Why Cooling and Geothermal go together

Practical and advanced examples of concepts

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Keywords: Cooling, electronics, absorption air conditioning, down-hole tools

Introduction

It is obvious to use geothermal heat directly for heating industrial, public or residential buildings, though it is a constant and continuously available source. But in many cases, mostly half a year, there is only low demand of heat i.e. for hot water. In summertime or generally in warm regions as well as in cases where other heat sources like thermal discharges shall be used for heating or even produce a surplus, geothermal cooling is a possible approach.

For an efficient use of geothermal energy sufficiently high temperatures must be expected. At the same time reliable exploration and quality management require drilling tools as well as devices for investigation and interaction in wells, which are adjusted to the challenging ambient conditions down-hole. One of the key challenges is high temperature in combination with high performance electronic components. Therefore, suitable cooling systems whether for short term or continues temperature management can be advantageous.

For both named cases cooling machines running a thermodynamic two-phase cycle play a major role. For the cooling of electronic components in down-hole tools, a compression cooling machine adjusted to common borehole conditions is part of investigation at the Karlsruhe Institute of Technology KIT. Absorption cooling machines are investigated as possible linking element between heat surpluses and cooling demand.

Heat production inside down-hole tools

For clarifying that overheating of electronic components is a risk, even with high performance insulation and in relatively cold environments, different simulations have been done.

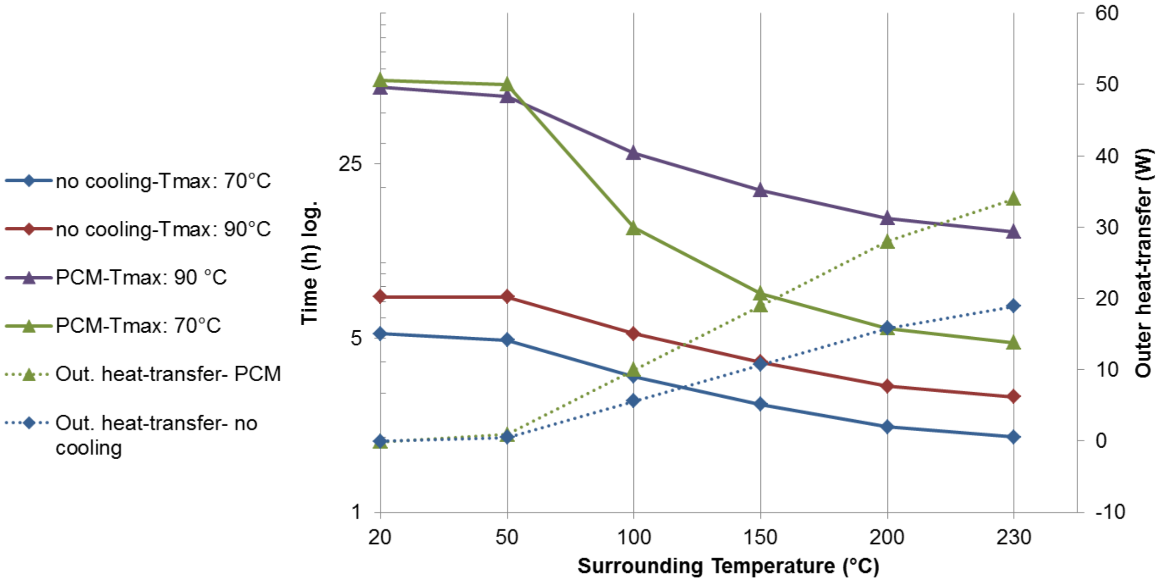

Figure 1: Temperature profiles of cooled and uncooled electronics for different maximal temperatures

As **Figure 1** shows clearly, cooling using a Phase Change Material (PCM) heat sink (purple and green lines) expands the time till reaching a critical temperature of electronics inside tools in comparison with the uncooled case (blue and red lines). It is also visible, that this time is limited even in relatively cold areas below 100 °C. This is due to the internal heat production by electrical loss, which depends on the power and efficiency of used electronic components. On the other hand the additional housing surface causes additional heat input from outside. This effect becomes more significant with increasing surrounding temperatures (dotted blue and green lines).

For the described simulation an electronic housing length of 1 m is assumed. In case of PCM heat sink usage an additional length of 1 m is set. The heat evolution inside is modeled through a correlation of the heat capacity of the electronic heat sources inside and the temperature gradient between inside and outside the tool. It is conducted for different maximal temperatures for the electronics. 70 °C for common standard electronics and 90 °C for industrial standard electronics are therefore set. Due to the used simplifications the absolute values are not reliable. However the result profiles show a general trend of different time limitations in the both cases of uncooled and PCM-cooled tools.

Continuing cooling cycle at 350 °C

Besides temporary cooling by using heat sinks, long operation periods of several days or even unlimited operations may be helpful i.e. in case of casing repairs or measurements of long-term reaction parameters. This can be realized by using a thermodynamic cycle where the surrounding itself is used as a heat-sink for transferring the excess heat from inside the electronic housing.

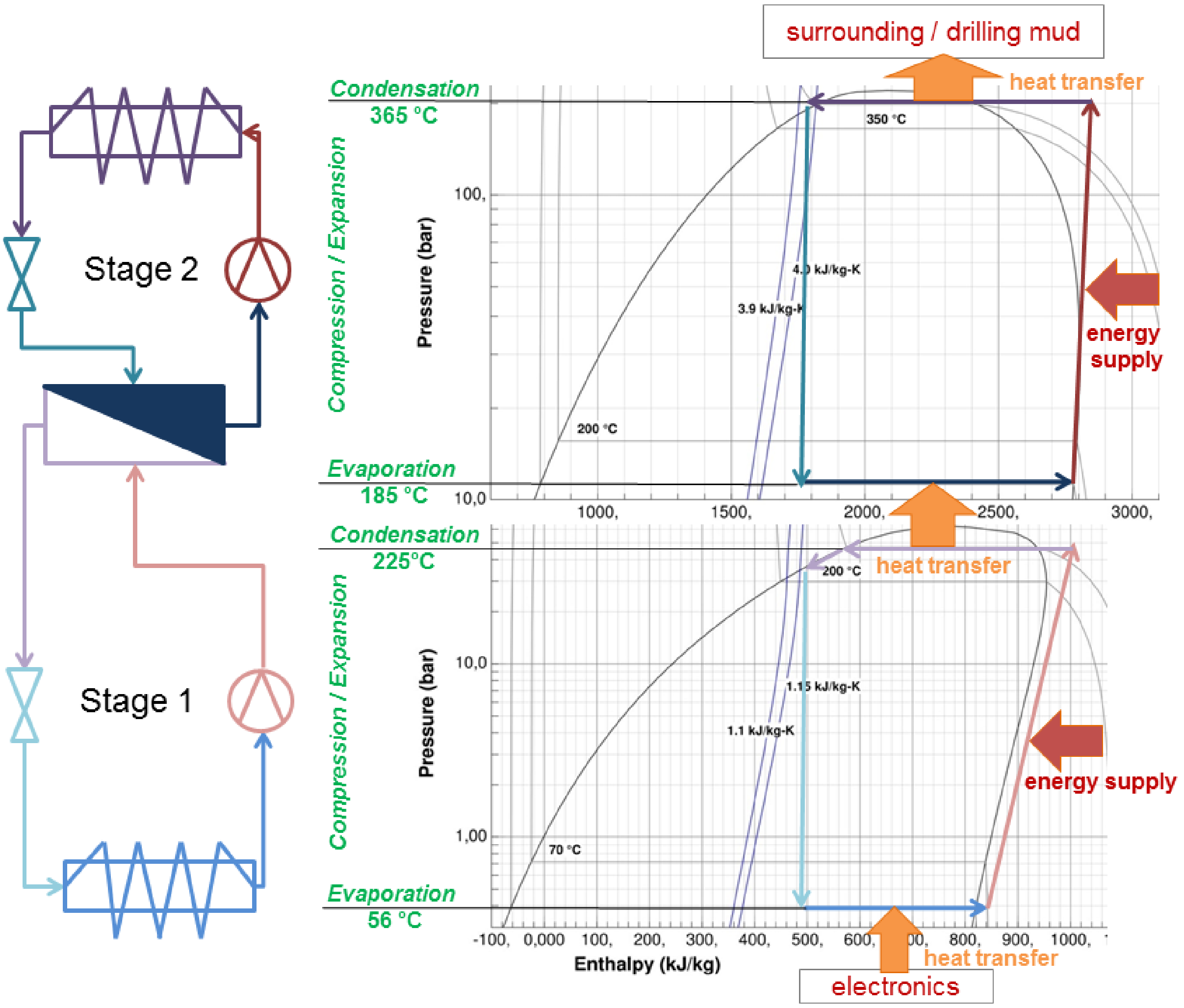

Figure 2: Concept of a two-stage cooling machine for down-hole tools with thermodynamic cycle

The concept displayed in **Figure 2** shows the principle of a two-stage cooling machine. At the left the basic components of each stage and the performed sub-processes are described: Evaporator (blue), compressor (red), condenser (purple) and throttle (turquoise).

For cooling a refrigerant evaporates inside evaporator 1 at approximately 55 °C, taking heat from electronics. The steam is compressed in compressor 2 at approximately 40 bar. At this pressure it condenses at around 225 °C, transferring heat to evaporator 2. The condensate expands to evaporation temperature (start pressure) and hence closes the cycle.

In evaporator 2 a second refrigerant evaporates, taking heat from condenser 1. The so produced steam is compressed at a pressure of approximately 200 bar in compressor 2, before it condenses at around 365 °C. During this condensation, heat can be transferred to a surrounding of up to 350 °C. Afterwards the condensed refrigerant passes an expansion to initial temperature and pressure of stage 2 and closes the 2nd cycle.

The described double process makes it possible to keep the temperature of electronic components below 70 °C at up to 350 °C surrounding temperature, without time limitation. Therefore both compressors need power supply. As refrigerant for stage 1 acetone, ethanol, methanol, different ethane constellations and mixtures of the mentioned substances are investigated. The target is to find an optimal balance between needed pressure ratio and achievable cooling capacity.

The power supply for the compression can be done electrically or hydraulically using pressure. The hydraulic solution is an advantage when using the cooling machine integrated into a drill-string; because no electricity is needed instead the mud pressure directly drives the compressor. This usage brings the additional benefit, that the drilling mud can be used as heat sink for the condenser. The high flow rates represent a huge heat capacity. Besides the mud temperature is usually significantly lower than the surrounding temperature, hence lower pressures and condensation temperatures and even a reduction to a single stage system could be possible at the same surrounding temperatures.

However the development of the cooling machine components is challenging. Due to the combination of high pressures, temperatures and aggressive refrigerants, a focus is laid at the thermo-mechanical design and the material choice. Dimensioning, design, fabrication, testing and optimization of the components and systems are performed at the KIT.

Absorption cooling machine with geothermal heat source

An absorption cooling machine runs similar to a compression cooling machine in terms of evaporation, condensation and expansion process. Absorber and desorber as additional components replace the compressor and two substances absorbent and refrigerant are used. The refrigerant steam is absorbed by the absorbent. The saturated liquid is pumped to slightly higher pressure with negligible effort. Instead of electricity for compression, heat is used for making the refrigerant desorb from the absorbent.

As shown in **Figure 3** the absorption and desorption form a closed cycle. The big advantage of this cooling process is that heat instead of electricity is used as energy supply. Especially for geothermal heat sources this is a practical application for using surplus heat.

Absorption cooling using heat from geothermal or other heat sources is being investigated within the scope of the “Energy Lab 2.0” project at the KIT. The aim of the project is to investigate the electrical grid stability regarding the amount of renewables in the energy production and to find solutions for prevention and troubleshooting. This also contains a test lab for actual field tests with energy producers and consumers. Thereby heating or more generally said heat management which also includes air conditioning and cooling have a not negligible importance. Firstly heating and cooling represent an important part of the total energy consumption and secondly heat systems imply a big potential as energy storages.

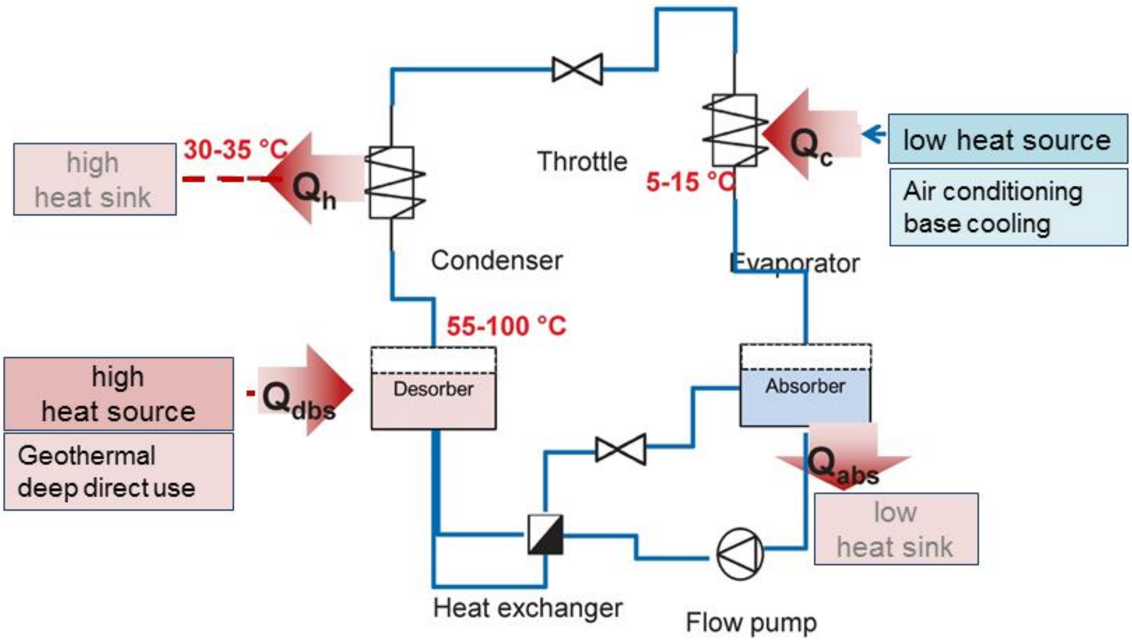

Figure 3: Diagram of the absorption cooling machine principle

For the Energy Lab 2.0 test, the idea of absorption air conditioning and cooling is to achieve an optimal usage of available heat, while saving electrical energy. Different heat sources such as direct geothermal heat as well as thermal discharges of power electronics and electricity plants are investigated. On the cold site, cooling targets like server-rooms, big electronics and usual living room air conditioning in summertime are part of the investigations. Actually the conceptual design of different experimental set ups is being developed.

Conclusion

Both examples of actual research work in this paper show that cooling is an important topic in the field of geothermal energy.

In case of the compression cooling machine for electronic components cooling is necessary for allowing advanced investigation and interaction operations at high temperatures, which are important for an efficient exploration and quality management. These high temperatures are the targeted conditions for geothermal projects with high performance electricity and heat production. Secondly the use of geothermal heat or other available heat surplus for cooling, by using the absorption cooling machine principle is being investigated.

Both principles contain several similarities in terms of technical component constraints, thermodynamic cycle and energy exchange processes with actual surroundings. Beyond that both are connected to geothermal well conditions whether as energy source or as operation environment.

Through the parallel investigation and development of the different concepts, valuable impulses for both topics are expected.