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Innovative approach for heating of buildings using water from a flooded coal mine through an open loop based single shaft GSHP system

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Abstract

Geothermal energy, deep and shallow, has always been identified as an important renewable energy resource. The stable temperature and relatively low enthalpy of mine water contained in the abandoned and flooded coal mines have the potential to form a geothermal resource to be used in conjunction with heat pumps to provide heating and cooling for buildings. The usage of heat pump for space heating and cooling can be classified as a low carbon technology and if heat pump is powered by solar or wind energy it can be classified as a truly renewable technology. This paper presents a novel application of Ground Source Heat Pump (GSHP) for space heating and cooling using a flooded coal mine through an open loop based single shaft system. In this novel application, a single shaft is used for both extraction and injection of mine water for the heating application. This research work will report on the performance of the system and its long term potential in comparison to standard gas boilers heating systems. The usage of a single shaft system has been found effective in developing an efficient heating system with reduced cost and neutral environmental impact.

Keyword: GSHP, Open loop, Mine water, Heat Exchanger, Low Carbon Technology

1. Introduction

Coal mining was in the past century one of the major industries in the UK and Europe where it played a key role in the economy of the nation as well as the communities in towns and villages surrounding the mines. When the mines were in operation, to make it safe for the workers, the underground galleries were kept dry by pumping the water out to maintain a safe working environment for the miners. With the

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closure the coal mines, pumping of water ceased and water has started to rise to the ground water level and most abandoned workings are now filled with low enthalpy water. This low enthalpy resource does not have much use for direct practical thermal applications. However heat pumps can be used to upgrade the low enthalpy water resource into a high enthalpy resource and to be used for heating and cooling of buildings.

Previous studies have described the process of harnessing the low enthalpy energy from coal mine water and using it for space heating and cooling applications through an open loop system. Examples of the concept of mine water application of heating and cooling and examples of working systems have been given [1] and [2]. The district heating at Herleen, Netherlands based on mine water has been described in [3]. Further details on usage of mine water based heating system around the world have been mentioned in [4]. The feasibility of mine water heating systems in Canada and USA has been mentioned in [5]. The feasibility of mine water based heating system at Coal Mining Museum at Wakefield has been discussed in [6]. Performance of a mine water based heating system in Scotland has been described in [7]. Reference [8] presents the recent developments in geothermal energy and the use of mine water for heating and cooling. The feasibility of mine water in heating and cooling in Spain has been outlined in [9].
The application GSHP for mine water and optimising the performance of the system through reliable system design requires availability of high quality data. This paper describes the system, instrumentation and data monitoring of a mine water based GSHP pilot plant at Alkane Energy control centre in Markham.

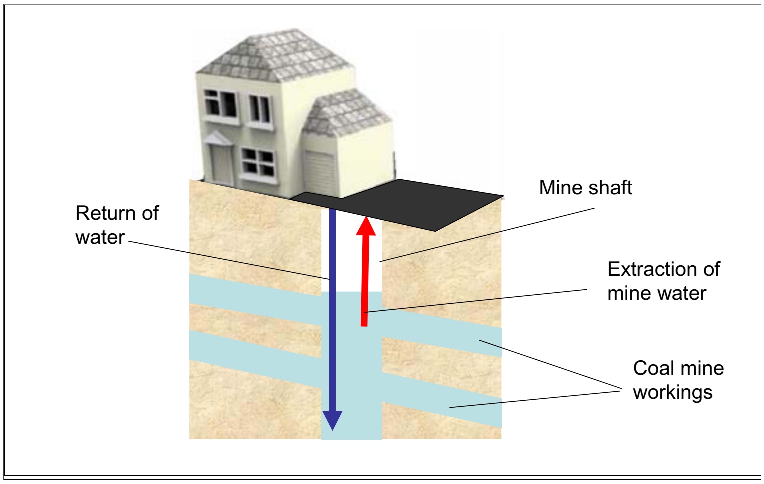

Figure 1: A schematic diagram of a single shaft coal mine GSHP system

2. Coal Mine Location

Markham Colliery was one of the largest collieries in UK and operated from 1905 until its closure in 1993. The underground galleries were accessed through four shafts present in the colliery complex. After the closure of the colliery three of the four shafts were filled, the No.3 shaft being left open to vent mine gas. This shaft was subsequently utilised by Alkane Energy to extract Coal Mine Methane (CMM) for the purpose of electricity generation. In 2006 the methane flow was cut off by the rising mine water sealing off the main roadway of inflow paths of methane to the shaft. Alkane Energy converted this site as their control centre and a maintenance depot, from where they could control all their operations across the various sites remotely. The water from the Markham Colliery shaft 3 is being used to heat all the office buildings of the Alkane Energy at Markham through a GSHP.

3. GSHP System

The GSHP system consist of a single 20 kW commercial Danfoss heat pump, counter flow shell and tube type heat exchanger, a 300 litre buffer tank, mesh filter and pipes connecting all the units. The borehole pump is installed in the mine shaft at a depth of 235 m below the ground level. The return hose of the borehole is at a depth of 250 m below the ground level. As a safety mechanism the methane in the mine shaft is monitored and would shut down the system if the methane level crosses a preset level.

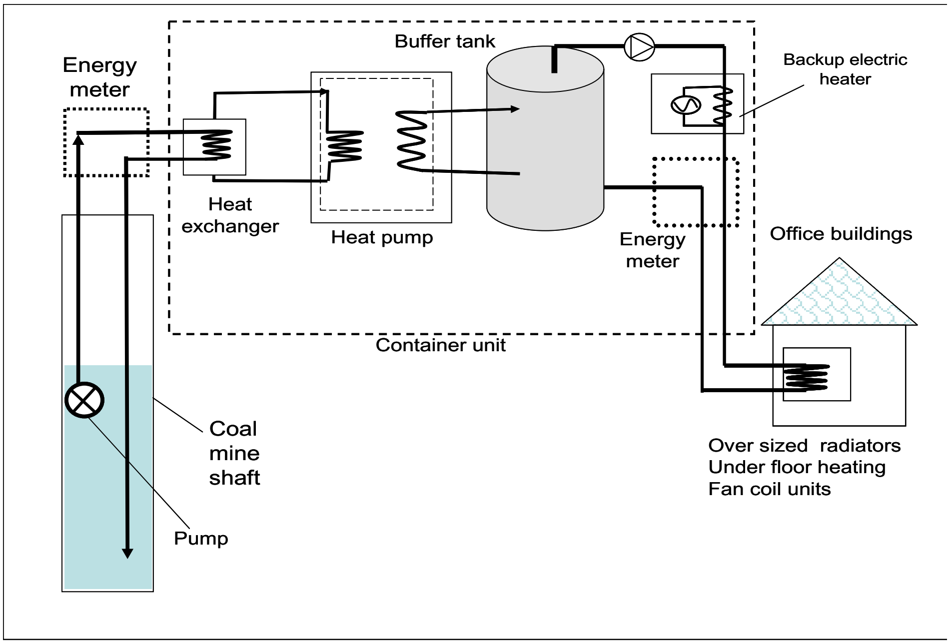

Figure 2: A simplified shematic system of the single shaft GSHP system at Markham, UK.

4. Instrumentation and Monitoring of the system.

The main parameters which need to be monitored are energy consumption and heat transfer rates between the mine water and the brine and these are determined by measuring the instantaneous fluid flow rate and out and return temperatures. Energy meters are installed to measure the electricity consumption of heat pump and mine pump. The SHARKY 775 heat meters are used to monitor the both the mine water and the heat pump output parameters. The heat meter measures the flow rate in m3/hr, ΔT of the water, instantaneous energy in kWh and cumulative energy in MWh. The SHARKY 775 consists of an integrated flow and temperature sensors and an integrator to calculate the energy based on the flow and temperature values. The entire monitoring system is coupled to telemetry and the data is continuously collected. Figure 3 presents some of the main parts of the instrumentation of the system.

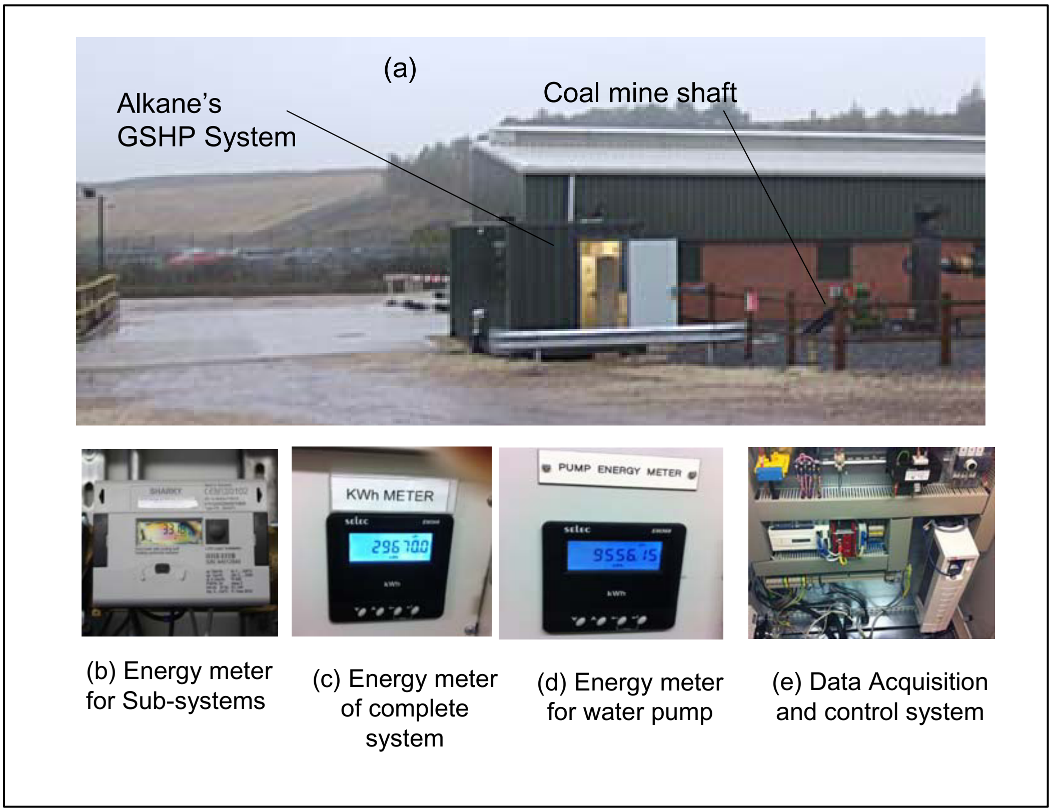

Figure 3: Alkane's GSHP system (a), the energy meter for the coal mine water (b), the energy meter for the complete system (c), the energy meter for the water pump (d) and the data acquisition and control system (e).

5. Performance parameters

The efficiency of the GSHP system is measured in terms of COP (Coefficient of Performance). It is the main parameter of interest. It is defined as the ratio of the energy extracted by the heat pump to the electrical energy consumed by the heat pump. The amount of the energy extracted and consumed by the heat pump mainly depends upon the heat transfers between the mine water and brine, brine and evaporator of the heat pump and between condenser of the heat pump and building heat fluid. Figure 4 shows the difference in temperature between the extraction and return line of the mine water taken through using infrared thermography. COP of heat pump is the ratio between the energy produced and energy consumed by the system. The heat pump is the component in the system that extracts the energy from the coal mine water via heat exchangers, see Figure 2. The main components that consume electricity are the heat pump to power the circulation pumps and the compressor, in addition to the water pumps that pump the water from the coal mine and the circulate the water to the building. The consumption of the heat pump will depend on it design and the efficiency which is based on the input and output level of temperatures. The second aspect is the depth of the water in the coal mine and water flow rate since significant energy will be consumed to pump the water to ground level. Based on the system in consideration and its variables.

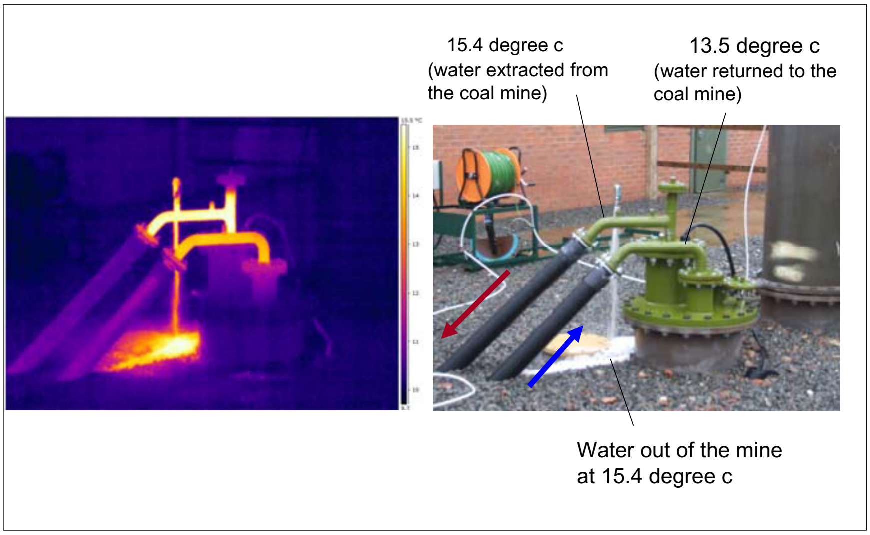

Figure 4: Infrared image of the extraction and return lines (left) and the corresponding visual image (right)

Figure 5 presents the relationship between the depth of water in Markham and its relationship with the COP values. At the depth of 120 meters, the COP value is about 2.7. This means for every 1KWh consumed by the system, 2.7 KWh is produced. The difference in energy is the energy extracted from the water in the mine. The water will sustain regulated temperature due to the geothermal energy and the significant volume of water in the coal mine. Due to the rising water level in the shaft, the COP is expected to reach a value of approximately of 3.95 at a depth of 15 meters. Figure 6 presents the relationship between the flow rate of coal mine water at depth of 235m and the COP of the system at different target output temperatures. It is evident that the increase in the flow rate will reduce the COP of the system for a given heating demand since no further energy will be extracted from the coal mine water. Also the increase in the target temperature will reduce the COP since the increase in temperature will increase the work needed by the heat pump to transfer the heat to a higher energy level.

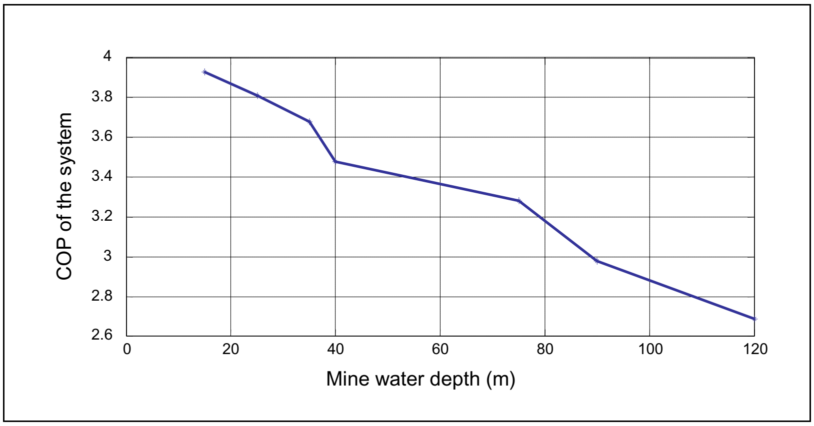

Figure 5: The relationship between the depth of water in the coal mine and COP of the system.

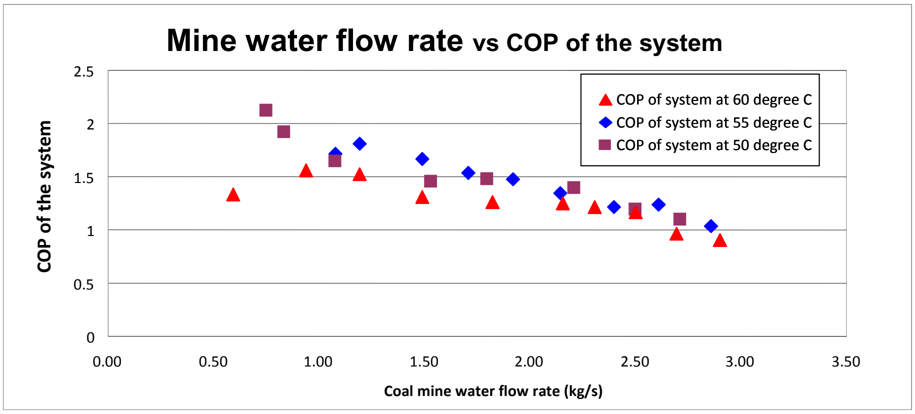

Figure 6: The relationship between mine water flow rate and COP of the system at different output temperatures (at water depth of 235m).

6. Conclusions

This paper has highlighted a novel application of for heating of buildings using water from a flooded coal mine through an open loop based single shaft GSHP system. It has been found that the COP of the system will depend on, *inter alia*, the depth of water in the coal mine, the flow rate of the water for a given heating capacity, and the target output temperature of the system. In comparison to a gas heater, the GSHP systems are much more efficient and produce much less carbon emission and consumes much less energy from the same heating demand. For example when compared with a modern boiler with 90% efficiency, the GSHP will produce 300% and 433% more energy for the same consumed energy for system COP of 2.7 and 3.9 respectively.

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Biography

Professor Amin Al-Habaibeh is a professor of Intelligent Engineering Systems within the Product Design team at Nottingham Trent University. He is currently leading the Innovative and Sustainable Built Environment Technologies research group (iSBET). Amin’s interest also includes condition monitoring, intelligent systems, sustainable technologies, product design and advanced manufacturing technologies.