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# How Air Conditioners Work

by Marshall Brain

When the temperature outside begins to climb, many people seek the cool comfort of indoor air conditioning. Like water towers and power lines, air conditioners are one of those things that we see every day but seldom pay much attention to.

**A window AC unit**

Wouldn't it be nice to know how these indispensable machines work their magic? In this article, we will examine air conditioners -- from small to huge -- so you know more about what you're seeing!

## The Many Faces of Cool

Air conditioners come in various sizes, cooling capacities and prices. One type that we see all the time is the window air conditioner.


**Window air conditioners are an easy and economical way to cool a small area.**

Most people who live in suburban areas usually have one of these in their backyard:


If you live in an apartment complex, this is probably a familiar sight:


Most businesses and office buildings have condensing units on their roofs, and as you fly into any airport you notice that warehouses and malls may have 10 or 20 condensing units hidden on their roofs:


And then if you go around back at many hospitals, universities and office complexes, you find large cooling towers that are connected to the air conditioning system:


Even though each of these machines has a pretty distinct look, they all work on the same principles. Let's take a closer look.

## The Basic Idea

An air conditioner is basically a refrigerator without the insulated box. It uses the evaporation of a **refrigerant**, like Freon, to provide cooling. The mechanics of the **Freon** evaporation cycle are the same in a refrigerator as in an air conditioner. According to the Merriam-Webster Dictionary Online, the term Freon is generically "used for any of various nonflammable fluorocarbons used as refrigerants and as propellants for aerosols."

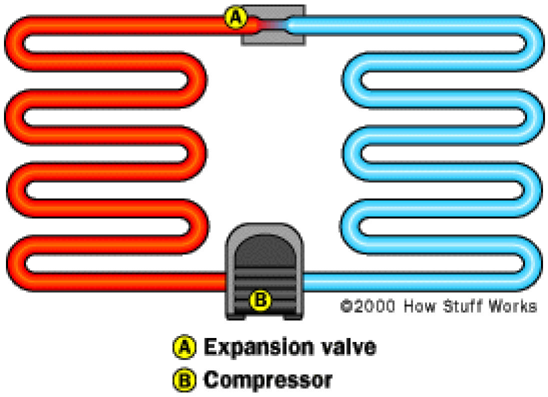



**Diagram of a typical air conditioner**

This is how the evaporation cycle in an air conditioner works (See How Refrigerators Work for complete details on this cycle):

1. The compressor compresses **cool Freon gas**, causing it to become **hot, high-pressure Freon gas** (red in the diagram above).
2. This hot gas runs through a set of coils so it can dissipate its heat, and it condenses into a **liquid**.
3. The Freon liquid runs through an expansion valve, and in the process it evaporates to become **cold, low-pressure Freon gas** (light blue in the diagram above).
4. This cold gas runs through a set of coils that allow the gas to absorb heat and cool down the air inside the building.

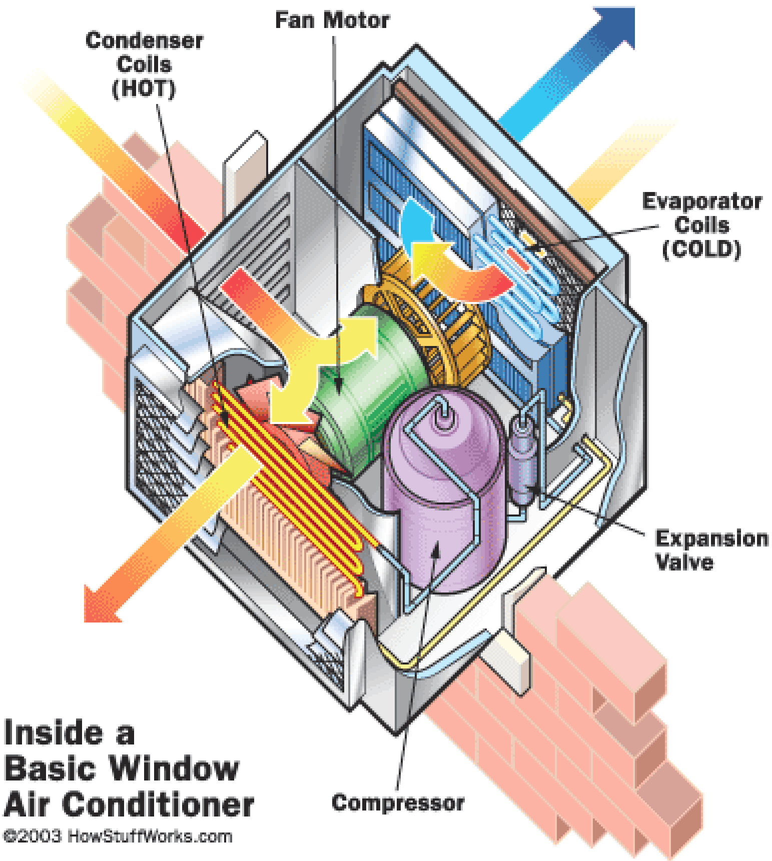
Mixed in with the Freon is a small amount of a lightweight oil. This oil lubricates the compressor.

## Window Units

A **window air conditioner** unit implements a complete air conditioner in a small space. The units are made small enough to fit into a standard window frame. You close the window down on the unit, plug the unit in and turn it on to get cool air. If you take the cover off of an unplugged window unit, you will find that it contains:


- A **compressor**
- An **expansion valve**
- A **hot coil** (on the outside)
- A **chilled coil** (on the inside)
- **Two fans**
- A **control unit**

The fans blow air over the coils to improve their ability to dissipate heat (to the outside air) and cold (to the room being cooled).




## BTU and EER

Most air conditioners have their capacity rated in **British thermal units** (**BTU**). Generally speaking, a BTU is the amount of heat required to raise the temperature of one pound (0.45 kg) of water 1 degree Fahrenheit (0.56 degrees Celsius). Specifically, 1 BTU equals 1,055 joules. In heating and cooling terms, 1 "ton" equals 12,000 BTU.

A typical window air conditioner might be rated at 10,000 BTU. For comparison, a typical 2,000-square-foot (185.8 $m^2$) house might have a 5-ton (60,000-BTU) air conditioning system, implying that you might need perhaps 30 BTU per square foot. (Keep in mind that these are rough estimates. To size an air conditioner for your specific needs, contact an HVAC contractor.)

The **energy efficiency rating** (**EER**) of an air conditioner is its BTU rating over its wattage. For example, if a 10,000-BTU air conditioner consumes 1,200 watts, its EER is 8.3 (10,000 BTU/1,200 watts). Obviously, you would like the EER to be as high as possible, but normally a higher EER is accompanied by a higher price.

## Is the higher EER is worth it?

Let's say that you have a choice between two 10,000-BTU units. One has an EER of 8.3 and consumes 1,200 watts, and the other has an EER of 10 and consumes 1,000 watts. Let's also say that the price difference is $100. To understand what the payback period is on the more expensive unit, you need to know:

1. Approximately how many hours per year you will be operating the unit
2. How much a kilowatt-hour (kWh) costs in your area

Let's say that you plan to use the air conditioner in the summer (**four months a year**) and it will be operating about **six hours a day**. Let's also imagine that the cost in your area is **$0.10/kWh**. The difference in energy consumption between the two units is 200 watts, which means that every five hours the less expensive unit will consume 1 additional kWh (and therefore $0.10 more) than the more expensive unit.

Assuming that there are 30 days in a month, you find that during the summer you are operating the air conditioner:

**4 mo. x 30 days/mo. x 6 hr/day = 720 hours**

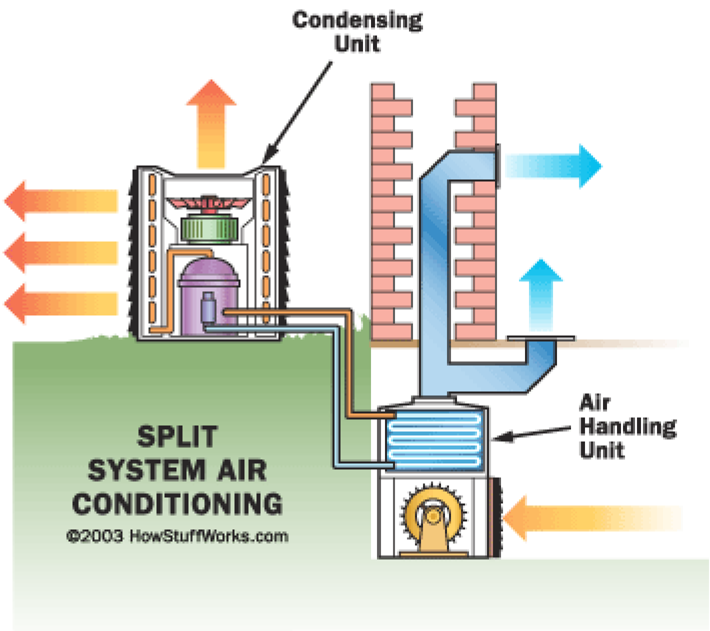
**(720 hrs x 200 watts/hr) / (1000 watts/kW x $0.10/kWh) = $14.40**

Since the more expensive unit costs $100 more, that means that it will take about seven years for the more expensive unit to break even.

See this page for a great explanation of **seasonal energy efficiency rating** (SEER).

## Split-system Units

A **split-system air conditioner** splits the hot side from the cold side of the system, like this:




The **cold side**, consisting of the expansion valve and the cold coil, is generally placed into a furnace or some other **air handler**. The air handler blows air through the coil and routes the air throughout the building using a series of ducts. The **hot side**, known as the **condensing unit**, lives outside the building. In most home installations, the unit looks something like this:


The unit consists of a **long, spiral coil** shaped like a cylinder. Inside the coil is a **fan**, to blow air through the coil, along with a **weather-resistant compressor** and some **control logic**. This approach has evolved over the years because it is low-cost, and also because it normally results in reduced noise inside the house (at the expense of increased noise outside the house). Besides the fact that the hot and cold sides are split apart and the capacity is higher (making the coils and compressor larger), there is no difference between a split-system and a window air conditioner.

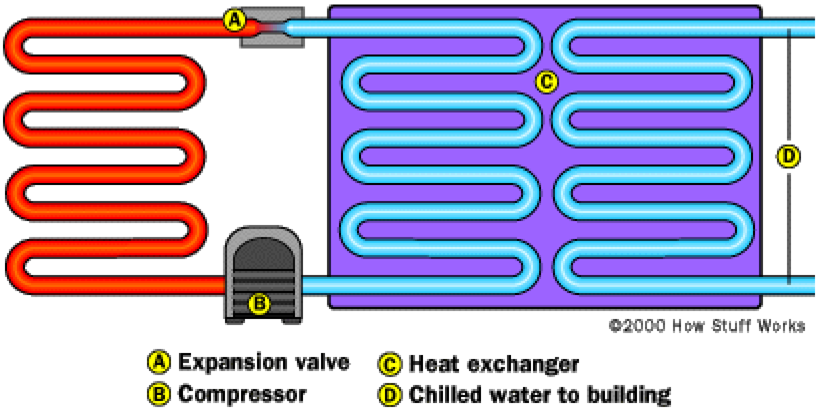
In warehouses, businesses, malls, large department stores, etc., the condensing unit normally lives on the roof and can be quite massive. Alternatively, there may be many smaller units on the roof, each attached inside to a small air handler that cools a specific zone in the building.

Let's take a look now at a chilled-water air conditioner.

## Chilled-water System

In larger buildings and particularly in multi-story buildings, the split-system approach begins to run into problems. Either running the pipe between the condenser and the air handler exceeds distance limitations (runs that are too long start to cause lubrication difficulties in the compressor), or the amount of duct work and the length of ducts becomes unmanageable. At this point, it is time to think about a **chilled-water system**.

In a chilled-water system, the entire air conditioner lives on the roof or behind the building. It cools water to between 40 and 45 F (4.4 and 7.2 C). This chilled water is then piped throughout the building and connected to air handlers as needed. There is no practical limit to the length of a chilled-water pipe if it is well-insulated.



You can see in this diagram that the air conditioner (on the left) is completely standard. The heat exchanger lets the cold Freon chill the water that runs throughout the building.

## Cooling Towers

In all of the systems described earlier, air is used to dissipate the heat from the outside coil. In large systems, the efficiency can be improved significantly by using a **cooling tower**. The cooling tower creates a stream of lower-temperature water. This water runs through a heat exchanger and cools the hot coils of the air conditioner unit. It costs more to buy the system initially, but the energy savings can be significant over time (especially in areas with low humidity), so the system pays for itself fairly quickly.


**Cooling tower**

Cooling towers come in all shapes and sizes. They all work on the same principle:

1. A cooling tower blows air through a stream of water so that some of the water evaporates.
2. Generally, the water trickles through a thick sheet of open plastic mesh.
3. Air blows through the mesh at right angles to the water flow.
4. The evaporation cools the stream of water.
5. Because some of the water is lost to evaporation, the cooling tower constantly adds water to the system to make up the difference.


**Cooling towers**

## Humidity and Pressure are Key

The amount of cooling that you get from a cooling tower depends on the relative humidity of the air and the barometric pressure.

For example, assuming a 95 F (35 C) day, barometric pressure of 29.92 inches (sea-level normal pressure) and 80-percent humidity, the temperature of the water in the cooling tower will drop about 6 degrees to 89 F (3.36 degrees to 31.7 C).

If the humidity is 50 percent, then the water temperature will drop perhaps 15 degrees to 80 F (8.4 degrees to 26.7 C).

If the humidity is 20 percent, then the water temperature will drop about 28 degrees to 67 F (15.7 degrees to 19.4 C). Even small temperature drops can have a significant effect on energy consumption.

To understand how the relative humidity and atmospheric pressure control the temperature drop in a cooling tower on any given day, check out USA Today: How a sling psychrometer works.

Whenever you walk behind a building and find a unit that has large quantities of water running through a plastic mesh, you will know you have found a cooling tower!

In many office complexes and college campuses, cooling towers and air conditioning equipment are centralized, and chilled water is routed to all of the buildings through miles of underground pipes.

For more information about air conditioners and related topics, check out the links on the next page.

# Lots More Information

## Related HowStuffWorks Articles

- How Water Towers Work
- How Humidifiers Work
- How Refrigerators Work
- How Car Cooling Systems Work
- How Snow Makers Work
- How Home Thermostats Work
- How Ozone Pollution Works
- How Allergies Work
- Could a car run on compressed air?
- What is the heat index that they talk about on the weather?
- How does a dehumidifier work?

## More Great Links



- Epinions.com: Ten Tips on Buying a New Air Conditioner
- iHomeline - New Home and Remodeling Information Guide
- Air-Conditioning and Refrigeration Institute
- Air Conditioning, Heating & Refrigeration NEWS Online
- Energy-Efficient Air Conditioning
- Carrier Systems
- Trane Systems
- SHINWA Cooling Towers
- Delta Cooling Towers
- EBSciences: Circulating Water Heater/Chillers