

COOLING WITH HEAT PUMPS: PASSIVE AND ACTIVE

Hansueli Bruderer, Dr. sc. tech. ETHZ
Viessmann (Schweiz) AG, Division SATAG Thermotechnics
male
75s

ABSTRACT

Experiences with heat pumps working with ground heat exchangers in their cooling modes: passive or natural with lowest energy consumption; active with high performance factors as in the heating mode by using a transformer function. Best practice: applications in Europe, America, Far East; recommended hydraulic diagrams, difference between passive and active cooling mode, control system and sensor positions.

KEY WORDS: Cooling, heat pump, natural cooling, active cooling, heating + cooling

INTRODUCTION

Why cooling? Different reasons create more demand for cooling also in moderate climate areas:

- Average temperatures are rising since second half of last century. Especially in summertime it becomes uncomfortable (e.g. summer 2003 in Europe).
- Climatisation in holiday resorts gets common
- Construction wise: more glass surface
- In-house heat wells: waste heat from office equipment
- Rising demand for comfort in general (e.g. in sleeping rooms)
- Efficiency at working place (room temperature should be $< 28\text{ °C}$)

Why cooling with Heat Pump? Generally cooling is done by a central climatisation equipment, single room climatisation or mobile cooling apparatus (like small electric ovens for heating). There are the following reasons for cooling with heat pumps:

- Only one equipment for heating and cooling. That means compact installation (less space needed), lower investment, lower maintenance cost.
- Better performance factors. Comparable systems under conditions corresponding to Eurovent (COP 10/40-45 °C, EER 12-7/30-35 °C) have significant different performances. Climatisation equipment has EER 3.0 – 3.9 and COP 3.0 – 3.7, heat pumps however can reach EER 4.3 and COP 4.2 – 4.5.
- Positive effect on “ground source” by recharging via ground heat exchanger (double use).

HOW COOLING WORKS WITH HEAT PUMPS

The working process for cooling is depending on the heat pump type. For ground coupled heat pumps two possibilities exist:

- Natural cooling (free respectively passive cooling). The cooling effect results only by circulation of the brine.
- Active cooling. The cooling effect needs the compressor running and the heat flow has to be reverse.

With Air/Water heat pumps only active cooling is possible. They use the reverse function with blow out hot air when in cooling mode, as it is also done in climatisation). Using preheating/precooling with underground inlet tubes, the power and performance can be improved also for air/water heat pumps. More details are given later in this paper.

HEATING AND COOLING WITH GROUND COUPLED HEAT EXCHANGERS

In Aarau, Switzerland the heat flow of a ground heat exchanger was measured with a research program. The following diagram of March 2003 – March 2004 shows with the curve the outdoor temperature (°C) and with the bars the energy taken from the ground in cold months respectively brought in the ground in warm periods (MWh).

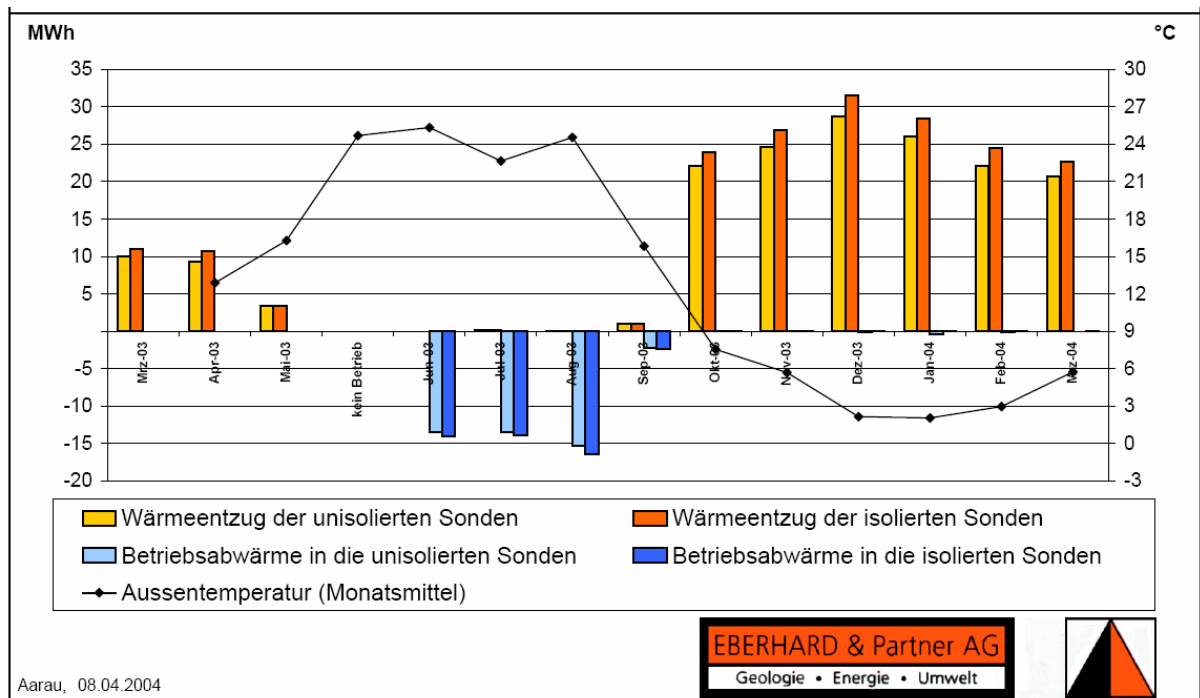


Figure 1. Heat consumption and heat deposition in a ground heat exchanger (MWh) with indication of the outdoor temperature (°C)

The **hydraulic systems** in a simplified version show the main differences between natural and active cooling.

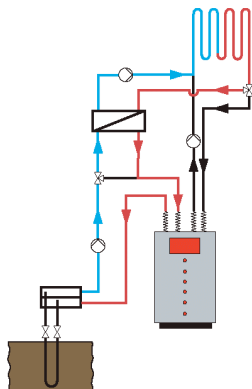


Figure 2. Natural cooling (simplified)
Ground coolness direct for space cooling

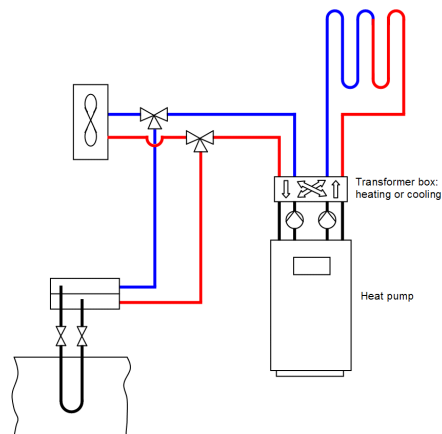


Figure 3. Active cooling (simplified):
Space cooling by compressor

In the following examples of hydraulic schemes details are shown, the first two schemes for natural cooling and next two schemes for active cooling.

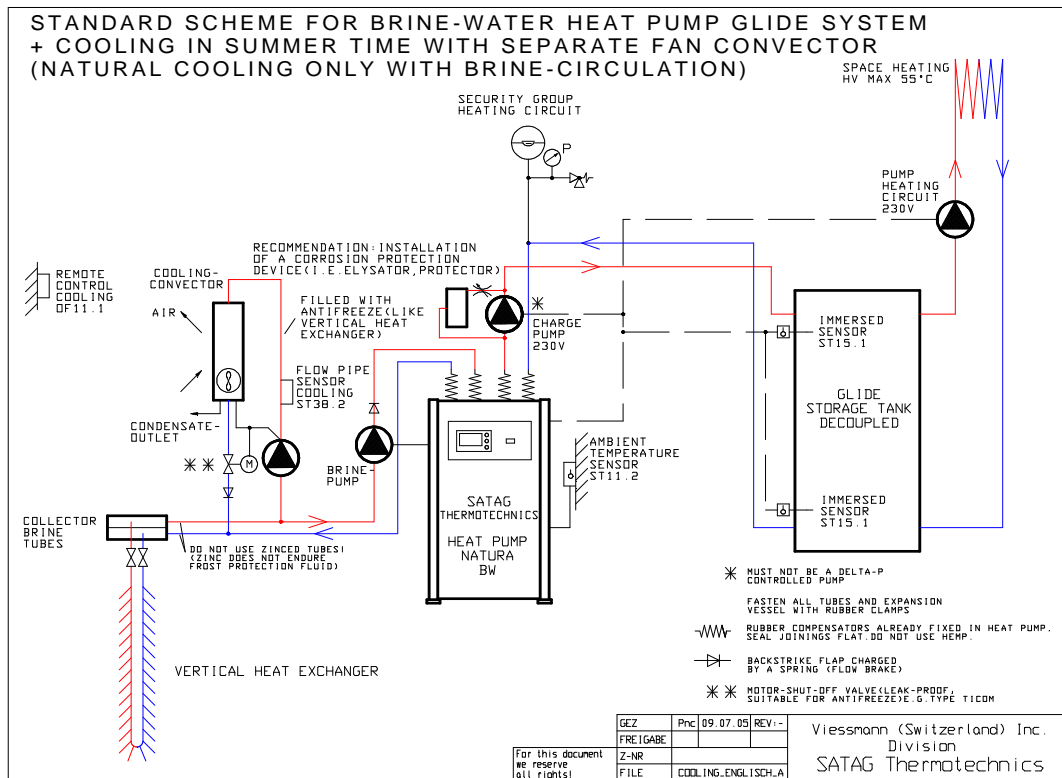


Figure 4. Natural Cooling of single room(s) with Ground Coupled Heat Pumps (e.g. for sleeping room)

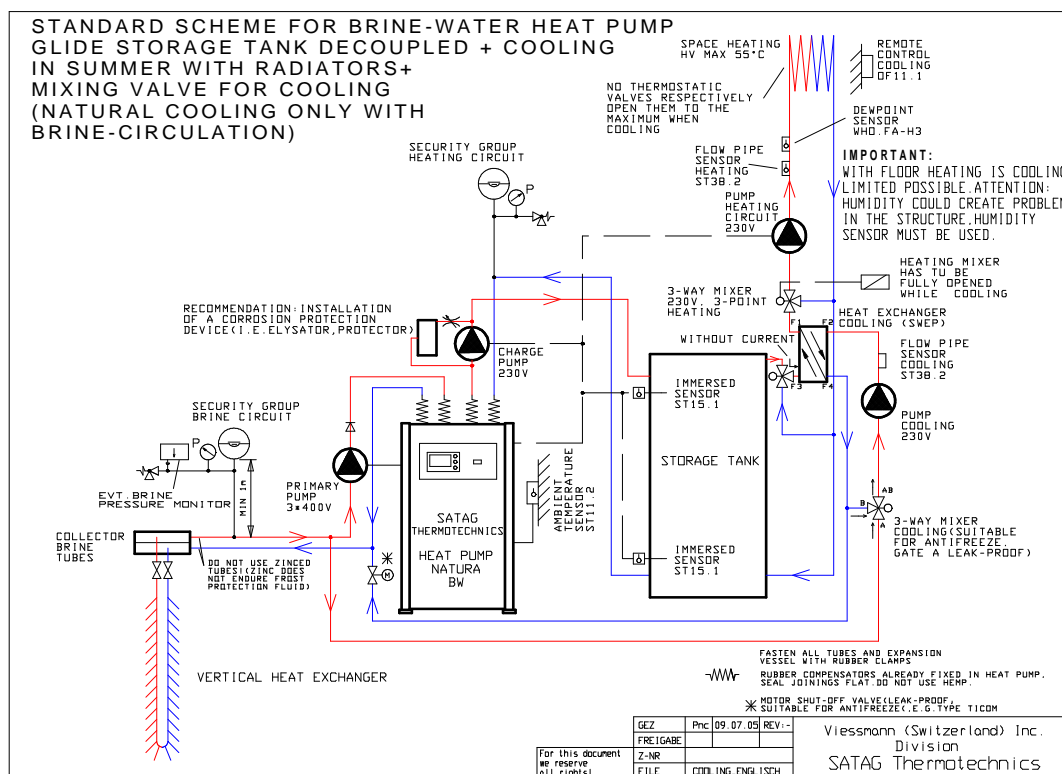


Figure 5. Natural Cooling with Ground Coupled Heat Pumps (space cooling or heating with the same circuit in the rooms)

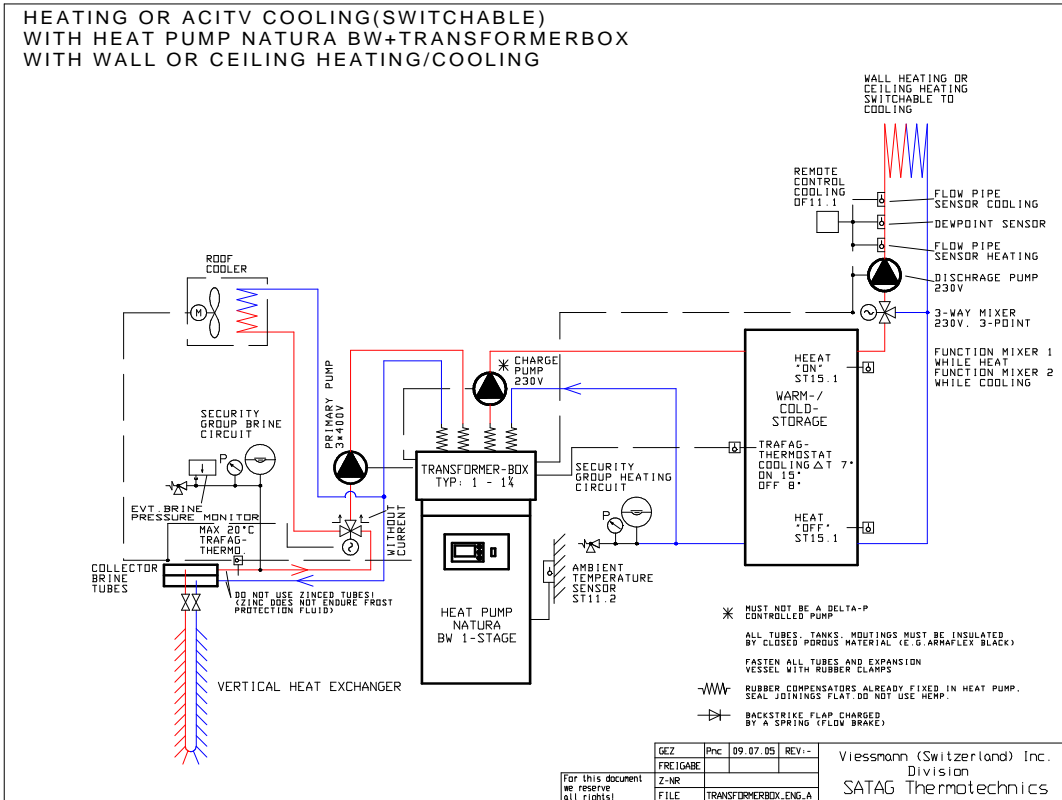


Figure 6. Active Cooling with Ground Coupled Heat Pumps, using a transformer function to switch from cooling to heating

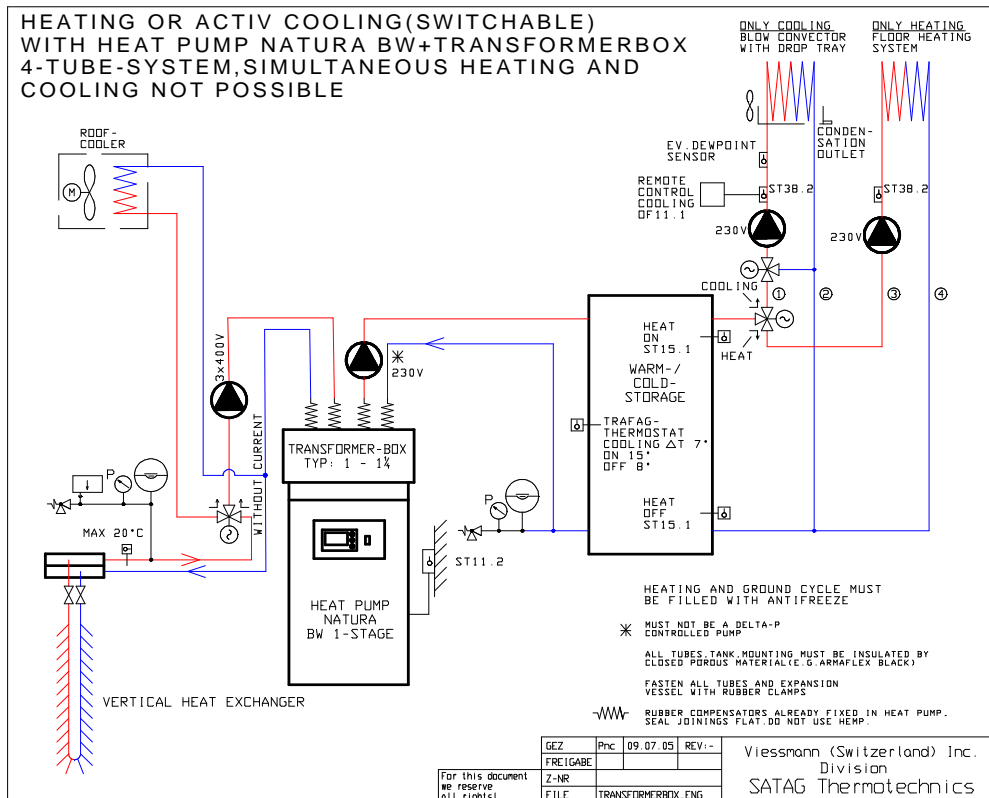


Figure 7. Active Cooling with Ground Coupled Heat Pumps using separate circuits for cooling and heating.

Table 1. The functioning and control is in the different modes and to switch automatically from one to the other is shown in the following table.

	Heating mode	Cooling mode
Activation of heating or cooling	Heating limit (e.g. $< + 16\text{ }^{\circ}\text{C}$ $T_{\text{ext.}}$)	Cooling limit (e.g. $> + 26\text{ }^{\circ}\text{C}$ $T_{\text{ext.}}$)
Control room temperature	Heating curve	Cooling curve
Mixer heating/cooling cycle	Ev.	Yes, with in house remote control
Protection vertical heat exchanger	Low pressure switch	Limiting thermostat (e.g. $+ 20\text{ }^{\circ}\text{C}$)
Condensate protection	No	Condensate drain or dew point sensor (switch at 95% humidity)
Buffer tank management	Two temperature sensors	Control thermostat (e.g. on at $+ 15$, off at $+ 8\text{ }^{\circ}\text{C}$)

Table 2. For choice and dimensioning how to cool with a heat pump, the following criteria are most relevant

	Natural Cooling	Active Cooling
System choice	If lowest possible energy consumption is required (only energy for circulation pumps)	If exact cooling power or a limited room temperature is required
Cooling power	Ca. 30 W/m with vertical heat exchanger; ca. 15 W/m^2 with horizontal heat exchanger (32 x 3 mm)	Cooling power of heat pump in operating point (e.g. $+8/+35\text{ }^{\circ}\text{C}$)
Cooling energy / year	Ca. $20\text{-}30\text{ kWh/m}$ resp. ca. $10\text{-}20\text{ kWh/m}^2$	No limitation with switch on air cooler
Thermostatic valve	Must be open	Must be open
Tube insulation	Insulation for cold	Insulation for cold
Shut-off valves	Leak-proof	Leak-proof
Application	Villas, dwellings, small enterprises, etc.	Industrial, Commerce, low energy buildings, etc.

BEST PRACTICE: EXAMPLES

Since the eighties of last century ground heat exchangers are used for cooling also. In the following some newer examples are listed with some information, cooling power and length of ground heat exchanger (kW / m). More details of the examples are given at the presentation.

- Pharmacy, glass construction, Switzerland, natural cooling, 2002, (22 / 880)
- Office and Logistic building: Switzerland, natural cooling, 2000, (125 / 4760)
- Private home with whirl pool Switzerland, natural cooling, 2002, (4 / 130)
- Office building Japan, active cooling, 2001, (21 / 350)
- Ancient Palazzo Italy, active cooling, 2003, (40 / lake water)
- Private homes, resort Canada, active cooling, 2005 (11 / 200)
- Private home, passive house standard Switzerland, active cooling, 2004 (1/ 50 (air tubes))

A private home in Switzerland in the surrounding of Zurich is equipped with a heat pump for active cooling, installed 2003. In the following we see two photos of the house and the heat pump. The hydraulic diagram is according to Figure 7.



Figure 8. Private home equipped with heat pump for heating and active cooling (brine/water heat pump with transformer box to switch automatically from heating to cooling mode and inverse. Cooling power is 14.4 kW (at +8/+35 °C).

CONCLUSIONS

For cooling with heat pumps two alternatives are possible: natural and active cooling. The advantages of using heat pumps for cooling also are: Only one system (investment, maintenance, control, installation), well known application in the dual function (since eighties of last century), high efficiency compared with normal climatisation

Notes: choice and dimensioning must be done carefully, pay attention to the limitations of the primary side (cold power, max. temperature), thermostatic valves must be open in summer time, the cold cycle must be insulated with cold insulation material. If the notes are considered well and the planning is done state-of-the-art, an excellent cooling can be done by heat pumps. The trend for heat pumps and trend for cooling reinforce each other.

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