CHAPTER 45

UNITARY AIR CONDITIONERS AND UNITARY HEAT PUMPS

THE AIR-CONDITIONING and Refrigeration Institute (ARI) defines a **unitary air conditioner** as one or more factory-made assemblies that normally include an evaporator or cooling coil and a compressor and condenser combination. It may include a heating function as well. ARI defines an **air-source unitary heat pump** as consisting of one or more factory-made assemblies, which normally include an indoor conditioning coil, compressor(s), and an outdoor coil. It must provide a heating function and possibly a cooling function as well. A **water-source heat pump** is a factory-made assembly that rejects or extracts heat to and from a water loop instead of from ambient air. A unitary air conditioner or heat pump having more than one factory-made assembly (e.g., indoor and outdoor units) is commonly called a **split system**.

Unitary equipment is divided into three general categories: residential, light commercial, and commercial. Residential equipment is single-phase unitary equipment with a cooling capacity of 65,000 Btu/h or less and is designed specifically for residential application. Light commercial equipment is generally three phase, with cooling capacity up to 135,000 Btu/h, and is designed for small businesses and commercial properties. Commercial unitary equipment has cooling capacity higher than 135,000 Btu/h and is designed for large commercial buildings.

In the development of unitary equipment, the following design objectives are considered: (1) user requirements, (2) application requirements, (3) installation, and (4) service.

User Requirements

The user primarily needs either space conditioning for comfort or a controlled environment for products or manufacturing processes. Cooling, dehumidification, filtration, and air circulation often meet those needs, although heating, humidification, and ventilation are also required in many applications.

Application Requirements

Unitary equipment is available in many secondary system configurations, such as

- **Single zone, constant volume**, which consists of one controlled space with one thermostat that controls to maintain a set point.
- **Multizone, constant volume**, which has several controlled spaces served by one unit that supplies air of different temperatures to different zones as demanded (Figure 1).
- **Single zone, variable volume**, which consists of several controlled spaces served by one unit. Supply air from the unit is at a constant temperature, with air volume to each space varied to satisfy space demands (Figure 2).

Such factors as size, shape, and use of the building; availability and cost of energy; building aesthetics (equipment located outdoors); and space available for equipment are considered to determine the type of unitary equipment best suited to a given application. In general, roof-mounted single-package unitary equipment is limited to five or six stories because duct space and available blower power become excessive in taller buildings. Indoor, single-zone equipment is generally less expensive to maintain and service than multizone units located outdoors.

The building load and airflow requirements determine equipment capacity, whereas the availability and cost of fuels determine the energy source. Control system requirements must be established, and any unusual operating conditions must be considered early in the planning stage. In some cases, custom-designed equipment (discussed in Chapter 8) may be necessary.

Manufacturers' literature has detailed information about geometry, performance, electrical characteristics, application, and operating limits. The system designer then focuses on selecting suitable equipment with the capacity for the application.

Installation

Unitary equipment is designed to keep installation costs low. The equipment must be installed properly so that it functions in accordance with the manufacturer's specifications. Interconnecting diagrams for the low-voltage control system should be documented for proper servicing in the future. Adequate planning for the installation of large, roof-mounted equipment is important because special rigging equipment is frequently required.

The refrigerant circuit must be clean, dry, and leak-free. An advantage of packaged unitary equipment is that proper installation minimizes the risk of field contamination of the circuit. Care must be taken to properly install split-system interconnecting tubing (e.g., proper cleanliness, brazing, and evacuation to remove moisture). Some residential split systems are provided with precharged line sets and quick-connection couplings, which reduce the risk of field contamination of the refrigerant circuit. Split systems should be charged according to the manufacturer's instructions.

In the installation of split systems, lines must be properly routed and sized to ensure good oil return to the compressor. Chapters 5 and 6 of the *ASHRAE Handbook—Refrigeration* have more details on appropriate refrigerant piping practices.

Unitary equipment must be located to avoid noise and vibration problems. Single-package equipment of over 20 ton capacity should be mounted on concrete pads if vibration control is a concern.

The preparation of this chapter is assigned to TC 7.6, Unitary and Room Air Conditioners and Heat Pumps.

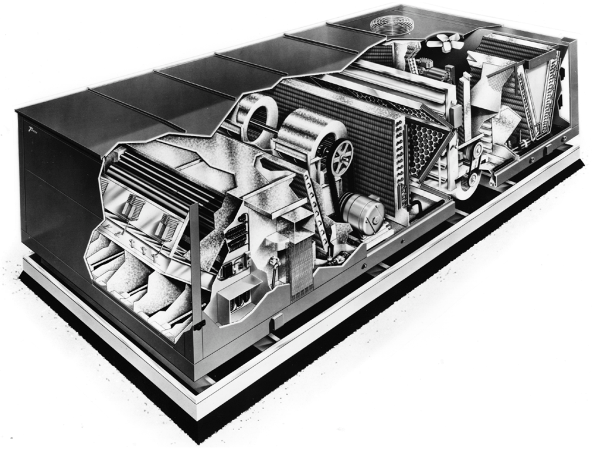


Fig. 1 Typical Rooftop Air-Cooled Single-Package Air Conditioner (Multizone)

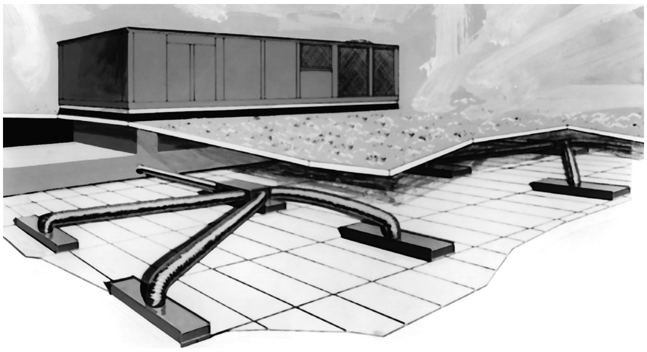


Fig. 2 Single-Package Air Equipment with Variable Air Volume

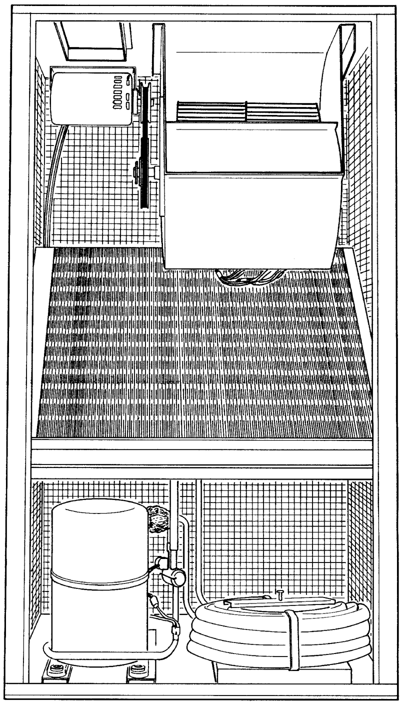


Fig. 3 Water-Cooled Single-Package Air Conditioner

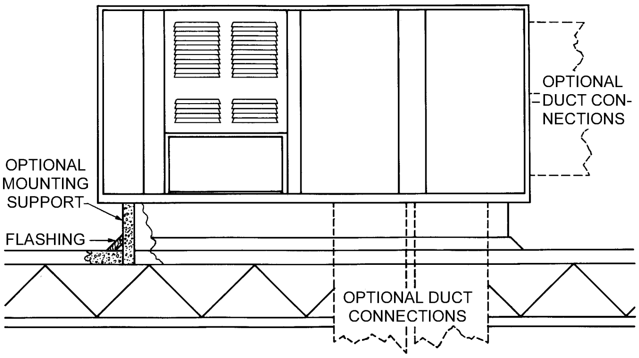


Fig. 4 Rooftop Installation of Air-Cooled Single-Package Unit

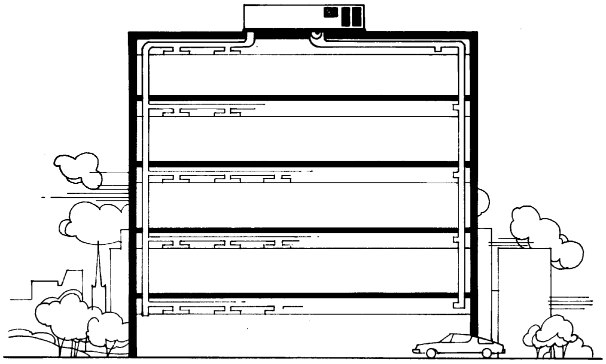


Fig. 5 Multistory Rooftop Installation of Single-Package Unit

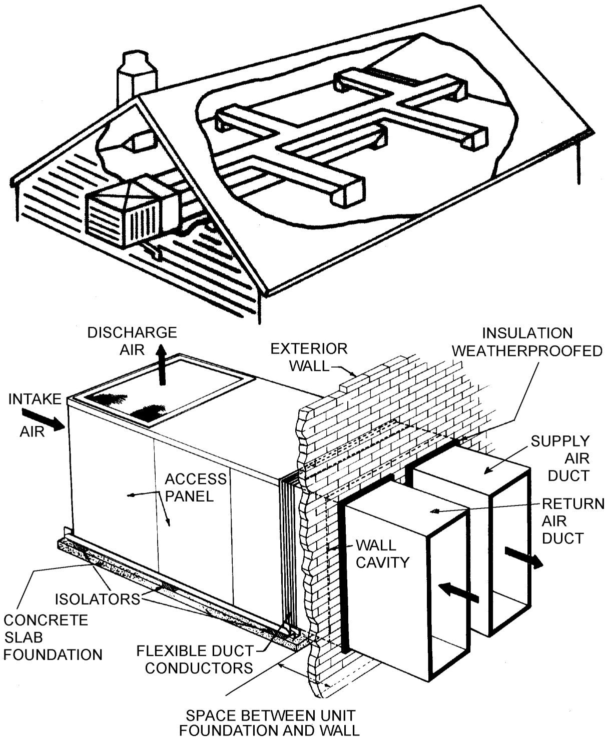


Fig. 6 Through-the-Wall Installation of Air-Cooled Single-Package Unit

Large-capacity equipment should be roof-mounted only after the structural adequacy of the roof has been evaluated. If they are located over occupied space, roof-mounted units with return fans that use ceiling space for the return plenum should have a lined return plenum according to the manufacturer's recommendations. Duct silencers should be used where low sound levels are desired. Weight and sound data are available from many manufacturers. Additional installation guidelines include the following:

- In general, install products containing compressors on solid, level surfaces.
- Avoid mounting products containing compressors (like remote units) on or touching the foundation of a house or building. A separate pad that does not touch the foundation is recommended to reduce any noise and vibration transmission through the slab.
- Do not box in outdoor air-cooled units with fences, walls, overhangs, or bushes. Doing so reduces the air-moving capability of the unit, thus reducing efficiency.
- For a split-system remote unit, choose an installation site that is close to the indoor portion of the system to minimize the pressure drop in the connecting tubing.
- Contact the unitary equipment manufacturer or consult the installation instructions for further information on installation procedures.

Unitary equipment should be listed or certified by nationally recognized testing laboratories to ensure safe operation and compliance with government and utility regulations. The equipment should also be installed to comply with the rating and application requirements of the agency standards to ensure that it performs according to industry criteria. Larger and more specialized equipment often does not carry agency labeling. However, power and control wiring practices should comply with the *National Electrical Code* (NFPA *Standard* 70). Local codes should be consulted before the installation is designed; local inspectors should be consulted before installation.

Service

A clear and accurate wiring diagram and a well-written service manual are essential to the installer and service personnel. Easy and safe service access must be provided in the equipment for periodic maintenance of filters and belts, cleaning, and lubrication. In addition, access for replacement of major components must be provided and preserved.

The availability of replacement parts aids proper service. Equitable warranty policies, covering 1 year of operation after installation, are offered by most manufacturers. Extended compressor warranties may be standard or optional.

Service personnel must be qualified to repair or replace mechanical and electrical components and to recover and properly recycle or dispose of any refrigerant removed from a system. They must also understand the importance of controlling moisture and other contaminants within the refrigerant circuit; they should know how to clean an hermetic system if it has been opened for service (see Chapter 6 of the *ASHRAE Handbook—Refrigeration*). Proper service procedures help ensure that the equipment will continue operating efficiently for its expected life.

TYPES OF UNITARY EQUIPMENT

Table 1 shows the types of unitary air conditioners available, and Table 2 shows the types of unitary heat pumps available. The following variations apply to some types and sizes of unitary equipment.

Arrangement. Major unit components for various unitary air conditioners are arranged as shown in Table 1 and for unitary heat pumps as shown in Table 2.

Heat Rejection. Unitary air conditioner condensers may be air cooled, evaporatively cooled, or water cooled; the letters A, E, or W follow the ARI designation.

Table 1 ARI Classification of Unitary Air Conditioners

System Designation	ARI Type[a]	Heat Rejection	Arrangement	
Single package	SP-A	Air	Fan	Comp
	SP-E	Evap Cond	Evap	Cond
	SP-W	Water		
Refrigeration chassis	RCH-A	Air		Comp
	RCH-E	Evap Cond	Evap	Cond
	RCH-W	Water		
Year-round single package	SPY-A	Air	Fan	
	SPY-E	Evap Cond	Heat	Comp
	SPY-W	Water	Evap	Cond
Remote condenser	RC-A	Air	Fan	
	RC-E	Evap Cond	Evap	Cond
	RC-W	Water	Comp	
Year-round remote condenser	RCY-A	Air	Fan	
	RCY-E	Evap Cond	Evap	Cond
	RCY-W	Water	Heat	
			Comp	
Condensing unit, coil alone	RCU-A-C	Air	Evap	Cond
	RCU-E-C	Evap Cond		Comp
	RCU-W-C	Water		
Condensing unit, coil and blower	RCU-A-CB	Air	Fan	Cond
	RCU-E-CB	Evap Cond	Evap	Comp
	RCU-W-CB	Air		
Year-round condensing unit, coil and blower	RCUY-A-CB	Air	Fan	
	RCUY-E-CB	Evap Cond	Evap	Cond
	RCUY-W-CB	Water	Heat	Comp

[a] Adding a suffix of "-O" following any of the above classifications indicates equipment not intended for use with field-installed duct systems.

Table 2 ARI Classification of Unitary Heat Pumps

	ARI Type[a]			
System Designation	Heating and Cooling	Heating Only	Arrangement	
Single package	HSP-A	HOSP-A	Fan	Comp
	HSP-W	HOSP-W	Indoor Coil	Outdoor Coil
Remote outdoor coil	HRC-A-CB	HORC-A-CB	Fan	
			Indoor Coil	Outdoor Coil
			Comp	
Remote outdoor coil with no indoor fan	HRC-A-C	HORC-A-C	Indoor Coil	Outdoor Coil
			Comp	
Split system	HRCU-A-CB	HORCU-A-CB	Fan	Comp
	HRCU-W-CB	HORCU-W-CB	Indoor Coil	Outdoor Coil
Split system, no indoor fan	HRCU-A-C	HORCU-A-C		Comp
			Indoor Coil	Outdoor Coil

[a] A suffix of "-O" following any of the above classifications indicates equipment not intended for use with field-installed duct systems.

Heat Source/Sink. Unitary heat pump outdoor coils are designated as air-source or water-source by an A or W, following ARI practice. The same coils that act as a heat sink in the cooling mode act as the heat source in the heating mode.

Unit Exterior. The unit exterior should be decorative for in-space application, functional for equipment room and ducts, and weatherproofed for outdoors.

Placement. Unitary equipment can be mounted on floors, walls, ceilings, roofs, or a pad on the ground.

Indoor Air. Equipment with fans may have airflow arranged for vertical upflow or downflow, horizontal flow, 90° or 180° turns, or multizone. Indoor coils without fans are intended for forced-air furnaces or blower packages. Variable volume blowers may be incorporated with some systems.

Location. Unitary equipment intended for indoor use may be placed in the conditioned space with plenums or furred-in ducts or concealed in closets, attics, crawl spaces, basements, garages, utility rooms, or equipment rooms. Wall-mounted equipment may be attached to or built into a wall or transom. Outdoor equipment may be mounted on roofs or concrete pads on the ground. Installations must conform with local codes.

Heat. Unitary systems may incorporate gas-fired, oil-fired, electric, hot water coil, or steam coil heating sections. In unitary heat pumps, these heating sections supplement the heating capability.

Ventilation Air. Outdoor air dampers may be built into the equipment to provide outdoor air for cooling or ventilation.

Desuperheaters. Desuperheaters may be applied to unitary air conditioners and heat pumps. These devices recover heat from the compressor discharge gas and use it to heat domestic hot water. The desuperheater usually consists of a pump, a heat exchanger, and controls, and it can produce about 5 to 6 gph of heated water per ton of air conditioning (heating water from 60 to 130°F). Because desuperheaters improve cooling performance and reduce the degrading effect of cycling during heating, they are best applied where cooling requirements are high and where a significant number of heating hours occur above the building's balance point (Counts 1985). While properly applied desuperheaters can improve cooling efficiency, they can also reduce space-heating capacity. This causes the unit to run longer, which reduces the cycling of the system above the balance point.

Ductwork. Unitary equipment is usually designed with fan capability for ductwork, although some units may be designed to discharge directly into the conditioned space.

Accessories. The manufacturer of any unitary equipment should be consulted before installing any accessories or equipment not specifically approved by the manufacturer. Such installations may not only void the warranty, but could cause the unitary equipment to function improperly or create fire or explosion hazards.

Combined Space-Conditioning/Water-Heating Systems

Unitary systems are available that provide both space conditioning and potable water heating. These systems are typically heat pumps, but some are available for cooling only. One type of combined system includes a full-condensing water-heating heat exchanger integrated into the refrigerant circuit of the space-conditioning system. Full-condensing system heat exchangers are larger than desuperheaters; they are generally sized to take the full condensing output of the compressor. Thus, they have much greater water-heating capacity. They also have controls that allow them to heat water year-round, either independently or coincidentally with space heating or space cooling. In spring and fall, the system is typically operated only to heat water.

Another type of combined system incorporates a separate, ancillary **heat pump water heater** (HPWH). The evaporator of this heater uses the return air (or liquid) stream of the space-conditioning system as a heat source. The HPWH thus cools the return stream during both space heating and cooling. In spring and fall, the space-conditioning blower (or pump) operates when water heating is needed.

As is the case with desuperheaters, simultaneous space and water heating reduces the output for space heating. This lower output is partially compensated for by the reduced cycling of the space-heating system above the balance point.

Combined systems can provide end users with significant energy savings and electric utilities with a significant reduction in demand. The overall performance of these systems is affected by the refrigerant charge and piping, the water piping, and the control logic and wiring. It is important, therefore, that the manufacturer's recommendations be closely followed. One special requirement is to locate the water-containing section(s) in areas not normally subjected to freezing temperatures.

Typical Unitary Equipment

Figures 1 through 6 show various types and installations of single-package equipment. Figure 7 shows a typical installation of a split-system, air-cooled condensing unit with indoor coil—the most widely used unitary cooling system. Figure 8 and Figure 9 also show split-system condensing units with coils and blower-coil units. Chapter 47 describes engine-driven heat pumps and air conditioners.

Many special light commercial and commercial unitary installations include a single-package air conditioner for use with variable air volume systems, as shown in Figure 2. These units are often equipped with a factory-installed system for controlling air volume in response to supply duct pressure (such as dampers or variable-speed drives).

Another example of a specialized unit is the **multizone unit** shown in Figure 1. The manufacturer usually provides all controls, including zone dampers. The air path in these units is designed so that supply air may flow through a hot deck containing a means of heating or through a cold deck, which usually contains a direct-expansion evaporator coil.

To make multizone units more efficient, a control is commonly provided that locks out cooling by refrigeration when the heating unit is in operation and vice versa. Another variation to improve efficiency is the three-deck multizone. This unit has a hot deck, a

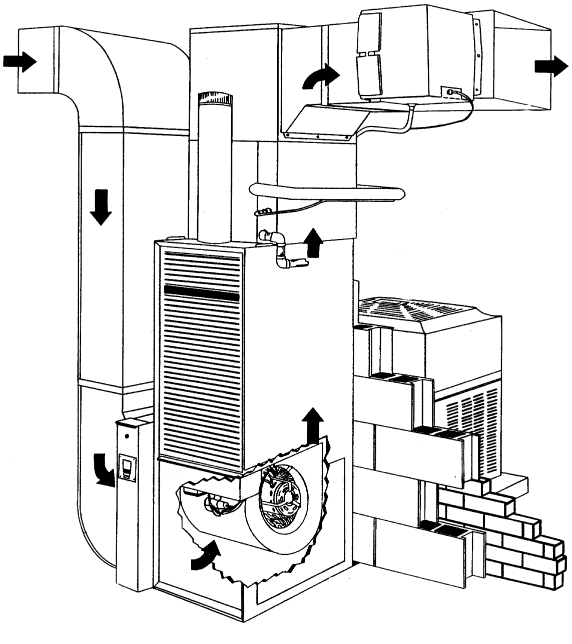


Fig. 7 Residential Installation of Split-System Air-Cooled Condensing Unit with Coil and Upflow Furnace

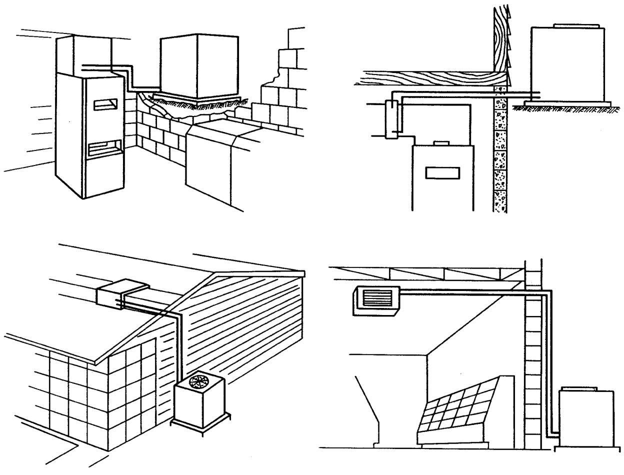


Fig. 8 Outdoor Installations of Split-System Air-Cooled Condensing Units with Coil and Upflow Furnace or with Indoor Blower-Coils

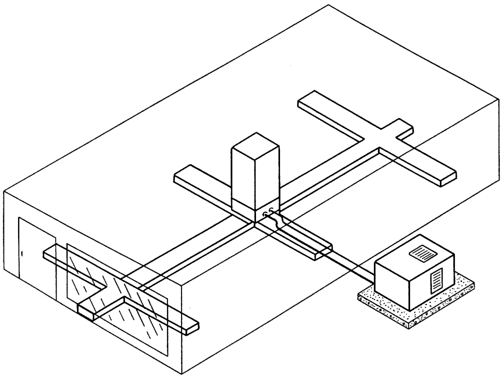


Fig. 9 Outdoor Installation of Split-System Air-Cooled Condensing Unit with Indoor Coil and Downflow Furnace

cold deck, and a neutral deck carrying return air. Hot and/or cold deck air mixes only with air in the neutral deck.

EQUIPMENT AND SYSTEM STANDARDS

Energy Conservation and Efficiency

In the United States, the Energy Policy and Conservation Act, (Public Law 95-163) requires the Federal Trade Commission (FTC) to prescribe an energy label for many major appliances, including unitary air conditioners and heat pumps. The National Appliance Energy Conservation Act (NAECA) (Public Law 100-12) provides minimum efficiency standards for major appliances, including unitary air conditioners and heat pumps.

The U.S. Department of Energy (DOE) testing and rating procedure is documented in Appendix M to Subpart 430 of Section 10 of the *Code of Federal Regulations*, Uniform Test Method for Measuring the Energy Consumption of Central Air Conditioners. This testing procedure provides a seasonal measure of operating efficiency for residential unitary equipment. The **seasonal energy efficiency ratio** (SEER) is the ratio of the total seasonal cooling output measured in Btu to the total seasonal watt-hours of input energy. This efficiency value is developed in the laboratory by conducting tests at various indoor and outdoor conditions, including a measure of performance under cyclic operation.

Seasonal heating mode efficiencies of heat pumps are similarly expressed as the ratio of the total heating output to the total seasonal input energy. This measure of efficiency is expressed as a **heating seasonal performance factor** (HSPF). In the laboratory, HSPF is determined from the test results at different conditions, including a measure of cyclic performance. The calculated HSPF depends not only on the measured equipment performance, but also on the climatic conditions and the heating load relative to the equipment capacity.

For HSPF rating purposes, the DOE has divided the United States into six climatic regions and has defined a range of maximum and minimum design loads. This division has the effect of producing about 30 different HSPF ratings for a given piece of equipment. DOE has established Region 4 (moderate northern climate) and the minimum design load as being the typical climatic region and building design load to be used for comparative certified performance ratings.

SEER, HSPF, and operating costs vary appreciably with equipment design and size and from manufacturer to manufacturer. SEER and HSPF values, size ranges, and unit operating costs for DOE-covered unitary air conditioners that are certified by ARI are published semiannually in the ARI *Directory of Certified Unitary Products.*

In the United States, the Energy Policy Act of 1992 requires unitary equipment with cooling capacities from 65,000 to 240,000 Btu/h to meet the minimum efficiency levels prescribed by ASHRAE *Standard* 90.1.

ARI Certification Programs

Equipment up to 135,000 Btu/h. ARI conducts three certification programs relating to unitary equipment up to 135,000 Btu/h, which are covered in ARI *Standard* 210/240 and ARI *Standard* 270. These standards include the performance requirements necessary for good equipment design. They also include the methods of testing established by ASHRAE *Standard* 37.

As part of its certification program, ARI publishes the *Directory of Certified Unitary Products*. Issued twice a year, this directory identifies certified products enrolled in one or more programs and lists the certified capacity and energy efficiency for each unit. Certification involves the annual audit testing of approximately 30% of the basic unitary equipment models of each participating manufacturer.

ARI *Standard* 210/240 established definitions and classifications, testing and rating methods, and performance requirements. Ratings are determined at ARI standard rating conditions, rated nameplate voltage, and prescribed discharge duct static pressures with rated evaporator airflow not exceeding 37.5 cfm per 1000 Btu/h. The standard requires that units dispose of condensate properly and have cabinets that do not sweat under cool, humid conditions. The ability to operate satisfactorily and restart at high ambient temperatures with low voltage is also tested.

For certification under ARI *Standard* 270, outdoor equipment is tested in accordance with Acoustical Society of America (ASA) *Standard* 92. Test results obtained on a one-third octave band basis are converted to a single number for application evaluation. Application principles are covered in ARI *Standard* 275.

Equipment over 135,000 Btu/h. Unitary air conditioners and heat pumps exceeding 135,000 Btu/h can be tested in accordance with ARI *Standard* 340/360. Unitary condensing units with capacities of 135,000 Btu/h or larger are covered by ARI *Standard* 365. ARI has a certification program for large unitary air-conditioning, heat pump, and condensing units with cooling capacities from 135,000 to 250,000 Btu/h. The ARI *Directory of Certified Applied Air-Conditioning Products*, published twice a year, contains the certified values for such equipment.

Safety Standards and Installation Codes

Approval agencies list unitary air conditioners complying with a standard like Underwriters Laboratories (UL) *Standard* 1995, Heating and Cooling Equipment (CSA *Standard* C22.2 No. 236). Other UL standards may also apply. An evaluation of the product determines that its design complies with the construction requirements specified in the standard and that the equipment can be installed in accordance with the applicable requirements of the *National Electrical Code*; ASHRAE *Standard* 15, Safety Code for Mechanical Refrigeration; NFPA *Standard* 90A, Installation of Air Conditioning and Ventilating Systems; and NFPA *Standard* 90B, Installation of Warm Air Heating and Air Conditioning Systems.

Tests determine that the equipment and all components will operate within their recognized ratings, including electrical, temperature, and pressure, when the equipment is energized at rated voltage and operated at specified environmental conditions. Stipulated abnormal conditions are also imposed under which the product must perform in a safe manner. The evaluation covers all operational features (such as electric space heating) that may be used in the product.

Products complying with the applicable requirements may bear the agency listing mark. An approval agency program includes the auditing of continued production at the manufacturer’s factory.

AIR CONDITIONERS

Unitary air conditioners consist of factory-matched refrigerant circuit components that are applied in the field to fulfill the requirements of the user. The manufacturer often incorporates a heating function compatible with the cooling system and a control system that requires a minimum of field wiring.

A variety of products is available to meet the objectives of nearly any system. Many different heating sections (gas- or oil-fired, electric, or condenser reheat), air filters, and heat pumps, which are a specialized form of unitary product, are available. Such matched equipment, selected with compatible accessory items, requires little field design or field installation work.

REFRIGERANT CIRCUIT DESIGN

Chapters 21, 34, and 35 describe coil, compressor, and condenser designs. Chapters 2, 5, 6, and 7 of the *ASHRAE Handbook—Refrigeration* cover refrigerant circuit piping selection, chemistry, cleanliness, and lubrication. Proper coil circuiting is essential for adequate oil return to the compressor. Crankcase heaters are usually incorporated to prevent refrigerant migration to the compressor crankcase during shutdown. Oil pressure switches and pumpdown or pumpout controls are used when additional assurance of reliability is economical and/or required.

Safety Controls

High-pressure and high-temperature limiting devices, internal pressure bypasses, current limiting devices, and devices that limit compressor torque prevent excessive mechanical and electrical stresses. Low-pressure or temperature cutout controllers may be used to protect against loss of charge, coil freeze-up, or loss of evaporator airflow.

Flow Control Devices

Refrigerant flow is most commonly controlled either by a fixed metering device such as a short tube restrictor or capillary tube or by thermostatic expansion valves. Capillaries and short tube restrictors are simple, reliable, and economical, and they can be sized for peak performance at rating conditions. The evaporator may be overfed at high condensing temperatures and underfed at low condensing temperatures because of changing pressure differential across the fixed metering device. When such conditions exist, a less-than-optimum cooling capacity usually results. However, the degree of loss varies with the design of the condenser, the volume of the system, and the total refrigerant charge. The amount of unit charge is critical, and a capillary-controlled evaporator must be matched to the specific condensing unit.

Properly sized thermostatic expansion valves provide constant superheat and good control over a range of operating conditions. Superheat is adjusted to ensure that only superheated gas returns to the compressor, usually with 7 to 14°F superheat at the compressor inlet at normal rating conditions. This superheat setting may be higher at a lower outdoor ambient temperature (cooling tower water temperature for water-cooled products) or indoor wet-bulb temperature. Compressor loading can be limited with vapor-charged thermostatic expansion valves. Low discharge pressure (low ambient) operation causes a diminished pressure drop across valves and capillaries so that full flow is not maintained. Decreased capacity, low coil temperatures, and freeze-up can result unless low ambient condensing pressure control is provided.

Properly designed unitary equipment allows only a minimum amount of liquid refrigerant to return through the suction line to the compressor during abnormal operation. Normally, the heat absorbed in the evaporator vaporizes all the refrigerant and adds a few degrees of superheat. However, any conditions that increase refrigerant flow beyond the heat transfer capabilities of the evaporator can cause liquid carryover into the compressor return line. Such an increase may be caused by a poorly positioned thermal element of an expansion valve or by an increase in the condensing pressure of a capillary system, which may be caused by fouled condenser surfaces, excessive refrigerant charge, reduced flow of condenser air or water, or the higher temperature of the condenser cooling medium. Heat transfer at the evaporator may be reduced by dirty surfaces, low-temperature air entering the evaporator, or reduced airflow caused by a blockage in the air system.

Piping

Transient flow conditions are a special concern. During off periods, refrigerant migrates and condenses in the coldest part of the system. In an air conditioner within a cooled space, this area is typically the evaporator. When the compressor starts, the liquid tends to return to the compressor in slugs. The severity of **slugging** is affected by temperature differences, off time, component positions, and traps formed in suction lines. Various methods such as suction-line accumulators, specially designed compressors, the refrigerant pumpdown cycle, nonbleed port thermostatic expansion valves, liquid-line solenoid valves, or limited refrigerant charge are used to avoid equipment problems associated with excessive liquid return. Chapter 2 of the *ASHRAE Handbook—Refrigeration* has further information on refrigerant piping.

Strainers and filter dryers minimize the risk of foreign material restricting capillary tubes and expansion valves (e.g., small quantities of solder, flux, and varnish). Overheated and oxidized oil may dissolve in warm refrigerant and deposit at lower temperatures in capillary tubes, expansion valves, and evaporators. Filter dryers are highly desirable, particularly for split-system units, to remove any moisture that may have been introduced during installation or servicing. Moisture contamination can cause oil breakdown, motor insulation failure, and freezing or other restrictions at the expansion device.

Capacity Control

Buildings with high internal heat loads require cooling even at low outdoor temperatures. The capacity of air-cooled condensers can be controlled by changing airflow or flooding tubes with refrigerant. Airflow can be changed by using dampers, adjusting fan speed, or stopping some of the fan motors in a multifan system.

Suction pressures drop momentarily during start-up. Circuits with a low-pressure cutout controller may require a time-delay relay to bypass it momentarily to prevent nuisance tripping.

In cool weather, air conditioners operate for short periods only. If the weather is also damp, high levels and wide variances in humidity may occur. Properly designed capacity-controlled units operate for longer periods, which may improve humidity control and comfort. In any case, cooling equipment should not be oversized.

Units with two or more separate refrigerant circuits permit independent operation of the individual systems, which reduces capacity while better matching the changing load conditions. Larger, single-compressor systems may offer capacity reduction through the use of cylinder-unloading compressors, variable-speed or multispeed compressors, multiple compressors, or hot-gas bypass controls. At full-load operation, efficiency is unimpaired. However, reduced capacity operation may increase or decrease system efficiency, depending on the type of capacity-reduction method used.

Variable-speed or multispeed compressors and use of multiple compressors can improve efficiency at part-load operation. Cylinder unloading can increase or decrease system performance, depending on the particular method used. Multispeed and variable-speed compressors, multiple compressors, and cylinder unloading generally produce higher comfort levels through lower cycling and better matching of the capacity to the load. Hot-gas bypass does not reduce capacity efficiently, although it generally provides a wider range of capacity reduction. Units with capacity-reduction compressors usually have capacity-controlled evaporators; otherwise the evaporator coil temperatures may be too high to provide dehumidification. Capacity-controlled evaporators are usually split, with at least one of the expansion valves controlled by a solenoid valve. Evaporator capacity is reduced by closing the solenoid valve. The compressor capacity-reduction controls or the hot-gas bypass system then provides maximum dehumidification, while the evaporator coil temperature is maintained above freezing to avoid coil frosting. Chapter 2 of the *ASHRAE Handbook—Refrigeration* has details on hot-gas bypass.

AIR-HANDLING SYSTEMS

High airflow, low static pressure performance, simplicity, economics, and compact arrangement are characteristics that make propeller fans particularly suitable for nonducted air-cooled condensers. Small-diameter fans are direct-driven by four-, six-, or eight-pole motors. Low starting torque requirements allow the use of single-phase shaded pole and permanent split-capacitor (PSC) fan motors and simplify speed control for low outdoor temperature operation. Many larger units use multiple fans and three-phase motors. Larger diameter fans are belt driven at a lower rpm to maintain low tip speeds and quiet operation.

Centrifugal blowers meet the higher static pressure requirements of ducted air-cooled condensers, forced-air furnaces, and evaporators. Indoor airflow must be adjusted to suit duct systems and plenums while providing the required airflow to the coil. Some small blowers are direct-driven with multispeed motors. Large blowers are always belt-driven and may have variable-pitch motor pulleys for airflow adjustment. Vibration isolation reduces the amount of noise transmitted by bearings, motors, and blowers into cabinets. (See Chapter 18 for details of fan design and Chapters 16 and 17 for information on air distribution systems.)

Disposable fiberglass filters are popular because they are available in standard sizes at low cost. Cleanable filters offer economic advantages when cabinet dimensions are not compatible with common sizes. Electronic or other high-efficiency air cleaners are used when a high degree of cleaning is desired. Larger equipment frequently is provided with automatic roll filters or high-efficiency bag filters. (See Chapter 24 for additional details about filters.)

Provision for introducing outdoor air for economizer cooling and/or ventilation is made in many units; rooftop units are particularly adaptable for receiving outdoor air. Air-to-air heat exchangers can be used to reduce the energy losses from ventilation. Some units have automatically controlled dampers to permit cooling by outdoor air, which increases system efficiency.

ELECTRICAL DESIGN

Electrical controls for unitary equipment are selected and tested to perform their individual and interrelated functions properly and safely over the entire range of operating conditions. Internal line-break thermal protectors provide overcurrent protection for most single-phase motors, smaller sizes of three-phase motors, and hermetic compressor motors. These rapidly responding temperature sensors, embedded in motor windings, can provide precise locked rotor and running overload protection.

Branch-circuit, short-circuit, and ground-fault protection is commonly provided by fused disconnect switches. Time-delay fuses allow selection of fuse ratings closer to running currents and thus provide backup motor overload protection, as well as short-circuit and ground-fault protection. Circuit breakers may be used in lieu of fuses where their use conforms to appropriate code requirements.

Some larger compressor motors have dual windings and contactors for step starting. A brief delay when energizing contactors reduces the magnitude of inrush current.

The use of 24 V (NEC Class 2) control circuitry is common for room thermostats and interconnecting wiring between split systems. It offers advantages in temperature control, safety, and ease of installation. Electronic, communicating microprocessor thermostats and control systems are becoming common.

Motor speed controls are used to vary evaporator airflow of direct-drive fans, air-cooled condenser airflow for low outdoor temperature operation, and compressor speed to match load demand. Multitap motors and autotransformers provide one or more speed steps. Solid-state speed control circuits can provide a continuously variable speed range. However, motor bearings, windings, overload protection, and the motor suspension system must be suitable for operation over the full speed range.

In addition to speed control, solid-state circuits provide reliable temperature control, motor protection, and expansion valve refrigerant control. Complete temperature control systems are frequently included with the unit. Control system features such as automatic night setback, economizer control sequence, and zone demand control of multizone equipment contribute to improved comfort and energy savings. Chapter 46 of the *ASHRAE Handbook— Applications* has additional information on control systems.

MECHANICAL DESIGN

Cabinet height is important for rooftop and ceiling-suspended units. The size limitations of truck bodies, freight cars, doorways, elevators, and various rigging practices must be considered in large unit design. In addition, structural strength of both the unit and the crate must be adequate for handling, warehouse stacking, shipping, and rigging.

The following criteria are also important: (1) cabinet insulation must prevent excessive sweating in high-humidity ambient conditions; (2) insulated surfaces exposed to moving air should withstand air erosion; (3) air leakage around panels and at cabinet joints should be minimized; and (4) the cabinet insulation must be adequate to reduce energy transfer losses from the circulating airstream.

Also, cooling coil air velocities must be low enough to ensure that condensate is not blown off the coil. The drain pan must be sized to contain the condensate and must also be protected from high-velocity air. Service access must be provided for installation and repair. Versatility of application, such as multiple fan discharge directions and the ability to install piping from either side of the unit, is another consideration. Weatherproofing requires careful attention and testing.

ACCESSORIES

Using standard cataloged accessories, the designer can often incorporate unitary products in special applications. Typical examples (Figures 4, 6, 7, and 8) are plenum coil housings, return air filter grilles, and diffuser-return grilles for single-outlet units. Air duct kits offered for rooftop units (Figure 4) permit concentric or side-by-side ducting, as well as horizontal or vertical connections. Mounting curbs are available to facilitate unit support and roof flashing. Other accessories include high static pressure fan drives, controls for low outdoor temperature operation, and duct damper kits for control of outdoor air intakes and exhausts.

HEATING

It is important to install cooling coils downstream of furnaces so that condensation does not form inside the combustion and flue passages. Upstream cooling coil placement is permissible when the furnace has been approved for this type of application and designed to prevent corrosion. Burners, pilot flames, and controls must be protected from the condensate.

Chapter 23 describes hot water and steam coils used in unitary equipment, as well as the prevention of coil freezing from ventilation air in cold weather. Chapters 26, 28, and 31 discuss forced-air and oil- and gas-fired furnaces commonly used with, or included as part of, year-round equipment.

AIR-SOURCE HEAT PUMPS

Capacities of unitary air-source heat pumps range from about 1.5 to 30 tons, although there is no specific limitation. This equipment is used in residential, commercial, and industrial applications. Multi-unit installations are particularly advantageous because they permit zoning, which provides the opportunity for heating or cooling in each zone on demand. Application factors unique to unitary heat pumps include the following:

- The unitary heat pump normally fulfills a dual function—heating and cooling; therefore, only a single piece of equipment is required for year-round comfort. Some regions, especially central and northern Europe and parts of North America, have little need for cooling. Some manufacturers offer heating-only heat pumps for these areas and for special applications.
- A single source of energy can supply both heating and cooling requirements.
- Heat output can be as much as two to four times that of the purchased energy input.
- Vents and/or chimneys may be eliminated, thus reducing building costs.

In an air-source heat pump (Figure 10), the outdoor coil rejects heat to outdoor air when in the cooling mode and extracts heat from outdoor air when in the heating mode. Most residential applications consist of an indoor fan and coil unit, either vertical or horizontal, and an outdoor fan-coil unit. The compressor is usually located in the outdoor unit. Electric heaters are commonly included in the indoor unit to provide heat during defrost cycles and during periods of high heating demand that cannot be satisfied by the heat pump alone.

Add-On Heat Pumps

An air-source heat pump can be added to new or existing gas- or oil-fired furnaces. This unit, typically called an add-on, dual-fuel or hybrid heat pump, normally operates as a conventional heat pump. During extremely cold weather, the refrigerant circuit is turned off and the furnace provides the required space heating. These add-on heat pumps share the air distribution system with the warm air furnace. The indoor coil may be either parallel to or in series with the furnace. However, the furnace should never be upstream of the indoor coil if both systems are operated together.

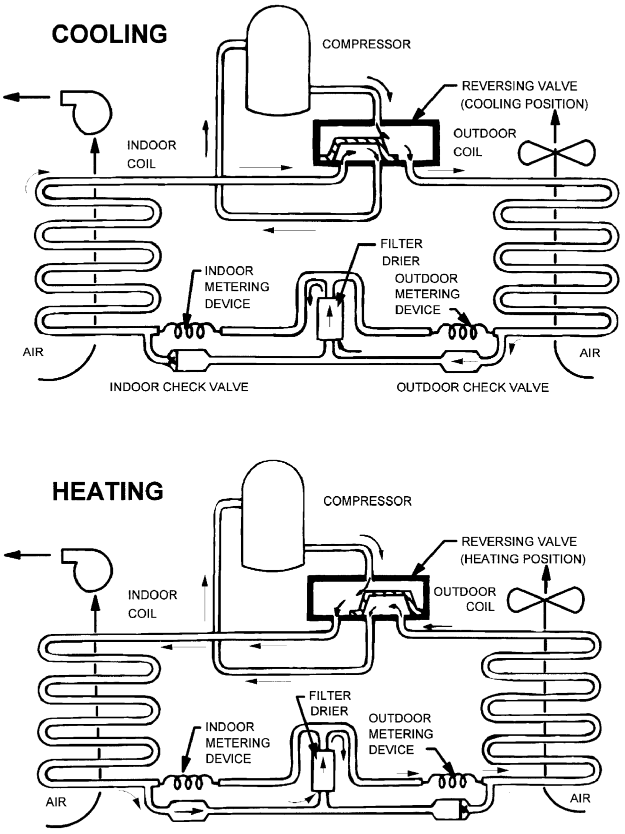


Fig. 10 Typical Schematic of Air-to-Air Heat Pump System

Special controls are available that prevent simultaneous operation of the heat pump and the furnace in this configuration. Such operation raises the refrigerant condensing temperature, which could cause a compressor failure. In applications where the heat pump and furnace operate at the same time, the following conditions must be met: (1) the furnace and heat pump indoor coil must be arranged in parallel, or (2) the furnace combustion and flue passages must be designed to avoid condensation-induced corrosion during the cooling operation.

SELECTION

Figure 11 shows performance characteristics of a single-speed, air-source heat pump, along with the heating and cooling loads for a typical building. The heat pump heating capacity decreases as the ambient temperature decreases. This characteristic is opposite to the trend of the building load. The outdoor temperature at which the heat pump capacity equals the building load is called the **balance point**. When the outdoor temperature is below the balance point, supplemental heat (usually electric resistance) must be added to make up the difference, as shown by the shaded area. The COP shown in Figure 11 is for the refrigerant circuit only and does not include supplemental heat effects below the balance point.

In selecting the proper size heat pump, the cooling load for the building is calculated using standard practice. The heating balance

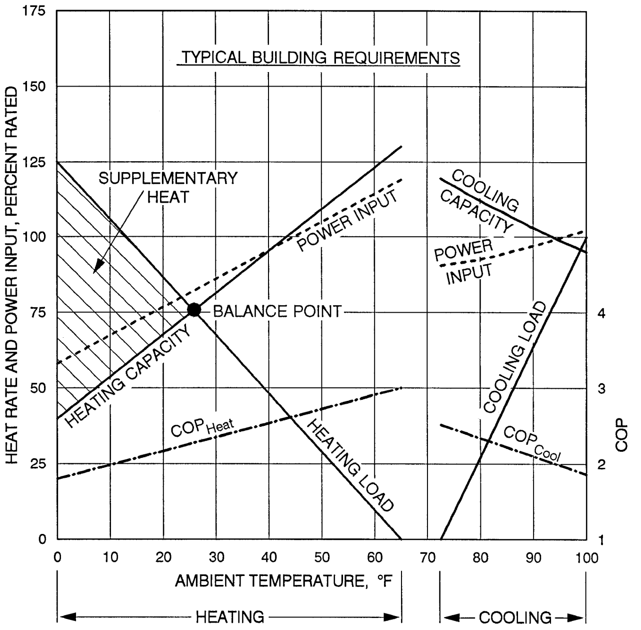


Fig. 11 Operating Characteristics of Single-Stage Unmodulated Heat Pump

point may be lowered by improving the thermal performance of the structure or by choosing a heat pump larger than the cooling load requires. Excessive oversizing of the cooling capacity causes excessive cycling, which results in uncomfortable temperature and humidity levels in cooling.

Use of variable-speed, multispeed, or multiple compressors and variable-speed fans can improve the matching of both heating and cooling loads over an extended range. This equipment can reduce cycling losses and provide improved comfort levels as well.

REFRIGERANT CIRCUIT AND COMPONENTS

Heat pump yearly operating hours are often up to five times those of a cooling-only unit. In addition, heating extends over a greater range of system operating conditions at higher stress conditions, so the design must be thoroughly analyzed to ensure maximum reliability. Improved components and protective devices contribute to better reliability, but the equipment designer must select components that are approved for the specific application.

For a reliable and efficient heat pump system, the following factors must be considered: (1) outdoor coil circuitry, (2) defrost and water drainage, (3) refrigerant flow controls, (4) refrigerant charge management, and (5) compressor selection.

Outdoor Coil Circuitry

When the heat pump is used for heating, the outdoor coil operates as an evaporator. The refrigerant in the coil is less dense than when the coil operates as a condenser. To avoid an excessive pressure drop during heating, the circuitry is usually a compromise between optimum performance as an evaporator and optimum performance as a condenser.

Defrost and Water Drainage

During colder outdoor temperatures, usually below 40 to 50°F, and high relative humidities (above 50%), the outdoor coil operates below the frost point of the outdoor air. The frost that builds up on the surface of the coil is usually removed by the **reverse-cycle defrost** method. In this method, the refrigerant flow in the system is reversed, and hot gas from the compressor flows through the outdoor coil, melting the frost. A typical defrost takes 4 to 10 min. The outdoor fan is normally off during defrost. Because the defrost is a transient process, capacity, power, and the pressures and temperatures of refrigerant in different parts of the system change throughout the defrost period (Miller 1989, O'Neal 1989a).

The performance of the heat pump during the defrost cycle can be enhanced in several ways. Improved defrost times and water removal can be achieved by ensuring that adequate refrigerant is routed to the lower refrigerant circuits in the outdoor coil. Properly sizing the defrost expansion device is critical for reducing defrost times and energy use (O'Neal 1989b). If the expansion device is too small, suction pressure can be below atmospheric, defrost times become long, and energy use is high. If the expansion device is too large, the compressor can be flooded with liquid refrigerant. During the conventional reverse-cycle defrost, there is a significant pressure spike at defrost termination. Starting the fan 30 to 45 s before defrost termination can minimize the spike (Anand et al. 1989). In cold climates, the cabinet should be installed above grade to provide good drainage during defrost and to minimize snow and ice buildup around the cabinet. During prolonged periods of severe weather, it may be necessary to clear ice and snow from around the unit.

Several methods are used to determine the need to defrost. One of the more common, simple, and reliable control methods is to initiate defrost at predetermined time intervals (usually 90 min). Demand-type systems detect a need for defrosting by measuring changes in air pressure drop across the outdoor coil or changes in temperature difference between the outdoor coil and the outdoor air. Microprocessors are applied to control this function, as well as numerous other functions (Mueller and Bonne 1980). Demand defrost control is preferred because it requires less energy than other defrost methods.

Refrigerant Flow Controls

Separate refrigerant flow controls are usually used for the indoor and outdoor coils. Because the refrigerant flow reverses direction between the heating and cooling mode of operation, a check valve bypasses in the appropriate direction around each expansion device. Capillaries, fixed orifices, thermostatic expansion valves, or electronically controlled expansion valves may be used; however, capillaries and fixed orifices require that greater care be taken to prevent excessive flooding of refrigerant into the compressor. A check valve is not needed when an orifice-type expansion device or a biflow expansion valve is used. The reversing valve is the critical additional component required to make a heat pump air-conditioning system.

Refrigerant Charge Management

Extra care is required to control compressor flooding and the storage of refrigerant in the system during both heating and cooling. The mass flow of refrigerant during cooling is greater than during heating. Consequently, the amount of refrigerant stored may be greater in the heating mode than in the cooling mode, depending on the relative internal volumes of the indoor and outdoor coils. Usually, the internal volume of the indoor coils ranges from 110 to 70% of the outdoor coil volume. The relative volumes can be adjusted so that the coils not only transfer heat but also manage the charge.

When capillaries or fixed orifices are used, the refrigerant may be stored in an accumulator in the suction line or in receivers that can remove the refrigerant charge from circulation when compressor floodback is imminent. Thermostatic expansion valves reduce the flooding problem, but storage may be required in the condenser. Use of accumulators and/or receivers is particularly important in split systems.

To maintain performance reliability, the amount of refrigerant in the system must be checked and adjusted in accordance with the manufacturer's recommendations, particularly when charging a heat pump. Manufacturer’s recommendations for accumulator installation must be followed so that good oil return is assured.

Compressor Selection

Compressors are selected on the basis of performance, reliability, and probable applications of the unit. In good design practice, equipment manufacturers often consult with compressor manufacturers during both design and application phases of the unitary equipment to verify proper application of the compressor. Compressors in a heat pump operate over a wide range of suction and discharge pressures; thus, their design parameters, (e.g., refrigerant discharge temperatures, pressure ratios, clearance volume, and motor-overload protection) require special consideration. In all operating conditions, compressors should be protected against loss of lubrication, liquid floodback, and high discharge temperatures.

SYSTEM CONTROL AND INSTALLATION

The installation should follow the manufacturer’s instructions. Because the supply air from a heat pump is usually at a lower temperature (typically 90 to 100°F) than that from most heating systems, ducts and supply registers should control air velocity and throw to minimize the perception of cool drafts.

Low-voltage heating/cooling thermostats control heat pump operation. Both models that switch automatically from heating to cooling operation and manual selection models are available. Usually, heating is controlled in two stages. The first stage controls heat pump operation, and the second stage controls supplementary heat. When the heat pump cannot satisfy the first stage’s call for heat, supplementary heat is added by the second-stage control. The amount of supplementary heat is often controlled by an outdoor thermostat that allows additional stages of heat to be turned on only when required by the colder outdoor temperature.

Microprocessor technology has led to night setback modes and intelligent recovery schemes for morning warm-up on heat pump systems (see Chapter 46 of the *ASHRAE Handbook—Applications*).

WATER-SOURCE HEAT PUMPS

A water-source heat pump (WSHP) is a single-package reverse-cycle heat pump that uses water as the heat source when in the heating mode and as the heat sink when in the cooling mode. The water supply may be a recirculating closed loop, a well, a lake, or a stream. Water for closed-loop heat pumps is usually circulated at 2 to 3 gpm per ton of cooling capacity. A groundwater heat pump (GWHP) can operate with considerably less water flow. The main components of a WSHP refrigeration system are a compressor, a refrigerant-to-water heat exchanger, a refrigerant-to-air heat exchanger, refrigerant expansion devices, and a refrigerant-reversing valve. Figure 12 shows a schematic of a typical WSHP system.

Designs of packaged WSHPs range from horizontal units located primarily above the ceiling or on the roof, to vertical units usually located in basements or equipment rooms, to console units located in the conditioned space. Figure 13 and Figure 14 illustrate typical designs.

SYSTEMS

WSHPs are used in a variety of systems. These include the following:

1. Water-loop heat pump systems (Figure 15A)
2. Groundwater heat pump systems (Figure 15B)
3. Closed-loop surface water heat pump systems (Figure 15C)
4. Surface water heat pump systems (Figure 15D)
5. Ground-coupled heat pump systems (Figure 15E)

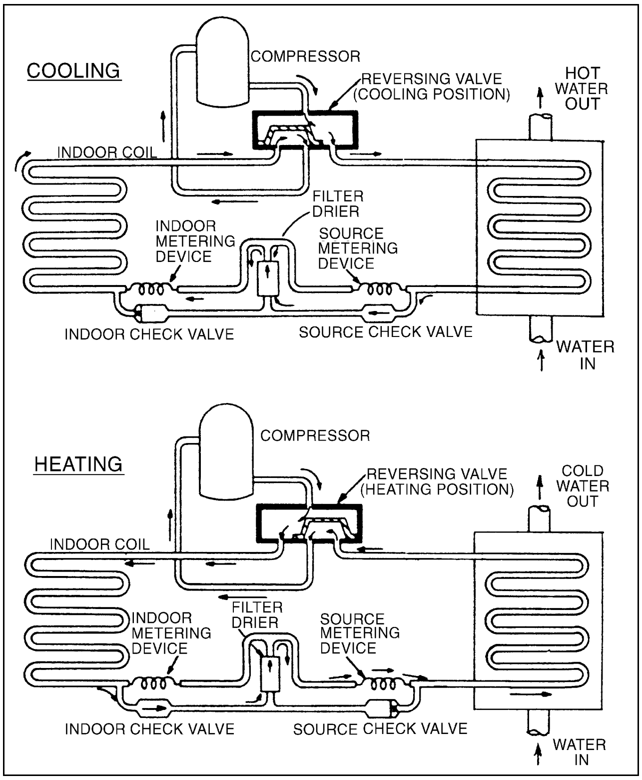


Fig. 12 Schematic of a Typical Water-Source Heat Pump System

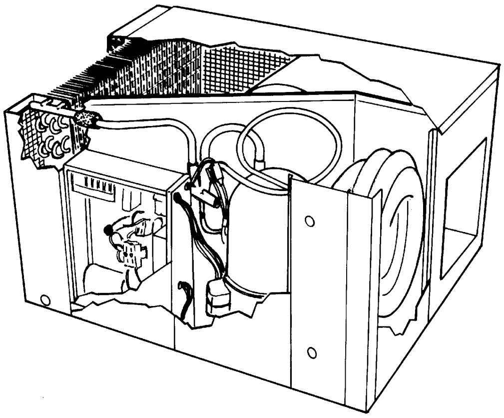


Fig. 13 Typical Horizontal Water-Source Heat Pump

A **water-loop heat pump** (WLHP) uses a circulating water loop as the heat source and the heat sink. When the loop water temperature exceeds a certain level during cooling operation, a cooling tower dissipates heat from the water loop into the atmosphere. When the loop water temperature drops below a prescribed level during heating operation, heat is added to the circulating loop water, usually with a boiler. In multiple-unit installations, some heat pumps may operate in the cooling mode while others operate in the heating mode, and controls are needed to keep the loop water temperature within the prescribed limits. Chapter 8 has more information on water-loop heat pumps.

A **groundwater heat pump** (GWHP) uses groundwater from a nearby well and passes it through the heat pump’s water-to-refrigerant heat exchanger where it is warmed or cooled, depending on

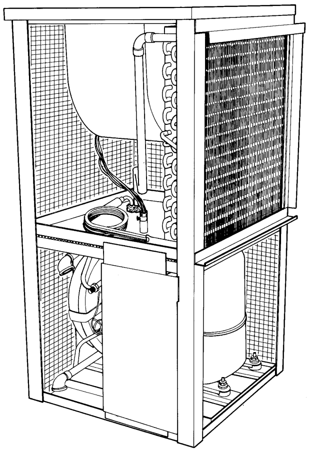


Fig. 14 Typical Vertical Water-Source Heat Pump

the operating mode. It is then discharged to a drain, a stream, or a lake, or it is returned to the ground through a reinjection well.

Many state and local jurisdictions have enacted ordinances relating to the use and discharge of groundwater. Because aquifers, the water table, and groundwater availability vary from region to region, these regulations cover a wide spectrum.

A **surface water heat pump** (SWHP) uses water from a nearby lake, stream, or canal. After passing through the heat pump heat exchanger, it is returned to the source or a drain several degrees warmer or cooler, depending on the operating mode of the heat pump. **Closed-loop** surface water heat pumps use a closed water or brine loop that includes pipes or tubing submerged in the surface water (river, lake, or large pond) that serves as the heat exchanger. The adequacy of the total thermal capacity of the body of water must be considered.

A **ground-coupled heat pump** (GCHP) system uses the earth as a heat source and sink. Usually, plastic piping is installed in either a shallow horizontal or deep vertical array to form the heat exchanger. The massive thermal capacity of the earth provides a temperature-stabilizing effect on the circulating loop water or brine. Installing this type of system requires detailed knowledge of the climate; the site; the soil temperature, moisture content, and thermal characteristics; and the performance, design, and installation of water-to-earth heat exchangers. The *Design/Data Manual for Closed-Loop Ground-Coupled Heat Pump Systems* (ASHRAE 1985) has detailed information on design of GCHP systems. Additional information on GCHP systems is presented in Chapter 32 of the *ASHRAE Handbook—Applications*.

Entering Water Temperatures

These various water sources provide a wide range of entering water temperatures to WSHPs. Not only do the entering water temperatures vary by water source, but they also vary by climate and time of year. Due to the wide range of entering water or brine temperatures encountered, it is not feasible to design a universal packaged product that can handle the full range of possibilities effectively. Therefore, WSHPs are rated for performance at a number of standard rating conditions.

PERFORMANCE CERTIFICATION PROGRAMS

ARI maintains the following certification programs for water-source heat pumps:

1. ARI *Standard* 320 for Water-Source Heat Pumps. A water-source heat pump is typically one of multiple units using fluid circulated in a common piping loop as a heat source/heat sink. The temperature of the loop fluid is usually mechanically controlled within a moderate temperature range of 60 to 90°F.

   Units tested in accordance with ARI *Standard* 320 have standard cooling ratings at 85°F entering water temperature and standard heating ratings at 70°F entering water temperature. Maximum operating conditions are checked at the upper temperature level at 90°F entering water temperature and at the lower temperature level at 60°F leaving water temperature. The range of test conditions covers the extremes of entering water temperatures typically encountered in WLHP systems.
2. ARI *Standard* 325 for Groundwater-Source Heat Pumps. A groundwater-source heat pump typically uses water pumped from a well, lake, or stream as a heat source/heat sink. The temperature of the water is related to climatic conditions and usually ranges from 45 to 75°F for deep wells.

   Units tested in accordance with ARI *Standard* 325 have standard cooling and heating ratings at both 50 and 70°F entering water temperature. Rated efficiencies include an allowance for water pumping power. Maximum operating conditions are checked at the upper temperature level at 75°F entering water temperature and at the lower temperature level at 45°F entering water temperature. These water temperatures bracket the range of groundwater temperatures found across the United States.
3. ARI *Standard* 330 for Ground-Source Closed-Loop Heat Pumps. A ground-source closed-loop heat pump typically uses fluid circulated through a subsurface piping loop as a heat source/heat sink. The heat exchange loop may be placed in horizontal trenches or vertical bores, or may be submerged in a body of surface water. The temperature of the fluid is related to climatic conditions and usually ranges from 25 to 100°F.

   Due to the low temperatures that may be encountered in closed-loop ground-coupled systems, units tested in accordance with ARI *Standard* 330 circulate an antifreeze solution instead of water. This rating procedure provides standard cooling ratings at 77°F entering fluid temperature and standard heating ratings at 32°F entering fluid temperature. Rated efficiencies include an allowance for power to circulate the fluid. Maximum operating conditions are checked at 100°F entering fluid temperature when operating in the cooling mode and 25°F entering fluid temperature when operating in the heating mode.

The ARI *Directory of Certified Applied Air-Conditioning Products* lists the cooling capacity, cooling efficiency, heating capacity, and heating COP of units rated in accordance with the three ARI standards.

Canadian Standards Association CAN/CSA *Standard* C446 for ground-source and water-source heat pump systems is essentially the same as ARI *Standards* 330 and 325.

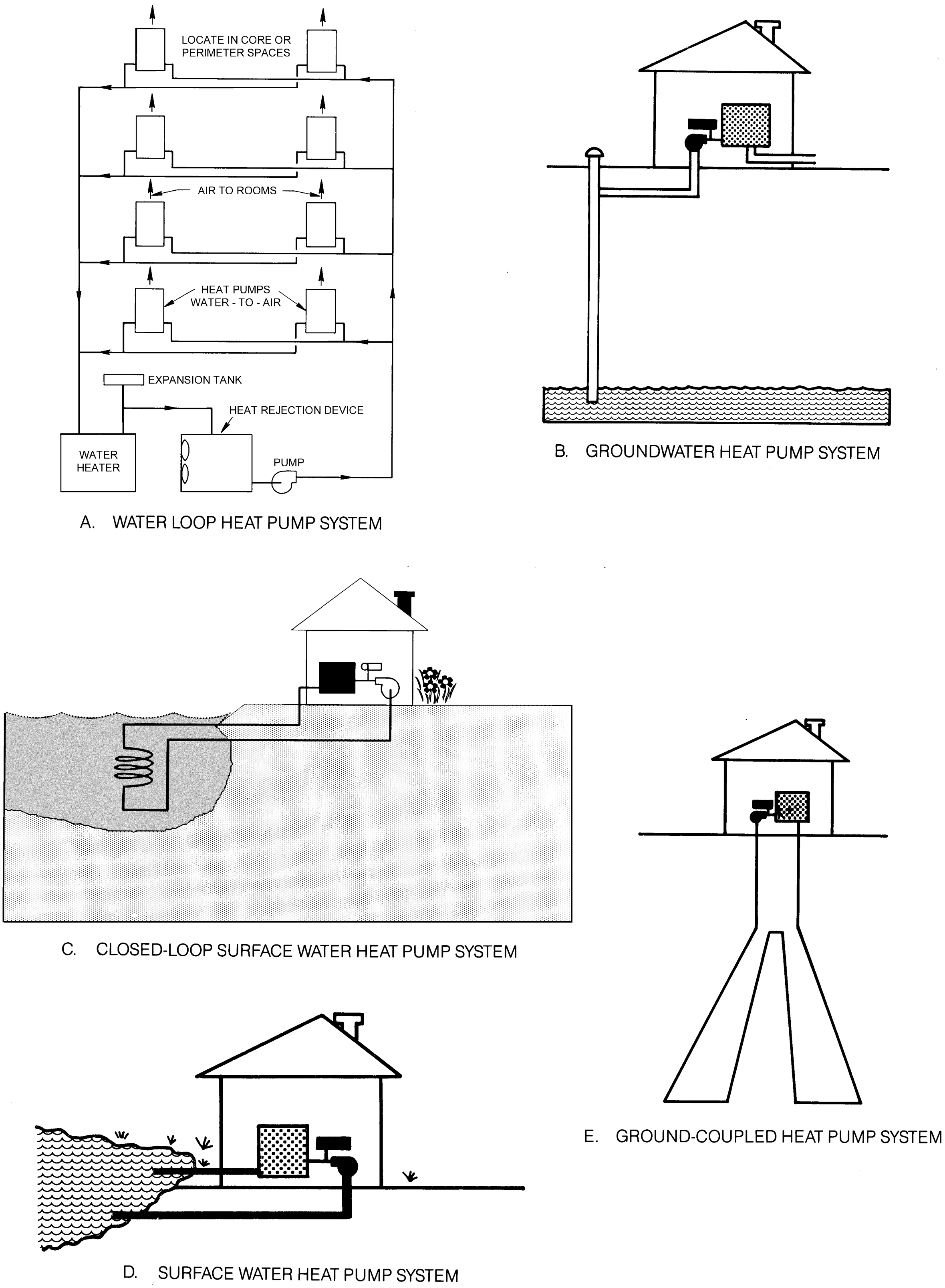
There are no ARI certification programs for water-source heat pumps designed specifically for surface water applications.

EQUIPMENT DESIGN

Water-source heat pumps are designed to match differing levels of entering water temperatures by optimizing the relative sizing of the indoor refrigerant-to-air heat exchanger and the refrigerant-to-water heat exchangers and by matching the expansion devices to the refrigerant flow rates.

Compressors. WSHPs usually have single-speed compressors, although some high-efficiency models use multispeed compressors. Higher capacity equipment may use multiple compressors. The compressors may be of the reciprocating, rotary, or scroll type. Single-phase units are available at voltages of 115, 208, 230, and 265. All larger equipment is for three-phase power supplies with voltages of 208, 230, 460, or 575. The compressors are usually provided with electromechanical protective devices.

Indoor Air System. Console WSHP models are designed for free delivery of the conditioned air. Other models have ducting



A. WATER LOOP HEAT PUMP SYSTEM

B. GROUNDWATER HEAT PUMP SYSTEM

C. CLOSED-LOOP SURFACE WATER HEAT PUMP SYSTEM

D. SURFACE WATER HEAT PUMP SYSTEM

E. GROUND-COUPLED HEAT PUMP SYSTEM

Fig. 15 Water-Source Heat Pump Systems

capability. Smaller WSHPs have multispeed, direct-drive centrifugal blower wheel fan systems. Large capacity equipment has belt-drive systems. All units have provisions for air filters of fiberglass, metal, or plastic foam.

Indoor Heat Exchanger. The indoor heat exchanger of WSHP units is a conventional plate-fin coil of copper tubes and aluminum fins. The tubing in the coil is circuited so that it can function effectively as an evaporator with the refrigerant flow in one direction and as a condenser when the refrigerant flow is reversed.

Refrigerant-to-Water Heat Exchanger. The heat exchanger, which couples the heat pump to source/sink water, is of the tube-in-tube, tube-in-shell, or brazed-plate type. It must function in either the condensing or evaporating mode, so special attention is given to refrigerant-side circuitry. Heat exchanger construction is usually of copper and steel, and the source/sink water is exposed only to the copper portions. Cupronickel options to replace the copper are usually available for use with brackish or corrosive water. Brazed-plate heat exchangers are usually constructed of stainless steel, which reduces the need for special materials.

Refrigerant Expansion Devices. WSHPs rated in accordance with ARI *Standard* 320 operate over a narrow range of entering water temperatures, so most use simple capillaries as expansion devices. Units rated according to ARI *Standard* 325 or 330 usually use thermostatic expansion valves for improved performance over a broader range of inlet fluid temperatures.

Refrigerant-Reversing Valve. The refrigerant-reversing valves in WSHPs are identical to those used in air-source heat pumps.

Condensate Disposal. Condensate, which forms on the indoor coil when cooling, is collected and conveyed to a drain system.

Controls. Console WSHP units have built-in operating mode selector and thermostatic controls. Ducted units use low-voltage remote heat/cool thermostats.

Size. Typical space requirements and weights of WSHPs are presented in Table 3.

Table 3 Space Requirements for Typical Packaged Water-Source Heat Pumps

Water-to-Air Heat Pump	Length × Width × Height, ft	Weight, lb
1.5 ton vertical unit	2.0 × 2.0 × 3.0	180
3 ton vertical unit	2.5 × 2.5 × 4.0	250
3 ton horizontal unit	3.5 × 2.0 × 2.0	250
5 ton vertical unit	3.0 × 2.5 × 4.0	330
11 ton vertical unit	3.5 × 3.0 × 6.0	720
26 ton vertical unit	3.5 × 5.0 × 6.0	1550

Note: See manufacturers' specification sheets for actual values.

Special Features. Certain models of WSHPs include

Desuperheater. Uses discharge gas in a special water/refrigerant heat exchanger to heat water for a building.

Capacity modulation. Multiple compressors, multispeed compressors, or hot-gas bypass may be used.

Variable air volume (VAV). Reduces fan energy usage and requires some form of capacity modulation.

Automatic water valve. Closes off water flow through the unit when the compressor is off and permits variable water volume in the loop, which reduces pumping energy.

Outdoor-air economizer. Cools directly with outdoor air to reduce or eliminate the need for mechanical refrigeration during mild or cold weather when outdoor humidity levels and outdoor air quality are appropriate.

Water-side economizer. Cools with loop water to reduce or eliminate the need for mechanical refrigeration during cold weather; requires a hydronic coil in the indoor air circuit that is valved into the circulating loop when loop temperatures are relatively low and there is a call for cooling.

Electric heaters. Used in WLHP systems that do not have a boiler as a source for loop heating.

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