International Electrotechnical Commission (IEC) *Standard* 60335-2-40 and (2) International Organization for Standardization (ISO) *Standard* 5151.

Product Standards

CSA *Standard* C22.2 No. 117 and UL *Standard* 484 are similar in content. In *Standard* 484, the construction section involves items such as the unit enclosure (including materials), ability to protect against contact with moving and uninsulated live parts, and means for installation or attachment. Attention is also given to the refrigeration system's ability to withstand operating pressures, system pressure relief in a fire, and refrigerant toxicity. Electrical considerations include supply connections, grounding, internal wiring and wiring methods, electrical spacings, motors and motor protection, uninsulated live parts, motor controllers and switching devices, air-heating components, and electrical insulating materials.

The performance section of the standard includes a rain test for determining the unit's ability to stand a beating rain without creating a shock hazard because of current leakage or insulation breakdown. Other tests include (1) leakage current limitations based on UL *Standard* C101, (2) measurement of input currents for the purpose of establishing nameplate ratings and for sizing the supply circuit for the unit, (3) temperature tests to determine whether components exceed their recognized temperature limits and/or electrical ratings (AHAM *Standard* RAC-1), and (4) pressure tests to ensure that excessive pressure does not develop in the refrigeration system.

Abnormal conditions are also considered, such as (1) failure of the condenser fan motor, which may lead to excessive pressure in the system; and (2) possible ignition of combustibles in or adjacent to the unit on air heater burnout. A static load test is also conducted on window-mounted room air conditioners to determine whether the mounting hardware can adequately support the unit. As part of normal production control, tests are conducted for refrigerant leakage, dielectric strength, and grounding continuity.

Plastic materials are receiving increased consideration in the design and fabrication of room air conditioners because of their ease in forming, inherent resistance to corrosion, and decorative qualities. When considering using plastic, the engineer should consider the tensile, flexural, and impact strength of the material; its flammability characteristics; and (concerning degradation) its resistance to water absorption and exposure to ultraviolet light, ability to operate at elevated temperatures, and thermal aging characteristics. Considering product safety, some of these factors are less important because failure of the part will not cause a hazard. However, for some parts (e.g., bulkhead, base pan, and unit enclosure) that either support components or provide structural integrity, all these factors must be considered, and a complete analysis of the material must be made to determine whether it is suitable for the application.

INSTALLATION AND SERVICE

Installation procedures vary because units can be mounted in various ways. It is important to select the mounting for each installation that best satisfies the user and complies with applicable building codes. Common mounting methods include the following:

- **Inside flush mounting.** Interior face of conditioner is approximately flush with inside wall.
- **Balance mounting.** Unit is approximately half inside and half outside window.
- **Outside flush mounting.** Outer face of unit is flush with or slightly beyond outside wall.
- **Special mounting.** Examples include casement windows, horizontal sliding windows, office windows with swinging units (or swinging windows) to allow window washing, and transoms over doorways.
- **Through-the-wall mounts or sleeves.** This mounting is used for installing window-type chassis, complete units, or consoles in walls of apartment buildings, hotels, motels, and residences.

Although very similar to window-mounted units, through-the-wall models do not have side louvers for condenser air; air comes from the outdoor end of the unit.

Room air conditioners have become more compact to minimize both loss of window light and projection inside and outside the structure. Several types of expandable mounts are now available for fast, dependable installation in single- and double-hung windows, as well as in horizontal sliding windows. Installation kits include all parts needed for structural mounting, such as gaskets, panels, and seals for weathertight assembly.

Adequate wiring and proper fuses must be provided for the service outlet. Necessary information is usually given on instruction sheets or stamped on the air conditioner near the service cord or on the serial plate. It is important to follow the manufacturer's recommendation for size and type of fuse. All units are equipped by the manufacturer with grounding plug caps on the service cord. Receptacles with grounding contacts correctly designed to fit these plug caps should be used when units are installed.

Units rated 265 or 277 V must provide for permanent electrical connection with armored cable or conduit to the chassis or chassis assembly. Manufacturers usually provide an adequate cord and plug cap in the chassis assembly to facilitate installation and service.

One type of room air conditioner is the **integral chassis** design, with the outer cabinet fastened permanently to the chassis. Most electrical components can be serviced by partially dismantling the control area without removing the unit from the installation. Another type is the **slide-out chassis** design, which allows the outer cabinet to remain in place while the chassis is removed for service.

PACKAGED TERMINAL AIR CONDITIONERS

The Air-Conditioning and Refrigeration Institute (ARI) defines a packaged terminal air conditioner (PTAC) as a wall sleeve and a separate unencased combination of heating and cooling assemblies intended for mounting through the wall. A PTAC includes refrigeration components, separable outdoor louvers, forced ventilation, and heating by hot water, steam, or electric resistance. PTAC units with direct-fired gas heaters are also available from some manufacturers. Cooling-only PTACs need not include heating elements. A packaged terminal heat pump (PTHP) is a heat pump version of a PTAC that provides heat with a reverse-cycle operating mode. A PTHP should provide a supplementary heat source, which can be hot water, steam, electric resistance, or another source.

PTACs are designed primarily for commercial installations to provide the total heating and cooling functions for a room or zone and are specifically for through-the-wall installation. The units are mostly used in relatively small zones on the perimeter of buildings such as hotels and motels, apartments, hospitals, nursing homes, and office buildings. In larger buildings, they may be combined with nearly any system selected for environmental control of the building core.

PTACs and PTHPs are similar in design and construction. The most apparent difference is the addition of a refrigerant-reversing valve in the PTHP. Optional components that control the heating functions of the heat pump include an outdoor thermostat to signal the need for changes in heating operating modes, and, in more complex designs, frost sensors, defrost termination devices, and base pan heaters.

SIZES AND CLASSIFICATIONS

Packaged terminal air conditioners are available in a wide range of rated cooling capacities, typically 6000 to 18,000 Btu/h, with comparable levels of heating output. Units are available as sectional types or integrated types. A sectional-type unit (Figure 2) has a separate cooling chassis; an integrated-type unit (Figure 3) has an electric or a gas heating option added to the chassis. Hot-water or steam heating options are usually part of the cabinet or wall box. Both types include the following:

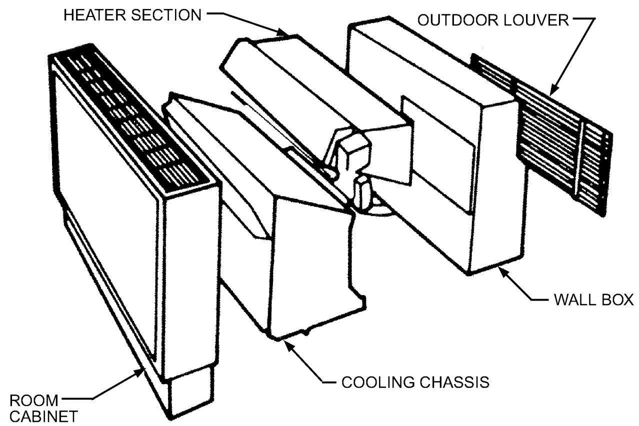

Fig. 2 Sectional Packaged Terminal Air Conditioner

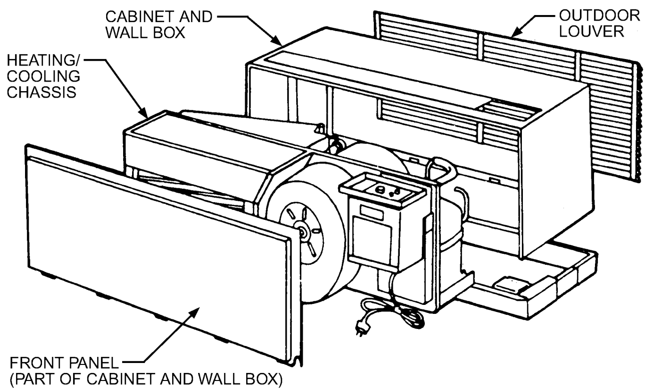

Fig. 3 Integrated Packaged Terminal Air Conditioner

- Heating elements available in hot water, steam, electric, or gas heat
- Integral or remote temperature and operating controls
- Wall sleeve or box
- Removable (or separable) outdoor louvers
- Room cabinet
- Means for controlled forced ventilation
- Means for filtering air delivered to the room
- Ductwork

PTAC assemblies are intended for use in free conditioned-air distribution, but a particular application may require minimal ductwork with a total external static resistance up to 0.1 in. of water.

GENERAL DESIGN CONSIDERATIONS

Packaged terminal air conditioners and packaged terminal heat pumps allow the HVAC designer to integrate the exposed outdoor louver or grille with the building design. Various grilles are available to blend with or accent most construction materials. Because the product becomes part of the building's facade, the architect must consider the product during the conception of the building. Wall sleeve installation is usually done by ironworkers, masons, or carpenters. All-electric units dominate the market. Recent U.S. market statistics indicate that 45% are PTHPs, 49% are PTACs with electric resistance heat, and 6% involve other forms of heating.

All the energy of all-electric versions is dispersed through the building via electrical wiring, so the electric designer and electrical contractor play a major role. Final installation is reduced to sliding in the chassis and plugging the unit into an adjacent receptacle. For these all-electric units, the traditional HVAC contractor's work involving ducting, piping, and refrigeration systems is bypassed. This results in a low-cost installation and allows installation of the PTAC/PTHP chassis to be deferred until just before occupancy.

When comparing a gas-fired PTAC to a PTAC with electric resistance heat or a PTHP, evaluate both operating and installation costs. Generally, a gas-fired PTAC is more expensive to install but less expensive to operate in heating mode. A life-cycle cost comparison is recommended (see Chapter 36 of the 2007 *ASHRAE Handbook—HVAC Applications*).

One main advantage of the PTAC/PTHP concept is that it provides excellent zoning capability. Units can be shut down or operated in a holding condition during unoccupied periods. Present equipment efficiency-rating criteria are based on full-load operation, so an efficiency comparison to other approaches may suffer.

The designer must also consider that total capacity is the sum of the peak loads of each zone rather than the peak load of the building. Therefore, total cooling capacity of the zonal system will exceed that of a central system.

Because PTAC units are located in the conditioned space, both appearance and sound level of the equipment are important considerations. Sound attenuation in ducting is not available with the free-discharge PTAC units.

The designer must also consider the added infiltration and thermal leakage load resulting from perimeter wall penetrations. These losses are accounted for during the *on*-cycle in equipment cooling ratings and PTHP heating ratings, but during the *off*-cycle or with other forms of heating, they could be significant.

Widely dispersed PTAC units also present challenges for effective condensate disposal.

Most packaged terminal equipment is designed to fit into a wall aperture approximately 42 in. wide and 16 in. high. Although unitary products can increase in size with increasing cooling capacity, PTAC/PTHP units, regardless of cooling capacity, are usually constrained to a few cabinet sizes. The exterior of the equipment must be essentially flush with the exterior wall to meet most building codes. In addition, cabinet structural requirements and the slide-in chassis reduce the available area for outdoor air inlet and relief to less than a total of 3.5 ft^2. Manufacturers' specification sheets should be consulted for more accurate and detailed information.

Outdoor air recirculation must be minimized, and attention must be given to architectural appearance. These factors may increase air-side pressure drop. With a cooling capacity range that usually spans about a 3 to 1 ratio, this makes maintaining unit efficiency at higher levels of output more difficult.

DESIGN OF PTAC/PTHP COMPONENTS

Compressor. PTAC units are designed with single-speed compressors, either reciprocating or rotary. They normally operate on a single-phase power supply and are available in 208, 230, and 265 V versions. Smaller units are available in 115 V versions. Compressors usually have electromechanical protective devices, with some of the more advanced models using electronic protective systems.

Fan Motor(s). In some PTACs, a single, double-shafted direct-drive fan motor drives both the indoor and outdoor air-moving devices. This motor usually has two speeds, which affect the equipment sound level, throw of conditioned air, cooling capacity, efficiency, sensible-to-total heat capacity ratio, and condensate disposal.

Full-featured models have two fan motors: one moves indoor air and the other brings in outdoor air. Two motors provide greater flexibility in locating components, because indoor and outdoor fans are no longer constrained to the same rotating axis. They also allow different fan speeds for the indoor and outdoor systems. In this case, the outdoor fan motor is usually single-speed, and the indoor fan motor has two or more speeds. Also, the designer has a broader selection of air-moving devices and can provide the user with a wider range of sound level and conditioned air throw options. Efficiency can be maintained at lower indoor fan speeds. When heating (other than with a heat pump), the outdoor fan motor can be switched off automatically to reduce electrical energy consumption, decrease infiltration and heat transmission losses through the PTAC unit, and prevent ice from entrapping the fan blade.

Indoor Air Mover. Airflow quantity, air-side pressure rise, available fan motor speed, and sound level requirements of the indoor air system of a PTAC indicate that a centrifugal blower wheel provides reasonable indoor air performance. In some cases, proprietary mixed-flow blowers are used. Dual-fan motor units permit the use of multiple centrifugal blower wheels or a cross-flow blower to provide more even discharge of the conditioned air.

Indoor Air Circuit. PTACs have an air filter of fiberglass, metal, or plastic foam, which removes large particles from the circulating airstream. In addition to improving indoor air quality, this filter also reduces fouling of the indoor heat exchanger. The PTAC also provides mechanical means of introducing outdoor air into the indoor airstream. This air, which may or may not be filtered, controls infiltration and pressurization of the conditioned space.

Outdoor Air Mover. Outdoor air movers may be either centrifugal blower wheels, mixed-flow blowers, or axial-flow fans.

Heat Exchangers. PTACs may use conventional plate-fin heat exchangers, which have either copper or aluminum tubes. The fins are usually aluminum, which may be coated to retard corrosion. Because PTACs are generally restricted in size, performance improvements based on increasing heat exchanger size are limited. Therefore, to improve performance or reduce costs, some manufacturers install heat exchangers with performance enhancements on the air side (lanced fins, spine fin, etc.) and/or the refrigerant side (internal finning or rifling).

Refrigerant Expansion Device. Most PTACs use a simple capillary as an expansion device. Off-rating-point performance is improved if expansion valves are used.

Condensate Disposal. Condensate forms on the indoor coil when cooling. Some PTACs require a drain to be installed to convey condensate to a disposal point. Other units spray condensate on the outdoor coil, where it is evaporated and dispersed to the outdoor ambient air. This evaporative cooling of the condenser enhances performance, but the potentially negative effects of fouling and corrosion of the outdoor heat exchanger must be considered. This problem is especially severe in a coastal installation where salt spray could mix with the condensate and, after repeated evaporation cycles, build a corrosive saltwater solution in the condensate sump.

A PTHP also produces condensate in heating mode. If the outdoor coil operates below freezing, the condensate forms frost, which is melted during defrost. This water must be disposed of in some manner. If drains are used and the heat pump operates in below-freezing weather, the drain lines must be protected from freezing. Outside drains cannot be used in this case, unless they have drain heaters. Some PTHPs introduce condensate formed during heating onto the indoor coil, which humidifies the indoor air at the expense of heating capacity. Inadequate condensate disposal can lead to overflow at the unit and potential staining of the building facade.

Controls. PTAC units usually have a built-in manual mode selector (cool, heat, fan only, and off) and a manual fan-speed selector. A thermostat adjustment is provided with set points (usually subjective, such as *high*, *normal*, and *low*). Some units offer automatic changeover from heating to cooling. Most manufacturers offer low-voltage remote heat/cool thermostats. Some units have electronic controls that provide room temperature limiting, evaporator freeze-up protection, compressor lockout in the case of actual or impending compressor malfunction, and service diagnostic aids. Advanced master controls at a central location allow an operator to override the control settings registered by the occupant. These master controls may limit operation when certain room temperature limits are exceeded, adjust thermostat set points during unoccupied periods, and turn off certain units to limit peak electrical demand.

Wall Sleeves. A wall sleeve is a required part of a PTAC unit. It becomes an integral part of the building structure and must be designed with sufficient strength to maintain its dimensional integrity after installation. It must withstand the potential corrosive effects of other building materials, such as mortar, and must endure long-term exposure to the outdoor elements.

Outdoor Grille. The outdoor grille or louvers must be compatible with the building's architecture. Most manufacturers provide options in this area. A properly designed grille prevents birds, vermin, and outdoor debris from entering; impedes entry of rain and snow; and, at the same time, provides adequate free area for the outdoor airstream to enter and exit with minimum recirculation.

Slide-In Components. The interface between the wall sleeve and slide-in component chassis allows the components to be easily inserted and later removed for service and/or replacement. In the event of serious malfunction, the slide-in component can be quickly replaced with a spare, and the repair can be made off the premises. An adequate seal at the interface is essential to exclude wind, rain, snow, and insects without jeopardizing the slide-in/slide-out feature.

Indoor Appearance. Because PTACs are located in the conditioned space, their indoor appearance must blend with the room's decor. Manufacturers provide a variety of indoor treatments, which include variations in shape, style, and materials.

HEAT PUMP OPERATION

Basic PTHP units operate in heat pump mode down to an outdoor temperature just above the point at which the outdoor heat exchanger would frost. At that point, heat pump mode is locked out, and other forms of heating are required. Some units include two-stage indoor thermostats and automatically switch from heat pump mode to an alternative heat source if space temperature drops too far below the first-stage set point. Some PTHPs use control schemes that extend heat pump operation to lower temperatures. One approach allows heat pump operation down to outdoor temperatures just above freezing. If the outdoor coil frosts, it is defrosted by shutting down the compressor and allowing the outdoor fan to continue circulating outdoor air over the coil. Another approach allows heat pump operation to even lower outdoor temperatures by using a reverse-cycle defrost sequence. In those cases, the heat pump mode is usually locked out for outdoor temperatures below 10°F.

PERFORMANCE AND SAFETY TESTING

PTACs and PTHPs may be rated in accordance with ARI *Standard* 310/380, which is equivalent to CSA International *Standard* C744.

ARI issues a *Directory of Certified Applied Air-Conditioning Products* semiannually that lists cooling capacity, efficiency, and heating capacity for each participating manufacturer's PTAC models. The listings of PTHP models also include the heating COP.

Cooling and heating capacities, as listed in the ARI directory, must be established in accordance with ASHRAE *Standard* 37 for unitary equipment, or *Standard* 16 for room air conditioners and PTACs. All standard heating ratings should be established in accordance with ASHRAE *Standard* 58.

Additionally, PTAC units should be constructed in accordance with ASHRAE *Standard* 15 and should comply with the safety requirements of UL *Standard* 484.

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