ECES Annex 12

"High Temperature Underground Thermal Energy Storage"

8th report to the Executive Committee
16.10.2001

Annex 12 of the ECES Implementing Agreement of IEA is a task-sharing annex. There are four countries participating in the annex, comprising the locations of most of the operational HT-UTES plants and the institutions where work towards HT-UTES is done:

- Belgium
- Canada (?)
- Germany
- Sweden

A fifth country, the Netherlands, is participating through some industry involvement and assistance to the work of the annex. Norway attended the experts meeting in spring 2001 as an observer.
Funding for the work is fully available in Belgium and Germany, and currently limited in Canada and Sweden. In the Netherlands, a study on optimum storage temperatures for UTES is funded (not officially part of the annex).

No experts meeting has been conducted since the last ExCom meeting:
The next meeting was planned mid November 2001 in Canada; however, due to reasons in that country, the meeting will be held in Germany (Neubrandenburg) about the same time.

Work on monitoring and on the site test methods for aquifer chemistry and ground thermal parameters is continuing. Currently monitored are:

- Neckarsulm, BTES (D)
- Rostock, ATES (D)
- Berlin, ATES (D)
- Hooge Burch, ATES (NL)

New HT-UTES projects are under construction or in planning, and will be monitored:

- Anneberg, BTES (S) start of operation spring 2001
- Attenkirchen, BTES (D) still under construction
- Mol, BTES (B) start of operation summer 2002
- Neubrandenburg, ATES (D) re-start of project in summer 2001 (see below)

With the current end of phase 2 in June 2002, data from Anneberg might be included; for Mol and Attenkirchen, only the experiences from the design and construction phase will be available by then.

The test equipment for aquifer chemistry and groundwater behaviour could be made operational in Stuttgart, Germany, in early 2001, and after first test run in Stuttgart and further completion in Lüneburg, the trailer was brought to Nijmegen to be demonstrated during the annex 12 and annex 13 experts meetings in spring 2001. More tests in Stuttgart and Lüneburg followed, and then the rig was used for the first time to work on a prospective HT-ATES site on the island of Pellworm off the west coast of Schleswig-Holstein (North Friesian islands) in late August / early September 2001. A description of the equipment and the tests made by now is given in Appendix A with a paper presented at a conference in Germany in September 2001.

For borehole heat exchangers, many more thermal response tests have been done in the participating countries. An international workshop will be held in Lausanne/Switzerland on Oct. 25/26, 2001, with input from the IEA group.

An independent homepage for Annex 12 is still under construction at Justus-Liebig-University, and will be linked to the ECES-homepage in Turkey. The current status can be seen under:
The institute´s homepage: http://www.uni-giessen.de/~gg1068/
IEA work directly: http://www.uni-giessen.de/~gg1068/html/iea.html
There is also an explanation of UTES and a paper in pdf-format under:
http://www.uni-giessen.de/~gg1068/html/erdwaermespeicherung.html

It seems that the interest on HT-UTES is stagnating. No new participating countries can be seen, and few new projects. For the monitoring, more data will have to be collected to make first evaluations from the (new) existing plants. However, the Annex is a valuable platform for exchange of information, to start new projects, and to launch individual co-operations. The next XM in November will have to adjust the workplan to the changing situation (and countries), and to secure a good output documentation from the Annex at its probable closing next summer.

I close with a short update on some future HT-UTES projects in Germany not mentioned above:

- Pellworm: Geology, Hydrogeology and Hydrochemistry is favourable, but a UTES seems not to be required at least in the first stage of the biomass-cogeneration-project.
- Neubrandenburg: After more than a year of a moratorium, the project is relaunched and will eventually turn a geothermal doublet (s. Appendix B) into a ATES storing waste heat from power generation.
- Schrobenhausen: A geothermal plant is under planned based on an existing well (and further drilling), but due to relatively low geothermal water temperatures a ATES with deep wells is now considered.
- Crailsheim: In this city the feasibility for a BTES similar to the one in Neckarsulm is investigated.

Report given by: Dr. Burkhard Sanner
Operating Agent Annex 12

Appendix A:

Paper given at the International Summer School for Direct Applications of Geothermal Energy in Bad Urach, 17.-22.9.2001

Mobile Test Equipment for Investigations on Groundwater for Use in High Temperature Aquifer Thermal Energy Storage Plants (HT-ATES) – First Results

Guido Knoche, Michael Koch and Jörg W. Metzger

University of Stuttgart, Institute for Sanitary Engineering, Water Quality and Solid Waste Management, Dep. of Hydrochemistry, Bandtaele 2, D-70569 Stuttgart, Germany

Introduction

Subsurface storage of process and waste heat or even heat from renewable sources is a promising opportunity to comply with requirements of a global sustainable energy (re-)use. Suitable techniques such as Aquifer or Borehole Thermal Energy Storage (ATES; BTES) have been developed and examined since the early 1970s (Sanner, 1999). Operational experience at ATES plants sometimes showed technical problems with scaling and corrosion (Ruck et al., 1990; Koch & Ruck,.1993).

Within the ongoing IEA Implementing Agreement „*Energy Conservation through Energy Storage*“ (ECES) Annex 12 „*High Temperature Underground Thermal Energy Storage (HT-UTES)*“ a current R&D-project deals with the development of a mobile test equipment (MTE) for pre-investigations on groundwater suitability in High Temperature Aquifer Thermal Energy Storage Plants (HT-ATES) and its operation at scheduled ATES plants (Sanner & Knoblich, 2000). The development and investigations are taking place in co-operation with the University of Gießen (Institute for Applied Geosciences) and the University of Lüneburg (Institute for Ecology and Environmental Chemistry), Germany.

Design and construction of MTE

The MTE (Fig. 1, schematic overview) allows the simulation of loading the aquifer (heating of groundwater) in plate heat exchanger 1 (HE 1, see Fig. 1) and the recovery of energy in plate heat exchanger 2 (HE 2). The main focus is to determine scaling by indirect (heat transfer coefficient, operated by University of Lüneburg) and direct (scaling products, operated by University of Stuttgart) measurements. The MTE is integrated in a car trailer (Fig. 2). A data logging unit records simultaneously temperatures, measured by Pt100 resistance thermometers (T1, T2, T3, T4, T5, and T6), and flow data (Q1 and Q2), recorded as weight of flow-through per minute in both heating and groundwater cycles (see Table 1) and activates computerised control device for the heating source (gas boiler). The latter is realised by a contineous control of the gas inlet into the gas boiler with a mass flow controller (MFC, see Fig. 1).

Table 1: Reading points of temperature and flow-through in the MTE

Reading point	Description
T1	heating (hot, inlet into HE 1)
T2	heating (cold, outlet of HE 1)
T3	groundwater (inlet into HE1)
T4	groundwater (hot, outlet of HE 1)
T5	heating (outlet of HE 2)
T6	groundwater (outlet of the MTE)
Q 1	flow-through in the groundwater cycle
Q 2	flow-through in the heating cycle

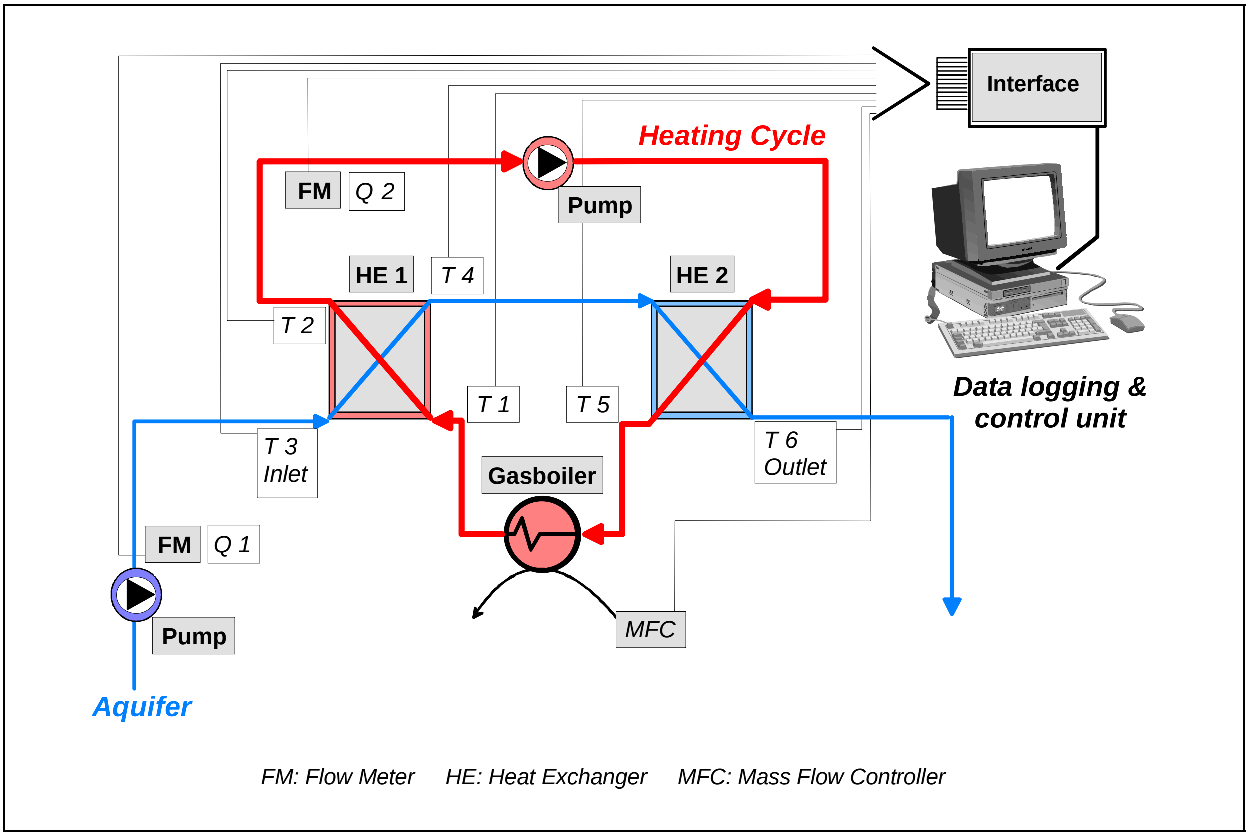

Figure 1: Schematic overview of MTE

The scope of the investigation programme (direct measurements) is:

- chemical analysis of precipitation in heat exchangers and groundwater at scheduled ATES plants and
- mass detection of scaling products at different temperature levels above 50°C by opening the heat exchanger HE 1.

Comparison of different test sites with various geological (background) conditions will give basic information on the chemical behaviour of diverse groundwater types in order to evaluate a standardised test method for groundwater suitability in ATES.

Further investigations on suitable water treatment techniques, precipitation in heated groundwater and corrosion characteristics of the cooled groundwater are intended.

Figure 2: MTE in operation at Institute for Sanitary Engineering, Water Quality and Solid Waste Management, in Stuttgart (Germany)

Experiences from first operation acttvities

So far the MTE has been successfully operated *(only test purposes)* for more than 200 hours in Nijmegen, The Netherlands, and Stuttgart, Germany. Experimental details (total duration, medium temperature at T4, total flow-through volume, medium flow-through per hour in groundwater cycle) of the experiments are listed in Table 2.

Both the data logging unit and the computerised control device of the heating source have proved to be stable. As shown in Fig. 3 the temperature at reading point T4 (groundwater, hot) decreases within the second half of the operation in consequence of decreasing heat transfer (calculated as heat transfer coefficient k_m, see Fig. 4) due to precipitation processes in the heat exchanger.

As shown in Figure 6 the chemical analyse data of cations (e.g. calcium and magnesium) in the outlet of the MTE show qualitative and quantitative distinctions. The content of magnesium in the outlet of the MTE nearly doesn't indicate any variation between the two temperature levels. Furthermore it was found, that concentration of magnesium within both experiment A 2 and B 2 and in addition of calcium in experiment B 2 coincide more or less with analyse data of raw groundwater at Stuttgart test site. In contrast to this the concentration of calcium in experiment A 2 is significantly lower (up to 10 %) at the outlet of the MTE than that measured in experiment B 2. Thus the higher the temperature level of groundwater a reading point T4 the lower the concentration of calcium in the outlet of the MTE can be expected, indicating the occurrence of precipitation of calcareous compounds.

Table 2: Experimental details of operations in Nijmegen and Stuttgart

Test sites/ experiment	**Duration** [h]	**Temperature** [°C]	**Total Volume** [m³]	**Flow-through** [L * h^{-1}]
Nijmegen				
A	5.32	92.5	1.37	258
B	7.15	79	2.24	313
Stuttgart				
A1	5.32	90	1.5	282
B1	7.88	80	2.19	279
A2	76.3	90	29.8	391
B2	77.9	65	30.25	392

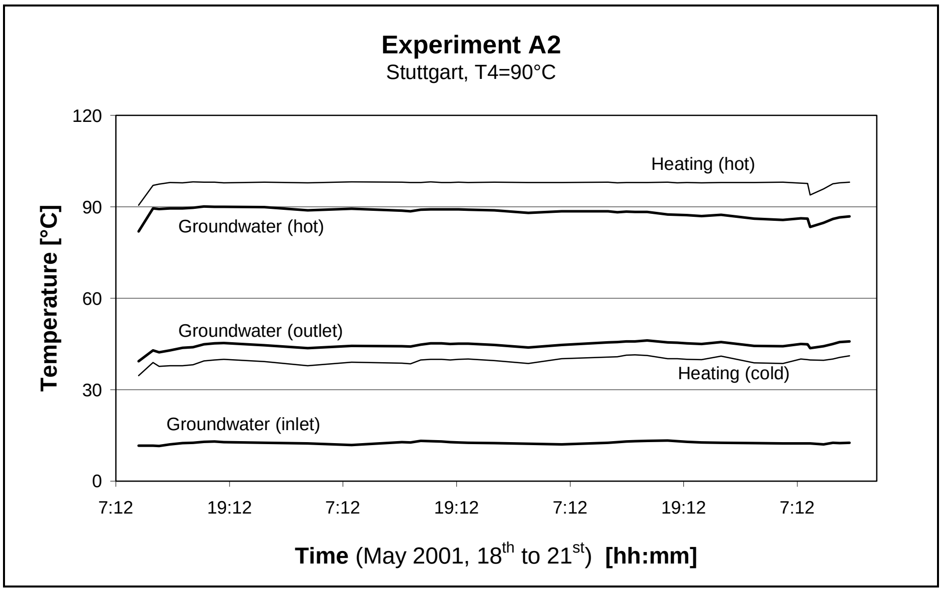

Figure 3: Temperature readings within experiment A2

A general occurrence of scaling processes on heat exchanger plates to a greater extent can be observed at high groundwater temperature levels (T=90°C, at reading point T4, HE1) than at lower temperatures (T=80°C and lower, at T4). Figure 5 gives an overview on calculated calcium loads on heat exchanger plates related to total flow-through volume of groundwater for the experiments in Stuttgart and Nijmegen.

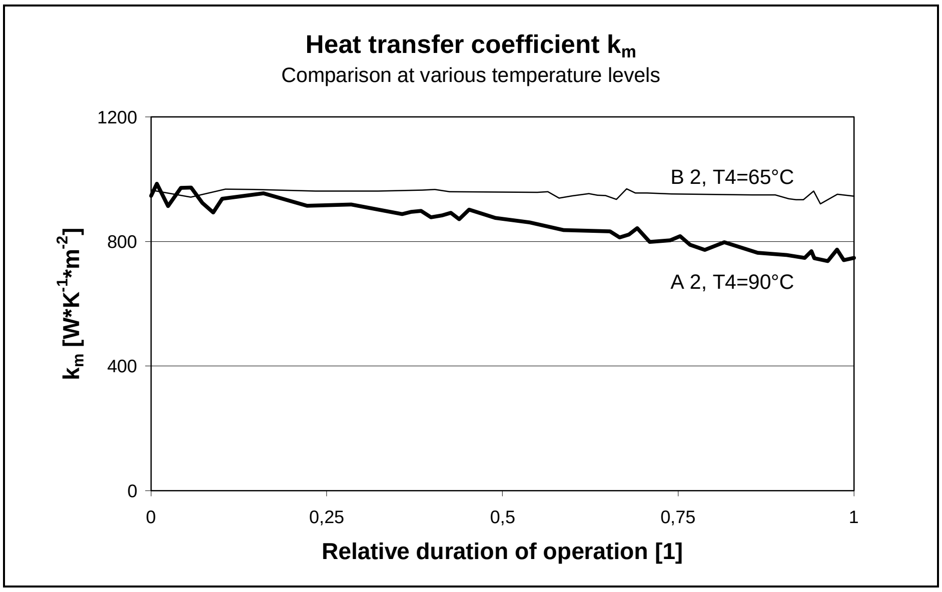

Figure 4: Comparison of heat transfer coefficient k_m at different temperature levels within experiments A2 and B2

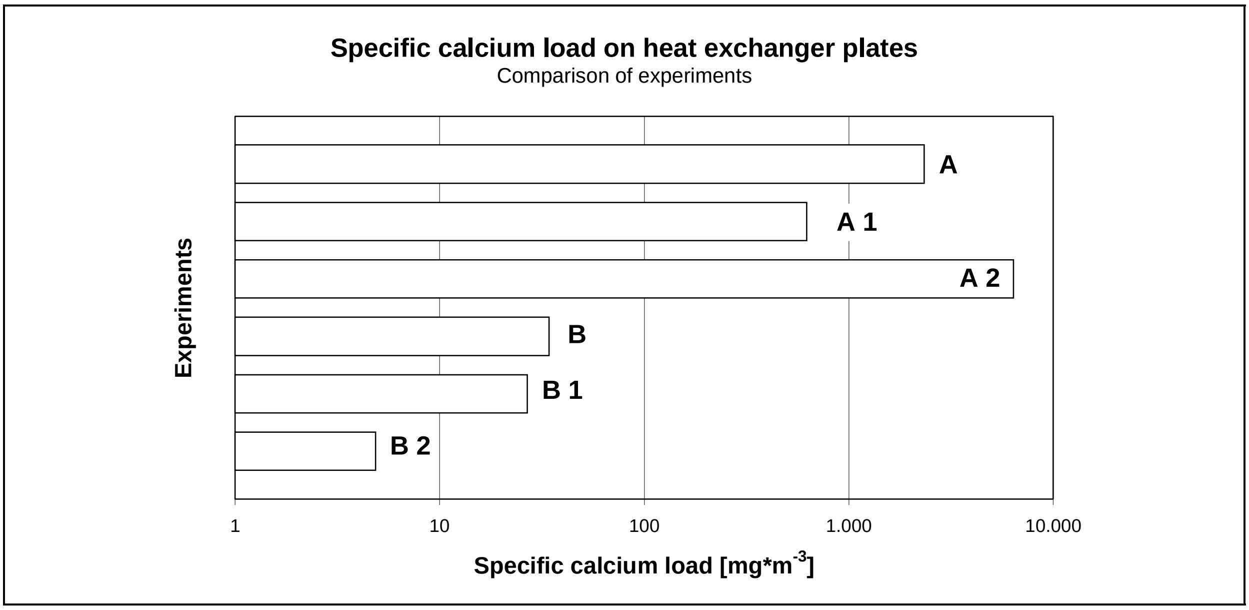

Figure 5: Comparison of specific calcium load (related to total flow-through volume of groundwater) at various experiments

Nevertheless, up to now the results of the first experiments in Stuttgart and Nijmegen do not allow any accurate prediction of groundwater suitability for ATES plants, neither in respect to a particular temperature level nor concerning its general suitability.

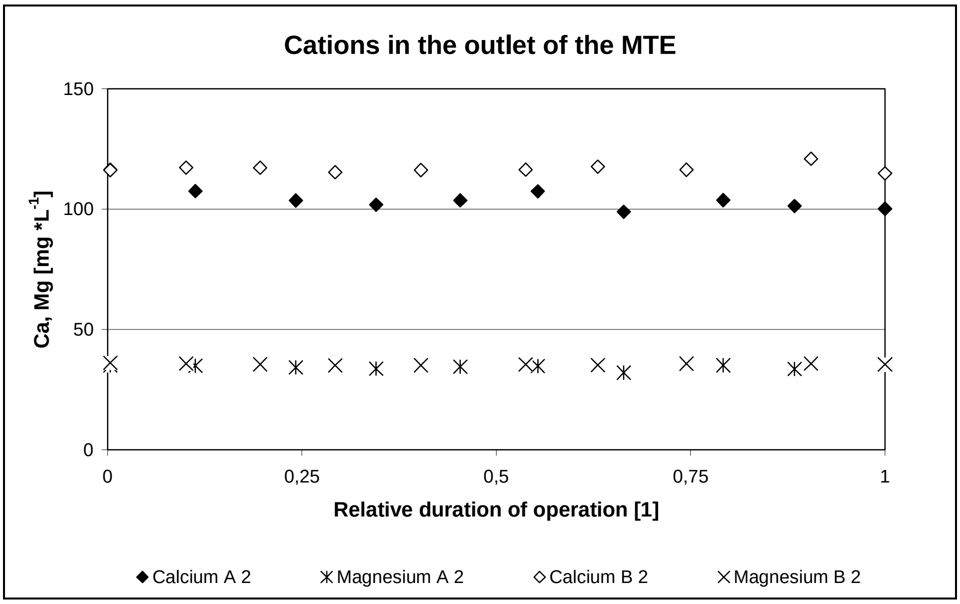

Figure 6: Hydrographs of concentration (calcium, magnesium) in the outlet of the MTE within experiments A2 and B2

Therefore future work will be focussed on:

- the beginning phase of scaling processes depending on operation time and run through volume of groundwater in the MTE at different temperature levels above 50°C
- the total water hardness (concentrations of calcium and magnesium) at the outlet of the MTE.

Literature

Koch, M., & Ruck, W. (1993): Der Einfluß von Wasserbehandlungsmethoden auf das Grundwasser bei der Wärmespeicherung im Aquifer. - Stuttg. Ber. Siedlungswasserwirtsch. 124, 107-116

Ruck, W., Adinolfi, M., & Weber, W. (1990): Chemical and environmental aspects of heat storage in the subsurface. - Z. Angew. Geowiss. 9, 119-129

Sanner, B. (ed.) (1999): High Temperature Underground Thermal Energy Storage, State-of-the-art and Prospects. - 158 S., Giessener Geologische Schriften 67, Giessen

Sanner, B. & Knoblich, K. (2000): IEA ECES Annex 12 - High Temperature Underground Thermal Energy Storage. - Proc. TERRASTOCK 2000, S. 17-24, Stuttgart

Appendix B:

Description of the Neubrandenburg geothermal plant from:

- SANNER, B., HOPKIRK, R., KABUS, F., RITTER, W. & RYBACH, L. (1996): Practical experiences in Europe of the combination of geothermal energy and heat pumps. - Proc. IEA Conference on Heat Pumping Technologies 96, Toronto, Vol. I, pp. 111-123

6.3. Example in Neubrandenburg, Germany

Since 1988 a hydrogeothermal doublet exists in Neubrandenburg, in the northeast of Germany. Originally equipped with 4 compression heat pumps, the plant has been refurbished in 1993 with an absorption heat pump totalling 9.35 MW heating capacity. Two boilers with 2.3 MW each cover peak loads. Two district heating nets are served, one with low temperature of 65 °C supply and one with higher temperature of up to 90 °C, heating a high school, approx. 800 apartments, and other consumers; extension is planned (fig. 5).

The hot water source is a heavily mineralized geothermal fluid from sandstones in 1270 m depth, with 56 °C at the wellhead. 2 production and 2 injection wells 1200 m apart tap the sandstones from the triassic-jurassic-boundary. The geothermal share of the total system capacity is 3.85 MW. In 1995 26'500 MWh have been delivered to the consumers, 17'500 MWh of which were from the geothermal source.

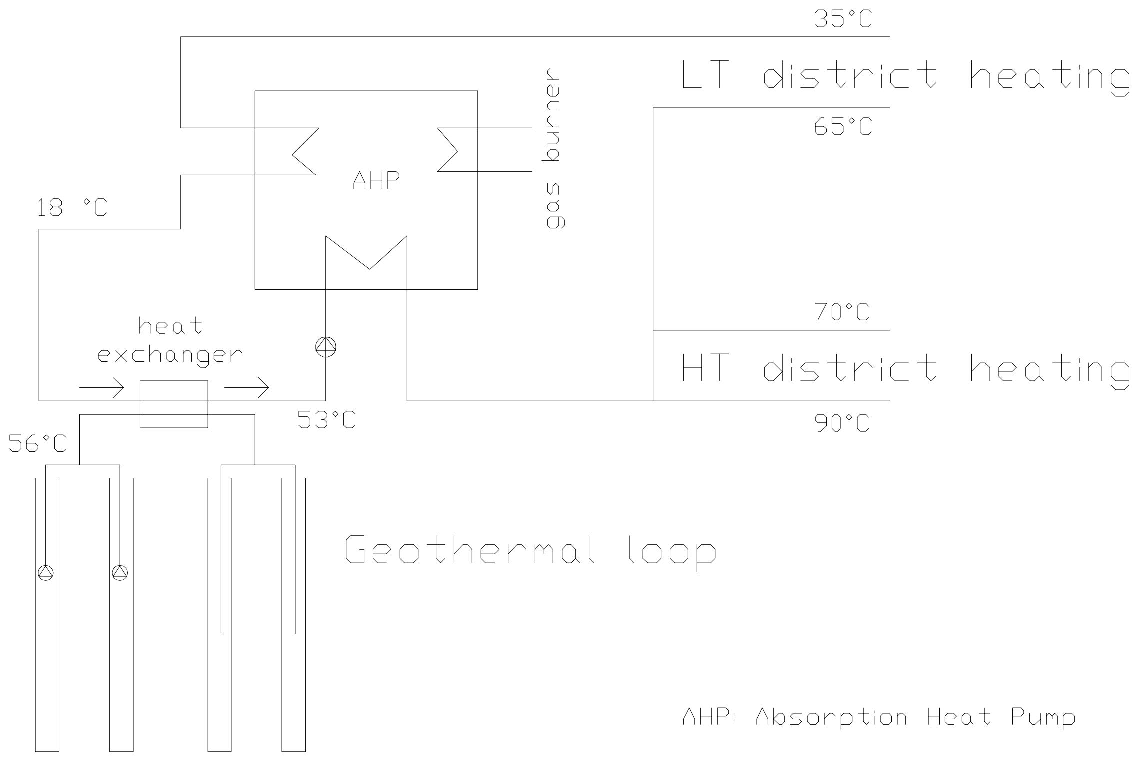

Fig. 5: Simplified schematic of Neubrandenburg hydrogeothermal plant