Real World Connections
Matter (Part 2)
Hannah

How Refrigerators Work

from HOW STUFF WORKS

Introduction to How Refrigerators Work

In the kitchen of nearly every home in America there is a refrigerator. Every 15 minutes or so you hear the motor turn on, and it magically keeps things cold. Without refrigeration, we'd be throwing out our leftovers instead of saving them for another meal.

The refrigerator is one of those miracles of modern living that totally changes life. Prior to refrigeration, the only way to preserve meat was to salt it, and iced beverages in the summer were a real luxury.

In this article, you'll find out how your refrigerator performs its magic.

The Purpose of Refrigeration

The fundamental reason for having a refrigerator is to keep food cold. Cold temperatures help food stay fresh longer. The basic idea behind refrigeration is to slow down the activity of bacteria (which all food contains) so that it takes longer for the bacteria to spoil the food.

For example, bacteria will spoil milk in two or three hours if the milk is left out on the kitchen counter at room temperature. However, by reducing the temperature of the milk, it will stay fresh for a week or two -- the cold temperature inside the refrigerator decreases the activity of the bacteria that much. By freezing the milk you can stop the bacteria altogether, and the milk can last for months (until effects like freezer burn begin to spoil the milk in non-bacterial ways).

Refrigeration and freezing are two of the most common forms of food preservation used today.

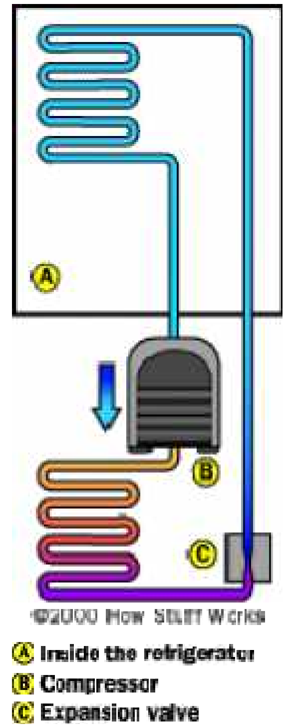
Parts of a Refrigerator

The basic idea behind a refrigerator is very simple: It uses the evaporation of a liquid to absorb heat. You probably know that when you put water on your skin it makes you feel cool. As the water evaporates, it absorbs heat, creating that cool feeling. Rubbing alcohol feels even cooler because it evaporates at a lower temperature. The liquid, or refrigerant, used in a refrigerator evaporates at an extremely low temperature, so it can create freezing temperatures inside the refrigerator. If you place your refrigerator's refrigerant on your skin (definitely NOT a good idea), it will freeze your skin as it evaporates.

There are five basic parts to any refrigerator (or air-conditioning system):

- **Compressor**
- **Heat-exchanging pipes** - serpentine or coiled set of pipes outside the unit
- **Expansion valve**
- **Heat-exchanging pipes** - serpentine or coiled set of pipes inside the unit
- **Refrigerant** - liquid that evaporates inside the refrigerator to create the cold temperatures.

The basic mechanism of a refrigerator works like this:



1. The compressor compresses the refrigerant gas. This raises the refrigerant's pressure and temperature (**B**), so the heat-exchanging coils outside the refrigerator allow the refrigerant to dissipate the heat of pressurization (**B to C**).
2. As it cools, the refrigerant condenses into liquid form and flows through the expansion valve (**C**).
3. When it flows through the expansion valve, the liquid refrigerant is allowed to move from a high-pressure zone to a low-pressure zone, so it expands and evaporates (**A**). In evaporating, it absorbs heat, making it cold.
4. The coils inside the refrigerator allow the refrigerant to absorb heat, making the inside of the refrigerator cold. The cycle then repeats.

This is a fairly standard -- and somewhat unsatisfying -- explanation of how a refrigerator works. So let's look at refrigeration using several real-world examples to understand what is truly happening.

Understanding Refrigeration

To understand what is happening inside your refrigerator, it is helpful to understand refrigerants

Experiments

These experiments can help you understand the properties of gases and their role in refrigeration.

Experiment 1

You will need:

- A pot of water
- A thermometer that can measure up to at least 250 degrees F
- A stove

Put the pot of water on the stove, stick the thermometer in it and turn on the burner. You will see (if you are at sea level) that the temperature of the water rises until it hits 212°F. At that point, it will start boiling, but will remain at 212°F -- this is the boiling point of water at sea level. If you live in the mountains, where the air pressure is lower than it is at sea level, the boiling point will be lower -- perhaps between 190 and 200°F. This is why many foods have "high-altitude cooking directions" printed on the box. You have to cook foods longer at high altitudes.

Experiment 2

You will need:

- An oven-safe glass bowl
- A thermometer that can measure up to at least 450°F
- An oven

Put the thermometer in your container of water, put the container in the oven and turn it to 400°F.

As the oven heats up, the temperature of the water will again rise until it hits 212°F, and then start boiling. The water's temperature will stay at 212°F even though it is completely surrounded by an environment that is at 400°F. If you let all of the water boil away (and if the thermometer has the range to handle it), as soon as the water is gone the temperature of the thermometer will shoot up to 400°F.

a little better. Here are two experiments that help you see what is happening.
The second experiment is extremely interesting if you think about it in the following way: Imagine some creature that is able to live happily in an oven at 400 degrees Fahrenheit. This creature thinks 400°F is just great -- the perfect temperature (just like humans think that 70 F is just great). If the creature is hanging out in an oven at 400°F, and there is a cup of water in the oven boiling away at 212°F, how is the creature going to feel about that water? It is going to think that the boiling water is REALLY cold. After all, the boiling water is 188 degrees colder than the 400°F that this creature thinks is comfortable. That's a big temperature difference!

(This is exactly what is happening when we humans deal with liquid nitrogen. We feel comfortable at 70 F. Liquid nitrogen boils at -320 F. So if you had a pot of liquid nitrogen sitting on the kitchen table, its temperature would be -320 F, and it would be boiling away -- to you, of course, it would feel incredibly cold.)

Modern refrigerators use a regenerating cycle to reuse the same refrigerant over and over again. You can get an idea of how this works by again imagining our oven creature and his cup of water. He could create a regenerating cycle by taking the following four steps:

1. The air temperature in the oven is 400 degrees F. The water in the cup boils away, remaining at 212°F but producing a lot of 400°F steam. Let's say the creature collects this steam in a big bag.
2. Once all the water boils away, he pressurizes the steam into a steel container. In the process of pressurizing it, its temperature rises to 800°F and it remains steam. So now the steel container is "hot" to the creature because it contains 800°F steam.
3. The steel container dissipates its excess heat to the air in the oven, and it eventually falls back to 400°F. In the process, the high-pressure steam in the container condenses into pressurized water (just like the butane in a lighter -- see sidebar).
4. At this point, the creature releases the water from the steel pressurized container into a pot, and it immediately begins to boil, its temperature dropping to 212°F.

Butane Lighters

If you go to the local store and buy a disposable butane lighter with a clear case (so that you can see the liquid butane inside), what you are seeing is liquid butane stored in a high-pressure container. Butane boils at 31 degrees F at normal atmospheric pressure (14.7 PSI). By keeping butane pressurized in a container, it remains liquid at room temperature. If you took a cup of butane and put it on your kitchen counter, it would boil, and the temperature of the boiling liquid would be 31°F.
The boiling point of butane, by the way, also explains why butane lighters don't work very well on cold winter days. If it is 10 degrees Fahrenheit outside, the butane is well below its boiling point, so it cannot vaporize. Keeping the lighter warm in your pocket is what allows it to work in the winter.

By repeating these four steps, the creature now has a way of reusing the same water over and over again to provide refrigeration.

Now let's take a look at how these four steps apply to your refrigerator.

The Refrigeration Cycle

The refrigerator in your kitchen uses a cycle that is similar to the one described in the previous section. But in your refrigerator, the cycle is continuous. This is what happens to keep the refrigerator cool:

1. The compressor compresses the refrigerant gas. The compressed gas heats up as it is pressurized.
2. The coils on the back of the refrigerator let the hot refrigerant gas dissipate its heat. The refrigerant gas condenses into liquid at high pressure.
3. The high-pressure liquid flows through the expansion valve.

You can think of the expansion valve as a small hole. On one side of the hole is high-pressure refrigerant liquid. On the other side of the hole is a low-pressure area (because the compressor is sucking gas out of that side).

4. The liquid immediately boils and vaporizes, its temperature dropping to about -25°F. This makes the inside of the refrigerator cold.
5. The cold refrigerant gas is sucked up by the compressor, and the cycle repeats.

By the way, if you have ever turned your car off on a hot summer day when you have had the air conditioner running, you may have heard a hissing noise under the hood. That noise is the sound of high-pressure liquid refrigerant flowing through the expansion valve.

You may have heard of refrigerants know as CFCs (chlorofluorocarbons), originally developed by Du Pont in the 1930s as a non-toxic gas for use in refrigeration and air conditioning and sold as Freon® . In the 1970's we began to notice a thinning of the ozone layer high in the atmosphere. It is this layer that absorbs much of the ultraviolet radiation coming from the sun. Ultraviolet radiation causes sunburn and skin cancer. The cause of the thinning was determined to be the Freon® that had come from leaking or discarded refrigerators and air conditioners. Freon® breaks down ozone into oxygen gas. The reaction is shown below.

$$2O_3(g) \xrightarrow{\text{freon}} 3O_2(g)$$

As of the 1990s, all new refrigerators and air conditioners use refrigerants that are less harmful to the ozone layer. Use of highly purified liquified propane gas as a refrigerant is gaining favor, especially in systems originally designed for Freon®. Yes, the same liquid used in barbeque grills. As such, it is designated as R-290 and is marketed under the trade name Duracool®. Although propane is flammable, in home and automotive systems it is present in quantities small enough to not pose an undue fire hazard if a system should develop a leak. Moreover, propane is nontoxic.