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Aquifer Storage of Waste Heat Arising from a Gas and Steam Cogeneration Plant – Concept and First Operating Experience

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ABSTRACT

An aquifer for storage of the waste heat arising from the gas and steam cogeneration plant of the Neubrandenburger Stadtwerke GmbH (public utilities) was installed and comissioned in 2004. The plant is based on the wells and surface installations of a geothermal heating plant which has been operated since 1987 using Hettangian and Upper Postera aquifers at a depth between 1,200 and 1,300 m. After retrofitting, the waste heat arising from the cogeneration plant in summer at a temperature of 80 °C and amounting to approx. 4 MW will be stored in the subsoil. In the next winter, this heat will serve to supply the base load of a district heat supply network with a connected load of 12 MW.

This paper describes the plant concept and presents first operating data of the phase of commissioning.

1. INITIAL SITUATION ON THE SITE OF NEUBRANDENBURG

Major parts of the stock of buildings in Neubrandenburg are connected to a central district heat supply network with the below nominal parameters:

- heating capacity 200 MW
- feeding flow temperature 130 °C
- return flow temperature 60 °C

The base load in this network is covered by a gas and steam cogeneration plant supplying power and heat in a coupled process:

- power 77 MW
- heat 90 MW

This process allows for the utilisation of the energy content of the natural gas with an efficiency of nearly 90 % provided, however, that both kinds of energy can be used when generated. Since the heat supplied in summer in Neubrandenburg is used mainly for sanitary hot water preparation, the heating demand set up is rather low – as a rule, it is even below the amount of heat arising from power generation at minimum load. By now, the differential amount had to be released into the atmosphere via a re-cooling unit .

The Neubrandenburger Stadtwerke GmbH operates another, smaller district heat supply system along with the one described above.

- heating capacity 12 MW
- feeding flow temperature 80 °C
- return flow temperature 45 °C

From 1987 to 1998, the network "Rostocker Straße" was supplied geothermally:

- productive horizons Hettangian/ Upper Postera
- wells 2 doublets
- depth 1,200 m – 1,300 m
- flowrate 150 m^3/h
- thermal water temperature 53 °C – 55 °C
- mineralisation 120 – 130 g/l

The direct heat exchange of the thermal water and the heating network achieved small volumes only. The installed hot water-driven absorption-type heat pump had to be added to the system quite often which reduced both the energetic and the economic efficiency. The small heat sales in summer put another load on the result. The damage of the wells stated in 1998 which was mainly caused by corrosion was just the last trigger of the intensive search for an alternative use of the geothermal plant.

2. CONCEPT

The described problems of both energy generation plants

- excess heat arising from the gas and steam cogeneration plant in summer to be released into the atmosphere via cooling towers
- too low thermal water temperatures in the geothermal heating plant requiring continuous additional heating; extremely small heat sales in summer; rehabilitation of the plant is necessary

are solved by retrofitting the geothermal plant as an aquifer heat store.

- The excess heat arising from the cogeneration plant in summer which has been led by now to the cooling towers is supplied to the central district heat supply network and fed via a newly installed connecting pipeline to the geothermal heating plant.
- This excess heat arising in summer fulfils two duties in the geothermal heating plant:
  - securing the sanitary hot water supply via the network "Rostocker Straße"
  - leading the heat into the subsoil, thus increasing the heat potential existing here at large depth by approx. 30 °C up to 80 °C.
- In winter, the heat store is operated as by now the geothermal heating plant, but the thermal water temperature is 80°C – 65 °C when produced.

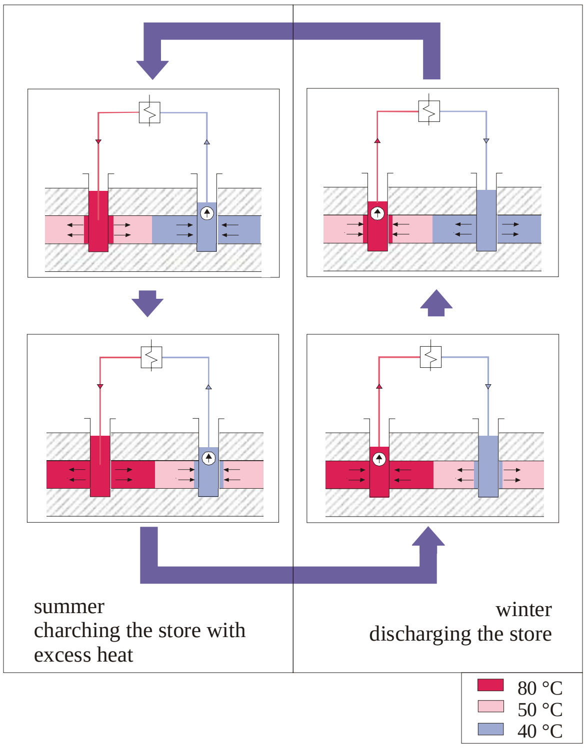

Figure 1: Scheme of heat storage

Based on the result of thermodynamic calculations assuming:

- maximum thermal water flowrate 100 m^3/h
- heat charging temperature 80 °C

it is expected that an amount of 12,000 MWh of heat can be fed into the aquifer store from April through September. 8,800 MWh shall be recovered in direct heat exchange in winter at an output from 4.0 to 2.9 MW. In the first year, the discharging temperature will decrease to approx. 62 °C in the course of the winter, in the fifth year of operation it will be 67 °C.

3. TECHNICAL WORK

The work described below was completed in spring 2004.

After thourough inspections, two of the four wells of the geothermal heating plant were selected for re-installation as heat store wells. The "warm" well is based on the production well Gt N 1/86 which developed the Upper Postera horizon. In the course of the work, the initial concept of almost unchanged re-use had to be given up, however. Especially the bad condition of the wire-wrapped screen called for a completely new installation which included finally even a fiber glass-reinforced protective casing reaching down into the store section. In addition, a new well head was installed so that later the thermal water can be produced via the pump riser and injected through the annular space. The injection well Gt N 4/86 of the geothermal plant which develops the Hettangian horizon will be used as the "cold" well. The well was drilled deeper to reach the Upper Postera horizon, the screen was installed, and the old perforation in the Hettangian was sealed by a 7" liner which was installed and cemented. Moreover, a glass fiber protective casing, a submersible pump and a new well head were installed. A scheme of the well construction is shown in Figure 2.

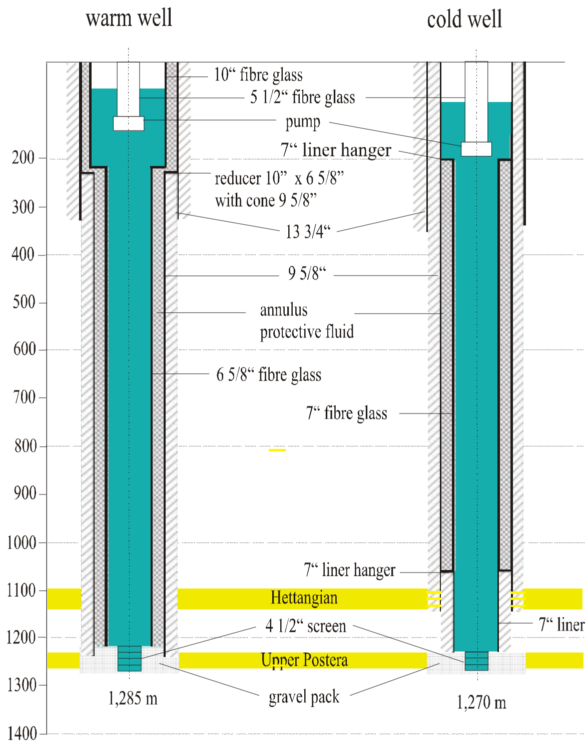

Figure 2: Well construction

- Most of the existing pipe system is re-used in the surface loop. At several points, bypasses were installed to manage the reverse direction of the thermal water flow, in particular around the filter groups. In addition, a pressure-maintenance unit was added including a nitrogen loop to fill the annular space in the respective production well.
- A modern automation units provides reliable operation of the thermal water loop and regulates the integration of store into the overall heat supply system of the Neubrandenburger Stadtwerke GmbH. The aquifer store is monitored from the central control room of the cogeneration plant.

4. COMMISSIONING AND FIRST OPERATING DATA

Commissioning and trial run of the aquifer store began in March 2004 after completion of an extensive program of production, injection and circulation tests. The excess heat arising from time to time already at moderate outdoor temperatures allowed the "heat charging" mode of operation.

Figure 3 shows a simplified flow chart of the technical units. The two district heat supply networks which form the heat source and the heat sink of the store and the storage loop itself are shown, but without the peak-load units, the absorption-type heat pump and all secondary systems.

The network "Rostocker Strasse" will be separated completely from the storage loop when heat is fed into the aquifer store, i.e., whenever surplus heat exists in the central district heat supply system exceeding the demand of the above network. A sub-section fulfils now the duty of an intermediate loop between the central district heat supply network and the storage loop. The store is charged exclusively with these surplusses which is controlled by the differential pressure. The flowrate in the storage loop is determined by the desired injection temperature in the "warm" well.

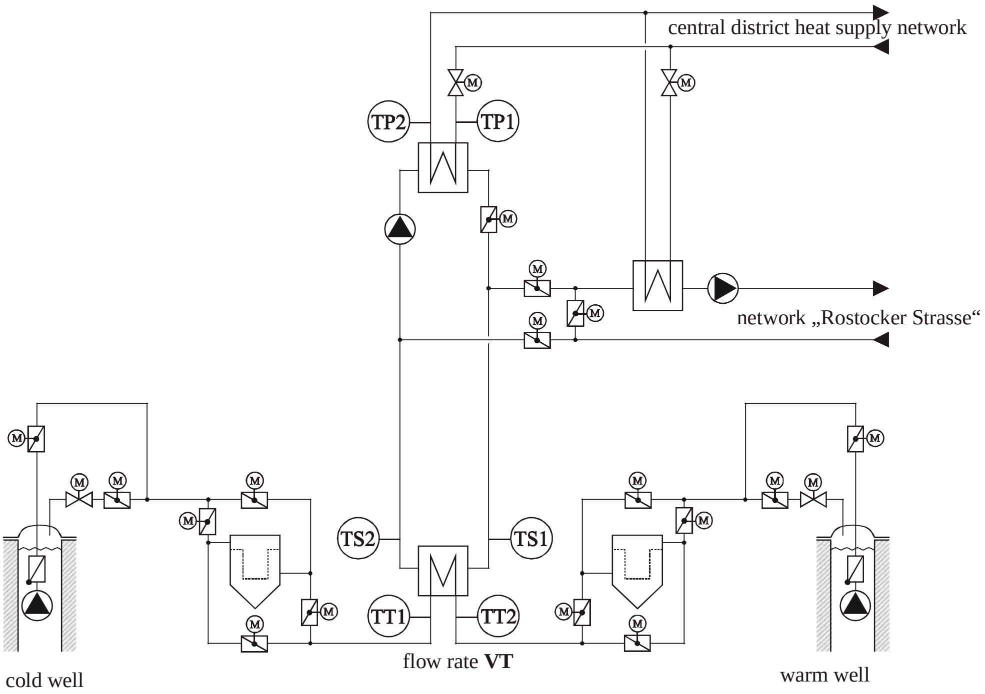

Figure 3: Simplified flow chart of the process

When heat is discharged from the store, the return flow of the network “Rostocker Strasse” is led directly to the thermal water heat exchanger. Now, the thermal water flowrate is determined by the specified temperature at the outlet of the apparatus on the heating network side. The central district heat supply network or the existing peak-load boilers allow for additional heating.

Figure 4 highlights an essential aspect to be considered when preparing the installation of aquifer stores. The systems are not able to implement short-term load changes or fast switching-in or –off processes. On the one hand, this shall support a reservoir-saving mode of operation and avoid the passing of unadmissable temperature ranges. On the other hand, processes of heating-up in the wells, in the surface thermal water system and on the heating side require longer periods of time. The cold start of the Neubrandenburg plant nearly needs 1.5 hours from the commissioning of the intermediate loop (A) via the commissioning of the thermal water loop (B) until the specified injection temperature (C) is reached.

The below Figure 5 to Figure 8 illustrate the operation of the plant on a typical day with the charging of heat in the transitional period. A surplus of approx. 3.5 MW is available from the cogeneration plant which can be led to the network "Rostocker Strasse" / heat store. During the night, this value will increase due to reduced demand on the central district heat supply network.

Figure 5 indicates clearly the extent of the direct use of this heat in the network “Rostocker Strasse”. During the night, less heat is consumed. The heat store follows the difference between the surplusses and the direct heat use. Consequently, the injection flowrate will increase during the night up to 80 m³/h (cf. Figure 7).

In the months of summer, the surplusses will increase and the demand in the network “Rostocker Strasse” will decrease to approx. 500 kW. In the context of an increase of the injection temperature up to 80 °C as planned – a process which will be accompanied by investigations - the heat charging capacity shall approach approx. 4.0 MW.

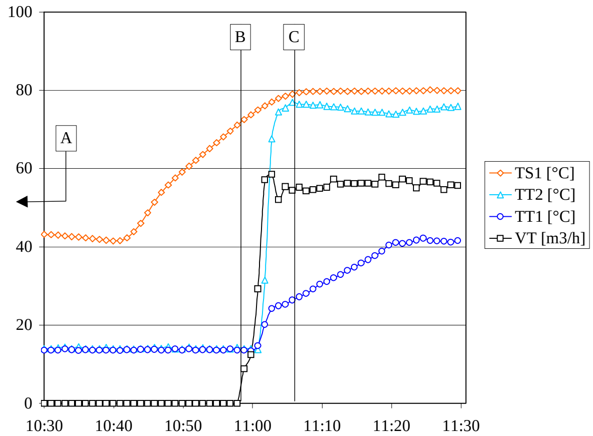

Figure 4: Thermic parameters in the state of start-up

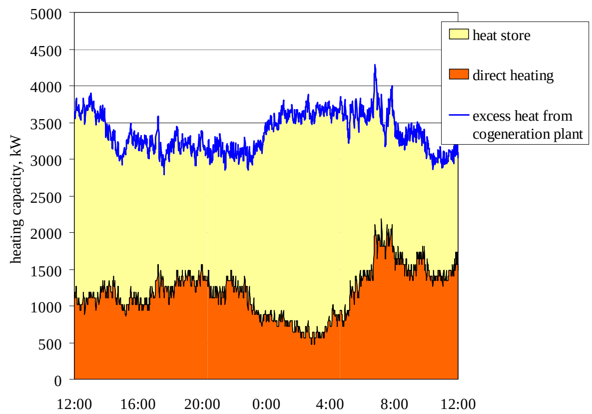

Figure 5: Heat surplusses and their use on 12 May 2004

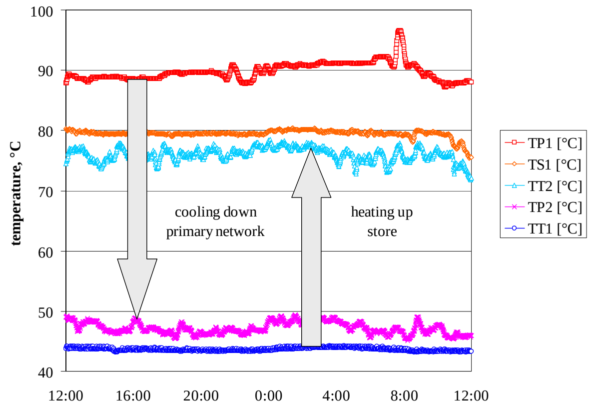

Figure 6: Temperatures in the district heat supply system and in the heat storage loop on 12 May 2004

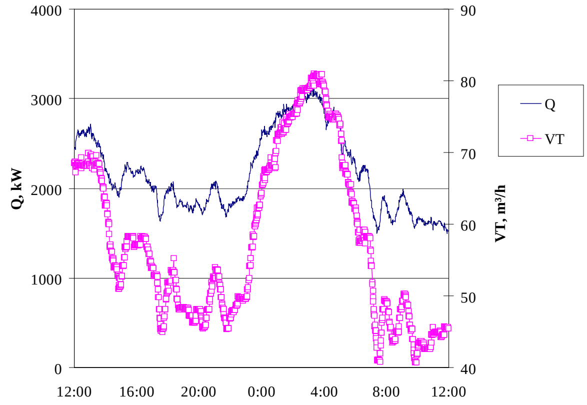

Figure 7: Flowrate in the storage loop and charged heat on 12 May 2004

Figure 8 illustrates the hydraulic behaviour of the two wells. Although the parameters are very favourable in each case, it becomes clear that the injection of a certain amount of thermal water needs a stronger change of the water head than production. Principally the same result was produced by test evaluations with a reverse flow direction, although the "cold" well generally has slightly better values.

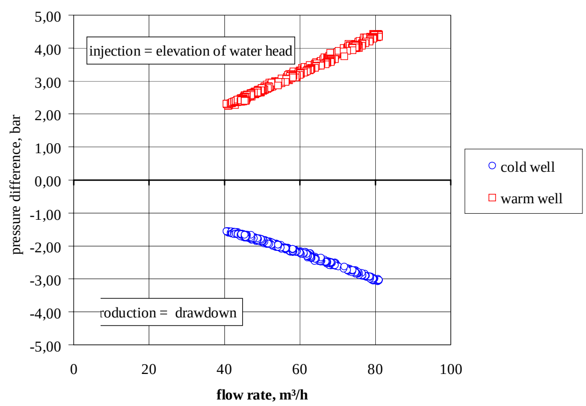

Figure 8: Drawdown of the water head in the "cold" well and its elevation in the "warm" well (12 May 2004)

5. CONCLUSION

Efforts aiming at minimisation of the primary energy use by combination of different processes of energy transformation are hindered often by the seasonal diverging of energy offer and energy demand. The development of efficient and economically reasonable techniques of long-term heat storage, such as ATES, may contribute significantly to the solution of this problem.

The aquifer heat store which was commissioned in Neubrandenburg in 2004 will help in the next years to further develop the know-how in the field of underground thermal energy storage at a high temperature level. Therefore, the operation will be accompanied by an adequate monitoring programme – the results will be reported at a later date.

Figure 9: "Cold" well head

Figure 10: Heat exchanger between district heat supply network and intermediate loop

Figure 11: Coarse filtration of the thermal water at the "cold" well

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