Environment Protection Engineering

Vol. 38 2012 No. 2

DOI: 10.5277/epe120213

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ECOLOGICAL HEATING SYSTEM OF A SCHOOL BUILDING. DESIGN, IMPLEMENTATION AND OPERATION

The concept, construction and analysis of a hybrid heating system have been presented for a school building in Wielka Wieś near Wojnicz, district of Tarnów. Because of technical wear of old existing heating system and increasing energy costs it was decided to complete its modernization. In consultation with the ENION energy company in Tarnów, a complex analysis of the possibility and advisability of the use of heat pumps for heating purposes has been made. Favourable environmental conditions in the vicinity of the premises such as available land and shallow ground water reservoir is located, were decisive in the fundamental way of the economic support of the proposed project.

1. DESCRIPTION OF THE OBJECT BEFORE MODERNIZATION

The Primary School and Middle School in Wielka Wieś is located in the valley of Dunajec on clay soils. The area has several acres next to the building as possible to install a gas manifold, and in addition, these sites have rich deposits of shallow ground water.

Fig. 1. Building of the primary school in Wielka Wieś [2]

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School building (Fig. 1) was built in traditional technology before 1987. Its surface area is approximately 1107 m^2 and capacity of 3538 m^3. In order to reduce heat losses, old windows were replaced with new ones before modernization of the heat source and central heating system [1, 2].

The building is located in the 3rd climate zone. The demand for thermal power amounts 105.4 kW. The boiler room was equipped with a gas boiler with the capacity of 145 kW (for lack of data, its efficiency was assumed at 80%) and in an unused old coal boiler (Fig. 2). Central heating was made in an open system of steel pipes, corroded, requiring replacement. Heat was transferred through cast iron radiators equipped with faulty valves. The internal installation was designed to the power of ca. 105 kW and heating water parameters of 90/70 °C.

Fig. 2. Boiler room in school;
Jubam gas boiler and an old coal boiler [1]

The wells drilling showed the presence of groundwater resources with the parameters relevant to the needs of the planned installation. As a peak source remained the existing gas boiler water.

The analysis based on real data confirmed the return on investment for customers by reducing costs and the optimum selection system, which after the first year of operation delivered 87% of the heat required to heat the building. It should be stressed that the current demand for heating power is 105 kW, while the heat pump heating output only 32 kW, provides 30.5% of demand. This choice of heating system and pump power proved to be suitable both in terms of technical and economic feasibility, and investment for the recipient, the Office for the District, which finances energy management utilities.

2. ASSUMPTIONS FOR THE TECHNICAL-ECONOMIC ANALYSIS

The basis for the analysis was the invoice for the gas received from the Office for the District. The estimated annual energy demand was ca. 500 GJ/year. Due to the nature of the project, it was assumed that the heat pump will not be able to cover peak power demand, but will be the basis with the power of ca. 30 kW and annual production of approximately 255 GJ/year. This is to ensure continuous operation of the device in the heating season and at the same time to maximize the power of the device. For the municipal office is expected to deliver a cheaper supply of heat energy, and for ENION SA Tarnów permanent warm reception [2, 4].

Horizontal ground collector is a polyethylene tube, inside which circulates antifreeze fluid (usually aqueous solution of polyethylene glycol), transporting heat. Polyethylene jacket eliminates the possibility of corrosion. The collector is arranged in the ground below the freezing zone. Surface alignment of the collector should be around 1.2–2 times greater than the surface of the heated building. Vertical ground collector is usually made as a heat exchanger in the U-shaped tubes filled with polypropylene freeze fluid, and placed in vertical wells 15–100 m deep. The average distance between wells is about 7 m. Water extracted by means of deep wells is the most preferred lower heat source for heat pumps, because it guarantees a high heat capacity throughout the year. Water after cooling by 4 °C in the heat pump will be discharged to absorbing well. More often as a lower heat source air is used. However, it can be a source of heat in the temperature range from –15 °C to 25 °C, thus it is mostly used in the bivalent heating systems, consisting of primary sources (heat pump) and peak (eg. gas boiler).

It was assumed that the lower heat source would be a flat plate collector placed in the field adjacent to the school. Finally, as a lower heat source was proposed and realized vertical collector using groundwater. By using such a collector improving heat pump efficiency was expected and making investment cost lower than those of the ground exchanger [2, 5].

3. GEOLOGICAL ANALYSIS

The next stage of operation was to order the execution of the project (NOT Tarnów) of geological wells and aquifers to determine the resources (June 2003. *Design work on the implementation of hydrogeological wells drilled in the Quaternary to the collection for heating purposes in Great Village on the plot No. 683* was made in June 2004. The deposits of groundwater were estimated to be more efficient than 10 m^3/h, while ca. 6 m^3/h was needed. For the safety of investments, it was foreseen in the project execution of 4 deep wells (2 production wells and 2 injection wells) [5].

4. IMPLEMENTATION AND TESTING OF PRODUCTION WELLS

Promising assessment of the draft was the basis for drilling a production well (June 2004). Drill spoil was rinsed with pressurized water from the hole causing a diversion of material to the surface.

The drilling confirmed that the geological strata situated in the draft, that is impermeable layer rich in clay, reached the depth of ca. 8 m below the surface, followed by 3.5 m in the aquifer containing coarse gravel with a high performance filtration of about 25 m/day and a layer of impermeable clay beginning at 12 m below the surface.

Then the pumping test was performed – for 24 h pumping water with the yield of 10 m^3/h caused a decrease in water level from 0.6 m below the surface by about 2.5 m. The study confirmed the efficiency of the actual deposit of the design data [2].

Table 1

Bacteriological indicators [2]

Parameter	Test result	Highest permissible value for human consumption
The number of colony-forming bacteria in 1 ml of water at 37 °C after 24 h	122	20
Total coliforms in 100 cm^3 of water	above 300	0
The number of thermotolerant coliforms and *E. coli* suspected in 100 cm^3 water	0	0

Table 2

Indicators of physical, chemical and organoleptic features [2, 5]

Parameter	Test result	
Turbidity	5.3	mg/dm^3 SiO_2
Colour	3.0	mg/dm^3 Pt
Smell	g1R	–
Reaction pH	7.4	–
Iron	0.73	mg/dm^3
Ammonia	0.5+/–0.059	
Nitrites as nitric oxide	0.005	
Nitrates as nitric oxide	4.39	
Manganese	0.291	
Sulfur	1967	
Free chlorine	below the detection limit	
Conductivity[a]	887	$\mu S\cdot cm^{-1}$

Related to the temperature of 20 °C with temperature measured 20.6 °C

In order to examine the composition of water in terms of mineral content, water sample retrieved from the reservoir was commissioned to study 29 Jun 2004 in the County Sanitary-Epidemiological Station in Tarnów. Tests were conducted in the period from 29 June to 8 July 2004. The results are shown in Tables 1 and 2. The study showed a high content of iron, but did not exclude the application of heat pumps.

5. IMPLEMENTATION AND TESTING OF INJECTION WELLS

Well damping was performed on 22.12.2004 by "Hydrodol". The technology used by this company is drilling the well's dry. This ensures that there is in this case, the leaching of ore under pressure, which can cause additional erosion of walls of the hole and the porous soil adhesion to the pipe above the filter. The profile found during drilling was very beneficial, because the level of about 8.3 m below the surface was impermeable layer of dust and clay, followed by about 3.5 m layer of gravels and sands, and clay beginning from 12.8 m below the impermeable layer. Aquifer started 9.25 m below the surface and remained stable at this level. The resulting profile of the layers turned out to be very promising for use as a discharge of water from the heat pump. In order to confirm the assumptions, 24-hour pumping test were made (by using fire hoses), which confirmed execution of the absorption bed and tightness. The study was conducted at constant inspection of the drilling company representative [5, 6].

6. SELECTION OF HEAT PUMP SUPPLIERS

Selection of heat pump suppliers required the announcement and completion of the tender procedures. The tender was won by the Ochsner Heat Pump, the value of the works and equipment amounted to 48 838 ZLP. Assembly work included involvement in the heating system, installation of a buffer with the capacity of 1 m^3, heat pumps, heat meter on the output of the PC, submersible pump, the main electricity distribution and the relevant RCD and overcurrent protection, and making connections with the water pipes stacked wells. Eventually heat pump OCHSNER Golf Maxi GMWW 38 was mounted (Figs. 3–5) [6].

7. START-UP PERIOD AND INITIAL RESULTS

The final stage was the final acceptance of work connected with the training of people who will deal with the operation of the heat pump (05.01.2005) [2].

Preliminary measurements of the parameters of the device gave [4],

- water temperature in the flow of production well 11°C,
- decrease of water temperature after flow through the heat exchanger in the HP 3.5°C,
- temperature at the exit from the HP and power supply to the buffer 51.5 °C,

- temperature at the entrance to the HP and the return of the buffer, 42 °C,
- efficiency of the whole heating system with heat pump (with a circulating pump and submersible) ca. 3.0.

Fig. 3. Heat pump with no external casing
OCHSNER Golf Maxi GMWW 38 [1]

Fig. 4. Assembled heating system, heat pump, buffer tank,
electricity distribution, water installation [1, 6]

Preliminary analysis indicated the technical parameters of the heat pump system. Intermittent increased heat demand is covered by switching on the gas boiler, working in parallel with the heat pump.

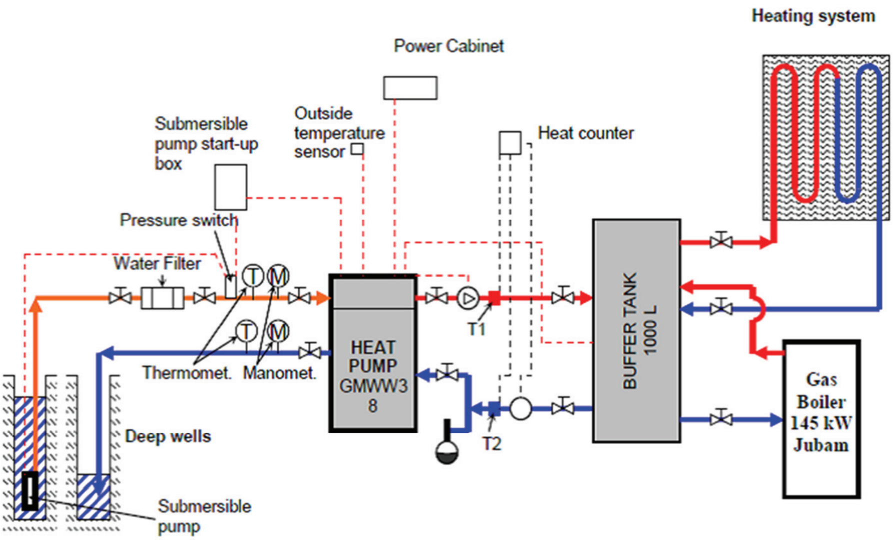

Fig. 5. Scheme of the heating system [2]

8. OPERATION OF THE HEATING SYSTEM

The technical-economic project assumed heat consumption from the heat pump at the level of 255 GJ/year and the unit price 37 ZLP/GJ Gross. The average working time during the heating season was approximately 10 h/day. Return of investment costs was predicted after nine years of operation [1].

Currently, heat production is carried out continuously for 24 h a day (in the winter months, typically). Energy production from 3 January 2005 to 2 January 2006, amounted to 458 GJ. Based on these data, it can be expected that with the heat production of 460 GJ/year, the payback period will reduce to less than 7 years [2, 5].

The main objective of installing a heat pump was to reduce heating costs. The results of calculations show the extent to which this has been achieved in 2005 and 2009 (Figs. 6–10) [3]. In the year preceding the installation of heat pumps, gas consumption by the school was at the level of 20 893 m^3/year, of which about 1440 m^3/year were used for the preparation of meals, while the remaining 19 453 m^3/year served to produce heat. Amount of heat produced was 500 GJ/year. Due to such a high consumption, it has been changed to the tariff W4. Taking into account changes of gas tariffs, , the cost of gas for heating purposes in 2005 would be 17 990 ZLP/year.

After mounting the heat pump, gas consumption decreased to around 4200 m^3/year, with the gas furnace of ca. 2320 m^3/year. However, total heat production for the facility amounts to approximately 522 GJ/year. Due to a significant decrease in consumption, the object should be accounted for in the tariff W3. The cost of gas for heating will be in this case approximately 2541 ZLP/year. After adding up the cost of gas for the manufacture of heat in the gas furnace and heat cost of the heat pump, the total cost is 16 340 ZLP/year. The result is a decrease in costs for the purposes of central heating, which is approximately 9.2% [1]. Increasing economic effect is caused mainly by an increase in gas prices (reference costs) and in addition, in the tariff change (W3 for W4), where the share of fixed costs is much smaller.

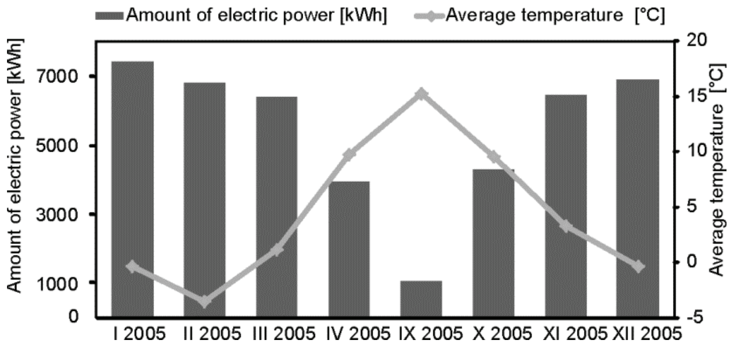

Fig. 6. Expenditure of electric power in heating months (2005) for the heat pump [1, 2]

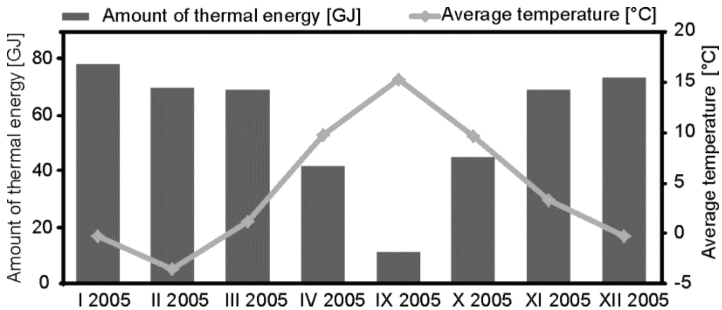

Fig. 7. Production of thermal energy in heating months of 2005 by HP [1, 2]

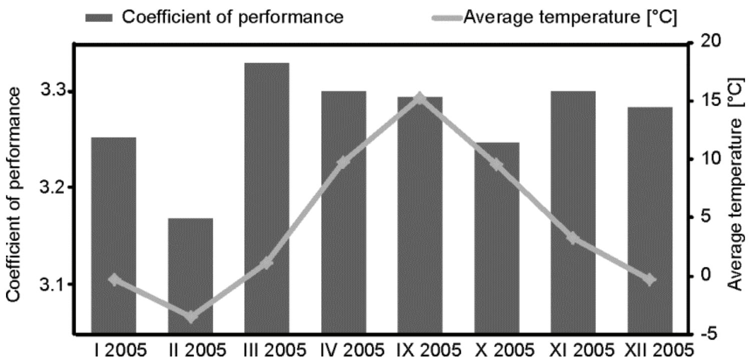

Fig. 8. COP of heat pump in heating months of 2005 [1, 2]

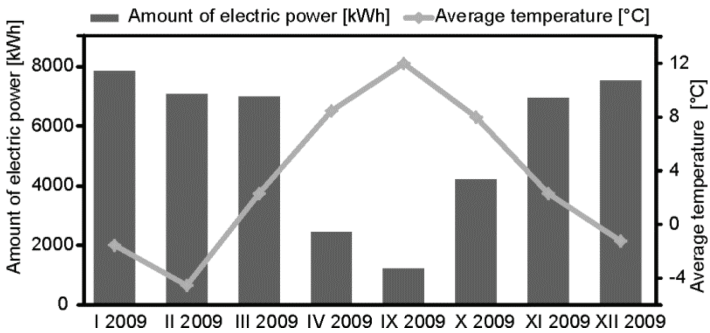

Fig. 9. Electricity consumption by HP in heating months of 2009 [1, 2]

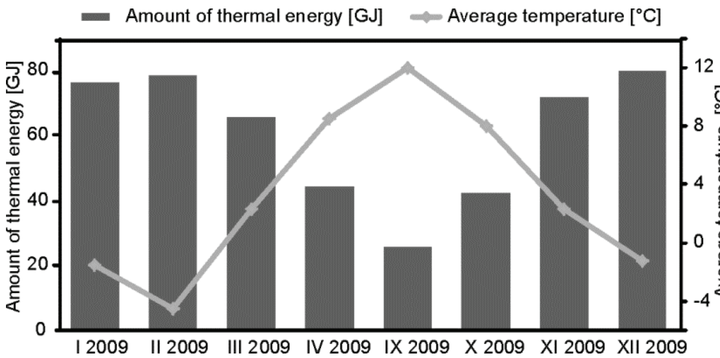

Fig. 10. Heat production by HP in heating months of 2009 [1, 2]

9. CONCLUSIONS

The analysis based on real data confirmed the return on investment for customers by reducing costs and optimum selection of the device that after the first year of work produced as many as 87% of the heat needed to heat the building.

It should be noted that the demand for power facility is calculated to 105 kW, while the pump has the heat output of only 32 kW, which represents 30.5% of the demand. It turns out that such selection proved to be optimum in terms of investment for the owner of a heat pump – ENION Tarnó SA Energy Company, as well as economical for the customer – the Office for the District.

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