S-4 Independent Learning Pursuit Submittal

S-4 Competency: Can describe and explain connections among diverse aspects of nature.

1. Describes one or more natural systems.
2. Explains how parts of the system are interconnected.
3. Demonstrates how such connections are found elsewhere in nature.

Rain and Shine: Mankind's Use of Natural Systems

Introduction

This essay will explore the solar, water, geothermal and gaseous systems of the Earth's environment and the energy sources that drive them. It will also explain the ways in which these systems interact with each other, and the ways in which mankind exploits these natural systems to produce comfortable habitation spaces.

Preface

I have been a licensed general contractor in the city of Chicago since 2001. In 2012, my business began focusing exclusively on energy efficiency and Indoor Air Quality (IAQ) consulting and improvements. The Building Performance Institute (BPI) sponsors classes that help professionals in the building trades to better understand building science, analysis and retrofit work (BPI Website). BPI certification is a requirement for several state and federally funded building remediation programs (EI2 Website), in addition to utility-sponsored energy-efficiency financing programs (AFCFirst Website).

In 2013, I passed the final exams for both the Building Analyst (BA) and Envelope Professional (EP) BPI certifications. Armed with my new training and over fifteen years of

experience in the field, I have been able to help my clients understand the benefits of designing their building projects the "green" way. I can calculate how much time it will take to reap a financial return on specific building energy efficiency investments; I can also help clients solve existing building performance problems because of the analytical skills I developed at the BPI training.

Natural Systems & Man

Humans and their hominid predecessors have been using natural cave formations for over 750,000 years as shelter (Shen, 2009). Although dark and often wet, caves provide natural temperature moderation by staying approximately 54 degrees Fahrenheit year-round (NPS website). As human civilization and technology have progressed over time, the natural systems man uses to make himself comfortable at home and at work have grown more complex. In order to understand how a building will perform in response to different natural systems, one must understand the varied energy, water and gas cycles that take place on (and in) the planet Earth.

Solar Energy

At sea level on a clear day, the Earth receives approximately 1,000 watts per square meter of solar energy. Put another way, the amount of solar energy that falls onto the state of Texas is 300 times more energy than produced at all the world's power stations combined (U of Tennessee Institute of Agriculture Website). As the sun's rays strike different substances, the energy is absorbed and redirected in many ways:

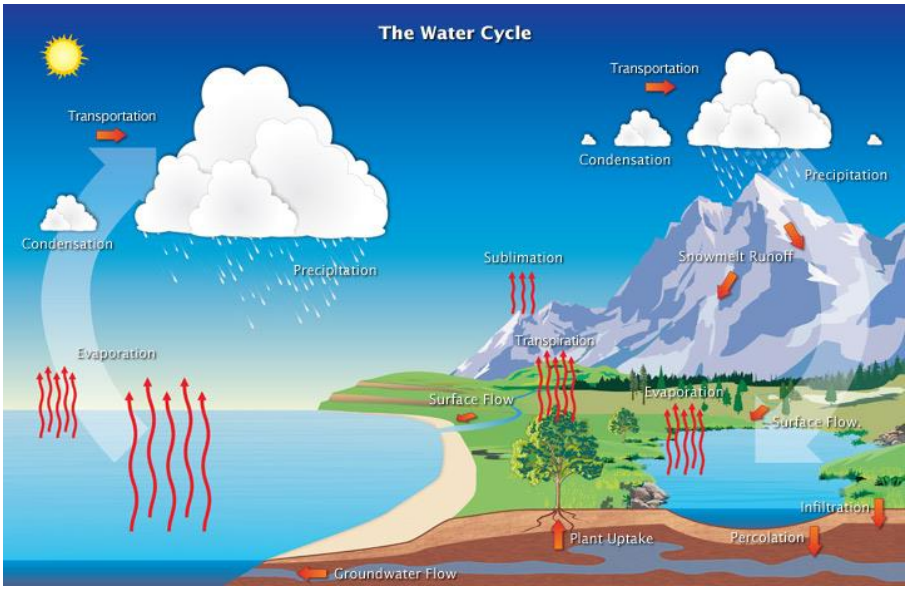
Convection occurs when heat moves via a flowing liquid or gas, such as when hot air rises above a hot blacktop road and is visible as a false "oasis".

Conduction occurs when heat flows between two surfaces that are in direct contact, like a lizard warming itself on a hot stone.

Radiance is the flow of heat from a warmer surface to a cooler surface, without being facilitated by moving air or physical contact. If the abovementioned lizard stood next to the hot stone without touching it, his cool body would absorb heat from the hot stone via radiation.

Evaporation occurs when solar energy excites water (or other liquid) molecules to the point where they leave the fluid state and float away as a gas. This is the driving force behind the water cycle (see below). It should be noted that heat can cause evaporation, but evaporation also draws heat away from a surface, such as the cooling effect of sweat evaporating on one's skin.

The Water Cycle



1 Image Courtesy of NASA.Gov

The water cycle is a continuous process that shapes most of our planet. Energy from the sun causes surface water to evaporate. This water, now a vapor, rises to cloud level and condenses (returns to the liquid state from a vapor) on fine dust particles in the air to form clouds. When the air containing clouds becomes so humid that it cannot hold any more water vapor, it rains. This rain falls to the earth and collects in streams and rivers, and eventually drains into lakes and oceans, where the process repeats (see fig. 1).

This cycle occurs in a miniature form inside buildings as well. Water vapor from breathing, cooking and washing increases the humidity of indoor air. In the summertime, this water vapor can condense on a cold glass of lemonade, necessitating a coaster under the glass to prevent rings on furniture. In the winter, this water vapor can be carried by warm air rising (convection) up to the attic. There, the vapor condenses back into liquid form and saturates the underside of the cold roof. These cool, wet surfaces are perfect places for growing mold (Krigger, 2009).

Geothermal Energy

Geologists estimate the temperature of the Earth's core to be 10,000 degrees Fahrenheit, or roughly the temperature of the surface of the sun. It is thought that most of this heat is caused by the decay of radioactive elements (Christiansen, 1995). This heat makes its way slowly to the surface via convection in the Earth's core and conduction through the upper layers to the ground under our feet. This heat is eventually radiated out into space, but much of it heats substances, people and animals on its way. Geothermal heat is the reason many small lakes and ponds do not freeze solid in the winter (enabling fish and other aquatic life to survive). It is also the reason why, 4 feet underground, the soil temperature is between 45 and 60 degrees planet wide (Sigenthaler, 2004).

Temperature/Volume/Pressure Equilibrium

As taught in high school chemistry, a gas is a cloud of atoms or molecules bouncing around the vessel they are contained in. This vessel can be a car tire, a balloon or the earth's atmosphere. Pressure is defined as the force these bouncing gas particles produce evenly

against the walls of the vessel. Temperature is the measurement of energy of a substance, quantified by the vibration rate of the atoms of which the substance is comprised. The hotter a substance, the more rapid the vibrations. In theory, these vibrations cease at absolute zero.

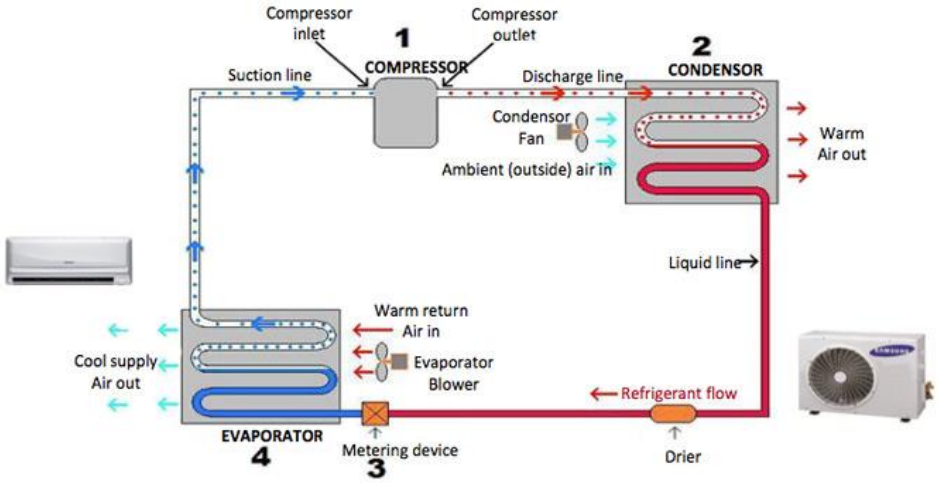
This basic chemistry is the reason for the constant equilibrium between the Temperature, Volume and Pressure (TVP) of a gas. For example, to inflate a car tire, an air compressor is a machine that takes air (a mixture of many different gasses, but mostly nitrogen) and squeezes into a smaller space, like a storage tank. This increases the pressure of the air by decreasing its volume. The rate of the air molecule vibrations increases, since they have less space to bounce around in. This increases the temperature, which is why gas compressors usually have cooling fins. From the storage tank, a hose leads to the car tire, where the higher pressure in the tank forces the air through the hose and into the tire. The pressure inside the tire increases, since it cannot expand in volume. In the process, the air left in the tank decreases in pressure and temperature, and the tire gets slightly warmer as is pressurizes.

The Refrigeration Cycle

The TVP equilibrium and the processes of evaporation and condensation are exploited in the air conditioning systems of buildings and automobiles. A specially manufactured gas called a refrigerant is first pressurized by a compressor (see #1 in diagram, below). It then passes through many finned tubes cooled by outside air pushed by a fan, where the refrigerant condenses into a liquid (#2 in diagram). This liquid is piped inside, where it passes through a small restriction inside the tube called a metering device (#3). In older, less efficient systems the device is simply a small hole, called the orifice. In newer, high-efficiency systems the

metering device is a Thermostatic Expansion Valve (TXV), which constantly changes the size of the restriction based on system temperatures. Thus, the metering device holds back most of the pressurized refrigerant, and as the liquid passes through the restriction it depressurizes and cools significantly in the process.

This cooling takes place just before another set of finned tubes, called the evaporator (#4). As the cooled and depressurized liquid flows through the evaporator, warm air to be conditioned is passed over the fins by another fan (in a typical home, this is the furnace fan). The liquid refrigerant is heated to the point where it evaporates and becomes a gas again. This hot gas leaves the conditioned space and heads back to the condenser, where the process repeats.



The Refrigerant Cycle, Courtesy Samsung Co.

Interconnections

A trained building performance analyst must understand all these natural systems and the interplay between them to fully understand how buildings can keep people comfortable and healthy. As another example, a home builder has a client who wants a high-efficiency home built. The home design includes a geothermal heating and cooling system. A geothermal system employs the same refrigerant cycle as described above, but is reversible, and uses water run in buried pipes to release heat in the summer or gain it in the winter. The system must have a capacity that meets the needs of the building, but not be so large that it is inefficient.

The builder, along with the project architect, must consider the effect of many different natural systems on the home:

Solar Energy Effects – The home plan should be oriented in a way that minimizes heat gain in the summer and maximizes it in the winter. Windows facing the rising and setting sun should have Low-E (low emissivity) coatings to prevent summer heat gain. Windows facing south should not have Low-E coatings to allow winter heating. A large section of south-facing roof can be used to mount a solar photovoltaic panel array. Care should also be taken in selecting exterior wall siding and roof shingle color, as darker colors absorb more heat. Proper insulation types and installation can prevent radiant heat gain through the attic and walls. Window awnings, large building overhangs and mature trees will all provide shade that needs to be considered in the design as well.

Water Cycle Effects – The basement foundation walls and floor should have moisture barriers to prevent ground water and water vapor from permeating the foundation and entering the home. Humid air from the kitchen and bathrooms should be vented outside to

prevent high humidity levels and unwanted condensation. Condensation on the cold air conditioning coils (which is intentional) should be routed to a proper drain to prevent re-evaporation inside.

Geothermal System Design Factors – In order to properly design a geothermal heating and cooling system, the system design must take into account all the factors listed above, plus the climate zone where the house is to be built, the size of the home and the number of expected occupants. The soil type and soil moisture levels at the build site must be analyzed to calculate the amount of heat-transfer tubing to be buried, and to what depth. Usually buildings in the northern climate zones need more heating than cooling, so a system properly sized to cool a home may not be large enough to heat it in the winter, and an auxiliary heat source may necessary.

Follow the Drop

One day, after the home is complete and occupied by the new homeowner, a drop of water falls from the sky as rain. It lands in the vegetable garden next to our newly built house. The drop filters through the garden soil and is absorbed by the roots of a tomato plant. The water is drawn up the stem of the plant and fleshes out a plump, red tomato. The new homeowner picks the tomato and uses it in a pasta sauce.

As the sauce cooks in a lidded pot, the drop of water in the tomato evaporates. Some of the water vapor condenses on the underside of the pot lid, and drips back into the sauce. The rest of the evaporated drop escapes the pot and floats away into the house air. During dinner, the part of the drop left in the sauce is eaten by the homeowner and absorbed by her body.

Since it's a hot summer day, the late-day sun heats the house and she starts to sweat. She turns the air conditioning system on, which uses the TVP equilibrium, geothermal cooling and the water cycle to cool and dehumidify the air. The homeowner's evaporated sweat and the water vapor that escaped the sauce pot earlier condense on the cold air conditioning evaporator coil to re-form our raindrop and make its way down the drain. The drain leads first to a sewage processing station, then discharges into a local river. From there, the drop runs all the way to the Mississippi river and into the Gulf of Mexico. Once in the ocean, our drop evaporates in the hot sun, rises up to help form a cloud, and the entire process repeats.

Connections

Energy from inside the Earth and the sun's rays are critical to the functioning of many different grand and discrete natural systems. Survival of all life on the planet depends on the systems driven by this energy, from deep-sea tube worms to condo owners in skyscraper buildings. Ancient cavemen wouldn't be surprised that mankind was still using holes in the ground to stay cool and to keep from freezing. The technology of human habitation continues to progress, but it will always be rooted in the same basic laws of chemistry.

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Submission Originally Included scans of 1) a City of Chicago – Department of Buildings General Contractor's License, 2) a Geothermal Water Source and Loop Training Certificate, and 3) a Refrigerant Recycling Training Certificate.