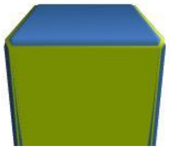
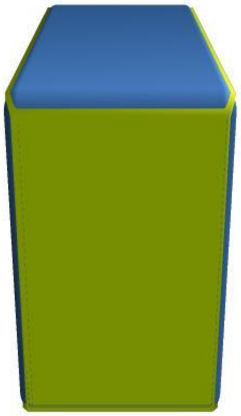
Thermal generating devices and their functions.
A note on terminology in this presentation.

Heating.

Thermal heat generating systems include gas and oil fired furnaces, electric heaters, and the sun. The sun's thermal energy is utilized by solar collectors of some type such as solar-to-electric cells or simple water absorbing system to absorb the sun's heat energy. For this presentation we are interested in the thermal energy that comes from central core of the earth. Consequently we will be discussing geothermal sources which a) may be near the surface and manifest themselves as geysers; b) may be deeper sources such as in Boise Idaho which require drilling; or c) may be in the geologically inactive regions where the source is a large chunk or block of the crust. In this and related presentations we will use a *'block-symbol'* (1st figure) as a symbol for the block of the earth's crust that is being used. As shown in the following figures, this '*block-symbol'* can be stretched in various directions according to the particular application for better visual representation. For example if deep wells are used then one would be have a *'block-symbol'* stretched in the vertical direction. Some geothermally active heat sources may be deep. Note that in Boise Idaho the regions are not only relatively large but utilize 1000 foot deep blocks of the earth’s crust, so the '*block-symbol'* might look like the 2nd figure. The blocks maybe shallow and stretched horizontally, 3rd figure, such as is often the case in the application of *Ground Source GTHP Pump Technology*.

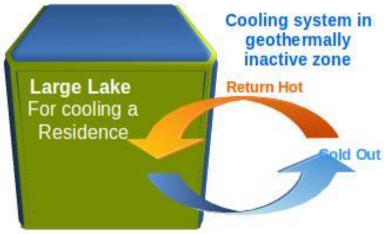




Cooling.

We are all familiar with various sorts of refrigerating machines that extract heat from the region to be cooled and dump it to air or water sinks. This course is about geothermal energy. In the discussion of definitions it is clear that geothermal is a source of heat from the earth. Since it is a heat source it cannot be used for cooling. However there are other geological regions that can be used as heat sinks. For example there are rivers and lakes on the surface of the earth. However a more significant thermal sink potential occurs in the geologically inactive regions of the earth's crust.

Summary.



Thus in this presentation we will be discussing blocks of the earth's crust as heat sources and/or sinks. Then on the "*block-symbol"* we can enter the particular information that is appropriate. The exception to this is lakes, rivers or other thermal sinks for cooling on top of the earth's crust which are not blocks of the earth's crust. In this case, we could enter the term "large lake cooling", or "deep well cooling sink" on the *'block-symbol'*, 4th figure.

The author hopes that these visual aids Make the reading easier and more pleasant because the human prefers to receive information as a picture rather than as words- because the human brain processes more information more rapidly and stores it more easily as a visual image whereas strings of words are difficult to remember and not natural. The author would welcome any suggestions from attendees and thank you in advance for any suggestion.

COURSE REVIEW

This review will cover both the fundamental principles and concepts of the learning objectives in detail. More importantly it will cover the practical application that is tested by the quiz. It will therefore be useful in the final application of this course.

Fundamental principles. In the general field of geology, tectonics is the study of the structural features of an object, in this case the planet earth. Applied to the earth, this describes a) the crustal surface and faults and folds within it and b) how the Earth's crustal surface changes over time. The basic and common definition of the word thermal is heat. Geo comes from the Greek word which means earth or of the earth. For example, geo-structure means the geological structural features. Consequently the combination of Geo plus thermal produces the word geothermal. So this means for our practical application: [a) of; b) relating to; or c) using the natural heat] produced inside the Earth. Another important basic geology definition is the word climate. Climate means the conditions at, or just above, the surface of the earth that affect local conditions. Climate and climatic are interchangeable, that is they mean the same thing. Because we live on the surface of the earth, the conditions at the surface are of more interest than the inner and upper core and the lower and upper mantel. For both heating and cooling, climatic conditions are of the utmost importance in both the theoretical analysis and the practical application. Focusing on the more practical application, geothermal energy is commonly used to mean pockets of hot water or steam at the earth surface that can be easily accessed at a reasonable cost. Practically speaking there are only three locations in the world where live steam is available near the surface. Since these fields have limited life, are minuscule in the overall scheme of geothermal utilization, direct thermal utilization of available geothermal energy which are the focal point of discussions in this presentation. Two other definitions of importance are a) geologically active regions and b) geologically inactive regions of the earth. Geo-inactive regions can be used as either a heat sink or source in the continental U.S. and so are applicable to the *Ground Source GTHP Pump Technology*. Geologically active regions areas are directly useful for thermal heating and are therefore of great potential value. They are not of value for cooling. Climate is important because it involves the conditions at the surface of the earth as well as conditions just above the surface of the earth. These affect the local conditions and therefor the application of the technology. For this presentation we are primarily interested in the thermal energy that emanates from central core of the earth. For practical purposes we will be discussing geothermal sources which a) may be near the surface and manifest themselves as geysers; b) may be deeper sources such as in Boise Idaho which require drilling; or c) may be in the geologically inactive regions where the source is a large chunk or block of the crust. The meaning of “GTHP” is Ground *Source GTHP Pump Technology.*

About the Geo structure of the earth and Thermal Heating for Geo-active & inactive Regions. Geo-structures of the crust consist of the continental crust and the oceanic crust. The oceanic plates are approximately 6 to 10 km thick whereas that continental plates are approximately 30 to 70 km thick. As shown in the included tables 1.3a and b, there are alternate definitions and terms used for the same or overlapping regions starting at the center of the earth and going to the surface. Since we are interested in the surface, we will focus on the region near the surface. The topmost tectonic regions are the crustal plate, lithosphere, and the upper mantle. Because we live on the surface of the earth, the tectonic region of most practical interest is the crust or crustal plate. Plate conditions that cause circulating eddies of magma are: a) converging crustal plates in the aesthenosphere; b) oceanic plates sliding under continental plates, and c) continental plates climbing over continental plates. Circulating magma brings the geothermal energy from the hot core to the cooler upper mantel. Thus economically accessible geothermal deposits occur near regions where magma is circulating. Such accessible geothermal deposits will occur just below the crust, in the crust, and in the lithosphere. Because current drilling technology for geothermal deposits is limited to 4000 feet, economically accessible geothermal deposits are just below the crust, in the crust, or in the lithosphere. Water transports the geothermal heat from the magma to the surface. The source of this water is rainwater or earth surface water. The fluid transporting the heat may be water, brine, steam, gases or a mixture of these. The temperature gradient near the earth's surface depends on the depth of magmatic intrusion. The temperature gradients in the crust are approximately 32°C for kilometer. Temperature gradients in the crust in active geothermal regions are approximately 35 to 70°C per km. For economic purposes the use of geothermal energy refers to heating of an individual facility or district heating that is heating of a large group of facilities but it does not include spas, bathing or other recreational purposes. Geothermal district heating include Klamath Falls Oregon and Boise Idaho. District heating systems in Boise and surrounding areas have been successfully operating for more than 30 years. Referring to the maps, the percentage of area that can power large district heating systems for a depth of three km is 45%. Referring to the maps, the percentage of area that can power large district heating systems for a depth of six km is 45%. Current drilling technology limits drill depths to 6 km. referring to the applicable map for 6 km, the percentage of the total US continental area that can be utilized is 43% for geothermally inactive zones. Thus the inactive area potential usable as a heat and/or cooling source/sink is approximately 43% of the total. Referring to the six km depth map, the geographical regions best suited for geothermal heating projects are located in the Midwest both northern and southern regions and in the West Coast particularly including the Rocky Mountains. Note that this dips downward to include the region around New Mexico. As of 2004, the date of publication of Thermal Heating DOE.pdf, the largest geothermal greenhouse in the nation is the Burgett Geothermal Greenhouse near Animas in southwestern New Mexico. This 32-acre facility produces high-quality cut roses contributing to the local economy. Also in the same area, AmeriCulture facilities are heated at much lower costs, compared to fossil fuels like propane, with a down-hole heat exchanger installed in a 400-foot (122-meter) depth well. Many fish species have accelerated growth rates in warm water, adding to energy-saving advantages. In Idaho, thermal waters are used for electric production, fish growing, and greenhouses as well as heating. Reykjavik Iceland is an example of a geothermally active region capable of producing electricity and thermal heating. In Reykjavik, the temperature of the water is hotter than required for heating. In Reykjavik, hot water is mixed with warm water, then distributed for heating. Referring to that same map, the percent of remaining area potentially suitable for *Ground Source GTHP Pump Technology* is between 5% and 40%. Again referring to that same map, the remaining area best suited for *Ground Source GTHP Pump Technology* small district heating systems is between 10 and 40%. *Ground Source GTHP Pump Technology* is applicable to Geo-inactive regions. In Geo-inactive regions the temperature is constant below 100 feet. At a depth of 10 feet the temperature is constant at a given latitude, but may have a seasonal variation. A specific case depends on the local climatic variations. The temperature gradient between 10 and 100 feet is approximately 32°C per kilometer. *Ground Source GTHP Pump Technology* systems can be either open or closed loop systems. Closed loop systems may be vertical, horizontal, or at an angle. The number and length of pipes depends on the size of the structure, the specifics of the structures, such as heat generators like refrigerators, lighting and other electrical fixtures, and it also depends on the HDD and the CDD.   Vertical systems can be used for commercial buildings, small district systems, in large structures such as schools and public buildings. Vertical systems general use vertical multiple pipes connected by headers. Vertical ground source pipe loops are from 100 to 400 feet deep. Vertical pipe loops require well pipes that are 4 inches in diameter. Closed loop system's benefit economically if surface water is available. Viable surface water types are ponds, small or large lakes, and/or rivers. We now switch our attention from closed loops to open loops systems. Open loop systems may use well water, large lakes, rivers, or small ponds. Economic viability is determined in addition to other factors by HDD for the winter season and CDD for the summer season. In very cold climates economic viability is determined by the HDD. In very hot climates economic viability is determined by the CDD.

General considerations other. District heating system generally refer to a system that heats a sizable geographic region. For example a system that can heat an entire city or region such as 30% of the state. The principal consideration for determining the economics of the geothermal site are its location. The economic profitability of a specific site are affected by the local selling price of fuel other than geothermal, local ambient and resource temperature, and the specific structure HDD. It is not affected by regional HDD or structural HDD. The numerical value of HDD is correctly calculated using general formulas for the typical local case. Structural properties that should be included for correct calculation of HDD are insulation, equipment and lighting. The case study for Boise Idaho include the city mall, the city region proper, the regional area around this city region, and an extended region beyond that extending into nearby regions. HDD is the number of days in one year to heat a structured to some comfort level which would typically be 65°F. It is also defined as being the sum of all the HDD's for each day summed for one year. The annual HDD may also be calculated by summing the mean comfort temperature level minus the outdoor temperature for each and only each heating day of the year. The annual HDD for Boise Idaho city Mall has a value of about 6500. It is also building specific dependent and therefore must be calculated for the city mall itself. Calculation of HED is complicated by size of the structure, the environment where there might be shade and/or exposure and or wind, by the structural installation itself, by internally produce heat by various items such as lighting machines like refrigerators, electronic equipment and so on plus many others. The practical correct way to estimate HDD using any of the preceding procedures is to use monthly averages derived from NOAA data, adjust the heating mode for the specific building location, for the specific building insulation, and for the specific building internal heat generating equipment. The actual measured HDD for Boise over 30 years average is 6757. Please note that the correct calculation procedure, both fundamentals and practical application, are described in another PDH Course. The approximate conceptual data for economic analysis of geo-active systems includes the US map for annual heating degree days, HDD, local climatic data for the specific locale, and specific data on the buildings as described above.

Inactive geothermal regions.

In geothermally inactive regions the production varies from a depth of approximately 4 feet to approximately 50 feet. Estimating performance for *Ground Source GTHP Pump Technology* analogy is similar to that for estimating HDD for geothermal heating systems. The approximate conceptual data for economic analysis of geo-inactive systems includes the US map for annual cooling days CCD and annual heating days, HDD, local climatic data for the specific locale, and specific data on the buildings similar to that described for geothermal heating. The economic analysis can be applied to individual homes or business, small commercial structures such as stores, schools and public buildings, and also to small district heating systems consisting of many structures in a relatively small region. Optimization of a *Ground Source GTHP Pump Technology* project requires including climatic conditions, the near surface Geo-structure, and the geographic location.