Understanding Thermal Energy

Most Americans are very aware of how thermal energy impacts us. Many experience hot summers, cold winters, and all kinds of weather in between, and we go to great lengths to keep ourselves comfortable. Very little is worse than being hot and sweaty or cold and shivery. It's difficult to think about anything except how hot or cold we are in such circumstances.

What exactly is **thermal energy**? Thermal energy is the internal energy within a substance that causes its particles to move. The more thermal energy an object has, the faster its particles – its atoms and molecules – are moving. As you might expect, the molecules in a block of ice (solid) are just vibrating in place while the molecules in a glass of water (liquid) are moving around each other. The ice molecules have less thermal energy than the water molecules do, and they are held in place. If you boil water, the molecules in the steam (gas) have enough thermal energy to break free from each other and move around independently.

When we build schools, homes, and office buildings, significant thought is put into how the inside of the building will remain comfortable for the occupants – the people inside. The materials selected must be able to keep warm air from mixing with cool air; they must be good insulators, and limit the transfers of thermal energy.

Heat ≠ Temperature

Measuring the temperature of something does not directly tell you how much thermal energy that object has. However, it does give you an idea of how much thermal energy the atoms or molecules in that object might have. High temperatures tell us that the particles have more energy, on average. Low temperatures indicate that the particles have less energy.

Please Pass the Heat

Suppose you have a very large room, like a gym, and suppose it is a very cold, winter day. To keep everyone comfortable, you should try to heat the gym. But what is the best way to accomplish this? You will need to transfer thermal energy from a warm place to a cool place.

If you build a fire in a fire pit in the gym, the end of the room with the fire will get warm because thermal energy will spread out, or **radiate**, from it. This is great for getting the area immediately around the fire warm, but the other end of your gym will still be quite cold.

If you connect very long pieces of metal to the fire pit, and lay them across the room, they will carry the thermal energy from the fire throughout the pieces of metal. Metals are good at this because they **conduct** thermal energy well.

By now you may have decided that a fire on one end of the gym, even with long, conducting metal pieces extending from it, is not the best way to heat your large room. Another good way to warm this space is to place a large fan behind the fire and turn it on. The moving air will be warmed by the fire and then carried to the other side of the room on a **convection** current.

These three ways of warming the room, radiation, conduction, and convection, are the three ways thermal energy can be transferred. Radiation transfers thermal energy through waves that spread out from the heat source. Conduction transfers thermal energy by directly touching the heat source. Convection transfers thermal energy by warming a fluid such as air or water, then circulating the fluid. Regardless of which method is used, keep in mind that thermal energy always transfers from high temperature to low temperature, and stops when everything is the same temperature. In other words, you can't throw an ice cube into hot chocolate expecting the chocolate to get hotter and the ice cube to get colder.

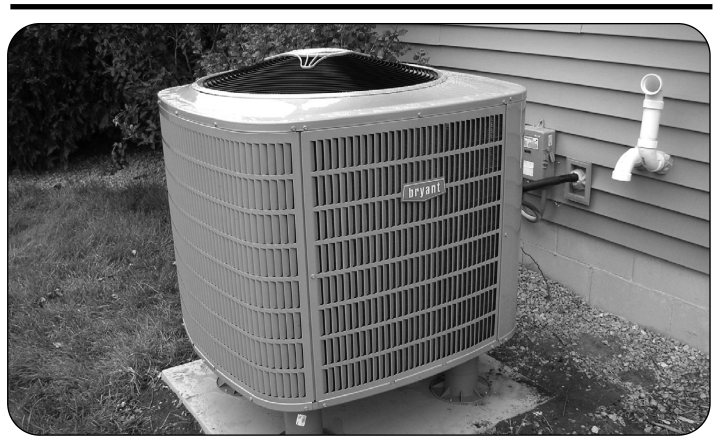
Most heating or cooling systems use convection to transfer thermal energy. A forced air furnace will heat air, then use a fan to blow the warm air through duct work into the rooms of the building. Boiler systems heat water and then circulate water through piping systems in the rooms. Air conditioners remove thermal energy from air, then blow the cooled air into the warm room. The lower temperature air mixes with the higher temperature air in the room and reduces the overall temperature.

Heating and Cooling Systems

Heating and cooling systems use more energy than any other systems in residential and commercial buildings. Natural gas and electricity are usually used to heat, and electricity is used to cool. The energy sources that power these heating and cooling systems contribute carbon dioxide emissions to the atmosphere. Using these systems wisely can reduce environmental emissions.

With all heating and air conditioning systems, you can save energy and money too, by having proper **insulation**, sealing air leaks, maintaining the equipment, and practicing energy-saving behaviors.

AIR CONDITIONING SYSTEM



Programmable Thermostats

Programmable **thermostats** automatically control the temperature of buildings for time of day and can save energy and money. During heating seasons, for example, they lower the temperature of a building when no one is using it. When people are active in the building, the thermostat automatically raises the temperature. These controls are available for commercial buildings, from as simple as one programmable thermostat to a whole system of temperature sensors connected to a computer, depending on the building's size. Many newer schools and those that have been upgraded with new heating systems have a central computer that monitors the temperature in each room and adjusts the heating system accordingly.

Insulation and Weatherization

Air leaking into or out of a building wastes energy. Insulation prevents thermal energy transfer to keep the interior room comfortable and separated from the exterior air. Building owners can reduce heating and cooling costs by investing in proper insulation and weatherization products. Insulation is rated using an **R-value** that indicates the resistance of the material to thermal energy transfer. The R-value needed varies, depending on the climate, ceilings, walls, attics, and floors. In very cold climates, a higher R-value is recommended.

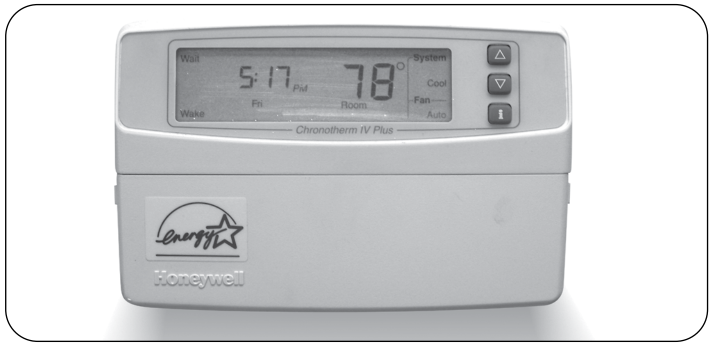
Insulation is like a blanket for buildings, but air can still leak in or out through small cracks. Often, the effect of many small leaks is the same as leaving a door wide open. One of the easiest energy-saving measures is to caulk, seal, and weather-strip cracks and openings to the outside. Building performance professionals can seal air leaks in attics and basements. Homeowners can typically save up to $200 a year in heating and cooling costs by air sealing their homes and adding insulation. Commercial buildings, which tend to be larger, can save even more by following the same procedures.

Doors and Windows

Some air leaks occur around and through the doors and windows. Doors should seal tightly and have door sweeps at the bottom to prevent air leaks. Insulated storm doors provide added barriers to leaking air. School entryways with two sets of doors are designed to keep cold air from blasting inside during the winter and outside during the summer. Both sets of doors should always be kept closed.

Most buildings have more windows than doors. The best windows shut tightly and are constructed of two or more pieces of glass. Caulk or seal any cracks around the windows and make sure they seal tightly. With older windows, install storm windows or sheets of clear plastic to create added air barriers. Insulated blinds also help to prevent air flow—during heating seasons, open them on sunny days and close them at night. During cooling seasons, close them during the day to keep out the sun.

PROGRAMMABLE THERMOSTAT



INSULATION

Image courtesy of Owens Corning

Moisture

Moisture is a term used to describe water in both liquid and vapor form. Like heat and air, it is important to have the right amount of moisture in a building. Most moisture indoors exists as water vapor. The amount of water vapor in the air plays an important role in determining our health and comfort.

Humidity is a measurement of the total amount of water vapor in the air. It is measured with a tool called a **hygrometer**. Relative humidity measures the amount of water vapor in the air compared to the amount of water vapor the air is able to hold. The relative humidity depends on the temperature of the air.

Air acts like a sponge and absorbs water through the process of evaporation. Warmer air, with greater energy, can support more water vapor than colder air, which has less energy. When cold air from outdoors is heated, it feels very dry and makes the occupants of the building uncomfortable. Furthermore, moisture in the air in a room will help it resist changes in temperature, which can reduce the number of times a heating or air conditioning system has to run.

The correct humidity level can also help promote a healthy indoor environment. Humidity levels should be kept between 30% and 60%. Using a dehumidifier in the summer and a humidifier in the winter can help condition the air to maintain appropriate humidity levels.

Ventilation

Something that is always taken into consideration in a school is ventilation. Each person in the building is a living, breathing carbon dioxide and heat machine, pumping both out at a constant rate. At home, this is handled by opening and closing doors as you enter and leave the house. Schools, though, are more tightly sealed, and have more people in them without opening a door for a long time. The buildup of stale, carbon dioxide-laden air is a problem.

Building code regulations require that the air inside a commercial building be exchanged with fresh air on a regular basis. The type of building use, room size, and number of people in the room determine how much fresh air must be brought in. For the average classroom with 25 students, the air in the room is changed about 2 ½ times every hour.

Bringing in fresh air from outdoors in winter puts more demand on the heating system to keep the interior space comfortable. That cold air must be warmed to a comfortable temperature.

Ventilation plays a very important role in controlling moisture in a building, too. When cold air from outside is warmed without moisture being added in, the air feels very dry. This not only causes us to have dry lips and skin, it can create some health problems when our sinuses are too dry. Additionally, dry air does not hold as much thermal energy as humidified air and the heating system must run more often as a result.

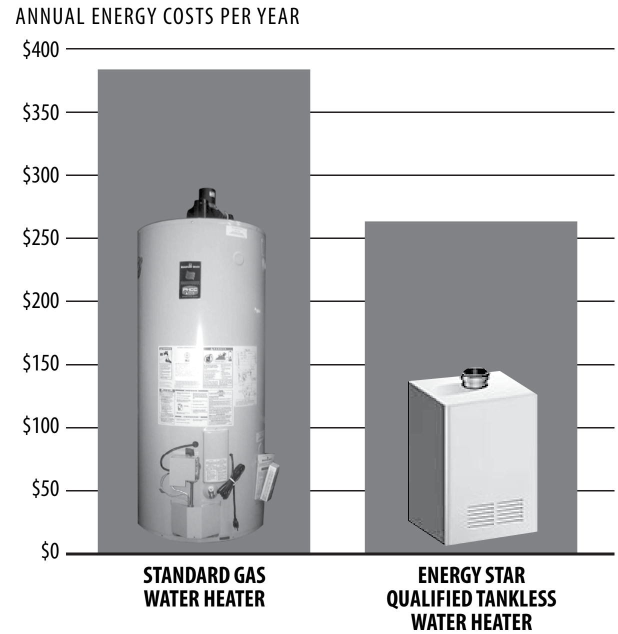
However, a more threatening situation occurs when there is too much moisture in a room, especially a room like a classroom where paper and books are found. As you know, paper is made from wood, and while our bodies are not designed to fully digest the fibers in paper and wood, other organisms do a great job. In fact, it is because of these other organisms that dead trees decompose into dirt on a forest floor. Fungi, including molds and mildew, thrive in warm, moist, dark places. When moisture is allowed to build up on a surface, mold and mildew also build up. As the molds prosper and grow, they release spores, which are carried in the air to other surfaces where they, in turn, may grow. These spores present a serious health hazard if people breathe them in.

A lack of fresh air combined with an excess of moisture spell disaster for schools because of the amount of paper products inside of them. Once a book begins to mildew it is very difficult to get it cleaned and acceptable for others to use; most mildewed books are thrown away. Thus it is important for schools in humid climates that run cooling systems on a regular basis to clean the ventilation and cooling equipment to make sure that mold and mildew are not building up in hidden areas where condensation may be accumulating. It is important for the people in a school as well as the books, papers, and other educational materials that the moisture levels inside be maintained properly.

Landscaping

Although you cannot control the weather, you can plant trees and bushes to block the wind and provide shade. Properly placed landscaping can reduce the energy needed to keep buildings comfortable. Deciduous trees, for example, are good to plant on the south side of a building in the Northern Hemisphere, since their leaves provide shade in summer and their bare branches allow sunlight through in the winter. Clusters of trees can be planted to reduce "heat islands" in areas like parking lots, and act as wind blocks during the winter. In tropical and warmer climates taller trees like palms and shades are used on a building's exterior to block the sun while allowing a breeze to flow.

Water Heater Comparison



Data: ENERGY STAR®

Water Heating

You don't think too much about the hot water you need at school, but it is definitely needed. At home you probably have a hot water heater that holds 40 or 50 gallons of hot water and is fueled by natural gas or electricity. When you turn the hot water tap on in the kitchen or bathroom, you have to let the water run a bit before it's warm. However, having one hot water heater in one central location in a school would mean letting the water run for a very long time before it ran warm in rooms far from the heater. Most schools have one or more 100-gallon (or sometimes even bigger) hot water heaters, and the hot water supply is constantly circulating through the school with a pump. Thus, turning the hot water on in a distant classroom should provide hot water fairly quickly.

The temperature of the water at school is important. At home, you probably have your hot water heater set at 120-140 °F, and rarely any higher because of the danger of serious injury by scalding. This is true for the hot water at school except in the kitchen. To comply with health department regulations, the cafeteria workers must wash all dishes and serving equipment in water that is at least 160 °F. But at this temperature, scalding injuries happen very quickly. Very young or distracted students would easily get their hands burned if water came out of the faucet at this temperature.

Most building designs handle this dilemma in one of two ways. One is to have two separate water heating systems, one for the cafeteria and the other for the rest of the school. The cafeteria water supply is kept very hot while the rest of the school is kept at a safer, lower temperature. The other way is to keep the entire school supply at a safe temperature, but have a booster heating system in the cafeteria that heats the water to the necessary temperature for cleaning.