**Projekt**info **06**/2012

Detailed information on energy research

# Corrosion in geothermal plants

## Researchers in Potsdam are investigating materials and deep waters at the geothermal facility in Groß Schönebeck

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*Geothermal energy can make a much greater contribution to supplying Germany's energy than has been the case so far. However, more advanced technologies will be required that are specially adapted to geothermal energy and its mostly highly saline waters. One of the aims is to prevent corrosion on pipes, pumps and heat exchangers as economically as possible. At the geothermal research laboratory at Groß Schönebeck, basic research is being conducted, for example, on corrosion processes, the composition of deep waters and material properties in order to develop site-dependent recommendations.*

Together with the Federal Institute for Materials Research and Testing (BAM) and Schmidt + Clemens GmbH + Co. KG, the German Research Centre for Geosciences (GFZ) in Potsdam is carrying out basic geothermal research as part of a sub-project on corrosion being conducted at the Groß Schönebeck geothermal facility. Results from laboratory experiments are being transferred to a real geothermal plant (in situ laboratory) at the facility. Thanks to its location in a sediment basin with an average geothermal gradient (approximately 30 °C per km) and a high salt content of the geothermal water, GroßSchönebeck offers conditions that are representative for many geothermal sites in Germany.
Deep geothermal plants in northern and southwestern Germany, including both hydrothermal and petrothermal ones, often process highly saline water. The

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plants use natural thermal water volumes that are stored in hot layers of rock and which can be recovered using existing or generated fracture systems. In order to ensure the reliable and economic operation of geothermal plants it is important that the composition of the fluid is known precisely in order to be able to estimate the possible physical and chemical fluid-material interactions. These are influenced, for example, by the drop in temperature that occurs on route from the reservoir to the plant facilities above ground as well as by the heat extraction. The high salt concentration in combination with high temperatures, high pressure and dissolved gases can cause considerable corrosion to all metal components in the geothermal plant. The project will conclude by developing a fluid-specific and location-dependent material deployment catalogue. This will also take economic aspects into consideration.

## Fluid monitoring

Fluids are complex multi-component mixtures whose composition depends, for example, on the rocks and flow pathways underground. At the parts of the plant that come into contact with this thermal water, various parameters influence fluid-material interactions. These include the salt content and proportion of individual salts, the oxygen content, dissolved gases, further particles including their size and mineral composition, as well as the temperature, pH value, density, pressure, redox potential, volumetric flow rate and fluid conductivity. Some parameters are subject to operation-dependent fluctuations. This is because precipitation or degassing can occur within the thermal water circuit in the plant as a result of, for example, the heat extraction – which cools the fluid from 150 to 70 °C – and pressure losses.
A new pump system installed at a depth of 1,200 metres enables all relevant underground parameters to be measured during the ongoing operation. In addition, a mobile fluid monitoring system (FluMo) has been developed at the German Research Centre for Geosciences that records and stores the chemical and physical properties of the thermal water under above ground in situ conditions (online monitoring). Parallel to this, a gas monitoring system has been installed that enables the gas-chromatographic and mass-spectrometric online measurement of the gases that are also extracted. In combination with supplementary laboratory experiments, this enables the processes in the reservoir and boreholes as well as the chemical material-fluid interactions to be better understood in the installations above ground. This will provide help in future projects when it comes to selecting corrosion-resistant components in accordance with specific sites.

## Corrosion and material qualification

Corrosion causes components to wear out more quickly and the released particles can cause deposits to form and abrasion. This compromises the reliability of the components such as pumps and heat exchangers, and causes maintenance work, production downtimes and repair costs. In Groß Schönebeck, components and defined material samples consisting of, for example, simple, high-strength carbon steels, other steel types as well as nickel and titanium alloys are tested in terms of their corrosion resistance. Preventative, active and passive procedures for corrosion protection are also tested out.

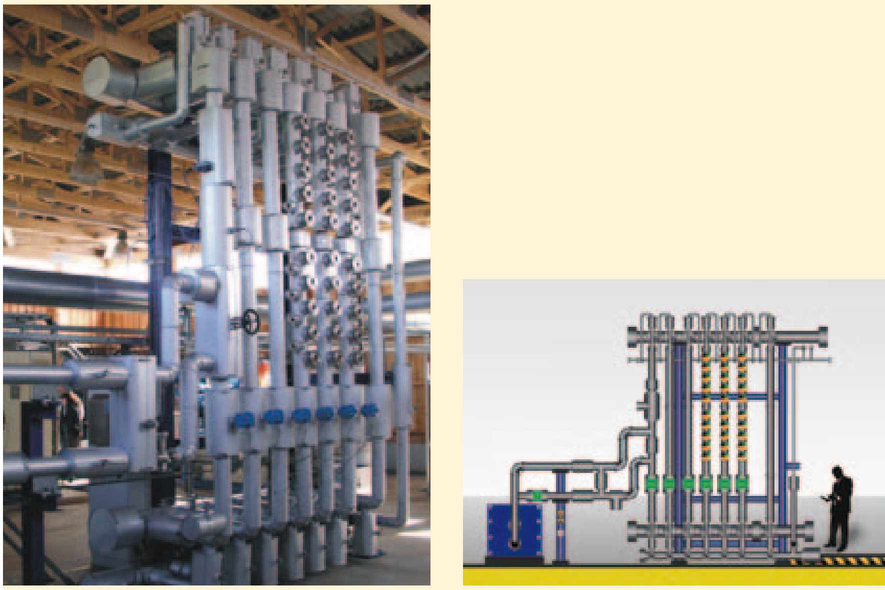

Fig. 1 *Test track for corrosion investigations and monitoring.*
*Source: German Research Centre for Geosciences in Potsdam, Schmidt + Clemens*

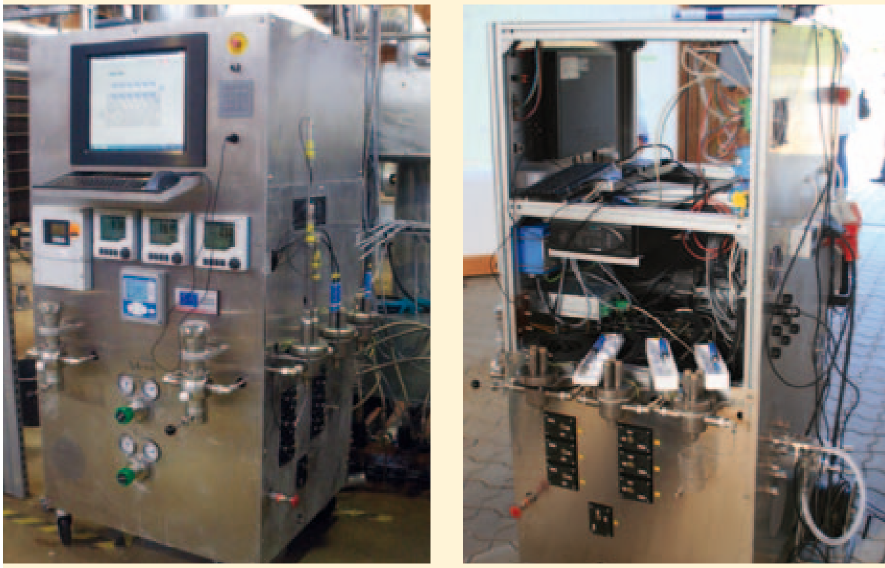

Fig. 2 *The fluid monitoring system (FluMo).*
*Source: German Research Centre for Geosciences in Potsdam*

The results from previous laboratory investigations also undergo practical testing for several months directly at the geothermal plant until the reactions on the material surfaces reach equilibrium. The investigations take place under realistic operating conditions with alternating full and partial load phases. At a depth of 1,200 metres, a corrosion cell has been installed beneath the extraction pump in which materials are tested under underground conditions. At the surface, bypasses have been installed in the thermal water circuit that consist of different materials and are made by different manufacturers. The centrepiece of the corrosion tests is a corrosion test track, which with a total of 30 access points makes it possible to conduct diverse experiments with material samples and to test several corrosion monitoring systems. Parallel to this, material samples are tested under laboratory conditions using real fluid in autoclaves.
During the ongoing operation, the monitoring systems used for the investigations record all changes to materials and the fluid with high local and temporal resolutions and enable online data access. Similar systems have already been successfully deployed in chemical process technology. Since

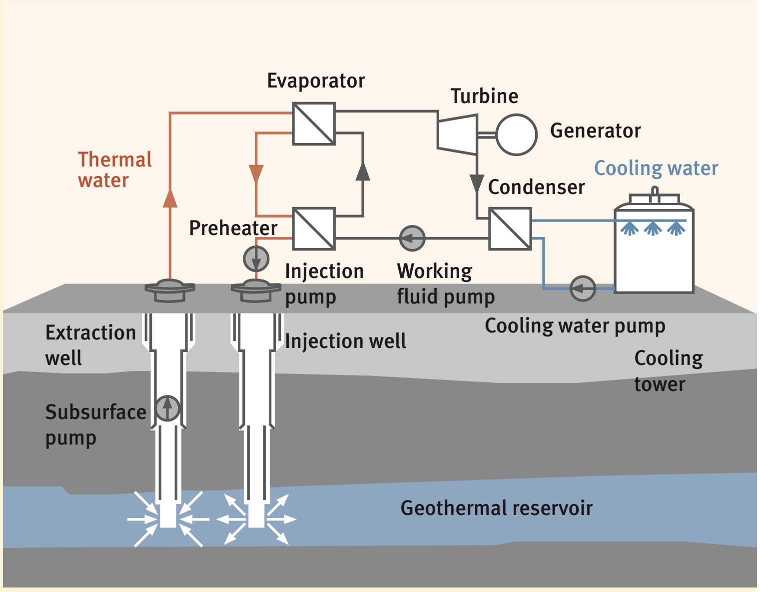


Fig. 3 *Principle of geothermal electricity generation using the ORC process*
*Source: German Research Centre for Geosciences in Potsdam*

Fig. 4 *Corrosion research in a bypass of the thermal water circuit in Groß Schönebeck.*
*Source: German Research Centre for Geosciences in Potsdam*

## In situ laboratory at Groß Schönebeck

Groß Schönebeck is situated approximately 50 km northeast of Berlin on the southern edge of the North German Basin. In 2001, an old natural gas well was deepened into the Rotliegend sandstone to a depth of 4,309 metres. This was followed by a second well in 2007, which has a depth of 4,400 metres. The wells are 28 metres apart at the surface but are up to 475 metres apart underground. They form a geothermal doublet with a production well in which hot water is pumped upwards with a pump 1,200 metres below ground and a re-injection well in which the water is returned below ground using a second surface pump once the heat has been extracted from it. Measurement instruments in the wells and the thermal water circuit record changes in the geothermal reservoir, the fluid and the material.

Large volumes of water were injected with overpressure in order to tap the geothermal reservoir. This formed a fracture system underground and thus created a geological heat exchanger (EGS system). The extracted fluids have a total salt content of 265 g/l, the underground temperature is 150 °C and the pH value is 5.7. The surface system runs at overpressure to prevent degassing, fluid evaporation and the penetration of atmospheric oxygen. In 2011 the thermal water circuit was closed and the basic research was started.

## Corrosion in geothermal plants

The most well-known form of corrosion is the rusting of iron. The resulting iron oxide is porous and, owing to the increase in mass and volume, accelerates the material degradation. Corrosion generally means that a material reacts with its environment and thus changes its material properties. This also usually impedes the functionality of the material.

corrosion in aqueous media is an electrochemical process, it can be easily monitored and assessed using electrochemical methods. In addition to traditional exposure tests to determine the corrosion resistance, electrochemical measurements are therefore implemented in the corrosion test track whose temporally resolved measurement values enable the corrosion processes to be assessed in accordance with the extraction conditions and, if required, the fluctuating fluid properties.

### Further key focus areas

In 2011, a research power plant with three mutually coordinated ORC modules was conceived and constructed at Groß Schönebeck. These modules can be operated individually or together and are designed for a total electrical output of 1 MW. Approaches for improving geothermal electricity generation are being tested at the research power plant. At Groß Schönebeck, this therefore enables all relevant processes that occur in geothermal plants, including the processes in the underground reservoir, to be scientifically monitored (plant monitoring) and optimised during geothermal electricity generation.

### Results and perspectives

Laboratory investigations on carbon steels, high-alloy stainless steels, nickel alloys, and titanium materials have shown the corrosive effect of hot, highly saline water relative to the expected forms of surface, pitting and crevice corrosion. However, not all influencing factors can be taken into account in the laboratory.

Groß Schönebeck supplements knowledge on the suitability of the North German Basin as a geothermal region. Fluid parameters from other geothermal sites in other regions are also incorporated into the investigations. The results enable individual materials and components to be assessed in terms of their use in geothermal plants in a more differentiated manner.

The project has created fundamental knowledge on characterising fluids and understanding corrosion mechanisms. With the newly developed FluMo-system, a mobile analysis system has been successfully tested for geothermal fluids. The insights gained at Groß Schönebeck will improve the assessment of newly tapped geothermal resources in terms of their economic feasibility, system stability and achievable energy yields.

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## Overcoming constraints

*In addition to corrosion-resistant components, deep geothermal energy also requires further technological developments in other areas. So far, procedures and components have been deployed that predominantly stem from oil and gas production. However, different deployment and environment conditions prevail there. Components and technologies specially tailored to geothermal energy can therefore help improve the prospects for success and the economic viability of heat energy extracted from the deep underground.*

*Up to two thirds of the investment costs for geothermal plants are spent on drilling wells. Reducing these costs requires not just improved exploration (2D/3D seismics) but also changed drilling technologies and strategies, whereby the focus is on increasing the service life of the drilling equipment and reducing the energy and material consumption for the drilling. This also requires separation processes that protect the reservoirs. More precise knowledge of the local geological conditions, such as is provided by the GeotIS geothermal information system (see below), constitutes another factor in reducing the drilling risks and the associated costs.*

*Because of the conditions that prevail at great depth, geothermal plants place considerable demands on the pumps used. More advanced systems will be required to replace the current pumps used in extracting hydrocarbons and which do not satisfactorily meet the aforementioned requirements. New pumps designed for daily geothermal use should be temperature-resistant up to 200 °C, able to cope with volume flows of up to 150 l/s, flexible in use, capable of resisting high well pressures, and corrosion-resistant. They must also be maintenance-free and cheap. This improves the economic feasibility.*

*Germany has a competent research infrastructure for geothermal energy with close collaboration between science and industry. The scientifically monitored pilot and commercial geothermal plants provide many years of practical experience in the utilisation of geothermal resources at a low temperature level. Similar underlying conditions prevail in many regions around the world. The potential for exporting geothermal technologies and concepts is therefore far from being exhausted.*

## Project participants


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## Links and literature


>> www.gfz-potsdam.de/geothermie | www.geotis.de | www.forschungsjahrbuch.de (⟶ Geothermie)

>> Transforming waste heat into electricity. BINE-Projektinfo brochure 13/2011

>> On the trail of deep geothermal energy. BINE-Projektinfo brochure 09/2011

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