

The idea of utilising old production wells for borehole heat exchangers in the near depleted oil field in Iwonicz Zdrój Poland

Tomasz Śliwa and Andrzej Gonet
Drilling, Oil and Gas Faculty
University of Mining and Metallurgy
Cracow, Poland
E-mail: sliwa@uci.agh.edu.pl

Abstract

In geothermal developments the highest cost is connected with drilling. Old production oil or gas wells can be used for geothermal heat exploitation. One of the possibilities is running the wells as borehole heat exchanger (BHE). At present the number of wells in Poland appropriated for liquidation is about 3 thousand. This report presents the idea of a pilot project utilising oil wells as BHE. The Iwonicz Zdrój oil Field is located in a spa resort in the Carpathians (S-Poland). It was discovered in 1890 and at present the resources of oil and gas are nearly depleted (97,5% of the gas and 97,7% of the oil are exploited). Two wells, located in the Iwonicz Zdrój oil field, are close to a large heat consumer. These wells, which are both appropriated for liquidation were thoroughly analysed as BHE. The analysis includes technical-economical aspects of adapting the wells for BHE and to exploit the heat. The paper includes the conclusion of the analysis and presents the idea of optimal BHE exploitation parameters and utilisation of the heat. The analysis of the cost of well adaptation, including heat pump and surface pipelines, shows that it can be lower than the cost of well liquidation. After that, the contractor takes profits connected with heat generation. The verification of results will be possible only by building a pilot installation. There is much to be said about the development of the pilot BHE installation in Iwonicz Zdrój. First of all it is the ecological aspect (Iwonicz Zdrój is a spa) and a high number of wells in the oil field, which will be closed very soon.

Keywords: borehole heat exchangers (BHE), heat pumps, oil wells appropriated for liquidation, geothermal heating.

1 Introduction

On 15 January 2003, the Polish Oil and Gas Company inaugurated the Ignacy Łukasiewicz Year, thus celebrating the 150th anniversary of lighting the first oil lamp. This innovation by I. Łukasiewicz was a milestone in the development of the world civilisation.

Oil has been known for thousands of years all over the world, e.g. in the Middle East it was used for construction works, conservation of timber and sealing of boats. Some 2.500 years ago the Persians used oil in medicine. In the 13th century Marco Polo reported on oil seepages in the area of the Caspian Sea.

In Poland, natural oil exhalations along the northern edge of the Carpathians were known and described in 13th century documents. Many centuries elapsed and in 1853 the Carpathian oil was first used for lightening a hospital and streets. Since that time a big scale industrial oil production started. In 1854 Ignacy Łukasiewicz organized the first in the world's history crude oil mine. Then there was established the first oil company, where crude oil was exploited, processed and sold.

The end of the 19th and the beginning of the 20th century was a period of an "oil rush" in the S-E Poland. Potential profits from oil discovery and its utilization, gave

spur to big scale drilling works. The need for oil in the world's economy and industry started to grow rapidly. Oil prospecting at greater depths, and perfection of drilling tools and methods were a consequence of this situation. A number of oil production wells were drilled and intensive prospecting and drilling works were carried out in the Galicia region. As a result, rich oil deposits were discovered.

By March 1896, 210 boreholes and wells had been drilled or dug in the whole Galicia area. At the end of the 19th century 156 oil mines and companies operated.

The first oil intake in the world oil is still in operation and is one of the main attractions of the oil industry museum in Bóbrka, near Krosno (Fig. 1).



Figure 1: Location of Krosno and Iwonicz Zdrój towns on the map of Poland.

At the end of last century, oil exploitation in this region declined rapidly. Consequently the Polish Oil and Gas Company started systematically in 1991 to close down the oil production wells. This was prompted by legal regulations. Over 100 wells are closed down each year. The total number of decommissioned wells in the successive years is given in Figure 2.

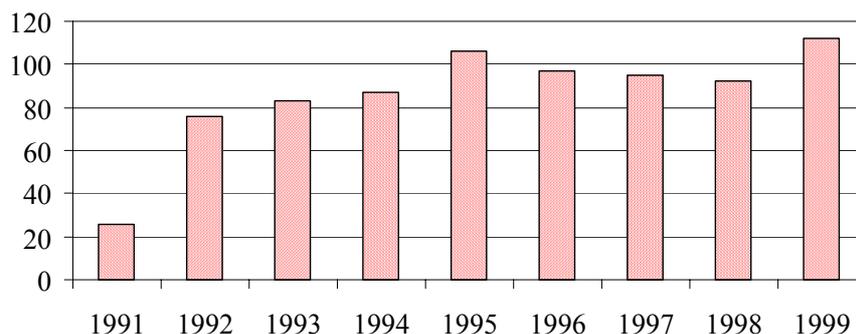


Figure 2: Number of wells closed down by the Polish Oil and Gas Company, Section in Krosno during the years 1991 to 1999 (Liput and Szmyd, 2000).

The number of all wells appropriated for liquidation is about 3000 in Poland (Macuda et al., 2001). Most of them belong to the first in the world oil basin in the Carpathians.

Drilling works are the most costly element of geothermal activities. Some kind of utilization of the existing oil wells may significantly reduce the cost, especially as funds are necessary for closing the wells down. According to Śliwa (2002), the cost of decommissioning may exceed the cost of adapting the wells for heat exploitation purposes (surface heat exchange and reception systems including).

What speaks for the geothermal use of wells is the fact that a number of wells are sited in densely populated areas. Deposits and wells are often sited within towns, near developed areas, making the use of surface installations for heat management unnecessary.

Old, exploited wells can be used for geothermal heat production. This can be realized in a variety of ways. The most favourable solution lies in geothermal waters exploitation or injection. In the case of deposit hydration, water can be exploited with oil and/or gas. After separating hydrocarbons on the surface, heat can be recovered from the reservoir water. Such water can be injected on the deposit contours, thus increasing reservoir pressure. Another way in which the wells can be used (Śliwa et al., 2000) is for borehole heat exchangers (BHE).

1 Profits from adaptation of wells for BHE in Iwonicz Zdrój

Iwonicz Zdrój is one of the fields with depleting oil and gas resources. It was discovered in 1890. By the year 2000 about 97.5% of the gas and 97.74% of the oil reserves were exploited in 41 wells from intervals at a depth of 150 to 950 m (Wałęcki, 2000).

The Polish Oil and Gas Company, Section of Mining Works in Krosno selected two wells in the Iwonicz Zdrój Mine for technical-economic analysis. The wells are to be decommissioned due to uneconomic exploitation of hydrocarbons. The wells selected are wells Elin 3 and Elin 10. The following selection criteria were considered:

- 1) Relatively short distance from wells to a big heat consumer receiver (Excelsior Sanatorium complex belonging to the Iwonicz Resort Company). The length of earth works related with surface pipe-lines sum up to about 600 m.
- 2) Variety of heating systems in the Excelsior Sanatorium. The most favourable elements of the heating system are those which employ low-temperature heat and which are used all year long. The peak heat demand for such a customer's

Excelsior Sanatorium in Iwonicz Zdrój is presented in Table 1.

Table 1: Heating power of heat receivers in the Excelsior Sanatorium.

Heat consumer	Installed peak heating power, kW
Warm tap water	495
Warm mineral water	150
Healing mud heating	42

- 3) Length of heating season. It follows from the analysis of average monthly temperatures across the years that the heating season in Iwonicz Zdrój is longer than in other parts of Poland. In the years from 1981 to 1990 the average winter time duration, with average daily temperatures below 0°C was 90 days, whereas for average summer time duration, with average daily temperatures above 15°C, was only 78 days.
- 4) Resort-recreation character of Iwonicz Zdrój, which additionally speaks for the use of clean methods for energy production by adaptation and adding of a greater number of wells to the system.

2 Selected technical parameters of BHE

At present the wells Elin 3 and Elin 10 are pumped. The surface equipments consists of wellheads with a gland and a pump stick, whereas the downhole equipments consist of pump pipes, downhole pumps and pump rods.

Partial closing down of the well Elin 3, which can be adapted for BHE, lies in injecting bentonite mud to the well, making cement plugs at a depth of 586 to 550 m and 510 to 470 m with the use of a special cement slurry, making tightness tests and cleaning the walls of the well. Similar works should be made in well Elin 10. However, the top of the last cement plug should be at 590 m of depth.

Thermal properties of rocks in the well Elin 10 are presented in Table 2.

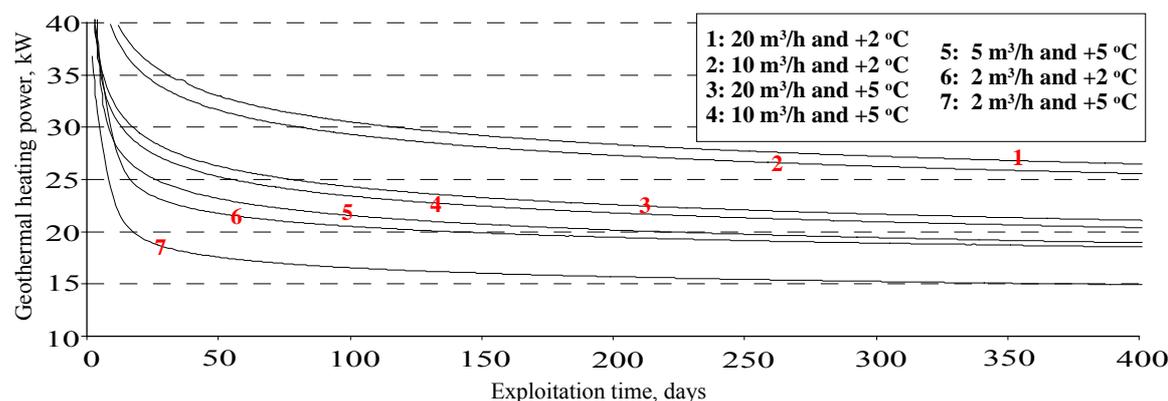
Table 2: Thermal properties of rocks from well Elin 10, (Plewa, 1994).

	Interval	Lithology	Thermal conductivity	Specific heat	Density
	m		$W \cdot m^{-1} \cdot K^{-1}$	$J \cdot kg^{-1} \cdot K^{-1}$	$kg \cdot m^{-3}$
1	0–115	I Ciężkowice sandstone	2.60	921.5	2430
2	115–139	II spotted shales	2.04	844.6	2550
3	139–282	II Ciężkowice sandstones	2.60	921.5	2430
4	282–341	III spotted shales	2.04	844.6	2550
5	341–415	III Ciężkowice sandstones	2.60	921.5	2430
6	415–455	IV spotted shales	2.04	844.6	2550
7	455–860	IV Ciężkowice sandstone	2.60	921.5	2430
Weighed average			2.52	910.5	2447

A complex technical-economic analysis of the well adaptation to borehole heat exchangers was made for the two wells (to be closed down) in the Iwonicz Zdrój field. A numerical analysis of the exploitation of such a BHE with different exploitation parameters was also carried out. The results of the analysis for these two wells are compared in Table 3. A dependence of potential heat power from BHE in well Elin 10 is presented in Figure 3.

Table 3: BHE exploitation parameters for wells Elin 3 and Elin 10 in Iwonicz Zdrój.

Well	Depth, m	Inner diameter of well, mm	Volume of heat carrier, m ³ /h	Temperature of heat carrier, °C		Duration of exploitation, years	Obtained heating power, kW
				Input	output		
Elin 3	470	118	10	2	3.48	3	18.02
Elin 3	470	118	10	2	3.62	1	19.76
Elin 10	590	185	2	2	10.00	1	18.66
Elin 10	590	185	10	2	4.21	1	22.58

**Figure 3: Calculated heating power output during BHE exploitation of well Elin 10 as a function of exploitation time (to 590 m depth, but for different volumes of heat carriers and injection temperatures).**

3 Heat carrier system

It follows from the economic analysis that the most significant parameters influencing the profitability of the BHE investment are: 1) distance from the well to the customer, 2) cost of the materials, and 3) the characteristics of the heating system. In the most advantageous situation, the heat source (in its low-temperature form) should be used as long as possible during a year. Thanks to this, cheap energy use can be increased and high efficiency heat pumps applied.

Therefore, tap water in the Excelsior Sanatorium should receive geothermal energy produced by heat exchangers in Iwonicz Zdrój. Due to the high daily demand for warm water it is possible to fully use the BHE heating power. Distribution of heat in time by the use of containers with stored warm water will enable daily and yearly use of that source of heat.

In surface instalments (Fig. 4), cut-off valves (1) will be used. Their task is to prevent back flow of the heat carrier. The separator (2) will catch oil-products left out after cleaning operations. The circulation pump (7) is to force heat carrier circulation in BHE and heat pump (11). A shunt (4) should be used. Heat carrier will be prepared in the container (14), whereas the pressure container (20) will assume the role of an equilibrium container with a pump (18). The use of useful water heating system and full utilization of heat requires the use of a container for warm useful water (22) and additional circulation pump (30).

Moreover, return valves (3, 17, 28, 29), cut-off valves (5, 8, 10, 19, 21, 25, 27, 31), safety valve (12), air (9, 24) and mud (15) removers, temperature sensors (6, 23), manometer (13), pressure gauge (16) and energy meter (26) should be used.

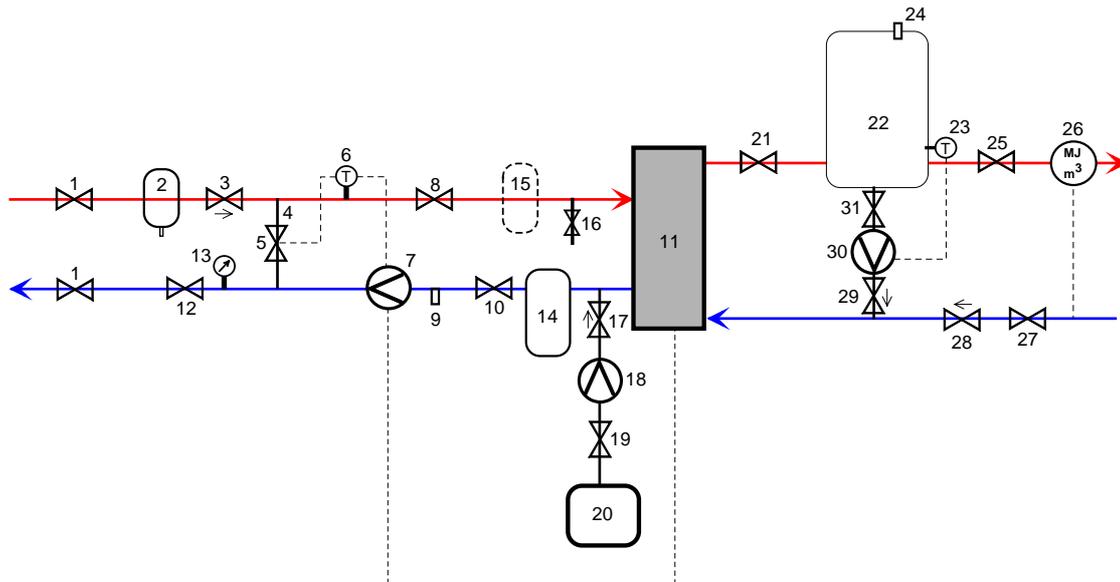


Figure 4: Scheme of a heat carrier circulation system in Excelsior Sanatorium.

The circulation of the heat carrier within BHE is similar to the reverse drilling mud circulation. The heat carrier will run down the angular space, collecting heat from the rock mass and returning to the surface through the inner column made of thermally resistive materials. The wells should be equipped with special circulation wellheads on the surface.

4 Conclusions

- Old, oil and gas production wells, drilled in the Carpathians should have been analyzed some 100 years ago for technical and economic qualities in view of their adaptation for geothermal purposes.
- It follows from the analysis of cost of BHE adaptation of wells Elin 3 and Elin 10 that such costs in Poland can be lower than the costs of closing down.
- The results of the analyses should be verified by a pilot research instalment.
- The pilot instalment of borehole heat exchangers in old oil wells should be made in Iwonicz Zdrój. The arguments for that are as follows:
 - small distance from wells Elin 3 and Elin 10 to a big consumer of heat,
 - characteristic of this heat consumer enable a variety of heat uses throughout the year, the main use being heating of tap water,
 - existence of several more wells which in the future can be used in the heat reception systems,
 - ecology aspects, owing to the spa character of the town.
- The method presented in this paper and the examples of result of the calculations show that it is profitable to convert old oil wells into BHE.

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5 References

- Liput, A. and Szmyd, P. (2000). *The Borehole Liquidation Issues on The Polish Oil and Gas Company, Section of Mining Works in Krosno Sites*, Report for the 1st Technical Science Conference "The reconstruction and liquidation of oil and gas boreholes in Carpathians and Przedgórze", Rudawka Rymanowska-Bóbrka (in polish). 16 pp.
- Macuda, J., Nagy, S., Siemek, J. and Zawisza, L. (2001). *The Geothermal Utilization of the Boreholes Intended for Liquidation*. Report for the conference "The renewable energy sources at the XXI century threshold", Warsaw (in polish). 7 pp.
- Plewa, S. (1994). *The Disposition of Geothermal Parameters on Area of Poland*. Minerals and Energy Economy Research Centre of the Polish Academy of Sciences Publishing, Cracow (in polish). 138 pp.
- Śliwa, T. (2002). *The Technical and Economic Issues of Exploited Wells Adaptation for Borehole Heat Exchangers*. Doctorate thesis, Drilling, Oil and Gas Faculty, University of Mining and Metallurgy, Cracow (in Polish). 132 pp.
- Śliwa, T., Gonet, A., Munia, J., Koziół, W. and Pająk, L. (2000). *The New Direction in Utilization of Wells Intended for Liquidation*, Report for the 1st Technical Science Conference "The reconstruction and liquidation of oil and gas boreholes in Carpathians and Przedgórze", Rudawka Rymanowska-Bóbrka (in polish). 14 pp.
- Wałęcki, I. (2000). *Geological and Exploitational Characteristics of Oil and Gas Deposits Exploited by The Polish Oil and Gas Company, Section of Mining Works in Krosno*. Report for the 1st Technical Science Conference "The reconstruction and liquidation of oil and gas boreholes in Carpathians and Przedgórze", Rudawka Rymanowska-Bóbrka (in polish). 15 pp.