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Comparative performance of 'U-tube' and 'coaxial' loop designs for use with a ground source heat pump

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ABSTRACT

The installation cost and coefficient of performance (COP) of a ground source heat pump (GSHP) system can be greatly affected by the design of its ground loop. An experimental investigation was conducted to compare the performance of two loop designs for use with the ground source heat pump of an 'energy pile' installation or a conventional borehole system. A coaxial loop (a 40 mm OD coaxial tube with a 20 mm OD interior pipe) and a U-tube (20 mm OD pipes) of a length of 72 m were constructed, tested and analysed in terms of ground heat extraction capability and hydraulic flow characteristics. The use of the coaxial loop design could potentially reduce the cost of drilling boreholes and make the installation easier on site, as the effective diameter would be smaller than a comparable U-tube with the same mass flow rate, considering that the U-tube requires a minimum 10 mm spacer between the legs. Hydraulic performance tests have shown that the U-tube achieved the transitional-turbulent flow at a glycol flow rate of approximately 0.14L/s, whereas the flow in the coaxial remained laminar across the glycol flow rate range of 0.05–0.25L/s. Heat pump performance tests have shown that the U-tube achieved a COP of at least 0.08 greater than the coaxial loop across the range of glycol flow rates investigated, while the heat output was at least 12% greater when using the U-tube. Therefore, it can be concluded that the coaxial loop in its current form is seen not to add any performance benefit against the U-tube.

1. Introduction

Following the Kyoto protocol in 1997 the UK pledged to reduce its CO_2 emissions by 12.5% compared to 1990 levels by 2012. Further from this the 2008 climate change bill has pledged that the UK will increase this cut to at least 80% by 2050 [1]. The energy required to heat, light and run various buildings amounts to nearly 50% of the total UK energy consumption and contributes to a similar percentage of the UK CO_2 emissions [2]. Ground source heat pumps (GSHPs) are an efficient method for supplying heat to many kinds of buildings and typically have seasonal efficiencies of between 350 and 400%. Great interest is therefore being given to GSHPs as they are now considered to be an effective way of reducing the primary energy demand of a building. A large volume of research has been performed to date with regards to GSHPs in areas such as whole system and loop modelling in addition to actual testing of installed systems [3–9]. Wood *et al.* [10,11] has shown that the use of foundation piles for new build residential buildings is particularly applicable to the incorporation of ground loops which act as ground heat exchangers.

The loop design has a direct impact upon the efficiency of a GSHP system, primarily for two reasons. Firstly if the pipe pressure (head) loss is too high for reasons such as a high fluid velocity and a small pipe diameter then the electrical energy input will rise. Secondly in terms of ground heat extraction, an increase in thermal resistance of a ground loop results in a lowering of the circulating fluid (glycol) temperature in order to extract the required ground heat. In this situation, the evaporating pressure would correspondingly reduce and the compressor would be required to perform more work to achieve the set condensing condition. The overall efficiency (Coefficient of performance (COP), which is the ratio of heat output and electrical energy input) of the GSHP system would therefore reduce and in turn the ground heat extraction per unit length of the ground loop would also fall.

Many researchers have investigated the effects of utilising different loop designs in terms of performance and efficiency [12–17]. The wide choice of pipe materials, differing lengths and borehole conditions mean that results tend to be specific to the experimental arrangement. However such tests are useful for further correlations against simulation models and optimisation of the GSHP system.

One of the earliest investigations into heat transfer by use of a foundation pile was by Morino *et al.* [12], where a steel pile was

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