# CENTRAL HEAT PUMP AND AIR CONDITIONER INSTALLATION

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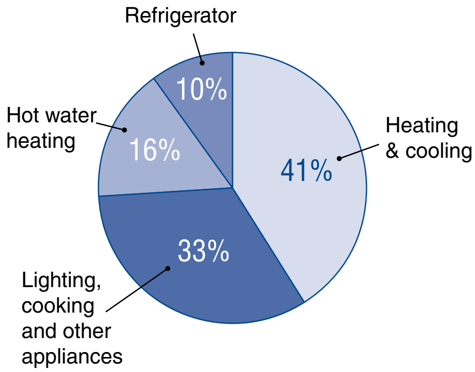
- Conducts R&D on technologies and concepts for energy efficiency, working closely with the building industry and with manufacturers of materials, equipment, and appliances
- Promotes energy/money saving opportunities to both builders and buyers of homes and commercial buildings
- Works with State and local regulatory groups to improve building codes, appliance standards, and guidelines for efficient energy use

## INTRODUCTION

A typical family may spend 40 to 60 percent or more of its annual utility budget on heating and cooling. Careful installation of heating and cooling equipment can increase operating efficiency, increase occupant comfort, and reduce utility costs.

HOME ENERGY COSTS




## WHY IS INSTALLATION IMPORTANT?

Incorrect installation of central heat pumps and air conditioners leads to high electric bills, poor indoor comfort, and maintenance problems. Many studies have shown that heat pumps and air conditioners — even new units — are often improperly charged, which can reduce system capacity and efficiency by 20 percent or more.

Incorrect air flow across the indoor coil is another common problem in air conditioner and heat pump installations, with a subsequent impact on indoor comfort and operating costs. Low air flow affects the cooling and heating capacity and efficiency of the unit. Excess air flow is a less common problem, but it can cause poor dehumidification during cooling, duct noise, and drafts.

Reduced air flow across the outdoor coil or inadequate air circulation around the outside unit also lowers capacity and operating efficiency. This often occurs when bushes are planted too close to the unit, the unit is installed under a porch, or the outdoor coil becomes clogged with leaves, pollen, or lint from a dryer.

Improperly installed controls can cause poor humidity control during cooling operation and inefficient operation of a heat pump during the heating season. Other installation problems that lower capacity and operating efficiency and cause maintenance problems include refrigerant lines that are too long, incorrectly pitched, or crimped.

## DESIGN AND INSTALLATION ELEMENTS

Proper heat pump and air conditioner installation is just one of four elements needed to provide an economical, efficient, and comfortable heating and cooling system. The design and installation of central heat pump and air conditioner systems must also address the following elements before or during equipment installation:

- Equipment must be properly selected and sized to meet house heating and cooling loads and to be as efficient as possible.
- The duct system must be correctly designed to work with the air conditioning and heat pump equipment and to distribute conditioned air properly throughout the house.
- The duct system must be properly installed and sealed to ensure its design performance.

## INSTALLATION GUIDELINES

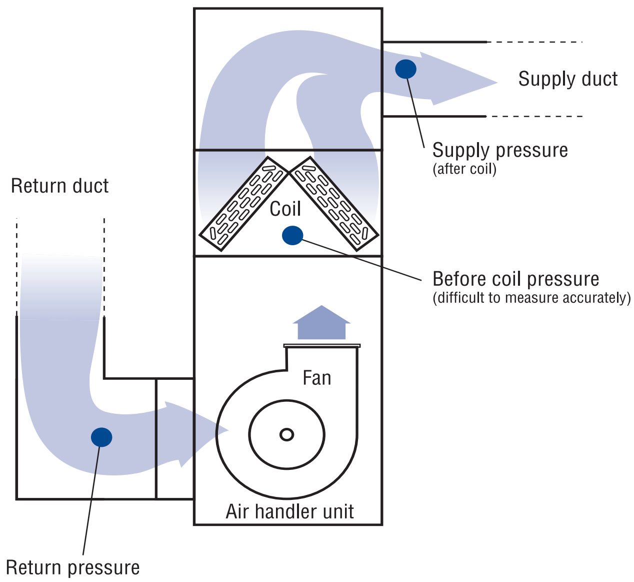
Heat pumps and air conditioners should be installed by knowledgeable technicians according to the manufacturer's installation instructions and all national and local code requirements. General installation guidelines are applicable to most units and should be followed insofar as they do not conflict with these other requirements.

Proper air conditioner and heat pump installation can be achieved by addressing four critical areas:

- indoor air handler, especially the air flow over the fan-coil unit and through the forced-air duct system
- refrigerant system, especially the refrigerant charge
- outdoor unit, especially its air supply
- control system, especially the thermostat that turns the equipment on and off.

### STATIC PRESSURES

To measure air flow




## INDOOR AIR HANDLER

### ✓ Indoor Air Flow

For most heat pump and air conditioning equipment, air flow over the indoor coil should be 400 cubic feet per minute (cfm) per ton of air conditioning capacity (plus or minus 50 cfm/ton) when the air conditioner has been operating long enough to wet the indoor coil (usually about 15 minutes). If wet coil conditions cannot be obtained (e.g., installation during the winter), then air flow should be 425 to 450 cfm/ton (plus or minus 50 cfm/ton). In humid climates where removing humidity from the interior air is an important function, the best system efficiency may occur where the air flow is between 350 and 400 cfm/ton. In dry climates where little dehumidification is needed, the best system efficiency may occur when the air flow is between 400 and 450 cfm/ton.

Before indoor coil air flow measurements are performed, the duct system should be inspected and tested to ensure that leaks are minimized. Although no technique for air flow measurement currently has universal acceptance, the best flow measurement method available should be performed to verify and document that the air flow is within acceptable ranges.

There are several air flow measurement approaches:

- The most common technique involves measuring the static pressure across the air handler unit and using the manufacturer's static pressure vs. flow rate curves for the air handler to estimate air flow. The manufacturer's curves will usually be based on the pressure between the return plenum and the area either before or after the indoor coil. Measuring the pressure before the coil is difficult, so it may be easier to calculate it by measuring the pressure after the coil and compensating for the pressure drop across the indoor coil.

  This method can give good results if accurate pressure measurements can be made and flow curves are available. However, pressure measurements are often not accurate because pressures fluctuate significantly around the air handler unit fan and coil as a result of flow turbulence induced by the fan, abrupt changes in flow direction near the air handler, etc. Flow curves are often not available to technicians in the field, and curves developed for new fans and coils are often not applicable to fans and coils that have become dirty while operating in the field.

  A variation of this method is to measure the static pressure across the indoor coil and use a flow curve supplied by the coil manufacturer to infer flow rate. Again, measuring the pressure before the coil is difficult and leads to errors.
- A second method is applicable just to heat pump systems equipped with supplementary strip heaters. The unit is operated with just the strip heaters on. The air flow rate can be calculated by measuring the temperature rise of air across the strip heaters and the energy consumption of the strip heaters

and indoor fan [air flow rate (cfm) = 3.16 x energy use (watts)/$\Delta T$ (°F)]. The accuracy of this method depends on the accuracy of the temperature and energy consumption measurements. In making the temperature measurements, it is important that the air be well mixed where the temperature is being measured and that the temperature sensor be out of the line of sight of the strip-heat elements to avoid an inaccurately high temperature reading due to radiative effects. The air flow measured using this technique must be corrected to wet coil conditions. Also, in some equipment, the fan speed during operation in the strip-heat mode is different from that during operation in the air-conditioning mode unless the thermostat and/or fan is properly configured by the technician for the test.

- Another method involves the use of flow hoods to measure air flow rates. In this approach, air flow rates are measured at the return registers or supply registers and added to obtain the total flow rate for the system. Researchers have found that many flow hoods used in residential applications in this manner are relatively inaccurate because of low air flow rates, non-uniform air flow through the flow hood, and other reasons. In addition, flow hoods underestimate the actual flow across the indoor coil when duct leaks are present.
- A new method that shows much promise for simplifying the measurement process while providing sufficiently accurate results is a specially designed orifice plate. The air filter in the system is removed and the orifice plate is inserted in its place. The pressure drop across the orifice plate is measured and used to estimate the system air flow rate using a flow curve for the orifice plate and a small correction factor for the different pressure drop induced by the orifice plate compared with the air filter. Non-uniform air flow entering the orifice plate (due to bends in the return duct before the orifice plate) reduces the accuracy of this method. As with flow hoods, duct leaks make this method underestimate the actual air flow across the indoor coil if the air filter is not located at the air handler.
- A final, more costly and complicated method involves use of a duct blower to measure air flow. A duct blower is a device used to measure duct leakage in an air distribution system. It comes equipped with its own fan and a flow metering system. First, the pressures in the supply and return ducts are measured under normal air-conditioning operation. The duct blower is then connected to the return register or the air handler directly (blocking off the existing return) so that all return air flows through the duct blower. The equipment is again operated in its normal air-conditioning mode, with the duct blower fan operated so that the same pressures are achieved in the supply and return ducts. The flow measured through the duct blower is the same as the flow rate through the equipment during normal operation.

#### ✓ Air Filters

Air filters should be located as close to the indoor fan and coil as possible and where they are easily accessible by the occupants. Forced-air heat pump and air conditioning systems use air filters to minimize the accumulation of dust on the indoor coil and fan because dust accumulation can reduce system efficiency. An air filter that is left in place too long will become plugged and will reduce air flow across the coil. Most manufacturers recommend replacing filters monthly, which requires frequent and ready access by the occupants.

### REFRIGERANT SYSTEM

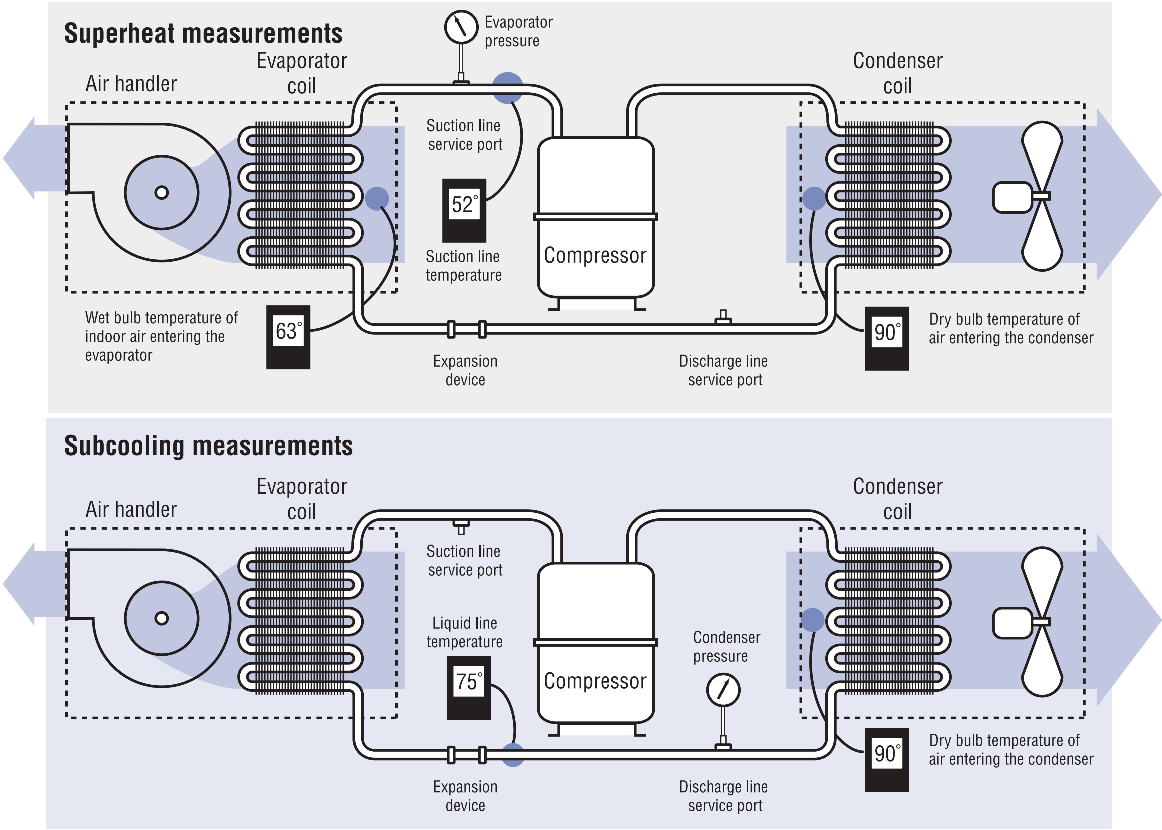
#### ✓ Charge

Proper refrigerant charge is critical to efficient and reliable operation of air conditioners and heat pumps. Before new systems or lines that have been exposed to the atmosphere are charged, they should be evacuated by the *deep vacuum method*. This method of system evacuation requires use of a gauge that can accurately measure pressures at least as low as 500 microns of mercury and a pump that can achieve those levels of evacuation. The low pressures are needed to eliminate moisture from the refrigerant loop.

After the system is assembled and before refrigerant is added, the system should be evacuated to a pressure no higher than 500 microns. The pump should be valved off and the system pressure monitored and recorded once a minute for a minimum of five minutes. Subsequent action depends on the measurements obtained.

- In a tight, dry system, the pressure will quickly rise to about 1000 microns and then remain stable. Such a system is ready to receive an initial charge.
- In a tight system that contains too much moisture, the pressure will rise above 2000 microns before stabilizing. Continued pumping is needed to remove the moisture.
- A system that has a leak will show pressure that does not stabilize, slowly rising to atmospheric pressure. A leaky system must be sealed and re-evacuated.

## SUPERHEAT AND SUBCOOL METHODS




Once the system has been properly evacuated, refrigerant can be weighed into the system per specifications or a pre-charge stored in the outdoor unit can be released (package systems are most often shipped fully charged). In both cases, account for any additional charge needed for refrigerant line lengths.

After the initial charge has been introduced and the correct air flow rate across the indoor coil had been verified, the charge should be checked after the system has operated for 15 minutes before the system can be considered accurately charged. There are three preferred methods of testing the refrigerant charge of heat pumps and air conditioners: superheat method, subcooling method, and approach method.

- The **superheat method** is suitable for systems that use fixed metering systems (e.g., a capillary tube or a fixed orifice). In general, the following measurements are made: the evaporator (indoor coil) pressure at the suction line service port, the suction line temperature within five feet of the compressor (e.g., at the suction line service port for split units, just before the accumulator of packaged units), the dry bulb temperature of the air entering the condenser (outdoor coil), and the wet bulb temperature of the indoor air entering the evaporator. The actual superheat is calculated by subtracting the saturation temperature based on the evaporator pressure from the suction line temperature. The desired superheat is determined from manufacturer specifications based on the entering evaporator and condenser air temperatures. The actual superheat is compared with the desired superheat, and the refrigerant charge is adjusted (refrigerant is added if the actual superheat is too high and removed if it is too low) until the actual superheat is within 2°F of the desired value. The system should operate for at least 10 minutes between adjustments.
- The **subcooling method** is used for systems with thermostatic expansion valves (TXVs). In general, the following measurements are made: the condenser pressure at the discharge line service port, the discharge (liquid) line temperature (e.g., entering the expansion valve, the condenser

outlet), and the dry bulb temperature of the air entering the condenser (outdoor coil). The actual subcooling is calculated by subtracting the discharge (liquid) line temperature from the saturation temperature based on the condenser pressure. The desired subcooling is determined from manufacturer specifications, possibly based on the entering condenser air temperature. The actual subcooling is compared with the desired subcooling, and the refrigerant charge is adjusted (refrigerant is added if the actual subcooling is too low and added if it is too high) until the actual subcooling is within 2°F of the desired value. The system should operate for at least 10 minutes between adjustments.

- The **approach method** is a less widely used method recommended by some manufacturers. Two measurements are made: the discharge (liquid) line temperature (between the condenser outlet and expansion device) and the dry bulb temperature of the air entering the condenser (outdoor coil). The difference between these two values is the approach temperature. The charge should be adjusted until the recommended approach temperature is achieved. The system should operate for at least 10 minutes between adjustments.

If ambient temperatures are below 80°F and the manufacturer does not provide superheat or subcooling data for outdoor temperatures below this value, then the tests must be modified to simulate higher outdoor temperatures, usually by partially blocking air flow to the outdoor coil.

The correct charge generally ensures that the evaporator and condenser operate at their design pressure and temperature. As a final check on system operation, the temperature difference across the indoor coil should be between 10 and 20°F (usually about 15°F).

### ✓ Refrigerant Lines

In split system designs:

- Refrigerant lines should be as short and straight as possible to minimize heat loss/gain and pressure drop. Normally, refrigerant lines should be less than 50 feet long, with a vertical length of less than 20 feet. Where longer runs are necessary, lines must comply with special manufacturer requirements.
- Refrigerant lines should be pitched and trapped according to manufacturer specifications. Bends and elbows should have a large radius (greater than twice the pipe diameter) to minimize pressure loss. Lines should be supported with hangers that avoid cutting the line or insulation.
- Suction lines should be insulated with a minimum 3/8-inch-thick closed-cell elastomeric foam pipe insulation to prevent condensation and heat gain. Refrigeration line insulation located outside should have a waterproof covering and should be protected from ultraviolet radiation (i.e., sunlight). Liquid lines normally do not need to be insulated.
- The hole in the outside wall through which the refrigerant lines go should be caulked. Similarly, the entry hole into the indoor unit should be sealed.
- Unless otherwise specified by the manufacturer, a liquid-line filter/dryer should be installed.

### OUTDOOR UNIT

The outdoor unit of heat pumps and air conditioners exchanges heat with outdoor air. To ensure effective heat dissipation, the outdoor unit should be located where air can circulate around it freely. Most outdoor units have a coil surrounding a centrally-located fan that pulls air through the coil. There should be no obstruction within 36 inches on the side with the service panel to allow for maintenance access, and there should be no obstructions within 12 inches on any of the remaining sides to allow for free air circulation. There should be no obstructions (e.g., porches) within 48 inches of the vertical air discharge from the unit that would force discharged air to recirculate directly back to the fan intakes. Landscaping should be kept at least 3 feet away from the outdoor unit so that leaves, seeds, and pollen do not plug the unit.

To prevent maintenance and other problems, the outdoor unit should be placed:

- on a level concrete (or equivalent) pad, elevated (if necessary) to prevent problems from snow or water accumulation, and leveled
- away from where collected rainwater, snow, or ice are likely to fall on it (e.g., under roof eaves)
- away from dryer vents (lint can plug the outdoor coil and chlorine in the dryer exhaust can cause corrosion)
- away from decks and windows to prevent the noise from disturbing occupants.

# CENTRAL HEAT PUMP AND AIR CONDITIONER INSTALLATION

*For more information, contact:*


***Energy Efficiency and Renewable Energy Clearinghouse (EREC)***
*1-800-DOE-3732*
*www.eere.doe.gov*


*Or visit the Building Technologies Program Web site at www.buildings.gov*

*Or refer to the* Specification of Energy-Efficient Installation and Maintenance Practices for Residential HVAC Systems, *Consortium for Energy Efficiency*
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*www.cee1.org/resid/rs-ac/hvac.php3*

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## CONTROL SYSTEM

### ✓ Thermostat

The heart of the control system is the thermostat. The thermostat should be placed on an inside wall, in a central area of the house, in a location protected from direct sunshine, and out of drafts induced by air supply registers. The interior wall cavity on which the thermostat is installed should be sealed at the top and bottom to prevent circulation of cool air in winter and warm air in summer, which would cause the thermostat to operate ineffectively. Make sure the control voltage of the thermostat is matched to the voltage specified by the thermostat manufacturer. Verify the correct operation of the thermostat by checking the anticipator setting and the cut-on and cut-off temperatures relative to the set point.

Programmable thermostats automatically allow different temperature settings during the day and week to save energy, although not all users are comfortable with their complexity. Setback can be performed manually using standard thermostat models, but a consistent pattern is usually not achieved in practice. If a programmable thermostat is installed, it should be one with an Energy Star® label. Energy Star® thermostats allow better control of heating and cooling equipment by ensuring essential programming features and accuracy.

### ✓ Heat Pump Considerations

For heat pump systems, a thermostat compatible with such systems must be installed. Changeover between heating and cooling should be performed manually rather than automatically. The thermostat should be equipped with an emergency heat switch that permits all resistance heaters to be energized when the refrigerant system is inoperative and activates an indoor indicator light. Programmable models for heat pumps that meet Energy Star® requirements ensure that costly back-up heat is not engaged under routine conditions or in using setback practices.

If the unit is not installed with an outdoor-lockout thermostat, such a device should be installed to prevent the supplemental heat from operating when the ambient temperature is above the heat pump balance point (that is, the temperature at which the heat pump has just enough capacity to keep the house warm, typically 25 to 40°F), especially when a non-intelligent or non-ramping thermostat is used. The outdoor-lockout should not prevent emergency heat operation or strip heat operation during defrost.

Check the operation of the resistance heaters to ensure that they are wired correctly to their control circuits (that they cycle correctly, are stagged properly, and are not on all the time).

The heat pump should preferably have a microprocessor defrost control to better defrost the system just when needed. Conventional defrost controls use temperature or pressure difference across the outdoor coil or time to initiate the defrost cycle; these should be set to provide the highest operating efficiency for the local weather conditions.

## DOCUMENTATION

Proper installation of heat pump and air conditioning equipment should be documented by providing the following information:

- results of the deep evacuation test that notes the initial evacuation pressure and time, and the system pressure each minute for at least five minutes after the initial pressure rise
- air flow rate across the indoor coil and the method used to measure this rate
- initial and final measurements and calculations relating to the charge check, as well as the manufacturer specifications
- temperature difference across the indoor coil.


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