# CONTINUING ADVANCES IN PEX DOWNHOLE EXCHANGERS FOR DIRECT-USE HEATING APPLICATIONS

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## INTRODUCTION

Installation and monitoring of the first known cross-linked polyethylene (PEX) downhole heat exchanger (DHE) was described in previous work by Chiasson, et al., (2005). This article describes the second-known PEX DHE installation for direct-use heating applications.

PEX is a material known for its relatively high temperature and pressure rating, durability, and chemical resistance. The PEX DHE described in this article was designed and installed as a retrofit in a geothermal well providing space heating and domestic hot water to two residences in Klamath Falls, OR. The DHE was installed in October 2006, and monitored for one heating season. System temperatures were recorded at 15-minute intervals with a data logger, and no operating problems with the PEX have been encountered since its installation.

## BACKGROUND

A DHE is a closed-loop pipe with a "U-bend" at the bottom, and is installed in geothermal wells to provide space heating and domestic hot water. Their most widespread use is in the United States, Turkey, and New Zealand, with less common and/or experimental uses reported in Iceland, Hungary, Russia, Italy, Greece, and Japan. In the United States, the most concentrated uses of DHEs are in Klamath Falls, OR (over 500 installations) and Reno, NV.

The most common construction of DHEs in Klamath Falls has been black iron pipe due to its low cost and availability. However, with the sharp price increases (i.e. more than double) of all metallic piping in the past few years, along with the limited life of metallic piping due to corrosion, PEX DHEs are emerging as an attractive alternative to black iron DHEs. With more suppliers entering the PEX market, PEX costs are decreasing. Another advantage of a PEX DHE is that the installation (and perhaps removal) can be a do-it-yourself project for the homeowner.

## THE PEX DHE PROJECT

### *Project Overview*

A homeowner in Klamath Falls, OR decided to replace a leaking DHE in October 2006. The leak was occurring down in the well, and was diagnosed with pressure gauges installed in the piping system. The DHE was constructed of 2-inch nominal diameter black iron pipe, and provided space heat and domestic hot water to two residences with plan areas of 960 $ft^2$ and 740 $ft^2$. Each home also has an "unconditioned" basement that is kept warm by the geothermal distribution piping serving the living space.

The space heat in each home is provided by hydronic radiant baseboard finned-tubes. Domestic hot water is provided directly by the DHE, and no hot water storage tanks are used. All the thermal energy is provided by passive thermosiphoning of water in the DHE, and thus no pumping is necessary. Based on field observations and a temperature log of the well by the Geo-Heat Center, the well depth is approximately 140 ft with a static water level of about 100 ft below grade. The average temperature of the water column in the well was measured at about 200˚F. The age of the well is uncertain; no well log exists, suggesting that the well was drilled in the 1940s or earlier. An 8-inch steel well casing is visible, which extends to an unknown depth. It had been noted by the homeowner that the black iron DHE did not provide adequate heat on very cold days.

The well is located in a challenging position for DHE removal. The well was originally drilled in a yard to serve a single home, but the second home was subsequently built over the well, and the well was presumably cut down to grade at that time, where it now exists in the basement of the second home. The well is accessible from the ground surface by removing a wooden porch structure at the back door of the newer house, which exists in a completely enclosed backyard. Thus, it is not possible to access the DHE directly by truck, and the DHE had previously been removed (only two years prior) by a manually operated winch. In short, the homeowner sought a longer-term solution to potential frequent replacements of this difficult black iron DHE, and decided to install a PEX DHE.

### *Removal of the Old Black Iron DHE*

As mentioned above, the only way to remove the black iron DHE was with a manually-operated winch. A photograph of the DHE removal process is shown in Figure 1. Figure 2 is a photograph from the basement location of the well, showing heavy scale and corrosion of the black-iron DHE as it is being pulled from the well. Not visible in the photograph are several pinholes that were observed in the black iron pipe, which were the cause of the water leaks.

### *Installation of the New PEX DHE*

The two main design parameters controlling PEX DHE sizing are the length and diameter of the pipe. The length is the most important parameter affecting the overall heat extraction rate from the well, but given the relatively short water column (i.e. 40 ft), it was decided to install the PEX DHE such that it rested on the well bottom. Initially, there was some concern whether the DHE could be reliably installed to the well bottom by hand, but by weighting the DHE with a metallic object and then filling the PEX tubing with water once it had been inserted to the groundwater level in the well, the installation procedure was quite simple.

Two PEX loops of 1-inch nominal diameter pipe were installed. In addition, a single ¾-inch red PEX tube was also installed with the DHE to act as an access tube for well temperature monitoring and also to act as a convection promoter. To promote convection of hot water within the well, the ¾-inch PEX tube was perforated at its lower end and at the level of the water table.

*Figure 1. Photograph of removal of old black iron DHE.*

*Figure 2. Photograph of removal of old black iron DHE, showing heavy scale deposits and corrosion.*

*Figure 3. Photograph of double u-tube PEX DHE assembly prior to insertion into the well with dark (red) promoter pipe.*

*Figure 4. Photograph of the completed double u-tube PEX DHE.*

A photograph of the entire PEX DHE assembly prior to insertion into the well is shown in Figure 3. The final installation is shown in Figure 4. The entire installation process of the PEX DHE into the well was completed easily in less than an hour with three people.

***Performance Monitoring of The New PEX DHE and Operating Experiences***

Temperature sensors were installed at the inlet and outlet of the PEX DHE, and were connected to a data logger that was set to record temperatures at 15-minute intervals. Data have been recorded since October 29, 2006. Figure 5 shows the recorded temperatures for January 2007, the coldest month of the monitoring period, along with high and low ambient air temperatures for Klamath Falls, OR as recorded by the National Weather Service.

A review of the temperature data in Figure 5 shows that the DHE supply water temperatures to the houses are relatively stable on average. During cold days when the

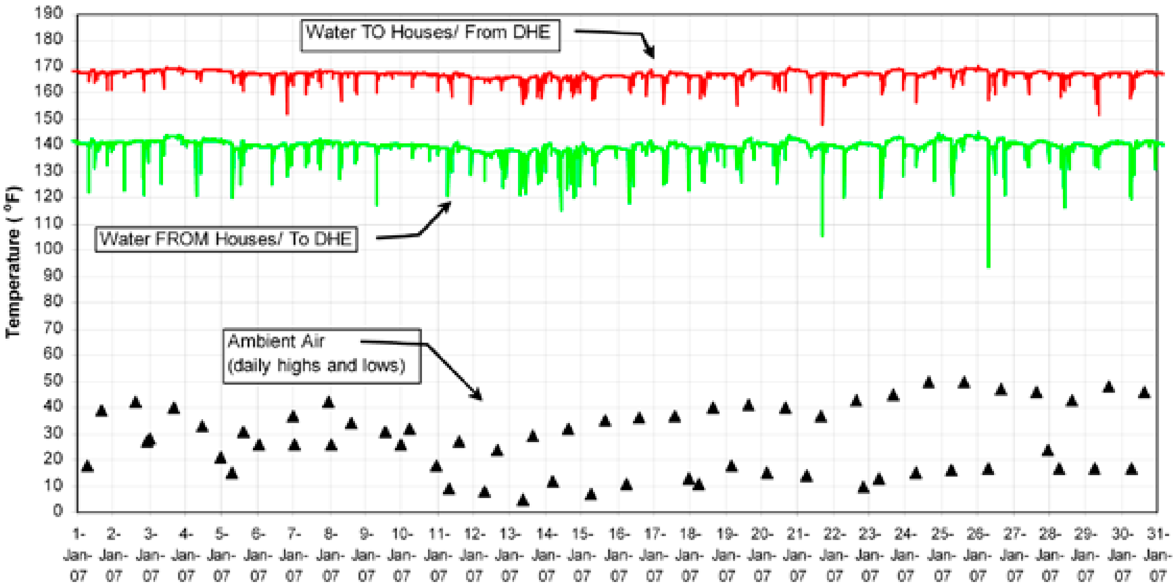


*Figure 5. Measured PEX DHE inlet and outlet temperatures (15-minute intervals) along with daily high and low air temperatures for Klamath Falls, OR*

outdoor air temperature dropped below 10˚F, the average DHE supply temperature was still above 160˚F. The temperature "spikes" are due to domestic water usage, as cold water from the city water main enters the DHE to be heated up. During the month of January, the lowest supply water temperature of 148˚F was recorded, which occurred during a time of heavy domestic water use. The temperature differential between the DHE supply and return is impressive, averaging about 30˚F throughout the study.

During very cold days, the occupants reported that the space temperature in one home drops to about 60˚F. The previous black iron DHE was also known to provide insufficient heat on cold days. This is actually surprising, given the adequately high supply water temperatures to the houses, and suggests other factors may be responsible for inadequate heat transfer to the home, such as insufficient length of baseboard radiant finned tubes. The homeowner installed more insulation in the attic space, which seemed to help maintain more comfortable space temperatures.

To estimate the useful heat extraction rate from the well during peak heating load, the combined heat losses from both homes (including basement heat losses) are estimated at 85,000 Btu/hr at an indoor-outdoor temperature differential of 52˚F (i.e. 72˚F-20˚F). Below about 20˚F outdoor air temperature, the indoor temperature reportedly begins to drop below 72˚F. With the observed DHE supply/return temperature differential of 30˚F, this means that the water in the DHE is thermosiphoning at 5 to 6 gpm.

## UPDATED ECONOMICS OF PEX DHEs

This project has shed more light on the economics of PEX DHEs, rendering the economics previously reported by Chiasson, et al., (2005) outdated. With more market competition due to increased demand for PEX, PEX costs have dramatically decreased in recent years, while metallic piping prices have dramatically increased. As a result, a new PEX DHE is less expensive than an equivalent black iron DHE. Nominal 1-inch PEX can now be purchased for about $1/ft, while the cost of 1½-inch black iron pipe is about $3/ft. Thus, for a double U-tube PEX DHE the cost is about $4/ft as compared to $6/ft for a black iron DHE. Further, as demonstrated with this project, PEX DHE installation can be done by the homeowner, while a black iron DHE needs to be installed with a crane truck and crew at a cost of about $125-$150/hr (in southern Oregon).

## CONCLUDING SUMMARY

This article has described installation and monitoring of the second known cross-linked polyethylene (PEX) plastic downhole heat exchanger (DHE) for direct-use heating in a geothermal well. The main differences between this installation described here and the first installation described by Chiasson et al. (2005), are that this second installation serves more than one home and provides domestic hot water in addition to space heating.

The main lessons learned with this second installation were that the PEX DHE can be installed by hand without the need of a crane truck, and that the DHE can be rested on the well bottom. The fact that the DHE can be placed on the well bottom is important because it eliminates tensile stress on the PEX potentially caused when the PEX is suspended in the well. Finally, this project has demonstrated PEX to be a cost-effective alternative to black iron DHEs.

## REFERENCES

Chiasson, A.D., G.G. Culver, D. Favata, and S. Keiffer, 2005. "Design, Installation, and Monitoring of a New Downhole Heat Exchanger". GRC Transactions, Vol. 29, Davis, CA.