The wells of the Lipinki oil field in the aspect of borehole heat exchangers retrained

***Tomasz Śliwa*[1], *Andrzej Gonet* and *Andrzej Grasela*[2]**

Využitie vrtov ropného ložiska Lipinki pre výmenníky tepla

Geological conditions of the Gorlice-Lipinki structure are presented in the paper. The construction of a well in the Lipinki oil field was characterized on this basis. The authors analysed an adaptability of the wells intothe borehole heat exchangers (BHE) with its potential heating power estimation on the basis of an example. In the article, a discussion of the heat consumer choose, which can be buildings by a local communite utilization.

***Key words**: Borehole heat exchangers, geothermal energy, abandoned wells*

Introduction

Each year the exploitation of a number of wells in Poland becomes inefficient because of the depletion ofoil or natural gas fields. Such wells are designed for closing, which requires some financial means. Such wells, however, can be used for other purposes (Gonet et al., 2005). The solution proposed in this paper lies in extending the life of some wells by adapting them to the borehole heat exchangers (BHE). The solution lies in a partial closing of the existing wells and disposing of a special system enabling the circulation of a heat carrier and the exchange of energy with the rock mass (Śliwa, Gonet, 2004).

Adaptations should be made in wells situated close to the heat consumers, which has an economic justification. Besides, a clean thermal energy can be recuperated with heat pumps from the rock mass. One of the depleted fields is the oil field in Lipinki discovered in 1860. There are 271 operational wells, 16 are designated for closing (Wałęcki, 2000). A number of wells is localized close to the potential heat consumers.

Geological conditions

The cross-section of the oil field Libusza-Lipinki is presented in Fig. 1. The Gorlice-Lipinki fold is an element of the Silesian Unit, most protruded to the south. The boundary between the Silesian and Magura Unit passes through Sękową, south of Dominikowice, Kryg and Lipinki, going to NE into the so-called Harklowa Penninsula. Its west part extends to the north the so-called Łużna-Szalowa Penninsula. Therefore, both ends of the Gorlice-Lipinki fold are hiding under the Magura „penninsulas”, forming the Gorlice bay).

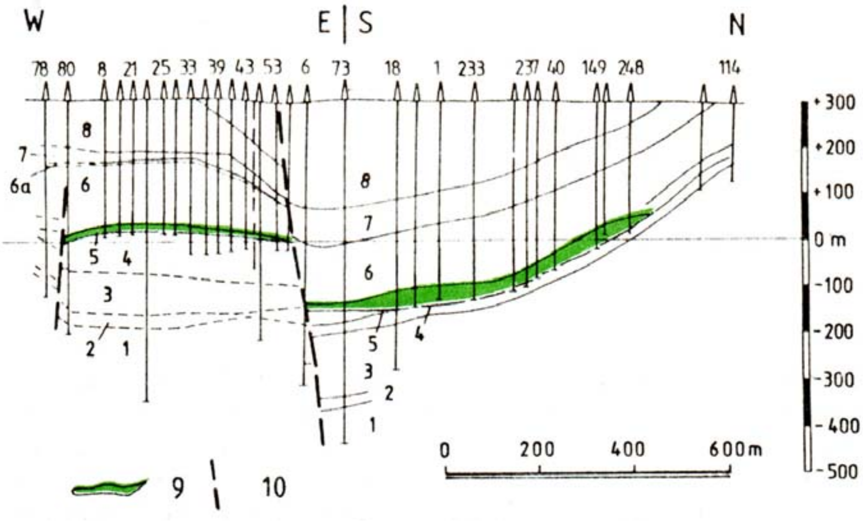

Fig. 1. Libusza-Lipinki oil field, 1 – III Ciężkowice sandstone, 2 – III variegated shales, 3 – II Ciężkowice sandstone 4 – II variegated shales, 5 – I Ciężkowice sandstone, 6 – I variegated shales, 6a – red shales intercalation, 7 – menilite shales, 8 – Krosno beds, 9 – oil field, 10 –dislocations (Karnkowski, 1993).

[1] *dr. inž.Tomasz Śliwa, prof. Andrzej Gonet*, AGH University of Science and Technology,Drilling, Oil and Gas Faculty, Drilling and Geoengineering Department. al. Mickiewicza 30, 30 059 Cracow, Poland
[2] *inž. Andrzej Grasela,* Polish Oil and Gas Company, Dpt. ZRG in Krosno, ul. Łukasiewicza 93, 38-400 Krosno, Poland
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The maximal width of the fold in the east Sokół-Kobylanka cross-section is reduced owing to the overthrust of the Magura nappe. The fold was passive when the Magura nappe was overthrusting, which can be proved by wedging of the nappe in the Krosno beds in the south wing of the Gorlice-Lipinki fold and in the area of the mines Hanka in Lipinki. From the north, the Gorlice-Lipinki fold is limited by the overthrust line, along which it contacts the upper Krosno beds in the south wing of the Biecz fold. The fold is dislocated and cut with transverse and longitudial faults. Three folds can be distinguished: the south, central and the north, the forefield of which is made of the Krosno strata. The Czarna Rzeka beds occur in the core parts of the fold (Karnkowski, 1993).

Geological-technical state of the wells

The field has been drilled for several years. Gradually, the new wells were completed and new resources discovered the development of drilling technologies could be observed. Accordingly, the wells have different designs. Exemplary data containing the catalog state of well LIPA 80 (scheme in Fig. 2) are presented in Table 1. The adaptation analysis of a production well to a borehole heat exchanger will be made on this example.

Tab. 1. List of data of well LIPA 80.

<table>
<tr><td colspan="2">Drilling time</td><td colspan="2">16.03.1946 – 23.05.1946</td></tr>
<tr><td colspan="2">Final depth</td><td colspan="2">388.7 m</td></tr>
<tr><td colspan="2">Production since the beginning to the year 2002</td><td colspan="2">507.15 Mg oil</td></tr>
<tr><td colspan="2">Open interval</td><td colspan="2">388.7 – 387.3 m</td></tr>
<tr><td colspan="2">Top of the proposed sealing plug</td><td colspan="2">350 m</td></tr>
<tr><td colspan="2">Inner diameter of BHE</td><td colspan="2">9``</td></tr>
<tr><td rowspan="4">Drilled lithological profile</td><td colspan="2">Lower Krosno series</td><td>0 – 21 m</td></tr>
<tr><td colspan="2">Menilite shales</td><td>21 – 140 m</td></tr>
<tr><td colspan="2">I Variegated shales</td><td>140 – 335 m</td></tr>
<tr><td colspan="2">I Ciężkowice sandstone</td><td>335 – 388.7 m</td></tr>
<tr><td rowspan="3">Well's design</td><td>10``</td><td>0 – 237.8 m</td><td>Water cut off</td></tr>
<tr><td>9``</td><td>0 – 370.36 m</td><td>Water cut off</td></tr>
<tr><td>7``</td><td>365.3 – 387.3 m</td><td>Liner</td></tr>
</table>

Adaptation technique

Wells in the present technical state cannot be used as BHE for the energy exploitation. For maintaining heat sources, the following should be done:

- partial closing of the well to cut off the formation fluid flux,
- replacement of the surface well's utilities,
- surface installment enabling the circulation of a heat carrier between the well and the consumer.

The description of adaptation procedures is in Table 2. Owing to the long operation time of these wells, their actual state may differ from the catalogue parameters. During the adaptation works, it should be determined if the state of the wells does not differ from the described one. If so, it should be verified and adjusted to the real conditions.

One of the most important elements of borehole heat exchanger is the inner column of pipes. The inner pipes, forming an isolating column, should be made of a material of a relatively low heat conductivity coefficient.

The economic efficiency of a BHE is influenced by exploitation costs. They depend on the quality of energy which should be supplied to the heat pump, and also to provide a circulation of the heat carrier. Hence, the geometry of the heat carrier flow should be accounted for when selecting the inner column, as it determines the pressure loses of circulation.

Geometrical parameters of BHE are especially important in view of ability to recuperate heat energy. The thicker is the wall of the inner column, the better are its insulation properties. Unfortunately, the increase of the thickness of the inner column wall is unfavourable for the flow pressure loses. The increase of thermal insulation properties is related with the increased cost of fighting the pressure loses of heat carrier flow and unit prices of the pipes. Geometrical parameters of the well after partial closing and adaptation to BHE for the well LIPA 80 is given in table 3.

Partial closing of the well LIPA 80 will require:

- injection of bentonite mud,
- performing cement plug at 388.7 m – 350 m of depth,
- checking the top of the cement plug,
- making tightness tests of the cement plug and the well.

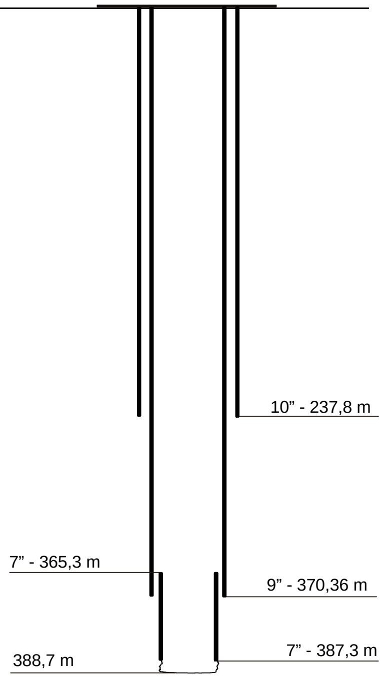

Fig. 2. Scheme of design of well LIPA 80.

Tab. 2. Description of adaptation of wells to BHE.

Task	Description
Making sealing plugs	Making sealing plugs should account for temperatures in the BHE. The relevant properties of the plug: permeability, thermal expansion and the accompanying strains, possibility of washing out in the course of flow of the heat carrier.
Tightness test	Tightness test should be performed in the wells, e.g. with water. In the case of a negative result, the well should be sealed up or a U-shaped circulation system should be employed for the heat carrier.
Cleaning of BHE	Considerable sediments of heavy oil fractions can scale on oil wells. A paraffin layer has a favourable corrosion-protection effect on the well. It may, however, also result in a rise of pressure loses of heat carrier flow in the well and in the surface installments. It may also deteriorate the heat exchange both in the well and in the heat exchanger of heat pump. Before tripping the inner column, the well should be cleaned, brushed and washed with warm water with surfactants.
Tripping inner column	The inner column should be made of thermally resistant material. If the inner column is made of material of lower specific gravity than that of fluid filling the well during tripping operation, it will not be necessary to use high capacity hoist. During tripping inner pipes the scales may be removed from the inner walls of the well. This sediment over the plug may hinder the ductibility of the circulation system. The tripped column may be stuck as well. To ensure ductibility, the downhole section of pipes should be perforated.
Centralization of inner column	The central position of inner column enables maximal use of the walls as a surface of heat exchange. Stable centralizers should be used. Spring centralizers may increase friction forces in the course of hoisting operations. They can be neglected in the cased part of the well. Centralizers disturb the fluid's movement. Owing to the increased value of heat penetration, the laminar flow may be advantageous for the exchange of heat with the rock mass. The dimensions of centralizers should not interfere with the hydraulic pressure loses of the flowing heat carrier.
Loading of inner column	If the inner column is made of material of specific gravity lower than that of the heat carrier, the pipes may need a load on them, especially during tripping operations. This function can be performed by centralizers or collars at the end of the inner casing column.
Exchange of surface wellheads	Utilities installed in the wells should enable circulation of the heat carrier. The circulation wellhead shall hold the insulating column or its U-shape system.

Tab. 3. Geometrical parameters of the well LIPA 80 after reconstruction.

Diameter of well			Depth of sealing plug's top	Length of inner column	Diamater of inner column	
nominal		inner			external	inner
9``	228.6 mm	221 mm	350 m	345 m	110 mm	50 mm

Energy potential of BHE

Thermal properties of rocks have a deciding influence on the quantity of energy recuperated from the BHE. The thermal properties of rocks of the well LIPA 80 determined on the basis of available data (Plewa, 1994) are listed in Table 4.

Tab. 4. Thermal parameters of rocks in the well in Lipinki.

Drilled rocks	Thermal conductivity coefficient, $W \cdot m^{-1} \cdot K^{-1}$	Temperature conductivity coefficient, $10^{-3}\ m^2 \cdot h^{-1}$	Density, $kg \cdot m^{-3}$
Lower Krosno strata	2.60	4.18	2430
Menilite shales	2.04	3.41	2550
I Variegated shales	2.04	3.41	2550
I Ciężkowice sandstone	2.60	4.18	2430

The assumed temperatures on the bottom of the BHE were determined in line with the geothermal gradient after the literature data (Plewa, 1994). The collected thermal properties of rocks in the well LIPA 80 are presented in Table 5.

Tab. 5. Thermal properties of rocks in the well LIPA 80 in Lipinki.

Specification	Interval	Thickness
Lower Krosno strata	0 - 21 m	21 m
Menilite shales	121 – 140 m	119 m
I Variegated shales	140 – 335 m	195 m
I Ciężkowice sandstone	335 – 345 m	10 m
Average weighted thermal conductivity coefficient	2.09 $W \cdot m^{-1} \cdot K^{-1}$	
Average weighted temperature conductivity coefficient	3.48 $10^{-3}\ m^2 \cdot h^{-1}$	
Weighted average of rock density	2539 $kg \cdot m^{-3}$	
Bottomhole temperature	16.4°C	

The energy stream obtainable from the BHE in the well LIPA 80 and other analyzed wells in Lipinki, as well as the heat values are given in Table 6.

Tab. 6. Predicted heating capacity of BHE and the annual energy yield.

Well	Depth	**Heating capacity**, kW		**Energy yield**, GJ/year	
		1	2	1	2
LIPA 80	345 m	24.84	18.63	783.4	587.5
Total of 6 chosen wells in Lipinki	1895 m	125.96	94.47	3972.2	2979.2

[1] *average 15 m/kW at the injection temperature of the heat carrier below 2°C,*
[2] *average 20 m/kW at the injection temperature of the heat carrier up to 2°C.*

Utilization of heat from BHEs

The analysis of the heat demand in the Lipinki county reveals that there exists a number of possibilities of adapting the heating system in view of the heat pump application. Unfortunately, a thorough analysis of the energy state of the county is required, especially of objects localized in the vicinity of the closing wells.

The school in Lipinki is one of potential heat customers. The school covers an area of 484.6 m^2, and its cubature is 1551 m^3. The annual demand for heat for this object was assessed 1043.8 GJ, out of which nearly 800 GJ/year shall be spent for the central heating. The remaining part is planned to be used for heating useful water. At present, the school is supplied with heat coming from the combustion of natural gas. The total yearly gas consumption in the school totals to almost 27,000 m^3.

Other objects in Lipinki which could use of the heat recuperated with BHE are the County Administration objects, kindergarten, the Culture Center and the Health Center. Moreover, much energy is used each year by communal objects in other towns in the county, e.g. the yearly natural gas demand of communal objects in Kryg totals to 44,000 m^3.

Conclusions

1. The geothermal energy in Poland must be recovered through drilling wells. Making the drilling wells is the most expensive part of the capital cost. The existing, already exploited oil wells are systematically closed. A part of them can be used as a source of local pure thermal energy in objects localized close to the depleted wells and as heat storages, being a part of rational power management policy.
2. The analysis of use of wells frequently localized in a direct vicinity of potential heat consumers should be based on detailed calculations encompassing economic aspects.
3. The economic analysis should account for the load and heat characteristic of the consumer in the context of parameters of downhole exchangers supplying the energy to the heat pump and the distance to the consumer.
4. A part of nearly 300 wells made on the field Libusza-Lipinki is located in the immediate neighbourhood of potential heat consumers. The adaptation of wells to heat exchangers may be very advantageous.
5. Remaking wells for heat exchangers requires sealing the productive interval, checking for tightness, providing pipes for the heat carrier circulation and the circulation wellhead on the surface.

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