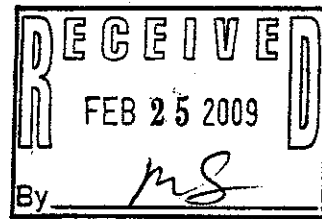


A COPY FOR LIBRARY
FOR THE REF # A08011

City of Paisley Renewable Energy Feasibility Study

Progress Report

February 20, 2009



Prepared by:
Bob Rogers, P.E.
Oregon Renewable Energy Center
Oregon Institute of Technology
3201 Campus Drive
Klamath Falls, Oregon 97601

The following report summarizes the work to date and identifies next steps for the Paisley School fuel saving alternatives project.

Project Goal

Paisley school was analyzed for fuel saving alternatives that could significantly reduce the energy costs of the oil heating bill for the school of \$45,000 for last year. This analysis included:

- 1) The evaluation, through clean-out drilling, of the existing Paisley geothermal well
- 2) Evaluating significant energy efficiency
- 3) Conversion of the existing heating system to Geothermal Heat Pumps.

Item #1 the well test was performed and identified \$25,000 in improvement costs to be effective and was discontinued. (See Attachment #1 - Norm Seavey well drilling report)

Item #2 identified three energy efficiency upgrades that are economically viable including wall insulation, floor insulation, double pane glass and boiler firing up-grades. All of these efficiency measures fall within the Oregon State Guideline for Energy Efficiency and Renewable Energy loans of having simple payback of less than 10 years.

	\$ Savings per year	Simple Payback - years
Measure #1 – Energy Savings Wall Insulation	\$4,731	5.2 to 10.4 years
Measure #2 – Energy Replace windows with Double Pane	\$4,735	4.3 to 6.3 years
Measure #3 – Energy Provide R-Floor Insulation	\$1,121	8 to 12 years

Item #3 the Geothermal Heat Pump fuel-oil replacement system met Oregon State Guidelines for Energy Efficiency and provided important health standard up-grades as well as significant maintenance cost reduction.

Geothermal Heat Pump	With Energy Efficiency Measures	Without Energy Efficiency Measures
Savings/yr	\$24,256/yr	\$30,000/yr
Simple Payback - years	5.7 to 9.4	5.6 to 9.3

Grants and loans through the Oregon Department of Energy are specifically available for this project. The Oregon Department of Energy BETC pass through credit will apply to the energy conservation portions of this project at a rate of 30.5% credit. The geothermal heat pump system will require prior approval for a pass-through tax credit of 30.5% by demonstrating comparable performance on equivalent or better energy performance as

documented by whole building modeling, is commissioned, and is verified by an independent third-party.

Another recent funding grant opportunity for schools comes from the Williams Oil settlement where funds have been used specifically for schools. The Oregon Department of Energy has specific funds available for schools including low interest energy loans. Principal Mark Jeffries, principal of Paisley School, said that his board would consider loan and grant opportunities to achieve these energy goals.

The Paisley School is critical to the continuance of the community of Paisley. The school has been awarded an exceptional Oregon Charter School designation because of the commitment by the faculty and staff. The school includes a dormitory that houses ten foreign students each year to add to the diversity of the school and community. Mark Jeffries, Paisley School principal, will be providing a letter describing the vital role of this school in this rural Oregon community.

Item #1 - Fuel Oil Conversion System – Geothermal Well

The initial concept of conversion of the fuel oil system was to use the Paisley City Geothermal well. The existing Paisley City well is located within ½ mile of the school was identified by the well log as having a temperature potential of 140 degree.

Norm Seavey well drilling of Klamath Falls was hired to re-drill the well. In summary, the well driller evaluated the well drilling report for this well as well as several others located in the vicinity. From these reports he determined that there was a potential for 140 degree water at this well and with a flow capacity that would meet the needs of the school.

He recommended that a camera test should be performed prior to moving the rig on site to determine the conditions of the existing well. The camera test indicated that cleaning the well with the drilling rig could restore the well to original conditions. The camera test did not identify the well collapse that occurred during the cleaning process.

During the well cleaning process, which required rotary drilling of the existing well, drillers found that the well probably had the 140 degree potential that would be required but the well caved in during the drilling process. The only way to possibly make this well useable would be to case the well with piping all the way from top to bottom. The expense of this was estimated at \$25,000 at the time the well rig was on site. The well drillers could not ensure that this well would even be functional with this improvement. Funding was not available for this improvement and without the insurance that an effective well would be the result.

Betty Riley, in consultation with this engineer, determined that the well casing cost was beyond the scope of the project and the well project was terminated.

Item #2 - Energy Efficiency Measures

The following tables describe the best energy efficiency measures for Paisley School. These measures are identified as feasible by using the Oregon Department of Energy Loan Program guideline of energy measures with pay-backs of up to 10 years. The cost of these efficiency measures is the next step in this Paisley project to determine exact costs.

These measures include:

- 1) Insulating the existing solid concrete walls
- 2) Replacing the double pane windows with single pane windows
- 3) Insulating below the floors
- 4) Upgrading the fuel oil boiler – This measure was eliminated because of the recent boiler firing upgrades of 2007.

	Existing single pane windows and no wall insulation	Measure #1 – R-11 wall insulation.	Measure #2 Double pane windows	measure #3 R-19 floor insulation
Heating BTU/hr Load	679,556	626,979	626,902	668,438
Heating BTU/Hour Savings		52,577 BTU/hr.	65,987 BTU/hr.	11,118 BTU/hr
Heating Gallons Oil per year	15,602 gallons	14,357 gallons	14,356	15,307
Heating \$/year - last year average *	\$59,287	\$54,556	\$54,552	\$58,166
Savings \$/year	\$ 0	\$4,731	\$4,735	\$1,121

* Assumptions for calculations included Lakeview Oregon Heating Degree Days of 7072, Boiler efficiency of 80%, 138,000 BTUH per gallon fuel and \$3.80 per gallon fuel cost – 2007-2008.

	BTU/Hr Savings	\$Savings per year ***	\$ Installed Cost /square foot	\$ Installed Cost *	\$ Installed Cost – 30.5% BETC	Simple Payback years
Measure #1 – Energy Savings Wall Insulation **	45,769 BTU/hr.	\$4,731	\$10 to \$20	\$24,600 to \$49,200	\$17,097 to \$34,194	3.6 to 7.2 years
Measure #2 – Energy Replace windows with Double Pane	60,202 BTU/hr.	\$4,735	\$10 to \$15	\$20,040 to \$30,060	\$14,178 to \$21,267	3 to 4.5 years
Measure #3 – Energy Provide R-Floor Insulation	59,860 BTU/Hr.	\$1,121	\$2 to \$3	\$8,062 to \$12,093	\$5,603 to \$8,404	5 to 7.5 years

* Installed costs of construction in Paisley require a much more detailed analysis than using standard construction costs. Paisley is 150 miles from the closest contractors that will likely bid on these projects.

** Energy measure #1 requires insulating the existing concrete block walls. The least expensive method would be to fur out the inside walls and insulate with new interior sheet rock.

*** Assumptions for calculations included Lakeview Oregon Heating Degree Days of 7072, Boiler efficiency of 80%, 138,000 BTUH per gallon fuel and \$3.80 per gallon fuel cost – 2007-2008.

Item #3 - Fuel Oil Conversion System – Geothermal Heat Pump

The geothermal heat pump technology is one that is very familiar to this engineer as he has had the experience of installing five of these systems and consulting on the design of the systems to sizes of 1,000 tons or 120,000,000 BTU/Hr. of capacity. (Consultant for CSHQA of Boise, Idaho). These systems are identified as the highest efficiency heating and cooling system available today by both the DOE and EPA. (Attachments 2 - 5)

The geothermal heat pump systems have and installed first cost of less than a geothermal hot water system if the Paisley City well would have produced. These mechanical systems have a life expectancy of over 50 years and there are over 2 million of them installed in the US. The newest energy funding incentives by the federal government

offers a \$2,000 incentive to homeowners for the installation of these systems and the State of Oregon offers \$600-\$900.

A remarkable example and case study of the use of these systems is found in the article Geothermal Heat pump System for the Chiloquin Community Center (Attachment 6). The architectural design for the new Lakeview Library Building utilizes a Geothermal Heat Pump.

The Geothermal Heat pump system bury pipe in the ground through trenches that transfer the constant earth temperature of about 50 degrees through a heat pump to heat or cool a building or residence. These systems currently operate with efficiencies of 300 to 400%. This translates into energy costs that are 1/4 to 1/3 of electric heating costs. Since the cost of oil heating with oil in Lake County and Paisley is essentially the same as the cost of heating with straight electricity, these systems would reduce heating costs by 1/4 to 1/3.

The load calculations for this school identify a peak heating load in the building of 679,556 BTU per hour. This load could be reduced to 549,874 BTU per hour by implementing the three energy efficiency measures described below.

A rough estimated cost for a geothermal Heat Pump System would cost between \$3,000 and \$4,000 per 12,000 BTU per hour of heating. \$230,000 to \$270,000 with energy efficiency upgrades and \$280,000 to \$340,000 without upgrades.

Energy savings are expected to a minimum of 2/3 of existing energy costs. A rough estimate of these savings would be to reduce fuel costs from \$45,000 per year to \$15,000 per year or a savings of \$30,000 per year. The exact cost benefit in energy savings will be determined in detail in phase 2 of this project.

Geothermal Heat Pump	with Energy Upgrades	without Energy Upgrades
System Cost **	\$140,000 to \$230,000	\$170,000 \$280,000
System Cost after 30.5% BETC Credit	\$97,300 to \$159,400	\$118,200 to \$194,600

Oil fuel costs/yr *	\$36,400	\$45,000
Energy Costs for Geothermal heat Pump/yr	\$12,133	\$15,000
Savings/yr	\$24,256/yr	\$30,000/yr
Simple Payback - years	4.1 to 6.6	4 to 6.4

* Assumptions for calculations included Lakeview Oregon Heating Degree Days of 7072, Boiler efficiency of 80%, 138,000 BTUH per gallon fuel and \$3.80 per gallon fuel cost – 2007-2008.

** Installed costs of construction in Paisley require a much more detailed analysis than using standard construction costs. Paisley is 150 miles from the closest contractors that will likely bid on these projects.

Other Geothermal Heat Pump Benefits

In addition to these benefits of energy savings, reduced maintenance costs and better health are that each classroom and office has its own heating or cooling unit. Each teacher has individual comfort control for that classroom.

The existing HVAC system for this school should have been upgraded for indoor air quality, health and code reasons years ago. In this facility it was determined that the nearly 100 year old hot water heating system does not circulate the required outside air amounts to meet minimal code compliance.

The original school hot water distribution system, built in the early 1900's, is being used to circulate water through the existing classroom heat exchangers. Parts are no longer available for any of the components of the existing heat water system. When failures occur custom manufacturing of the existing equipment is performed by machine shops in Portland at a cost of 3 to 4 times the cost of off the shelf heating

The maintenance operator of the system has specialized skills for maintaining the existing system. He is competent in boiler operation and customized maintenance of heating equipment. He has machining and welding skills. He has done an outstanding job of maintaining a system that is 100 years old.

Next Step

Step #1 Paisley City well and performed energy audit

Step #1 of the original grant has been completed which cleaned out the existing Paisley City Well and performed an energy audit to identify significant energy savings opportunities for Paisley School.

Step #2 Cost and economic analysis of energy measures and Geothermal Heat Pump

Step #2 of the project is to do a thorough cost analysis of the identified energy savings measures and the new Geothermal Heat Pump system to determine accurate cost paybacks. The time required to complete this cost analysis is 100 hours. Step #2 would be completed by the end of April.

Step #3 Identification of funding opportunities and interaction with School Board

Step #3 includes identification of funding opportunities and interaction with the school principal and board in proceeding with funding sources. The identification of existing funding sources that are available to the school district to pay for this up-grade and make presentations to the board would require an additional 100 hours of work. This includes the elements of grant and loan preparation required by the Paisley School district and the final report.



Attachment 1



Norm Sevey Well Drilling, Inc.

5619 LELAND DRIVE KLAMATH FALLS, OREGON 97603

PHONE 882-3504

Re: Geothermal well at Paisley, Oregon

Our company was contacted by Robert L. Rodgers and Betty Riley to try to determine the feasibility of using the old well at Paisley, Oregon as a geothermal source. The first step taken was to review the well log for the well and surrounding wells. The original driller stated he hit hot water. However the well bore was caving in near the bottom and would need to be cased.

After discussing the options, mechanical engineer Robert L. Rodgers and I decided the first thing to do would be to video the well to see the condition of the well bore and see if the bottom of the well was clear of any drilling tools left in the hole from the previous driller.

We sent a camera down the hole but to our surprise the camera could only go down about 90 feet. So the decision was made to bring the drilling rig to Paisley to clean out the hole and get a temperature and flow test.

The drilling rig found only a bridge at 90 feet. However the well was now caving in from 200 to 230 feet, well above the original completed depth. We air tested the well. It produced about 30 GPM from 200 feet at 104 degrees Fahrenheit.

At this point we felt we would have to case off the caving spot just to see if we could get a usable geothermal well. The estimated cost to clean out the well and case it would be approximately \$25,000.00. The decision was made by mechanical engineer Robert L. Rodgers and Betty Riley SCOEDD that it wasn't worth the risk to spend that much money on the well just to see if it might produce any measurable geothermal benefits.

Sincerely,

A handwritten signature in cursive script that reads "Stephen Hughes". The signature is written in black ink and is positioned above the typed name.

Stephen Hughes
Norm Sevey Well Drilling, Inc.

Attachment 2

U.S. Department of Energy - Energy Efficiency and Renewable Energy A Consumer's Guide to Energy Efficiency and Renewable Energy Geothermal Heat Pumps

Geothermal heat pumps (sometimes referred to as GeoExchange, earth-coupled, ground-source, or water-source heat pumps) have been in use since the late 1940s. Geothermal heat pumps (GHPs) use the constant temperature of the earth as the exchange medium instead of the outside air temperature. This allows the system to reach fairly high efficiencies (300%-600%) on the coldest of winter nights, compared to 175%-250% for air-source heat pumps on cool days.

While many parts of the country experience seasonal temperature extremes—from scorching heat in the summer to sub-zero cold in the winter—a few feet below the earth's surface the ground remains at a relatively constant temperature. Depending on latitude, ground temperatures range from 45°F (7°C) to 75°F (21°C). Like a cave, this ground temperature is warmer than the air above it during the winter and cooler than the air in the summer. The GHP takes advantage of this by exchanging heat with the earth through a ground heat exchanger.

As with any heat pump, geothermal and water-source heat pumps are able to heat, cool, and, if so equipped, supply the house with hot water. Some models of geothermal systems are available with two-speed compressors and variable fans for more comfort and energy savings. Relative to air-source heat pumps, they are quieter, last longer, need little maintenance, and do not depend on the temperature of the outside air.

A dual-source heat pump combines an air-source heat pump with a geothermal heat pump. These appliances combine the best of both systems. Dual-source heat pumps have higher efficiency ratings than air-source units, but are not as efficient as geothermal units. The main advantage of dual-source systems is that they cost much less to install than a single geothermal unit, and work almost as well.

Even though the installation price of a geothermal system can be several times that of an air-source system of the same heating and cooling capacity, the additional costs are returned to you in energy savings in 5–10 years. System life is estimated at 25 years for the inside components and 50+ years for the ground loop. There are approximately 50,000 geothermal heat pumps installed in the United States each year.

- [Types of Geothermal Heat Pump Systems](#)
- [Benefits of Geothermal Heat Pump Systems](#)
- [Selecting and Installing a Geothermal Heat Pump System](#)

Learn More

Financing & Incentives

- [Find State and Local Incentives](#)
Database of State Incentives for Renewables and Efficiency
- [DOE Financial Opportunities for Consumers](#)
- [Financing](#)
ENERGY STAR®
- [Find Federal Tax Credits for Energy Efficiency](#)
ENERGY STAR®

Product Information

- [Geothermal Heat Pumps](#)
ENERGY STAR®

Professional Services

- [Accredited GHP Installers](#)
International Ground Source Heat Pump Association

Department of Energy Resources

- [Geothermal Heat Pumps](#)
Geothermal Technologies Program
- [How to Buy an Energy-Efficient Ground Source Heat Pump](#)
Federal Energy Management Program

State & Local Resources

- [Geothermal Heat Pumps](#)
California Energy Commission's Consumer Energy Center

Related Links

- [Geo-Heat Center](#)
- [Geothermal Heat Pump Consortium, Inc.](#)
- [Residential](#)
International Ground Source Heat Pump Association
- [Frequently Asked Questions](#)
International Ground Source Heat Pump Association
- [Geothermal Heat Pumps](#)
PATH (Partnership for Advancing Technology In Housing) Technology Inventory

Reading List

- Rafferty, K. (February 2001). "An Information Survival Kit for the Prospective Geothermal Heat Pump Owner." ([PDF 229 KB](#)). Geo-Heat Center, Oregon Institute of Technology.
- "Heat from the Earth: Geothermal Heat Pumps." (October 1996). *The Family Handyman* (46:9); pp. 9-12.
- "Space Conditioning: The Next Frontier." (April 1993). 430-R-93-004: Environmental Protection Agency.
- Rock Smith, B.; Arco, J. (November/December 1996). "[Do You Dig Ground-Source Heat Pumps?](#)" *Home Energy*.
- Rafferty, K. (March 2000). "A Guide to On-Line Geological Information and Publications for Use in GSHP Site Characterization." ([PDF 366 KB](#)). Oregon Institute of Technology's Geo-Heat Center.
- Rafferty, K. (July 1999). "Scaling in Geothermal Heat Pump Systems." ([PDF 1.2 MB](#)). Geo-Heat Center, Oregon Institute of Technology.
- Cataldo, S. (September/October 1999). "[Ground-Source Heat Pumps Dig In.](#)" *Home Energy*.

[Consumer's Guide Home](#) | [EERE Home](#) | [U.S. Department of Energy](#)
[Webmaster](#) | [Web Site Policies](#) | [Security & Privacy](#) | [USA.gov](#)
Content Last Updated: December 30, 2008

Attachment 3

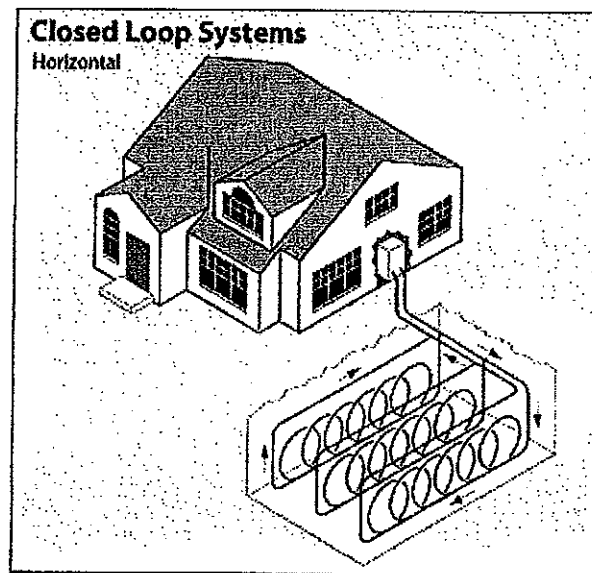
U.S. Department of Energy - Energy Efficiency and Renewable Energy A Consumer's Guide to Energy Efficiency and Renewable Energy Types of Geothermal Heat Pump Systems

There are four basic types of ground loop systems. Three of these—horizontal, vertical, and pond/lake—are closed-loop systems. The fourth type of system is the open-loop option. Which one of these is best depends on the climate, soil conditions, available land, and local installation costs at the site. All of these approaches can be used for residential and commercial building applications.

Closed-Loop Systems

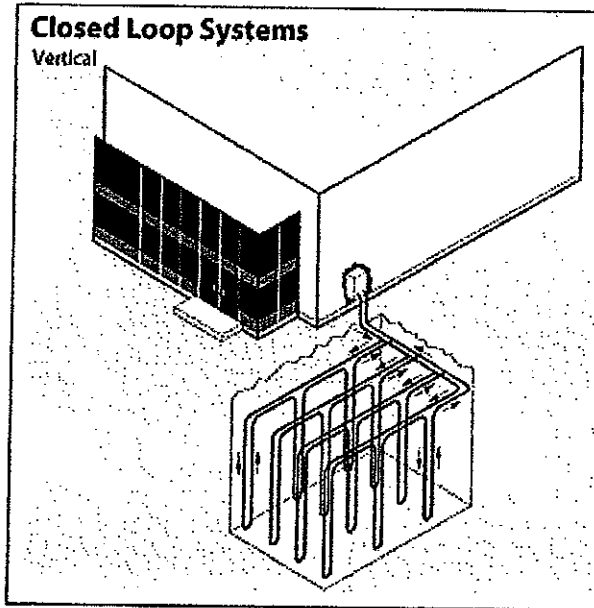
Horizontal

This type of installation is generally most cost-effective for residential installations, particularly for new construction where sufficient land is available. It requires trenches at least four feet deep. The most common layouts either use two pipes, one buried at six feet, and the other at four feet, or two pipes placed side-by-side at five feet in the ground in a two-foot wide trench. The Slinky™ method of looping pipe allows more pipe in a shorter trench, which cuts down on installation costs and makes horizontal installation possible in areas it would not be with conventional horizontal applications.



Vertical

Large commercial buildings and schools often use vertical systems because the land area required for horizontal loops would be prohibitive. Vertical loops are also used where the soil is too shallow for trenching, and they minimize the disturbance to existing landscaping. For a vertical system, holes (approximately four inches in diameter) are drilled about 20 feet apart and 100–400 feet deep. Into these holes go two pipes that are connected at the bottom with a U-bend to form a loop. The vertical loops are connected with horizontal pipe (i.e., manifold), placed in trenches, and connected to the heat pump in the building.



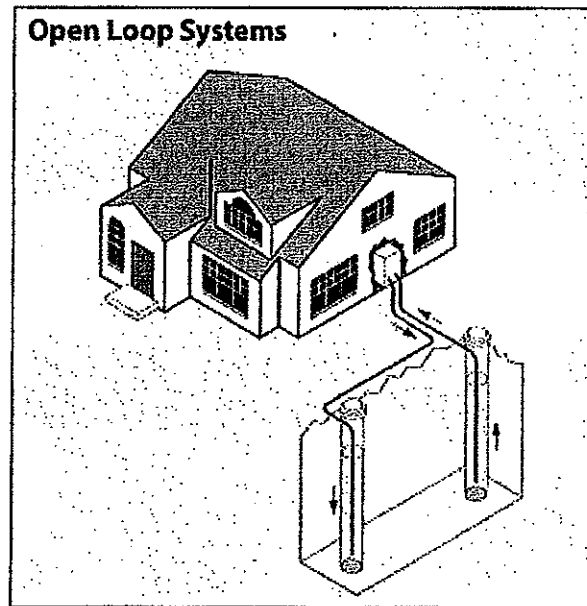
Pond/Lake

If the site has an adequate water body, this may be the lowest cost option. A supply line pipe is run underground from the building to the water and coiled into circles at least eight feet under the surface to prevent freezing. The coils should only be placed in a water source that meets minimum volume, depth, and quality criteria.



Open-Loop System

This type of system uses well or surface body water as the heat exchange fluid that circulates directly through the GHP system. Once it has circulated through the system, the water returns to the ground through the well, a recharge well, or surface discharge. This option is obviously practical only where there is an adequate supply of relatively clean water, and all local codes and regulations regarding groundwater discharge are met.



**Learn More
Financing & Incentives**

- [Find Federal Tax Credits for Energy Efficiency ENERGY STAR®](#)

Product Information

- [Geothermal Heat Pumps ENERGY STAR®](#)

Department of Energy Resources

- [Geothermal Heat Pumps](#)
Geothermal Technologies Program
- [How to Buy an Energy-Efficient Ground Source Heat Pump](#)
Federal Energy Management Program

State & Local Resources

- [Geothermal Heat Pumps](#)
California Energy Commission's Consumer Energy Center

Related Links

- [Geo-Heat Center](#)
- [Geothermal Heat Pump Consortium, Inc.](#)
- [Residential](#)
International Ground Source Heat Pump Association
- [Frequently Asked Questions](#)
International Ground Source Heat Pump Association
- [Geothermal Heat Pumps](#)
PATH (Partnership for Advancing Technology in Housing) Technology Inventory

Reading List

- Rafferty, K. (February 2001). "An Information Survival Kit for the Prospective

Geothermal Heat Pump Owner." ([PDF 229 KB](#)). Geo-Heat Center, Oregon Institute of Technology.

- "Heat from the Earth: Geothermal Heat Pumps." (October 1996). *The Family Handyman* (46:9); pp. 9-12.

[Consumer's Guide Home](#) | [EERE Home](#) | [U.S. Department of Energy](#)
[Webmaster](#) | [Web Site Policies](#) | [Security & Privacy](#) | [USA.gov](#)
Content Last Updated: December 30, 2008

GeoExchange Systems
The New Heating, Ventilation and Air-Conditioning (HVAC) Technology

by Roger L. French P.E. BSEE

Definitions

What is a GeoExchange System?

A geoechange system is an electrically powered heating and cooling system for interior spaces. This system utilizes the earth (or a pond or lake) for both a heat source and a heat sink. Components of this system include a heat pump, a hydronic pump, a ground heat exchanger, and a distribution subsystem. Most geoechange systems utilize air ducting for the distribution system, and polyethylene piping in the earth for the heat exchanger.

What is a Heat Pump?

A heat pump is an electrically powered mechanical device that takes heat from one location and moves it to another location. A typical air conditioner is a form of a heat pump in that it takes heat out of the interior space and then rejects that heat outdoors. However, a true heat pump can work in either direction, unlike a typical air conditioner. A heat pump can take heat out of an interior space, or it can put heat into an interior space.

What is a GeoExchange Heat Pump?

Unlike the air conditioner that rejects heat into the surrounding air through the condenser (which resembles a caged box, sits outside the house, and makes noise when it turns on), the geoechange heat pump rejects heat into the earth during the cooling mode, and takes heat out of the earth while in the heating mode. GeoExchange Heat Pumps are more commonly referred to as Ground Source Heat Pumps. (See Notes)

Understanding the GeoExchange System

(Portions of the following are excerpted from "Outstanding Home Comfort Through Advanced Technology" by the Geothermal Heat Pump Consortium)

How GeoExchange Systems Work

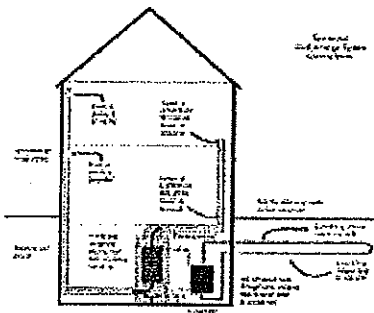
GeoExchange systems, like common heat pumps and air conditioners, make use of a refrigerant to help transfer (or pump) heat into and out of your home. The refrigerant helps the GeoExchange system take advantage of two primary principles of heat transfer:

1. Heat energy always flows from areas of higher temperature to areas of lower temperature.
2. The greater the difference in temperature between two adjacent areas, the higher the rate of heat transfer between them.

Attachment 4

Refrigerators, air conditioners, and heat pumps all operate by pumping refrigerant through a closed loop in a way that creates two distinct temperature zones--a cold zone and a hot zone.

The simplest example of such a system is the universally familiar home refrigerator. In a refrigerator, a fan blows the air inside the box over tubes containing refrigerant that is very cold (typically below 0° F). Heat flows from the interior air to the cooler refrigerant. The refrigerant is then pumped to the high-temperature section, which is exposed to room air outside the refrigerator box. Because the refrigerant is hot in this zone, it gives up heat to the relatively cooler air in the room, before flowing back to the cold zone to begin the loop again.



[See larger image \(78k\)](#)

An air conditioner works in exactly the same way, except that it extracts heat from the air inside a room or building and transfers it to the air outside the building.

A conventional heat pump adds a reversing capability, so the hot zone and the cold zone can be switched. With the zones reversed, it can extract heat from the outside air in the winter and transfer it inside.

Granted, being able to extract heat from frigid winter air seems like it shouldn't work, but it will if we can expose the cold air to refrigerant that's even colder than it is. And modern heat pumps can do that.

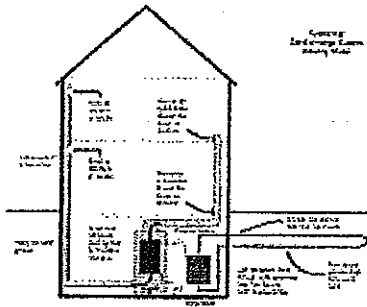
When the outside air gets extremely cold, the conventional (air source) heat pump has to resort to electric resistance heating. This reduces efficiency dramatically.

The Super Efficiency of GeoExchange

Standard (air source) heat pumps, while relatively simple to operate, face one major challenge: their operating efficiency is lowest when demand is highest. That is, heat pumps (air source) have to work hardest when we demand the most performance from them.

As we've just seen, a regular heat pump (air source) extracts heat energy from outside air in the winter, and rejects heat to outside air in summer. Unfortunately, the colder the outside air, the more difficult it is to extract heat from it, and the hotter the outside air, the harder it is to transfer heat to it. The temperature difference between the air and the refrigerant is small in both cases, lowering heat transfer rates within the system.

Attachment 4



Yet, the colder it gets outside, the higher the rate of heat loss through windows, around doors, and through walls and roofs, and the more heat we need to pump inside to keep indoor temperatures comfortable. In summer, we face a similar dilemma. The hotter it gets outside, the higher the rate of heat infiltration into the house, and the more heat removal we need to maintain comfort.

A GeoExchange system eliminates this dilemma by using the relatively constant temperature of the earth as a heat source in winter and a heat sink in summer, instead of outside air.

[See a larger image \(78k\)](#)

Throughout most of the U.S., the temperature of the ground below the frost line (about 3 to 5 feet below the surface) remains at a nearly constant temperature, generally in the 45 ° -50 ° F range in northern latitudes, and in the 50 ° -70 ° F range in the south. So, in the winter, a GeoExchange unit can extract heat from the earth that's relatively warm compared to the cold outside air, and in the summer, it can discharge heat to the earth that is relatively cool, compared to the hot outside air. Since the difference between the refrigerant temperature and the ground temperature remains relatively high in both seasons, so do heat transfer rates. Consequently, the GeoExchange system operates at much higher year-round efficiencies than a standard heat pump.

The Cleanliness of GeoExchange Systems

Installing a GeoExchange system is environmentally responsible. Since a GeoExchange system merely transfers heat from the ground into your home in winter, you don't need to burn any fossil fuels to create a warm interior environment. The approach drastically reduces carbon dioxide emissions (a greenhouse gas) compared with the operation of other heating systems, and completely eliminates the heating system as a potential source of carbon monoxide fumes within your home - making the GeoExchange system an environmentally friendly as well as safe and healthy alternative to traditional oil and gas furnaces.

Making The Ground (Earth) Connection

The unique aspect of the GeoExchange system, and the key to its lengthy list of benefits, is the "ground loop." The ground loop provides the means of transferring heat to the earth in summer, and extracting heat from the earth in winter. There are "closed loop" and "open loop" systems. First, let's look at typical closed loop systems that recycle the same water (the reffridgerant) endlessly.

Physically, the ground loop consists of several lengths of plastic pipe typically installed either in horizontal trenches or vertical holes that are subsequently covered with earth and landscaping of your choice. Water inside the ground loop piping is pumped through a

Attachment 4

heat exchanger in the GeoExchange unit. In the summer, it absorbs heat from the refrigerant hot zone and carries it to the ground through the ground loop piping. In winter, it absorbs heat from the earth through the ground loop, and then transfers that heat to the refrigerant cold zone.

The length of the ground loop will be determined by the heating and cooling loads, which are determined in turn by the size of your home, its design and construction, its orientation, and the climate where you live. Whether the ground loop is most efficiently installed in horizontal trenches or in vertical boreholes depends on the type of soil near the surface (rocky, sandy, clay-laden, etc.), the geology of the deeper terrain in your area, and the amount of land available. Generally, horizontal loops are less expensive to install, but require more land area. Vertical holes require much less land area, but require the expense of drilling.

Another ground connection scheme - an "open loop" system - involves using wells instead of closed loop piping. Where water is plentiful, it can be pumped out of a well, through the heat exchanger at the GeoExchange unit, and then pumped back into another well to return to the groundwater. Since the water merely absorbs or gives up heat, but is not altered in any other way, it leaves the GeoExchange unit as pure as it was when it entered it.

Any one of these installation schemes results in the same high efficiency, when properly sized.

Moreover, once the ground loop is installed, you can typically forget about it. The polyethylene piping (the same type used for cross-country natural gas lines) does not degrade, corrode, or break down in ground or water contact, so sound installations are expected to last 50 years or more.

Free Hot Water

As a side benefit, most GeoExchange systems can be designed to produce free hot water during the summer, by using waste heat extracted from the interior air during the air conditioning season. Even in the winter, waste heat from the GeoExchange heat pump can be converted to hot water to reduce the energy costs of the hot water heater.

Conclusion

GeoExchange is the most energy-efficient, environmentally clean, and cost-effective space conditioning system available, according to the Environmental Protection Agency. The EPA confirmed the superior efficiency of GeoExchange, finding that even on a source fuel basis - accounting for all losses in the fuel cycle including electricity generation at power plants - GeoExchange systems average 40% greater efficiency than air source heat pumps, 48% greater efficiency than gas furnaces, and 75% higher efficiency than oil furnaces. Today's best GeoExchange systems outperform the best gas

Attachment 4

technology, gas heat pumps, by an average of 36% in the heating cycle and 43% in the cooling cycle.

GeoExchange systems use the Earth's energy storage capability to heat and cool buildings, and to provide hot water. The earth is a huge energy storage device that absorbs 47% of the sun's energy -- more than 500 times more energy than mankind needs every year -- in the form of clean, renewable energy. GeoExchange systems take this heat during the heating season at an efficiency approaching or exceeding 400%, and return it during the cooling season.

In addition to operating cost benefits, GeoExchange provides:

1. Heating without combustion of fossil fuels
2. No carbon monoxide or carbon dioxide
3. Increased safety
4. Simpler design, maintenance, and operation
5. Free hot water in the summer

No unsightly/noisy air conditioning or air source heat pumps in the y

Just How Much More Efficient are GeoExchange Heat Pumps?

The Environmental Protection Agency and the U.S. Department of Energy have both recognized geexchange technology as the most efficient and environmentally friendly home heating and cooling system available. According to studies by the Environmental Protection Agency, GeoExchange systems achieved a 48% increase in efficiency over gas furnaces, a 75% increase in efficiency over oil furnaces, and 40% greater efficiency over air source heat pumps. This all sounds wonderful, but just how does this relate to the consumer in California where electricity costs are sky high, or to the homeowner in New England thinking about replacing an oil furnace?

This analysis seeks to investigate the actual comparison costs of GeoExchange systems to other conventional HVAC systems. The emphasis here is to present real world cost comparisons to be used by consumers as a tool for determining expected operating expenses, and payout times for new and replacement installations.

GeoExchange vs. Air Conditioning

Nearly all conventional residential and light commercial buildings use refrigerant type air conditioning systems for cooling the interior space. These units all have the familiar outdoor condenser units. Variations include packaged heating/cooling units and air source heat pumps. All use outside air to cool the refrigerant, while rejecting heat into the surrounding air. For the purposes of this discussion, all of these units will be referred to as "air source" equipment.

Comparisons between GeoExchange Heat Pumps (GHP) and conventional air source units are convoluted because of the sharp decrease in efficiency of air source equipment as a function of outside air temperature. Manufacturers of air source equipment are quick to post impressive EER and SEER numbers on their "high efficiency" models, but a closer examination of the actual performance data shows that these lofty numbers do not correlate well under realistic installed conditions.

A typical example of a 3-ton air source unit shows manufacturer's SEER as 12.0. However, a closer look at performance values yields a calculated EER value of 10.5, at rated conditions (95° F entering condenser air, 67° F wet bulb evaporator). This would represent a daytime temperature of about 90° F.

When the outside temperature rises to 100° F, the air source EER drops to 9.2, which represents a reduction in efficiency of 12%. If outside temperature rises to 110° F, the air source EER drops even further to 7.7, which represents a reduction in efficiency of 27%. This means that the unit is requiring 27% more electricity to yield the same cooling.

Attachment 5

Another aspect of the air source units is that the cooling ability of the unit is also a function of outside air temperature. A typical 3-ton unit can put out 3 tons of air conditioning when the outside air temperature (at the condenser) is 95° F. But, if the outside air temperature rises to 110° F (115° F entering the condenser), the unit can only put out approximately 2.6 tons, a reduction of 14%. Condensers that are clogged with dirt or debris will have even further reduction in efficiency.

The performance of an appropriately designed GeoExchange system is independent of changes in outside air temperature and humidity. Since the temperature of the earth where the geoechange occurs is relatively unchanged throughout the year, the GHP's efficiency of both heating and cooling seasons is fixed. Typical efficiency for a 3-ton GHP in cooling mode with entering water temperature (EWT) of 60° F is approximately 18 EER. Comparing GHP to air source units as outside temperature varies:

EER Comparison of GHP vs. Air Source Cooling

<i>Outside Temperature</i>	<i>90 °F</i>	<i>100°F</i>	<i>110°F</i>
<i>GeoExchange</i>	18	18	18
<i>Air Source</i>	11	9	8

As indicated in the chart above, GHP systems for air conditioning are considerably more efficient than the conventional air source units. Simple calculations show that energy costs for a GHP are nominally 40% less than air source; 50% less than air source at 100 degrees; and can be as much as 55% less than air source as temperatures rise further.

This efficiency analysis has attempted to examine like units for an "apples and apples" comparison. It has not included the effect of a GHP desuperheater, the hot water feature capability. In the summer, if the GHP is used to provide supplemental hot water to a conventional gas or electric water heater, the efficiency disparity becomes even greater. With the GHP's desuperheater in service, hot water in the summer essentially becomes free.

GeoExchange vs. Gas Furnaces

Cost comparisons between GeoExchange Heat Pump systems and Gas Fired Furnaces are difficult to evaluate for a number of reasons. First and foremost is the drastic difference in prices of both gas and electricity over time and location. From data collected by the Energy Information Administration, consumer prices for residential natural gas (per MCF) in 2000 varied from a low of \$3.57 in Alaska to \$21.87 in Hawaii. Even ignoring

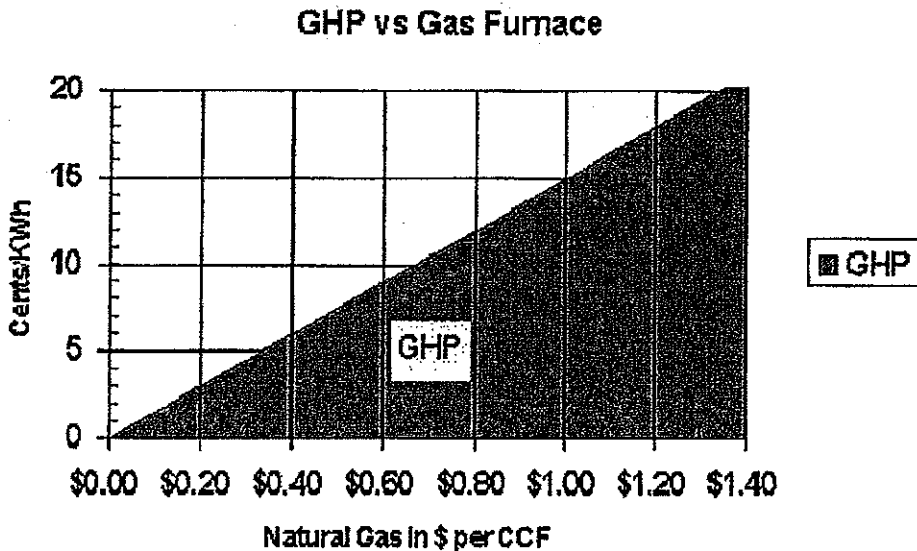
Attachment 5

these two states, there is still a variation between \$5.17 paid in Michigan and \$11.29 paid in Connecticut. Attempting to establish a suitable electric rate is equally as difficult. Again from data put out by the EIA, electrical rates (per KWh) for residential consumers in 2000 varied from \$.05 in Washington to \$.16 in Hawaii.

Other factors to consider in making attempts to compare GHP to gas furnaces include seasonal price fluctuations. In general, natural gas prices to consumers are higher in the winter, while electrical rates many times are lower in the winter.

In this analysis, we will compare a typical gas-fired high efficiency furnace and a GeoExchange heat pump. The gas furnace efficiency is 80%; the GHP COP is 3.5.

Calculations show that the break-even point occurs when the price of electricity per KWh is equal to 0.15 times cost of 1 CCF of gas. For example, if the energy cost of consumer gas is \$1.00 per CCF, the break-even point for a GHP system is where electricity cost is \$.15 per KWh. So if the cost of electricity is less than \$.15 per KWh, the GHP is more economical. This is shown graphically in the chart below.



To see how some real world conditions apply to the chart above, this analysis has considered the average cost of natural gas and electricity for all states during the winters of 1999-2000, and 2000-2001. We have also used the average residential electrical rate average for all states during the same time period. Since the cost of natural gas was so dramatically increased in 2000-2001, we will look at both cases individually. Actual numbers assume units operating at 36,000 BTU/Hr.

Attachment 5

Average natural gas prices during the winter of 1999-2000 were \$.68/CCF, while electrical rates averaged 8 cents/KWh. From the chart, we can clearly see that the intersection of those points is in the "green" area. Actual calculations show that the cost to operate the 3-ton heating units were \$.31 per hour for the gas unit and \$.23 per hour for the GHP. This represents a **reduction in energy cost of approximately 26%**.

Average natural gas prices during the winter of 2000-2001 were \$.94/CCF, while electrical rates still averaged 8 cents/KWh. From the chart, we can clearly see that the intersection of those points is further in the "green" area. Actual calculations reveal that the cost to operate the 3-ton heating units were \$.42 per hour for the gas unit and \$.23 per hour for the GHP. This represents a **reduction in energy cost of approximately 45%**.

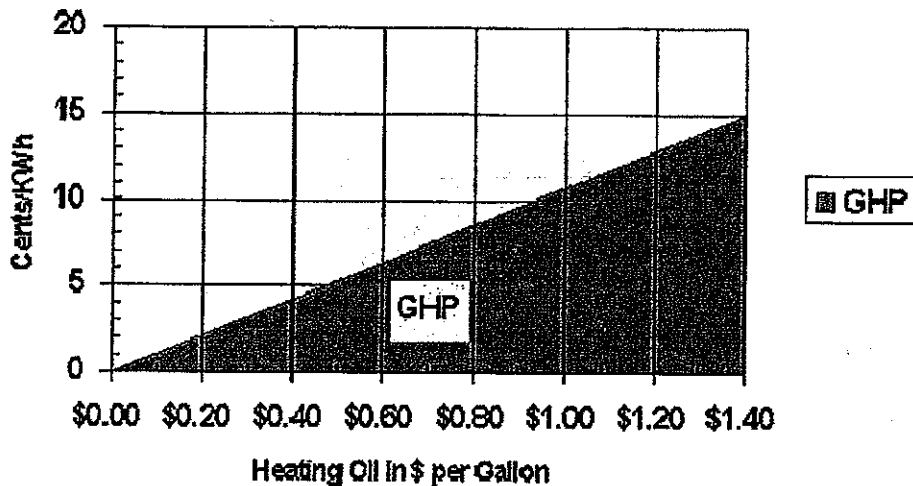
GeoExchange vs. Heating Oil Furnaces

Like the comparisons to natural gas, cost comparisons between GeoExchange Heat Pump systems and Heating Oil Furnaces are difficult to evaluate. Heating oil prices fluctuate due to seasonal demands, and the cyclical nature of crude oil prices.

In this analysis, we will compare a typical oil fired high efficiency furnace and a GeoExchange heat pump. The oil furnace efficiency is 80%; the GHP COP is 3.5.

Calculations show that the break-even point occurs when the price of electricity per KWh is equal to 0.107 times cost of a gallon of heating oil. For example, if the energy cost of heating oil is \$1.00 per gallon, the break-even point for a GHP system is where electricity cost is 10.7 cents per KWh. So if the cost of electricity is less than 10.7 cents per KWh under these conditions, the GHP is more economical. This is shown graphically in the chart below.

GHP vs Oil Furnace



Analyzing real world energy costs, the Energy Information Administration has projected the average winter price of residential heating oil for winter 2001-2002 at \$1.29 per gallon. Residential electric rates for the last two years have averaged 8 cents per KWh. From the chart, we can again see that the intersection of these two points is clearly in the "green" area. The "green" area shows us graphically that the GHP is more economical than the oil-fired furnace.

Comparing 3-ton units, calculations show that the cost to operate an oil furnace is \$.41 per hour. The cost to operate a GHP is \$.23 per hour. Therefore, operating the GHP represents a 41% reduction in energy cost.

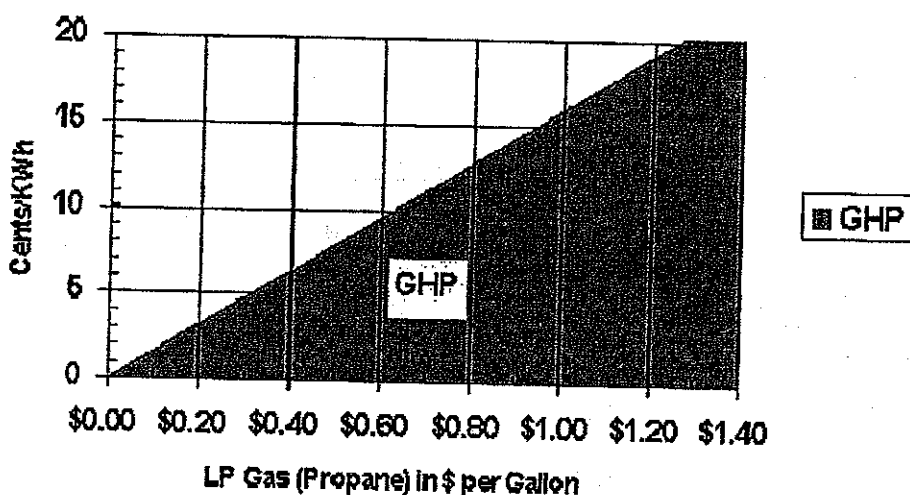
GeoExchange vs. LP Gas (Propane) Furnaces

Like the case with natural gas, comparisons with furnaces operating on propane are subject to the same difficulties due to fuel cost variations. In this analysis, we will again compare a typical gas-fired high efficiency furnace and a GeoExchange heat pump. The gas furnace efficiency is 80%; the GHP COP is 3.5.

Calculations show that the break-even point occurs when the price of electricity per KWh is equal to 0.16 times cost of a gallon of LP Gas. For example, if the cost of LP Gas is \$1.00 per gallon, the break-even point for a GHP system is where the electricity cost is 16 cents per KWh. So if the cost of electricity is less than 16 cents per KWh under these conditions, the GHP is more economical. This is shown graphically in the chart below.

Attachment 5

GHP vs LP Gas Furnace



In our effort to do some real world analysis, we find that the Energy Information Administration has provided us with average propane costs for residential consumers. In 2000, average annualized cost of LP Gas was \$1.17 per gallon. For six months into 2001, the same gallon of LP Gas has averaged \$1.36 per gallon. With our two-year average electricity rate of 8 cents per KWh, we can clearly see that the intersection of these two points is clearly in the "green" area for both 2000, and 2001. Again, the "green" area shows us graphically that the GHP is more economical than the LP Gas-fired furnace.

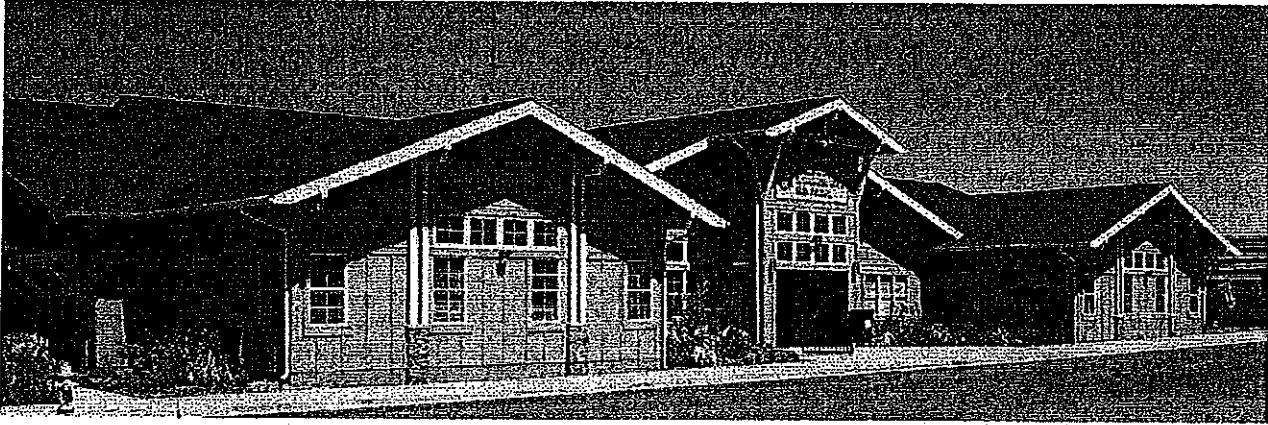
Comparing 3-ton units, calculations show that the cost to operate an LP Gas-fired furnace is \$.57 per hour for 2000, and \$.67 per hour for 2001. The cost to operate a GHP is \$.23 per hour. Therefore, operating the GHP represents energy cost reductions of 60% and 67% respectively.

Conclusion

The analysis here is consistent with the EPA's results, although our assumptions appear to have been chosen more conservatively. Regardless, it is clear that GeoExchange systems are significantly more efficient and less costly to operate than all other methods of heating and air conditioning systems.

CHILOQUIN COMMUNITY CENTER CHILOQUIN, OREGON

Andrew Chiasson
Geo-Heat Center



LOCATION & BACKGROUND

The Chiloquin Community Center is located in Chiloquin, Oregon, which is in southern Oregon, about 30 miles (48 km) north of Klamath Falls, and about 250 miles (402 km) south of Portland. It is a single-level, 13,000 ft² (1,210 m²) structure that provides space for the Chiloquin Public Library, the Two Rivers Art Gallery, public arts and crafts work-rooms, a large public meeting room with full kitchen, and also leases offices to the local Sheriff's Department. Portions of the building are in use 7 days per week, year round. A sketch of the building footprint and borefield are shown in Figure 1.

The building is constructed of insulated concrete form (ICF) walls and a conventional wood frame roof. As a consequence of using ICF with fixed windows, the building is extremely well insulated and air-tight. The entire slab is insulated using 1-inch polystyrene board to reduce downward heat loss in winter.

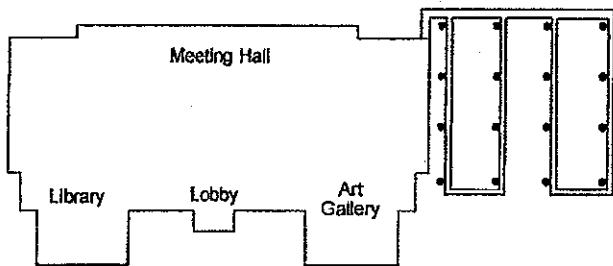


Figure 1. Chiloquin Community Center site sketch showing ground loop field.

The building was constructed in 2003-2004, and formally opened in the Spring of 2004. The ground-source heat pump system installation began prior to the commencement of the main building with the drilling of the network of vertical bores comprising the earth heat exchanger for the facility.

Average high temperatures in the area in July are about 85°F (29.4°C) and average low temperatures in January are about 22°F (-5.6°C). There are approximately 7000 (3890°C-day) heating degree days and 200 (110°C-day) cooling degree days per year (65°F (18°C) base).

SYSTEM DESCRIPTION

Ground Source System

The ground source system (shown in Figure 1) is a vertical network of 16 bores, each 6-inch (152-mm) diameter and 320 ft (98 m) deep, and arranged in a rectangular grid with a bore-to-bore spacing of 20 ft (6.1 m). The u-tube assemblies were fabricated using 1" (25.4 mm) diameter high-density polyethylene pipe (HDPE). Following insertion of the u-tubes, a bentonite/silica sand grout was pumped into the bores to achieve a nominal grout thermal conductivity of 1.0 Btu/hr-ft-°F (1.7 W/m-°C).

To aid in the design of the borefield, an in-situ thermal conductivity analysis was performed on a test bore. The resulting test data were used to determine that the average thermal conductivity of the earth surrounding the bore is approximately 0.62 Btu/hr-ft-°F (1.07 W/m-°C). The mean earth temperature was measured at 56°F (13.3°C).

The geology at the site, based on the drilling logs, consists of sands and gravels to a depth of approximately 16 ft (4.9 m), with the remainder of the bore depths consisting of gray clay deposits interspersed with occasional sandstone

layers. The drilling was accomplished using air-rotary methods (Figure 2).

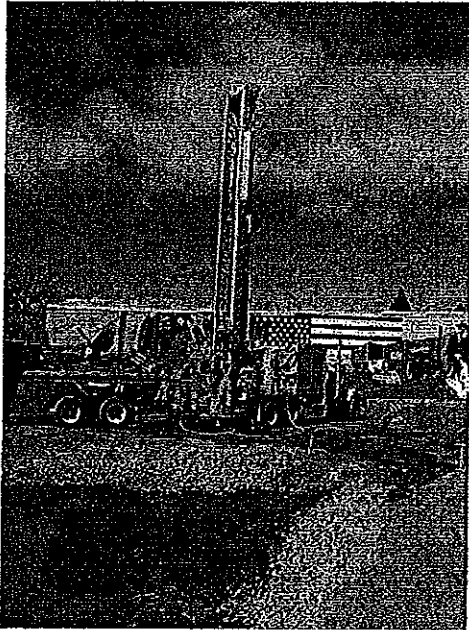


Figure 2. Photograph of drilling activities

Interior System

A highly unusual integrated system design was conceived for the project that addressed the energy efficiency goals of the building owners, and built on the very high thermal integrity of the shell. A crucial initial step in this process was agreement on design criteria that allowed for a wider range of indoor air temperatures than is typical for a building of this type. This determination facilitated the choice to use radiant floor heating as the primary means of thermal distribution, and this concept was then extended to include radiant floor cooling.

The building's 15 control zones are connected by a hydronic piping system to a central plant that has only one heat pump. The heat pump is a water-to-water unit (Figure 3) with a nominal rating of 15 tons (53 kW), and is equipped with a single compressor and refrigerant circuit. To prevent short-cycling, a thermal energy storage tank (Figure 4) is employed on the building side of the heat pump a significant buffer volume and de-coupling the control of building water distribution from the operation of the heat pump.

Because the building has no operable windows, all ventilation air is provided by mechanical means. A heat-wheel type air handling unit with a nominal capacity of 4000 cubic feet per minute (cfm) (6,800 m³/hr) is installed in the attic space, together with ducting to distribute the air to each zone. At the zonal level, occupancy sensors operate a damper in the ventilation duct to minimizing the air handled by the fan system. These occupancy sensors also control lighting in the individual zones. The fan speed is modulated by means of variable frequency drives.

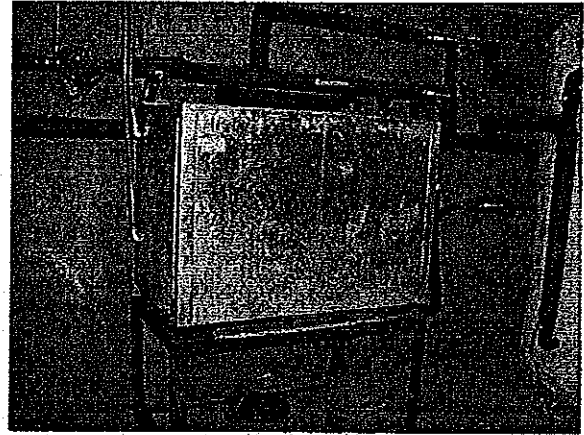


Figure 3. Photograph of the 15 ton water-water heat pump serving the entire building. Note the storage tank on the right.

The building's hydronic circulation pumps are in-line centrifugal types, with variable frequency drives that are controlled based on pressure in the supply pipe. At the heat pump, the ground loop pump is also controlled with a variable frequency drive. The tank circulation pump between heat pump and thermal storage tank is constant speed.

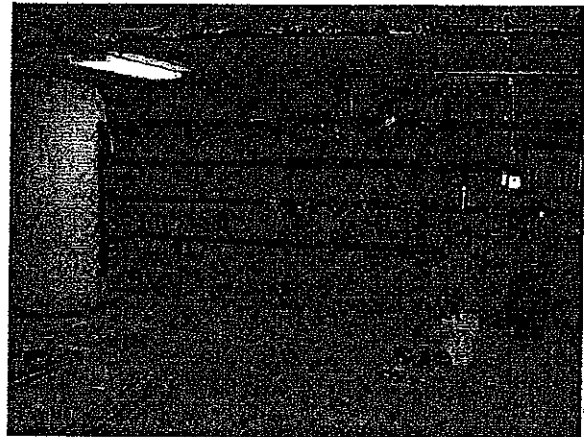


Figure 4. Photograph of the mechanical room, showing the distribution piping and storage tank.

To allow the programming of desired control sequences, a direct-digital control (DDC) system was installed. The system uses ASHRAE's BACnet communications protocol set over TCP/IP. It is therefore possible to use conventional internet browser software to access and interact with the control system, and a dedicated server is located in the building to accomplish this task.

PROJECT COSTS

The installed cost of the interior HVAC system was \$189,400 or \$14.57/ft² (156.83/m²) and the cost of the ground loop was approximately \$48,000 or \$9.38/ft

(\$30.77/m) of vertical borehole. Thus, the total installed cost of the entire ground-source heat pump system was \$237,400 or \$18.26/ft² (196.55/m²).

PacifiCorp provided incentives to the owners, underwriting the costs of pre-design analysis and construction. Additional efficiency incentives were provided through the State of Oregon's Business Energy Tax Credit (BETC) program. Together these incentives totaled approximately \$80,000.

SYSTEM PERFORMANCE AND OPERATING COST

The first full year of operation has just completed, and the building has proven itself to be even more efficient than anticipated. Average energy use index is 19,800 Btu/ft²/yr or 5.8 kWh/ft²/yr (62.4 kWh/m²/yr), which is especially impressive because the building operates with no night setback due to the dynamics of the radiant slab.

Sub-metering of the building zones allows the HVAC energy costs to be broken out and tracked. From utility bills, the operating cost of the HVAC system for the first year was about \$5,350 or \$0.41/ft² (\$4.41/m²).

OPERATING EXPERIENCES

Chiloquin Visions in Progress (CVIP), a non-profit organization who raised funds to construct the building, report that they are very happy with the low energy use and operating cost of the building. Low operating costs are an especially attractive feature for non-profit organizations.

As anticipated, the building design does not provide for rapid adjustment to load changes with its radiant slab heating/cooling systems. This might be perceived as a drawback, but the building has no morning warm-up or cool-down time since it is operated without night setback of thermostatic controls. As designed, it seems to work reasonably well with the normal functional requirements of the building.

One rapid load change scenario that has been somewhat difficult to deal with is the occasional large public gathering in the meeting hall room. To best provide for the sudden cooling load, it has been necessary to anticipate the event by overcooling the room, and then keeping the supply water temperature lower than would normally be called for at the central thermal storage tank. In addition, decorative ceiling fans have been proposed in the meeting hall room to increase air circulation as well as to give occupants a visual perception of air movement.

ACKNOWLEDGEMENTS

The Geo-Heat Center wishes to thank Gene Johnson of Solarc Architecture and Engineering, Inc. for providing the data and information for this case study, and Chuck Wells and Jim Walthers of CVIP for providing the drilling and utility cost information.

OVERALL SUMMARY

Building Description:

Location: Chiloquin, Oregon

Occupancy: Community Center with continuous occupancy in some zones

Gross Floor Area: 13,000 ft² (1,210 m²)

Number of Floors: 1

Type of Construction: New

Completion Date: 2003

July Avg. High Temp.: 85°F (29.4°C)

Jan Avg. Low Temp.: 22°F (-5.6°C)

Annual Heating Degree Days: 7000°F-day (3890°C-day)

Annual Cooling Degree Days: 200°F-day (110°C-day)

Interior System:

Total Installed Heat Pump Capacity: 15 tons (53 kW)

No. of Heat Pump Units: 1

Pumping System: Central pumping, variable speed control

Additional notes: Radiant floor heating and cooling

Ground-Source System:

Geologic Materials: Sediments

Mean Ann. Ground Temp.: 56°F (13.3°C)

Type: Vertical closed loop, single U-tube

Configuration: 16 boreholes (4x4 grid pattern)
300 ft (98 m) deep, 20 (6.1 m) ft spacing

Borehole per ton: 342 ft/ton (29.6 m/kW)

Heat Transfer Fluid: Methanol/water solution

Economic Analysis:

Installed Geothermal HVAC Capital Cost:
\$237,400 (\$18.26/ft²) (196.55/m²)

Estimated Conventional HVAC Capital Cost:
\$130,000 (\$10.00/ft²) (107.64/m²)

Annual HVAC Energy Use:
19,800 Btu/ft² (62.4 kWh/m²)

Annual HVAC Energy Cost:
\$5,350 (\$0.41/ft²) (\$4.41/m²)

00

00

Paisley School Energy Efficiency Measures

NO FLOOR / NO WALL INSUL
 DOUBLE PANEGASS

	COOLING DATA AT Jul 1600			HEATING DATA AT DES HTG		
	COOLING OA DB / WB 90.0 °F / 62.0 °F			HEATING OA DB / WB -3.0 °F / -4.5 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	2040 ft²	60433	-	2040 ft²	-	-
Wall Transmission	2460 ft²	9473	-	2460 ft²	56922	-
Roof Transmission	8390 ft²	35327	-	8390 ft²	40844	-
Window Transmission	2040 ft²	12026	-	2040 ft²	98580	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	4031 ft²	-3173	-	4031 ft²	24456	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	14498 W	49452	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	8787 W	28979	-	0	0	-
People	519	127167	108431	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
Zone Conditioning	-	310638	108431	-	219323	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	20200 CFM	0	-	20200 CFM	0	-
Ventilation Load	5926 CFM	75430	-106441	5926 CFM	407579	0
Supply Fan Load	20200 CFM	0	-	20200 CFM	0	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
Central Cooling Coil	-	386070	0	-	0	0
Central Heating Coil	-	0	-	-	626902	-
Key:	Positive values are ckg loads Negative values are htg loads			Positive values are htg loads Negative values are ckg loads		

FLOOR INSUL AND WALL
 SINGLE PANE GLASS

	COOLING DATA AT Jul 1600 COOLING OA DB / WB 90.0 °F / 62.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB -3.0 °F / -4.5 °F		
	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
ZONE LOADS						
Window & Skylight Solar Loads	2040 ft²	68844	-	2040 ft²	-	-
Wall Transmission	2460 ft²	9473	-	2460 ft²	56922	-
Roof Transmission	8390 ft²	34655	-	8390 ft²	40037	-
Window Transmission	2040 ft²	18305	-	2040 ft²	150054	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	4031 ft²	-2251	-	4031 ft²	17350	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	14499 W	49452	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	8787 W	29979	-	0	0	-
People	519	127167	106431	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
Zone Conditioning	-	326707	106431	-	261655	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	21152 CFM	0	-	21152 CFM	0	-
Ventilation Load	5926 CFM	77303	-106442	5926 CFM	406883	0
Supply Fan Load	21152 CFM	0	-	21152 CFM	0	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
Central Cooling Coil	-	406009	0	-	0	0
Central Heating Coil	-	0	-	-	569436	-
Key:	Positive values are clg loads Negative values are htg loads			Positive values are htg loads Negative values are clg loads		

NO FLOOR. NO WALL INSUL
 SINGLE PANE GLASS

BASE

ZONE LOADS	COOLING DATA AT Jul 1600			HEATING DATA AT DES HTG		
	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	2040 ft²	68844	-	2040 ft²	-	-
Wall Transmission	2460 ft²	9473	-	2460 ft²	56922	-
Roof Transmission	8390 ft²	35327	-	8390 ft²	40844	-
Window Transmission	2040 ft²	18306	-	2040 ft²	150054	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	4031 ft²	-3173	-	4031 ft²	24458	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	14499 W	49452	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	8787 W	29979	-	0	0	-
People	519	127167	106431	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
Zone Conditioning	-	322940	106431	-	271985	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	21132 CFM	0	-	21132 CFM	0	-
Ventilation Load	5926 CFM	75383	-106442	5926 CFM	407571	0
Supply Fan Load	21132 CFM	0	-	21132 CFM	0	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
Central Cooling Coil	-	398322	0	-	0	0
Central Heating Coil	-	0	-	-	679556	-
Key:	Positive values are cig loads Negative values are htg loads			Positive values are htg loads Negative values are cig loads		

PO FLOOR - TWALL / USV
 SINGLE PANE GLASS

ZONE LOADS	COOLING DATA AT Jul 1600 COOLING OA DB / WB 90.0 °F / 62.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB -3.0 °F / -4.5 °F		
	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	2040 ft²	68844	-	2040 ft²	-	-
Wall Transmission	2460 ft²	1764	-	2460 ft²	11920	-
Roof Transmission	8390 ft²	35327	-	8390 ft²	40844	-
Window Transmission	2040 ft²	18308	-	2040 ft²	150054	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	4031 ft²	-3173	-	4031 ft²	24458	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	14489 W	49452	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	8787 W	29979	-	0	0	-
People	519	127167	106431	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
Zone Conditioning	-	316535	106431	-	220767	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	20578 CFM	0	-	20578 CFM	0	-
Ventilation Load	5926 CFM	75739	-106442	5926 CFM	406213	0
Supply Fan Load	20578 CFM	0	-	20578 CFM	0	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
Central Cooling Coil	-	392274	0	-	0	0
Central Heating Coil	-	0	-	-	626979	-
Key:	Positive values are clg loads Negative values are htg loads			Positive values are htg loads Negative values are clg loads		

NO FLOOR INSUL
 PAISLEY - NO WALL INSUL -
 - SINGLE PANE GLASS

ZONE LOADS	COOLING DATA AT Jul 1500 COOLING OA DB / WB 90.0 °F / 62.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB -3.0 °F / -4.5 °F		
	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	2040 ft²	68626	-	2040 ft²	-	-
Wall Transmission	2460 ft²	9473	-	2460 ft²	56922	-
Roof Transmission	8390 ft²	25833	-	8390 ft²	29433	-
Window Transmission	2040 ft²	18305	-	2040 ft²	150047	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	0 ft²	0	-	0 ft²	0	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	14499 W	49452	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	8787 W	29979	-	0	0	-
People	519	127167	108431	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
Zone Conditioning	-	318694	108431	-	239090	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	20752 CFM	0	-	20752 CFM	0	-
Ventilation Load	5926 CFM	75337	-106441	5926 CFM	408244	0
Supply Fan Load	20752 CFM	0	-	20752 CFM	0	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
Central Cooling Coil	-	394031	0	-	0	0
Central Heating Coil	-	0	-	-	647334	-
Key:	Positive values are ckg loads Negative values are htg loads			Positive values are htg loads Negative values are ckg loads		

	COOLING DATA AT Jul 1400			HEATING DATA AT DES HTG		
	COOLING OA DB / WB 89.0 °F / 61.7 °F			HEATING OA DB / WB -3.0 °F / -4.5 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	2040 ft²	88373	-	2040 ft²	-	-
Wall Transmission	2460 ft²	1701	-	2460 ft²	13339	-
Roof Transmission	8390 ft²	27466	-	8390 ft²	29433	-
Window Transmission	2040 ft²	16467	-	2040 ft²	150047	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	0 ft²	0	-	0 ft²	0	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	14499 W	49451	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	8787 W	29879	-	0	0	-
People	519	127166	108431	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
Zone Conditioning	-	318342	108431	-	193268	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	20190 CFM	0	-	20190 CFM	0	-
Ventilation Load	5926 CFM	71780	-108448	5926 CFM	408299	0
Supply Fan Load	20190 CFM	0	-	20190 CFM	0	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
Central Cooling Coil	-	388102	0	-	0	0
Central Heating Coil	-	0	-	-	601565	-
Key:	Positive values are ckg loads Negative values are htg loads			Positive values are htg loads Negative values are ckg loads		

PAISLEY - R-11 FLOOR INSULATION -

*NO WALK
 NO STAG PANE*

	COOLING DATA AT Aug 1500 COOLING OA DB / WB 90.0 °F / 62.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB -3.0 °F / -4.5 °F		
	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
ZONE LOADS						
Window & Skylight Solar Loads	2040 ft²	50560	-	2040 ft²	-	-
Wall Transmission	2460 ft²	8896	-	2480 ft²	56922	-
Roof Transmission	8390 ft²	23061	-	8390 ft²	29433	-
Window Transmission	2040 ft²	12018	-	2040 ft²	98523	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	4031 ft²	-2353	-	4031 ft²	18140	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	14489 W	49452	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	8787 W	29979	-	0	0	-
People	519	127167	106431	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
Zone Conditioning	-	298217	106431	-	203239	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	19236 CFM	0	-	19236 CFM	0	-
Ventilation Load	5926 CFM	78459	-106440	5926 CFM	409737	0
Supply Fan Load	19236 CFM	0	-	19236 CFM	0	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
Central Cooling Coil	-	376677	0	-	0	0
Central Heating Coil	-	0	-	-	812975	-
Key:	Positive values are clg loads Negative values are htg loads			Positive values are htg loads Negative values are clg loads		

Paisley School Energy Simulation

Hourly Simulation Results for Paisley School

Project Name: Paisley School
 Prepared by: Oregon Institute of Technology

02/23/2009
 09:20AM

Table 1.1 Hourly Air System Simulation Results for Tuesday, January 28

Hour	Central Cooling Coil Load (MBH)	Central Cooling Eqpt Load (MBH)	Central Unit Clg Input (kW)	Central Heating Coil Load (MBH)	Central Heating Coil Input (kW)	Supply Fan (kW)	Lighting (kW)
0000	0.0	0.0	0.0	493.2	144.5	0.0	14.5
0100	0.0	0.0	0.0	497.6	145.8	0.0	14.5
0200	0.0	0.0	0.0	499.5	146.4	0.0	14.5
0300	0.0	0.0	0.0	500.5	146.7	0.0	14.5
0400	0.0	0.0	0.0	502.0	147.1	0.0	14.5
0500	0.0	0.0	0.0	507.7	148.8	0.0	14.5
0600	0.0	0.0	0.0	511.9	150.0	0.0	14.5
0700	0.0	0.0	0.0	517.0	151.5	0.0	14.5
0800	0.0	0.0	0.0	487.9	143.0	0.0	14.5
0900	0.0	0.0	0.0	461.2	135.2	0.0	14.5
1000	0.0	0.0	0.0	430.0	0.0	0.0	14.5
1100	0.0	0.0	0.0	420.0	0.0	0.0	14.5
1200	0.0	0.0	0.0	406.2	119.0	0.0	14.5
1300	0.0	0.0	0.0	385.2	112.9	0.0	14.5
1400	0.0	0.0	0.0	382.6	112.1	0.0	14.5
1500	0.0	0.0	0.0	380.4	111.5	0.0	14.5
1600	0.0	0.0	0.0	385.9	113.1	0.0	14.5
1700	0.0	0.0	0.0	389	0.0	0.0	14.5
1800	0.0	0.0	0.0	391.0	114.6	0.0	14.5
1900	0.0	0.0	0.0	394.7	115.7	0.0	14.5
2000	0.0	0.0	0.0	393.7	115.4	0.0	14.5
2100	0.0	0.0	0.0	401.0	117.5	0.0	14.5
2200	0.0	0.0	0.0	398.8	116.9	0.0	14.5
2300	0.0	0.0	0.0	403.4	118.2	0.0	14.5
Total	0.0	0.0	0.0	9301.4	2726.0	0.0	348.0

4
1
2
3

1898
1553
~~1228~~
1568
4372

$$\frac{1808}{4} = 452$$

$$\frac{1553}{4} = 388$$

$$\frac{1568}{4} = 392$$

$$\frac{4372}{12} = 364$$

Hourly Simulation Results for Paisley School

Project Name: Paisley School
 Prepared by: Oregon Institute of Technology

02/23/2009
 09:20AM

Table 1.1 Hourly Air System Simulation Results for Sunday, January 26

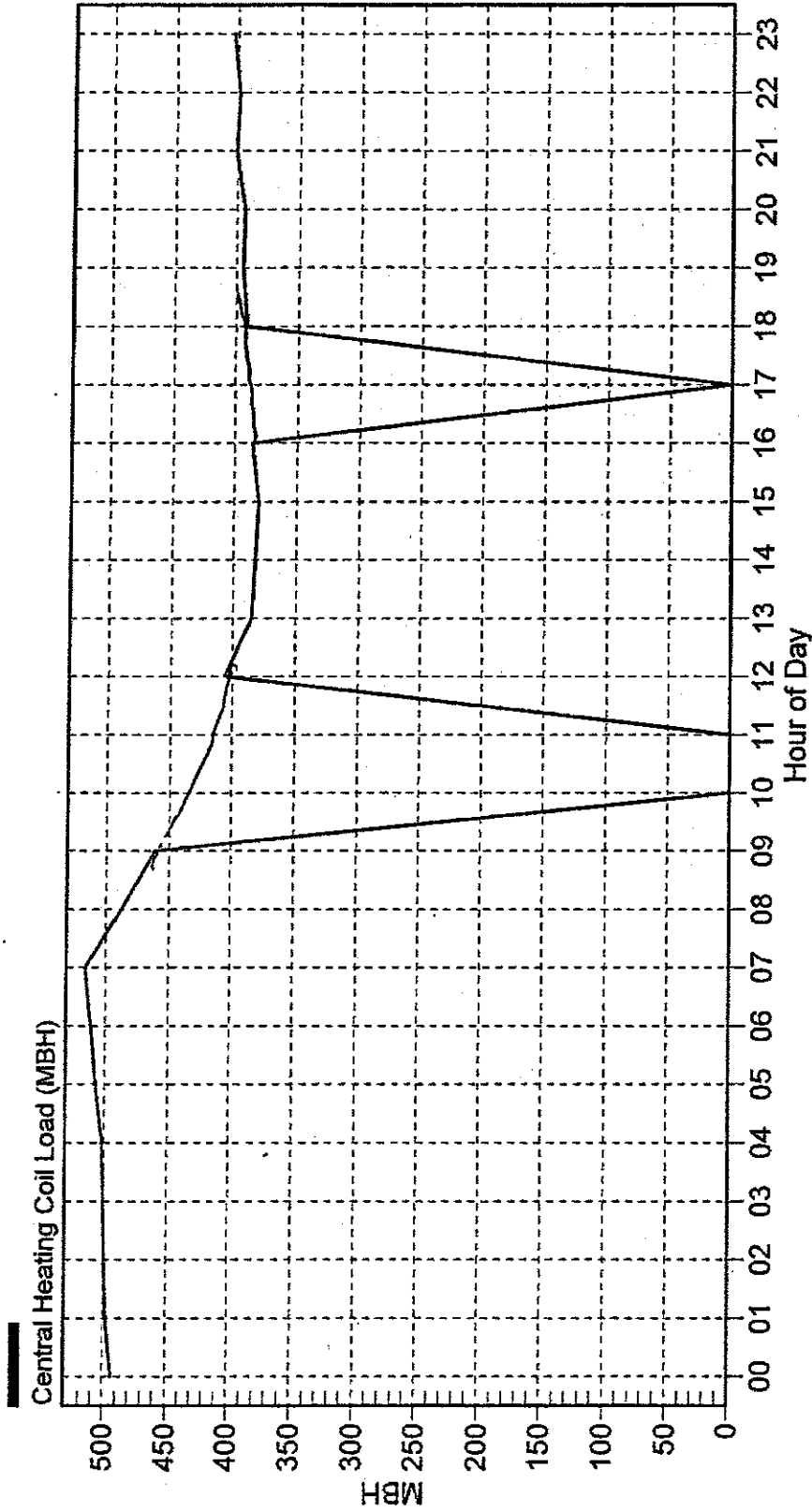
Hour	Central Cooling Coil Load (MBH)	Central Cooling Eqpt Load (MBH)	Central Unit Ctg Input (kW)	Central Heating Coil Load (MBH)	Central Heating Coil Input (kW)	Supply Fan (kW)	Lighting (kW)
0000	0.0	0.0	0.0	238.9	70.0	0.0	14.5
0100	0.0	0.0	0.0	0.0	0.0	0.0	14.5
0200	0.0	0.0	0.0	0.0	0.0	0.0	14.5
0300	0.0	0.0	0.0	0.0	0.0	0.0	14.5
0400	0.0	0.0	0.0	0.0	0.0	0.0	14.5
0500	0.0	0.0	0.0	273.0	80.0	0.0	14.5
0600	0.0	0.0	0.0	0.0	0.0	0.0	14.5
0700	0.0	0.0	0.0	0.0	0.0	0.0	14.5
0800	0.0	0.0	0.0	0.0	0.0	0.0	14.5
0900	0.0	0.0	0.0	311.5	91.3	0.0	14.5
1000	0.0	0.0	0.0	0.0	0.0	0.0	14.5
1100	0.0	0.0	0.0	0.0	0.0	0.0	14.5
1200	0.0	0.0	0.0	0.0	0.0	0.0	14.5
1300	0.0	0.0	0.0	0.0	0.0	0.0	14.5
1400	0.0	0.0	0.0	315.6	92.5	0.0	14.5
1500	0.0	0.0	0.0	323.1	94.7	0.0	14.5
1600	0.0	0.0	0.0	324.0	95.0	0.0	14.5
1700	0.0	0.0	0.0	0.0	0.0	0.0	14.5
1800	0.0	0.0	0.0	0.0	0.0	0.0	14.5
1900	0.0	0.0	0.0	0.0	0.0	0.0	14.5
2000	0.0	0.0	0.0	0.0	0.0	0.0	14.5
2100	0.0	0.0	0.0	0.0	0.0	0.0	14.5
2200	0.0	0.0	0.0	0.0	0.0	0.0	14.5
2300	0.0	0.0	0.0	362.8	106.3	0.0	14.5
Total	0.0	0.0	0.0	2148.9	629.8	0.0	348.0

Hourly Simulation Results for Paisley School

Project Name: Paisley School
Prepared by: Oregon Institute of Technology

02/23/2009
09:28AM

Hourly Simulation Results for Tuesday, January 28 (day 28) thru Tuesday, January 28 (day 28)

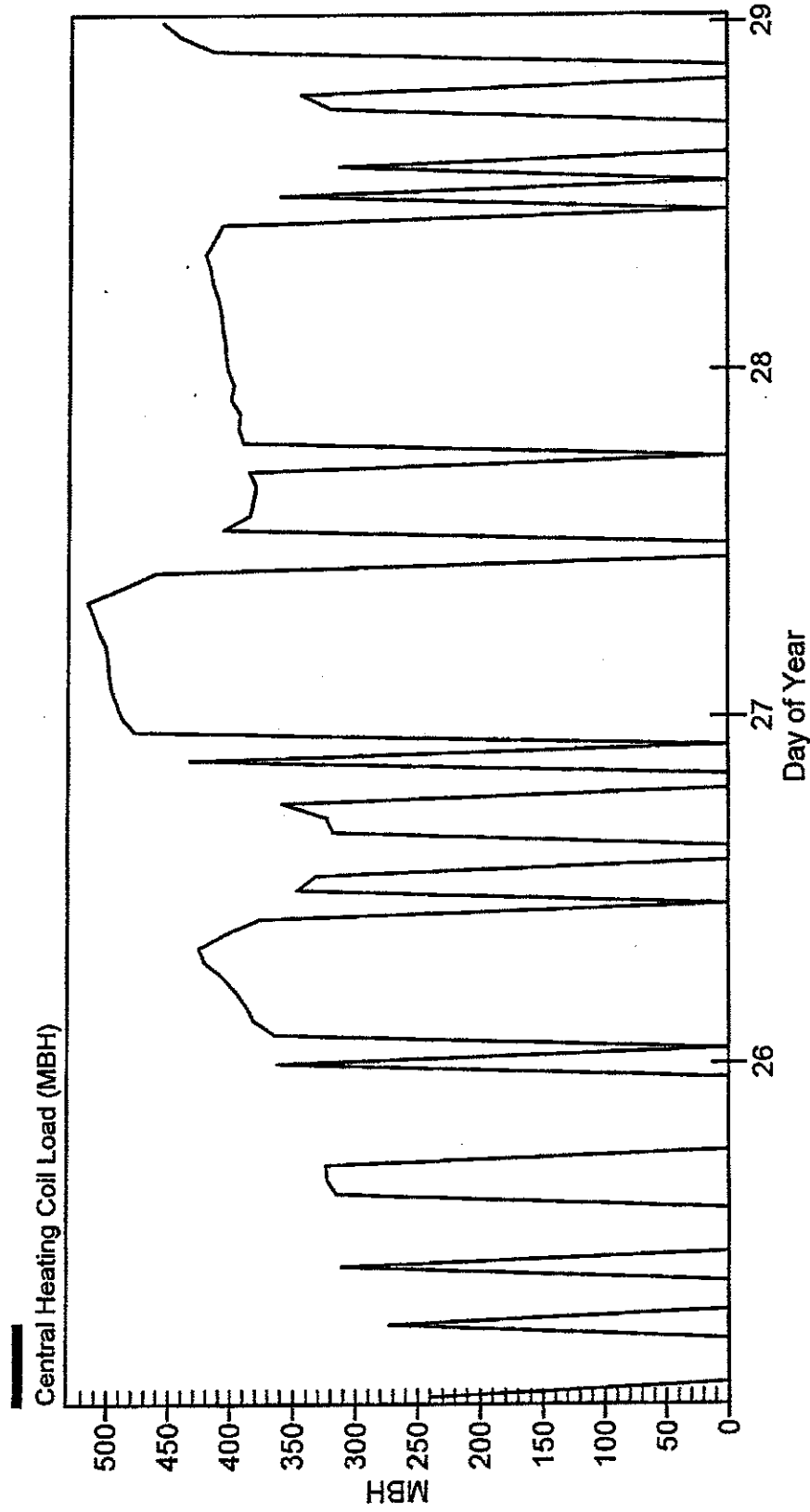


Hourly Simulation Results for Paisley School

02/23/2009
09:18AM

Project Name: Paisley School
Prepared by: Oregon Institute of Technology

Hourly Simulation Results for Sunday, January 26 (day 26) thru Wednesday, January 29 (day 29)

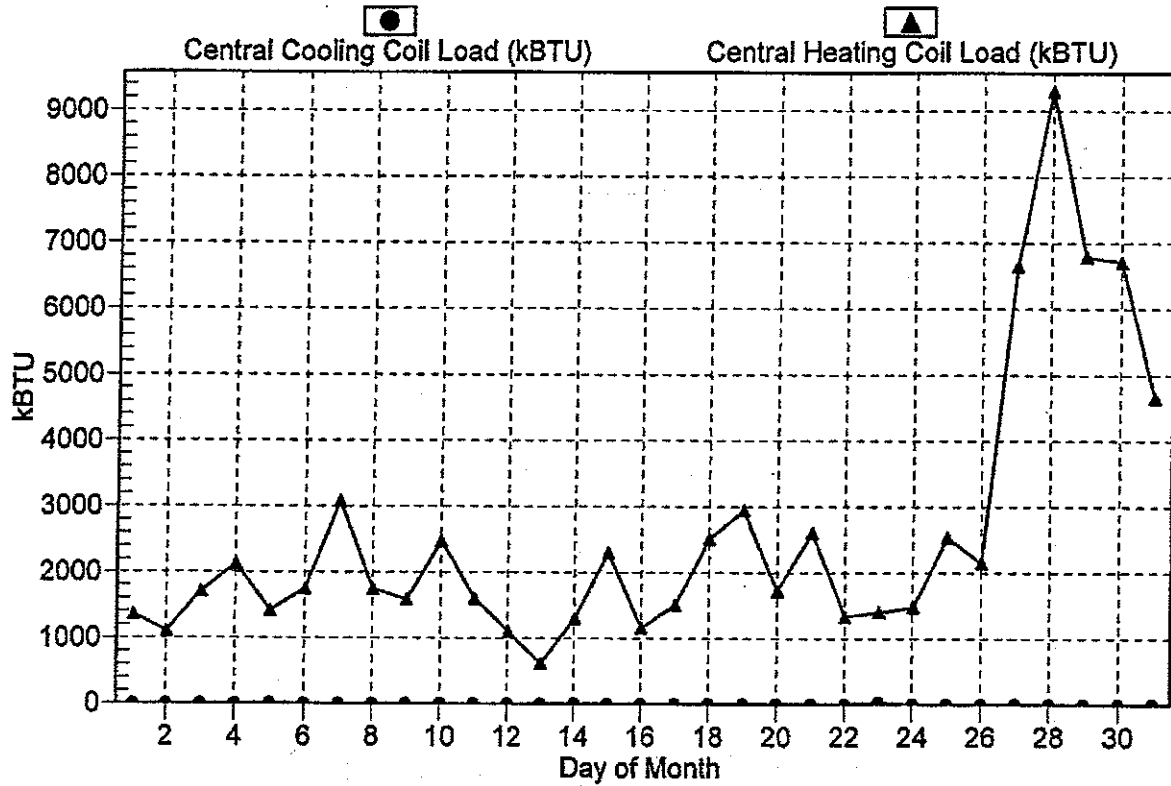


Daily Simulation Results for Paisley School

Project Name: Paisley School
Prepared by: Oregon Institute of Technology

02/23/2009
08:57AM

Daily Simulation Results for January



Monthly Simulation Results for Paisley School

Project Name: Paisley School
 Prepared by: Oregon Institute of Technology

02/23/2009
 08:51AM

Air System Simulation Results (Table 1) :

Month	Central Cooling Coil Load (kBTU)	Central Cooling Eqpt Load (kBTU)	Central Unit Ctg Input (kWh)	Central Heating Coil Load (kBTU)	Central Heating Coil Input (kWh)	Supply Fan (kWh)	Lighting (kWh)
January	30	10	1	80666	23641	0	10787
February	2367	1721	118	40854	11973	0	9743
March	3830	2311	160	33412	9792	0	10787
April	30846	25757	1901	12538	3675	0	10439
May	46616	38042	2796	8010	1761	0	10787
June	106192	98629	7775	1476	432	0	10439
July	134315	127465	10231	365	107	0	10787
August	128472	120712	9821	434	127	0	10787
September	76570	70182	5513	3173	930	0	10439
October	23605	19527	1430	17651	5173	0	10787
November	5497	4885	357	34056	9981	0	10439
December	531	379	26	49092	14367	0	10787
Total	558871	509622	40129	279727	81980	0	127008

Air System Simulation Results (Table 2) :

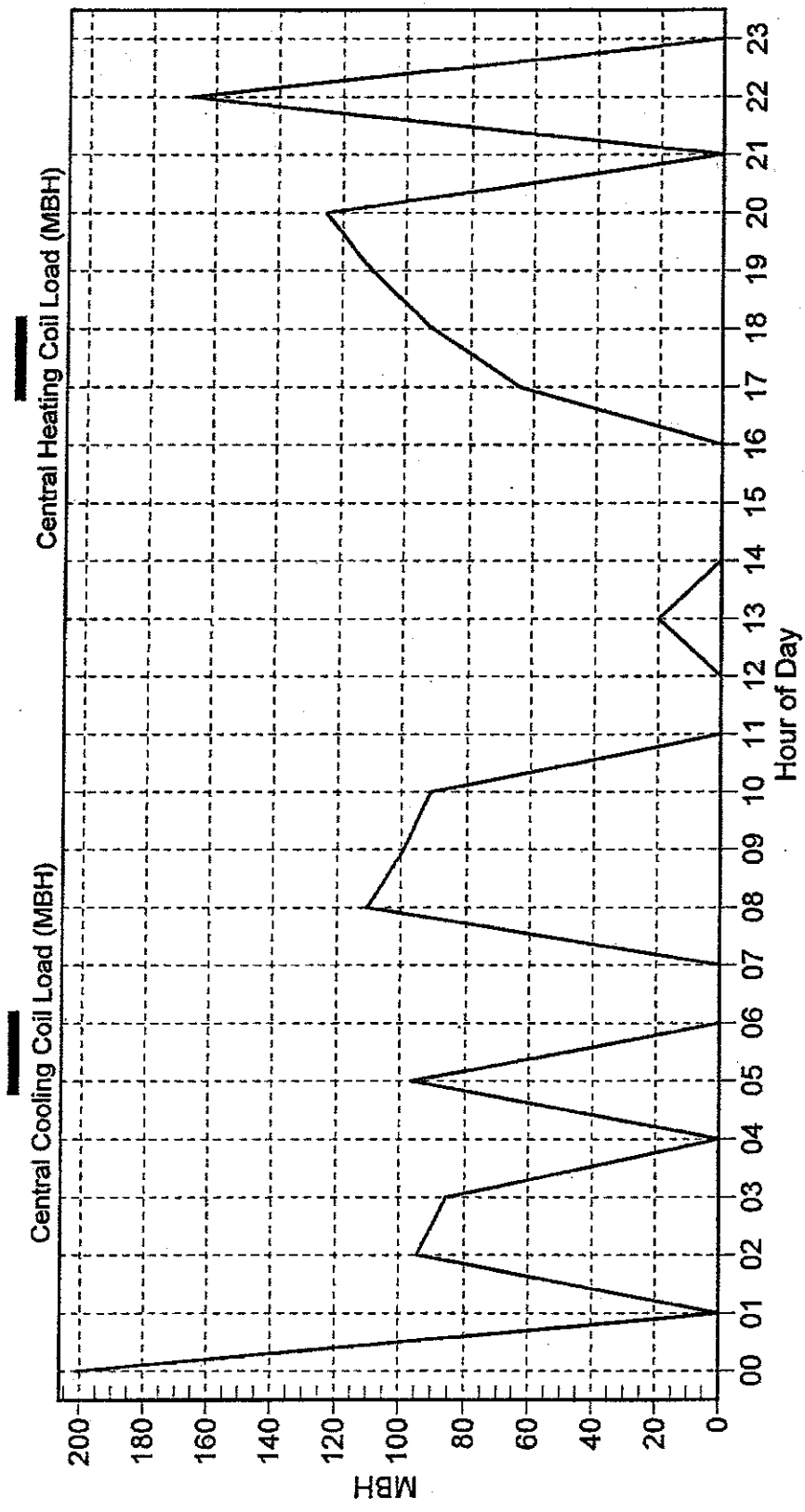
Month	Electric Equipment (kWh)
January	6538
February	5905
March	6538
April	6327
May	6538
June	6327
July	6538
August	6538
September	6327
October	6538
November	6327
December	6538
Total	76975

Hourly Simulation Results for Paisley School

Project Name: Paisley School
Prepared by: Oregon Institute of Technology

02/23/2009
08:59AM

Hourly Simulation Results for Wednesday, January 1 (day 1) thru Wednesday, January 1 (day 1)

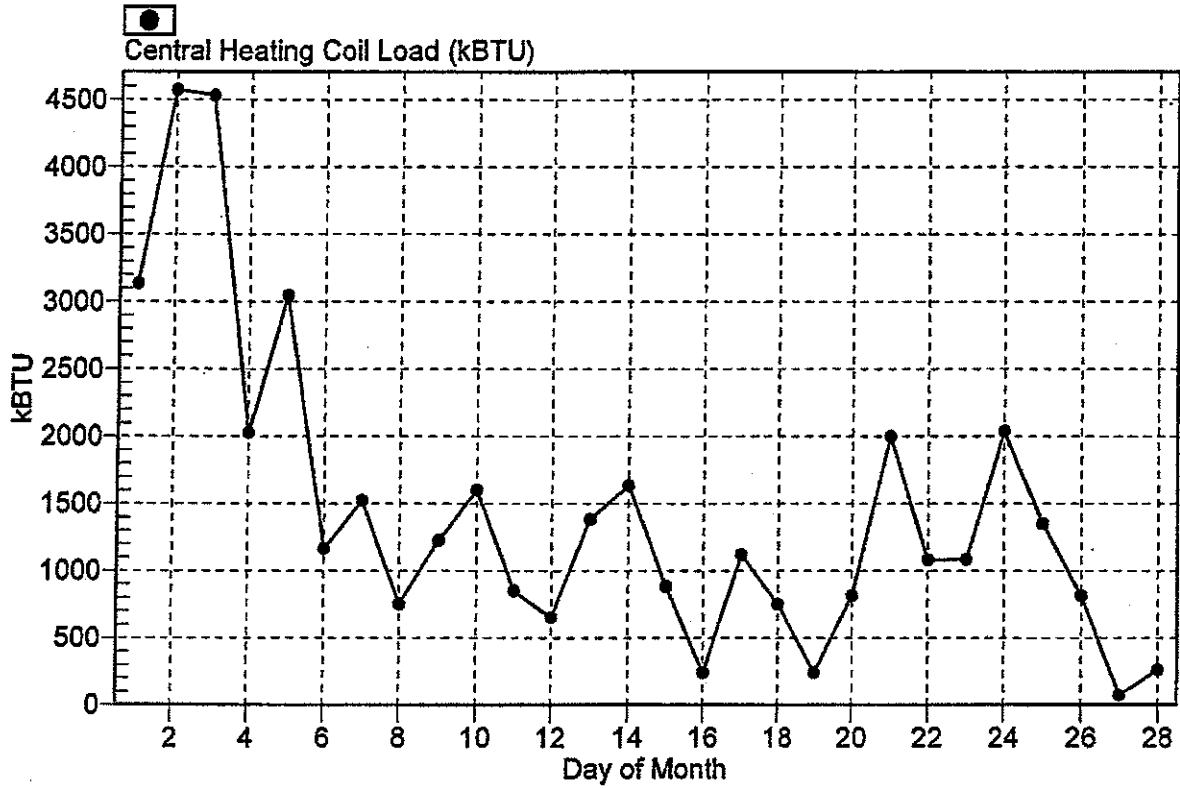


Daily Simulation Results for Paisley School

Project Name: Paisley School
Prepared by: Oregon Institute of Technology

02/23/2009
09:05AM

Daily Simulation Results for February

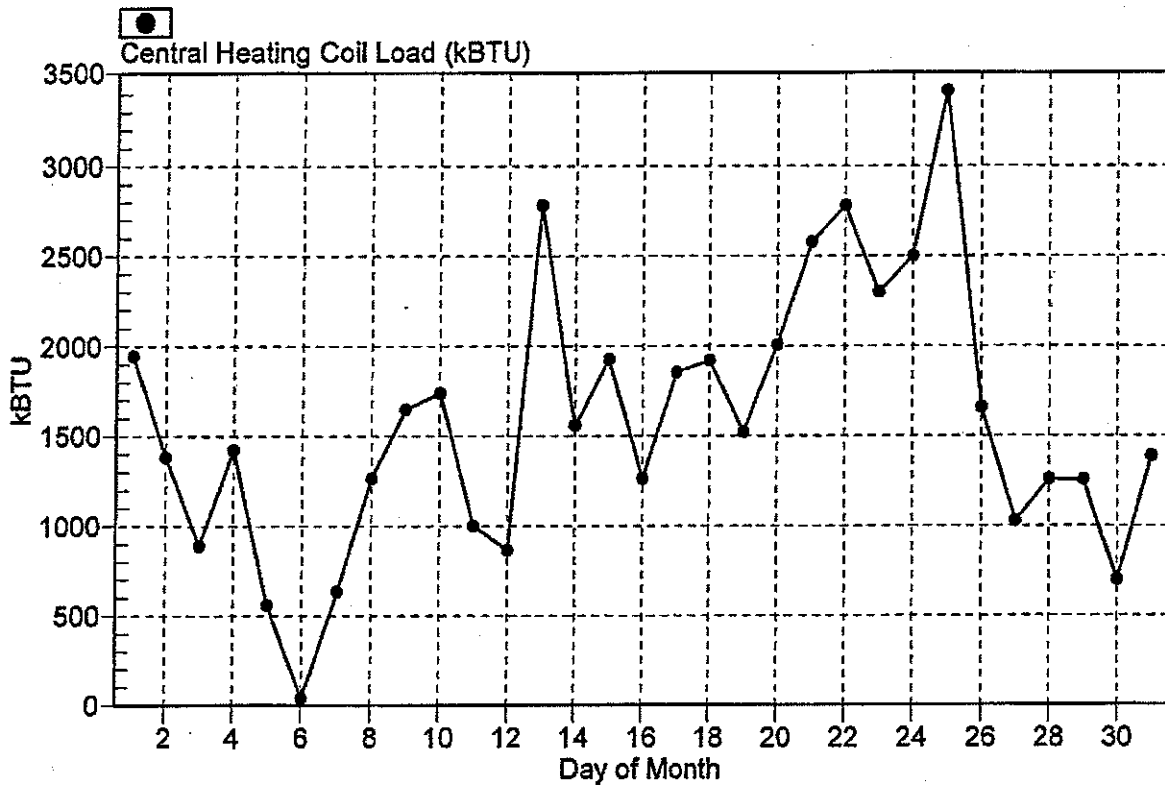


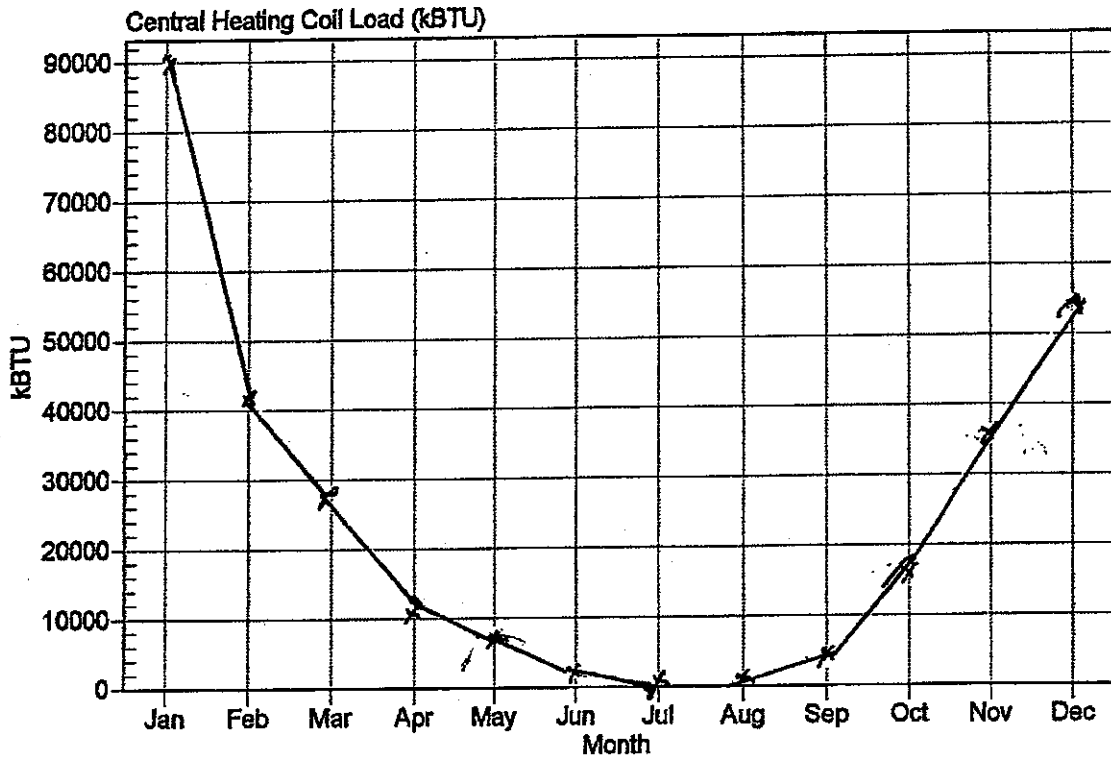
Daily Simulation Results for Paisley School

Project Name: Paisley School
Prepared by: Oregon Institute of Technology

02/23/2009
09:04AM

Daily Simulation Results for December





Daily Simulation Results for Paisley School

Project Name: Paisley School
 Prepared by: Oregon Institute of Technology

02/23/2009
 08:31AM

Daily Air System Simulation Results for January (Table 1) :

Day	Central Cooling Coil Load (kBTU)	Central Cooling Eqpt Load (kBTU)	Central Unit Ctg Input (kWh)	Central Heating Coil Load (kBTU)	Central Heating Coil Input (kWh)	Supply Fan (kWh)	Lighting (kWh)
1	0	0	0	1357	398	0	348
2	0	0	0	1103	323	0	348
3	0	0	0	1705	500	0	348
4	0	0	0	2124	622	0	348
5	4	0	0	1415	415	0	348
6	0	0	0	1749	512	0	348
7	0	0	0	3078	902	0	348
8	0	0	0	1748	512	0	348
9	0	0	0	1583	464	0	348
10	0	0	0	2469	724	0	348
11	0	0	0	1599	469	0	348
12	0	0	0	1104	324	0	348
13	0	0	0	618	181	0	348
14	0	0	0	1294	379	0	348
15	0	0	0	2296	673	0	348
16	0	0	0	1161	340	0	348
17	0	0	0	1502	440	0	348
18	0	0	0	2512	736	0	348
19	0	0	0	2949	864	0	348
20	0	0	0	1720	504	0	348
21	0	0	0	2599	762	0	348
22	0	0	0	1330	390	0	348
23	26	10	1	1399	410	0	348
24	0	0	0	1473	432	0	348
25	0	0	0	2532	742	0	348
26	0	0	0	2149	630	0	348
27	0	0	0	6647	1948	0	348
28	0	0	0	9301	2726	0	348
29	0	0	0	6785	1989	0	348
30	0	0	0	6712	1967	0	348
31	0	0	0	4656	1364	0	348
Total	30	10	1	80668	23641	0	10787